



White Paper

THE CASE FOR

AGRIPV IMPLEMENTATION

IN UTTAR PRADESH

About Vasudha Foundation

Vasudha Foundation is a non-profit organisation set up in 2010. We believe in the conservation of Vasudha, which in Sanskrit means the Earth, the giver of wealth, with the objective of promoting sustainable consumption of its bounties. Our mission is to promote environment-friendly, socially just and sustainable models of energy by focusing on renewable energy and energy-efficient technologies as well as sustainable lifestyle solutions. Through an innovative approach and data-driven analysis, creation of data repositories with cross-sectoral analysis, along with outreach to ensure resource conservation, we aim to help create a sustainable and inclusive future for India and Mother Earth.



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1

Introduction

During the 26th Meeting of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) (COP 26) in Glasgow, United Kingdom, India conveyed its commitment to intensify climate action. In August 2022, the Union Cabinet, under the leadership of Prime Minister Shri Narendra Modi, approved India's updated Nationally Determined Contributions (NDCs) to be communicated to the UNFCCC¹. According to the revised NDCs, India has pledged to reduce the emissions intensity of its GDP by 45% by 2030 compared to the 2005 level. Additionally, India aims to achieve approximately 50% of cumulative electric power installed capacity from non-fossil fuel-based energy sources by 2030.

As India rapidly advances in the deployment of solar PV capacity, the predominant focus has been on ground mounted photovoltaic (GM-PV) projects, constituting approximately 77.3%; of the total 89.43 GW of solar PV deployment². Despite the significant advantages of GM-PV projects over other renewable or fossil fuel electricity generation technologies, they encounter certain limitations. These projects, being land-intensive, often compete for natural and agricultural land, leading to unintended negative consequences.

Several challenges arise from GM-PV deployment, including potential decreases in soil organic carbon (SOC) stocks due to vegetation removal and soil conditioning³, enhanced greenhouse gas (GHG) emissions from changes in land use⁴, the PV heat island effect causing local temperature increases⁵, and biodiversity losses in diverse grazing lands and nearby ecosystem⁶. Additionally, the efficiency of solar energy generation is expected to decrease by 12% by 2050 due to warming associated with climate change⁷.

Addressing these challenges, a unique solution emerges in the form of Agrivoltaics, also known as AgriPV. This innovative approach aims to reconcile the competition between agriculture and photovoltaics, offering a holistic solution.

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1.1

Emergence of AgriPV as a Solution

AgriPV not only contributes to reducing fossil fuel use by generating sustainable energy but also provides crop protection against specific weather conditions and climate changes⁸. The synergistic integration of energy and plant production can enhance land productivity by up to 60%, mitigating the heat island effect, increasing water savings, improving SOC, and preserving biodiversity⁹.

Agri PV brings numerous benefits to agriculture, offering adaptation options such as limiting irradiation to reduce evapotranspiration, hail protection, and improving microclimates¹⁰. It also supports ongoing electrification and digitalization of the agricultural sector¹¹. While the acquisition cost of Agri PV is generally higher than that of conventional GM-PV systems, potential savings on operating expenses, especially related to land use and management costs, make it economically viable. Cleaning costs are reduced as the systems can be cleaned with irrigation water, and improved productivity and environmental benefits contribute to economic returns above pure PV deployment.

In the context of local energy production and the imperative for accelerated photovoltaic expansion, AgriPV presents a synergistic approach to simultaneously address energy demands and optimize agricultural practices.

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1.2 Objectives of the Paper

This white paper aims to provide a comprehensive understanding of AgriPV systems and their potential implementation in Uttar Pradesh (UP). Specifically, the objectives are:

- 1 To offer a detailed analysis of AgriPV technology, including types, components, and integration with agriculture.
- 2 To highlight the multifaceted benefits of AgriPV systems across social, economic, and environmental dimensions.
- 3 To assess the current renewable energy landscape in UP and project the potential benefits of AgriPV implementation in the state.
- 4 To examine existing AgriPV initiatives in UP and draw lessons from national and international best practices.
- 5 To provide policy recommendations for Uttar Pradesh to incorporate AgriPV support mechanisms into the existing UP solar policy.

By addressing these objectives, this paper seeks to build a compelling case for the adoption and promotion of AgriPV systems in UP, aligning with both the state's agricultural focus and its renewable energy ambitions.



Understanding AgriPV Technology

2.1 Definition and Concept of AgriPV

AgriPV, refers to the combination of solar power generation with agricultural activities on the same piece of land. This concept, originally proposed by Goetzberger and Zastrow in 1982¹², was developed to address the growing competition for land between renewable energy projects and agricultural needs. In its simplest form, AgriPV involves the installation of PV modules above crops, allowing the dual use of the same area for both electricity production and agricultural purposes.

The concept of AgriPV is based on the fact that plants do not require the entire spectrum of solar radiation to sustain growth. The Photosynthetically Active Radiation (PAR) is particularly influential on the biomass yield of crops. When solar PV modules are deployed on farmland, they create shade, leading to a reduction in PAR. However, as illustrated in the Figure 1, this reduction in PAR does not necessarily decrease the biomass yield for certain categories of crops, denoted by the symbols + and 0.

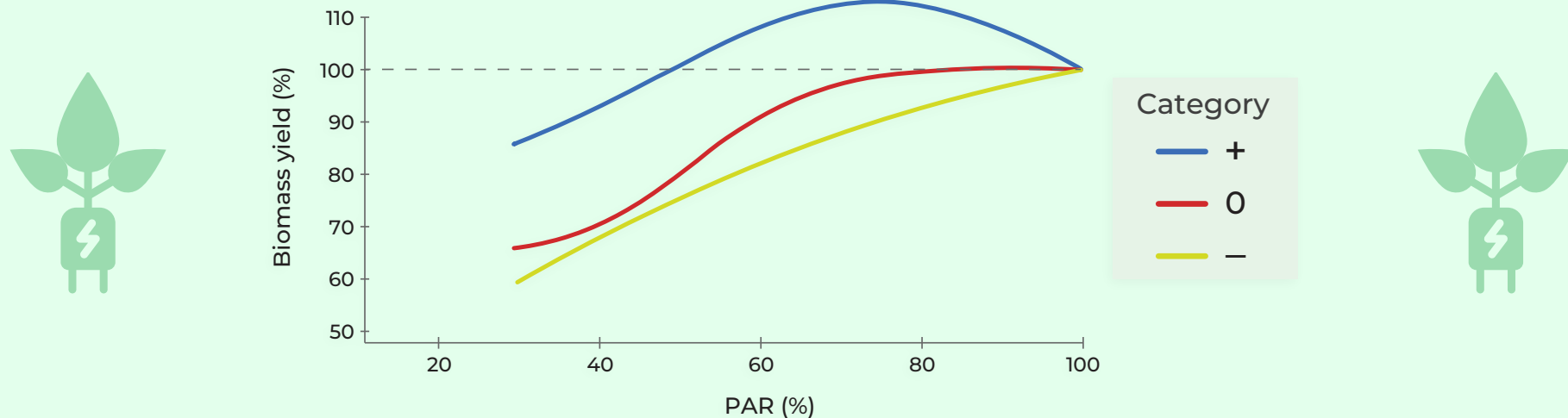


Figure 1: Biomass Yield v/s PAR¹³

Further exploration of this phenomenon can be achieved through the light response curve of crops. Generally, at low light levels, the rate of photosynthesis increases linearly with light intensity. Low light intensities can stress plants, as they cannot reach their full growth potential. As light intensity increases, the rate of photosynthesis begins to plateau until it reaches a species-specific light saturation point. Beyond this point, any further increase in the light intensity has no effect over the photosynthesis capability, as the capacity for light-harvesting reactions is limited. The exact shape of the light response curve varies among different plants subjected to same field conditions. Figure 2 illustrates a typical light response curve.

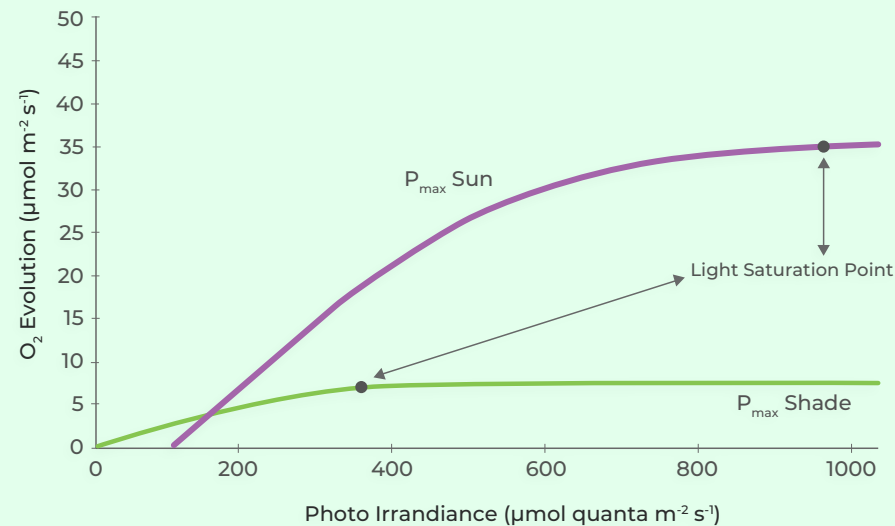


Figure 2: Light Response Curve of Two Different Crops¹⁴

The light saturation point is crucial for determining the shading ratio in an AgriPV system and for assessing the suitability of crops to be grown under such conditions. Crops with a lower light saturation point can tolerate more shade without yield losses.

However, for crops that have a high light saturation point, AgriPV systems can be customized to suit their requirements, as will be discussed in subsequent sections. This dual-use approach not only mitigates land-use conflicts but also offers additional benefits such as crop protection, improved microclimates, and increased overall productivity.

2.2 Types of AgriPV Systems¹⁵

AgriPV systems can be broadly classified into several types based on their design, structure, and mode of integration with agricultural activities. The two primary categories are open systems and closed systems, each with their unique characteristics and applications. **However, this paper focuses solely on designs that do not reduce agricultural yield by more than 10%.**

2.2.1 Open AgriPV Systems

Open AgriPV systems refer to installations that allow open-air agricultural activities. These systems are typically implemented in two configurations.



Overhead AgriPV Systems

In this setup, PV modules are installed on elevated structures (stilts) at heights ranging from 2 to 5 metres¹⁶. This design ensures that traditional agricultural machinery can still operate beneath the modules without significant modifications to farming practices as shown in Figure 3. The elevated height also reduces shading impacts, allowing sufficient sunlight to reach the crops below. Overhead AgriPV systems are particularly suitable for field crops, grazing lands, and horticultural applications.



Figure 3: Elevated AgriPV System¹⁷



Vertical Interspersed AgriPV Systems

This configuration involves the vertical installation of bifacial PV modules in an east-west orientation. The vertical alignment allows sunlight to reach the crops from both sides, generating more energy during the morning and late afternoon while minimising shading effects. This design is especially advantageous in regions with high solar irradiance, as it can enhance energy yields by up to 15% compared to traditional PV systems¹⁸. Vertical AgriPV systems also facilitate the use of conventional agricultural machinery between the rows of modules.

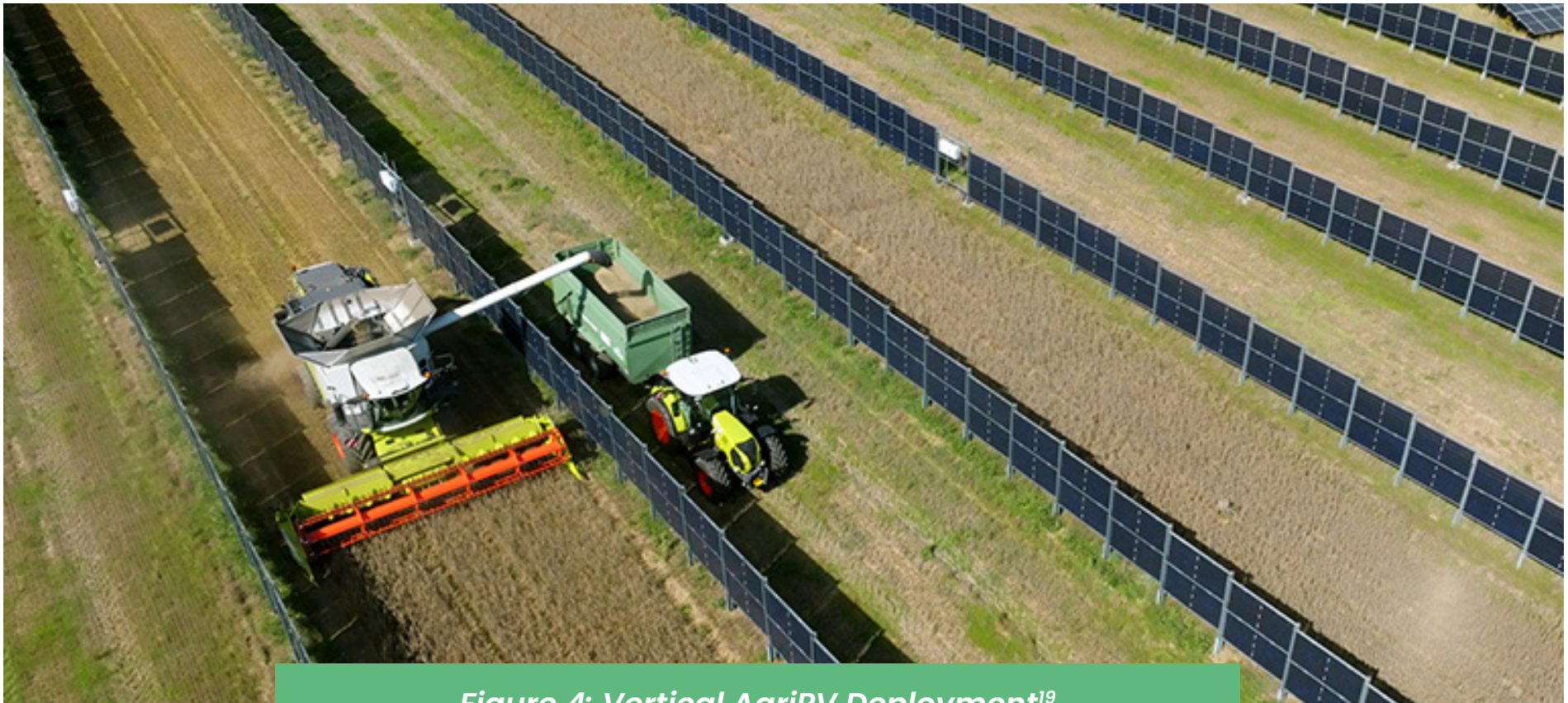


Figure 4: Vertical AgriPV Deployment¹⁹

2.2.2 Closed AgriPV Systems

Closed AgriPV systems refer to PV installations within controlled environments such as greenhouses. In these systems, PV modules are integrated into the greenhouse structure, providing both energy generation and a controlled microclimate for crop cultivation.



Figure 5: Solar PV Modules on Greenhouses

PV Greenhouses

These greenhouses are equipped with PV modules on the roof or integrated within the structure. The controlled environment inside the greenhouse allows for precise regulation of temperature, humidity, and CO₂ levels, optimising conditions for crop growth. PV greenhouses are particularly beneficial for high-value crops that require specific growing conditions, such as vegetables, flowers, and certain fruit varieties. The dual use of the greenhouse for both energy and food production make it a highly efficient and sustainable agricultural practice.

2.3 Components of AgriPV Systems

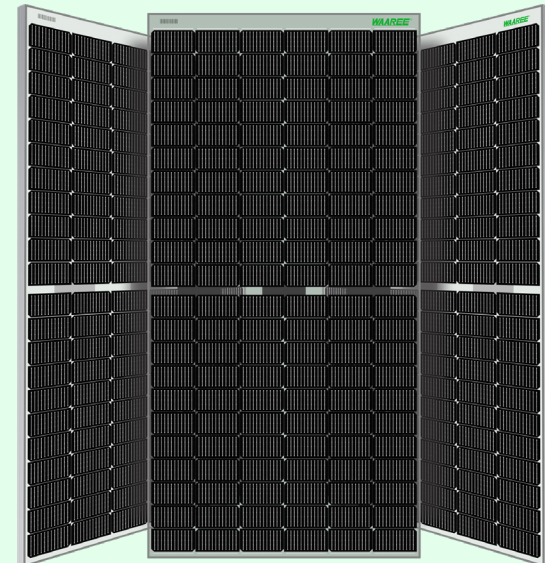
The effectiveness and efficiency of an AgriPV system depend on the careful selection and integration of various components, including solar modules, mounting structures, and agricultural practices. Three key components of AgriPV systems are provided below:

2.3.1 Solar Modules

The type of solar module used in an AgriPV system is critical to balancing energy generation with agricultural needs. The main types of solar modules include:

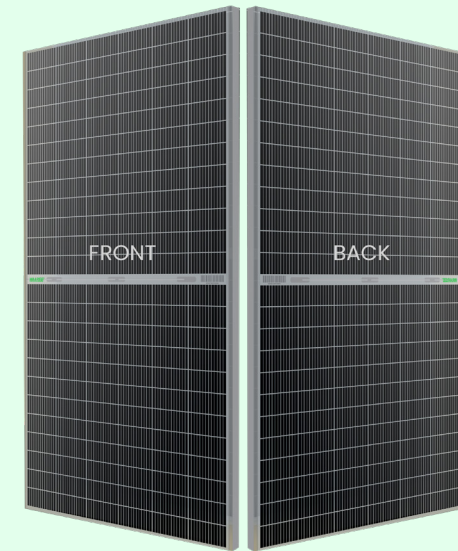
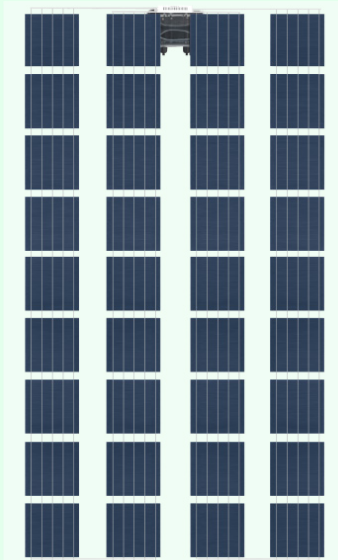
Monofacial Modules

Traditional PV modules that capture sunlight on only one side. These modules are often used in overhead AgriPV systems where they can be elevated above crops, providing partial shading while generating electricity.



Bifacial Modules

Bifacial modules capture sunlight on both the front and rear sides, increasing overall energy output. These modules are particularly effective in AgriPV systems due to their ability to utilise reflected light from the ground. The choice of bifacial modules can be optimised based on factors like row spacing, module height, and ground albedo. They are often preferred in vertical AgriPV systems where maximising energy capture throughout the day is essential. These modules also feature some level of transparency (estimated to be 8% for the pre-design)¹⁵, allowing more sunlight to pass through and be utilised by the plants beneath the modules.



Semi-transparent Modules

Semi-transparent c-Si modules feature spatially segmented cells that permit some of the irradiation to pass through. The design offers considerable flexibility, with adjustable levels of transparency, cell layout, colour, and glass substrate type. However, there is a direct trade-off between transparency and efficiency, and their cost per watt-peak (USD/Wp) is higher compared to opaque modules. Semi-transparent modules are commonly used in PV greenhouses or overhead systems where it's crucial to balance light penetration for crops with energy generation.

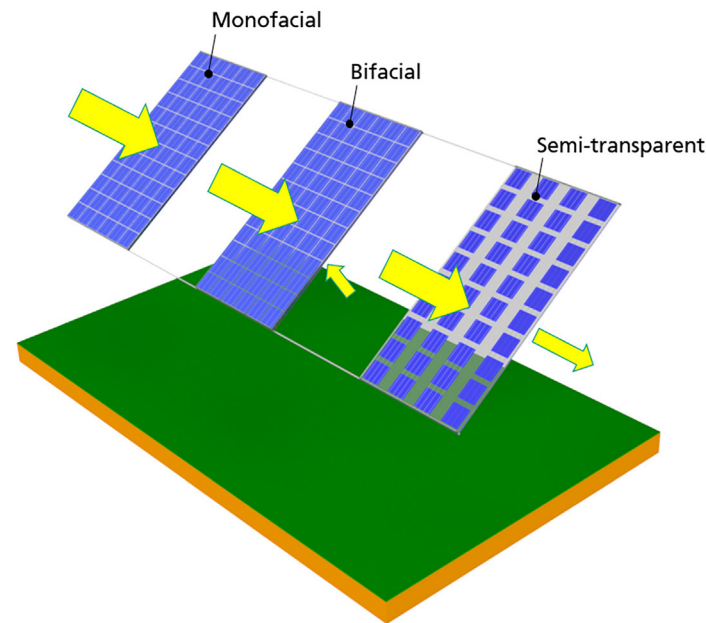


Figure 6: Illustration of Various Solar PV Modules Types

2.3.2 Mounting Structures and Layouts

The design of mounting structures and the layout of solar modules in AgriPV systems are crucial factors that vary based on the specific type of AgriPV system employed and the agricultural activities being conducted underneath. The choice of structure and layout is influenced by the need to optimise both solar energy generation and agricultural productivity, ensuring that neither function is compromised.

In overhead AgriPV systems, PV modules are typically installed at an elevated height, with the module mounting structures ranging between 2 to 5 metres above the ground. This elevation is designed to allow sufficient space for agricultural machinery to operate beneath the modules and to provide adequate light for crop growth. However, not all crops respond equally to the shading effects created by high-density PV modules. For certain crops, excessive shading may lead to reduce yields, necessitating adjustments to the module layout.

To address these challenges, several strategies can be employed:

Checkerboard Pattern Layout

In cases where high-density shading might negatively impact crop yields, PV modules can be arranged in a checkerboard pattern. This layout increases the homogeneity of shade across the field, reducing the risk of localised over-shading and allowing for more uniform light distribution. The checkerboard pattern ensures that crops receive a balanced amount of sunlight, optimizing growth conditions while maintaining energy production. However, this layout will lead to reduced solar PV deployment on the same parcel of land.

Smaller Modules for Better Light Distribution

Another approach is to use smaller PV modules or semi-transparent modules that allow more light to pass through. This minimises the overall shading effect and helps distribute light more evenly across the crops. Adjusting the size and transparency of the modules can lead to a more favourable microclimate for plant growth, particularly for shade-sensitive crops.



Figure 7: Checkerboard Pattern Layout



Figure 8: Smaller PV Modules²⁰

These adjustments in layout and module design may necessitate changes in the construction of mounting structures as seen in Figure 9, ensuring they can support the specific configuration of modules while maintaining structural integrity and operational efficiency.

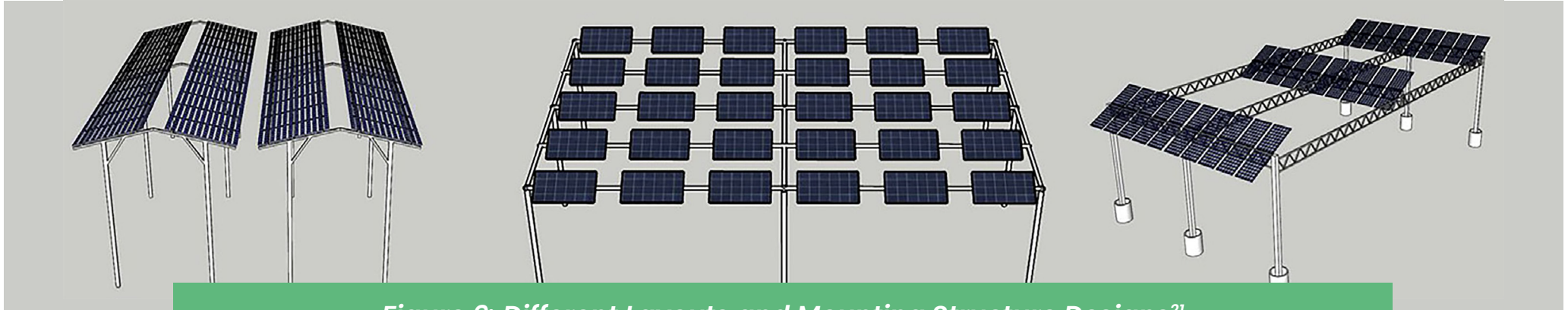


Figure 9: Different Layouts and Mounting Structure Designs²¹

On the flip side, the vertical interspaced AgriPV systems represent a different approach, where the PV modules are installed in a vertical orientation rather than overhead. In these systems, the design of the mounting structures differs significantly from overhead systems:

Reduced Height Requirements

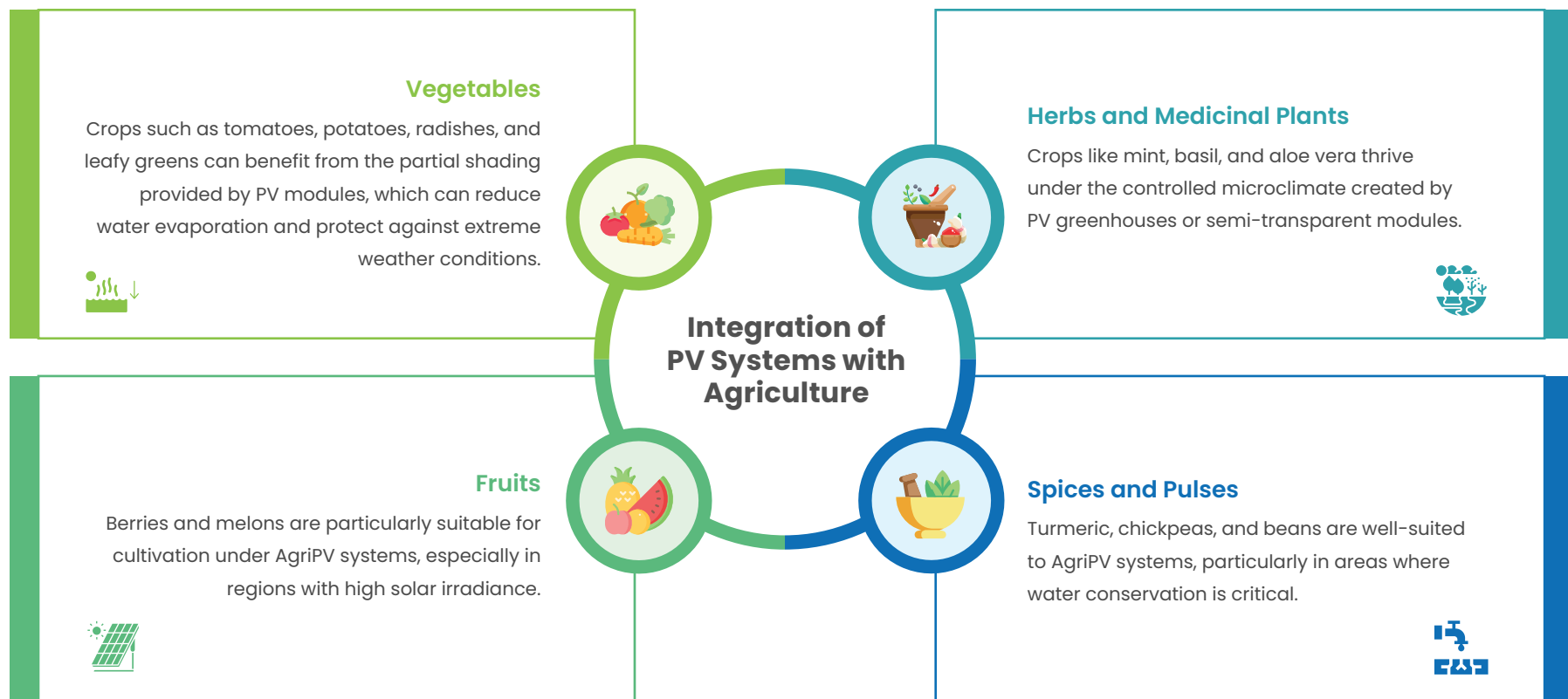
Unlike overhead systems, these installations do not require tall mounting structures. The height of the mounting structures in vertical systems typically ranges from 0.5 to 1.5 metres above the ground, just sufficient to support the modules while allowing for agricultural activities to take place around them.

Inter-Row Spacing Optimisation

A critical factor in vertical AgriPV systems is the spacing between rows of modules, which generally varies between 10 to 15 metres¹⁵. This spacing is optimised to ensure that farm equipment, such as tractors and harvesters, can easily navigate between the rows without obstruction. Additionally, wider spacing helps reduce shading impacts on the crops, allowing for sufficient sunlight penetration to support healthy growth.

2.4 Integration with Agriculture: Crops and Best Practices

The integration of PV systems with agriculture requires careful consideration of the types of crops grown and the agricultural practices employed. AgriPV systems can be adapted to a wide variety of crops including:



Crop Varieties Compatible with AgriPV Systems^{22, 23, 24, 25, 26}

Vegetables

 Ginger	 Potato	 Taro Root	 Radish	 Carrot	 Spinach	 Chilli	 Onion	 Garlic
 Mushroom	 Pea	 Rapeseed	 Cucumber	 Cauliflower	 Coriander	 Broccoli	 Lettuce	 Brinjal
 Capsicum	 Okra	 Bitter Gourd	 Bottle Gourd	 Ridge Gourd	 Sugarbeet	 Pumpkin	 Corn	

Fruits

 Berries (Raspberry, Strawberry)	 Melons (Muskmelon, Watermelon)	 Tomato	 Grapes	 Cherry Tomato
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Flowers

All shade tolerant varieties like



Hibiscus



Alfalfa



Tuberose



Rose



Marigold

Spices



Turmeric



Cumin

Pulses and Oilseeds



Moong Bean



Moth Bean



Cluster Bean



Chick Pea



Bajra



Maize



Grams



Soybean



Mustard

Herbs & Medicinal Plants



Mint



Coriander



Lemongrass



Basil



Cilantro



Aloe Vera



Sankhpushpi



Fenugreek

Plantation Crops



Coffee

Fibre Crops



Cotton

Fodder Crops

All

Best Practices for AgriPV Integration:

Rainwater Harvesting

AgriPV systems can be equipped with rainwater harvesting mechanisms that collect and store water for irrigation and cleaning of solar modules. This practice not only conserves water but also ensures that the crops receive adequate irrigation without the risk of waterlogging or heat stress from direct module runoff²⁷.

Shading Management

Proper shading management is essential to prevent photoinhibition²⁹, a condition where excessive sunlight inhibits photosynthesis in crops. By carefully designing the layout and density of PV modules, AgriPV systems can create optimal light conditions that enhance crop yields.

Soil Management

The presence of PV modules can impact soil conditions underneath them. To prevent problems like soil compaction or nutrient depletion, it is crucial to manage soil fertility and moisture levels carefully. For this, installation should be conducted during periods of low soil moisture. Using lighter machinery and mobile construction roads can also help to mitigate soil compaction.



Figure 10: Rainwater Harvesting in AgriPV

2.5 Monitoring and Maintenance of AgriPV Systems

The long-term success of AgriPV systems hinges on effective monitoring and maintenance. Regular monitoring ensures that both the PV systems and the agricultural activities are operating at optimal levels.

Monitoring AgriPV Performance

Using various sensors and smart monitoring systems, the performance of solar modules can be tracked in real-time. This data can be used to detect issues such as shading, soiling, or equipment malfunction, enabling timely maintenance actions.

Agricultural Monitoring

Monitoring crop growth, soil moisture, and microclimatic conditions is crucial for ensuring that the agricultural component of the AgriPV system remains productive. Sensors and automated systems can help track these parameters, allowing for precision agriculture practices that enhance yields.

Maintenance Practices

Routine maintenance of both the PV system and the agricultural land is necessary. For solar modules, this includes regular cleaning to remove dust and debris, which can reduce energy output. For the agricultural aspect, maintenance involves managing crop health, ensuring proper irrigation, and adjusting agricultural practices to suit the microclimate created by the PV system.



A grayscale photograph of a person's hands holding a handheld electronic device, possibly a data logger or a small tablet, in front of a large array of solar panels. The background is a bright, slightly hazy sky.

3

National Policy Framework for AgriPV

Presently, AgriPV projects are being executed under Component A of the Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM-KUSUM) Scheme in India³⁰. Under this scheme, AgriPV is facilitated by permitting the installation of solar power plants on elevated stilts above arable land, allowing for crop cultivation beneath the solar modules. These plants, ranging from 500 kW to 2 MW in capacity, can be established by individual farmers, farmer groups, cooperatives, panchayats, Farmer Producer Organizations (FPOs), or Water User Associations (WUAs). In cases where these entities cannot arrange the necessary equity for AgriPV projects, they have the option to collaborate with developers or local Distribution Companies (DISCOMs), designated as Special Purpose Groups (SPGs) in such scenarios.

DISCOMs are authorized to purchase the power generated through this arrangement at a predetermined feed-in tariff determined by the State Electricity Regulatory Commission (SERC). Furthermore, DISCOMs are eligible for a Performance Based Incentive (PBI) at the rate of Rs. 0.40 per unit purchased or Rs. 6.6 lakh per MW of installed capacity, whichever is lower, over a five-year period from the Commercial Operation Date (COD). It's essential to acknowledge that regulations regarding electricity and land use may vary among different states in India.

Under the PM Kusum scheme, AgriPV is facilitated by permitting the installation of solar power plants on elevated stilts above arable land, allowing for crop cultivation beneath the solar modules.



4

Pricing and Business Models for AgriPV

4.1 Pricing

The pricing of AgriPV systems varies significantly depending on the type of system. For example, overhead AgriPV installations typically require a higher investment than conventional GM-PV systems. This is due to the need for elevated mounting structures, additional site preparation, and the integration of systems for cleaning and water management to support both solar energy generation and agricultural activities. On average, overhead AgriPV systems incur 30 percent to 40 percent higher capital expenditures (CAPEX) compared to conventional GM-PV systems³¹.

For example, the cost of a 1 MW interspaced vertical AgriPV system is approximately INR 6.3 crore³². The key cost drivers for such systems include specialised mounting structures, which are not mass-produced, bifacial modules, additional land requirements due to lower deployment density per hectare, as well as the costs associated with agricultural infrastructure, design, and engineering.

4.2 Business Models

Exploring business models for deploying AgriPV systems is essential because they determine the financial viability and scalability of these projects. By identifying the most effective models, stakeholders can optimise resource use, maximise returns on investment, and ensure sustainable integration of agricultural and energy production. Well-structured business models can also address the unique challenges of AgriPV systems, such as higher upfront costs and dual land-use requirements, making them more attractive to investors and farmers alike.

Primarily there are four business models applicable for AgriPV in India.

1

Individual Farmer-owned

The individual farmer-owned model enables farmers to independently invest in and own AgriPV plants on their land. These farmers may secure financing through a combination of loans, equity, and government schemes to cover the costs of the system. Farmers retain full control over the installation, operation, and maintenance of the AgriPV system, allowing them to generate revenue from electricity sales via Power Purchase Agreements (PPAs) with DISCOMs and from agricultural produce cultivated under the solar modules. This model offers lower Levelized Cost of Electricity (LCOE) compared to others but requires substantial upfront investment, technical expertise, and sufficient land. Strategic planning, access to financing, and effective project management are essential for overcoming challenges and ensuring the success of AgriPV projects at the individual farmer level.



2

Community-owned Model

In the community-owned model led by Farmer Producer Organisations (FPOs), multiple farmers collectively contribute land and resources to install and manage the AgriPV system. The FPO, as the project owner, oversees financing, installation, and day-to-day operations. Revenue generated from electricity sales to DISCOMs and the sale of agricultural produce grown under the solar modules is shared among the participating farmers proportionately. This model allows small and marginal farmers to benefit from renewable energy and agricultural production without bearing the full financial burden individually. By pooling resources and sharing risks, farmers gain access to financing and technical expertise while fostering community development.



3

Developer-owned Model

In the developer-owned model, solar developers lease or rent farmland from rural landowners to install the system, while the land remains under the ownership of the farmers. The solar developers manage the installation, operation, and maintenance of the PV modules, generating electricity that is sold through PPAs with DISCOMs or used for captive consumption. Farmers receive regular lease payments, providing them with a stable source of additional income without significant disruption to their agricultural activities. Additionally, developers may offer farmers the opportunity to be hired for cleaning the modules when notified, providing farmers with an additional source of income. This model reduces financial risks for farmers, as the developers bear the primary costs and responsibilities, but it also requires careful management of land use agreements, technical considerations, and policy frameworks to ensure successful implementation.



4

DISCOM-owned Model

In this model, DISCOMs lease land from farmers to install and operate AgriPV systems. These systems are often installed near substations and are deployed with the aim to addressing power quality issues like voltage sagging at the grassroots level. DISCOMs handle financing, installation, and maintenance of these plants, while farmers receive lease payments, providing them with a steady income stream. Farmers retain control over agricultural activities on the leased land, allowing them to cultivate crops or raise livestock compatible with the solar setup. This model relieves farmers of the technical and financial burdens of solar PV installation, while DISCOMs benefit from efficient grid integration and reduced transmission losses. However, success requires careful negotiation of lease agreements, community engagement, and effective plant maintenance.





5

Case Studies and Best Practices

India, the seventh-largest country globally, spans approximately 3.28 million square kilometres with abundant arable land totalling 180.88 million hectares³³. The abundant availability of cultivable land, a well-established solar value chain, improved Land Equivalent Ratio (LER), the Government of India's (GOI) ambitious goal to double farmers' income, and the constraint on significant land usage for GM-PV collectively create a favourable environment for the incorporation of AgriPV within India's solar framework.

Industry experts estimate that India holds an extraordinary AgriPV potential exceeding 1.2 terawatts (TW)³⁴. This underscores the immense scope and viability of integrating solar technology with agriculture. Recent findings from a study conducted by Fraunhofer ISE highlight the transformative impact of AgriPV³⁵. The study suggests that converting just 1 percent of India's agricultural land into AgriPV, with a density of 450 kilowatts peak (kWp) per hectare, could contribute an astonishing additional photovoltaic capacity of around 630 GW³⁶.

The technology is currently in the demonstration phase, with numerous projects established on a pilot basis. The total quantum of AgriPV plants in India is around 20.38 MW, which are located in the various demographics of the country³⁷. This section provides a detailed description of three distinct plants, each varying in capacity, type, and cropping pattern.

The Government of India's (GOI) ambitious goal to double farmers' income, and the constraint on significant land usage for GM-PV collectively create a favourable environment for the incorporation of AgriPV within India's solar framework.



Case Study I **Sawai Madhopur AgriPV Plant**



The AgriPV plant in Sawai Madhopur, Rajasthan, marks a significant step forward in combining solar energy with agriculture. With over 1.5 years of operation, the results have been outstanding. The system, with a capacity of around 400 kW, is spread across approximately 1.5 acres of land. The success of this plant has also captured the interest of farm labourers, who are now eager to implement similar systems on their farms.



Key Features of the Plant

1 | Crops and Yield



Variety of Crops

The AgriPV plant supports the cultivation of a diverse range of crops under the solar modules. These include:

- Vegetables: Corn, okra, ridge gourd, bitter gourd, bottle gourd, green chilli, pumpkin, and taro root (arbi)
- Other Crops: Peppermint, pulses, and sugarcane



Yield Improvement

The implementation of AgriPV has led to increased crop yields due to reduced damage from extreme temperatures, demonstrating a positive impact on agricultural productivity



Mounting Structure Height



Lowest Point – **4.3 meters**

Highest Point – **4.8 meters**

Row Spacing



The distance between solar module rows is **3.5 meters**

Compatibility



The mounting structure does not affect traditional farming practices, and existing tractors are compatible with the structure height

2 | Installation and Structure



3 | Water Management



Water Consumption



There is a significant reduction in water use, averaging a **25% decrease** on a yearly basis



Microclimate Improvement

The installation has improved the microclimate, reducing temperature and evaporation rates



Water Recycling

Water used for cleaning the modules is directly utilized for irrigating the crops below

4 | Labor and Productivity

Worker Comfort

The improved microclimate has enhanced worker comfort

Decreased Effort

There is less effort required for weeding and pest control, and fewer issues with monkeys and birds

Equipment and Practices

No changes are required in farming equipment or practices

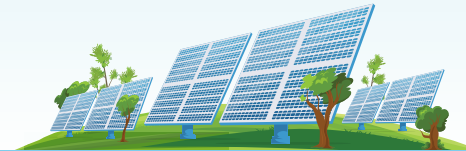
● Daily Generation

Average of **1600 units of energy/ day**

● Efficiency

Efficiency compared to GM-PV systems due to the cooler microclimate

5 | Energy Generation



Cleaning Frequency

Modules are cleaned every **10 days**



Maintenance Tools

A specialized ladder and cleaning toolkit are available on-site



Contract

There is a **5-year** maintenance contract with the developer



Training

Farm laborers are trained for module cleaning



Safety

Wiring installation is managed with overhead cable trays to ensure safety.



6 | Module Maintenance



7 | Economic Aspects



● Costs

The total cost of the AgriPV system is **₹2.2 crores**



Case Study II

Dayalbagh Educational Institute AgriPV Plant



The Dayalbagh Educational Institute, Agra boasts of an AgriPV plant with an installed capacity of 200 kWp DC. Commissioned in January, 2020, the plant spans over an area of 1 acre, utilizing semi-transparent mono-crystalline glass modules in a single column design. The system features a checkerboard pattern of monofacial and transparent modules, aided by 18 foot elevation and single-axis tracking system, leading to an increased energy yield of upto 20%.



Key Features of the Plant

1 | Type of Agrivoltaic Plant

- Single column



- Semi-transparent glass modules, monocrystalline
- Towers include monofacial modules, transparent modules, and a checkerboard pattern of mixed modules
- Space between modules designed to mitigate storm damage

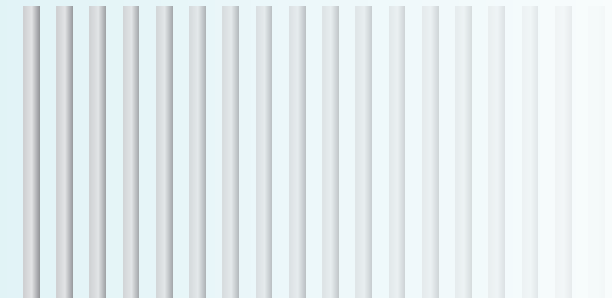
2 | Module Technology



Elevation height

18 ft

19 towers



each with **50 modules**

3 | Mounting Structure



4 | Tracking and Efficiency



Tracking System

Single axis tracking with azimuth tracking, claimed to increase yield by up to **20%**



Challenges

Storms previously damaged gearboxes; mitigated by additional mechanical locks



5 | Cleaning and Water Management



Cleaning Method

R&D in progress; variable pressure sprinkler system

Previous Cleaning

Manual cleaning every 15 days using a ladder



Ploughing



Easily done with a tractor

Crops



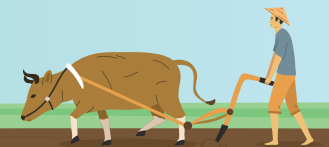
Grams, brinjal, tomato, wheat, spinach, cauliflower, carrot, gourds

Crop Size



Should not exceed **8 ft**

6 | Agricultural Aspects



7 | Crop Cultivation

● Irrigation

- Drip irrigation for all vegetables
- STP water used for grams (approximately **50-50%**)

● Tillage

1 – 2 ft; cables laid below **3 ft**





Case Study III

NISE Vertical AgriPV Plant

The National Institute of Solar Energy (NISE) initiated a pioneering pilot project near Gurgaon, Haryana, focusing on the vertical installation of bifacial module. This 5 kWp project, operational since June 2021, aims to explore the potential and performance of vertical bifacial PV installations, particularly in an AgriPV context.

Key Features of the Plant



1 | System Specifications



Type of Agrivoltaic Plant
Vertical Installation



Module Technology
Bifacial (mono-PERC) with
a bifaciality **factor of 0.85**



Cleaning

Not needed as the vertical
installation leads to reduced
soiling of solar panels

2 | Agricultural and Environmental Aspects



Soil Type

Loamy sand



Crops

Any





6

Comprehensive Benefits of AgriPV

AgriPV represents a transformative approach to land use, offering a range of benefits that extend beyond the individual realms of agriculture and solar PV. By integrating these two essential sectors, AgriPV systems provide multiple, synergistic advantages across social, economic, environmental, and technological dimensions. This section explores the comprehensive benefits of AgriPV, illustrating its potential to enhance land-use efficiency, increase agricultural productivity, and contribute to broader societal goals such as energy and food security.

Agricultural Benefits



1



Enhanced Agricultural Productivity³⁸

- AgriPV systems can create optimal growing conditions for crops by providing partial shade, which can be beneficial for certain plant species.
- The modified microclimate can lead to increased yields and improved crop quality.

2



Crop Protection³⁹

- The solar modules act as a physical barrier, protecting crops from extreme weather conditions such as hail, heavy rain, or excessive sunlight⁴⁰.
- This protection can reduce crop damage and losses.

3



Reduced Weed Growth⁴¹

- The shade provided by solar modules can inhibit weed growth, potentially reducing the need for herbicides and manual weeding.

4



Improved Irrigation Prospects⁴²

- AgriPV systems can be integrated with advanced irrigation technologies, allowing for more efficient water distribution.
- The shade from modules can reduce evaporation, making irrigation more effective.

5



Soil Quality Improvement⁴³

- AgriPV could potentially increase soil nitrogen availability, promoting plant and microbial growth.
- This can lead to healthier soil ecosystems and improved crop nutrition.

Environmental Benefits



6



Preservation of Agricultural Land

- AgriPV allows for the dual use of land for both energy production and agriculture, helping to preserve farmland that might otherwise be converted to solar farms.

7



Wind-Shielding Effect

- The structure of AgriPV systems can provide significant wind protection for crops, reducing wind-related stress and damage.

Economic Benefits



8



Economic Benefits for Farmers

- AgriPV provides an additional income stream through energy production or lease rent, diversifying farmers' revenue sources.
- It can also lead to reduced operational costs through on-site energy usage.

9



Risk Mitigation and Income Assurance

- The dual income from crops and energy production/lease rent helps farmers mitigate risks associated with crop failures or market fluctuations.



Energy-related Benefits

10



Energy and Food Security

- AgriPV contributes to both energy and food production, enhancing overall security in these critical sectors.

11



Enhanced Energy Generation

- Recent field tests show that AgriPV modules can be cooler compared to conventional solar farms, leading to a 3% increase in power generation during growing months.

12



Farm Operation Optimization

- Power generated can be used for various farm operations such as processing harvested products, electrifying machinery, and powering irrigation systems.



Land Use & Efficiency

13



Increased Land-Use Efficiency

- AgriPV maximizes land use by combining energy production with agriculture on the same plot.

14



Enhanced Human Comfort

- The shade provided by solar modules can reduce heat stress for farmers during their daily activities, improving working conditions.

15



Lightning Protection

- AgriPV systems can provide protection from lightning for farmers working in open fields, enhancing safety.



Human Factors



7

AgriPV in the Context of Uttar Pradesh

7.1

Overview of Renewable Energy Landscape

UP has huge potential for solar generation, due to it being located in the equatorial sunbelt region⁴⁴. It receives average solar irradiation between 2.9–3.9 kWh/m²/day⁴⁵. Land statistics from 2015–16 suggest 8537.06 sq. km of wasteland is present in the state⁴⁶. These geographical factors combine to give the state a good utility scale solar potential of around 22.83 GWp⁴⁷. To date, it had a total installed RE capacity of 6181.14 MW⁴⁸. The breakdown of the state’s installed RE capacity is provided in Table 1:

Table 1: UP Installed Capacity (in MW) of Renewable Power as of July 2024⁴⁸

 Small Hydro Power 49.1	 Wind Power 0	 Bio-Power Biomass Power/ Bio Gasses 1957.5 Biomass 165.26 Waste to Energy 0 Waste to Energy (Off Grid) 114.63 Total Bio Power 2237.39
 Solar Ground Mounted Solar 2700.02 Rooftop Solar 378 Hybrid Solar 0 Comp. Off-grid Solar/ KUSUM Solar 315.03 Total Solar Power 3393.05	 Large Hydro Power 501.6	Total RE 6181.14

The UP Solar Energy Policy 2022 aims to increase solar power to 22 GW within a period of 5 years from issuance. Figure 11 shows the sector-wise breakdown of the target.

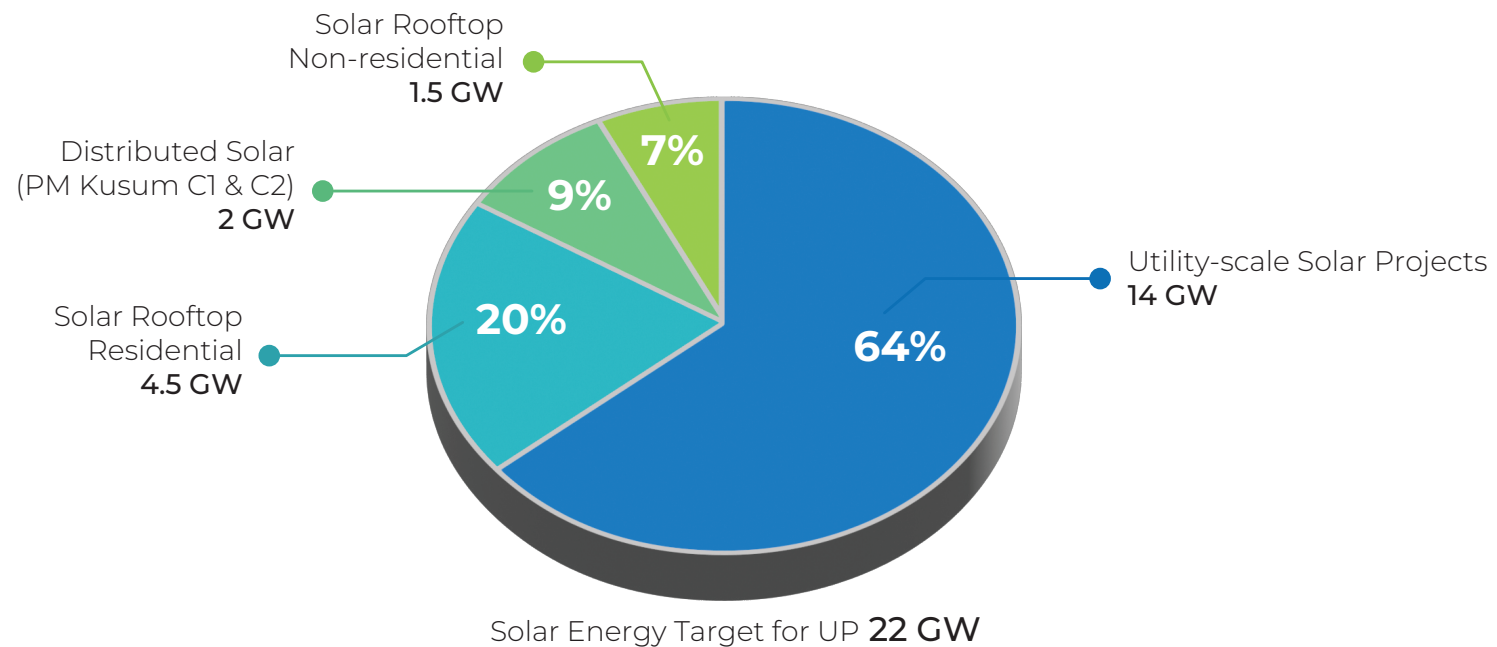


Figure 11: Solar Energy Target as per UP Solar Energy Policy 2022⁴⁹

Three projects totalling 196 MW are in the pipeline as of August 2024². Further, under the Solar City Programme, Ayodhya city has been declared as a model solar city (10% reduction in conventional energy demands from the installation of renewable energy systems and through energy efficiency measures⁵¹). Overall, 16 municipal corporations of the state and Noida city will be developed as solar cities in this policy's tenure.

7.2 Agricultural Profile

UP, often referred to as the “Granary of India,” is one of the most agriculturally significant states in the country. Spanning an area of 2,40,928 square kilometers⁵², it is the fourth largest state by area and the most populous, with 19.98 crore inhabitants⁵³. Agriculture forms the backbone of the state’s economy, employing 51.9% of its workforce⁵⁴. The gross state value added (GSVA) at current prices stands at INR 4,380,343 crores, contributing approximately 26.15% to the total GSVA at current prices⁵⁵. As of 2021-22, it contributes to 17.77% of all foodgrain production in the country, by far the highest among all states. The state’s agricultural prominence is further reflected in its leading position in producing essential crops like wheat, sugarcane, and rice, among others.

7.2.1. Agro-Climatic Conditions

UP spans a vast area, encompassing a variety of agro-climatic zones. It is divided into nine distinct agro-climatic zones: Terai, Western Plains (WP), Mid-Western Plains (MWP), Western Semi-Dry Plains (WSDP), Mid-Western South Plains (MWSP), South-Western Semi-Dry Plains (SWSDP), Bundelkhand (BUND), North Eastern Plains (NEP), and Vindhyachal (VIND). Figure 12 depicts the nine zones below. These zones experience significant climatic variations, with Bundelkhand being particularly drought-prone, while eastern UP frequently faces floods and waterlogging.

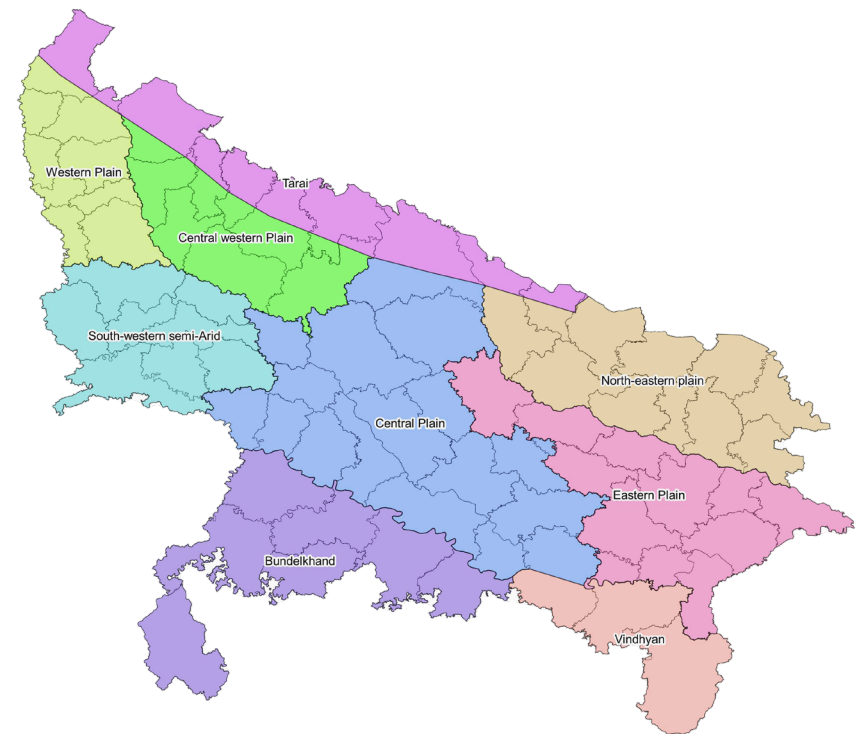


Figure 12: Agro Climatic Regions in UP⁵⁶

7.2.2 Major Crops and Agricultural Outputs

As of 2021-22, UP has a total net sown area of 16.09 million hectares⁵⁷, making it a significant contributor to India's agricultural output. The state is the largest producer of wheat in the country⁵⁶, with extensive cultivation in the Western and Central Plains. UP also leads in sugarcane production⁵⁶, with vast areas in the Western Plains dedicated to this crop, which plays a crucial role in the state's economy and employment. Rice is another staple crop, especially in the Eastern Plains, with both kharif and rabi varieties being cultivated. Additionally, the state produces a variety of pulses, such as lentils, gram, and pigeon pea, along with oilseeds like mustard and groundnut, which are integral to crop rotation and nutrition. A summary of the total area under and production of some principal crops grown in the state is provided below in Table 2.

Table 2: Area Under & Production of Principal Crops in UP

S.No	Crops	Area in 1000 ha (2022-23)	Production in 1000 tonnes (2022-23)
	Cereals	18611	59544
1	Rice	6179	16562
2	Wheat	10193	38070
3	Barley	193	591
4	Juar	198	315
5	Bajra	947	2046
6	Maize	891	1952
7	Other cereals	10	8

S.No	Crops	Area in 1000 ha (2022-23)	Production in 1000 tonnes (2022-23)
	Pulses	2756	2979
8	Urad	608	325
9	Moong	112	76
10	Arhar	349	428
11	Gram	680	917
12	Other Pulses	1006	1233
S.No	Oilseeds	1806	2157
13	Rapeseed and mustard+	1275	1909
14	Groundnut	98	115
15	Other Oil seeds	432	133
S.No	Other Crops	3576	263850
16	Sugarcane	2853	239462
17	Potato	694	24294
18	Tobacco	23	92
19	Cotton	4	1
20	Jute	2	1

Horticultural crops, including fruits like mangoes, guavas, and bananas, and vegetables like potatoes, tomatoes, and onions, account for 8.9% of the total cultivated area and contribute 12.8% to the state's overall crop production (yield)⁵⁸. The state's diverse climate allows for the cultivation of a wide variety of horticultural crops. Tables 3 and 4 provide the percentage share of area under and production of some major horticulture crops in UP.

Table 3: Percentage Share of Area Under and Production of Major Vegetable Crops in UP (2018)

S.No	Major Crops	Area Share (%)	Production Share (%)
1	Bitter Gourd	0.19	23.63
2	Bottle Gourd	1.05	16.67
3	Brinjal	0.67	18.46
4	Cabbage	0.74	37.08
5	Carrot	0.39	15.62
6	Cauliflower	1.48	20.87
7	Kaddu/Pumpkin	1.36	20.11
8	Okra /Ladies Finger	1.13	18.63
9	Onion	1.6	1.59
10	Peas (Green)	9.3	6.28
11	Pointed Gourd /Parwal	0.21	17.51
12	Potato	55.75	24.47
13	Raddish	0.55	23.59
14	Sweet Potato	0.85	1.67
15	Tomato	3.09	30.7
16	Other Vegetables	19.46	7.41

Table 4: Percentage Share of Area Under and Production of Major Fruit Crops in UP (2018)

S.No	Major Crops	Area Share (%)	Production Share (%)
1	Aonla/Gooseberry	7.43	3.66
2	Banana	14.47	29.98
3	Guava	10.38	8.84
4	Jackfruit	0.13	0.14
5	Litchi	0.89	0.35
6	Mango	55.89	43.0
7	Muskmelon	4.40	5.18
8	Papaya	0.40	0.88
9	Watermelon	2.84	5.81
10	Other Citrus	0.84	0.15
11	Other Fruits	2.33	1.61

7.2.3. Pricing of Crops

Gol sets the Minimum Support Price (MSP) for 22 key agricultural crops each year, based on recommendations from the Commission for Agricultural Costs & Prices (CACP), along with input from state governments and relevant central ministries. In the 2018-19 Union Budget, the government committed to ensuring that MSPs are at least 1.5 times the cost of production, providing farmers with a minimum 50% return on their investment⁵⁹. Since then, the MSPs for kharif, rabi, and other commercial crops have consistently increased, ensuring better financial security for farmers. The details of MSP adjustments over the past three years, as shown in Table 5, including notable increases for the 2022-23 and 2023-24 seasons, reflect the government's ongoing efforts to support agricultural producers through fair pricing.

Table 5: Minimum Support Prices (MSP) (Rs. per Quintal)

	S.No.	Commodity	Variety	2021-22	2022-23	2023-23
KHARIF CROPS	1	Rice	Common	1940	2040	2183
			Grade 'A'	1960	2060	2203
	2	Jowar	Hybrid	2738	2970	3180
			Maldandi	2758	2990	3225
	3	Bajra		2250	2350	2500
	4	Ragi		3377	3578	3846
	5	Maize		1870	1962	2090
	6	Tur (arhar)		6300	6600	7000
	7	Moong		7275	7755	8558
	8	Urad		6300	6600	6950
	9	Groundnut		5550	5850	6377
	10	Sunflower seed		6015	6400	6760
	11	Soyabean (yellow)		3950	4300	4600

	S.No.	Commodity	Variety	2021-22	2022-23	2023-23
KHARIF CROPS	12	Sesamum		7307	7830	8635
	13	Nigerseed		6930	7287	7734
	14	Cotton	Medium Staple	5726	6080	6620
			Long Staple	6025	6380	7020
RABI CROPS	15	Wheat		2015	2125	2275
	16	Barley		1635	1735	1850
	17	Gram		5230	5335	5440
	18	Masur (lentil)		5500	6000	6425
	19	Rapeseed & mustard		5050	5450	5650
	20	Safflower		5441	5650	5800
OTHER CROPS	21	Copra (calendar year)	Milling	10335	10590	10860
			Ball	10600	11000	11750
	22	Jute		4500	4750	5050

7.2.4 Land Use Patterns and Farm Holdings

The land use patterns in UP reflect a dynamic agricultural landscape with significant variations over the years. In 2021-22, the total reporting area was 23,514 thousand hectares, a slight decrease from the previous years as shown in Table 6.

Table 6: Land Utilization in UP (in 000' hectares)

Items	2019-20	2020-21	2021-22
Reporting area+	24,170	24,170	23,514
Forest	1,771	1,771	1,772
Barren and unculturable land	438	438	392
Land put to non-agricultural uses	3,278	3,278	3,015
Culturable waste land	387	387	369
Permanent pastures and other grazing land	70	70	70
Land under miscellaneous trees, crops, and groves	249	249	237
Current fallows	992	992	966
Other fallow	618	618	596
Net area sown	16,368	16,368	16,096
Area sown more than once	10,741	10,741	12,250

Forest land remained relatively stable at around 1,772 thousand hectares, while barren and unculturable land decreased to 392 thousand hectares. Land put to non-agricultural uses also saw a reduction to 3,015 thousand hectares. The area of culturable waste land slightly declined to 369 thousand hectares, and permanent pastures and other grazing lands were consistent at 70 thousand hectares. Land under miscellaneous trees, crops, and groves decreased to 237 thousand hectares. Both current and other fallow lands showed a decrease, with current fallows at 966 thousand hectares and other fallows at 596 thousand hectares. Notably, the net area sown decreased to 16,096 thousand hectares, while the area sown more than once increased to 12,250 thousand hectares, indicating a trend towards intensified cropping practices. This data underscores the ongoing adjustments in land use and agricultural practices in response to changing environmental and economic conditions.

The data on agricultural landholdings in UP for the year 2015-16, as shown in Table 7, reveals a diverse distribution of land across various holding sizes.

Table 7: Number, Area and Average Size of Agricultural Landholdings in UP 2015-16⁵⁵

Category	Number of Operational Holdings	Percentage of Total Holdings	Area of Operational Holdings (Hectares)	Percentage of Total Area	Average Size of Holdings (Hectares)
Marginal	1,90,99,828	80.30%	72,98,325.75	41.80%	0.38
Small	30,08,403	12.60%	41,74,659.29	23.90%	1.39
Semi-Medium	13,13,695	5.50%	35,59,517.75	20.40%	2.71
Large	3,76,790	1.60%	20,74,622.78	11.90%	5.51
All	2,38,21,625	100%	1,74,50,370.04	100%	0.73

In UP, the distribution of agricultural holdings underscores a significant concentration of marginal and small farms, which dominate both in number and area. Marginal holdings represent 80.3% of the total number of operational holdings and account for 41.8% of the total agricultural area, with an average holding size of just 0.38 hectares. Small holdings follow, comprising 12.6% of the total number of holdings and covering 23.9% of the area, with an average size of 1.39 hectares. Semi-medium and large holdings, though fewer in number, cover substantial areas, with semi-medium holdings representing 5.5% of the total number but occupying 20.4% of the area, and large holdings making up 1.6% of the total number and 11.9% of the area. This distribution highlights the prevalence of small-scale farming and the potential impact of AgriPV systems.

7.3 AgriPV Policy Framework

The UP Solar Energy Policy 2022 sets an ambitious target of achieving 22 GW of solar power capacity by 2026-27. Of this, 14 GW is earmarked for utility-scale projects, which include Distributed RE initiatives. Under this framework, the Uttar Pradesh Power Corporation Limited (UPPCL) and DISCOMs will procure the solar power generated by these utility-scale solar projects, including AgriPV, in alignment with the Renewable Purchase Obligation (RPO) as determined by the Uttar Pradesh Electricity Regulatory Commission (UPERC). This policy underscores the state's commitment to integrating agricultural practices with solar energy generation, promoting sustainable development, and optimizing land use for both energy and agriculture.

7.4 Potential Benefits of AgriPV for Uttar Pradesh

AgriPV presents a significant opportunity for UP, a state with a robust agricultural sector and diverse land use patterns. Given that agriculture dominates the land use in the state, with the net sown area accounting for 68.4% of the total reported area⁵⁷, integrating solar energy generation with farming can enhance land productivity and provide additional revenue streams to farmers. UP, divided into nine agro-climatic zones, faces diverse climatic challenges, including drought-prone areas in Bundelkhand and flood-prone regions in Eastern UP. AgriPV systems can help mitigate these challenges by promoting sustainable agricultural practices and reducing the dependence on traditional, water-intensive farming techniques. The following section delves into these and other benefits in detail.

Potential Benefits of AgriPV

**Additional
Revenue Stream
for Farmers**



**Sustainable
Water Use &
Management**



**Protection Against
Deaths Due to
Lightning**



**Horticulture Crops
and Improved
Storage**



**Protection
Against Excessive
Heat**



**Energy
Infrastructure
Benefits**





Additional Revenue Stream for Farmers

The state's agricultural landscape is characterized by small and fragmented landholdings, with an average landholding size of 0.73 hectares below the national average of 1.08 hectares⁵⁵. In this context, AgriPV can be particularly beneficial for marginal and small farmers, who constitute the majority (~92%)⁵⁵ of the state's farming community and have a land holding of meagre 0.38 hectares. Six of the principal crops grown in UP- Maize, moong, gram, mustard, potato, corn- are suitable for AgriPV deployment⁶¹. Nine of the major vegetable crops grown in UP (bitter gourd, bottle gourd, brinjal, cauliflower, okra, onion, peas, potato and raddish) are suitable for AgriPV deployment, alongside two of the major fruit crops- muskmelon and watermelon.

Moreover, AgriPV's importance is further emphasized by the low income faced by the farmers in the state. The average income of an agricultural household in UP was INR 8,061, considerably lower than the national average of INR 10,218⁶⁰, as displayed in Figure 13.

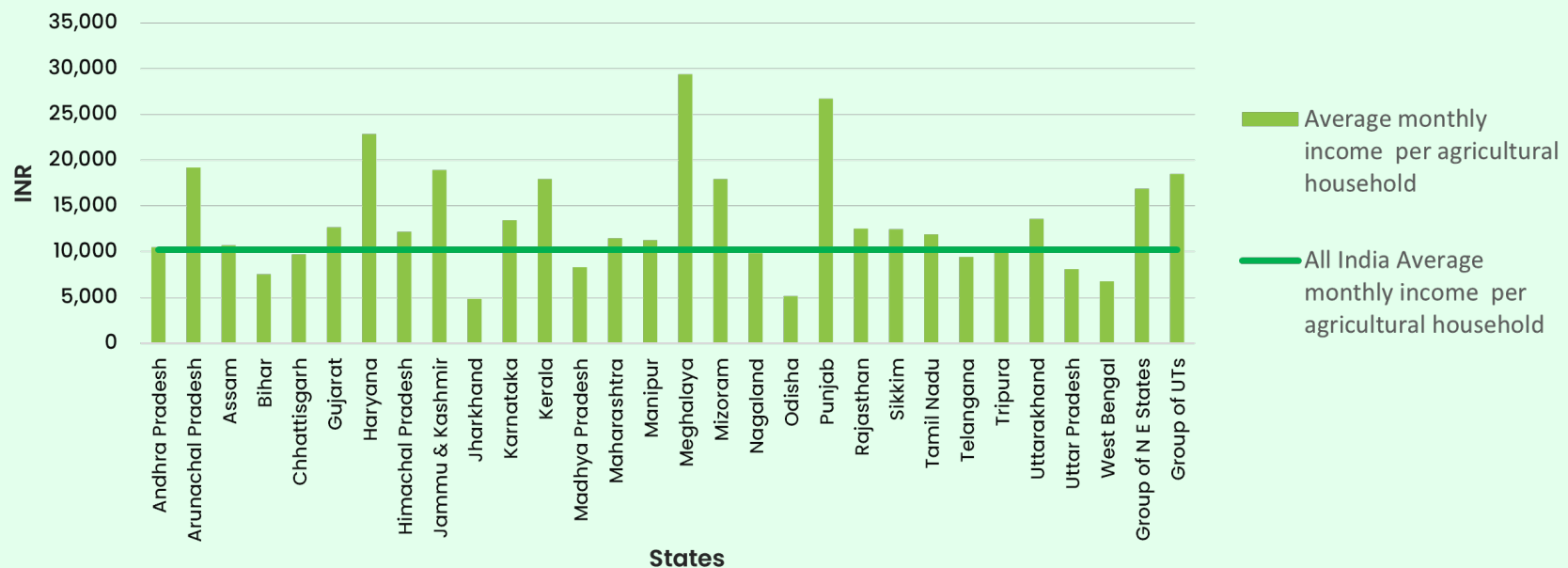


Figure 13: State-wise Average Monthly Income Per Agricultural Household in 2018-19⁶⁰

By installing solar modules over their fields, these farmers can generate additional income through the sale of electricity, lease rent, etc., while simultaneously continuing to cultivate crops beneath the modules. This dual use of land is especially relevant in a state where the pressure on agricultural land is high, and there is a need to maximize the utility of every hectare.



Horticulture Crops and Improved Storage

As seen above, UP has a substantial area under horticulture, which accounts for 8.9% of the total cropped area and 12.8% of the state's total crop production (yield)⁵⁸. In 2018, UP led in vegetable crop area and production in the country, with 14.0% of the area and 15.6% of production⁵⁸. During the same period, UP ranks third in both area and production of total fruit crops, following Maharashtra and Andhra Pradesh. Integrating AgriPV with horticultural practices can improve crop yields by providing partial shading, which is beneficial for certain crops, while also enabling creation of cold storage and processing infrastructure. This will ensure that perishable produce like fruits and vegetables are stored efficiently and reach markets in good condition.



Sustainable Water Use and Management

UP depends heavily on both canal and groundwater irrigation, but the latter has resulted in declining water tables in certain areas. Implementing AgriPV, which often incorporates rainwater harvesting and efficient water management systems, as well as reducing evaporation from the soil underneath, can help the state promote sustainable water use. This is vital for ensuring the long-term viability of agriculture, particularly in regions like Bundelkhand where water scarcity is an increasing concern.



Protection against Excessive Heat

In recent years, heat intensity has risen in several parts of India, making it increasingly challenging for people to perform daily activities under the scorching sun, let alone engage in farming. UP has experienced over 100 days in the past few years where the maximum temperature exceeded 35 degrees Celsius, as illustrated in Figure 14. The shading provided by an AgriPV system can significantly reduce heat stress, offering much-needed relief to farmers, as confirmed by the case studies discussed in section 5.

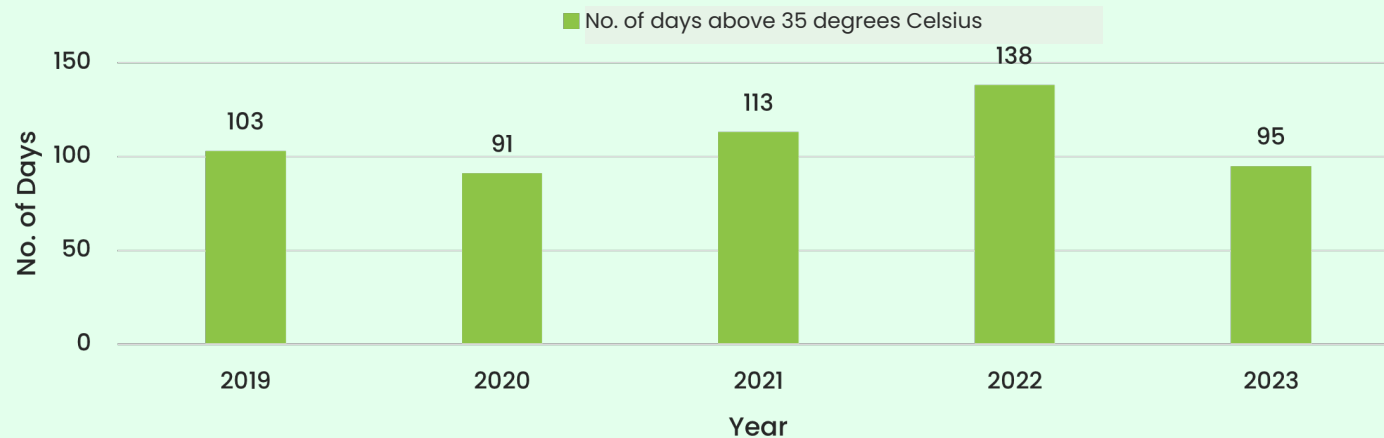


Figure 14: No. of Days above 35 Degrees Celsius in UP⁶²



Protection against Deaths Due to Lightning

UP, along with states like Bihar, Jharkhand, Odisha, and West Bengal, ranks high in lightning-related deaths⁶³, highlighting the urgent need for protective measures. The state had a total of 844 accidental deaths due to lightning between 2019 and 2021, as shown in Figure 15, the fourth highest among all states.

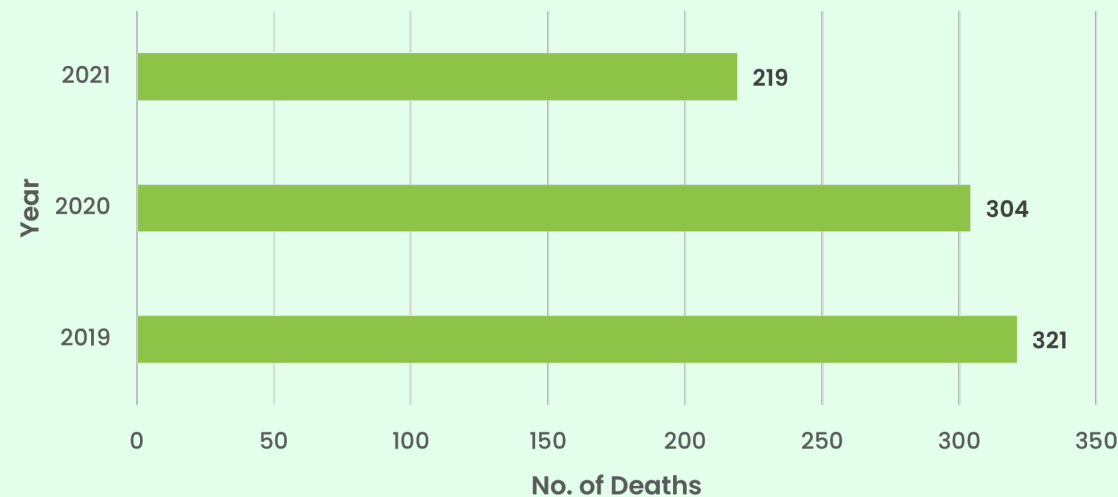


Figure 15: Number of Accidental Deaths Due to Lightning in UP between 2019–21⁶³

Integrating AgriPV systems in agricultural areas can provide a dual benefit: improving crop yields and offering a safer environment for farmers. The metal structures of AgriPV systems if properly grounded, can serve as a protective shield against lightning strikes, reducing the risk of fatalities. Additionally, the installation of surge protector and lightning rod along with the AgriPV plant can help protect both the system and the people around from lightning strikes.



Energy Infrastructure Benefits

Moreover, the state's energy infrastructure can benefit significantly from the widespread adoption of AgriPV. UP, with its large rural population, has a high demand for electricity, particularly for agricultural purposes. AgriPV can contribute to meeting this demand by generating RE at the point of use, reducing transmission losses, and enhancing the reliability of the power supply in rural areas. This aligns with the state's broader goals of promoting RE and reducing carbon emissions.

7.5 Existing AgriPV Initiatives in Uttar Pradesh

AgriPV Project Details	Amity University	Dayalbagh Educational Institute
Location	Noida, Gautam Buddh Nagar District, UP	Agra, UP
Date of Commission	2017	26th January 2020
Installed Capacity	10 kWp DC	200 kWp DC
Project Developer	Amity University, in-house development	Dayalbagh Educational Institute (DEI), Faculty of Engineering
EPC	Not Applicable	Dayalbagh Educational Institute
Ownership Structure	Amity University	Dayalbagh Educational Institute
Funding Agency	Department of Science and Technology, Government of India	Department of Science and Technology (DST) Mission Innovation
Operation & Maintenance	Amity University	Dayalbagh Educational Institute
Scientific Partner	Amity University	Dayalbagh Educational Institute (Deemed University)
Financing Structure	Project cost: 24.9 lakh INR; electricity used for self-consumption	Project investment: 3 crore INR (150,000 INR/kWp); payback time: 7 years
Type of Agrivoltaic Plant	Single column	Single column
Module Technology	Monofacial, polycrystalline (330 Wp), Canadian	Semi-transparent glass modules, monocrystalline; transparent & regular tedlar sheets

AgriPV Project Details	Amity University	Dayalbagh Educational Institute
Mounting Structure	Optimum tilt angle	18ft elevation height
	4.6m height of mounting pole	19 towers, each with 50 modules
	Area: 630 m ² ; 159 kWp/ha	3.5 tons per column, ongoing R&D to reduce weight
Tracking	None	Single-axis azimuth tracking, increasing yield by up to 20%
Cleaning & Water Management	Automatic piping system for sprinkler module cleaning	R&D on variable pressure sprinkler system
	Drainage system implemented	Manual cleaning with a ladder every 15 days
Soil Type	Sandy loam	Deep loamy soils
Crops	Maize, potato, brinjal, mustard	Grams, brinjal, tomato, wheat, spinach, cauliflower, carrot, gourds
Crop Cultivation	Nearly 90% land utilized for cultivation	Drip irrigation for vegetables, STP water for grams
	Crop height up to 1m	Crop sizes up to 8ft
	Minimal shading impact, crop yield unchanged	Tillage of 1-2ft, cables laid below 3ft
Further Aspects	Farmer-friendly cabling above the ground attached to cleaning water pipes	Additional battery storage system implemented
	No storage of harvested water, directly drops onto fields reducing irrigation needs	Sheets and mulching applied for further water savings



8

Recommendations to Scale Up **AgriPV** Deployment in Uttar Pradesh

To harness the full potential of AgriPV in UP, a robust and multifaceted policy framework is essential. The following recommendations outline strategic actions across various domains, including pilot project deployment, government frameworks, financial incentives, capacity building, land policy amendments, and research and development support. These recommendations aim to create an enabling environment that promotes the adoption, scalability, and sustainability of AgriPV systems.

Key Recommendations

1



Pilot Projects

- Launch at least one 1 MWp AgriPV pilot projects in each district or agro-climatic zone of UP.

2



Governance and Promotion

- Create a dedicated agency responsible for coordinating AgriPV initiatives, providing technical assistance, serving as a knowledge hub.
- Integrate AgriPV into existing solar policy and introduce specific incentives to encourage adoption.
- Develop clear regulations outlining land use, installation standards, safety protocols, and maintenance requirements for AgriPV systems.
- Utilize multiple channels (e.g., workshops, digital platforms) to educate farmers about the benefits and operational aspects of AgriPV.
- Highlight case studies and testimonials from pilot projects to build trust and interest among potential adopters.

3



Market and Infrastructure Development

- Create markets for AgriPV-specific crops at the sub-district level.
- Provide cold-chain storage facilities at the sub-district level.

4



Capacity Building and Operational Support

- Develop and deliver training modules on the installation, operation, and maintenance of AgriPV systems. Topics should include solar module management, system troubleshooting, and safety protocols.
- Introduce certification programs for technicians and farmers who complete AgriPV training, ensuring a standard level of competence and encouraging professional development.

5



Financial Incentives

- Offer subsidies covering at least 30% of the capital expenditure (CAPEX) for AgriPV installations to reduce initial investment barriers.
- Offer preferential Feed-in-Tariffs (FiTs) to AgriPV systems to make them financially competitive with conventional solar installations.
- Facilitate access to low-interest loans for farmers and companies investing in AgriPV, reducing the financial burden of upfront costs.
- Combine various financial incentives (subsidies, loans, FiTs) to create comprehensive packages that address different financial needs and risk profiles of stakeholders.
- Encourage demand aggregation for deployment of AgriPV systems, enhancing bargaining power and reducing costs through economies of scale.

6



Land Policy Amendments

- Develop explicit guidelines that define permissible land uses for AgriPV installations, distinguishing them from other forms of solar projects.
- Amend land leasing policies to allow for AgriPV installations on agricultural land, provided that crop yield guarantees (e.g., maintaining at least 90% of reference yields) are met.
- Ensure that farmers retain ownership and control over their land when leasing it for AgriPV projects, protecting their land rights and ensuring fair compensation.
- Establish mechanisms to resolve land-use disputes related to AgriPV installations promptly and fairly.
- Integrate AgriPV considerations into broader agricultural and rural development plans, ensuring that energy projects align with agricultural goals and community needs.
- Simplify and expedite the permitting and approval processes for AgriPV projects to reduce administrative burdens and encourage swift adoption.

7



Farmer Support

- Ensure reliable and timely disbursement of solar lease income to participating farmers.
- Establish a dedicated grievance redressal committee with defined resolution timeframes.

8



Research and Development

- Allocate specific funding streams for AgriPV research within state renewable energy budgets.
- Encourage collaboration between government research bodies, private companies, and academic institutions to drive AgriPV innovation.
- Support the development of more efficient, durable, and crop-compatible solar modules, such as semi-transparent and bifacial modules tailored for agricultural use.
- Develop metrics to assess the sustainability and environmental impact of AgriPV systems.

Implementation Guidelines

- Extend benefits only when agricultural processes are ongoing beneath and between PV modules.
- Require annual reporting of crop yields.
- Mandate that agricultural yield post-AgriPV installation must be at least 90% of the reference yield (based on 3-year average before installation or comparable data).
- If conditions are not met, require removal of AgriPV systems and land restoration.



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