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CENTER FOR STUDY OF SCIENCE, TECHNOLOGY & POLICY

Integrated Value Chain Approach for Agrivoltaic Systems

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Introduction and Rationale

The narrative on agrivoltaics (agriPV) primarily revolves around farmers, recognising their central role in integrating solar energy with agriculture. Increasing farmer incomes and other co-benefits is a critical component in any government plan for agriPV across the globe. However, in a country as diverse as India, it is crucial to explore innovative strategies for agriPV that go beyond the farmer-centric business model. In this context, engaging companies working in the agricultural space can be instrumental for the advancement of agriPV. India has some large corporations that manufacture solar-PV panels and have integrated supply chains. These integrated value chain enterprises either own farmlands or have direct partnerships with farmers. They work hand in hand with farmers to ensure the cultivation of specific crops, make niche value-added products, and sell them at a higher profit margin. By leveraging the expertise and resources of these organisations, a broader implementation of agriPV can be achieved across various topographies.

Presently, agriPV systems cost more than their counterparts, such as ground-mounted or floating PV systems. For agriPV, a viable business case, i.e., a minimum internal rate of return (IRR) of 15%, requires tariffs to be in the range of INR 5.7–6/kWh. However, the current power purchase agreements (PPAs) for similar-sized ground-mounted PV systems are signed at around INR 3/kWh. This disparity discourages distribution companies (DISCOMs) from buying power from agriPV systems, necessitating mechanisms like viability gap funding and/or other government incentives to make agriPV commercially competitive. Herein lies the opportunity for integrated value chain enterprises to boost agriPV by merging their businesses of niche value-added agricultural products and solar-PV.

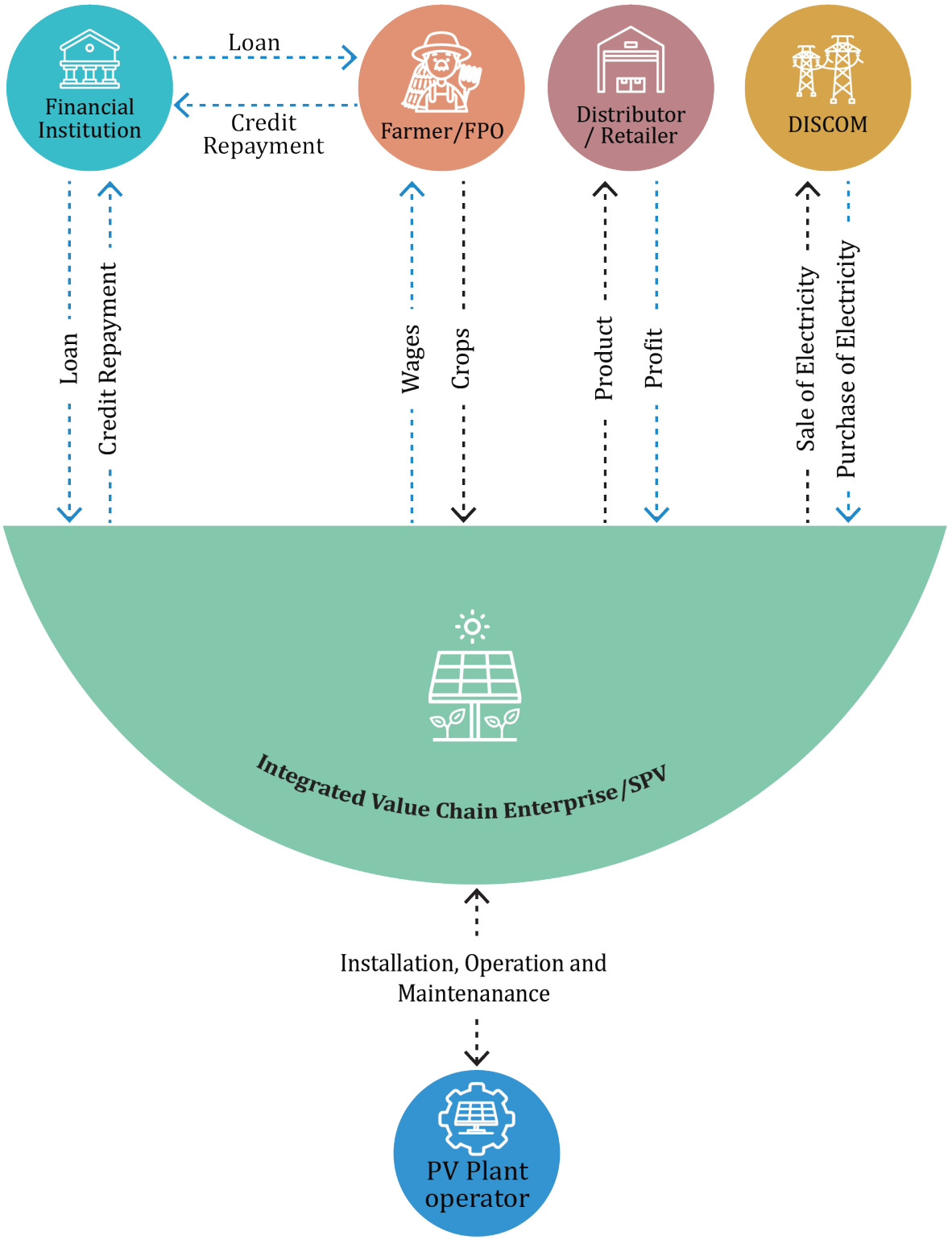
By selling products at a higher profit margin in retail markets and by saving money on crop purchases, these firms can offset the difference between the levelised cost of electricity (LCOE) and the prevailing PPA rates. Hence, they can implement agriPV without relying on capital subsidies. Simultaneously, they would contribute to the growth of the agriPV sector, benefitting farmers, farmer producer organisations (FPOs), developers, and distribution companies by creating sustainable business opportunities. Though agriPV is costlier than its counterparts, it does not eat into the profit margins of a company's established product lines and supply chains. To ensure food security is not compromised, the integrated value chain approach prioritises the utilisation of culturable wasteland, fallow land, and land with minimal or no existing agricultural activity. Shade-tolerant and hardy crops, such as aloe vera, henna, rosemary, and cumin can be grown in these regions to produce value-added products.

In our earlier policy brief "Exploring Business Models for Agrivoltaics in India", which assessed four business models, the income generated from selling crops was not considered. This policy brief examines the economic feasibility of the integrated value chain approach for agriPV systems, taking into account the income from selling crops and value-added products.

Proposed Approach

The integrated value chain approach offers a business model particularly suitable for companies that have a presence in the fast-moving consumer goods (FMCG) and solar-PV market. Companies in the FMCG market can also form a special purpose vehicle (SPV) by entering into partnerships with developers working in the agriPV, as well as in the solar-PV space. Under the approach:

- The integrated value chain enterprise/company installs the agriPV system with in-house expertise or partners with a solar-PV developer or an agriPV enterprise. It may own a farmland or lease it.
- Farmers from the local community are hired to cultivate shade-loving crops on culturable wasteland or fallow land. Harvested crops are transported to a processing facility to create value-added products.
- The company/SPV invests in agricultural equipment and incurs labour costs and other operational expenditure.
- It signs a PPA with the DISCOM for selling the power generated from the agriPV system.
- Alternatively, the company/SPV can explore the option of selling electricity generated by the agriPV system to industries through open-access mechanism at higher PPA rates.
- By cultivating shade-loving crops, the integrated value chain enterprise eliminates the need to source crops from external farmers.
- It pays operation and maintenance (O&M) charges to the engineering, procurement, and construction (EPC) company or uses in-house technicians for O&M.



Schematic diagram of the proposed approach

Case Study: Dried Rosemary Leaves

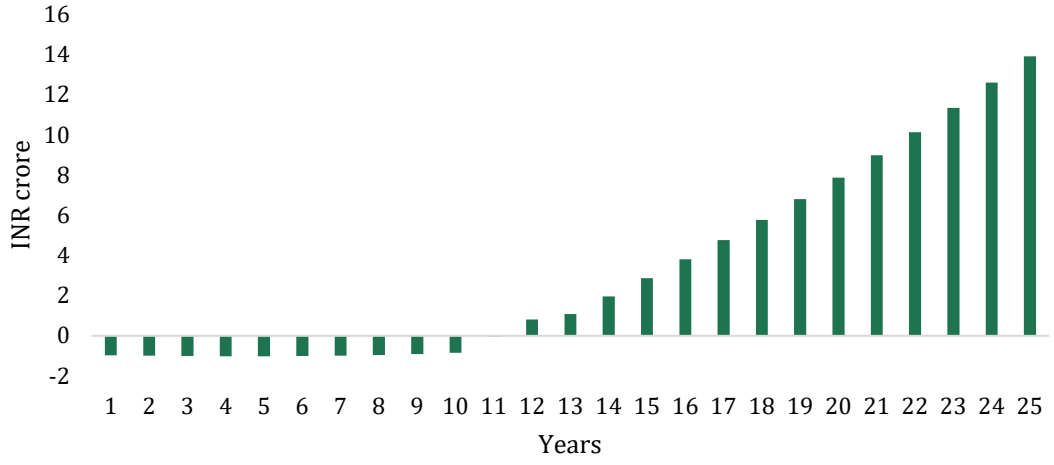
Rosemary thrives in indirect sunlight. A sample calculation was performed for rosemary cultivation in arid land by an integrated value chain enterprise. It is assumed that the enterprise earlier purchased rosemary leaves from external farmers. It is further assumed that the enterprise owns the farmland and will be paying wages to farmers.

Rosemary can be harvested once a year, and the leaves can be dried and sold to a distributor. Dried rosemary leaves have a high profit margin, which, along with the money saved from crop purchases, offsets any loss incurred due to a lower PPA rate. Approximately 8,400 kg of dried rosemary leaves can be produced from 2 hectares of land every year[1].

In this case study, the company invests INR 3.6 lakh on agricultural machinery and irrigation in the first year and spends roughly INR 1.2 lakh annually on labour, and harvesting and other operational expenditure[2]. Operational and capital expenditures are deducted from the sales revenue. The company generates annual profits worth INR 25 lakh with an annual escalation of 7%. The profits from selling dried rosemary leaves can be used to cross-subsidise the amount lost (36 lakhs) due to a lower PPA rate against the required PPA rate of INR 5.7/kWh. The feed-in tariff is varied to achieve an IRR of 15% for the integrated value chain enterprise.

It is important to note that this approach has been proposed mainly for culturable wasteland, fallow land, or land with little or no existing cultivation.

For a viable business case, the PPA rate for dried rosemary leaves has to be INR 3.5/kWh. Based on the prices listed on IndiaMART.com, the price at which dried rosemary leaves are sold to the distributor is assumed to be INR 300 per kg. Other assumptions made for this case study are given in the appendix.



Cumulative savings for the integrated value chain enterprise producing dried rosemary leaves with agriPV

[1] https://www.thehindu.com/news/cities/Coimbatore/more-farmers-take-up-rosemary-cultivation-in-talavadi-hills/article38307375.ece

[2] https://aromamission.cimap.res.in/aromamission/doubling_farm_income

Feed-In Tariffs Identified for Other Value-Added Products

Calculations similar to those made for dried rosemary leaves were carried out for other value-added products to arrive at their feed-in tariffs.

Value-added products	Feed-in tariffs identified
Aloe vera gel	INR 3.8/kWh
Cumin powder	INR 3.85/kWh
Henna powder	INR 4.1/kWh
Aloe vera juice	INR 4.4/kWh

Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis

Integrated value chain approach for developers

Strengths

- Allows for a lower feed-in tariff.
- Is cost-competitive (to ground-mounted PV) for some crops.
- Improves business opportunity.

Weaknesses

- Generates lower profits when solar-PV is installed on farmland, as opposed to just farming.
- Profitable only for some crops and niche value-added products.

Opportunities

- Creates new business avenues for integrated value chain enterprises.
- Potential linkages with Component C of PM-KUSUM scheme.
- Avoids capital subsidy for agriPV systems.

Threats

- Exploitation of farmers by integrated value chain enterprises and vice versa.
- Demands by renegade farmers to renegotiate lease/compensation rates.

Key Takeaways

Our analysis demonstrates that through the integrated value chain approach, agriPV systems can be installed without relying on subsidies. The key takeaways are:

- The viability of the agriPV system hinges on the type of crop being cultivated and the production of value-added products.
- Shade-loving crops with higher productivity and selling prices, as well as the value-added products that have a higher profit margin, contribute to the profitability of agriPV systems.
- Products like dried rosemary leaves, cumin powder, and aloe vera gel are profitable and allow for lower feed-in tariffs (between INR 3.5–3.8/kWh) that are closer to those of a ground-mounted PV system.
- Owing to the reduction in sanctioned load requirements under Green Energy Open Access in 2023 (from 1MW to 100 kW), agriPV systems can fetch higher PPA rates by selling power to industries. For crops with smaller profit margins, developers can sell power through this mechanism.

Way Forward

Pilot demonstrations specific to the Indian context should be conducted to validate this research and demonstrate the financial viability of agriPV systems implemented by large companies with integrated value chains.

Considering India's diverse climatic conditions, range of crops, and different farmer categories, it is crucial that agricultural pilot programmes reflect this diversity by encompassing a wide array of land parcels, agriPV technologies, and geographical topographies throughout the nation.

Appendix

Assumptions

Variable	Assumed value
Average monthly income of farmers	INR 3,798
Land size	2 hectares
AgriPV system that can be installed on the land	1 MW
Developer's stake	100%
Installation costs of a 1 MW agriPV system	INR 6 crore
Installation costs of the agriPV system considered for the case study	INR 6 crore
Loan-debt ratio	0.85
Loan amount (Principal)	INR 5.1 crore
Capacity utilisation factor	0.19
Electricity generated by 1MW agriPV system in a year	16,64,400 kWh
Electricity generated by the agriPV system considered (in a year)	16,64,400 kWh
Feed-in tariff required for agriPV in Karnataka	INR 5.7/kWh
Bank interest rate	8%
Loan tenure	10 years
Crops considered	Aloe vera, henna, rosemary, and cumin
Reduction in crop yield	15%
Crop yield from 1 hectare of land/harvest	Aloe vera: 15,000 kg/harvest/ha[3] Henna: 1,500 kg/harvest/ha[4] Rosemary: 4,900 kg/harvest/ha Cumin: 1,000 kg/harvest/ha[5]

[3] https://agritech.tnau.ac.in/horticulture/horti_medicinal%20crops_aloe.html#:~:text=Harvesting%20can%20be%20done%206,within%206%20hours%20after%20harvest.&text=An%20average%20leaf%20yield%20of%2015%20t%2Fha%20can%20be%20obtained.

[4] https://nopr.niscpr.res.in/bitstream/123456789/12294/1/NPR%202(6)%20306-307.pdf

[5] https://nrcss.icar.gov.in/Upload/637876998055478246.pdf

Number of harvests per year	Aloe vera: 2[10] Henna: 2[6] Rosemary: 1[7] Cumin: 3[8]
Capital costs of agricultural machinery	~ INR 2 lakh
Recurring agricultural costs	INR 60,000- INR 1,30,000[9]
Value-added produce from 1 kg of respective crops	0.15 litre of aloe vera gel[10] 0.9 kg of henna powder 0.9 kg of cumin powder
Cost of the shrub or flower/kg	Aloe vera: INR 20/kg Rosemary: INR 250/kg Cumin: INR 217/kg
Cost of the processed goods/kg	Aloe vera gel: INR 400/litre [11] Aloe vera juice: INR 100/litre Henna powder: INR 600/kg
Profit margin	40%

[6] https://www.agrifarming.in/henna-farming-information

[7] https://agritech.tnau.ac.in/horticulture/horti_aromatic%20crops_rosemary.html#:~:text=The%20green%20and%20dry%20leaves,of%203%20to%204%20months.

[8] https://nrcss.icar.gov.in/Upload/637876998055478246.pdf

[9] https://www.agrifarming.in/aloe-vera-farming-project-report-cost-and-profit

[10] https://www.sciencedirect.com/science/article/abs/pii/S0926669021003034

[11] https://icar.org.in/node/8065

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