



# **BUSINESS MODELS FOR AGRIVOLTAICS IN INDIA**

**ANALYSIS OF VARIOUS BUSINESS MODELS  
AND THEIR SOCIO-ECONOMIC IMPACT**







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**Organization**

The India Agrivoltaics Alliance is a collaborative platform of 48 organisations anchored at the NSEFI secretariat in New Delhi. The IAA aims to build partnerships and platform voices from the agriculture and solar sectors to address issues at the nexus of food-energy-water, including carbon emissions, rising food insecurity, and a need to enhance agrarian livelihoods and land productivity.

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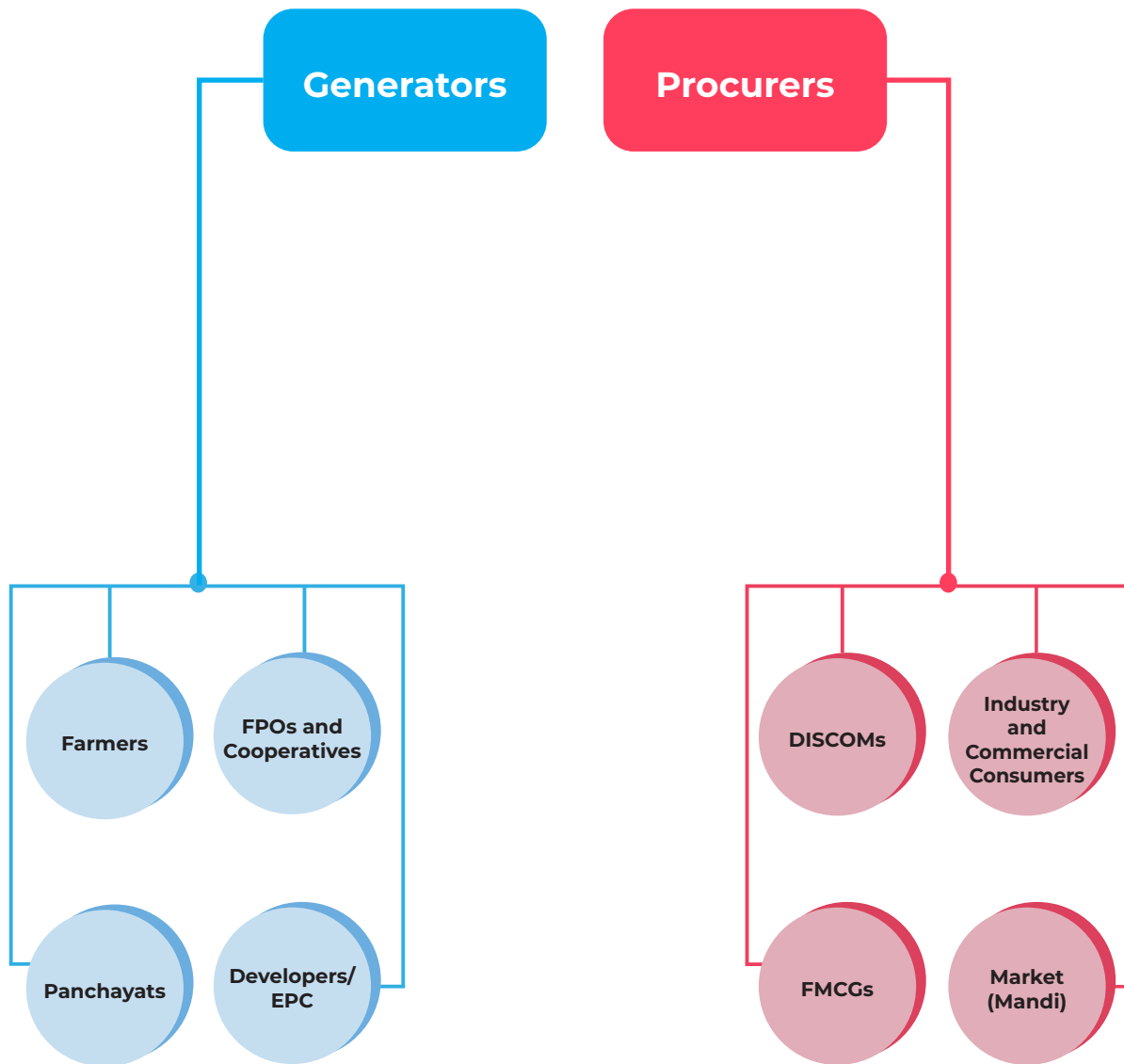
# CONTENTS

<b>1. Defining Players of Agrivoltaics Business Ecosystem</b> .....	<b>1</b>
<b>Generators</b> .....	<b>1</b>
Farmers .....	1
Farmer Producer Organizations (FPOs) and Cooperatives.....	1
Panchayats.....	2
Developers/EPC (Engineering, Procurement, Construction) .....	2
<b>Procurers</b> .....	<b>2</b>
DISCOMs (Distribution Companies).....	2
Industry and Commercial Consumers .....	2
Fast-Moving Consumer Goods Companies (FMCGs) .....	2
Market (Mandi).....	2
<b>2. Business Models for Agrivoltaics</b> .....	<b>3</b>
2.1 Individual Farmer Owned Model .....	3
2.2 Community-Owned by Farmer Producer Organizations (FPOs) Model .....	5
2.3 Developer Owned Model.....	8
2.4 DISCOM-Owned Model.....	10
2.5 Variant Models to accelerate the uptake of Agrivoltaic.....	13
A. Integration of Agrivoltaics with Value-Adding Infrastructure .....	13
B. Electricity Sale from agrivoltaics through Open Access.....	14
C. Agrivoltaics Plant Supplying Electricity and Agricultural Produce to FMCGs.....	15
D. Integration of Agrivoltaics with Clean Fuel Generation .....	16
<b>3. Socio-Economic Impacts of AGRIVOLTAICS BUSINESS MODELS</b> .....	<b>17</b>
<b>CONCLUSION</b> .....	<b>20</b>



# 1. Defining Players of Agrivoltaics

## BUSINESS ECOSYSTEM



### GENERATORS

#### Farmers

Farmers are the cornerstone of agrivoltaic systems, providing the land and managing agricultural activities. They balance crop production with solar panel placement to optimize both yields, ensuring that neither farming nor energy generation is compromised.

#### Farmer Producer Organizations (FPOs) and Cooperatives

FPOs and cooperatives aggregate resources and knowledge, enabling small-scale farmers to participate in agrivoltaic projects. They negotiate better terms, achieve economies of scale, and provide a platform for collective decision-making and resource management.

## **Panchayats**

As local governing bodies, panchayats play a crucial role in facilitating land access, obtaining regulatory approvals, and engaging with the community. Their support promotes local adoption and integration of agrivoltaics, ensuring that projects are aligned with community needs and regulations.

## **Developers/EPC (Engineering, Procurement, Construction)**

Developers and EPC companies are responsible for the comprehensive development of agrivoltaic projects. This includes planning, procurement of materials, construction, and commissioning, ensuring that projects are delivered on time and within budget.

## **PROCURERS**

### **DISCOMs (Distribution Companies)**

DISCOMs purchase the electricity generated by agrivoltaic systems and integrate it into the grid. They play a vital role in distributing renewable energy to end consumers, supporting the transition to sustainable energy sources.

## **Industry and Commercial Consumers**

Industrial and commercial entities purchase renewable energy to meet their operational energy needs and sustainability goals. Their demand drives the market for renewable energy and supports the economic viability of agrivoltaic projects.

### **Fast-Moving Consumer Goods Companies (FMCGs)**

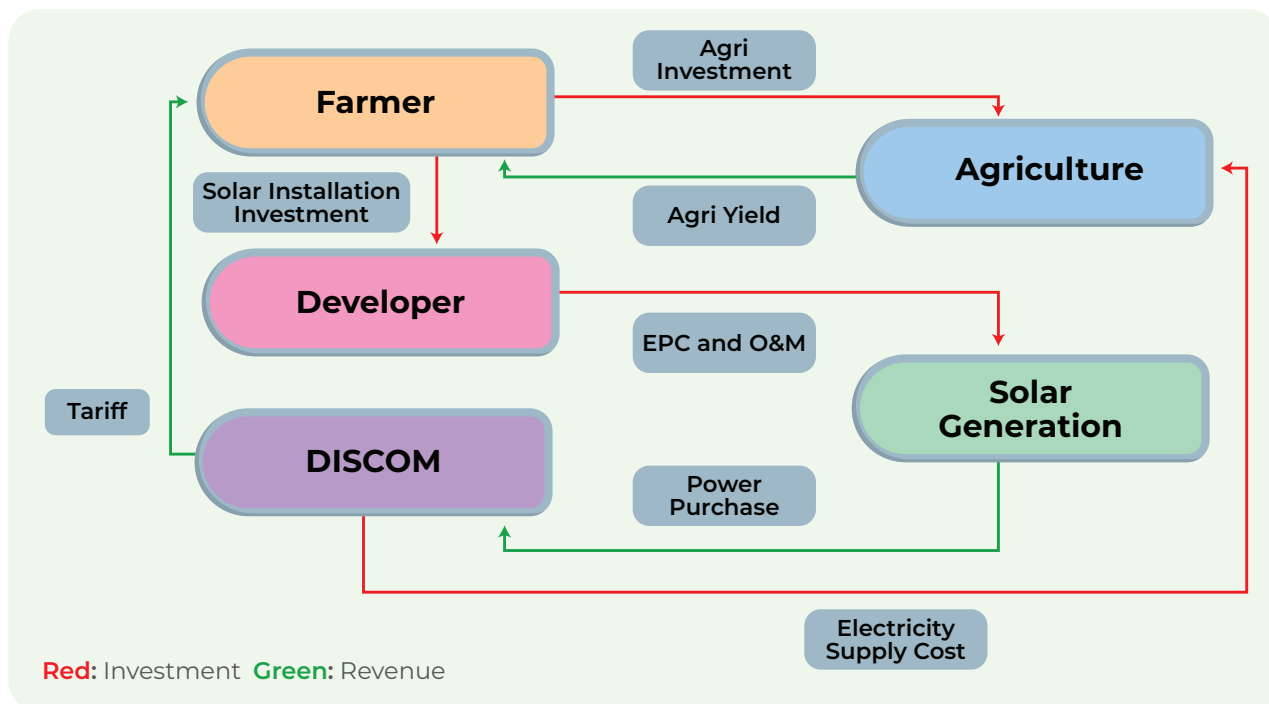
FMCGs may source agricultural products produced under agrivoltaic systems, supporting sustainable sourcing and enhancing their supply chains. Their involvement will ensure that agrivoltaic produce reaches a broad market.

### **Market (Mandi)**

Mandi acts as an intermediary between farmers, agricultural producers, and buyers (such as food processors, wholesalers, or retailers) in the Agrivoltaics ecosystem. They procure agricultural produce, or other processed products from farmers and suppliers, and sell them to buyers. Mandi act as a vital conduit, enabling the efficient flow of goods, services, and information within the Agrivoltaics business ecosystem.

# 2. Business Models for AGRIVOLTAICS

## 2.1 INDIVIDUAL FARMER OWNED MODEL



**Figure 1:** Schematic diagram for the individual farmer owned business model

In this business model, individual farmers independently invest and own Agrivoltaics plants on their own land. This business model is particularly for affluent farmers who have the financial strength to invest equity or apply for a loan. These farmers secure financing through a combination of loans and equity, either from financial institutions, government schemes, or private investors. This investment covers the costs associated with solar PV panels, mounting structures, inverters, and other necessary equipment.

The Agrivoltaics plant generates revenue through the sale of electricity via power purchase agreements (PPAs) with electricity distribution companies (DISCOMs) and through the sale of agricultural produce cultivated under the solar panels.

**Solar PV Installation:** Farmers own and oversee the installation of solar PV panels on their land, ensuring optimal placement to maximize energy generation while allowing for agricultural activities to continue beneath or around the panels.

### Advantages

Farmers retain full ownership and control over the Agrivoltaics plant, allowing them to make decisions regarding its management, maintenance, and operation.

Has a relatively lower LCOE compared to other business models.

### Challenges

The initial investment required for setting up an Agrivoltaics plant may be substantial, requiring farmers to secure financing and manage cash flow effectively.

Farmers need technical expertise or assistance to design, install, and maintain the Agrivoltaics system, including understanding solar PV technology, electrical systems, and agricultural practices compatible with solar panels - like the crops compatible to grow under panels, irrigation methods that may use the water used for cleaning the panels etc.

Farmers must have sufficient land available for installing Agrivoltaics plants without compromising essential agricultural activities or infringing on regulatory restrictions.

The individual farmer owned Agrivoltaics plant model offers farmers the opportunity to diversify income sources, promote energy independence, and practice sustainable agriculture. While challenges such as upfront investment, technical expertise, market risks, and land availability exist, strategic planning, access to financing, and proper project management can help overcome these challenges and ensure the success of Agrivoltaics projects at the individual farmer level.

## 1. EXPENDITURE/COSTS

### 1.1 Capital Expenditure (CapEx)

- Solar Panels and Installation: Initial investment in solar panels, mounting structures, and installation costs.
- Land Preparation: Costs for preparing land to accommodate both solar panels and agricultural activities.
- Agricultural Equipment: Purchase or upgrade of farming equipment to align with agrivoltaic practices like – irrigation systems
- Storage and Logistics: Investment in storage facilities for agricultural produce and logistical arrangements for electricity and crop distribution.

### 1.2 Operational Expenditure (OpEx)

- **Maintenance:** Regular maintenance of solar panels and agricultural infrastructure.
- **Labour:** Wages for farm workers for agricultural activities and technical staff for maintaining solar panels.
- **Insurance:** Insurance for both solar panels and agricultural produce.
- **Loan Repayments:** Servicing debt obtained to finance the initial investments.

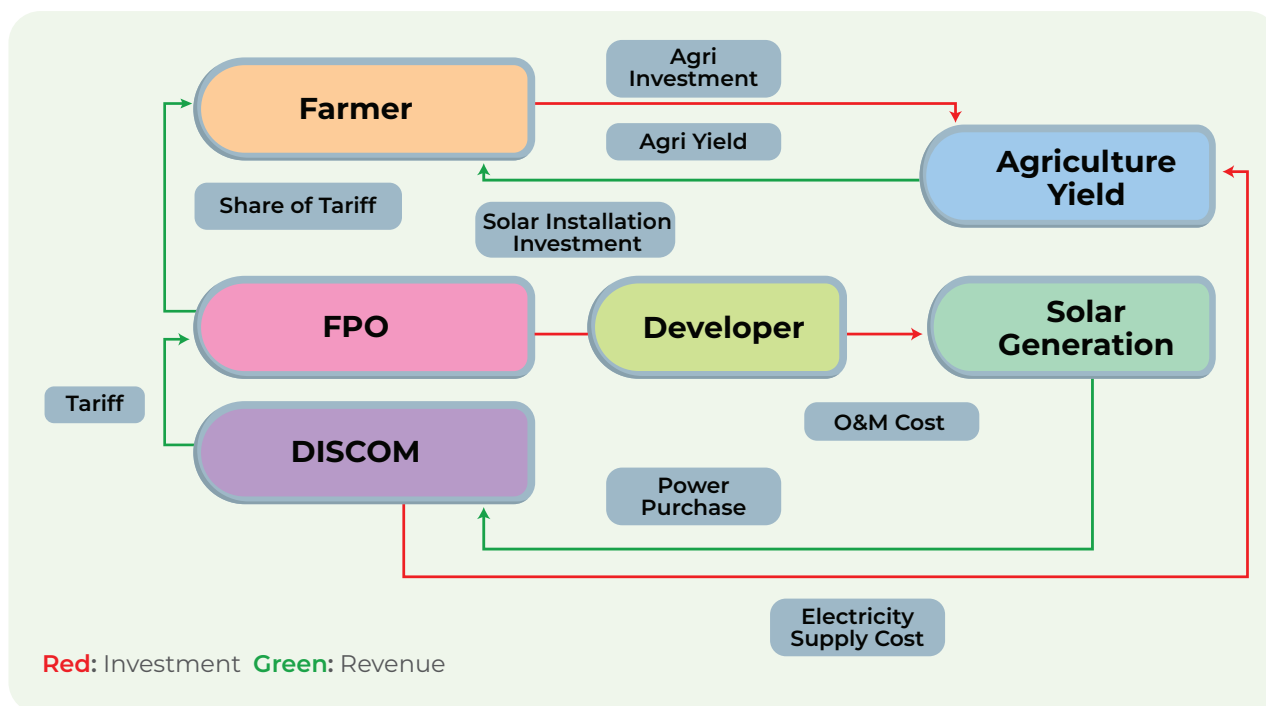
## 2. REVENUE

- Electricity Sales: Revenue from selling electricity generated by the agrivoltaic system to procurers.
- Agricultural Produce: Income from selling crops grown under the solar panels.
- Government Subsidies / Grants: Potential financial support from government schemes promoting renewable energy and sustainable agriculture.

## 3. CUSTOMERS

- Electricity Distribution Companies (DISCOMs): The primary customers for the electricity generated are the DISCOMs.
- Wholesale and Retail Markets: Buyers of agricultural produce, which can include local markets, supermarkets, and food processing companies.

## 2.2 COMMUNITY-OWNED BY FARMER PRODUCER ORGANIZATIONS (FPOS) MODEL



**Figure 2:** Schematic diagram for the FPO owned model

In this business model, Farmer Producer Organizations (FPOs) take the lead in installing and owning Agrivoltaics plants. Multiple farmers, often members of the FPO, contribute their land for the installation of solar PV panels. The FPO manages the project, including securing financing, overseeing installation, and managing operations. Revenue generated from electricity sales and agricultural produce is shared among participating farmers, providing them with additional income. This model makes way for small and marginal farmers to explore the ecosystem without bearing too much of financial burden.

### Key Components

**Formation of Farmer Producer Organization (FPO):** Farmers come together to form a FPO, a collective entity that represents the interests of its members and facilitates various

agricultural activities, including the development of Agrivoltaics projects.

**Land Contribution:** Participating farmers provide land for the installation of solar PV panels. The FPO aggregates these land parcels to establish the Agrivoltaics plant, ensuring optimal utilization of available resources.

**FPO Ownership and Management:** The FPO owns and manages the Agrivoltaics plant, undertaking responsibilities such as securing financing, procuring equipment, coordinating installation, and overseeing day-to-day operations.

**Revenue Sharing Mechanism:** Revenue generated from electricity sales to DISCOMs and proceeds from the sale of agricultural produce cultivated under the solar panels are shared among the participating farmers according to predefined agreements or profit-sharing models.

## Advantages

By pooling resources and forming an FPO, farmers benefit from collective ownership of the Agrivoltaics plant, enabling them to access financing, manage risks, and share responsibilities.

Risks associated with Agrivoltaics projects, such as financial risks, technical challenges, and market fluctuations, are shared among multiple stakeholders, reducing individual farmers' exposure to potential losses.

**Community Development:** Community-owned Agrivoltaics projects foster cooperation and collaboration among farmers, strengthening social ties, and promoting community development initiatives beyond the scope of the project itself.

## Challenges

**Coordination and Governance:** Effective coordination and governance within the FPO are essential for decision-making, resource allocation, and conflict resolution among members with diverse interests and priorities.

**Equitable Revenue Sharing:** Establishing fair and transparent mechanisms for revenue sharing among participating farmers requires careful consideration of factors such as land contribution, investment, and contribution to project success.

**Financial Viability:** Ensuring the financial viability of community owned Agrivoltaics projects may require access to affordable financing, favourable regulatory frameworks, and effective management of project costs and revenues.

Community-owned Agrivoltaics projects led by FPOs offer a promising approach to leveraging collective resources,

sharing risks and rewards, and promoting inclusive development in rural areas.

## 1. EXPENDITURE/COSTS

### 1.1. Capital Expenditure (CapEx)

- **Land Preparation:** Costs for clearing, leveling, and preparing the land for solar PV panel installation.
- **Solar PV Panels and Equipment:** Purchase of solar panels, inverters, mounting structures, and other necessary equipment.
- **Installation Costs:** Expenses related to the installation of the solar PV system, including labor, transportation, and equipment rental.
- **Infrastructure Development:** Costs for building necessary infrastructure such as access roads, fencing, and storage facilities.
- **Insurance:** Upfront cost of insurance premiums to cover potential risks such as damage to equipment, natural disasters, and liability issues.

### 1.2. Operational Expenditure (OpEx)

- **Maintenance and Repairs:** Regular maintenance of solar panels and equipment, as well as repairs and replacements as needed.
- **Labor Costs:** Wages for workers involved in the operation and maintenance of the Agrivoltaics plant and agricultural activities.
- **Utility Costs:** Expenses for utilities such as water for cleaning panels and irrigation for crops.
- **Administrative Costs:** Ongoing expenses for the management and administration of the FPO, including salaries for staff, office supplies, and communication costs.

- **Loan Repayments:** Periodic repayment of loans taken to finance the project.
- **Financial Services Fees:** Fees for financial services such as banking, auditing, and consulting.

## 2. REVENUE

### 2.1. Electricity Sales:

- **Sale to DISCOMs:** Revenue generated from selling electricity to distribution companies (DISCOMs) under power purchase agreements (PPAs).
- **Government Incentives:** Income from government subsidies, incentives, etc. for renewable energy projects.

### 2.2. Agricultural Produce

- **Crop Sales:** Revenue from the sale of agricultural produce grown under the solar panels.

### 2.3. Other Revenue Streams

- **Agri-tourism:** Income from developing agri-tourism activities around the Agrivoltaics plant, such as farm tours and educational programs.

## 3. CUSTOMERS

### 3.1. Electricity Customers

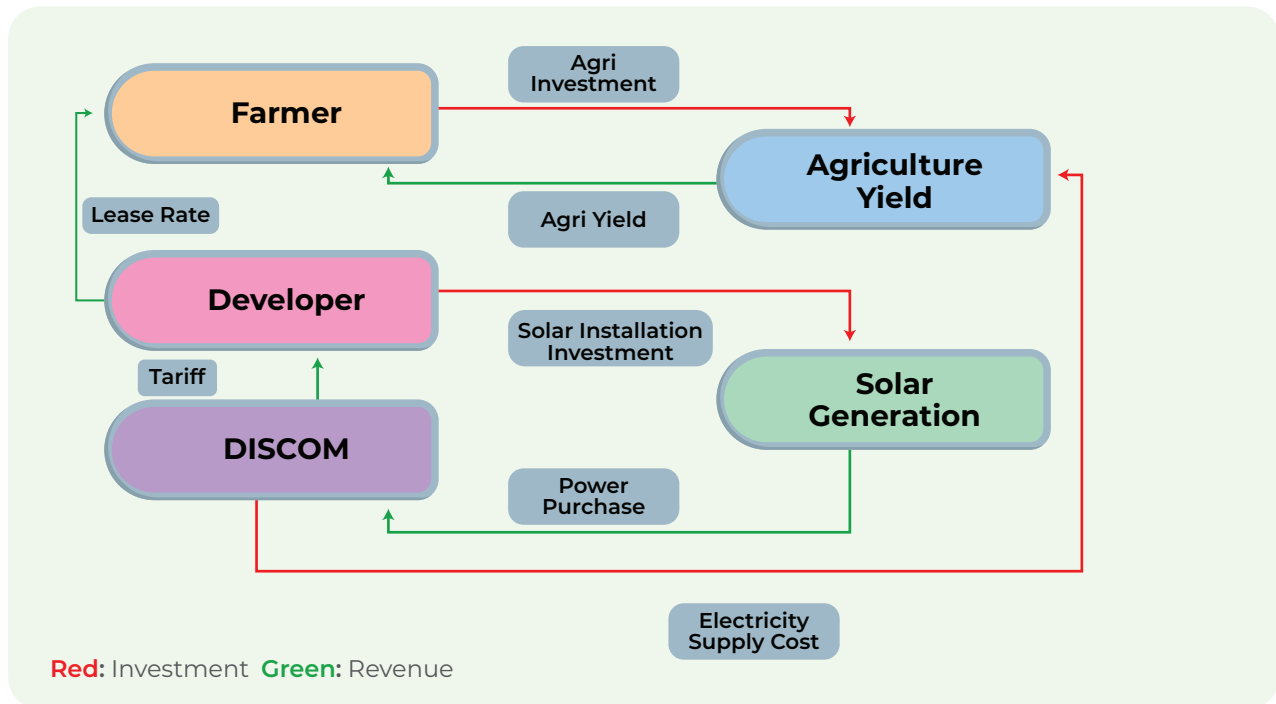
- **DISCOMs:** Primary customers purchasing electricity generated by the Agrivoltaics plant under PPAs.
- **Corporate Buyers:** Companies seeking renewable energy for their operations.

### 3.2. Agricultural Customers

- **Local Markets:** Consumers in local markets purchasing fresh produce from the FPO.
- **Wholesale Buyers:** Wholesalers and distributors buying agricultural products in bulk.
- **Retail Outlets:** Supermarkets, grocery stores, and other retail outlets sourcing produce from the FPO.
- **Food Processing Companies:** Businesses purchasing raw agricultural products for processing into value-added goods.



## 2.3 DEVELOPER OWNED MODEL



**Figure 3:** Schematic diagram for the developer owned model

In this business model, solar developers or companies lease or rent portions of farmland from rural landowners to install solar photovoltaic (PV) panels. The land continues to be owned by the farmers, but they receive lease payments from the solar developers for the use of their land. The solar panels are installed in such a way that they do not interfere significantly with agricultural activities, allowing farmers to continue cultivation around and underneath the solar panels.

### Key Components

**Land Lease Agreements:** Solar developers negotiate lease agreements with farmers or rural landowners for the use of their land for installing Agrivoltaics. These agreements typically outline the terms of the lease, including rental payments, duration, land use restrictions, and responsibilities of both parties.

**Solar PV Installation:** The solar developers install PV panels on the leased land, utilizing solar energy to generate electricity. The installation is done in a manner that minimizes disruption to agricultural activities and maximizes energy generation.

**Electricity Generation and Revenue:** The solar panels generate electricity, which is either fed into the grid or used for captive consumption, depending on the project's design. Revenue is generated through power purchase agreements (PPAs) with electricity distribution companies (DISCOMS), selling electricity at predetermined rates.

**Rental Income for Farmers:** Rural landowners receive rental income from the solar developers for the use of their land. This provides an additional source of revenue for farmers, supplementing their agricultural income.

## Advantages

Lease or rental payments provide a stable source of additional income for rural landowners, reducing dependence solely on agricultural income. The financial risks reduce due to the involvement of developer.

## Challenges

The developer owned model offers a secondary source of income to farmers. However, addressing challenges related to land use, convincing farmers to lease their land and the degree of ownership, technical considerations, policy frameworks, and financial viability is crucial for the successful implementation and scalability of such projects.

## 1. EXPENDITURE/COSTS

### 1.1. Capital Expenditure (CapEx)

- **Solar PV Systems:** Purchase of solar panels, inverters, mounting structures, and related equipment.
- **Installation Costs:** Expenses related to the installation of solar panels, including labor and machinery.
- **Site Preparation:** Costs for preparing the land, such as leveling and ensuring the ground is suitable for installation.
- **Infrastructure:** Investment in infrastructure for connecting the solar installation to the grid, such as transformers and wiring.

### 1.2. Operational Expenditure (OpEx)

- **Lease Payments:** Regular payments to landowners (farmers) for leasing their land (incurred by Developer).
- **Maintenance and Monitoring:** Ongoing maintenance costs and monitoring systems for solar panels and associated equipment to ensure

optimal performance and efficiency of solar installations.

- **Insurance:** Insurance costs to cover potential damages to the solar infrastructure and liability insurance.
- **Legal and Administrative Costs:** Expenses related to managing lease agreements, compliance with regulations, and other administrative tasks.
- **Permitting and Licensing:** Costs for obtaining necessary permits and licenses to operate the solar installations.

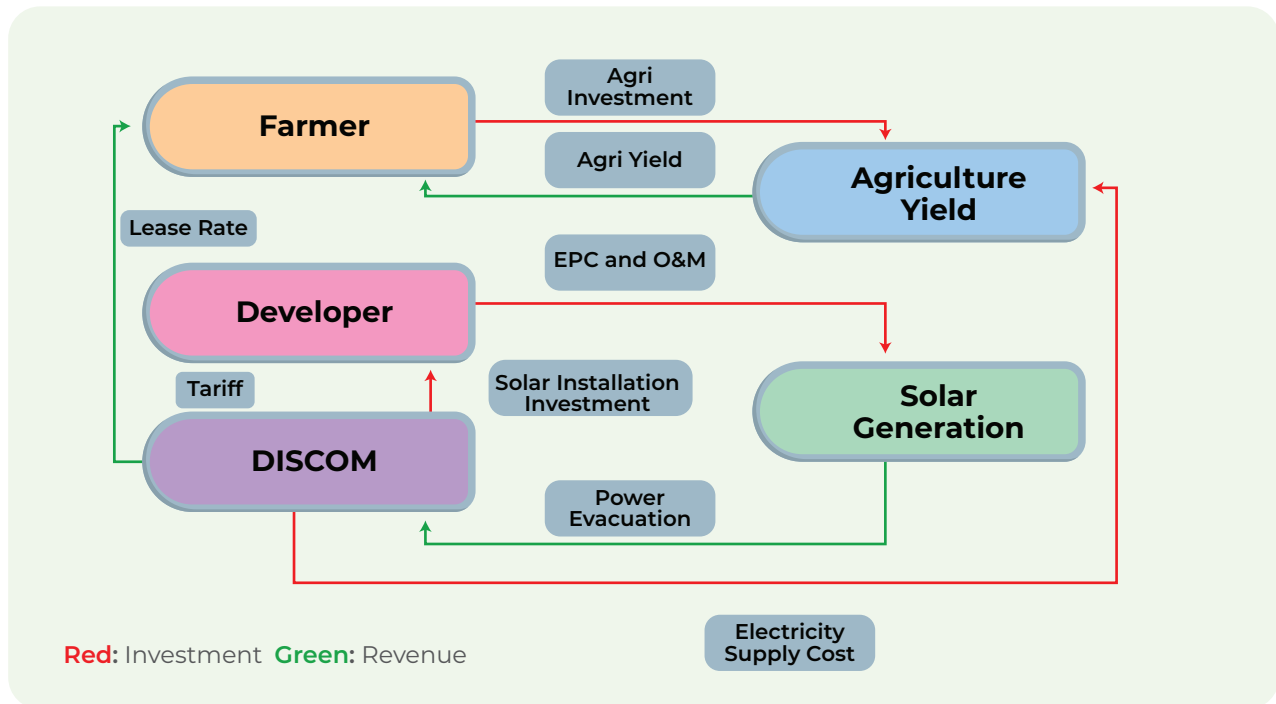
## 2. REVENUE

- **Electricity Sales:** Revenue from selling the electricity generated by the solar panels to DISCOMs through PPAs at predetermined rates to developers.
- **Tax Credits and Subsidies:** Financial incentives from government schemes for promoting renewable energy projects to developers.
- **Lease Rent:** Additional income for farmers (monthly/annually) for leasing out the rent.

## 3. CUSTOMERS

- **Electricity Distribution Companies (DISCOMs):** Primary customers purchasing the electricity generated by the solar installations.
- **Corporate Buyers:** Companies interested in purchasing renewable energy to meet sustainability goals or regulatory requirements.
- **Local Communities:** Indirect customers benefiting from enhanced energy access and reliability.
- **Wholesale and Retail Markets:** Buyers of agricultural produce, which can include local markets, supermarkets, and food processing companies.

## 2.4 DISCOM-OWNED MODEL



**Figure 4:** Schematic diagram for the DISCOM owned model

In this business model, electricity distribution companies (DISCOMs) take the initiative to install and operate Agrivoltaics plants by leasing land from farmers. In remote, hilly areas, the agrivoltaics plants can be installed near substations or suitable grid infrastructure to address the power quality issues. The DISCOMs are responsible for financing, installing, and managing the Agrivoltaics plants, while farmers receive lease payments for the use of their land. Farmers retain control over the cultivation and sale of agricultural produce grown under and around the solar panels. There can be potential linkages between this business model and the feeder-level solarisation component of KUSUM-C.

### Key Components

**Site Selection and Land Lease Agreements:** DISCOMs identify suitable land parcels near substations or grid infrastructure for installing Agrivoltaics plants. Lease

agreements are negotiated with farmers, specifying terms such as lease duration, rental payments, land use restrictions, and responsibilities of both parties.

**DISCOM Ownership and Operation:** DISCOMs undertake the ownership, financing, and operation of the Agrivoltaics. They may award to a developer either via CAPEX or OPEX mode plants. They are responsible for procuring solar PV equipment, managing installation, ensuring grid integration, and maintaining plant performance.

**Lease Payments to Farmers:** Farmers receive lease payments from DISCOMs for the use of their land for hosting Agrivoltaics plants. The lease amount is fixed in the agreement and provides farmers with a steady source of income, supplementing their agricultural earnings.

**Agricultural Activities:** Farmers retain control over agricultural activities on

the leased land, including cultivation, irrigation, and harvesting. They have the freedom to grow crops or raise livestock compatible with the Agrivoltaics setup, optimizing land use and diversifying income streams.

### Advantages

Farmers are relieved of the financial burden and technical complexities associated with installing and operating solar PV systems. They can focus on agricultural activities while earning additional income from leasing their land. Agrivoltaics plants can be strategically located near substations, maximizing grid integration efficiency, and minimizing transmission and distribution losses.

### Challenges

Negotiating fair and equitable lease agreements between DISCOMs and farmers require careful consideration of land values, rental rates, land use restrictions, and legal frameworks governing land leasing. Engaging with local communities and addressing their concerns regarding land use, environmental impacts, and socio-economic benefits is crucial for gaining acceptance and support for DISCOM-led Agrivoltaics projects.

DISCOMs must ensure the proper maintenance and operation of Agrivoltaics plants to optimize energy generation, prevent downtime, and uphold contractual obligations to farmers and electricity consumers.

## 1. EXPENDITURE/COSTS

### 1.1. Capital Expenditure (CapEx)

- **Land Lease Payments:** Upfront lease payments to farmers for securing land for the duration of the lease agreement (incurred by DISCOMs).

- **Solar PV Equipment:** Purchase of solar panels, inverters, mounting structures, and other necessary equipment.
- **Installation Costs:** Expenses related to the installation of the solar PV system, including labor, transportation, and equipments.
- **Infrastructure Development:** Costs for developing necessary infrastructure such as access to roads, fencing, and electrical connections to substations.
- **Grid Integration:** Expenses for integrating the Agrivoltaics plant with the existing grid infrastructure, including any necessary upgrades to substations or transmission lines.

### 1.2. Operational Expenditure (OpEx)

- **Labor Costs:** Wages for workers involved in the operation and maintenance of the Agrivoltaics plant.
- **Administrative Costs:** Ongoing expenses for the management and administration of the Agrivoltaics plant, including salaries for ground staff, office supplies, and communication costs.
- **Monitoring and Compliance:** Costs associated with monitoring plant performance, ensuring compliance with regulatory requirements, and reporting to stakeholders.
- **Maintenance and Repairs:** Regular maintenance of solar panels and equipment, as well as repairs and replacements as needed.

## 2. REVENUE

### 2.1. Electricity Sales:

- **Sale to Grid:** Revenue generated from selling electricity to the grid for local utilities.

- **Government Incentives:** Income from government subsidies, incentives, and feed-in tariffs for renewable energy projects.

## 2.2. Agricultural Produce (Farmer's Revenue)

- **Crop Sales:** Farmers earn revenue from the sale of agricultural produce grown under and around the solar panels.

## 3. CUSTOMERS

### 3.1. Electricity Customers

- **DISCOMs:** Primary customers purchasing electricity generated by the Agrivoltaics plant under PPAs.

- **Corporate Buyers:** Companies seeking renewable energy for their operations through corporate PPAs.

### 3.2. Agricultural Customers

- **Local Markets:** Consumers in local markets purchasing fresh produce from the farmers.
- **Wholesale Buyers:** Wholesalers and distributors buying agricultural products in bulk.
- **Retail Outlets:** Supermarkets, grocery stores, and other retail outlets sourcing produce from the farmers.
- **Food Processing Companies:** Businesses purchasing raw agricultural products for processing into value-added goods.



## 2.5 VARIANT MODELS TO ACCELERATE THE UPTAKE OF AGRIVOLTAICS

### A. Integration of Agrivoltaics with Value-Adding Infrastructure

In this innovative business model, the electricity generated from Agrivoltaics is utilized to power value-adding infrastructure for agriculture, enhancing the productivity and value of agricultural produce. Farmers continue to sell their agricultural goods in the market as usual, while leveraging the benefits of on-site value addition through facilities such as chaff cutters, cold storage units, food processing units, flour mills, chillers, and other processing equipment powered by solar energy. It enables rural communities to leverage modern technologies for farm mechanization, crop monitoring, and value-added processing, thereby enhancing productivity and market competitiveness. Additionally, reliable energy supply fosters education, entrepreneurship, and social development, empowering rural residents to pursue diverse opportunities and improve their quality of life.

#### Advantages

##### **Enhanced Productivity and Value:**

Value-adding infrastructure such as cold storage, food processing units, and flour mills enable farmers to enhance the quality, shelf life, and market value of their agricultural produce, thereby increasing their competitiveness and profitability in the market.

**Energy Self-Sufficiency:** By utilizing solar energy from Agrivoltaics to power value-adding infrastructure, farmers achieve energy self-sufficiency, reducing reliance on grid electricity and diesel generators, which can be and environmentally unsustainable.

**Diversified Income Streams:** In addition to revenue from agricultural produce sales, farmers may generate additional income streams from processing fees for value-added processing, value-added product sales, and other ancillary services associated with on-site value addition and processing facilities.

**Community Development:** The establishment of value-adding infrastructure contributes to rural development by creating employment opportunities, supporting agribusinesses, and fostering economic growth within the local community.

#### Challenges

**Technical Expertise:** Operating and maintaining value-adding infrastructure necessitates technical expertise in equipment operation, maintenance, and troubleshooting, which may require training or support from skilled personnel.

**Market Access:** Accessing higher-value markets for processed or value-added agricultural products requires market linkages, quality certifications, and marketing strategies to effectively differentiate and promote the value proposition to consumers.

## B. Electricity Sale from agrivoltaics through Open Access

In this business model, the electricity generated from Agrivoltaics is not sold directly to DISCOMs but rather through green energy open access arrangements. Farmers lease their land to Agrivoltaics developers or investors, who install and operate the solar PV panels. The electricity generated is then sold to industries, or commercial entities through open access agreements, while farmers retain control over the sale of agricultural produce grown on the same land.

### Advantages

Selling electricity through open access allows Agrivoltaics developers to access a broader market of consumers, industries, and commercial entities. This can result in better price discovery and potentially higher revenue compared to selling electricity to DISCOMs. Open access arrangements offer flexibility in pricing and contract terms, allowing Agrivoltaics developers to negotiate agreements tailored to the needs of individual consumers or industries. This can lead to more competitive pricing and improved revenue streams.

### Challenges

Open access arrangements are subject to regulatory and policy frameworks governing electricity markets, which may vary across states in India. Compliance with regulations, obtaining necessary approvals, and navigating regulatory complexities

can be challenging for Agrivoltaics developers. The electricity market under open access is competitive, with multiple suppliers vying for customers. Agrivoltaics developers must effectively differentiate their offerings, manage pricing strategies, and address customer preferences to remain competitive in the market. Open access arrangements require adequate grid infrastructure and connectivity to facilitate the transmission of electricity from Agrivoltaics installations to consumers. Grid constraints, congestion, and infrastructure limitations may pose challenges to seamless electricity delivery.



### **C. Agrivoltaics Plant Supplying Electricity and Agricultural Produce to FMCGs**

In this business model, Fast-Moving Consumer Goods (FMCG) companies directly procure electricity generated from Agrivoltaics through open access arrangements. Additionally, they source agricultural produce cultivated under and around the Agrivoltaics plant directly from farmers involved in the project. The Agrivoltaics plant functions as a dual-purpose facility, supplying both clean energy and high-quality agricultural products to FMCGs, while farmers benefit from lease payments and direct market access.

#### **Advantages**

Direct procurement of both electricity and agricultural produce from Agrivoltaics streamlines the supply chain for FMCG companies, reducing costs, minimizing intermediaries, and ensuring product traceability and quality control from farm to factory.

FMCG companies demonstrate their commitment to sustainability by sourcing clean energy and responsibly cultivated agricultural produce from Agrivoltaics plants. This aligns with SDGs and enhance brand reputation among environmentally conscious consumers.

#### **Challenges**

Coordinating logistics for the direct procurement of electricity and agricultural produce from multiple Agrivoltaics sites may pose challenges in terms of transportation, storage, and distribution, particularly for perishable goods.

Ensuring consistent quality and supply of agricultural produce meeting FMCGs' stringent standards requires effective quality assurance mechanisms, farmer training, and adherence to best agricultural practices throughout the supply chain.

Negotiating open access agreements for electricity procurement and supply contracts for agricultural produce entails complex contractual arrangements, pricing negotiations, and risk management strategies to address market uncertainties and regulatory compliance.

Aligning the production and supply of agricultural produce with FMCGs' demand forecasts and product specifications is essential to avoid supply-demand imbalances and maximize revenue opportunities for farmers and Agrivoltaics developers.

## D. Integration of Agrivoltaics with Clean Fuel Generation

In this business model, the electricity generated from Agrivoltaics is used to power facilities for the generation of clean fuels, such as green hydrogen, biogas, biofuels, etc. Farmers continue to sell their agricultural produce as usual, while the Agrivoltaics plant serves as a hub for diversified renewable energy production.

### Advantages

Integrating Agrivoltaics with other renewable energy generation facilities enables diversified production of green hydrogen, biogas, biofuels, and other sustainable energy sources, contributing to energy transition and decarbonisation efforts.

### Challenges

Integrating agrivoltaics with other renewable energy generation technologies require technological expertise, engineering design, and infrastructure development to ensure compatibility, efficiency, and reliability of energy systems.

Co-ordinating logistics for biomass feedstock supply, hydrogen storage and distribution, or biofuel transportation may pose challenges related to feedstock availability, transportation costs, and market access, particularly in rural or remote areas.

The economic viability of producing green hydrogen, biogas, biofuels, and other renewable energy sources depends on factors such as market demand, production costs, regulatory frameworks, and policy incentives. Ensuring profitability and competitiveness in renewable energy markets require careful market analysis and strategic planning.

Overcoming challenges related to technological integration, supply chain logistics, economic viability, and policy support requires collaboration among stakeholders, innovation, and strategic investments in renewable energy infrastructure. By leveraging the synergies between Agrivoltaics and renewable energy generation, India can accelerate its transition to a low-carbon and resilient energy future.



# 3. Socio-Economic Impacts of Agrivoltaics

## BUSINESS MODELS

Agrivoltaics offers a range of socio-economic benefits. This section explores these benefits in detail, highlighting their relevance to different agrivoltaics business models from a socio-economic perspective.

### 3.1 ECONOMIC BENEFITS

#### 3.1.1 Increased Income for Farmers

- **Individual Farmer-Owned Model:** In this model, farmers will invest in their own agrivoltaic systems. They will benefit from diversified income streams, earning revenue from electricity sales through power purchase agreements (PPAs) with electricity distribution companies (DISCOMs) and from agricultural produce. This dual income stream will enhance financial stability and reduce economic vulnerability.
- **Developer-Lease Model:** Farmers will lease their land to solar developers, receiving regular rental payments. This will provide a stable income source, mitigating financial risks associated with agricultural yield fluctuations and market prices.
- **FPO-Owned/Community-Led Agrivoltaics:** Farmer Producer Organizations (FPOs) will manage the agrivoltaics installations, with farmers collectively sharing profits from electricity sales and agricultural produce. This approach will ensure equitable income distribution, enhancing financial stability and reducing economic disparities within farming communities.
- **DISCOM-Owned Agrivoltaics:** Farmers will lease their land to DISCOMs, which will install and operate the solar panels. Lease payments will provide farmers with a regular income, offering financial security and reducing vulnerability to seasonal agricultural yields.
- **Value-Adding Infrastructure Model:** This model will involve processing agricultural produce on-site by using the electricity generated on-farm, increasing the product's value and quality. By enhancing the value of agricultural products, farmers will generate higher revenue, improving their economic well-being and enabling investment in better farming practices and technologies.
- **Open Access Model:** Farmers will receive lease payments and may also share in the revenue from electricity sales to industries through open access agreements. This model will provide multiple income streams, reducing the risk associated with fluctuating agricultural prices and ensuring a more stable financial foundation for farmers.
- **FMCG-Integrated Model:** Farmers will gain direct market access, eliminating intermediaries, and will receive lease payments. Direct market access will ensure that farmers receive fair prices for their produce, increasing their income and enhancing their ability to invest in sustainable agricultural practices.

- **Renewable Fuel Production Agrivoltaics:** Farmers will earn lease payments and additional income from the sale of biomass feedstock. This diversified income stream will help stabilize farmers' earnings and support the broader adoption of renewable energy technologies in rural areas.

### 3.1.2 Job Creation

- **Individual farmer-owned and FPO-Owned Agrivoltaics:** Local jobs will be created in the installation, operation, and maintenance of solar panels and agricultural activities. This will boost the local economy and can help reduce migration to urban areas by providing employment opportunities within rural communities.
- **Developer-Lease Model and DISCOM-Owned Agrivoltaics:** Employment opportunities will arise in managing the agrivoltaics plant, supporting the local workforce and developing technical skills in renewable energy contributing to the overall socio-economic development of rural areas.
- **Value-Adding Infrastructure Agrivoltaics Model:** Jobs will be created in operating and maintaining value-adding infrastructure, such as food processing units. This will foster local economic growth by creating new industries and supporting ancillary services and businesses.
- **Open Access Model:** Roles in the management and logistics of electricity sales will be needed, expanding employment opportunities in administrative, technical, and support functions within rural regions.
- **FMCG-Integrated Agrivoltaics Model:** Jobs in logistics, quality control, and

supply chain management will be generated. These roles will improve the efficiency of agricultural supply chains and provide local employment, enhancing community stability.

- **Renewable Fuel Production Agrivoltaics Model:** Employment will be created in renewable fuel production facilities. This will support the transition to a green economy and provide job opportunities in emerging sectors, promoting sustainable development.

### 3.1.3 Market Expansion

- **Individual Farmer-Owned Model and FPO-owned model:** Farmers will access broader markets for electricity and agricultural produce, increasing their revenue potential and market resilience. This expansion will help diversify their customer base and reduce dependence on local markets.
- **Developer-Lease Model and DISCOM-owned Agrivoltaics Model:** Integration into regional and national electricity markets will allow for larger-scale operations, enhancing the financial viability and sustainability of agrivoltaics projects.
- **Value-Adding Infrastructure Agrivoltaics Model:** Entry into higher-value markets for processed agricultural products will increase revenue potential, enabling farmers to invest in better technologies and practices.
- **Open Access Model:** Expanding market reach through direct electricity sales to industries will broaden revenue streams and enhance the economic sustainability of rural communities.
- **FMCG-Integrated Model:** Secure market access for agricultural

produce through FMCG partnerships will ensure stable demand and fair pricing, supporting the economic stability of farming communities.

- **Renewable Fuel Production Agrivoltaics Model:** Markets for green hydrogen, biogas, and biofuels will expand, promoting the adoption of sustainable energy solutions and supporting the global transition to a low-carbon economy.

## 3.2 SOCIAL BENEFITS

### 3.2.1 Community Empowerment

- **FPO-owned Agrivoltaics Model:** This model will strengthen community ties through collective ownership and decision-making. By working together, farmers will pool resources, share knowledge, and make joint decisions that benefit the entire community, fostering a sense of unity and cooperation.
- **Developer-Lease Model and DISCOM-owned Agrivoltaics Model:** Community involvement and benefits from lease agreements will promote local development. By engaging with DISCOMs, communities will influence project planning and implementation, ensuring that the benefits of agrivoltaics projects are widely shared.
- **Open Access Agrivoltaics:** Lease payments and involvement in energy projects will support local communities, providing funds that can be used for community development projects, such as building schools, healthcare facilities, and improving local infrastructure.
- **FMCG-Integrated Agrivoltaics:** Stable, long-term relationship between farmers and FMCG companies will

foster economic stability and social cohesion. These partnerships will also lead to community investments and development programs.

### 3.2.2 Skill Development

- **Individual Farmer-Owned Model and FPO-owned Agrivoltaics Model:** Training in renewable energy and advanced agricultural practices will enhance farmers' capabilities and employability. This continuous learning process will help farmers adapt to new technologies and improve productivity and efficiency.
- **Developer-Lease Model and DISCOM-owned Agrivoltaics:** Development of technical skills in energy management will benefit local workers, creating a skilled workforce that can support the growth of the renewable energy sector.
- **Value-Adding Infrastructure Agrivoltaics:** Skills in operating and maintaining value-adding equipment will be developed, enhancing local expertise and supporting the creation of new economic opportunities.
- **Open Access Agrivoltaics:** Training in energy market dynamics and regulatory compliance will equip local workers with the knowledge needed to navigate and succeed in complex energy markets.
- **FMCG-Integrated Agrivoltaics:** Expertise in quality control and supply chain logistics will ensure that farmers meet market standards, improving product quality and competitiveness.
- **Renewable Fuel Production Agrivoltaics:** Skills in renewable fuel technologies and processes will be enhanced, supporting the transition to a green economy and promoting sustainable development.

### 3.2.3 Improved Living Standards

- **Individual Farmer-Owned Model and FPO-owned Model:** Enhanced income stability and financial security will improve household living standards. Higher and more reliable income will enable families to invest in education, healthcare, and better housing, leading to an improved quality of life.
- **Developer-Lease Model, DISCOM-owned Model:** Steady lease payments will provide financial security, allowing families to plan for the future and invest in their well-being.
- **Value-Adding Infrastructure Agrivoltaics Model:** Increased revenue from higher-value produce will improve household incomes, enabling better access to essential services and amenities.
- **FMCG-Integrated Agrivoltaics:** Direct market access will ensure better prices for produce, improving living standards by providing higher and more predictable incomes.
- **Renewable Fuel Production Agrivoltaics:** Diversified income sources from renewable energy projects will enhance economic resilience, reducing vulnerability to market fluctuations and ensuring a stable quality of life.

## 3.3 ENVIRONMENTAL BENEFITS

### 3.3.1. Reduced Emissions

Agrivoltaics will significantly reduce greenhouse gas emissions by replacing fossil fuels with solar energy/clean energy. This reduction will contribute to global efforts to combat climate change and promote cleaner air and healthier

environments. In case of the Renewable Fuel Production Agrivoltaics Model, additional reductions will be achieved through the production and use of green hydrogen, biogas, and biofuels, further supporting the transition to a low-carbon economy.

### 3.3.2 Sustainable Agriculture

Agrivoltaics will promote sustainable farming practices under solar panels, such as crop rotation, organic farming, and soil conservation. It will also encourage eco-friendly agricultural practices, such as efficient water use. These practices will enhance long-term agricultural productivity and environmental health.

### 3.3.3. Climate Resilience

Agrivoltaics will increase resilience to climate change impacts through diversified income sources, crop protection, and sustainable energy solutions. This resilience will help protect communities from the adverse effects of climate change, such as extreme weather events and changing precipitation patterns. In case of the Renewable Fuel Production Agrivoltaics Model, it will ensure enhancement of energy security and reduce vulnerability to fossil fuel market fluctuations, supporting stable and sustainable economic growth.

By leveraging these socio-economic benefits, agrivoltaics will play a pivotal role in transforming rural economies, enhancing social well-being, and promoting environmental sustainability. Each business model will offer unique advantages that contribute to these broader goals, making agrivoltaics a versatile and impactful approach to integrated land use.

# CONCLUSION

The exploration of various business models for Agrivoltaics in India reveals a multitude of opportunities for integrating renewable energy generation with agricultural activities, thereby creating synergistic benefits for both sectors. Each model presents unique approaches to revenue generation, sustainability, and rural development, while emphasizing the value addition to the agriculture sector through Agrivoltaics. One significant aspect highlighted across all models is the potential for farmers to retain autonomy over their agricultural activities and sales while benefiting from additional revenue streams derived from renewable energy production.

By leveraging market mechanisms and innovative financing models, Agrivoltaics developers can overcome barriers to investment and achieve financial sustainability while delivering tangible benefits to rural communities. Additionally, partnerships with stakeholders across the renewable energy, agriculture, and finance sectors facilitate knowledge exchange, technology transfer, and capacity building, fostering collaborative

approaches to addressing complex socio-economic and environmental challenges.

In conclusion, the diverse array of business models explored for Agrivoltaics in India demonstrates the transformative potential of integrating renewable energy and agriculture to create value-added synergies and drive sustainable development. Through innovative approaches to revenue generation, technology integration, and stakeholder engagement, Agrivoltaics projects have the capacity to enhance energy access, agricultural productivity, and rural livelihoods while contributing to climate change mitigation and environmental conservation. Moving forward, continued investment, policy support, and research efforts are essential to scaling up Agrivoltaics initiatives and realizing their full potential as a catalyst for inclusive and sustainable development in India's agricultural sector.







