INDIA AGRIVOLTAICS ALLIANCE

India Climate Collaborative

Policy Recommendations for Accelerating Solarization of Agriculture through Agrivoltaics

Guidebook for Policy Makers

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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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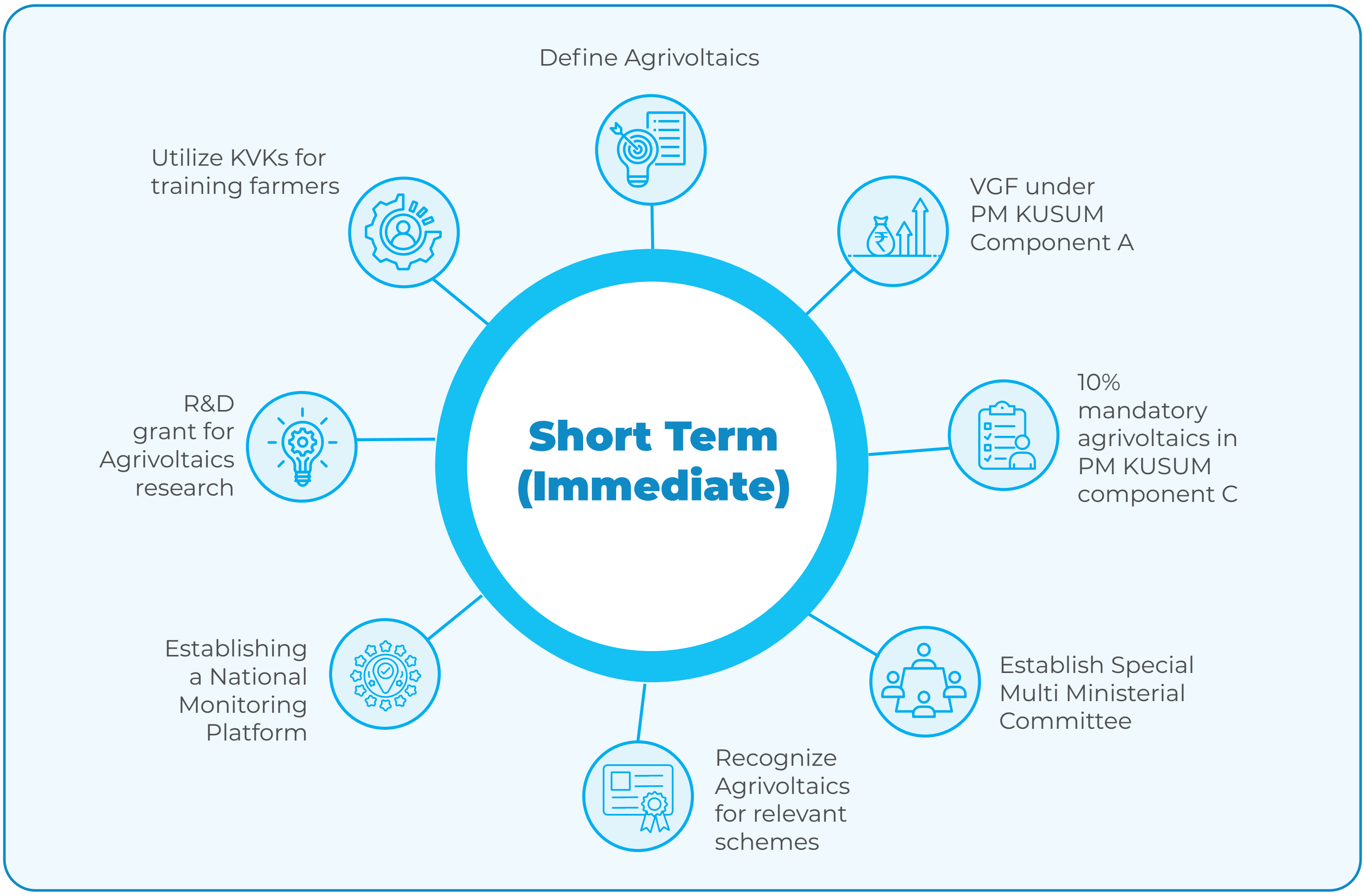
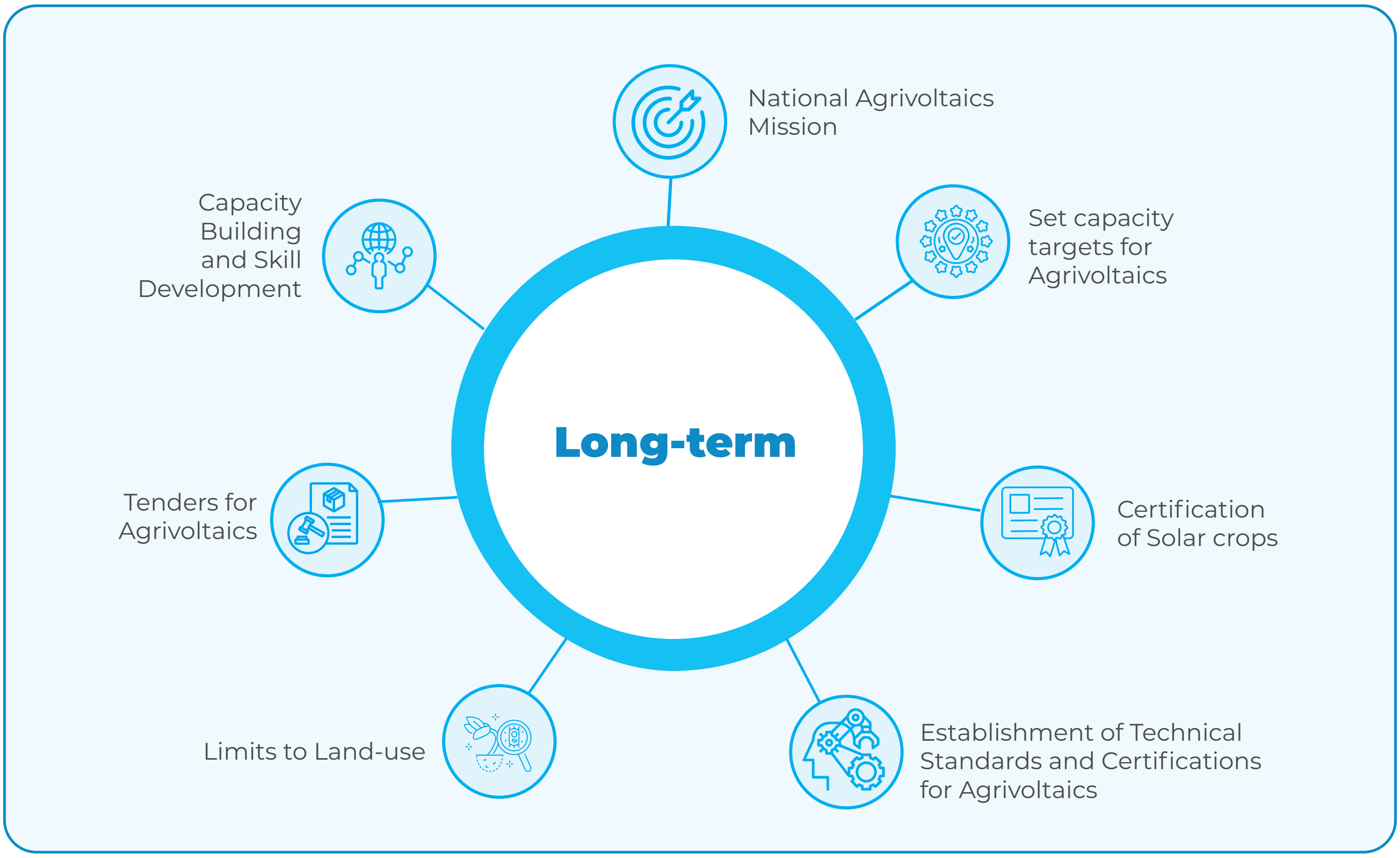
SUMMARY OF
THE RECOMMENDATIONS





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AGRIVOLTAICS

What is Agrivoltaics

Agrivoltaics, also known as Agrophotovoltaics or Solar sharing, is an innovative approach that involves the co-location of solar photovoltaic (PV) panels with agricultural activities on the same area of land. This integration offers several advantages that contribute to sustainable development across multiple sectors.

One of the primary benefits of agrivoltaics is the efficient utilization of land resources. By combining solar energy production with agricultural practices, agrivoltaics maximizes land productivity, allowing for dual land use without compromising either solar energy generation or agricultural output. This utilization of land is especially crucial in densely populated areas where land availability is limited, making agrivoltaics a valuable solution for optimizing land use efficiency. Additionally, agrivoltaics offers economic advantages for farmers and landowners. By diversifying income streams, agrivoltaic systems can provide additional revenue sources beyond traditional agricultural activities. Moreover, agrivoltaics contributes to environmental sustainability by promoting renewable energy production and reducing greenhouse gas emissions.

By displacing conventional energy generation with solar power, agrivoltaic systems help mitigate climate change and reduce dependence on non-renewable resources. Additionally, the shading provided by solar panels can provide microclimate benefits, such as temperature moderation and reduced water evaporation, which can positively impact plant growth and soil moisture retention.

Thus, agrivoltaics offers a multitude of benefits across various dimensions, including efficient land use, economic viability, environmental sustainability, and community development. By harnessing the synergies between solar energy production and agricultural activities, agrivoltaic systems present a promising solution for addressing the challenges of Food-Energy-Water nexus (FEW Nexus) challenge, and environmental conservation in India and beyond.

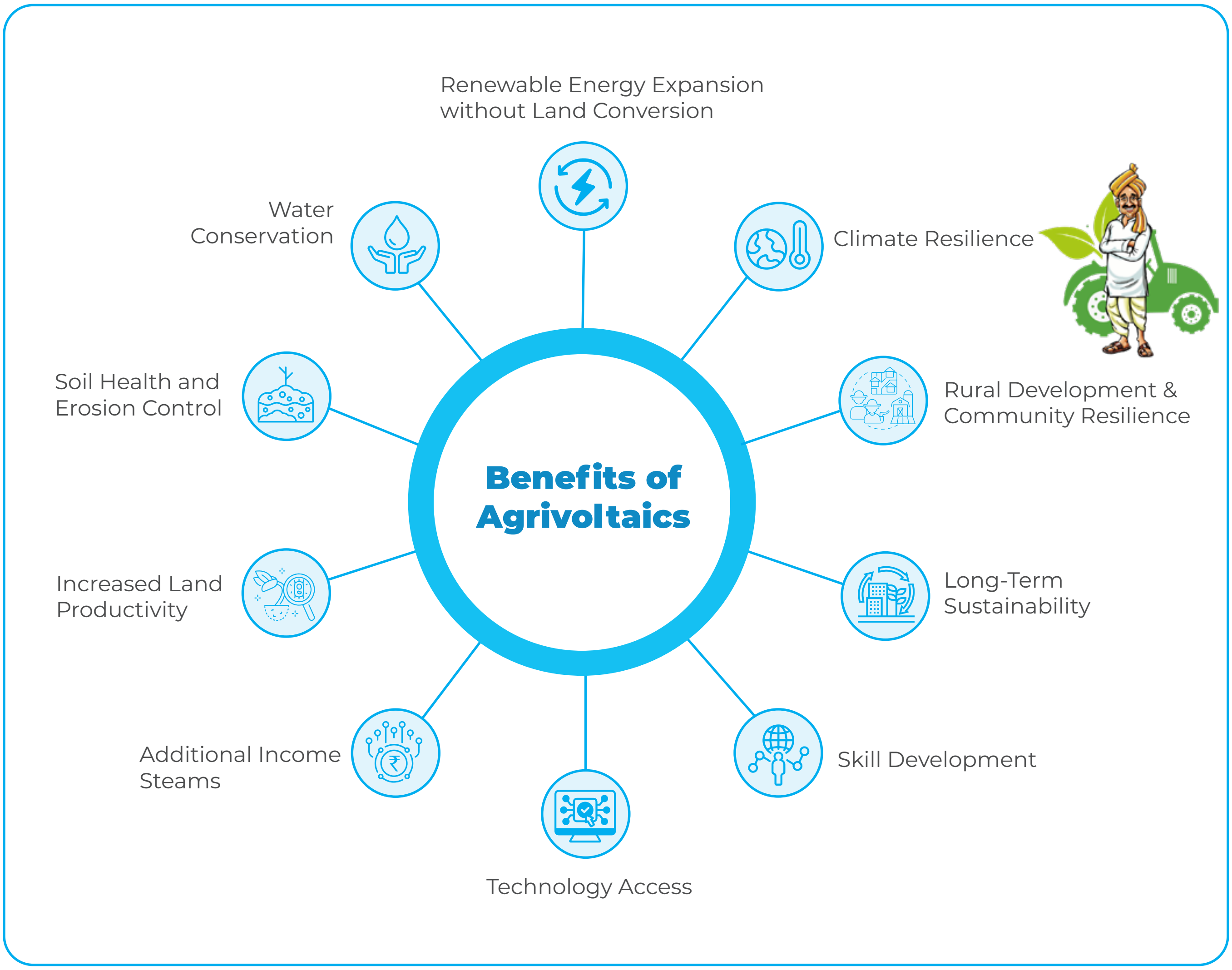


Figure 1: Benefits of Agrivoltaics

AGRIVOLTAICS – GLOBAL SCENARIO

Japan

In Japan, agrivoltaics, known locally as solar sharing, are encouraged as a method to utilize agricultural land for both solar power generation and farming without significant interference. The initiative involves erecting photovoltaic panels on poles above farmland, allowing sunlight to be shared between crop production and electricity generation. Solar sharing is permitted on various types of agricultural land, including degraded land, dilapidated farmland, and abandoned land and farmers are mandated to obtain temporary diversion permission every few years depending on specific conditions related to land use. The installations are required to ensure that the support structures are easily removable to maintain flexibility for agricultural activities. Japan offers procurement prices for solar electricity based on the capacity of the installation, incentivizing the adoption of solar sharing among farmers. Guidelines and standards, supervised by organizations like New Energy and Industrial Technology Development Organization (NEDO) and Ministry of Economy, Trade and Industry (METI), govern the technical specifications and operational requirements for these agrivoltaic systems, ensuring they integrate effectively with agricultural practices while promoting renewable energy development. **[1] [2] [3] [4] [5] [6] [7]**

China

Agrivoltaics lack a nationwide definition but encompass various models aimed at integrating PV systems with agriculture to promote dual-use efficiency and advance both sectors. These models include PV agriculture, which integrates PV modules without altering land use types, and PV composite projects that incorporate PV with agriculture, aquaculture, or animal husbandry. Agrivoltaics projects are typically located on general agricultural land, as construction on permanent basic farmland is strictly prohibited. To build PV stations on farmland, companies must grow crops under PV panels and ensure agricultural output, adhering to local government regulations. Although agrivoltaics projects are not exempt from land use taxes, they benefit from preferential policies at the local level. Despite the absence of a national standard, China has introduced group standards through the National Strategic Alliance for Collaborative Innovation in Modern Agricultural PV Industry (AMAPV) to guide the industry, with ongoing governmental support schemes like the 2021 subsidy initiative from Pinghu City, Zhejiang Province marking significant strides towards promoting agrivoltaics nationwide. **[8] [9] [10]**

France

France has legally defined Agrivoltaics as PV systems installed on agricultural land that provide multiple benefits without significantly reducing agricultural yield or income. These installations must offer services such as climate adaptation, protection from extreme weather, improved animal welfare, and agronomic support for specific crops. To qualify as an agrivoltaic system, the installations must obtain a construction permit from local authorities and demonstrate its capability to enhance, maintain, or marginally decrease agricultural yield. The law mandates that agrivoltaic structures be reversible, ensuring that agricultural activities remain the primary use of the land. Although specific subsidies and tax treatments for agrivoltaics are not defined, ongoing discussions and regulatory frameworks aim to integrate more PV installations on farm buildings, aligning with broader renewable energy goals and agricultural sustainability measures in France. **[11] [12]**

Germany

Germany defined agrivoltaics as the combined use of one and the same land area for agricultural production as the primary use, and for electricity production by means of a PV system as a secondary use. They require a construction permit from local authorities. Agrivoltaic installations are eligible for EU agriculture subsidies if they do not hinder conventional agricultural practices and reduce agriculturally usable land by no more than 15%. These installations maintain their agricultural and forestry property status, preserving associated tax benefits. Agrivoltaic systems must adhere to specific criteria regarding land use and agricultural productivity, with varying requirements based on installation height and yield considerations. Operators of systems exceeding 1 MW DC capacity must participate in tenders under EEG 2023 regulations, offering incentives like technology bonuses. Additional subsidies are available for agrivoltaics on drained peatland, promoting sustainability and biodiversity. Ongoing discussions aim to further integrate agrivoltaics into regulatory frameworks, aligning with Germany's renewable energy goals and agricultural sustainability policies. **[13] [14] [15] [16] [17] [18] [19] [20] [21]**

Italy

In Italy, agrivoltaics is formally defined as hybrid systems for agricultural and energy production, that do not adversely affect the use of land dedicated to agriculture. The guidelines classify agrivoltaic systems into different categories based on their integration with agricultural activities and eligibility for state incentives under the PNRR (National Recovery and Resilience Plan). Agrivoltaic installations are required to maintain at least 70% of their area devoted to agricultural activities and must achieve a minimum electrical productivity compared to standard PV systems. They also benefit from a simplified authorization process if located within proximity to commercial, industrial, or artisanal areas. The PNRR allocates significant funding, including capital grants and incentive tariffs, to support agrivoltaic projects, emphasizing their dual role in agricultural production and renewable energy generation. **[22] [23] [24]**

Israel

In Israel, agrivoltaics is not officially defined, and there are no specific regulations governing its implementation. However, a building permit is required for such projects. Recently, Israel launched a tender for 100 MW of agrivoltaic installations, where solar panels will be integrated with agricultural activities like orchards, field crops, flowers, spices, and vineyards. Selected projects will receive a fixed tariff of ILS 0.2091 ($0.06708) per kWh over a 23-year period. These agrivoltaic facilities are planned across various regions including the Golan Heights, Mount Hermon, Mateh Yehuda, the Jordan Valley, the Eilot region, the Springs Valley, the Upper Galilee, and the Negev desert. The initiative emphasizes collaboration between research institutes, farmers, and energy companies to advance sustainable energy solutions linked with agricultural practices. **[25] [26]**

South Korea

In Korea, agrivoltaics are categorized into rural and farming types under specific legal provisions. Rural photovoltaics involve farmers converting farmland into "hybrid land" and installing power generation facilities, typically for projects under 500 kW. Solar power plants can operate on reclaimed farmland with high salinity for up to 20 years, subject to restoration requirements. The initiative aims to promote renewable energy adoption while supporting agricultural activities, with guidelines ensuring that agrivoltaic projects are compatible with local farming practices and environmental considerations. **[27][28][28][29]**

Austria

Agrivoltaics is defined as the areas that are used simultaneously for electricity production by means of photovoltaics and used for agricultural production, the construction does not or only slightly interfere with the main agricultural use which is then not or only slightly affected. Eligible areas include unproductive land, permanent grassland, perennial crops, and arable land. Agrivoltaic projects must ensure that at least 75% of the land maintains agricultural use, with a maximum allowable loss due to sub-construction of 7%. Biodiversity measures are required for the remaining land not used for agriculture. Agrivoltaic installations enabled farmers to become eligible for EU agricultural funding under the EU Common Agricultural Policy Fund (CAP). Specific requirements under Austrian law include uniform distribution of photovoltaic modules, elevation of the modules to allow for agricultural workability, and infrastructure design that minimizes soil erosion and optimizes water distribution for crops. Financial incentives are available through the EAG (Erneuerbare-Ausbau-Gesetz – The Renewable Energy Expansion Act) for agrivoltaic systems that meet these criteria and enhance agricultural sustainability. **[30][31][32][33][34]**

Taiwan

Taiwan's recognizes agrivoltaics and defined it as systems installed on the roofs of agricultural facilities or on agricultural land before they do not affect agricultural operations. Agricultural land under 2 hectares is restricted from conversion, while land over 2 hectares requires approval from the Council of Agriculture. Applicants must show proof of agricultural production, with a minimum yield of 70% of the average yield of the past three years. Ground-type solar facilities cannot exceed 40% of the applied agricultural land area, and shading rates must not be higher than 40%. The installation must avoid changing the original topography, maintain sunlight penetration, and not affect the soil fertility or agricultural use of adjacent lands. **[35][36][37]**

Vietnam

In Vietnam, agrivoltaics is categorized under rooftop PV systems, including aqua-PV, and do not have a dedicated definition. These installations use the land use category "other agricultural land," which allows for construction. Conversion to this category is possible but subject to restrictions. While there was a feed-in tariff (FIT) for rooftop projects until 2020, currently, no FIT exists for new systems, limiting agrivoltaics to self-consumption purposes only.

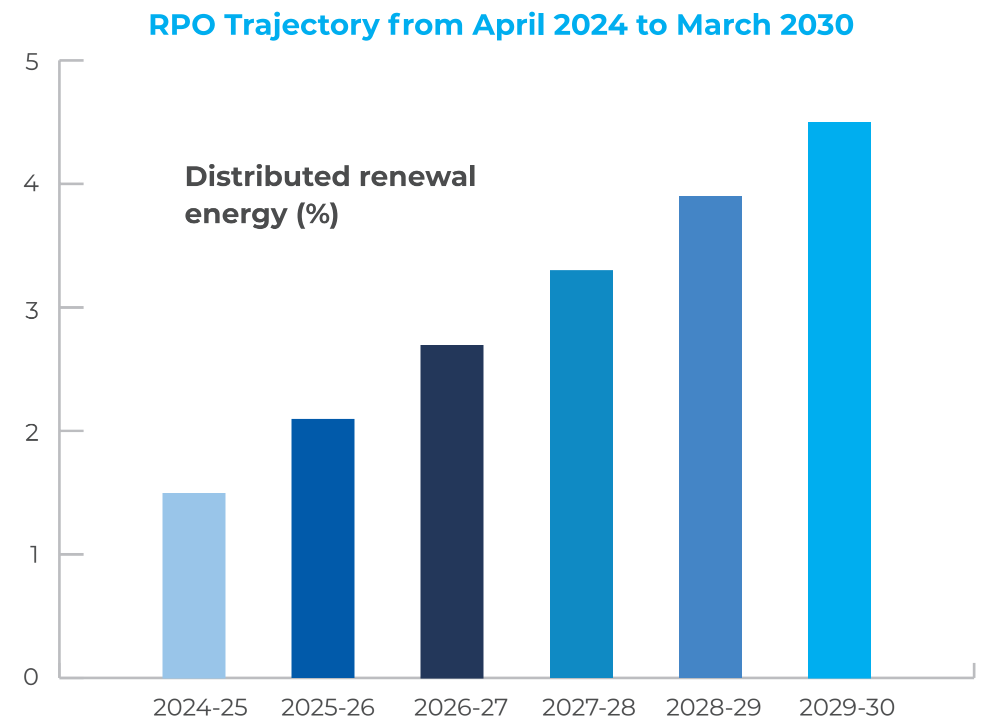
Front Runners in Agrivoltaics

- China had roughly 1.9 GW of capacity as of 2020
- Large-scale energy procurements are seeing agrivoltaics projects with sophisticated crop plans (e.g., vineyards, orchards).
- Released Policy on Agrivoltaics in 2023
- Amendment to the German Renewable Energy Act that went into effect in January 2021
- Guidelines for the Design, Construction and Operation of Agrovoltaic Plants in 2022

AGRIVOLTAICS FOR INDIA

In the context of India, agrivoltaics presents a compelling solution to address numerous challenges faced by the agriculture sector. The Indian agriculture sector encounters a myriad of difficulties, including fragmented land parcels, heavy reliance on fossil fuels for irrigation, lack of daytime power supply for irrigation purposes, and forecasted declining of agricultural productivity exacerbated by the impacts of climate change. Additionally, agricultural households in India grapple with low-income levels, with the average monthly income hovering around Rs. 10,218. **[38]** Furthermore, there is a pressing need for value addition in the agricultural sector to enhance its economic viability and competitiveness. Concurrently, soil degradation and water resource depletion pose significant threats to agricultural sustainability.

The challenges confronting the Indian renewable energy sector are also noteworthy. Land conflict may arise between food production and renewable energy installations, compounded by the limited availability of land suitable for ground mounted Solar energy installations. Moreover, there is a growing recognition of the necessity for distributed and decentralized renewable energy deployment to ensure equitable access and energy security across diverse geographical regions of India. This is also reflected in the amendments to the Renewable Purchase obligations notification by the Government of India in 2023 which mandates upto 4.5% of Distributed Renewable energy generation by 2030 for every Distributed Company in the Country.



Source: Ministry of Power

Agrivoltaics, hence, offers a strategic pathway to tackle these multifaceted challenges. Firstly, the integration of solar PV panels with agricultural activities optimizes land utilization, enabling farmers to generate solar energy while continuing agricultural production on the same land parcel. This approach also addresses the issue of fragmented land holdings by providing an additional source of income without requiring large contiguous land tracts. Moreover, agrivoltaic systems can mitigate fossil fuel dependency for irrigation by supplying clean, renewable energy for daytime power needs, thereby reducing agricultural operational costs and carbon emissions associated with conventional energy sources.

Furthermore, agrivoltaics aligns with India's ambitious renewable energy targets, including the installation of 500 GW of renewable energy capacity by 2030, with solar alone accounting for 300 GW and further help India's Net Zero target by 2070 which also requires India adding significant solar energy capacities [45] By leveraging agrivoltaics, India can accelerate progress towards these targets while simultaneously reducing CO_2 emissions by 1 billion tonnes by 2030, contributing significantly to the nation's climate change mitigation efforts. [46] Additionally, agrivoltaics can also help in diversifying the income streams of the farmers thereby enhancing rural livelihoods and economic resilience. **[39]** Coupled with livelihood generating activities that can be powered with Solar energy, Agrivoltaics has the potential to transform India's Agriculture and Food Systems.

In conclusion, agrivoltaics holds immense promise for addressing the challenges of Renewable Energy Generation. Diversifying farmer's income and decarbonizing the Agriculture energy use while enhancing agricultural productivity, promoting energy security, mitigating climate change, and fostering rural development and economic prosperity.

INDIA'S AGRICULTURE ECOSYSTEM

Economic and Employment Indicators

The Gross Value Added (GVA) of the Agriculture and Allied Sector at constant (2011-12) prices, as per the Second Advance Estimates for the year 2022-23, stands at Rs. 2,22,1092 crores. This indicates the total contribution of agriculture and its allied sectors to the economy and the share of the Agriculture and Allied sector in the Total GVA at current prices, according to the Second Advance Estimates for the year 2022-2023, is 21.1%. This illustrates the significant importance of agriculture in the overall economy of India. The growth rate of GVA in the Agriculture and Allied sector at constant (2011-12) prices, based on the Second Advance Estimates for the year 2022-23, is reported to be 3.3%.

The total value of agricultural exports for the year 2021-22 amounts to Rs. 3,75,662 crores. Additionally, the percentage share of the value of agricultural exports to national exports is reported to be 11.94%. This indicates the significance of agricultural exports in India's overall trade and the value of total agricultural imports for the year 2021-22 stands at Rs. 2,31,850 crores. Furthermore, the percentage share of the value of agricultural imports to national imports is reported to be 5.07%. This suggests that India has a higher value of agricultural exports compared to imports, indicating a favourable trade balance in agriculture. Overall, these macroeconomic indicators provide insights into the performance and significance of the agricultural sector in India's economy, highlighting its contribution, growth trajectory, and trade dynamics. **[44]**

The employment indicators of agriculture provide insights into the significant role of the agricultural sector in India's workforce and economy. As per the Census of 2011: **[40]**

a) The total number of cultivators in India was recorded at 118.8 million. Cultivators are individuals engaged in agricultural activities involving the cultivation of crops and management of farm operations.

b) Additionally, the Census reported a total of 144.3 million agricultural labourers. Agricultural labourers are individuals who primarily work on farms but do not own the land they cultivate. They are involved in various activities such as planting, harvesting, and tending to crop.

c) The percentage share of agricultural workers, including both cultivators and agricultural labourers, in the total workforce of India was 54.6%. This indicates that more than half of the country's population is engaged in agricultural activities, highlighting the sector's significance as a major source of employment and livelihood.

These employment indicators underscore the crucial role of agriculture in sustaining livelihoods, particularly in rural areas where agriculture remains a primary source of income for millions of households.

Table 2: Number and Area of Operational Holdings by Size Group [41]

No. of Holdings: '000 Number, **Area Operated:** '000 Hectare, **Average Size:** Hectare

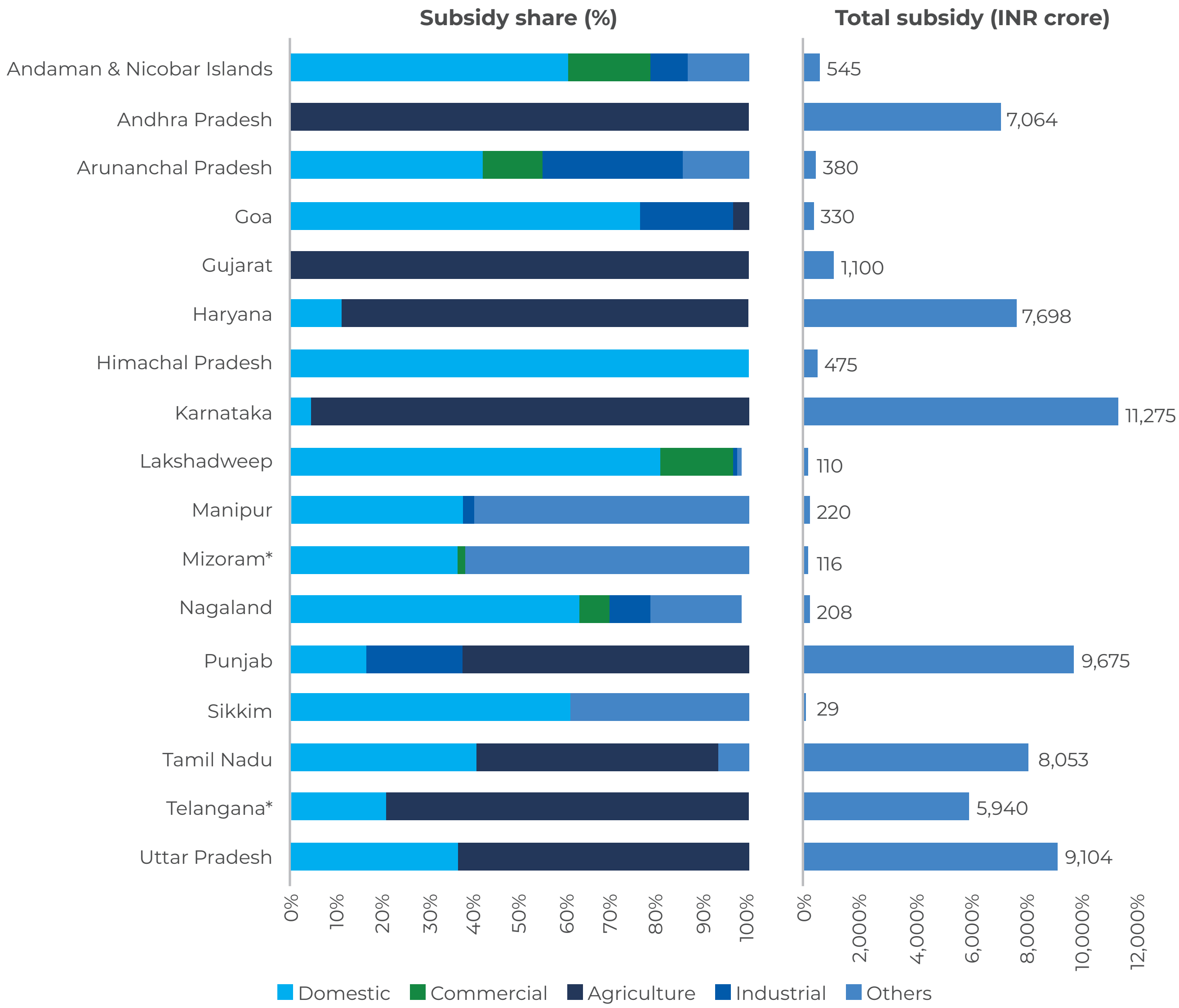
Category of Holdings	Number of Holdings			Area			Average Size of Holdings		
	2005-06*	2010-11	2015-16	2005-06*	2010-11	2015-16	2005-06*	2010-11	2015-16(P)
1	2	3	4	5	6	7	8	9	10
Marginal (Less than 1 hectare)	83694 (64.8)	92826 (67.1)	100251 (68.45)	32026 (20.2)	35908 (22.5)	37923 (24.03)	0.38	0.39	0.38
Small (1.0 to 2.0 hectare)	23930 (18.5)	24779 (17.9)	25809 (17.62)	33101 (20.9)	35244 (22.1)	36151 (22.91)	1.38	1.42	1.40
Semi-Medium (2.0 to 4.0 hectare)	14127 (10.9)	13896 (10.0)	13993 (9.55)	37898 (23.9)	37705 (23.6)	37619 (23.84)	2.68	2.71	2.69
Medium (4.0 to 10.0 hectare)	6375 (4.9)	5875 (4.2)	5561 (3.80)	36583 (23.1)	33828 (21.2)	31810 (20.16)	5.74	5.76	5.72
Large 10.0 hectare and above)	1096 (0.8)	973 (0.7)	838 (0.57)	18715 (11.8)	16907 (10.6)	14314 (9.07)	17.08	17.38	17.07
All Holdings	129222 (100.0)	138348 (100.0)	146454 (100.0)	158323 (100.0)	159592 (100.0)	157817 (100.0)	1.23	1.15	1.08

From Table-2 it can be observed that Marginal farmers hold the largest number of operational land holdings of about 68.45%. The average land holding size is 1.08 Hectares. Many states such as Bihar, Uttar Pradesh, West Bengal have an average land holding size less than that of the Indian average. Punjab, Haryana, and North-eastern states have higher average land holding size. It can also be observed that the number of operational holdings and land area of marginal and small farmers is increasing whereas medium and large farmers operational land holdings and land area is decreasing.

Agricultural Electricity Consumption

Agricultural electricity consumption in India plays a vital role in sustaining agricultural productivity and ensuring food security. In the fiscal year 2021-22, the consumption of electricity for agriculture amounted to 2,28,451 GWh, representing approximately 20.11% of the

Unpacking India's Electricity Subsidies Reporting, Transparency and Efficacy (CEEW Analysis)



total electricity consumption in the country. Despite a decreasing share of electricity supplied to the agricultural sector compared to other sectors, the total consumption of electricity in agriculture has witnessed a steady increase over the past decade. This upward trend is primarily attributed to the widespread adoption of tubewell irrigation practices across India, with over 2.13 crores of pump sets/tubewells electrified as of March 2020, including 2.82 lakh installations in the fiscal year 2019-20.

Electricity for irrigation purposes in the agricultural sector is often provided either free of charge or at subsidized rates by most state governments throughout India. However, this policy approach is driven largely by political considerations. While electricity subsidies are intended to enhance the profitability and productivity of the agricultural sector, they impose a significant financial burden on state governments. For instance, an estimated ₹90,000 crores were allocated for subsidizing power supplied to the agricultural sector in the fiscal year 2015-16.

The allocation of subsidies for agricultural electricity consumption varies considerably across states, with some states dedicating a substantial portion of their budget to this purpose. For example, power subsidies for agriculture range from 3.8% of the state budget in Andhra Pradesh to as high as 10% of the state budget in Punjab. This substantial financial commitment underscores the importance of energy autonomy and distributed renewable energy in agriculture. **[42]**

Given India's vast and diverse geography, Agro-climatic conditions, crop varieties, cropping patterns, and water availability, the country presents a unique set of opportunities and challenges for agrivoltaics implementation. This diversity necessitates comprehensive research and pilot projects across various Indian regions to fully understand agrivoltaics' dynamics and suitability. Tailoring agrivoltaics systems to fit the local conditions, crop types, and agricultural practices is crucial for maximizing their benefits and effectiveness. Such region-specific research will enable the identification of best practices, optimization strategies, and potential challenges, guiding the scalable and sustainable expansion of agrivoltaics across India.

Climate Change Effects on Agriculture

India's agricultural heartland, the Indo-Gangetic plains, faces additional threats from melting glaciers in the Himalayas. These glaciers serve as crucial water reservoirs, and their retreat affects river flows, which are essential for irrigation. With rising temperatures and erratic precipitation patterns, the reliability of water sources for agriculture diminishes, posing significant challenges for farmers.

In the absence of adaptation measures, climate projections paint a grim picture for India's staple crops. Wheat yields, for instance, could plummet by up to 23% by 2050, threatening food security and farmer livelihoods. Similarly, rice, another vital crop, may witness a decline of up to 10% in yields under similar conditions, further exacerbating the food security challenge.

Furthermore, the vulnerability of rainfed agriculture to climate change is starkly evident, with projected reductions in rice yields by 20% by 2050 and 47% by 2080 scenarios. Even irrigated rice, which is relatively less vulnerable, faces a decline of 3.5% by 2050 and 5% by 2080 scenarios, highlighting the widespread impact of climate change on agriculture. [**43**]

In conclusion, climate change poses unprecedented challenges to Indian agriculture, necessitating urgent and concerted efforts to enhance resilience and sustainability. Agrivoltaics presents a viable solution by harnessing solar energy while simultaneously supporting agricultural productivity and resilience, thereby contributing to India's quest for climate-smart agriculture.

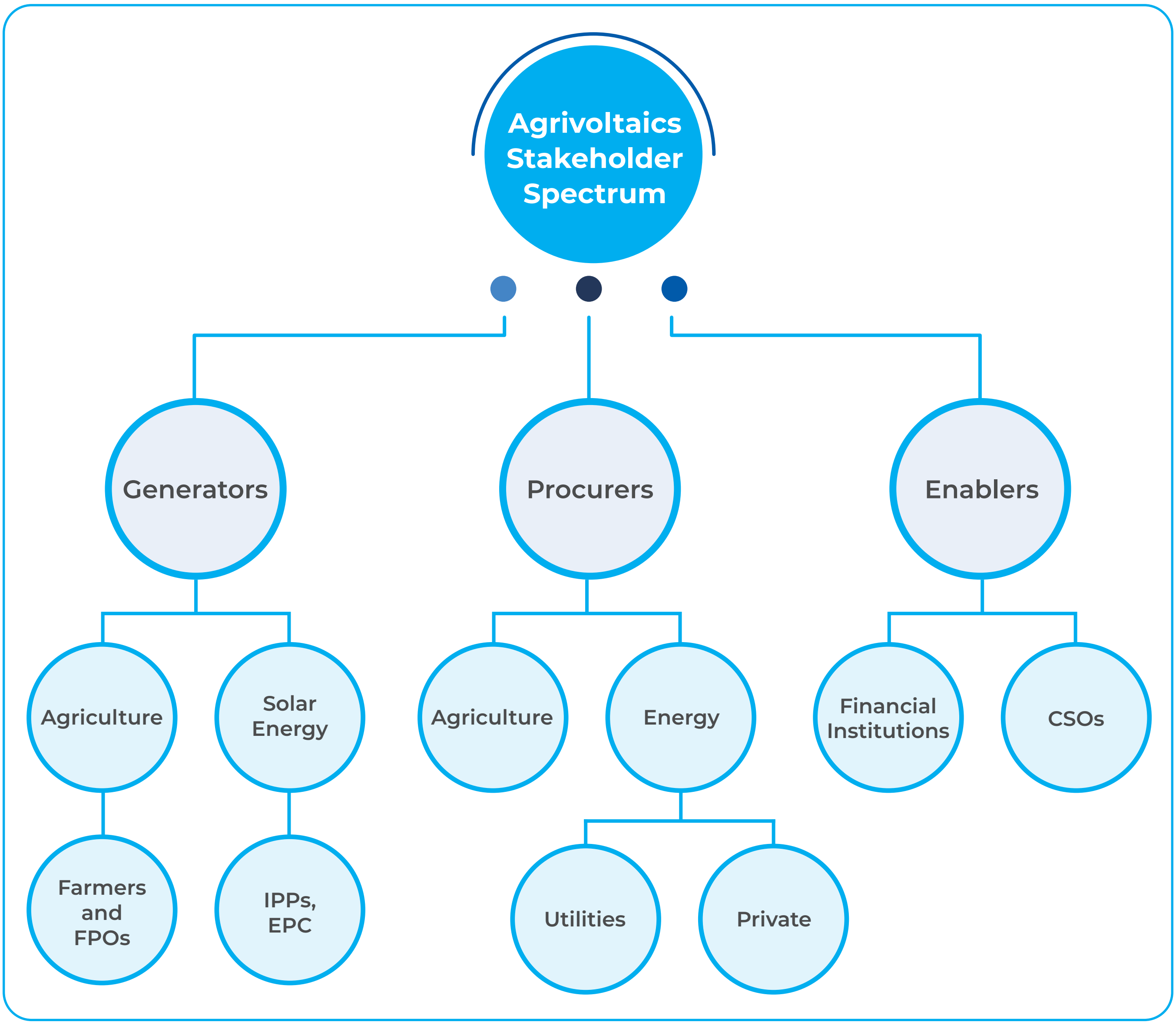
STAKEHOLDER SPECTRUM BENEFIT ANALYSIS

In the dynamic landscape of agrivoltaics, understanding the perspectives, capabilities, and concerns of various stakeholders is crucial for navigating the complexities of policy making for effective implementation of Agrivoltaics. Stakeholders, ranging from farmers and solar developers to FPOs and researchers, play pivotal roles in the ecosystem of agrivoltaics. Each stakeholder brings unique strengths, faces distinct challenges, and holds specific opportunities that can influence the success and scalability of agrivoltaic projects in India

The stakeholder spectrum can be broadly divided into 3 categories:

- The Generators
- The Enablers
- The Procurers

To facilitate a comprehensive understanding of this multifaceted domain, this section will analyse each of these stakeholders through a structured analysis, highlighting the internal and external factors that can help policy makers understand how each stakeholder interacts with Agrivoltaics and ultimately derive at the policy instruments that can benefit each of these stakeholders.



Generators

Farmers and FPOs

Farmers and the agricultural sector have a pivotal role in the adoption and success of agrivoltaics. As a primary stakeholder, farmers are directly impacted by changes in agricultural practices and environmental conditions. Integrating solar energy generation systems into agricultural landscapes can offer farmers additional income streams through land lease agreements and/or electricity generation along with supporting other livelihood generation activities, thereby enhancing their economic resilience.

Studies and experience from installations across the globe suggest that, in many cases Agrivoltaics can also contribute to sustainable agriculture by reducing water evaporation, mitigating soil erosion, and providing shade to crops, thus improving overall yield and crop quality. Farmers possess invaluable knowledge about local agricultural practices, soil types, and crop requirements, making their involvement crucial for the successful implementation and optimization of agrivoltaics systems.

Additionally, the agricultural sector stands to benefit from the adoption of agrivoltaics by enhancing energy efficiency, reducing greenhouse gas emissions, and promoting climate-resilient farming practices. Collaborative efforts between farmers, agricultural experts, and policymakers are essential for realizing the full potential of agrivoltaics in ensuring food security, enhancing rural livelihoods, and mitigating the adverse impacts of climate change on agriculture.

Strengths

- **Agricultural Expertise:** Deep understanding of local agricultural practices and conditions allows farmers to integrate agrivoltaics with minimal disruption to existing farming activities.
- **Government Support:** The sector enjoys strong support from the government through various schemes and policies aimed at supporting agriculture and welfare of farmers.
- **Human Resources:** With a substantial portion of the population engaged in agriculture, there is a large pool of knowledge and human resources available that can be upskilled to handle agrivoltaics installations.

Opportunities

- **Sustainability and Climate Resilience:** Agrivoltaics can offer a pathway to more sustainable and climate-resilient farming practices, possibilities of additional crops in the same land along with potentially shielding the yield from climate change induced extreme events.
- **Additional Income Streams:** By incorporating solar power generation, farmers can diversify their income sources, reducing dependency on traditional agriculture. Additionally, addition of value adding equipment powered by solar such as cold storage, dryers and chillers, food processing units, flour mills, chaff cutters etc can enhance the income generation
- **Reliable Electricity Supply:** Access to reliable day-time power supply due to the adoption of agrivoltaics potentially decreasing their dependency on free electricity which is often available at night hours.

Challenges

- **Yield reduction:** Solar installations on the agriculture fields have an impact on the yield and in cases for specific crops based on the configuration of the Agrivoltaics system contribute to yield losses
- **High Initial Capital Requirement:** The initial setup cost for agrivoltaic systems can be prohibitive for many farmers especially small and marginal farmers without access to financing or subsidies.
- **Technical Know-How:** Lack of technical knowledge regarding the installation, maintenance, and optimization of agrivoltaic systems can pose a significant barrier.
- **Perceived Risks:** Hesitancy to adopt new technologies due to the perceived risk of their primary income source from agriculture.

Solar Developers/EPCs

The solar energy sector plays a crucial role in the development and implementation of agrivoltaics. As stakeholders, solar energy companies bring expertise in, EPC, and O&M, which are essential for integrating solar PV systems into agricultural landscapes. By leveraging their experience and resources, solar energy firms can collaborate with farmers to design and deploy agrivoltaic projects that maximize energy generation while minimizing agricultural land use conflicts.

Moreover, the solar energy sector can contribute to agrivoltaic research and development, exploring innovative solutions to optimize the co-existence of solar panels and agricultural activities. Through partnerships with agricultural stakeholders, solar energy companies can access suitable land resources for solar installations, thus expanding their renewable energy portfolio and contributing to the transition towards sustainable energy systems. Additionally, promoting agrivoltaics aligns with the solar energy sector's goals of increasing renewable energy deployment, reducing carbon emissions, and fostering rural economic development. By embracing agrivoltaics, solar energy companies can demonstrate their commitment to environmentally responsible energy solutions while capitalizing on synergies between agriculture and renewable energy production.

S

Strengths

- **Technical Expertise:** Solar industry brings with them specialized knowledge in PV technology, including design, installation, and maintenance of solar systems. This expertise is crucial for developing efficient and reliable agrivoltaic systems.
- **Innovation:** Many solar companies are at the forefront of technological innovation, capable of designing agrivoltaic systems that optimize energy production while minimizing impacts on agricultural productivity.
- **Climate Targets:** The increasing demand for renewable energy sources triggered by India's ambitious targets make Indian Solar energy sector the single largest contributor for realizing clean energy as well as Climate change mitigation targets.

Opportunities

- **Distributed Solar Generation:** India's Solar installed capacity is predominantly consists of large utility scale plants. With the amended RPO (2023) along with the growing need for distributed Renewable Energy, Agrivoltaics presents an optimum solution.
- **Collaborations with Agriculture Sector:** Partnerships with farmers, agricultural researchers, and agribusinesses can bridge the knowledge gap, leading to better-designed systems and mutual benefits.
- **Technological Advancements:** Continuous innovation in solar PV and agrivoltaic-specific technologies can improve efficiency, reduce costs, and enhance the compatibility of solar energy production with farming.

Challenges

- **Agricultural Knowledge Gap:** Solar companies may lack detailed understanding of agricultural practices and needs, potentially leading to designs that are not fully optimized for agrivoltaics applications.
- **Integrated Business Models:** The development and deployment of agrivoltaics systems requires higher quantum of investments compared to conventional ground mounted Solar systems. In absence of viable integrated business models that consider both Agriculture and Solar Aspects, Solar Developers may find it challenging in installing or scaling up Agrivoltaics systems.
- **Land Use regulations:** Navigating the regulatory landscape for land use and energy generation can be complex and time-consuming, particularly for agrivoltaics projects that straddle these domains.
- **Grid Availability:** Conventional large scale utility projects are connected to high voltage transmission infrastructure. Whereas agrivoltaics projects get connected to Agriculture feeders or low voltage transmission infrastructure where down time is considerably higher than utility scale systems.

For solar energy players, the agrivoltaic sector represents a promising avenue for expansion and innovation, aligned with global shifts towards renewable energy and sustainable agriculture. However, realizing this potential requires addressing the unique challenges of integrating solar PV with farming, navigating regulatory landscapes, and fostering collaborations that leverage the strengths of both the energy and agricultural sectors.

Procurers

DISCOMs or Utilities

Distribution companies (DISCOMs) and grid operators are essential stakeholders in the adoption and implementation of agrivoltaics. As intermediaries between renewable energy producers and consumers, DISCOMs and grid operators play a critical role in integrating solar energy generated from agrivoltaic systems into the electricity grid. They are responsible for managing the transmission and distribution infrastructure, ensuring the stability and reliability of the grid, and balancing supply and demand dynamics.

In the context of agrivoltaics, DISCOMs and grid operators can collaborate with farmers and solar developers to facilitate grid connections for agrivoltaic projects, ensuring tail-end integration of solar power into the existing electricity infrastructure. By actively participating in the planning and execution of agrivoltaic initiatives, DISCOMs and grid operators can optimize grid operations, enhance grid resilience, decrease distribution losses and contribute to the overall decarbonization of the energy sector. Moreover, they can explore innovative grid management strategies, such as demand response programs and energy storage solutions, to accommodate the intermittent nature of solar power generation in agrivoltaic systems.

Additionally, DISCOMs and grid operators can leverage agrivoltaics to meet renewable energy target and RPOs, mitigate transmission losses, and improve energy access in rural areas, thereby fostering sustainable development and energy security. Through collaboration and coordination with other stakeholders, DISCOMs and grid operators can harness the full potential of agrivoltaics to build a more resilient, efficient, and sustainable electricity grid for the future.

S

Strengths

- **Infrastructure and Expertise:** DISCOMs and grid operators possess established infrastructure and expertise in managing electricity distribution networks, ensuring reliable power supply to consumers.
- **Grid Stability:** By leveraging grid-connected agrivoltaic systems, DISCOMs can enhance grid stability through the injection of renewable energy into the grid, reducing reliance on fossil fuels, decreasing transmission losses and mitigating greenhouse gas emissions.
- **Demand Aggregation Capabilities:** DISCOMs control the demand aggregation of power and is instrumental in deciding the installation capacities required in a particular region.

Opportunities

- **Reduction in Subsidy burden:** Realization from electricity supplied to Agriculture is less than 20% in India. Integration of generation systems at the agriculture fields or feeder level will bring down the cost of supply and also reduce the burden of subsidies for agricultural electricity consumption.
- **Reduced Transmission and Distribution Losses:** Since Agrivoltaic plants are intalled at the tail end of the grid, the inherent transmission and distribution losses are is a distributed renewable energy system, it reduces the transmission and distribution losses.
- **DRE RPO Fulfilment:** Agrivoltaics provides an opportunity for DISCOMS to fulfil their Distributed Renewable Energy targets as per the newly amended RPO. (increased to 4% until 2030)
- **Revenue Opportunities:** Agrivoltaic installations can provide additional revenue streams for DISCOMs through power purchase agreements (PPAs) under PM-KUSUM scheme (Performance Based Incentives)
- **Demand Response Programs:** Grid operators can leverage agrivoltaic installations to implement demand response programs, incentivizing flexible energy consumption patterns that align with solar generation peaks, thereby optimizing grid operations and reducing peak demand.

Challenges

- **Tariff:** DISCOMs might perceive the tariffs from decentralized systems higher than conventional large scale utility plants.
- **Grid Compatibility:** Integrating agrivoltaic systems into existing grid infrastructure may require upgrades or modifications to accommodate variable generation patterns and ensure grid stability, adding complexity and cost to grid operations.
- **Grid availability and access:** Availability of physical infrastructure of grid along with reliable and continuous supply at the nodes of injection in various agriculture feeders.

Enablers

Civil Society Organizations (CSOs)

Civil Society Organizations (CSOs) play a crucial role in promoting agrivoltaics and supporting its implementation at the grassroots level.

CSOs often have expertise in community development, environmental conservation, and renewable energy advocacy. They can raise awareness about agrivoltaics among rural communities, advocate for supportive policies and incentives at the local and national levels and mobilize resources for pilot projects and capacity-building initiatives. CSOs can also facilitate participatory decision-making processes, ensuring that the voices and priorities of farmers and local communities are heard and respected in the design and implementation of agrivoltaic projects.

Moreover, they can leverage their networks and partnerships to foster collaboration between diverse stakeholders, including government agencies, research institutions, private sector actors, and international donors, to promote knowledge exchange, innovation, and best practices in agrivoltaics. CSOs can empower farmers, strengthen rural livelihoods, and contribute to the sustainable development of agrivoltaics as a viable pathway towards climate resilience, energy access, and inclusive growth.

S

Strengths

- **Community Engagement:** CSOs have established networks and relationships within rural communities, enabling them to engage farmers and other stakeholders in agrivoltaic projects.
- **Technical Assistance:** CSOs often provide technical assistance, training, and capacity-building support to farmers, facilitating the adoption and management of agrivoltaic systems.
- **Advocacy and Outreach:** CSOs can advocate for supportive policies, mobilize public support, and raise awareness about the benefits of agrivoltaics, driving momentum for sustainable agriculture and renewable energy initiatives.

O

Opportunities

- **Partnerships and Collaboration:** Collaboration between CSOs, government agencies, and private sector actors can leverage complementary expertise, resources, and networks to scale up agrivoltaic initiatives and maximize impact.
- **Policy Advocacy:** These organizations can advocate for policy reforms, incentives, and support mechanisms that promote the adoption of agrivoltaics, advocating for the interests of smallholder farmers and marginalized communities thereby contributing in policy making.

Challenges

- **Resource Constraints:** Limited funding, staff capacity, and technical expertise may constrain the ability of CSOs to effectively support agrivoltaic projects and initiatives.
- **Fragmentation:** The proliferation of multiple organizations working on similar issues in the same geographic area can lead to duplication of efforts, competition for resources, and co-ordination challenges.
- **Dependency on External Funding:** Dependency on external funding sources or donor priorities may restrict the autonomy and long-term sustainability CSOs, potentially affecting their ability to support agrivoltaic projects independently.

Financial Institutions

Financial institutions, including banks, micro-finance institutions, and investment firms, play a critical role in facilitating the adoption and scaling up of agrivoltaics by providing the necessary funding and financial products. These institutions can offer various financing options tailored to the needs of farmers, solar developers, and other stakeholders involved in agrivoltaic projects. For farmers, financial institutions can provide loans or credit lines to cover the upfront costs of installing solar panels and associated infrastructure, such as mounting structures, inverters, and electrical wiring. These loans can be structured with flexible repayment terms and interest rates, considering the seasonal nature of agricultural income and the expected revenue streams from solar energy generation.

Financial institutions can also offer specialized products, such as green bonds or impact investments, to channel funds into agrivoltaic projects that align with environmental and social objectives. By leveraging their risk assessment tools and expertise in project finance, financial institutions can evaluate the feasibility and creditworthiness of agrivoltaic ventures, thereby mitigating investment risks and attracting capital from institutional investors and development finance institutions. Moreover, financial institutions can collaborate with government agencies, international organizations, and industry associations to develop innovative financing mechanisms, such as risk-sharing facilities, insurance products, and carbon credits, to incentivize private sector participation and mobilize additional resources for agrivoltaic initiatives.

Strengths

- **Capital Deployment:** Financial institutions have access to significant capital resources, enabling them to finance large-scale agrivoltaic projects and investments in renewable energy infrastructure.
- **Risk Management Expertise:** These institutions possess expertise in assessing and managing financial risks, allowing them to evaluate agrivoltaic projects' viability and structure financing arrangements that mitigate risks for investors.
- **Diversification:** Agrivoltaics offer financial institutions a diversification opportunity within their investment portfolios, complementing traditional energy and agricultural investments with a sustainable, dual-use approach.

Opportunities

- **Green Finance Opportunities:** Agrivoltaics offer financial institutions opportunities to participate in green finance initiatives, aligning with sustainable development goals, climate mitigation targets, and responsible investment principles.
- **Innovative Financing Mechanisms:** Financial institutions can develop innovative financing mechanisms, such as green bonds, impact investing funds, or blended finance structures, to attract capital and mobilize resources for agrivoltaic projects.
- **Partnerships and Syndication:** Collaboration with other financial institutions, development agencies, and private sector partners can facilitate syndication arrangements and risk-sharing mechanisms, enabling large-scale agrivoltaic investments.

Challenges

- **Lack of Familiarity:** Limited familiarity with agrivoltaic technologies and business models may pose a barrier to entry for financial institutions, requiring education and capacity-building efforts to build confidence and understanding.
- **Regulatory Uncertainty:** Uncertainty surrounding regulations, subsidies, and incentives for agrivoltaics may deter financial institutions from committing capital to these projects, particularly in jurisdictions with inconsistent or evolving policy frameworks.

KEY BOTTLENECKS FOR AGRIVOLTAICS IN THE CURRENT LANDSCAPE

1. **Lack of Formal Recognition for Agrivoltaics**

   One of the key challenges is the absence of formal recognition and a specific definition of agrivoltaics within the scheme. While agrivoltaics installations can potentially be accommodated under this component, the lack of explicit recognition may result in ambiguity and inconsistency in implementation. A formal definition and acknowledgment of agrivoltaics would provide clarity and guidance for stakeholders, facilitating the development and deployment of agrivoltaic projects within the framework of the scheme.

2. **Absence of Mandate for Continued Agriculture**

   The scheme allows for the integration of renewable energy installations on agricultural land; however, there is no mandate to ensure continued agricultural activities alongside energy production. Compulsory continuation of agriculture on the land where agrivoltaic installations are deployed could mitigate potential land conflicts and promote food security. By requiring simultaneous agricultural use, the scheme could strike a balance between energy production and agricultural productivity, maximizing the benefits for both sectors.

3. **Lack of Subsidy or Viability Gap Funding (VGF) under Component - A**

   Another key challenge is the absence of direct financial support mechanisms such as subsidies or Viability Gap Funding (VGF). While the scheme offers incentives like Performance-Based Incentives (PBIs) to DISCOMs, there is no provision for financial assistance to agrivoltaic project developers or landowners. Introducing subsidies or VGF schemes could incentivize greater participation in agrivoltaic projects, particularly among small and marginal farmers, thereby accelerating the adoption of this innovative technology.

4. **Inadequate Standards and Certifications for Agrivoltaics**

   The existing standards and specifications outlined by the Bureau of Indian Standards (BIS) may not be sufficient to address the unique requirements of agrivoltaic installations. Agrivoltaics represents a distinct paradigm with specific challenges and considerations, necessitating tailored certifications and specifications to ensure the quality, safety, and effectiveness of agrivoltaic systems. Without specific guidelines, there may be uncertainties and risks associated with the implementation of agrivoltaic projects, hindering their widespread adoption and success.

5. **Lack of Farmer Awareness**

   Despite the potential benefits of Agrivoltaics, the lack of farmer awareness remains a significant bottleneck to its widespread adoption in India. Many farmers are unaware of the concept of Agrivoltaics, its benefits, and how to implement it effectively. This knowledge gap hinders the uptake of Agrivoltaics, as farmers are hesitant to invest in a unfamiliar technology. Moreover, the lack of awareness also leads to skepticism and misconceptions about the impact of solar panels on crop yields and soil health. Educating farmers about the benefits and best practices of Agrivoltaics is essential to increase adoption rates and unlock the full potential of this innovative farming approach. Effective extension services, training programs, and demonstration projects can help bridge the knowledge gap and encourage farmers to embrace Agrivoltaics.

POLICY AND REGULATORY RECOMMENDATIONS

Short Term (Immediate)

1. **Define Agrivoltaics:** Countries with dedicated agrivoltaics policies have a clear definition of what kind of installations qualify the criteria to be considered as Agrivoltaics. This definition can be arrived considering the parameters including but not limited to Solar Capacity (Min and Max), Minimum compulsory area under agriculture, Maximum allowed yield loss, height of the structure, crops that are restricted, land restricted.

Based on various consultations with both agriculture and solar energy stakeholders, the Alliance proposes the following structure for defining Agrivoltaics

Parameter	Recommendation	Rationale
Solar Capacity	100kW- 5 MW	Expanding the Solar capacity from 100kW to 5 MW will enable India realize climate targets while accelerating Agrivoltaics Due to the increasing adoption of states for solarizing Agriculture feeders through KUSUM C, capacities between 100kW to 5 MW through
Height and Structure Specifications	Min 1.5 - 2m height from the ground	Adequate height to allow farming activities and equipment to pass under solar panels.
Crop and Yield Loss restrictions	Restrict Key Staple food crops Limit Maximum yield loss between 10 – 20% (Lowest in any country with Agrivoltaic policy)	Ensuring minimal impact on essential food crops; data from pilot projects can refine this limit.
Minimum Area under cultivation	At least 70% of land area	Ensuring that more than 70% of the land remains, under cultivation promoting significant agricultural activity alongside solar energy generation. This threshold can be adjusted based on findings from ongoing pilot projects.
Maximum Area under Solar	Not more than 30% of land area	Limiting the area under solar panels to less than equal to 30% ensures that the majority of the land is used for agricultural purposes providing a balanced approach to land use. Adjustments can be made based on pilot project outcomes.

2. **Enhancing Financial Viability through Tariff Adjustments and Viability Gap Funding under PM KUSUM Component A**

   Increasing tariffs at the state or national level for the PM KUSUM Component A directive, specifically offering a rate of 4.5/kWh for the initial two years, can significantly enhance the attractiveness of agrivoltaic projects. This adjustment would provide crucial financial viability to projects integrating solar PV systems with agricultural activities. By offering a higher tariff, states can effectively incentivize farmers and project developers to adopt agrivoltaics, mitigating initial investment risks and ensuring a reasonable return on investment during the crucial early stages of project implementation.

   Moreover, if states/centre opt to provide viability gap funding (VGF) instead of the tariff adjustments, it could further bolster the economic feasibility of agrivoltaic initiatives. VGF would bridge the financial gap between project costs and revenues generated from electricity sales. This support mechanism would encourage faster adoption of agrivoltaics, promote sustainable energy generation in rural areas, and stimulate economic growth through enhanced agricultural productivity and renewable energy deployment.

3. **Mandatory agrivoltaics Installations in KUSUM and Component C**

   Mandate 10% of the total capacity awarded to each state for Agrivoltaics plants in component C where Feeder level solarization is opted. Plants satisfying the definition of Agrivoltaics should be considered as agrivoltaics plants. One of the key challenges of agrivoltaics integration is the tariff. With component C, the subsidy part covers the cost overheads of the additional costs. Hence, it is recommended to mandate 10% of installations under KUSUM C for Agrivoltaics

4. **Establish Special Multi Ministerial Committee**

   Establishment of a Multi-Ministerial Committee for Agrivoltaics Recognizing the interdisciplinary nature of agrivoltaics and the need for coordinated action across various sectors, the establishment of a multi-ministerial committee is essential. This committee will serve as a platform for collaboration, policy coherence, and effective implementation of agrivoltaics initiatives, bringing together key stakeholders from relevant ministries and departments.

   The multi-ministerial committee should include representatives from ministries such as Agriculture and Farmers& Welfare (MoAFW), New and Renewable Energy (MNRE), Rural Development, Panchayati Raj, Environment, Forest, and Climate Change (MoEFCC), Water Resources (Jal Shakti), and Science & Technology, among others.

5. **Recognize Agrivoltaics to qualify for incentives from other schemes**

   Existing schemes such as the National Horticulture Mission, Pradhan Mantri Fasal Bima Yojana (PMFBY), and the Agriculture Infrastructure Fund (AIF) present significant opportunities to incentivize the adoption of agrivoltaic systems. By integrating support for agrivoltaics into these schemes, the government can provide substantial financial assistance to farmers, reducing the initial cost barriers associated with agrivoltaic installations. For instance, the National Horticulture Mission, which currently aids farmers in developing horticulture crops, could extend its assistance to partially cover the installation costs of solar PV systems that enhance horticulture productivity.

   The Agriculture Infrastructure Fund (AIF), with its allocation of Rs.1 lakh crore for financing farm gate infrastructure and community farming assets, provides a significant opportunity to support agrivoltaic projects. By including agrivoltaic systems under its purview, the AIF can provide financial support for installing solar panels on farms for supporting solar-powered dryers, cold storage, food processing units etc. to add value to the harvested crops.

   Additionally, the PMFBY crop insurance scheme could be adapted to offer additional coverage for yield losses specific to crops grown under agrivoltaic systems. This would mitigate the financial risks for farmers experimenting with agrivoltaic setups and encourage wider participation. Modifying the eligibility criteria of these schemes to include agrivoltaic projects would ensure a comprehensive support framework, facilitating the transition to sustainable and resilient agricultural practices. By leveraging existing schemes, the government can effectively promote agrivoltaics, enhancing both energy security and agricultural productivity across the country.

6. **Establishing a National Monitoring Platform for Agrivoltaics through Centre of Excellence for AgriPV**

   A critical initiative for advancing agrivoltaics involves the establishment of a national-level monitoring platform managed by the Centre of Excellence for Agrivoltaics (COE) hosted by Indian Agricultural Research Institute (IARI). This platform will serve as a centralized hub for collecting, analyzing, and disseminating comprehensive data on agrivoltaic systems across the country. It will systematically gather information on crop performance, solar energy generation, environmental impacts, and socio-economic outcomes from various agrivoltaic installations. By leveraging advanced data analytics and remote sensing technologies, the platform will provide real-time insights into the synergies between agriculture and solar energy production, facilitating evidence-based decision-making and policy formulation.

   The COE-managed platform will support transparency and accountability in the implementation of agrivoltaic initiatives, ensuring that projects adhere to predefined standards and contribute positively to both agricultural productivity and renewable energy goals. By promoting knowledge sharing and continuous improvement, the national monitoring platform will foster innovation, drive sustainable development, and facilitate the scaling up of agrivoltaics as a viable solution for integrating solar energy with agriculture nationwide.

7. Promoting Innovation through R&D Grants for Agrivoltaics

To accelerate the adoption and optimize the implementation of agrivoltaics across the country, the government should introduce robust research and development (R&D) grants focused on advancing agrivoltaic technologies. These grants would support pilot installations and comprehensive studies conducted by agricultural universities and research institutions. By allocating funds specifically for agrivoltaic R&D, the government can foster innovation and develop localized best practices that cater to diverse agricultural landscapes and climatic conditions in India.

Pilot installations funded through these grants will serve as testing grounds for integrating solar PV systems with various crops, assessing factors such as crop yield, water use efficiency, soil health, and energy generation efficiency and serve to address key challenges. Studies conducted by agricultural universities will generate valuable insights into optimal system design, crop selection, shading effects, and management practices tailored to different regions. Moreover, these initiatives will contribute to building a knowledge base of agrivoltaic technologies, enabling researchers and stakeholders to use it as reference. By supporting cutting-edge research and fostering collaboration between academia, industry, and agriculture, R&D grants for agrivoltaics will drive sustainable development, enhance agricultural resilience, and promote renewable energy integration in India's farming sector.

8. Utilizing Krishi Vigyan Kendras (KVKs) for Agrivoltaic Education and Training for Farmers

Krishi Vigyan Kendras (KVKs) can play a pivotal role in promoting the adoption of agrivoltaic systems by conducting targeted training sessions and workshops for farmers. These centers, already established as key hubs for agricultural extension services and knowledge dissemination, are ideally positioned to educate farmers about the benefits, installation processes, and maintenance of agrivoltaic systems. By leveraging their extensive reach and local expertise, KVKs can offer hands-on learning experiences and practical demonstrations that demystify the technology and address common concerns and misconceptions. These training programs will equip farmers with the necessary skills and knowledge to effectively integrate solar PV systems with their agricultural practices, ultimately enhancing productivity and sustainability.

Furthermore, KVKs can facilitate peer-to-peer learning by showcasing successful agrivoltaic installations and inviting early adopters to share their experiences and best practices. This community-based approach can significantly boost farmer engagement and adoption rates, as it provides real-world examples of agrivoltaics in action and fosters a sense of trust and confidence among participants. By integrating agrivoltaic education into their existing extension services, KVKs can play a crucial role in driving the widespread adoption of this innovative and sustainable farming practice across the country.

Long-term

1. National Agrivoltaics Mission

The Government may initiate a National Agrivoltaic Mission to adopt a visionary strategy integrating solar PV systems with agriculture. This mission will set ambitious targets for widespread deployment, establish stringent standards to ensure safety and environmental sustainability, and promote capacity building initiatives to educate stakeholders. Clear definitions and guidelines for agrivoltaic systems, including limits on land use proportions, will be crucial in optimizing agricultural productivity alongside solar energy generation.

2. Establishing Clear and Measurable Targets for Agrivoltaics Adoption

To effectively promote agrivoltaics across India, it is crucial to set clear and measurable targets at the several levels. These targets will serve as benchmarks to track progress, ensure accountability, and drive efforts towards widespread implementation.

Based on a potential estimate by the National Solar Energy Federation of India (NSEFI, 2023), if 1% of agricultural, barren, and other uncultivated lands are utilized for agrivoltaics, India has a potential of 629.69 GW from net area sown (agricultural lands) and 117.74 GW from fallow and other uncultivated lands alone. However, it was recommended that the targets could be modest and the Government may consider targeting around 15GW of Agrivoltaics in the next 10 years. Another scientific assessment using MoAFW district-level crop data estimated India's APV potential at 3.1–13.8 TW, suggesting further field-level data could improve accuracy (CSTEP, 2024). Therefore, a national level target will give a boost to the states to implement agrivoltaics. **[45]**

Furthermore, considering the unique agricultural and energy landscapes of each state, tailored targets are necessary. State-level targets will allow for consideration of regional variations in land use, solar potential, agricultural practices, and socio-economic factors fostering state ownership and prioritization based on local needs and opportunities.

3. Certification of Solar crops

Certification of solar crops is crucial to ensure quality, reliability, and market acceptance of agricultural products cultivated under agrivoltaic systems. Standardized certification protocols and quality assurance mechanisms are vital tools for policymakers to build consumer confidence, enhance supply chain transparency, and encourage farmers to adopt sustainable practices compatible with solar energy.

Certification will verify that agrivoltaic produce meets rigorous standards for chemical composition, nutritional value, and safety, demonstrating farmers' commitment to high-quality, environment-friendly crops. The certification will not only boost consumer trust but also open access to premium markets that value sustainability and ethical sourcing.

Solar-grown crops may risk consumer distrust and may struggle to compete in niche markets that prioritize certified organic or sustainably produced goods. Certification will prove essential for differentiating agrivoltaic products, securing premium pricing, and communicating sustainability efforts to consumers.

4. Establishment of Technical Standards and Certifications for Agrivoltaics

Agrivoltaics require standardized technical specifications and certifications to ensure safety, reliability, and compatibility with existing agricultural practices. Developing specific standards and certification processes is crucial for widespread adoption and to protect stakeholder interests. These standards set requirements for design, installation, operation, and maintenance, guarding against hazards like electrical issues and structural failures while ensuring crop protection. Certifications will validate compliance with these standards, boosting confidence among investors, developers, farmers, and policymakers and driving market growth by lowering costs and expanding access to agrivoltaic technologies.

5. Limits to Land-use

Guidelines to be established to define limits on the proportion of agricultural land that can be allocated for solar PV installations under agrivoltaic projects. These limits will be based on scientific assessments and considerations of agricultural productivity, ensuring that the integration of solar PV systems does not compromise food security or the sustainability of farming operations.

6. Tenders for Agrivoltaics

Implementing tenders tailored for agrivoltaics can serve as a strategic tool to promote widespread adoption of integrated solar PV systems in agriculture. These tenders signal governmental commitment to advancing renewable energy generation through innovative agricultural practices. By outlining clear targets, technical requirements, and financial incentives, policymakers can attract private sector participation, stimulate investment, and foster scalability in renewable energy deployment, thereby supporting agricultural sustainability. Tenders will enable policymakers to establish strict quality standards and performance criteria for agrivoltaic projects ensuring that installations adhere to industry best practices, safety standards, and environmental regulations.

Furthermore, through competitive bidding processes, developers are incentivized to propose novel design concepts and integration techniques that optimize land use, minimize environmental impact, and maximize energy generation while complementing agricultural activities.

7. Capacity Building and Skill Development

Capacity building in agrivoltaics is crucial to equip stakeholders with the knowledge, skills, and resources necessary to effectively plan, implement, and manage agrivoltaic projects. These initiatives will facilitate transfer of knowledge and best practices related to agrivoltaics, covering aspects such as site selection, system design, crop selection, maintenance practices, and integration with renewable energy infrastructure. Hands-on training, workshops, and demonstration projects will help stakeholders gain the technical expertise required to design, install, operate, and maintain agrivoltaic systems, fostering innovation, entrepreneurship, and job creation in rural areas.

Lack of capacity building significant knowledge gaps, technical deficiencies, and skill shortages among stakeholders can hinder the effective planning, implementation, and management of solar-agriculture systems. Lack of awareness, expertise, and training opportunities may impede the innovation, adoption, and optimization of agrivoltaic technologies, leading to suboptimal outcomes, inefficiencies, and missed opportunities for Agrivoltaic adoption.

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INDIA AGRIVOLTAICS ALLIANCE

India Climate Collaborative