



INTERNATIONAL
SOLAR
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AGRIVOLTAICS

REVOLUTIONIZING FARMING AND SOLAR ENERGY FOR A SUSTAINABLE FUTURE

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Role of Agri-photovoltaics

Agri-photovoltaics (or Agri-PV) combines the cultivation of crops and the generation of solar energy on the same land, optimizing the use of space for both food production and renewable energy generation. This innovative approach not only maximizes land efficiency but also helps in making agriculture more sustainable and energy-intensive processes more eco-friendly.

This fact sheet will delve into a comprehensive overview of agrivoltaics technology, highlighting its benefits, applications, and potential for enhancing sustainable agriculture and renewable energy production.

Potential Benefits



Increased Land efficiency:

Agri-PV systems increase overall land productivity by 35–73%, enabling energy generation together with agricultural production.*



Improved Crop Yield and Quality:

For certain crops like fruits and berries, improved microclimate helps mitigate heat stress, leading to increased yields of up to 16%.*



Environmental Impact Reduction:

Lowers GHG emissions and enhances biodiversity by providing habitats for various species and pollinators.*



Increased Economic Viability:

Extra electricity generated from solar panels can be sold to electricity companies, providing dual income streams to farmers.*



Water Conservation:

The shading effect of panels reduces evaporation rates by around 20-30%, leading to lower water requirements for irrigation.*



Community Development:

Job creation in both agricultural and renewable energy sectors through trainings in farming as well as O&M of solar panels.*

Types of Agri-PV Configurations

Agri-PV comes in different shapes and sizes, ranging from small solar greenhouses to utility-scale solar farms. The two main categories are elevated agri-PV and interspaced agri-PV, which can be used in different types of land as shown:

Agricultural Land			Land under protective cover
Arable land	Permanent crop land	Permanent meadows and pastures	
 1. Elevated Crop-PV	 4. Elevated perennial-PV	 6. Elevated PV with livestock grazing	 9. Elevated PV greenhouses
 2. Interspace Crop-PV	 5. Interspace perennial-PV	 7. Interspace PV with livestock grazing	 10. PV on farm buildings
 3. Eco-PV		 8. Hay-PV	

Source: Agrisolar Handbook, SolarPower Europe

Land use efficiency in elevated configuration:

63% solar + **90-116%** crops = **153-178%** total efficiency

Suitable for



Fruits
Apples, Apricots, Grapes



Leafy Greens
Lettuce, Spinach, Kale, Arugula



Fruit & Vegetable
Cucumbers, Tomatoes, Green chillies, Capsicum



Berries
Strawberries, Raspberries

Land use efficiency in interspaced configuration:

25% solar + **83-113%** crops = **108-123%** total efficiency

Suitable for



Root Vegetables
Carrots, Radishes, Beets, Turnips



Cereals
Wheat, Oat, Barley



Forages
Grasses

Source: Empowering farmers in Central Europe: the case for agri-PV, EMBER

Business Models

Business Models	Energy producer owns and operates PV project (in agreement with farmer)	Farmer owns and operates the project	Joint ownership	
Management of costs and risks for PV	Energy producer	Farmer	Farmer	Energy producer
Revenue generation and benefits from PV				
Revenue generation and benefits of the agricultural activity	Farmer			
Management of costs and risks to the agricultural activity				
Management of the PV system	Energy producer			

Source: Agrisolar Handbook, SolarPower Europe

Revenue Streams for Agri-PV

Sale of food produced and agricultural subsidies

Land lease agreements during operation phase

Sale of electricity & ecosystem services

Source: Agrisolar Handbook, SolarPower Europe

FRAMEWORK FOR AGRI-PV SYSTEMS

Site Selection Criteria

Optimal Slope:

The slope depends on the climate of the region and selected crop. For example, in the Mediterranean region, the slope is 31-33 degrees.*

Drainage Considerations:

Steeper slopes may pose challenges for both solar installations and farming due to increased runoff and potential soil erosion.*

Crop Orientation:

Planting rows parallel to panels help optimize light distribution and reduce shading effects on crops, ensuring adequate sunlight.*

Soil Composition:

High-quality soil with good fertility, structure, and drainage is crucial for successful crop production under agri-PV systems.*

Crop Selection Criteria

Shade Tolerance:

Solar panels create partial shade, which benefits some crops but hinder others. Choose crops based on their shade tolerance.*

Water Needs:

Shading from solar panels reduces evaporation, conserving soil moisture. Crops that thrive with less water are ideal.*

Climate & Regional Adaptability: Crops must be compatible with regional temperature ranges, soil pH and nutrient levels and seasonal weather patterns.*

Economic Value:

Select crops that has robust market demand or specialize in high-value niche products to maximize profitability.*

System Design Considerations

Optimal Height: A suitable height for the panels can be arrived at by considering factors such as shade requirement, visibility, and other public concerns.*

Panel Spacing: A spacing of 1.5 to 2 times the height of the panels between them is recommended to minimize shading effects while maximizing solar capture.*

Crop Interspacing: Crop rows require sufficient space in between, allowing airflow, light, and easier access for panel maintenance and harvesting activities.*

Irrigation Strategies: Integrated irrigation solutions like drip irrigation system installed under solar panels can be used to utilize water more efficiently.*

Implementation Guidelines

Implementing agri-PV systems requires adherence to specific guidelines that cover the construction and installation process, farming equipment requirements, and maintenance considerations.

- Site & Soil assessment
- Design specifications
- Permits & regulations
- Grid connectivity
- Installation techniques

Construction and Installation

Farming Equipment Requirements

- Farming equipment size
- Compatibility with panels
- Irrigation methods
- Crop management tools

- Regular inspection
- Cleaning regimen for solar panels
- Soil health monitoring
- Energy generation checkups

Maintenance Considerations

Source: Solar Market Research & Analysis, NREL

Best Practices and Case Studies

The following case studies are mostly sourced from developed countries, where there is generally better access to advanced technologies and more robust frameworks for implementation. These examples serve as valuable references from which other countries can adapt strategies to suit their unique contexts and developmental stages.

SunMaster Agrivoltaics Plant, Najafgarh, Delhi*



Capacity: The plant has a capacity of 2 MW, and adopts an overhead configuration with a 4.3m elevation. The system employs fixed tilt tracking system and automated cleaning and water management systems.

Agri-PV type and benefits: The plant serves as a research field, cultivating a diverse range of crops. Water evaporation was reduced by 50% and a 12% increase in production was recorded. Soil health also increased by an impressive 30%.

Strawberry PV Greenhouses In Eyrargues, France *



Capacity: Connected to the grid in 2018, this project built 9 PV greenhouses to produce strawberries and other seasonal crops on 1.1 hectares of land with a production capacity of 2 MW.

Agri-PV type and benefits: The shading of the greenhouses reduces the need for water by 20-30%. The site has a well with enough water available to ensure the agricultural production of vegetables, and the breeding of chickens throughout the year.

Fukushima, Japan's Mibet Agrivoltaic Project*



Capacity: 4 MW agrivoltaic plant expected to generate approximately 3.7 million kWh of electricity annually, which will be sold to power suppliers under a feed-in tariff scheme.

Agri-PV type and benefits: The PV panels were installed on Mibet's agrivoltaic mounting system at a height of 2.5 meters, with a tilt angle of up to 30 degrees. It can also withstand wind loads of 80 meters per second. Under the solar panels, seven types of grapes are cultivated, benefiting from the shade from the elevated panels.

Morogoro, Tanzania Agrivoltaic Project*



Capacity: From June 2022 to May 2023, the system generated 12.55 MWh of electricity, which the researchers estimate is equivalent to saving \$5,310 a year against electricity from the national grid.

Agri-PV type and benefits: Morogoro utilizes mounted panels raised 3m above the ground with 50% panel density. The runoff from panels irrigates the crops and a rainwater harvesting unit has been installed to supplement existing centralized irrigation. This system helped reduce irrigation demands and increased crop survivability.

Challenges

Improper placement and management of PV modules can introduce risks including decreased crop yields, land degradation, and reduced biodiversity.	During the construction phase of PV installations, poor practices such as extensive ground excavation can lead to land degradation and a decline in biodiversity.	Lack of a clear, robust and universal definition for agri-PV at national levels, as well as the absence of a dedicated standard can hinder implementation processes.
Large-scale deployment of Agri-PV needs to consider and ensure the welfare and income of farmers and hence price effects on agricultural land need to be regularly assessed.	Public awareness and acceptance amongst farmers and the rural communities is a major challenge, as it directly influences the large-scale deployment of Agri-PV.	Research on Agri-PV systems is still lagging. Focus should be on maximising electricity generation while also ensuring the lowest possible impact on crop yield production.

Way Forward

Policies and Regulations: Agri-PV is at the cross-roads of inter-disciplinary policy domains – agriculture, energy, and environmental policies – creating a more challenging setting, requiring coherence between these areas of policymaking.

Research and Development: Research studies, data analysis and innovative solutions contribute to more productivity, and a better integration of Agri-PV solutions into agricultural lands and operations.

Capacity building: Skilled manpower is crucial for successful implementation and operation of Agri-PV. This can be achieved by conducting capacity building programs and workshops.

*The Belgian government is financially supporting the implementation of energy efficiency techniques, as well as green heat and renewable energy related projects in the agricultural sector of the Flemish Region. **

*The robotics research at AgroSolar Europe aims to develop and implement automation tools & machines that are able to detect and efficiently mechanically remove weeds through AI-based detection systems. **

*The ISA recently convened a workshop on "Promoting Agrivoltaics in ISA Member Countries", attended by over 150 attendees from more than 50 nations, covering policy guidance, feasibility studies and knowledge sharing. **

Public sector initiatives: Apart from formulating policies and regulations, the initiatives from governments and organisations in the public sector play a crucial role in determining how these systems are integrated into the existing agricultural framework and contribution to SDGs.

Adoption of latest technologies: Increases yield and efficiency, enabling farmers to keep up in the competitive space. Different PV module technologies optimise light transmission, like Concentrator Photovoltaic (CPV) modules, semi-transparent modules and bifacial modules.

Establishing a multi ministerial committee to specifically coordinate all matters related to agri-PV can be effective. In India, such a committee can be made of members from MNRE, Ministry of Agriculture & Farmers Welfare and Ministry of Science and Technology, with the involvement of interest groups from Industry and Agriculture and states.

*Dynamic Agri-PV farming with solar erasure (light sharing between PV and crops) in Tresserre, France uses artificial intelligence powered trackers, resulting in effective protection against climatic hazards and significantly increased crop yield. **

Note: (*) indicate the sources for the information presented in the factsheet. The corresponding references are embedded directly within the text as links.



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