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A Financier's Guide to Assessing Viability of Clean Energy-powered Rural Livelihoods

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Insights from the DRE Livelihoods Financial Assessment Toolkit

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A Financier's Guide to Assessing Viability of Clean Energy-powered Rural Livelihoods

Insights from the DRE Livelihoods Financial Assessment Toolkit

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Image: CEEW/Emotive Lens

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Image: CEEW/Emotive Lens

About CEEW

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About Powering Livelihoods

A joint initiative between CEEW and Villgro, Powering Livelihoods (PL) is boosting India's rural economy by scaling up the penetration of clean energy–powered (decentralised renewable energy) livelihood technologies, especially amongst women. It is doing so by:

- providing deep technical and capital assistance to enterprises deploying clean energy-based livelihood technologies to achieve commercial scale.
- enabling sectoral partnerships with various enabling stakeholders including financiers, investors, and state government departments, and go-to-market partners.
- generating bespoke market research insights and evidence at scale about the impact and viability of DRE livelihood technologies.
- supporting national and sub-national policy frameworks to mainstream DRE livelihood technologies to positively impact rural incomes, especially of women.

Solar refrigerators, energy-efficient food processors, solar silk reeling machines, solar cold storages, solar dryers, etc., are some of the technologies supported under the programme. By leveraging these enterprises' growth, the programme generates rigorous evidence about these solutions' impact, viability, and scalability to garner the support of investors, financiers, and policymakers to realise a potential USD 50 billion market opportunity. Since its inception in 2020, the programme has enabled more than 39,000 livelihoods, driven by over 23,000 technology deployments.

Image: CEEW/Emotive Lens

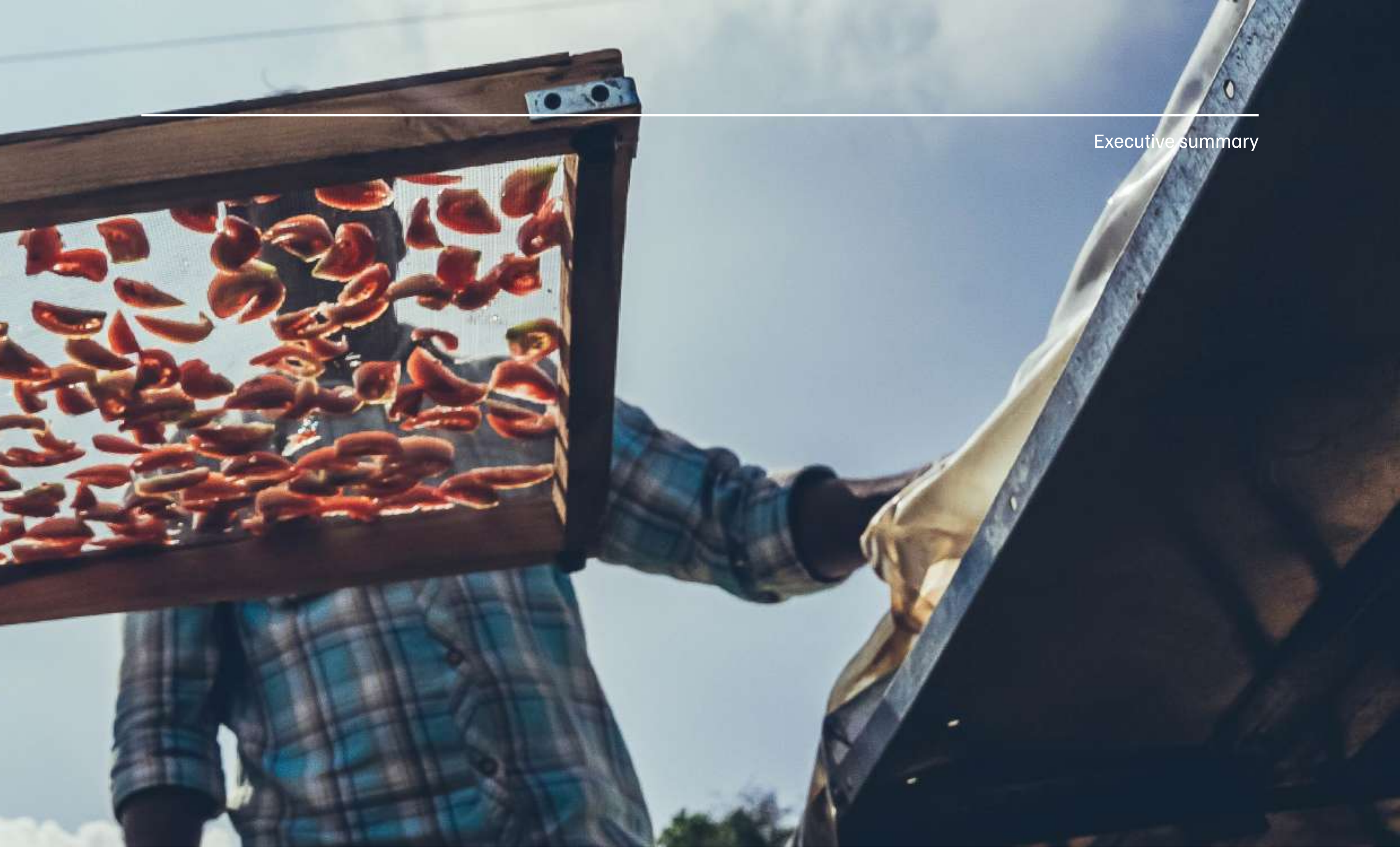
Contents

Executive summary

Decentralised renewable energy (DRE)-powered livelihood technologies, such as solar-powered dryers, solar-powered cold storage systems, and solar-powered vertical fodder grow units, have the potential to impact at least 37 million livelihoods in India (Jain et al. 2023). By 2047, scaling these solutions could create over 2.1 million full-time equivalent jobs and attract USD 160 million (INR 1,400 crore) in investments (Jain and Jhunjhunwala et al. 2025). With half a million units already deployed nationwide (Jain et al. 2023), the sector offers significant opportunities for commercially sustainable growth.

To date, however, a large share of these deployments have been supported through philanthropic funding and public subsidies–both of which have limited potential for scale. While subsidies play an important role in accelerating initial uptake, commercial deployment is critical for long-term sustainability and scalability. Given the high capital expenditure (CAPEX) and low operating expenses (OPEX) associated with DRE solutions, access to affordable finance is essential for enabling a self-sustaining and market-driven scale-up of DRE-powered livelihoods. Typical users of these technologies–farmers and micro entrepreneurs–are often unable to afford the upfront costs.

At present, affordable financing for DRE livelihood technologies remains constrained, primarily due to financiers' limited familiarity with and confidence in the sector. For financing institutions, lending decisions are anchored in established credit appraisal and risk assessment frameworks. DRE solutions, however, require additional assessment of technology- and context-specific income drivers, such as *asset utilisation, throughput, seasonal variation, or product-specific price dynamics*—which impact users' repayment capacity. Incorporating these parameters can strengthen viability assessments and lending decisions.



To catalyse end-user financing, it is therefore, essential to provide financiers' with capacity-building support for screening loan applications of end-users, thereby bridging the existing awareness and confidence deficit in the sector.[1]

The ***DRE Livelihoods Financial Assessment Toolkit*** was developed to address this precise gap. Grounded in real data and informed through extensive consultations—including **three** workshops across New Delhi, Mumbai and Guwahati with over **25 financiers**, technology enterprises, policymakers, social enterprises, and end users—the toolkit is a first of its kind **decision-support instrument** in the sector. **It complements existing appraisal processes** by assessing viability through systematic integration of technology and use-case specific income drivers.

Grounded in real data and consultations—including 3 workshops across 3 cities, the toolkit is a first of its kind decision-support instrument in the sector.

1. Based on stakeholder consultations.

__Kartik Iyer__, CEO, Human Ventures, a leading agri fintech, at the consultative workshop held in Mumbai in July 2024.

"The DRE Livelihoods Financial Assessment Toolkit is a game changer to unlock end user financing for DRE Asset class. Since this establishes cash flows and resultant ROIs for applications, it becomes easier to design credit models and financing solutions."

Kartik Iyer,
Founder and CEO, Human Ventures

Leading financiers and sectoral experts at the consultative workshop conducted in New Delhi in May 2024.

In addition to crucial sectoral learnings, this report synthesises key findings and actionable insights from the ***DRE Livelihoods Financial Assessment Toolkit*** to support awareness and capacity building among financiers. It also serves as a guide for those stakeholders–including non-governmental organisations (NGOs), state rural livelihood missions (SRLMs), and social enterprises, among others–supporting end-users in business decision-making related to the adoption of DRE-powered livelihood technologies. Accordingly, the toolkit used in conjunction with the report seeks to achieve four primary objectives:

Build awareness and interest among financiers by elaborating on the lending market potential, viability, and associated risks of DRE livelihood technologies.

Support financiers in evaluating loan applications by delineating key parameters that impact the economic viability and loan repayment capacity of end users across different contexts.

Highlight the general considerations and factors that financing institutions (FIs) should account for while financing DRE livelihood solutions.

Equip stakeholders with key insights needed to support end users in strategic business decision-making and to assist deployers in developing bankable projects related to DRE livelihood technologies.

The toolkit currently focuses on five relatively mature[2] DRE livelihood technologies:

1. Solar-powered dryers;
2. Solar-powered micro-horticulture processors;
3. Solar-powered vertical fodder grow units;
4. Solar-powered small refrigerators; and
5. Solar-powered cold storages

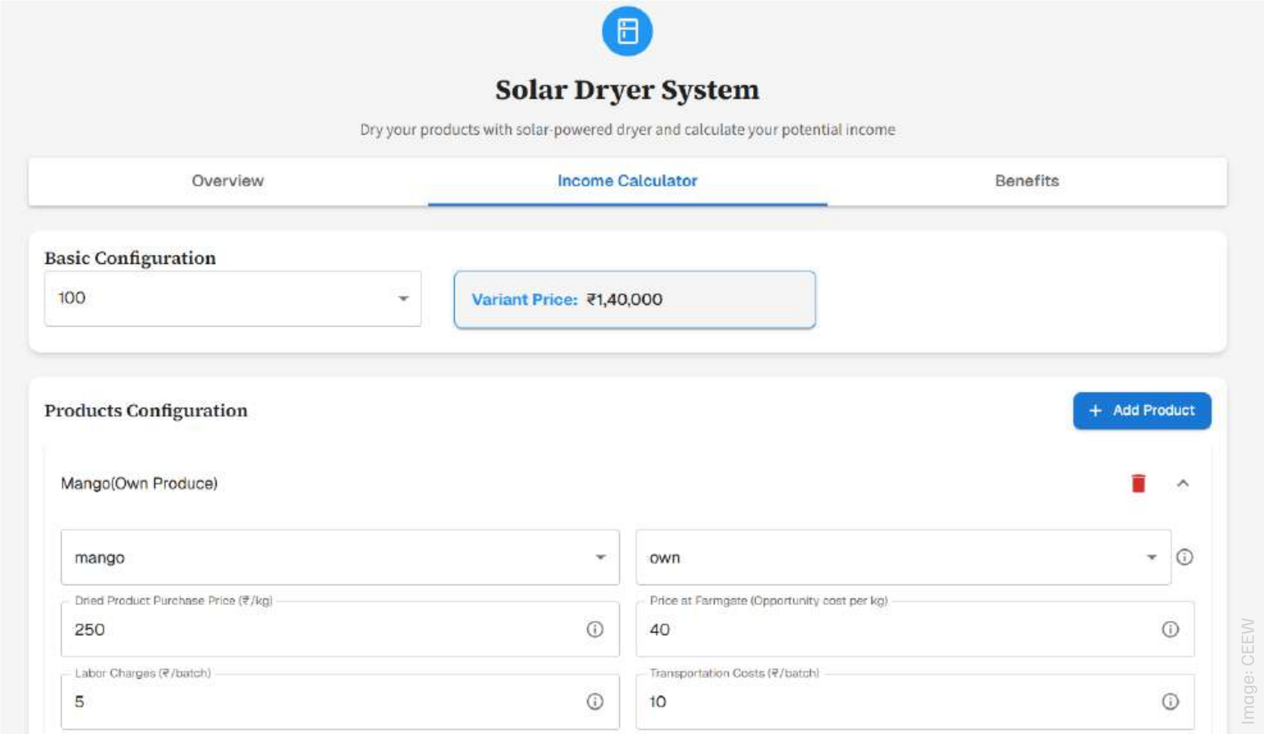
A. What does the toolkit do differently?

At the heart of the toolkit is an income calculator that allows financiers and organisations supporting end users to project context-specific income for five DRE livelihood technologies. Instead of relying on generic assumptions, financiers and supporting organisations can assess income and loan serviceability by adjusting real-world parameters, including:

- Technology type and capacity (e.g. 100 kg vs 500 kg solar dryer)
- Nature of ownership model (user-owned or service-based)
- Type of produce (e.g. mangoes vs rose buds)
- Asset utilisation, operational days, and local price dynamics, among others.

This shifts financing and business development decisions from *technology skepticism* to evidence-based assessment of income and repayment capacity.

2. Here, mature technologies refer to field-tested DRE solutions with at least 50 deployments and demonstrated impact (Jain et al. 2023). The 2023 report identified 19 such commercially mature DRE livelihood technologies, several of which have already scaled into the hundreds and even thousands of installations.



The toolkit will allow financiers and support organisations to assess context and technology specific income of DRE users.

B. How will the practical insights from the toolkit inform financiers and users/organisations supporting users?

Given the nascency of the sector, financiers have limited evidence and experience to assess the economic potential of various DRE livelihood technologies. Similarly, many end users have limited awareness of how these technologies can translate into tangible economic benefits. The practical insights generated through the toolkit provide clarity on the economic potential and financial implications of financing and adopting these technologies across different use cases and user contexts. The toolkit responds to several questions commonly raised by financiers and end users, which are summarised in Table ES1.

Table ES1. The toolkit answers key questions for financiers and prospective users by highlighting quantitative, qualitative, and strategic drivers for financing and adopting DRE livelihood technologies

Financiers	
Key questions asked	**How the toolkit and report responds**
Are DRE livelihood technologies economically and financially viable? If yes, what is the size of this opportunity?	Provides technology-wise projections of income, and loan serviceability across multiple contexts. Illustrates potential scale and profitability through scenario analysis and case studies.
What key parameters determine the economic and financial viability of DRE livelihood technologies?	Identifies key quantitative parameters (throughput, operational days, costs, market prices) and technology-specific parameters (e.g., dried matter proportion for solar dryers, capacity utilisation for cold storage) that influence income.
Do cash flows generated by a DRE livelihood technology vary with local context?	Enables context-specific variations through the toolkit and demonstrates sensitivity analysis for different technologies, produce types, and operating scales.
If cash flows vary with context, how can financiers make informed loan disbursement decisions across different contexts?	Provides a structured framework linking operational and technology specific parameters to income and repayment capacity, complemented by qualitative considerations such as durability, after-sales support, and training as well as pragmatic financing strategies to mitigate risk.
Are there any notable success stories of financing in the DRE livelihoods sector?	Showcases successful case studies of affordable financing, income enhancement and repayment.
Users	
Key questions asked	**How the toolkit and report responds**
What is the expected income generation from using a specific DRE livelihood technology in my context?	Enables end users/supporting organisations to project income based on inputs such as technology variant, scale, and local conditions.
How can I assess whether the generated income will be sufficient to service a loan for the technology?	Translates income projections into repayment feasibility under different scenarios.
Are there examples of microentrepreneurs successfully using DRE technologies?	Provides case studies illustrating how other users have leveraged affordable finance to enhance incomes and repay loans.
What are the key factors I need to consider before adopting a DRE livelihood technology?	Offers guidance on operational alignment (land, crops, market demand), technology-specific requirements, and qualitative factors like training, maintenance, and risk preparedness.

Source: Authors' analysis

Undertaking a technology-wise analysis, this publicly accessible toolkit is intended for FIs and other sector stakeholders seeking data or information around income and loan serviceability assessment for various DRE livelihood solutions across different contexts. Beyond financing, the toolkit in conjunction with the report offers critical information that can be leveraged to support business planning for end users. It enables users to assess the income potential of adopting particular DRE products and to make informed business decisions. Further, they can draw insights from case studies of successful ventures supported through DRE technologies. Moreover, the report sheds light on the parameters that (i) financiers should look for in loan applications, and (ii) project promoters should focus on when assisting users in developing loan applications.

a. The metrics that matter

Quantitative parameters impacting the economic and financial viability of DRE livelihood technologies

Understanding the parameters that impact the economic and financing viability of DRE livelihood technologies is important for both financiers and users. This report delineates the key quantitative parameters affecting income across various DRE livelihood technologies, as summarised in Table ES2.

Table ES2. Asset utilisation and cost price structure are some of the key parameters impacting the viability of many DRE livelihood technologies

Parameters impacting the economic and financial viability of DRE livelihood technologies	
Common parameters	Throughput (volume of raw materials processed or products stored per unit of time) Annual operational days Costs associated with raw materials and product processing/storage Prices of final products
Technology	**Parameters**
Solar-powered dryer	Dried matter proportion (percentage of dried produce obtained from processing fresh produce) Prices of dried products Raw material costs
Solar-powered micro horticulture processor	Output-to-input ratio (quantity of output processed from a given quantity of input) Prices of processed products Raw material costs
Solar-powered vertical fodder grow unit	Number of cattle fed Annual milking days Increase in milk yield (amount of milk produced by a dairy animal per unit of time) Milk prices Fodder tray price (for fodder-as-a-service models) Seed costs

Technology	Parameters
Solar-powered small refrigerator	Selling prices of the refrigerated products Cost prices of the refrigerated products
Solar-powered cold storage system	Capacity utilisation Market arbitrage Service fee (where applicable) Opportunity costs (reflects the cost incurred by the end user in storing the produce for sale at a later date instead of selling it immediately)

Source: Authors' analysis

These parameters include annual operational days, throughput (volume of raw materials processed or products stored), costs associated with raw materials and product storage (including packaging, labour, and transportation), and selling prices of final products, among others.

While several of these parameters are common across multiple DRE technologies, end-user income is also influenced by technology-specific factors. For instance, the economic and financial viability of solar-powered cold storage systems depends on parameters such as **capacity utilisation**, which indicates the percentage of the storage capacity in use to the total available capacity; **market arbitrage**, which reflects price differences of the products between the time of storage and sale; **storage duration**, which varies across various horticulture products; and **service fees** (for cooling-as-service models), which represent the price charged by the asset owner for providing cooling services to end users.

b. Why numbers alone do not tell the full story

While quantitative analysis helps assess sufficiency of projected cash flows, qualitative considerations explain how operational realities influence those cash flows in practice. Loan evaluation for DRE livelihood technologies must, therefore extend beyond quantitative metrics determining financial viability. Qualitative considerations, such as product durability, reliable after-sales support, availability of user training, and risk-sharing through warranties or buy-back facilities, directly influence repayment reliability. We showcase field examples to demonstrate how DRE enterprises integrate such measures to reduce downtime, strengthen user confidence, and improve asset utilisation, thereby enhancing the economic viability of these technologies.

Financiers should consider:

- **Product durability** to minimise maintenance requirements, reduce downtime, and lower the risk of operational failures.
- **Availability of guidance on optimal asset utilisation** to enhance product effectiveness.
- **Availability of technical and after-sales support** to enable prompt issue resolution and sustained product usage.

- **Provision of user training** to strengthen proper usage, minimise misuse, and maximise product life.
- **Warranties or guarantees on the product** to reduce perceived risk and increase confidence for both users and financiers.
- **Buy-back facilities on the asset or value-added end products** to reduce financial risk.

In parallel, users must ensure that technologies are aligned with their operational realities. Assessing landholding, available crop types, end-product market demand, affordability, and profitability is essential. Equally important are access to training, reliable after-sales services, and risk preparedness, which together enable sustained usage, stronger income flows, and timely loan repayments.

Potential users should consider:

- **Farmholding size** to assess production sufficiency for optimal asset utilisation.
- **Product demand and market opportunities** to reduce business and repayment risks.
- **Technology and operational costs** to understand the total investment required and ongoing expenditures.
- **Business profitability** to ensure sustained adoption.
- **Training and skill development** to maximise utility and returns.
- **Maintenance and after-sales service** to support sustained technology usage and minimise downtime.
- **Risk preparedness** to manage potential challenges, such as adverse weather, that may affect technology performance.

Together, these considerations explain why similar assets perform differently in practice and help identify applications where financing is more likely to succeed.

c. From viability to bankability

Pragmatic strategies to scale user financing for DRE livelihood technologies

While many challenges and risks associated with financing DRE livelihood technologies are similar to those encountered in lending to micro or nano enterprises, targeted strategies can significantly mitigate risk and improve access to finance.

According to a senior official at the country's leading development finance institution, the toolkit provides critical information for lending decisions that is typically unavailable to bankers.

Key strategies include:

- Flexible repayment structures aligned with income cycles
- Customised loan products for varied use cases
- Asset hypothecation to strengthen lender security
- Use of social capital as collateral

Instruments such as buy-back arrangements, first loss default guarantees (FLDG), and Pay-As-You-Go models further de-risk lending, support wider adoption, and help protect financier portfolios.

C. Way forward

By providing essential insights and guidance derived from the toolkit to stakeholders at both ends of the financial spectrum, this report seeks to enable informed decision-making and support the integration of DRE livelihoods into India's broader economic landscape. We also aim to engage with institutions such as the Bankers Institute of Rural Development (BIRD) and the National Institute of Bank Management (NIBM) to incorporate the tool into their curricula, thereby capacitating bankers at scale.

The successful implementation of the toolkit has the potential to drive inclusive growth, empower communities, and advance India's net-zero ambitions.

As a critical instrument to unlock the adoption of DRE livelihoods at scale, the successful implementation of the **toolkit** has the potential to drive inclusive growth, empower communities, and advance India's net-zero ambitions.

Image: CEEW/Emotive Lens

1. Introduction

Decentralised renewable energy (DRE) livelihood technologies—such as solar-powered dryers, cold storage systems, vertical fodder grow units, micro-horticulture processors, and small refrigerators—are increasingly being recognised as tools that can directly improve productivity, reduce post-harvest losses, and expand income opportunities for smallholder farmers and rural microenterprises (Yasaswi et al. 2025). These technologies go beyond enabling basic energy access or lighting homes; they play a central role in supporting and diversifying livelihoods. With an estimated potential to impact at least 37 million livelihoods in India and a market opportunity of USD 50 billion (Jain et al. 2023), DRE livelihood technologies present a significant opportunity within India's trillion-dollar push for energy transition (Wusqa and Khalid 2025). While the sector remains nascent, over half a million units have already been deployed nationwide, underscoring both the scale of opportunity and the momentum underway.

Contrary to common perception, these technologies are not restricted to contexts with unreliable or no access to conventional energy. Beyond mitigating on-and off-farm power availability issues, they have demonstrated the ability to create tangible socioeconomic and gender-inclusive benefits for end users. Among users experiencing increased incomes, about 48 per cent reported an increase in the number of earning days, and around 71 per cent reported enhanced productivity. Improvements in women's knowledge and skills (91 per cent), decision-making agency (86 per cent), and participation in public spaces (84 per cent) further highlight these benefits (Yasaswi et al. 2025). For instance, solar-powered dryers extend the shelf life of produce, cold storage systems enable farmers to achieve better price realisation through market arbitrage, solar-powered silk-reeling machines enhance the quality of silk yarn and reduce drudgery, and fodder grow units improve dairy productivity. Collectively, such applications strengthen resilience in rural economies while contributing to India's climate and energy transition goals.

1.1 Why financing matters

Despite their clear value proposition, most rural stakeholders still perceive DRE technologies as out of reach. The barrier is not operational costs—DRE systems typically require low recurring investment—but the **high upfront capital expenditure** and the lack of **affordable financing options**. Philanthropy and subsidies have supported early adoption, but they do not offer the scale or sustainability required for long-term impact. What is needed is a shift towards **commercial, market-driven financing** that enables rural users to adopt these technologies sustainably.

However, financiers often lack the evidence or tools needed to assess DRE technologies. They are unfamiliar with asset performance, uncertain about income-generating potential, and unclear about repayment viability across varied contexts. This lack of confidence restricts lending, resulting in a financing gap that inhibits the scale-up of proven solutions. End users also frequently lack the information needed to confidently determine whether investment in such technologies makes economic sense. Such a dilemma is exacerbated by limited access to affordable institutional finance, which constrains the technology uptake. Bridging this financing gap is therefore essential to scaling DRE livelihoods.

Experience from the *Powering Livelihoods Initiative* shows that creating affordable financing pathways catalyses DRE adoption (Wusqa and Khalid 2025). Blended finance, risk-sharing instruments, and tailored loan products can unlock scale, making it crucial to move beyond pilot projects for these solutions to become mainstream components of rural economies.

1.2 The rationale behind the *Decentralised Renewable Energy Livelihoods Financial Assessment Toolkit*

Bridging the financing gap requires more than the availability of capital; it calls for evidence, tools, and capacity-building. Financiers need clarity on the viability of DRE technologies, their income-generating potential, and the parameters that determine loan serviceability across diverse contexts. End users, meanwhile, require insights to make informed business decisions on technology adoption, market opportunities, and loan repayment capacity.

The ***DRE Livelihoods Financial Assessment Toolkit*** has been designed to address these gaps. This report, in conjunction with the toolkit provides financiers with structured insights into the economics of selected DRE technologies and the risks and opportunities involved in lending. It also serves as a reference for non-governmental organisations (NGOs), self-help groups (SHGs), producer organisations, and social enterprises that support rural users in navigating the adoption process. By doing so, it seeks to catalyse a more informed financing ecosystem capable of driving the next phase of scale.

Bridging the financing gap requires more than the availability of capital; it calls for evidence, tools, and capacity-building.

1.3 Financing as a catalyst for inclusive growth

Access to affordable finance does more than enable asset purchase; it creates pathways for inclusive economic growth. With agriculture and allied sectors employing nearly half of India's workforce (PIB 2025), scaling DRE livelihood technologies could have a transformative impact on rural incomes, resilience, and gender equity. Women, in particular, stand to benefit through improved access to time-saving technologies and opportunities to engage in value-added enterprises.

Unlocking financing for DRE livelihoods also aligns with India's broader policy goals, including doubling farmers' incomes, reducing post-harvest losses, and achieving net-zero emissions by 2070. By ensuring that climate-friendly technologies are accessible to rural and peri-urban users, financing interventions can address developmental, economic, and environmental priorities simultaneously.

1.4 Conclusion

The context for financing in DRE livelihoods is clear: the technologies are ready, the impact is evident, but financing remains the major missing link. Addressing this gap requires a concerted effort towards building confidence among financiers, equipping stakeholders with decision-making tools, and promoting strategies that align repayment structures with rural income flows. The insights derived from the toolkit, and synthesised in this report, are a step in that direction.

By situating financing at the centre of the DRE livelihoods agenda, this report aims to shift the discourse beyond pilots and subsidies towards sustainable and scalable adoption. In doing so, it highlights that informed decision-making, innovative financing models, and cross-sector collaboration can unlock the potential of DRE technologies while contributing to India's green economy transition.

> By situating financing at the centre of the DRE agenda, this report aims to shift the discourse beyond pilots and subsidies towards sustainable and scalable adoption.

Solar-powered vertical fodder grow units reduce fodder shortage for dairy farmers.

2. Methodology

This section outlines the methodology employed in the development of the *DRE Livelihoods Financial Assessment Toolkit (and the insights in the report)*, a comprehensive decision support tool designed to build the capacity of:

- financing institutions (FIs) in evaluating loan applications of end users of DRE livelihood technologies; and

- project promoters supporting end users in developing viable business models for the adoption of DRE livelihood technologies.

2.1 Research design

For the development of the toolkit and the corresponding insights synthesised here, a mixed-methods approach was employed, combining qualitative consultations with quantitative analysis. This approach was selected to comprehensively address the study's objectives. Qualitative insights gathered from consultations with financiers, DRE end users, technology manufacturers, and sector experts offered nuanced perspectives on the challenges faced by FIs, particularly those impeding the large-scale disbursement of loans in the sector. Additionally, the toolkit was developed through stakeholder consultations and secondary research, among other sources. Following its development, we conducted user testing with a range of financiers to gather feedback on its functionality and user-friendliness.

By integrating qualitative and quantitative methods, the toolkit and the corresponding insights synthesised in the report aim to provide a holistic framework that strengthens financiers' and stakeholders' ability to assess the viability of DRE technologies. This, will, in turn, support more accurate loan evaluations and improved business model development for end users.

The toolkit provides a holistic framework that strengthens financiers' and stakeholders' ability to assess the viability of DRE livelihood technologies.

2.2 Approach

The multifaceted nature of the research necessitated the use of both primary and secondary data sources. A purposive sampling method was used to gather information from relevant stakeholders.

Developing the research framework

Step 1: Multiple rounds of internal consultations with sector experts and social enterprise incubators, along with a review of secondary literature, were conducted to draft an initial skeleton of the toolkit.

Step 2: Consultations with some of the leading rural FIs were conducted to understand the financing landscape and inform the research structure.

Step 3: A consultative workshop with representatives from various FIs was held to discuss the structure refined through earlier consultations. As the inaugural session in a series, the workshop aimed to identify the challenges financiers face when extending loans to DRE technology users. The insights gathered through such an exercise were used to further refine and finalise the toolkit framework, giving it its definitive structure.

Data collection and development of the research content

Step 1: Detailed questionnaires were developed for DRE technology manufacturers/enterprises to elicit insights on their technologies, enterprise operations, and risk mitigation strategies. These inputs enriched the analysis with industry-specific information and will help guide FIs in adopting a comprehensive approach that goes beyond quantitative factors during loan application assessments. Insights gathered from sectoral experts also informed critical factors that can guide end-user decisions regarding the adoption of DRE livelihood technologies and the development of viable business models.

Step 2: Building on a previous study conducted by the Council on Energy, Environment and Water (CEEW) (Jain et al. 2023) on the viability of these technologies, as well as consultations with sector experts, key parameters determining user income—and therefore the serviceability of loans for DRE livelihood technologies—were identified.

Step 3: The *DRE Livelihoods Financial Assessment Toolkit* was developed using a previous CEEW study (Jain et al. 2023), consultations with sector experts, DRE livelihood technology end users, and various secondary sources. The toolkit employs empirical evidence to support financiers and other stakeholders in making informed decisions regarding loan approvals and business development, respectively. To ensure relevance and usability, it underwent user testing with a diverse group of financiers, whose feedback informed refinements to enhance its functionality and user experience.

Step 4: Case studies on loan disbursements and repayments were developed based on consultations with DRE technology manufacturers and end users, wherever applicable.

Comprehensive methodological documentation, coupled with an open-access financial assessment toolkit, enhances the study's replicability and accessibility for a broader audience.

Consultations with some of the leading rural FIs were conducted to understand the financing landscape and inform the research structure.

2.3 Definitions

The definitions presented here are limited to their representation/application in the report and the corresponding tool.

Overall

- **End users**: Any individual or group (including farmer producer organisations [FPOs] and SHGs) purchasing the technology by availing loans.
- **Livelihood-impact potential**: The number of livelihoods that can potentially be impacted by the intervention of DRE livelihood technologies.
- **Market potential**: The number of units that can potentially be deployed for any given DRE livelihood technology.
- **Credit opportunity**: The potential quantum of loan amount/credit that FIs can capture in their portfolios for a given DRE livelihood technology. Here, it is estimated on the assumption that FIs can finance 50–100 per cent of the product cost for the popular variants of each technology.
- **Asset utilisation**: The efficiency with which a DRE product is used, measured by how effectively its capacity (to store, dry, or process items) is leveraged for intended productive purposes, as well as its usage over time. It is typically expressed as the number of operational days per year.
- **Loan serviceability**: The borrower's ability to make timely repayments on a loan, including both principal amount and interest. Here, it is assessed based on the monthly cash flow generated from the use of DRE livelihood technologies.
- **Annual operational days**: The total number of days in a year that a technology is utilised or is operational.
- **Cost-to-price structure**: The relationship between the cost of a product and the price at which it is sold.
- **Purchase point**: The price at which the value-added, stored, dried or refrigerated product is sold in the market. It reflects the rate at which the end user can sell final products derived from the use of the DRE livelihood technologies.
- **Customer archetype**: A data-driven representation of a typical customer segment or a representative profile of an end user likely to adopt and benefit from DRE livelihood technologies. Customer archetypes can guide assessments of financial viability, inform the design of appropriate credit products, and support tailored business or delivery models for scale.

Table 1. Key characteristics of customer segments

Key customers	Characteristics	
Small farmers	Landholding: 3–10 acres	Grow 2–3 crops annually
Large farmers	Landholding: More than 10 acres	Grow 4–5 crops annually
Micro-entrepreneurs and micro, small, and medium enterprises (MSMEs)	Demonstrated proof of sales (e.g. invoices, receipts), file Goods and Services Tax (GST) returns	Own assets that can be used as collateral or for credit assessment
FPOs	Comprise 100+ members	Manage at least 1 cent of land and have existing market linkages

Source: Powering Livelihoods

Technology-specific

1. Solar-powered dryer

- **Quantity placed for drying or batch size**: The quantity of fresh produce placed in a solar-powered dryer (batch size) is a measure of how effectively the asset's input capacity is being utilised.
- **Dried matter proportion**: The percentage of dried produce generated by the solar-powered dryer from processing fresh produce.
- **Drying time**: The time taken by the solar-powered dryer to dry various products. Drying time typically ranges from one day for leafy greens and flowers to two to three days for fruits and vegetables.
- **Dried product purchase price**: The price at which the solar-dried products are purchased in the market.
- **Opportunity cost**: For solar-powered dryers, the opportunity cost reflects the cost incurred by the end user when drying produce for sale instead of selling it immediately in the market and using the revenue to pay off any production-related loans.

2. Solar-powered micro horticulture processor

- **Quantity of produce placed for processing or batch size**: A measure of how effectively the input capacity of a solar-powered micro horticulture processor is being used. For example, if an end user utilises a solar-powered micro horticulture processor to process 50 kg of mangoes per hour when the technology has a processing capacity of 100 kg per hour, then 50 kg is the quantity of produce placed for processing (batch size) relative to its optimal processing capacity.

- **Output-to-input ratio**: For a solar-powered micro horticulture processor, this is a measure of the quantity of output (processed horticultural products, such as juices, jams, etc.) processed from a given quantity of input (such as raw horticulture produce). It is calculated by dividing the total quantity of output by the total quantity of input.

- **Value-added product price**: The selling price of products that have undergone additional processing, enhancement, or packaging to increase their market value beyond raw horticultural produce.

- **Opportunity cost**: For solar-powered micro horticulture processors, the opportunity cost reflects the cost incurred by the end user when processing produce for sale instead of selling it in the market and using the revenue to pay off any production-related loans.

3. Solar-powered vertical fodder grow unit

- **Milking days**: The specific days during a lactation period when a dairy animal (such as a cow, goat, or sheep) is actively milked.

- **Milk yield**: The amount of milk produced by a dairy animal, typically a cow, over a specific period. Here, it is measured in litres (L) produced per day. The parameter under consideration reflects the increase in daily milk yield per animal due to the introduction of solar-powered vertical fodder grow units.

- **Concentrate feed**: A type of livestock feed that is rich in nutrients, particularly energy and protein. These feeds are formulated to supplement roughage (such as hay, silage, and pasture) that cattle consume, providing essential nutrients that may not be adequately available in their regular diet.

- **Fodder-as-a-service**: A model in which a solar-powered vertical fodder grow unit, specifically the fodder station, can be purchased by an individual or a group (such as an FPO or SHG), where fodder is provided as a service to users in return for a price/fee charged by the owner(s) of the asset.

4. Solar-powered small refrigerator

- **Profit margin**: The percentage of revenue that the user retains as profit after covering the cost price of products stored in a solar-powered small refrigerator. It measures the profit earned per unit of product sold.

5. Solar-powered cold storage system

- **Capacity utilisation**: A measure of how effectively the storage capacity of a solar-powered cold storage system is being used, typically expressed as a percentage of the capacity in use relative to the total available capacity.

  Capacity utilisation rate: (Space or capacity used/Total available capacity) × 100

- **Market arbitrage**: The strategic practice of leveraging price fluctuations in the market by storing perishable goods during periods of low prices and selling them when prices are higher. The difference in prices between the two periods reflects the market arbitrage.

Comprehensive methodological documentation, coupled with an open-access financial assessment toolkit, enhances the study's replicability and accessibility for a broader audience.

- **Opportunity cost**: For solar-powered cold storage systems, opportunity cost reflects the cost incurred by the end user when storing produce for sale at a later date instead of selling it immediately in the market and utilising the revenue to pay off any production-related loans.

- **Cooling-as-a-service**: A model in which a solar-powered cold storage system can be purchased by an individual or a group (such as an FPO or SHG), where cooling services are provided to users in return for a service fee charged by the owner(s) of the asset.

2.4 Stakeholder mapping

Table 2 provides an overview of the stakeholders relevant to the financial assessment toolkit for DRE livelihood technologies. It categorises their interest levels and roles in promoting and using the toolkit. This mapping is essential for understanding how different stakeholders can influence and benefit from the toolkit aimed at unlocking end-user finance for DRE technology adoption.

Table 2. Stakeholder landscape for the DRE Livelihoods Financial Assessment Toolkit

Stakeholder	Interest/ Relevance	Toolkit utilisation and associated roles
FIs, banks, micro-finance institutions (MFIs), non-banking financial companies (NBFCs), credit unions, development banks, NBFC-MFIs, etc.	High	Primary stakeholders–target users of the toolkit Use the toolkit to upscale financing of DRE technologies Leverage their networks to promote awareness of the financial assessment toolkit Facilitate partnerships and collaborations with relevant stakeholders
Civil society organisations (CSOs)	High	Primary stakeholders Use the toolkit to develop business models for the end users Leverage their networks to promote awareness of the financial assessment toolkit among users Facilitate partnerships and collaborations with relevant stakeholders
DRE livelihood technology manufacturers	High	Potential users of the toolkit Use the insights for adoption of risk mitigation strategies Beneficiaries of toolkit adoption by financiers
Users, micro-entrepreneurs, farmers, SHGs, FPOs, etc.	High	Primary stakeholders Use the toolkit to curate their business development plans Beneficiaries of toolkit adoption by financiers
Social enterprise incubators	High	Primary stakeholders Use the toolkit to assist end users in business-related decisions Contribute insights and expertise in the social financing landscape
Government	High	Primary stakeholders–potential users of the toolkit Use their website and platforms for the dissemination of the toolkit Develop schemes and programmes to provide financial support to DRE end users

Stakeholder	Interest/ Relevance	Toolkit utilisation and associated roles
Academic community researchers, educators	Medium	Secondary stakeholders–potential users of the toolkit Disseminate findings of the toolkit Use the toolkit for further research
Funding agencies, donors, grant providers, investors	Medium	Secondary stakeholders Provide line of capital or credit risk cover to financiers

Source: Authors' analysis

2.5 Limitations

Some of the limitations of the toolkit and the insights synthesised in the report are as follows:

- Reliance on self-reported data and insights provided by the original equipment manufacturers, DRE technology enterprises, and end users may be characterised by response bias.
- Demand-side analysis has not been accounted for.
- The sensitivity-analysis does not take into account regional variation in parameters impacting income.

Stakeholders at the consultative workshop held in Mumbai for the toolkit development in July 2024.


Image: Selvaprakash Lakshmanan/ Swiss Re Foundation/Fairpicture

3. Technology-specific key findings and practical insights

Chapter 3 highlights technology-specific key findings and practical insights from the financial assessment toolkit, complemented by qualitative insights. It is structured to provide a comprehensive and intelligible overview of the five DRE technologies under consideration, their associated investment opportunities, and their economic and financial viability.

Figure 1. Understanding technology and use-case specific determinants of income are crucial for financiers and users/support organisations to assess financial viability of DRE livelihood technologies

Technology overview

Typical capacities and price ranges, usage, income, market and livelihood impact potential, loan potential, discounted payback period, customer archetypes and key geographies with high deployment potential

Determinants of income

Key parameters impacting income determined via a sensitivity analysis of parameters

Financial assessment toolkit

A toolkit that helps assess income and loan serviceability for the DRE livelihood technology under different scenarios

Pragmatic financing strategies

Strategies to mitigate risks associated with financing endusers of DRE livelihood technologies

On-ground evidence of successful end-user financing

Successful case stories of end-user financing

Source: Authors' analysis

An outline of the content covered for each of the five technologies is provided as follows:

Overview

A detailed description of each DRE livelihood technology, including its functionality, applications, processing or storage capacity, pricing, typical usage, associated annual incremental income potential, and potential to impact livelihoods.

Investment and lending opportunities

This section provides insights into the investment and lending opportunities available for each technology. This entails the market opportunity or product deployment potential, the credit opportunity, the discounted payback period, and the key geographies where the technology has strong deployment potential.

Viability of DRE livelihood technologies

Chapter 3 presents a sensitivity analysis of the economic and financial viability of DRE livelihood technologies under varying parameters. This analysis is grounded in specific assumptions, typical scenarios, and insights gathered through consultations with DRE technology enterprises and users. The illustrative cases are representative in nature, intended to demonstrate how variation in key parameters affects the viability of these technologies. For accurate, case-specific calculations, please refer to the *DRE Livelihoods Financial Assessment Toolkit*.

Financial assessment toolkit

For detailed income and viability calculations, the financial assessment toolkit is hyperlinked here. It enables FIs to vary multiple cases and parameters according to their specific requirements when evaluating loan applications. It can also be used for business development purposes for the end-users.

Risks and mitigation strategies

This section delineates the risks associated with financing DRE livelihood technologies and presents potential strategies to effectively mitigate these risks, thereby ensuring a more secure investment for FIs. Additionally, a ready-to-use checklist to mitigate potential risks is provided for financiers to use when making loan approval decisions.

Case stories of end-user financing and impact

Real-life case stories (drawn from field insights and interviews) showcasing the impact of end-user financing on the adoption and success of DRE livelihood technologies are incorporated to highlight both the feasibility and practical benefits of financing clean technologies.

The following sections are curated to equip financiers and organisations supporting users with essential information and tools to make informed decisions about investing in and financing DRE technologies.

Solar-powered dryers reduce dependence on lesser efficient traditional sun drying methods.

3.1 Solar-powered dryers

Solar-powered dryers provide a climate-friendly mechanism for dehydrating perishable products, such as fruits, vegetables, spices, flowers, and seafood, thereby extending their shelf life. The technology enables effective drying by optimising heat supply while protecting the products from harmful UV radiation, pests, dust, and other polluting agents.

Drying 60 batches per year in ten units of 100 kg solar dryers enables CO_2e abatement of 20.3 MT.

Table 3. Overview and investment opportunity for solar-powered dryers in India

Overview of a typical solar-powered dryer		Investment opportunity
Input capacity 5–500 kg	**Price** INR 10,000[3]–2,00,000[4]	**Market potential** 1.7 million units[‡]
Typical usage 6 hours a day for 240 days per year[‡]	**Livelihood-impact potential** 3.4 million (34 lakh)[‡]	**Credit opportunity (INR)**[ϟ,5] INR ~11,900–23,800 crore[6]
Typical annual incremental Income INR 80,950[‡,7]	**Typical discounted payback period** 17 months[‡]	**States with the highest deployment potential** Maharashtra, Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, Gujarat, Karnataka, Bihar, Rajasthan[‡]
Customer archetype	B2B: FPOs, farmer cooperatives, SHGs; B2C: Micro-entrepreneurs	
Uptake of solar dryers can be facilitated through an individual and shared ownership model, with financing provided by small finance banks (SFBs), NBFCs, and banks, offering loan tenures of 1–3 years.[‡]		

Source: ‡ Data sourced from Jain et al. (2023), ϟ Authors' analysis

3. 5 kg.
4. 500 kg.
5. Based on the assumption that 50–100 per cent of the product cost is financed through loans.
6. For 100 kg variant.
7. For 100 kg variant.

Viability of solar-powered dryers[8]

- The viability of solar-powered dryers primarily depends on asset utilisation, dried matter proportion, and cost-to-price structure, among other parameters.
- The income generated is highly sensitive to the quantity of fresh produce placed for drying, dried matter proportion, prices of dried products relative to annual operational days, raw material, and opportunity costs.
- Most of these parameters vary across different items dried and impact the income and loan serviceability accordingly.

We showcase the impact of the delineated parameters on the economic and financial viability of the technology through typical scenarios:

1. **Asset utilisation**: The impact of the quantity of fresh produce placed for drying on income generation using a solar-powered dryer is more significant than the utilisation of the asset over time in terms of annual operational days.

    - **Quantity placed for drying (batch size)**: The quantity of fresh produce placed for drying in a solar-powered dryer (batch size) is a measure of how effectively the asset's input capacity is being utilised. Optimal batch sizes vary across products due to variations in size and volume. For instance, in a 100 kg solar-powered dryer, the optimal batch size is 30 kg for fresh rose buds, while it is 85 kg for bananas.[9] As illustrated in Table 4(a), a 50 per cent reduction in the quantity of rose buds or bananas placed in the solar-powered dryer leads to more than a 50 per cent reduction in the income generated. This demonstrates the critical importance of maximising batch size to optimal levels in order to enhance profitability.

        - **Farmholding size**: For end users who are farmers, farmholding size is a crucial determinant of viability. Each crop requires a minimum acreage to generate sufficient produce for optimal utilisation of the technology. This means that the farmholding must yield enough produce to justify adopting the technology and ensure its viability. The combined yield from all crops grown should meet, at a minimum, the dryer's capacity for optimal utilisation. For instance, to allocate 50 per cent of produce to processing in a 100 kg capacity variant of the solar-powered dryer for mangoes, bananas, and lemons, a minimum of ~0.5 acres, ~0.7 acres, and ~1.7 acres of farmholding, respectively, would be required to meet the annual optimal quantity required for processing. **Farmers may not always be able to expand their farmholdings; however, understanding the relationship between their existing farm size, yield per acre of the bundle of crops grown, and the solar-powered dryer's capacity can help them assess whether the technology will be a sustainable investment**. As illustrated in Table 4(b), with a reduction of quantity processed from 50 per cent to 30 per cent, the minimum acreage requirements increase to ~0.8 acres, ~1.1 acres, and ~2.8 acres, respectively.

    - **Annual operational days**: As illustrated in Table 4 (a), a 50 per cent reduction in annual operational days (based on the seasonal availability of raw materials)—from 154–77 days for rose buds and from 198–99 days for bananas—results in a proportional (50 per cent) reduction in income. This indicates that the income generated from the solar-powered dryer is more sensitive to batch size than to the asset's utilisation over time.

8. Here, a 10 per cent upfront user contribution is assumed for the 100 kg variant priced at INR 1,40,000. At a loan amount of INR 1,26,000, interest rate of 16 per cent, and loan tenure of 2 years, the equated monthly instalment (EMI) equals INR 6,169.
9. Data sourced from DRE enterprises.

While both parameters substantially affect income, batch size has a more pronounced impact. Maximising the quantity of raw material placed for drying to optimum levels is therefore more essential for enhancing income generation from solar-powered drying operations.

Table 4a. Income generated from the use of a solar-powered dryer is more sensitive to change in batch size than change in annual operational days

Product		Rose buds	Bananas
Utilisation in terms of fresh quantity of produce placed for drying (batch size)			
Typical scenario	Quantity placed per batch‡ (in kg)	30	85
	Quantity placed per year (in kg)	4,620	8,415
Typical outcome	Monthly income (INR)	5,198	7,724
	Loan serviceability	No	Yes
Scenario 1 (50% reduction from typical scenario)	Quantity placed per batch (in kg)	15	42.5
	Quantity placed per year (in kg)	2,310	4,207.5
Scenario 1 outcome	Monthly income (INR)	**578**	**1,325**
	Income reduction	**~89%**	**~83%**
	Loan serviceability	No	**No**
Utilisation in terms of annual operational days			
Typical scenario	Annual operational days‡	154	198
Typical outcome	Monthly income (INR)	5,198	7,724
	Loan serviceability	No	Yes
Scenario 2 (50% reduction from typical scenario)	Annual operational days	77	99
Scenario 2 outcome	Monthly income (INR)	**2,599**	**3,862**
	Income reduction	**50%**	**50%**
	Loan serviceability	No	**No**

Source: Authors' analysis

‡ Data sourced from DRE enterprises.

Table 4b. Income generated from the use of a solar-powered dryer is dependent on the farmholding size and yield per acre for farmer end users

Produce type		Mangoes	Bananas	Lemons
Typical scenario	Optimal quantity placed per year (kg)	1,980	8,415	5,940
	Annual average yield per acre (kg)	8,000	25,000	7,000
	Assumed quantity of produce processed	50%	50%	50%
	Minimum quantity of produce required (kg)	3,960	1,980	11,880
	Minimum farmholding required (acres)	0.5	8,000	1.7
Scenario 3	Assumed quantity of produce processed	30%	50%	30%
	Minimum quantity of produce required (kg)	6,600	3,960	19,800
	Minimum farmholding required (acres)	0.8	0.5	2.8
	Difference in acreage	60%	57%	65%

Source: Authors' analysis

2. **Dried matter proportion**: Dried matter proportion is the percentage of dried produce generated by the solar-powered dryer from the processing of fresh produce. The higher the proportion of dried matter, the higher the quantity of dried product available for sale; hence, the higher the income generated, ceteris paribus. This can be illustrated through two cases:

Box 1. Dried matter proportion is a critical determinant of income from the use of solar-powered dryers

Bananas vs lemons

Table 5 highlights a notable contrast between dried bananas and dried lemons. Although the purchase price of dried bananas (INR 250) is lower than that of dried lemons (INR 280), the income generated from drying bananas is significantly higher. This difference is primarily driven by the higher proportion of dried matter in bananas, which compensates for their lower purchase price.

A scenario analysis reveals that if the quantity of bananas placed for drying is reduced from 85 kg to 60 kg—equivalent to the optimal quantity for lemons—the income from drying bananas declines by approximately 48.7 per cent. Despite this reduction, the income from drying bananas is substantially higher than that from drying lemons, owing to the higher dried matter proportion of bananas.

Lemons vs tomatoes

As illustrated in Table 5, despite similar purchase prices for dried lemons and dried tomatoes (INR 280), the income generated from drying lemons is higher. This is attributed to the higher proportion of dried matter in lemons, even though fresh lemons are more expensive than fresh tomatoes.

If the proportion of dried matter in tomatoes is increased to 10 per cent, equivalent to that of lemons, the income from drying tomatoes increases by ~592 per cent. However, even with equal proportions of dried matter, the income from drying tomatoes is 34.8 per cent higher than from drying lemons. This is due to the lower cost of fresh tomatoes compared to fresh lemons, which significantly influences the overall profitability of the drying process.

Source: Authors' analysis

These cases illustrate that the proportion of dried matter is a significant parameter affecting income generation from the use of solar-powered dryers.

Table 5. Products with a higher proportion of dried matter generate higher incomes through solar-powered drying

Produce type		Bananas	Lemons
Bananas vs lemons			
Typical scenario	Dried matter proportion‡	12.50%	10%
	Fresh produce purchase price (INR per kg)‡	13	12
	Dried product purchase price (INR per kg)‡	250	280
	Quantity placed for drying (in kg)	85	60
Typical outcome	Monthly income (INR)	7,724	2,846
	Loan serviceability	Yes	No
Scenario 3	Dried matter proportion	12.50%	10%
	Quantity placed for drying (in kg)	60	60
Scenario 3 outcome	Monthly income (INR)	**3,960**	2,846
	Income reduction	**48.7%**	-
	Loan serviceability	**No**	No
Product type		**Lemons**	**Tomatoes**
Lemons vs tomatoes			
Typical scenario	Dried matter proportion‡	10%	6.67%
	Fresh produce purchase price (INR per kg)‡	12	10
	Dried product purchase price (INR per kg)‡	280	280
	Quantity placed for drying (in kg)	60	60
Typical outcome	Monthly income (INR)	2,846	-779
	Loan serviceability	No	No
Scenario 4	Dried matter proportion	10%	10%
Scenario 4 outcome	Monthly income (INR)	2,846	**3,836**
	Income increase	-	**592.4%**
	Loan serviceability	No	No

Source: Authors' analysis

‡ Data sourced from DRE enterprises.

3. **Cost-to-price structure**: The cost-to-price structure in case of solar-powered dryers largely depends on the prices of dried products, the cost of raw materials, and the opportunity costs of the fresh produce.

    - **Dried product purchase price**: The price at which the solar-powered dried products are purchased/sold in the market. Income generated from the use of a solar-powered dryer is highly sensitive to any fluctuations in these prices. An increase in dried product prices results in a substantially higher increase in income. As shown in Table 6, a 20 per cent increase in the prices of the dried products listed results in an increase in income of ~48–97 per cent.

Table 6. Income generated using solar-powered dryers is highly sensitive to changes in the prices of the dried products

Product type		Bananas	Rose petals	Rose buds	Lemons	Black grapes
Typical scenario	Dried product price (INR per kg)ǂ	250	450	600	280	320
Typical outcome	Monthly income (INR)	7,724	4,043	5,198	2,846	10,427
	Loan serviceability	Yes	No	No	No	Yes
Scenario 4 (20% increase from typical scenario)	Dried product price (INR per kg)	300	540	720	336	384
Scenario 4 outcome	Monthly income (INR)	**12,107**	**7,508**	**9,818**	**5,618**	**15,414**
	Income increase	**56.7%**	**85.7%**	**88.9%**	**97.4%**	**47.8%**
	Loan serviceability	Yes	**Yes**	**Yes**	No	Yes

Source: Authors' analysis
ǂ Data sourced from DRE enterprises.

- **Raw material and opportunity cost**: Sourcing raw materials either from the market or from users' own produce has a direct impact on income realised through solar-powered dryers. In the former case, raw material cost is the primary determinant of income. In the latter, opportunity cost (incurred when the user dries the produce instead of selling it in the market and uses the proceeds to pay off any production-related loans) becomes the key determinant of the technology's viability. Ceteris paribus, the higher the raw material and opportunity cost, the lower the disposable income. However, income generated from the use of solar-powered dryers is more sensitive to market fluctuations for end users who purchase raw materials relative to those who source raw materials from their own produce. As shown in Table 7, a 20 per cent reduction in raw material costs for the listed products results in an increase in income of more than 20 per cent across all cases. In contrast, a similar percentage reduction in opportunity cost does not result in a commensurate rise in income. Consequently, lending to end users who are farmers and can source raw materials from their own produce is less susceptible to market fluctuations and therefore more viable.

Table 7. Income generation is considerably higher and less sensitive to price fluctuations when raw material is available to the users from their own produce

Produce type		Bananas	Rose petals	Rose buds	Lemons	Black grapes
Scenario 1: If raw material is purchased						
Typical scenario	Raw material cost (INR per kg)ǂ	13	24	36	12	30
Typical outcome	Monthly income (INR)	7,724	4,043	5,198	2,846	10,427
	Loan serviceability	Yes	No	No	No	Yes
Scenario 5 (20% reduction from typical scenario)	Raw material cost (INR per kg)	10	19.2	28.8	9.6	24
Scenario 5 outcome	Monthly income (INR)	**9,547**	**5,891**	**7,970**	**4,034**	**12,765**
	Income increase	**23.6%**	**45.7%**	**53.3%**	**41.7%**	**22.4%**
	Loan serviceability	Yes	No	**Yes**	No	Yes
Scenario 2: If raw material is available from users' own produce						
Typical scenario	Opportunity cost (INR per kg)ǂ	8	20	30	10	25
Typical outcome	Monthly income (INR)	11,230	5,583	7,508	3,836	12,375
	Loan serviceability	Yes	No	Yes	No	Yes
Scenario 6 (20% reduction from typical scenario)	Opportunity cost (INR per kg)	6.4	16	24	8	20
Scenario 6 outcome	Monthly income (INR)	**12,352**	**7,123**	**9,818**	**4,826**	**14,323**
	Income increase	**~10%**	**27.6%**	**30.8%**	**25.8%**	**15.7%**
	Loan serviceability	Yes	**Yes**	Yes	No	Yes

Source: Authors' analysis
ǂ Data sourced from DRE enterprises.

Comparing viability: Single versus multiple use cases

Seasonal produce often results in inconsistent cash flows for solar-powered dryer users, making it challenging to service loans. For instance, reliance on a single crop, such as mangoes, may not generate sufficient income due to limited availability throughout the year. However, as illustrated in Table 8, diversifying the use cases by drying both mangoes and rose petals can result in higher incomes, thereby improving loan serviceability. While mangoes and rose petals may not individually yield sufficient returns, drying both can generate enough cash flows to service the loan. Therefore, drying multiple types of produce in line with their seasonal availability, rather than relying on a single use case, can enhance the viability of solar-powered drying operations.

Table 8. Drying multiple items across seasons can ensure higher incomes to service loans

Produce type		Mangoes	Rose petals
Typical scenario	Utilisation months (based on seasonal availability)	3	7
Typical outcome	Monthly income (INR)	2,434	5,583
	Loan serviceability	No	No
Multiple use-case scenario	Combined monthly income (INR)	8,016	
	Combined loan serviceability	**Yes**	

Source: Authors' analysis

What risks should FIs account for?

Table 9. Risk mitigation and checklist for financing solar-powered dryers

Risks	Mitigation strategy	Checklist for financiers
In areas with high rainfall, solar-powered dryers may experience reduced functionality, resulting in inadequate dehydration. Typically, under such conditions, only leafy vegetables achieve dehydration within an average timeframe of 2–3 days.	a. Technology providers or project promoters can combine solar-powered drying with auxiliary heating sources, such as biomass, gas, or electric heaters, to maintain drying efficiency during periods of low sunlight. b. When lending in geographies with prolonged rainy weather, financiers should structure loan products in line with the end users' income cycles.	• Are the materials used in the construction of solar-powered dryers weather-resistant and durable? • Are the dryers capable of handling different types of produce effectively, including non-leafy vegetables and fruits?
End users relying on only one or two products for drying in a solar-powered dryer face heightened risk due to market fluctuations or seasonal variations, which can impact income stability and loan repayment capacity.	End users should be encouraged to diversify the range of products they dry. Financing institutions can play a proactive role by advising or incentivising users to expand their product portfolio.	• Is the entrepreneur planning to dry multiple types of produce? • Is it possible to dry multiple types of produce based on local agricultural production and market demand?

Source: Authors' analysis

Case story

Smita Vithal Jadhav, from Maharashtra, identified spice drying as a lucrative business opportunity. The challenges associated with efficient drying prompted her to purchase a solar-powered dryer from Raheja Solar Food Processing Private Limited in 2021. To finance the purchase, Smita secured a loan of INR 20,000 from a bank at a nominal monthly interest rate of one per cent, with a repayment tenure of 12 months and a monthly instalment of INR 2,000. The income generated through the use of the technology has enabled her to repay the scheduled monthly instalments on time. The adoption of the solar-powered dryer marked a significant turning point for Smita's business.

Smita's spice-drying business has become lucrative through efficient solar-powered drying.

Prior to this, she relied on traditional open sun-drying methods, which often resulted in inconsistent quality, long drying periods, and limited market access. The solar-powered dryer improved the quality of her dried produce and enabled faster operations, driving profitability. Products that earlier took four days to dry can now be dried by her in a single day using the technology. Capitalising on the growing demand for dried spices and the superior quality of her dried products, Smita has expanded her market reach and begun supplying to other states. Her monthly income increased from INR 30,000–40,000 to around INR 1,00,000 during the peak season. She has been using the technology successfully for five years now, thereby enhancing the quantity, quality, and selling price of her dried produce. This, coupled with institutional financial support, underscores the success of her entrepreneurial endeavour.

3.2 Solar-powered small or micro-horticulture processors

Small or micro-horticulture processors powered by energy-efficient solar technology have the potential to decrease the spoilage of perishable fruits, vegetables, herbs, and flowers. At the same time, they enable value addition by processing these products into juices, pulp, and essential oils.

Micro horticulture processor users report an average increase in income of INR 59,000 after using the technology.

Table 10. Overview and investment opportunity for solar-powered micro horticulture processors in India

Overview of a typical solar-powered micro horticulture processor		Investment opportunity
Hourly output capacity 40–200 L	**Price** INR 2,50,000[10]–7,00,000[11]	**Market potential** 5,47,000 units[‡]
Typical usage 4 hours a day for 175 days per year[‡]	**Livelihood-impact potential** 1.1 million (11 lakh)[‡]	**Credit opportunity**[ϟ,12] INR ~10,082–20,164 crore[13]
Typical annual incremental income INR 96,000[‡,14]	**Typical discounted payback** period 18 months[‡]	**States with the highest deployment potential** Uttar Pradesh, West Bengal, Madhya Pradesh, Andhra Pradesh[‡]
Customer archetype	Farmers, FPOs, SHGs, krishi vigyan kendra (KVK) training centres, village-level entrepreneurs (VLEs), MSMEs	
Uptake of solar-powered micro horticulture processors can be facilitated through an individual and shared ownership model, with financing provided by SFBs, NBFCs, and banks, with loan tenures of one to three years.[‡]		

Source: ‡ Data sourced from Jain et al. (2023), ϟ Authors' analysis

10. 30–40 L per hour output processor.
11. 200 L per hour output processor.
12. Based on the assumption that 50–100 per cent of the product cost is financed through loans.
13. For 60–80 L per hour output processor variant.
14. For 40 L per hour output processor variant.

Viability of micro horticulture processors[15,16]

- The viability of micro horticulture processors primarily depends on asset utilisation, output-to-input ratio, and the cost-to-price structure, among other parameters.

- Income generated is highly sensitive to the quantity of produce placed for processing (batch size), annual operational days, and the prices of processed products relative to raw material and opportunity costs.

- Most of these parameters vary across products processed and impact the income and loan serviceability accordingly.

The impact of these parameters on the economic and financial viability of the technology is showcased through typical scenarios:

1. **Asset utilisation**: Income generated from the use of a micro horticulture processor is equally sensitive to utilisation in terms of both the quantity of produce placed for processing relative to optimal processing capacity and the number of annual operational days.

    - **Quantity placed for processing (batch size)**: It is a measure of how effectively the input capacity of a micro horticulture processor is utilised. As shown in Table 11(a), a 50 per cent reduction in the quantity of produce placed for processing results in a proportionate reduction in the income generated. This underscores the importance of maximising the quantity placed for processing to optimum levels to enhance profitability.

        - **Farmholding size**: For end users who are farmers, farmholding size is a key determinant of the viability of the micro horticulture processor. Each crop requires a minimum acreage to generate sufficient produce for optimal utilisation of the technology. This means that the farmholding must yield enough produce to justify adopting the technology and ensure its viability. The crops grown collectively and the quantum of produce generated should, at the very least, match the processor's capacity for optimal utilisation. For instance, to direct 70 per cent of the produce towards processing in a 60–80 kg processing-capacity variant of a micro horticulture processor, a minimum farmholding of ~5.4 acres for watermelon and ~5.2 acres for oranges would be required to meet the annual optimal processing quantity. **While farmers may not be able to expand their farmholdings, understanding the relationship between their existing farm size, the yield per acre of the bundle of crops grown, and the horticulture processor's capacity can help assess whether the technology will be a sustainable investment**. As illustrated in Table 11 (b), increasing the quantity processed from 70 per cent to 90 per cent reduces the minimum acreage required to ~4.2 acres for watermelon and ~4.0 acres for oranges.

    - **Annual operational days**: As illustrated in Table 11 (a), a 50 per cent reduction in annual operational days (reduction from 85 to 42.5 days for watermelons and 51 to 25.5 days for oranges) results in a proportional (50 per cent) reduction in income. This indicates that the income generated by the micro horticulture processor is equally sensitive to both batch size and annual operational days.

15. Here, a 10 per cent upfront user contribution is assumed for the 60 L per hour processing capacity variant priced at INR 1,51,512. At a loan amount of INR 1,36,361, an interest rate of 16 per cent, and a loan tenure of 2 years, the EMI equals INR 6,677.
16. Although there are solar-powered micro horticulture processors in the market, the scenario analysis here is with respect to the energy-efficient version of the technology, which has a higher demand and the price of which falls in the range of INR 85,000–2,71,872.

Both the utilisation of the asset, in terms of the quantity of produce placed for processing, and the annual operational days, substantially affect income. Maximising both parameters to optimum levels is therefore essential for enhancing income generation from solar-powered horticulture processing operations.

Table 11a. Income generated from the use of a micro horticulture processor is equally sensitive to changes in batch size and annual operational days

Product		Watermelons	Oranges
Processed product		Juice	Juice
	Utilisation in terms of batch size		
Typical scenario	Quantity placed for processing‡ (in kg/hour)	160	100
	Quantity processed per year (in kg)	42,500	17,850
Typical outcome	Monthly income (INR)	5,01,500	1,40,038
	Loan serviceability	Yes	Yes
Scenario 1 (50% reduction from typical scenario)	Quantity placed for processing (in kg/hour)	80	50
	Quantity placed per year (in kg)	21,250	8,925
Scenario 1 outcome	Monthly income (INR)	2,50,750	70,019
	Income reduction	50%	50%
	Loan serviceability	Yes	Yes
	Utilisation in terms of operational days		
Typical scenario	Annual operational days (based on seasonal availability)‡	85	51
Typical outcome	Monthly income (INR)	5,01,500	1,40,038
	Loan serviceability	Yes	Yes
Scenario 2 (50% reduction from typical scenario)	Annual operational days	42.5	25.5
Scenario 2 outcome	Monthly income (INR)	2,50,750	70,019
	Income reduction	50%	50%
	Loan serviceability	Yes	Yes

Source: Authors' analysis

Table 11b. Income generated from the use of a micro horticulture processor is dependent on the farmholding size and yield per acre for farmer end users

Product		Watermelons	Oranges
Processed product		Juice	Juice
	Utilisation in terms of batch size		
Typical scenario	Annual average yield per acre (kg)	18,000	7,000
	Assumed quantity of produce processed	70%	70%
	Minimum quantity of produce required (kg)	97,143	36,429
	Minimum farmholding required (acres)	5.4	5.2
Scenario 3	Assumed quantity of produce processed	90%	90%
	Minimum quantity of produce required (kg)	75,556	28,333
	Minimum farmholding required (acres)	4.2	4.0
	Difference in acreage	−22.2%	−23%

Source: Authors' analysis

~88% users of micro horticulture processors report decrease in wastage of produce.

2. **Output-to-input ratio**: The output-to-input ratio for a micro horticulture processor is a measure of the quantity of processed output (horticultural products, such as juices, jams, etc.) obtained from a given quantity of input (such as raw horticulture produce). It is calculated by dividing the total quantity of output by the total quantity of input. The higher the output-to-input ratio, the higher the processed product available for sale; hence, the higher the economic returns, ceteris paribus. For certain products, the output-to-input ratio exceeds 100 per cent, primarily due to their low moisture content. Consequently, in such cases, water is added during processing to produce marketable juice. This can be illustrated through two cases:

Box 2. Output-to-input ratio is a critical determinant of income from the use of micro horticulture processors

Pineapples vs tomatoes

Table 12 illustrates a notable contrast between processed pineapples and processed tomatoes. Although the purchase price of pineapple juice (INR 80) is lower than that of tomatoes processed into ketchup (INR 90), the income generated from processing pineapples is significantly higher. This holds true despite the higher purchase price of fresh pineapples and their more limited seasonal availability compared to tomatoes. The primary reason for this difference is the higher output-to-input ratio of pineapples, which offsets unfavourable values across other parameters.

Amlas vs bitter gourds

As illustrated in Table 12, despite similar purchase prices for amla and bitter gourd juice (INR 100), the income generated from processing bitter gourd is higher, largely due to its higher output-to-input ratio.

A scenario analysis reveals that if the output-to-input ratio of amla is increased to 2.5, equivalent to that of bitter gourd, the income from processing amla increases by ~ 909 per cent. Even with equal output-to-input ratios and a lower purchase price for fresh bitter gourd, the income from processing amla is ~69 per cent higher. This is due to the higher optimal processing capacity of amla compared to bitter gourd.

Source: Authors' analysis

These cases illustrate that the output-to-input ratio is a significant parameter impacting income generation from the use of micro horticulture processors, and its variation across various produce types translates into varying income levels across different processed products.

Table 12. Products with higher output-to-input ratios generate higher incomes through micro horticulture processing

Produce type		Pineapples	Tomatoes
Processed product		Juice	Ketchup
	Pineapple juice vs tomato ketchup		
Typical scenario	Output-to-input ratio‡	4	0.9
	Hourly processing capacity (in kg)‡	12	15
	Fresh produce purchase price (INR per kg)‡	40	10
	Processed product purchase price (INR per L)‡	80	90
Typical outcome	Monthly income (INR)	58,027	49,343
	Loan serviceability	Yes	Yes
Produce type		Amla	Bitter gourd
Processed product		Juice	Juice
	Amla vs bitter gourd		
Typical scenario	Output-to-input ratio‡	0.5	2.5
	Hourly processing capacity (in kg)	80	20
	Fresh produce purchase price (INR per kg)‡	20	15
	Processed product purchase price (INR per L)‡	100	100
Typical outcome	Monthly income (INR)	49,867	1,76,517
	Loan serviceability	Yes	Yes
Scenario 3	Output-input ratio	2.5	2.5
Scenario 3 outcome	Monthly income (INR)	5,03,200	1,76,517
	Income increase	909%	-
	Loan serviceability	Yes	Yes

Source: Authors' analysis
‡ Data sourced from DRE enterprises.

3. **Cost-to-price structure:** The cost-to-price structure for micro horticulture processors largely depends on the prices of processed or value-added products, as well as raw material and opportunity costs.

    - **Prices of processed/value-added products:** This refers to the selling price of products that have undergone additional processing, enhancement, or packaging to increase their market value beyond the raw horticultural produce. Income generated from the use of a micro horticulture processor is highly sensitive to fluctuations in these prices. An increase in processed product prices results in a substantially higher increase in income generated. As illustrated in Table 13, a 30 per cent increase in the prices of the processed products listed results in an increase in income of ~40–56 per cent.

Table 13. Income generated from using micro-horticulture processors is highly sensitive to the change in processed product prices relative to the change in raw material costs

Produce type		Pineapples	Tomatoes		Aloe vera
Processed product		**Juice**	**Puree**	**Ketchup**	**Pure juice**
Typical scenario	Value-added product prices (INR per L)‡	80	150	90	150
Typical outcome	Monthly income (INR)	58,027	5,78,850	49,343	3,87,600
	Loan serviceability	Yes	Yes	Yes	Yes
Scenario 4 (30% increase from typical scenario)	Value-added product prices (INR per L)	104	195	117	195
Scenario 4 outcome	Monthly income (INR)	**90,667**	**8,08,350**	**73,440**	**5,40,600**
	Income increase	**56.3%**	**40%**	**49%**	**40%**
	Loan serviceability	Yes	Yes	Yes	Yes

Source: Authors' analysis
‡ Data sourced from DRE enterprises.

- **Raw material and opportunity cost**: Sourcing raw materials either from the market or from users' own produce has a direct impact on income realised through micro horticulture processors. In the former case, raw material cost determines income. In the latter, opportunity cost (the cost incurred when the user processes the produce instead of selling it immediately and using the money to pay off any production-related loans) determines the technology's viability. Ceteris paribus, the higher the raw material and opportunity cost, the lower the disposable income. However, income generated from the use of micro horticulture processors is more sensitive to market fluctuations for end users who purchase the raw materials, relative to those who source raw materials from their own produce. As illustrated in Table 14, a 25 per cent increase in both raw material and opportunity costs for the items considered in the following table results in a greater reduction in income for users purchasing raw materials from the market. Therefore, lending to end users who are farmers and can source raw materials from their own produce is more viable.

Table 14. Income generation is relatively higher and less sensitive to price fluctuations when raw material is available to the end users from their own produce

Produce type		Pineapples	Lemons
Processed product		**Juice**	**Pure juice**
Scenario 1: If raw material is purchased			
Typical scenario	Raw material cost (INR per kg)‡	40	50
Typical outcome	Monthly income (INR)	53,493	3,33,200
	Loan serviceability	Yes	Yes
Scenario 5 (25% increase from typical scenario)	Raw material cost (INR per kg)	50	62.5
Scenario 5 outcome	Monthly income (INR)	**47,827**	**2,48,200**
	Income reduction	**11%**	**26%**
	Loan serviceability	Yes	Yes
Scenario 2: If raw material is available from users' own produce			
Typical scenario	Opportunity cost (INR per kg)‡	32	40
Typical outcome	Monthly income (INR)	58,027	401,200
	Loan serviceability	Yes	Yes
Scenario 6 (25% increase from typical scenario)	Opportunity cost (INR per kg)	40	50
Scenario 6 outcome	Monthly income (INR)	**53,493**	**333,200**
	Income reduction	**8%**	**17%**
	Loan serviceability	Yes	Yes

Source: Authors' analysis
‡ Data sourced from DRE enterprises.

Comparing viability: Single versus multiple use cases

Seasonal produce often results in inconsistent cash flows for micro horticulture processor users, which can make loan servicing challenging. For instance, reliance on a single crop, such as pomegranates, may not generate sufficient income due to various use-case-specific parameters determining their viability. However, as illustrated in Table 15, by diversifying use cases and processing various produce types, such as pomegranates, pineapples and amla, users can earn higher incomes, ensuring the loan becomes serviceable. Therefore, processing multiple produce types as per their availability across the year, instead of relying on a single use case, can generate enough cash flows to make a loan serviceable.

Table 15. Processing multiple items across seasons can ensure higher incomes to service the loan

Produce type		**Pomegranates**	**Pineapples**	**Amlas**
Processed product		**Pure juice**	**Juice**	**Pure juice**
Typical scenario	Utilisation months (based on seasonal availability)	3	4	4
Typical outcome	Monthly income (INR)	−935	53,493	40,800
	Loan serviceability	No	Yes	Yes
Multiple use-case scenario	Combined monthly income (INR)		93,358	
	Combined loan serviceability		**Yes**	

Source: Authors' analysis

What risks should FIs account for?

Table 16. Risk mitigation and checklist for financing solar-powered micro-horticulture processors

Risks	**Mitigation strategy**	**Checklist for financiers**
End products are at risk of perishing due to the varying environmental conditions required for their longevity and the lack of additional processing.	The shelf life of end products can be enhanced through refrigeration, drying, or value-added processes, such as conversion into jams, pickles, and candies.	• Are training programmes or support available to help users add value to end products? • Do end users have access to refrigeration facilities?
Absent or weak market linkages for processed horticulture products can result in reduced cash flows.	Technology providers or project promoters can provide buy-back guarantees for processed products. In addition, partnerships with other companies that have established market linkages in the horticulture sector can help provide end users with reliable market access.	• Are there existing market linkages for processed products in the geography where the processor will be deployed? • Does the technology provider or project promoter provide a buy-back facility to end users?

Source: Authors' analysis

Case story

Prakash Singh, a 50-year-old entrepreneur from Uttarakhand, operates a primary business focused on flour milling, spices, and fruit juices. Seeking to diversify his product offerings, he invested in a highly sought-after micro horticulture processor from Kissan Dharambir, specifically the V60 model, in February 2023. This strategic investment enabled him to expand his product line to include a variety of offerings, such as juices made from the Buransh flower, amla, and an array of Himalayan fruits, along with jams and chutneys.

Prakash Singh (at the centre) placing buransh flowers in a micro horticulture processor to produce juice.

To facilitate this expansion and cover business-related expenses, Prakash secured a loan of INR 5,00,000 at a nominal annual interest rate of 14 per cent, with a repayment tenure of 5 years and a monthly instalment of INR 7,000. The income generated from the use of the technology has enabled him to repay the scheduled EMIs on time.

The adoption of the micro horticulture processor proved transformative for Prakash's business. Prior to its purchase, his monthly earnings fell in the range of INR 15,000–20,000. However, post-adoption, his income increased substantially and now averages INR 40,000–50,000 per month.

Having used the technology for over two years now, the increased revenue stream has facilitated the sustainability and growth of Prakash's business while also delivering tangible personal benefits. Notably, it enabled him to finance the weddings of two of his daughters, underscoring the significant impact of the micro-horticulture processor on both his livelihood and household well-being.

3.3 Solar-powered vertical fodder grow units

Microclimate-controlled hydroponic[17] units powered by solar energy can help users bridge the green fodder deficit by enabling the cultivation of fresh green fodder with minimal water. This innovative solution can help boost the milk and meat yields of livestock, contributing to increased income for livestock rearers. Additionally, it can help reduce the time and effort spent on fodder procurement and preparation.

Solar-powered vertical fodder grow units enhance milk yields and fetch better prices for dairy farmers.

17. Hydroponics is the technique of growing plants using a water-based nutrient solution instead of soil. It can also include an aggregate substrate or growing media, such as vermiculite, coconut coir, or perlite.

Table 17. Overview and investment opportunity for solar-powered vertical fodder grow units in India

Overview of a typical solar-powered vertical fodder grow unit		Investment opportunity
Daily output capacity 10–15 kg to 25–30 kg	**Price** INR 24,000[18]–INR 35,000[⤳]	**Market potential** 33,80,000 units[‡]
Typical usage 12–24 hours a day for 240 days per year[‡]	**Livelihood-impact potential** 11.9 million (1.19 crore)[‡]	**Credit opportunity (INR)**[ϟ,19] INR ~5,831 crore–11,661 crore[⤳]
Typical annual incremental income INR 24,000[‡,⤳]	**Typical discounted payback period** 22 months[‡]	**States with the highest deployment potential** Uttar Pradesh, Rajasthan, Gujarat, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Madhya Pradesh, and Telangana[‡]
Customer archetype	Unit: Cattle-owning small and marginal farmers, VLEs Fodder station: SHGs, FPOs, gaushalas	
Uptake of solar-powered vertical fodder grow units can be increased through an individual ownership model, with financing provided by SFBs, NBFCs, and banks, offering loan terms of one to three years.[‡]		

Source: ‡ Data sourced from Jain et al. (2023), ϟ Authors' analysis
⤳ For the 25–30 kg output capacity variant

Viability of solar-powered vertical fodder grow units[20]

- The viability of solar-powered vertical fodder grow units primarily depends on the number of dairy animals owned and fed, annual milking days, increase in milk yield, and the cost-to-price structure, among other parameters.

- The income generated is substantially and equally sensitive to the number of dairy animals owned and fed, annual milking days, increases in milk yield, and milk and fodder tray (in case of a service model) prices relative to seed and concentrate feed costs.

The impact of the delineated parameters on the technology's economic and financial viability is illustrated as follows using typical scenarios.

1. **Number of dairy animals owned and fed per day**: The potential income that can be generated is highly sensitive to the number of dairy animals owned and fed with the fodder grown in solar-powered vertical fodder grow units. As illustrated in Table 18, a 100 per cent increase in the number of dairy animals fed per day (which depends on the number of dairy animals owned and the technology's output capacity) results in a higher-than-proportional increase (953 per cent) in the income generated.

18. For the 10–15 kg per day output unit.
19. Based on the assumption that 50–100 per cent of the product cost is financed through loans.
20. Here, a 10 per cent upfront user contribution is assumed for two variants: a 10–15 kg output capacity unit and a 25–30 kg output capacity unit, priced at INR 23,500 and INR 34,500, respectively. A 40 per cent upfront user contribution is assumed for the fodder station, priced at INR 23,37,600. At loan amounts of INR 21,150, INR 31,050, and INR 1,40,260, an interest rate of 16 per cent, and loan tenure of one, one, and four years, the EMI equals INR 1,919, INR 2,817, and INR 39,749 for the three variants listed here, respectively.

Table 18. Income generated is highly sensitive to the number of dairy animals owned by a user and fed using the solar-powered vertical fodder grow unit

Parameters		Vertical fodder unit
Typical scenario	Number of trays of output available per day‡	4
	Number of dairy animals owned and fed per day‡	2
Typical outcome	Monthly income (INR)	375
	Loan serviceability	No
Scenario 1 (100% increase from the typical scenario)	Number of trays of output available per day	4
	Number of dairy animals fed per day‡	4
Scenario 1 outcome	Monthly income (INR)	**3,950**
	Income increase	**953%**
	Loan serviceability	**Yes**

Source: Authors' analysis
‡ Data sourced from DRE enterprises.

2. **Annual milking days**: Milking days refer to the number of days during the lactation period when a dairy animal, such as a cow, goat, or sheep, is actively milked. Similar to the number of dairy animals owned and fed, the income generated using solar-powered vertical fodder grow units is highly sensitive to the number of annual milking days. The higher the number of milking days, the higher the milk yield and production for sale, and consequently, the higher the income, ceteris paribus. As illustrated in Table 19, a 50 per cent decrease in the number of annual milking days from 200 to 100 results in a proportional reduction (500 per cent) in income.

Table 19. Income generated is less sensitive to the number of milking days than to the number of dairy animals owned and fed

Parameters		Vertical fodder unit
Typical scenario	Annual milking days‡	200
Typical outcome	Monthly income (INR)	3,950
	Loan serviceability	Yes
Scenario 2 (50% reduction from the typical scenario)	Annual milking days	100
Scenario 2 outcome	Monthly income (INR)	**1,975**
	Income reduction	**50%**
	Loan serviceability	**No**

Source: Authors' analysis
‡ Data sourced from DRE enterprises.

3. **Increase in milk yield per animal**: Milk yield refers to the amount of milk produced by a dairy animal, typically a cow, over a specific period. Here, it is measured in litres (L) produced per day. It refers to the increase in milk yield per animal per day due to the introduction of a solar-powered vertical fodder grow unit. Income generated is highly sensitive to increases in milk yield following the consumption of green fodder by cattle. As illustrated in Table 20, a 50 per cent increase in milk yield per animal results in a proportional increase in income (~50 per cent).

Table 20. Income generated is highly sensitive to changes in milk yield following the use of a solar-powered vertical fodder grow unit

Parameters		Vertical fodder unit
Typical scenario	Increase in milk yield per dairy animal per day (L)ǂ	1
Typical outcome	Monthly income (INR)	~2,083
	Loan serviceability	**No**
Scenario 3 (50% increase from the typical scenario)	Increase in milk yield per dairy animal per day (L)	2
Scenario 3 outcome	Monthly income (INR)	**~4,417**
	Income increase	**~50%**
	Loan serviceability	**Yes**

Source: Authors' analysis
ǂ Data sourced from DRE enterprises.

4. **Cost-to-price structure**: The cost-to-price structure of the inputs and outputs of a solar-powered vertical fodder grow unit largely depends on the milk price, price per tray of fodder (fodder-as-a-service model), seed costs, and concentrate feed costs.

   - **Milk price**: The income generated through the use of a solar-powered vertical fodder grow unit is highly sensitive to changes in milk prices. As illustrated in Table 21, a 10 per cent increase in the milk price results in a proportional increase in income (10 per cent).

   - **Price per tray of fodder**: In addition to the delineated parameters, the income generated through the 'fodder-as-a-service' model is determined by the price per tray of fodder sold and the number of trays sold per day. In the fodder-as-a-service model, the solar-powered vertical fodder grow unit, specifically the fodder station, can be purchased by an individual or a group, such as an FPO or an SHG, and fodder can be provided as a chargeable service to users. The income generated from both the own-use and service models is sensitive to the prices of the final output (milk in the former case and fodder in the latter). As illustrated in Table 21, a 10 per cent increase in fodder tray prices results in a slightly higher than proportional increase in income (~12 per cent). Similarly, a 10 per cent reduction in the daily demand and sale of fodder trays results in a slightly greater than proportional decrease in income.

Table 21. The income generated using a solar-powered vertical fodder grow unit is equally sensitive to changes in milk prices in the own-use model and fodder tray prices in the service model; a 10 per cent increase in either results in a proportional increase in income

Parameters		Vertical fodder unit
	Own-use model	
Typical scenario	Milk price (INR)ǂ	35
Typical outcome	Monthly income (INR)	3,950
	Loan serviceability	Yes
Scenario 4 (10% increase from the typical scenario)	Milk price (INR)	38.5
Scenario 4 outcome	Monthly income (INR)	**~4,370**
	Income increase	**~10%**
	Loan serviceability	Yes
	Fodder-as-a-service model	
Typical scenario	Number of trays of output per day	96
	Price per tray (INR)ǂ	40
	Per day demand for trays	96
Typical outcome	Monthly income (INR)	51,500
	Loan serviceability	Yes
Scenario 5 (10% increase from the typical scenario)	Price per tray (INR)	44
Scenario 5 outcome	Monthly income (INR)	**57,900**
	Income increase	**~12%**
	Loan serviceability	Yes
Scenario 6 (10% decrease from the typical scenario)	Per-day demand for trays	86
Scenario 6 outcome	Monthly income (INR)	**44,833**
	Income reduction (INR)	**~13%**
	Loan serviceability	Yes

Source: Authors' analysis

ǂ Data sourced from DRE enterprises.

- **Seed and concentrate feed costs**: The income generated through the use of solar-powered vertical fodder grow units is significantly less sensitive to changes in seed and concentrate feed[21] costs relative to the other delineated parameters. As illustrated in Table 22, a 10 per cent increase in the seed and concentrate feed costs results in a less-than-proportional change in income (~3.2 and ~2.5 per cent, respectively). In the former case, income decreases by ~3.2 per cent, whereas in the latter case it increases by ~2.5 per cent. This is because an increase in concentrate feed costs results in higher disposable income, as less concentrate feed is required to feed the cattle using solar-powered vertical fodder grow units.[22]

Table 22. Income generated from a solar-powered vertical fodder grow unit shows similar sensitivity to fluctuations in seed and concentrate feed costs, though in opposite directions; a 10 per cent increase in either cost results in a less-than-proportional change in income

Parameters		Vertical fodder unit
	Seed costs	
Typical scenario	Seed costs (INR per kg)ǂ	25
Typical outcome	Monthly income (INR)	3,950
	Loan serviceability	Yes
Scenario 6 (10% increase from the typical scenario)	Seed costs (INR per kg)	27.5
Scenario 6 outcome	Monthly income (INR)	**3,825**
	Income decrease	**~3.2%**
	Loan serviceability	Yes
	Concentrate feed costs	
Typical scenario	Concentrate feed cost (INR per kg)ǂ	30
Typical outcome	Monthly income (INR)	3,950
	Loan serviceability	Yes
Scenario 7 (10% increase from the typical scenario)	Concentrate feed cost (INR per kg)	33
Scenario 7 outcome	Monthly income (INR)	**4,050**
	Income increase	**~2.5%**
	Loan serviceability	Yes

Source: Authors' analysis
ǂ Data sourced from DRE enterprises.

21. Concentrate feed for cattle refers to a type of livestock feed that is rich in nutrients, particularly energy and protein. These feeds are formulated to supplement the roughage (such as hay, silage, and pasture) that cattle consume, providing essential nutrients that may not be adequately available in their regular diet.
22. By reducing the need for concentrate feed, the solar vertical fodder grower shields the user from increases in feed prices. Without the technology, higher feed prices would increase costs, but with adoption, these costs are avoided, resulting in higher disposable income.

What risks should FIs account for?

Table 23. Risk mitigation and checklist for financing solar-powered vertical fodder grow units

Risks	Mitigation strategy	Checklist for financiers
Unavailability of seeds due to a two-fold challenge: • **Pest infestation caused by improper storage of seeds** • **Lack of logistical capacity to transport the stored seeds to end users.**	• Technology providers should invest in advanced storage techniques such as vacuum sealing, controlled atmosphere storage, and refrigeration to extend the shelf life of seeds. • Technology providers and project promoters can invest in a robust logistics network with reliable transportation and distribution channels to mitigate the challenge.	• Does the technology provider use advanced storage techniques such as vacuum sealing, controlled atmosphere storage, or refrigeration of seeds? • Are there pest control measures in place to reduce seed wastage? • Is there regular monitoring and maintenance of storage units to prevent pest infestation? • Does the technology provider have a robust logistics network to transport stored seeds to end users? • Are there reliable transportation and distribution channels in place to ensure timely delivery? • Are there contingency plans for logistical disruptions? • Are there documented standard operating procedures (SOPs) for both storage and logistics processes to ensure consistency and reliability?

Source: Authors' analysis

Case story

Sowmya Soundarajan, a dairy farmer from Karur district in Tamil Nadu, has over eight years of experience in managing a small dairy enterprise. Despite this, she had no access to formal credit, which limited her ability to invest in productivity-enhancing solutions. Determined to improve the productivity of her dairy unit, she invested in a Hydro Greens Kambali V2, a 32-tray hydroponic system, to produce high-quality, nutrient-rich feed for her cattle. To finance the installation of the hydroponic unit and feed her four cows, Sowmya secured a loan of INR 32,000 at an affordable EMI of INR 2890 from RangDe, a peer-to-peer (P2P) lending platform.

With a steady supply of fresh, green fodder, the investment resulted in a minimum increase of 500 ml in milk yield per animal, reduced fodder shortages during the summer months, and improved the overall efficiency of her operations. The technology also freed up time previously spent sourcing fodder, enabling her to take up part-time employment and supplement her household income. Importantly, this loan marked Sowmya's first entry into the formal financial system, allowing her to build a credit history and strengthening her ability to access future finance for livelihood expansion.

Sowmya has entered the formal credit system through the purchase of a solar vertical fodder grow unit.

3.4 Solar-powered small refrigerators

Efficient solar-powered small refrigerators provide an adept climate-friendly solution for preserving processed foods, dairy products, fishery items, beverages, and vaccines. By enhancing the storage and sale of perishable goods, this technology can help generate income by increasing marketable yield and extending shelf life

Solar refrigerators reduce the perishability of fishery products, thereby enhancing incomes for the fisher communities.

Table 24. Overview and investment opportunity for solar-powered small refrigerators in India

Overview of a typical solar-powered small refrigerator		Investment opportunity
Storage capacity 100–250 L	**Price** INR 95,000[23]–1,45,000[24]	**Market potential** 1.23 million units[‡]
Typical usage 24 hours a day (60 per cent duty cycle) for 333 days per year[‡]	**Livelihood-impact potential** 1.23 million (12.3 lakh)[‡]	**Credit opportunity (INR)**[ϟ,25] INR ~6,776 crore–13,552 crore[26]
Typical annual incremental income INR 96,000[‡,27]	**Typical discounted payback period** 29 months[‡]	**States with the highest deployment potential** Uttar Pradesh, West Bengal, Assam, Maharashtra, Odisha, Bihar, Andhra Pradesh, and Tamil Nadu[‡]
Customer archetype	Small local retailers, fisherfolk	
Uptake of solar-powered small refrigerators can be supported through individual or shared ownership models, with financing provided by SFBs, NBFCs, and banks, offering a loan tenure of two to four years.‡		

Source: ‡ Data sourced from Jain et al. (2023), ϟ Authors' analysis

23. For a 100 L capacity unit.
24. For a 250 L capacity unit.
25. Based on the assumption that 50–100 per cent of the product cost is financed through loans.
26. For a 200 L variant.
27. For a 100 L variant.
28. Here, a 10 per cent upfront user contribution is assumed for the 200 kg variant priced at INR 1,10,000. At a loan amount of INR 99,000, an interest rate of 16 per cent, and a loan tenure of two years, the EMI equals INR 4,847.

Viability of solar-powered small refrigerators[28]

- The viability of solar-powered small refrigerators primarily depends on the cost-to-price structure (profit margin), annual operational days, and the quantum of refrigerated products sold, among other parameters.
- The income generated is highly sensitive to the selling and cost prices of the refrigerated products and annual operational days relative to the quantum of refrigerated products sold.
- The primary use cases for solar-powered small refrigerators range from storing fishery products to fruit pulp, beverages, vaccines, and dairy products.

Most of these parameters vary across the items refrigerated and affect income earned and loan serviceability accordingly.

The impact of the delineated parameters on the economic and financial viability of the technology is showcased through typical scenarios:

1. **Cost-to-price structure**: The cost-to-price structure in case of solar-powered small refrigerators largely depends on the selling cost prices of the refrigerated products.
    - **Selling prices of refrigerated products**: The income generated from the use of solar-powered small refrigerators is highly sensitive to changes in the selling prices of the refrigerated products. As illustrated in Table 25, a 5 per cent increase in the selling prices of the refrigerated items considered results in a higher than proportional increase in income (~26–87 per cent).

Table 25. The income generated using a solar-powered small refrigerator is highly sensitive to changes in the prices of refrigerated products – a 5 per cent increase in the selling prices of the refrigerated products results in a higher than proportional increase in income

Product types		Fishery	Fruit pulp	Beverages	Vaccines	Dairy
Processed product		Pomfret fish	Mango pulp	Coke	Cattle vaccine (Provet)	Milk
Typical scenario	Cost price‡ (INR per kg/L/vial)	701	89	46	399	60
	Profit margin‡	10%	20%	10%	15%	5%
	Selling price (INR per kg/L/vial)	771	107	50	459	63
Typical outcome	Monthly income (INR)	32,663	9,120	5,220	7,858	6,525
	Loan serviceability	Yes	Yes	Yes	Yes	Yes
Scenario 1 (5% increase from the typical scenario)	Selling price (INR per kg/L/vial)	809	112	53	482	66
Scenario 1 outcome	Monthly income (INR)	50,008	11,519	7,472	10,439	12,195
	Income increase	53.1%	26.3%	43.1%	32.8%	86.9%
	Loan serviceability	Yes	Yes	Yes	Yes	Yes

Source: Authors' analysis

‡ Data sourced from DRE end users, enterprises, and IndiaMART (last accessed in June 2024).

Additionally, within each use case, there is a wide range of products that can be refrigerated. As illustrated in Table 26, although they have similar profit margins, the income generated from storing pomfret fish would be higher than that from Indian mackerel, due to differences in market values. Hence, the higher the product's market value, the higher the income generated from its refrigeration, ceteris paribus.

Table 26. Products with a higher market value and profit margin within a single use case generate higher incomes through the use of solar-powered small refrigerators

Product types		Fishery		Dairy	
Processed product		Pomfret fish	Indian mackerel	Milk	Ghee
Typical scenario	Profit margin‡	10%	10%	5%	5%
Typical outcome	Monthly income (INR)	32,663	7,596	6,525	45,450
	Loan serviceability	Yes	Yes	Yes	Yes

Source: Authors' analysis
‡ Data sourced from DRE end users and IndiaMART (last accessed in June 2024).

- **Costs of refrigerated products**: The income generated from the use of a solar-powered small refrigerator is highly sensitive to changes in the wholesale or cost prices of the refrigerated products. As illustrated in Table 27, a five per cent increase in the wholesale prices of items considered results in a greater-than-proportional decrease (~22–83 per cent) in income.

Table 27. The income generated using a solar-powered refrigerator is highly sensitive to changes in the wholesale/cost prices of the refrigerated products—a 5 per cent increase in the cost price results in a higher than proportional decrease in income

Produce type		Fishery	Fruit pulp	Beverages	Vaccines	Dairy
Processed product		Pomfret fish	Mango pulp	Coke	Cattle vaccine (Provet)	Milk
Typical scenario	Cost price‡ (INR per kg/L/vial)	701	89	46	399	60
	Selling price (INR per kg/L/vial)	771	107	50	459	63
Typical outcome	Monthly income (INR)	32,663	9,120	5,220	7,858	6,525
	Loan serviceability	Yes	Yes	Yes	Yes	Yes
Scenario 2 (5% increase from typical scenario)	Cost price (INR per kg/L/vial)	736	93	48	419	63
Scenario 2 outcome	Monthly income (INR)	**16,894**	**7,121**	**3,173**	**5,614**	**1,125**
	Income reduction	**48.3%**	**21.9%**	**39.2%**	**28.6%**	**82.8%**
	Loan serviceability	Yes	Yes	**No**	Yes	**No**

Source: Authors' analysis
‡ Data sourced from DRE end users and IndiaMART (last accessed in June 2024).

2. **Annual operational days**: The income generated from the use of a solar-powered refrigerator is substantially sensitive to the number of annual operational days. The higher the number of operational days, that is, the utilisation of the asset over time, the higher the quantity of products saved from perishing and, hence, the higher the income, ceteris paribus. As illustrated in Table 28, a 33.3 per cent decrease in the number of annual operational days, from 270 to 180 days, across the items listed, results in a proportional reduction (33.3 per cent) in income.

Table 28. The income generated from the use of solar-powered small refrigerators is substantially sensitive to the annual operational days of the asset – a 33.3 per cent decrease in the annual operational days results in a proportional decrease in income

Produce type		Fishery	Fruit pulp	Beverages	Vaccines	Dairy
Processed product		Pomfret fish	Mango pulp	Coke	Cattle vaccine (Provet)	Milk
Typical scenario	Annual operational days‡	270	270	270	270	270
Typical outcome	Monthly income (INR)	32,663	9,120	5,220	7,858	6,525
	Loan serviceability	Yes	Yes	Yes	Yes	Yes
Scenario 3 (33.3% reduction from the typical scenario)	Annual operational days	180	180	180	180	180
Scenario 3 outcome	Monthly income (INR)	21,775	6,080	3,480	5,239	4,350
	Income reduction	33.3%	33.3%	33.3%	33.3%	33.3%
	Loan serviceability	Yes	Yes	No	Yes	No

Source: Authors' analysis
‡ Data sourced from DRE end users and enterprises.

Further, while some users may have used ice boxes prior to using the technology, others may have used a grid-connected electric refrigerator. The switch to a solar-powered refrigerator will typically generate savings of up to INR 4,500 per month. Accordingly, users' disposable income will vary with their savings on alternatives.

3. **Quantity of refrigerated products sold**: Income generated is highly sensitive to changes in the quantity of refrigerated products sold. However, the impact of such a change on income is less substantial than that of changes in the cost–price structure and the asset's annual operational days. As illustrated in Table 29, a 40 per cent increase in the quantity of refrigerated products sold results in a less-than-proportional increase in income (~31–39 per cent).

Table 29. A 40 per cent increase in the quantity of refrigerated products sold results in a less than proportional increase in the income generated using solar-powered small refrigerators

Product types		Fishery	Fruit pulp	Beverages	Vaccines	Dairy
Processed product		Pomfret fish	Mango pulp	Coke	Cattle vaccine (Provet)	Milk
Typical scenario	Quantity sold of refrigerated products per day (kg/L/vial)ǂ	20	20	40	5	80
Typical outcome	Monthly income (INR)	32,663	9,120	5,220	7,858	6,525
	Loan serviceability	Yes	Yes	Yes	Yes	Yes
Scenario 4 (40% increase from the typical scenario)	Quantity sold of refrigerated products per day (kg/L/vial)	28	28	56	7	112
Scenario 4 outcome	Monthly income (INR)	**45,278**	**12,318**	**6,858**	**10,551**	**8,685**
	Income increase	**38.6%**	**35%**	**31.4%**	**34.3%**	**33.1%**
	Loan serviceability	Yes	Yes	Yes	Yes	Yes

Source: Authors' analysis
ǂ Data sourced from DRE end users.

What risks should FIs account for?

Table 30. Risk mitigation and checklist for financing solar-powered small refrigerators

Risks	Mitigation strategy	Checklist for financiers
Gaps in product knowledge hinder effective use and maintenance, reducing the impact of solar-powered small refrigerators.	Technology providers and market accelerators should conduct training programmes for sales agents, technicians, and end users.	• Is there a comprehensive training programme for technicians on the installation, maintenance, and repair of solar-powered refrigerators? • Are there ongoing training opportunities to help keep technicians updated on the latest technologies and troubleshooting techniques? • Are support materials provided to end users for effective product usage?
Sub-optimal utilisation of the solar-powered small refrigerator has direct implications for end users' repayment capacity.	Technology providers or project promoters can help determine the combination of end products (such as dairy and beverages) to be stored together, as well as the potential for value addition, to ensure the asset's utilisation across seasons.	• Is the entrepreneur planning to diversify the refrigerated products they offer? • Is the product combination to be refrigerated chosen based on availability, market value and co-storage suitability in the geographic region where the technology will be deployed?

Case story

Saroj runs a small bakery and soft drinks shop in Uttar Pradesh, offering an assortment of soft drinks, sodas, and water bottles. To enhance her business, extend the shelf life of her products, and address the challenge of frequent power cuts, she sought to buy a solar-powered refrigerator from Devidayal Solar Solutions.

However, as she had limited income, purchasing a 200 L solar-powered refrigerator out of pocket proved difficult. Determined to procure the product, she availed a loan of INR 37,313 from Ashv Finance. With a nominal annual interest rate of 9.33 per cent, which was paid upfront by Devidayal Solar Solutions, and a loan tenure of one year (12 months), Saroj has been able to pay the monthly instalment of INR 3,110. She testifies that had there been no loan facility, she would not have been able to purchase the product and realise a substantial increase in income, emphasising the significance of access to affordable finance.

Saroj displaying her solar refrigerator, which has reduced her monthly electricity bill by INR 500.

Following the adoption of the new technology, she witnessed a tangible improvement in her business operations and reduced her electricity bill by INR 500 every month. Having used the solar refrigerator for nearly three years, Saroj increased her annual income from INR 1,09,500 to INR 1,57,500.

Saroj's story exemplifies the power of accessible financial support in empowering sustainable livelihoods in India. Through strategic investments in RE solutions and tailored loan facilities, individuals like Saroj can enhance their income, drive business growth, and improve their quality of life. This case study serves as a compelling example for financiers and stakeholders, highlighting the viability and impact of initiatives that promote sustainable livelihoods.

3.5 Solar-powered cold storages

Cold storages powered by solar energy are modular devices that offer an efficient and portable solution for minimising food losses by storing perishable food items. By incorporating predictive market analytics for farmers, farmer cooperatives, entrepreneurs, and aggregators, the technology can help farmers/FPOs realise higher revenues.

Solar-powered cold storages support efficient cold-chain management, minimise spoilage, and enable better price realisation for farmers.

Table 31. Overview and investment opportunity for solar-powered cold storages in India

Overview of a typical solar-powered small refrigerator		Investment opportunity
Storage capacity 3–20 MT[29]	**Price** INR 9,00,000[30]–35,00,000[31]	**Market potential** 1,42,000 units[ǂ]
Typical usage 24 hours a day (33 per cent duty cycle) for 333 days per year[ǂ]	**Livelihood-impact potential** 4.3 million (43 lakh)[ǂ]	**Credit opportunity (INR)**[ϟ,32] INR ~ 14,869 crore–29,738 crore[ǂ]
Typical annual incremental income INR 3,19,400[ǂ,33]	**Typical discounted payback period** 59 months[ǂ]	**States and union territories with the highest deployment potential** West Bengal, Bihar, Tamil Nadu, Uttar Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Jammu & Kashmir, Andhra Pradesh[ǂ]
Customer archetype	FPOs, entrepreneurs, farmers, SHGs	
Uptake of solar-powered cold storages can be increased by promoting a community ownership model, with financing provided by SFBs, NBFCs, and banks, with loan terms of more than four years.[ǂ]		

Source: ǂ Data sourced from Jain et al. (2023), ϟ Authors' analysis

29. Metric tonne.
30. For a 3 MT cold storage unit.
31. For a 20 MT cold storage unit.
32. Based on the assumption that 50–100 per cent of the product cost is financed through loans.
33. For 5 MT variant.

Viability of solar-powered cold storages[34]

- The viability of the solar-powered cold storage primarily depends on asset utilisation and the cost-to-price structure, among other parameters.
- The income generated is highly sensitive to capacity utilisation, market arbitrage, and service fees relative to the annual operational days and opportunity costs.
- Most of these parameters vary across the different items stored, which affects income and loan serviceability accordingly.
- The impact of the delineated parameters on the economic and financial viability of the technology is illustrated below through typical scenarios.

Most of these parameters vary across the items refrigerated and affect income earned and loan serviceability accordingly.

1. **Asset utilisation**: The impact of capacity utilisation on the income generated through the use of a solar-powered cold storage is more significant than that of utilisation in terms of produce turnover.
   - **Capacity utilisation**: The capacity utilisation of a solar-powered cold storage system indicates how effectively its storage capacity is being used. It is typically expressed as a percentage of the total available capacity. The higher the quantity of produce stored, the higher the revenue realisation, ceteris paribus. As illustrated in Table 32 (a), a 20 percentage point increase(~25–67 per cent) in capacity utilisation results in a higher-than-proportional increase in income (~27–70 per cent). This underscores the importance of optimising capacity utilisation to enhance profitability.
     - **Farmholding size**: For end users who are farmers, farmholding size is a crucial parameter that determines the viability of solar-powered cold storage systems. Each crop requires a minimum farmholding size to generate the quantity of produce needed for the optimal utilisation of the technology. This means that the farmholding must yield enough produce to justify adopting the technology and ensure its viability. The bundle of crops grown and the quantum of produce generated should, at the very least, match the cold storage system's capacity for optimal utilisation. If the volume of produce available for storage is significantly lower than the system capacity, the solar-powered cold storage unit remains underutilised, reducing its financial viability. For instance, assuming 20 per cent of a farmholding's staple vegetable and apple produce are to be stored in a 10 MT solar-powered cold storage unit, a minimum of ~2.4 acres and ~5.7 acres of farmholding land, respectively, would be required to meet the typical capacity utilisation of the solar-powered cold storage system. **While farmers may not be able to expand their farmholdings, understanding the relationship between their existing farm size, the yield per acre of the bundle of crops grown, and the cold storage's typical capacity utilisation can help them assess whether the technology will be a sustainable investment**. As illustrated in Table 32 (b), when the quantity stored increases from 20 per cent to 40 per cent, the minimum acreage required changes to ~1.2 acres and ~2.9 acres for staple vegetables and apples, respectively.

34. Here, a 40 per cent upfront user contribution is assumed for the 10 MT variant priced at INR 20,94,230. At a loan amount of INR 12,56,538, an interest rate of 16 per cent, and a loan tenure of four years, the EMI comes to INR 35,611.

- **Produce turnover**: Produce turnover in a solar-powered cold storage refers to the number of cycles or batches of produce that move through the storage facility within a specified time frame, here, a year. Produce with a higher annual turnover, such as leafy greens (12 cycles) and flowers (10 cycles), generate a significantly higher monthly income than low-turnover items such as carrots (2 cycles) and lemons (4 cycles). The higher the turnover, the higher the produce inflow and revenue realisation, ceteris paribus. As illustrated in Table 32 (a), a 30 per cent decrease in the produce turnover for the items listed results in a less than proportional decrease in income. However, for low-turnover produce such as carrots, this reduction significantly lowers costs, resulting in a slight increase in income despite the decreased turnover.

Optimising capacity utilisation is essential to enhancing income generation from solar-powered cold storages.

Optimising capacity utilisation is therefore essential to enhancing income generation from solar-powered cold storages. A key factor in maximising the viability of a solar-powered cold storage system is ensuring year-round asset utilisation by bundling various products across seasons.

~84% users of renewable energy powered cold storages report improved price realisation for commodities.

Table 32a. The income generated from the use of a solar-powered cold storage is more sensitive to changes in the capacity utilisation of the asset relative to changes in annual produce turnover

Produce type		Leafy greens	Flowers	Carrots	Apples
Utilisation in terms of asset capacity					
Typical scenario	Capacity utilisation‡	30%	30%	50%	80%
Typical outcome	Monthly income (INR)§	2,07,333	1,38,889	24,556	54,444
	Loan serviceability	Yes	Yes	No	Yes
Scenario 1 (20 percentage point increase from the typical scenario)	Capacity utilisation	50%	50%	70%	100%
	Increase in capacity utilisation	67%	67%	40%	25%
Scenario 1 outcome	Monthly income (INR)	**3,37,500**	**2,27,500**	**33,578**	**69,222**
	Income increase	**68%**	**70%**	**46%**	**27%**
	Loan serviceability	Yes	Yes	**Yes**	Yes
Product types		**Leafy greens**	**Flowers**	**Carrots**	**Lemons**
Utilisation in terms of produce turnover (annual frequency at which the produce flows through the solar-powered cold storage)					
Typical scenario	Annual produce turnover‡	12	10	2	4
Typical outcome	Monthly income (INR)§	2,07,333	1,38,889	24,556	87,444
	Loan serviceability	Yes	Yes	No	Yes
Scenario 2 (30% reduction from the typical scenario)	Annual produce turnover	8	7	1	3
Scenario 2 outcome	Monthly income (INR)§	**1,59,133**	**1,29,889**	**25,161**	**61,989**
	Income change	**–23%**	**–6%**	**2%**	**–29%**
	Loan serviceability	Yes	Yes	No	Yes

Source: Authors' analysis

‡ Data sourced from DRE enterprises.

§ Based on maximum prices at the farmgate post storage (across different geographies).

Table 32b. The income generated from the use of a solar-powered cold storage is dependent on farmholding size and yield per acre for farmer end users

Product types		Staple vegetables	Apples
Typical scenario	Annual average yield per acre (kg)	25,000	7,000
	Quantity of produce stored	20%	20%
	Minimum quantity of produce required (kg)	60,000	40,000
	Minimum farmholding size required (acres)	2.4	5.7
Scenario 3 (20 percentage point increase from the typical scenario)	Quantity of produce stored	40%	40%
	Minimum quantity of produce required (kg)	30,000	20,000
	Minimum farmholding size required (acres)	1.2	2.9
	Difference in acreage	–50%	–49%

Source: Authors' analysis

2. **Cost-to-price structure**: The cost-to-price structure of a solar-powered cold storage system largely depends on the market arbitrage, service fees (in case of cooling-as-a-service), and opportunity costs.

    - Market arbitrage: Market arbitrage in the context of a solar-powered cold storage refers to the strategic practice of profiting from price fluctuations by storing perishable produce during periods of low prices and selling them when prices are higher. Farmgate prices before and after storage determine the profits from market arbitrage for the cold storage user. A higher price differential between the pre-storage and post-storage prices leads to higher incomes, ceteris paribus. For instance, an increase in farmgate prices from the modal to the maximum values (~71–157 per cent) for the items listed in Table 33 results in a higher-than-proportional increase in income (~77–206 per cent), thereby enhancing loan serviceability.

      The profits from market arbitrage for produce stored for longer periods are higher and positively impact income. However, other factors are also at play here–**the storage duration and seasonal availability of produce—**both of which impact income. While the perishability of various crops determines the suitable storage duration (ranging from 10 days for leafy greens to 120 days for apples), the seasonal availability of the produce determines its turnover in the solar-powered cold storage facility.

        - **Short-term storage**: For perishable items with shorter storage durations, such as leafy greens, the shorter the storage duration, the higher the produce turnover (depending on the seasonal availability) and potential immediate revenue. However, this implies fewer opportunities to capitalise on price increases.

        - **Long-term storage**: Longer storage durations can enhance opportunities for market arbitrage if prices rise significantly over time. For example, storing apples or plums for longer can yield higher prices, but total revenue might be affected by reduced produce turnover (due to limited availability across seasons).

There is a trade-off between immediate revenues from higher produce turnover and potential long-term gains from price increases. Longer-term storage can be advantageous if it yields higher market arbitrage, but it requires careful management to avoid reduced short-term revenue. Strategic storage practices—whether short-term for higher turnover or long-term to leverage price differentials—can ensure sustained income throughout the year by tailoring storage decisions to the perishability and seasonal availability of produce.

Table 33. An increase in market arbitrage results in a higher than proportional increase in income from the use of a solar-powered cold storage

Product types		Leafy greens	Staple vegetables	Flowers	Sweet potatoes	Apples
Typical scenario	Storage duration (in months)[‡]	0.33	0.5	0.66	2	3
	Annual produce inflow (in kg)	36,000	12,000	30,000	8,000	8,000
	Market arbitrage (INR per kg)[§]	42	17	30	32	35
Typical outcome	Monthly income (INR)	1,17,333	13,333	63,889	15,778	17,778
	Loan serviceability	Yes	No	Yes	No	No
Scenario 3 (increase from modal to maximum prices)	Market arbitrage (INR per kg)[₰]	72	37	60	67	90
	Increase in market arbitrage	71.4%	117.7%	100%	109.4%	157.1%
Scenario 3 outcome	Monthly income (INR)	**2,07,333**	**33,333**	**1,38,889**	**39,111**	**54,444**
	Income increase	**77%**	**150%**	**117%**	**148%**	**206%**
	Loan serviceability	Yes	No	Yes	**Yes**	**Yes**

Source: Authors' analysis

‡ Data sourced from DRE enterprises.

§ Based on modal prices at the farmgate post storage (across different geographies).

₰ Based on maximum prices at the farmgate post storage (across different geographies).

- **Service fee**: The service fee charged to users of the 'cooling-as-a-service' model[35] determines the income earned by asset owners and, hence, loan serviceability. In the cooling-as-a-service model, the solar-powered cold storage can be purchased by an individual or a group, such as an FPO or an SHG, wherein cooling is provided as a service to users in return for a 'service fee'. The service fee per kilogram per month is higher for produce with shorter storage cycles and vice versa. Consequently, the annual service fee or income generated for the owner of the cold storage unit varies with the type of produce stored. For instance, a 50 per cent increase in the service fee for the items listed in Table 34 results in a proportional increase in income (~50 per cent), thereby enhancing loan serviceability.

35. Such a model can be institutionalised through loan disbursements to groups such as FPOs or SHGs.

Table 34. The income generated by a solar-powered cold storage running on a service-based model is highly sensitive to fluctuations in the service fee

Produce type		Leafy greens	Staple vegetables	Flowers	Potatoes	Apples
Typical scenario	Monthly service fee per kg (INR)ǂ	25	25	8	2.5	2.25
Typical outcome	Monthly income (INR)	75,000	25,000	20,000	3,333	1,500
	Loan serviceability	Yes	No	No	No	No
Scenario 4 (50% increase from the typical scenario)	Monthly service fee per kg (INR)	38	38	12	4	3
Scenario 4 outcome	Monthly income (INR)	**1,12,500**	**37,500**	**30,000**	**5,000**	**2,250**
	Income increase	**50%**	**50%**	**50%**	**50%**	**50%**
	Loan serviceability	Yes	**Yes**	No	No	No

Source: Authors' analysis
ǂ Data sourced from DRE enterprises.

- **Opportunity costs**: Opportunity costs represent the minimum farmgate price the user forgoes by storing the produce instead of selling it immediately. It reflects the cost incurred by the end user when they store produce for sale at a later date, rather than selling it in the market and utilising the proceeds to pay off any production-related loans. As illustrated in Table 35, an increase in opportunity costs results in a greater reduction in income when post-storage prices are at average or modal levels, compared to when products can achieve the maximum possible prices through storage. For instance, a 50 per cent increase in the opportunity costs of storing the items listed in Table 35 results in an income reduction of ~10–56 per cent when post-storage prices are at average values, and approximately 5–18 per cent when post-storage prices are at their maximum value. Striking a balance between the opportunity costs incurred and the potential market arbitrage across various produce types is essential for maintaining the income generated from using solar-powered cold storages.

Table 35. When products achieve their maximum post-storage prices, the adverse impact of increased opportunity costs is low

Produce type		Leafy greens	Staple vegetables	Flowers	Sweet potatoes	Apples
At modal prices						
Typical scenario	Opportunity cost (INR per kg)ǂ	8	3	20	8	30
Typical outcome	Monthly income (INR)	1,17,333	13,333	63,889	15,778	17,778
	Loan serviceability	Yes	No	Yes	No	No
Scenario 5 (50% increase from the typical scenario)	Opportunity cost (INR per kg)	12	5	30	12	45
Scenario 5 outcome	Monthly income (INR)	1,05,333	11,833	38,889	13,111	7,778
	Income reduction	10%	11%	39%	17%	56%
	Loan serviceability	Yes	No	No	No	No
At maximum prices						
Typical scenario	Opportunity cost (INR per kg)ǂ	8	3	20	8	30
Typical outcome	Monthly income (INR)	2,07,333	33,333	1,38,889	39,111	54,444
	Loan serviceability	Yes	No	Yes	Yes	Yes
Scenario 6 (50% increase from the typical scenario)	Opportunity cost (INR per kg)	12	5	30	12	45
Scenario 6 outcome	Monthly income (INR)	1,95,333	31,833	1,13,889	36,444	44,444
	Income reduction	6%	5%	18%	7%	18%
	Loan serviceability	Yes	No	Yes	Yes	Yes

Source: Authors' analysis

ǂ Data sourced from DRE enterprises.

Comparing viability: Single versus multiple use cases

Seasonal production often results in inconsistent cash flows for solar-powered cold storage users, making it challenging for them to service loans. For instance, relying solely on carrots or yams will not generate sufficient income as they are available only during some months of the year. However, as illustrated in Table 36, by diversifying use cases and storing multiple types of produce, including capsicums, carrots, and yams, the cold storage system can be utilised year-round, enabling users to earn higher incomes and ensuring the loan becomes serviceable. Therefore, storing multiple produce types (as per their seasonal availability), instead of relying on a single use case, can generate sufficient cash flow to make a loan serviceable. However, it is essential to account for the varying temperature and moisture needs of different agricultural products when storing them together. Service providers should guide end users on which products have similar temperature and moisture requirements, making them suitable for co-storage.

Table 36. Storing multiple items in a solar-powered cold storage system across seasons can ensure higher incomes

Produce type		Capsicums	Carrots	Yams
Typical scenario	Capacity utilisation‡	30%	50%	20%
	Storage months (per year)	1.5	3	4
Typical outcome	Monthly income (INR)§	46,000	24,556	8,611
	Loan serviceability	Yes	No	No
Multiple use-case scenario	Combined monthly income (INR)		79,167	
	Combined loan serviceability		Yes	

Source: Authors' analysis

‡ Data sourced from DRE enterprises.

§ Based on maximum prices at the farmgate post storage (across different geographies).

What risks should FIs account for?

Table 37. Risk mitigation and checklist for financing solar-powered cold storage systems

Risks	Mitigation strategy	Checklist for financiers
Post-harvest practices like sorting and grading are yet to become the norm.	Technology providers and project promoters should provide handholding support to users to ensure that the quality of the stored crop is maintained until sale through proper sorting and grading.	• Does the technology provider have a detailed plan for providing handholding support to users? • Is the support tailored to the specific crops being stored and their environmental conditions? • Are there training programmes or workshops available for users on proper sorting and grading practices? • Are there SOPs for sorting and grading different types of produce? • Does the technology provider offer continuous monitoring and feedback mechanisms to ensure quality control?
Remote locations pose a greater challenge to ensuring zero wastage post-storage in the event of machinery breakdowns, due to long service and repair turnaround times.	Technology providers and project promoters should offer cluster-based services, maintain an inventory of spares and specific components, and enable remote access to the system to swiftly resolve non-hardware issues.	• Does the technology provider provide cluster-based services to reduce response times in remote locations? • Are spare parts and specific components available for quick repairs? • Are there systems in place for remote monitoring and access to diagnose and resolve technical issues? • Is there a documented process for swiftly addressing and resolving breakdowns? • Are there trained technicians available within reasonable proximity to service remote locations?

Risks	Mitigation strategy	Checklist for financiers
Sub-optimal utilisation of solar-powered cold storage systems has direct implications for end users' repayment capacity.	Technology providers can help determine the combination of end products to be stored together, along with potential value addition, to mitigate the risk of inefficient utilisation.	• Are the end users planning to bundle products for storage? • Are the products bundled based on their availability and market value in the geographic region that the technology will be deployed in? • Are the technology manufacturers/suppliers providing guidance to users on the products that can be effectively co-stored in a specific region based on their varying temperature and moisture requirements?

Source: Authors' analysis

Case story[36]

Farmers associated with Junnar Agro Fed Farmers Producer Company Limited, Pune, cultivate crops such as lemon, capsicum, marigold, chrysanthemum, and other flowers. Due to fluctuating prices for crops like marigold and chrysanthemum, especially during the festive season, they were forced to sell their produce at low prices, limiting their income potential. To address this, the company invested in a Biomass Powered GreenCHILL Refrigeration System with a 20 MT cold storage capacity in November 2022. The technology allowed them to store produce during periods of low demand and release it when market prices were higher, maximising their earnings. By storing flowers for 10 days during peak seasons, farmers could secure prices that were up to three times higher. Additionally, the storage facility is also used for other agricultural commodities to ensure full vehicle loads for market transportation and to effectively manage surplus production.

Two women users storing lemons in a renewable energy-powered cold storage.

36. While the report focuses on solar cold storage systems, the case for biomass-powered cold storage remains equally relevant. Therefore, we have included a case story on the latter to add diversity and broaden the perspective.

To bridge the funding gap for the cold storage system, priced at INR 14.5 lakh, they secured a loan of INR 5 lakh from Samunnati Financial Services at an interest rate of 18 per cent and a loan tenure of 12 months. By effectively leveraging income from cold storage operations and other sources, they repaid the loan in full within the stipulated period.

For FIs, loan evaluation must go beyond quantitative analysis to include considerations such as product durability, access to training, warranties, etc.

This investment significantly increased the farmers' annual income from INR 3.5–4 lakh to INR 5.5–6 lakh. Over two and a half years, the cold storage system has not only led to income growth but also brought greater stability, reducing losses from price fluctuations, enhancing incomes by capitalising on higher market prices, and reducing logistical costs through optimised transportation schedules.

Managing seasonal price fluctuations by storing flowers in a cold storage can help enhance farmer incomes.

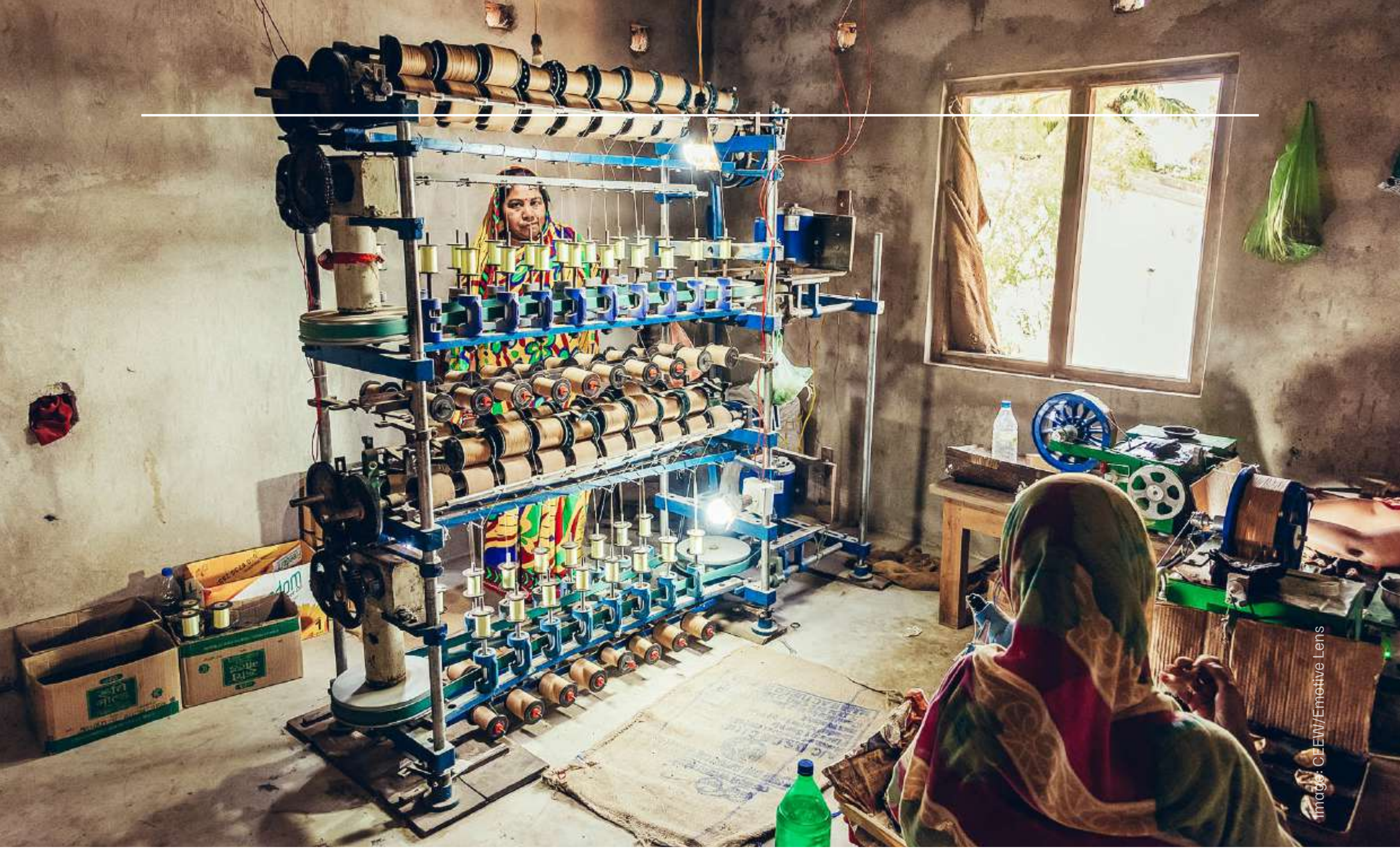


Image: CLEAN/Emotive Lens

4. Catalysing adoption of and financing for DRE livelihood technologies

The adoption and financing of DRE livelihood technologies depend not only on quantitative assessments of financial viability but also on a range of qualitative factors that shape long-term sustainability. These are determined by the dynamic interplay of financial, technical, and behavioural factors. For FIs, loan evaluation must go beyond quantitative analysis to consider qualitative dimensions, including product durability, guidance on optimal utilisation, access to training, after-sales services, and risk-sharing mechanisms such as warranties or buy-back facilities. These dimensions directly influence repayment capacity, reduce technology downtime, and strengthen the loan's overall viability. Equally important are the considerations that end users must assess when adopting DRE solutions and developing their business models. Landholding size, crop types, market demand, operational costs, training needs, and risk preparedness are critical determinants of sustained adoption and profitability. This chapter integrates the perspectives of both financiers and users while outlining pragmatic financing strategies to mitigate risks and unlock access. Together, these insights provide a sector-wide, holistic framework to accelerate the adoption and scale of DRE livelihood technologies.

4.1 Key qualitative considerations for financiers and users to assess DRE livelihood technologies

We outline the key qualitative considerations that should guide the financing and adoption of DRE livelihood technologies. These are essential to ensure reliable performance, sustained usage, and viability. We discuss these considerations separately for FIs, in the context of loan evaluation, and for users, in the context of technology adoption, in Sections (a) and (b), respectively.

a. For financing institutions

What qualitative considerations should guide FIs while evaluating the loan applications of DRE technology users?

The following table summarises key qualitative considerations for FIs when evaluating end users' loan applications for DRE livelihood technologies. These considerations include product durability and optimal asset utilisation, the availability of technical and after-sales support, user training, and warranties or buy-back facilities. Table 38 also provides real-world examples illustrating each point.

Table 38. Key qualitative considerations and examples from the ground to guide FIs' loan-making decisions for DRE livelihood technologies

Guiding qualitative considerations	Examples from the ground
Durability of the product High-performing and durable products minimise maintenance costs and downtime. This ensures consistent operations and reduces the risk of loan defaults due to operational failures.	To ensure durability, the storage chambers of **Cool Crop's** solar-powered cold storage systems feature sealed and locked insulation panels to prevent contamination of the system. Furthermore, their cold storage units can operate over a range of temperatures to store different crops. This can enhance the asset's utilisation by enabling the bundling of a variety of products across any given geography.
Optimal utilisation of the DRE product enhances product effectiveness. This ensures consistent operations and reduces the risk of loan defaults that can arise due to sub-optimal asset utilisation.	**Devidayal Solar Solutions** provides clear guidelines in the form of a do's and don'ts chart to end users to ensure that the solar-powered refrigerator is utilised optimally. Along with guidance on proper temperature maintenance and the prevention of vent blocking and overloading, the enterprise provides end users with guidance on which product combinations to store and which to avoid. For instance, end users are advised against mixing dairy and fruit pulp products with fishery items.

Guiding qualitative considerations	Examples from the ground
Availability of technical support, after-sales support, and grievance redressal mechanisms Reliable technical and after-sales support can ensure prompt issue resolution and sustained product usage, which in turn can enable steady income realisation. The higher the density of a particular DRE technology in a geography, the lower the response time for grievance redressal support.	For **Kissan Dharambir**, service requests raised by users of their micro-horticulture processors are processed by a technical team based in Haryana. For minor repairs, the faulty component is sent to Haryana by the end user, and the repaired version is returned by the enterprise. Complaints are resolved within 1–2 days through video calls. Alternatively, the technician visits the site to resolve the problems on the ground.
Need and availability of user training and provision of on-demand training Capacity building and training are crucial for enhancing user competency and ensuring proper usage and maintenance of the technology. They minimise misuse and maximise product life, thereby improving the likelihood of timely loan repayments.	**Cool Crop's** principal capacity-building method to familiarise users with its solar-powered cold storage systems is training and orientation. The enterprise's handover and training documentation includes an SOP, a temperature and storage guidance chart, warranty terms, and a detailed orientation and mobility training module. Training occurs once after commissioning, followed by two optional refresher modules over the next year. On-demand training is also available to users in the first year following installation of the system. Beyond this, continuous on-call or localised support for the operation, basic upkeep, and monitoring of the system, as well as market linkages, help build confidence and skills within the community.
Provision of warranties or guarantees for the product Warranties provide financial security and assurance to both users and financiers, reducing perceived risk and enhancing the attractiveness of the technology.	**Devidayal Solar Solutions** offers a two-year warranty for all the components of its solar-powered refrigerator, a three-year warranty for the battery, and a ten-year warranty for the solar panels. These warranties cover manufacturing defects and malfunctions under normal use conditions.
Provision of a buy-back facility for the asset or value-added end products Buy-back facilities mitigate market and asset risk for end users and provide assurance to financiers by improving income predictability, safeguarding residual asset value, and strengthening loan repayment confidence.	**Raheja Solar Food Processing** does not offer a buyback mechanism for its solar-powered dryer. However, the enterprise offers a buyback facility for the technology's value-added end products. To tackle the issue of market linkages, the enterprise has identified 15–20 major end products, such as dried tomatoes, bananas, pineapples, etc.

Source: Authors' analysis

b. For potential users

What qualitative considerations should users keep in mind while adopting DRE technologies and developing their business models?

The following table highlights key qualitative considerations that users should assess before adopting DRE livelihood technologies. Going beyond economics, these considerations – ranging from farm size and market demand to costs, training, and service support – help users evaluate whether a technology is economically feasible and sustainable for their context. By considering these aspects, users can strengthen their business models, reduce risks, and enhance long-term viability.

Table 39. Key qualitative considerations to guide users' adoption and business model development decisions for DRE livelihood technologies

Guiding qualitative considerations	Why is it important?	What can the user do?
Minimum farmholding required for viability	To ensure that there is sufficient production for the optimal utilisation of the DRE asset	**Assess land suitability** Evaluate whether the current landholding size is sufficient to generate the required output (e.g. crop yield) to make productive use of the DRE technology. **Choose the right technology size** Based on the land size, select a system of suitable operational scale to avoid under- or over-investment. **Explore collective models** If the landholding is too small, consider pooling resources with nearby farmers or joining a cooperative to jointly utilise DRE assets. **Focus on crop yields** Farmers should choose crops with the highest yield potential per acre, taking into account their region's climatic conditions. For example, they can choose a combination of high-value and high-yielding crops, like mangoes, hibiscus, or bananas, which would boost the DRE system's economic viability.
Understanding product demand and market opportunities	To mitigate risk by ensuring that there is a market for the products users are processing or storing	**Focus on local market needs** Leverage prior experience or speak with local traders to identify which products have high demand, reducing the risk of unsold inventory. **Coordinate with FPOs or SHGs** Work with FPOs and SHGs to leverage collective marketing resources or negotiate better rates.

Guiding qualitative considerations	Why is it important?	What can the user do?
Assessing technology and operational costs	Helps estimate the investment needed and operational costs of the technology	**Compare technologies and suppliers** to find the most cost-effective and reliable options. **Explore government and mainstream financing options**, including subsidies, loans, and group purchasing options, to reduce upfront costs. **Use the financial assessment toolkit** to evaluate monthly affordability.
Profitability of the business	Supports the long-term financial sustainability of the business	**Track costs versus income** Track all costs, including raw materials and processing costs, then set prices that guarantee an adequate profit margin while retaining competitiveness.
Availing training and skill development	To ensure that users can operate and maintain the system, minimising downtime and maximising performance and returns	**Attend training sessions** such as local workshops, seek online resources, or access hands-on training from technology providers or project promoters. **Form peer learning groups** with nearby users to share tips, challenges, and best practices.
Maintenance and after-sales service availability	Ensures sustained usage of the technology with minimal downtime	**Confirm service support** before purchase –ask about local technicians, service timelines, and warranty coverage. **Follow routine maintenance schedules** as advised by the provider to avoid breakdowns. **Choose vendors with a strong local presence** or partnerships for faster response times. **Keep the contact details** of service personnel or helplines handy. **Report issues promptly** and track service requests to ensure timely resolution.
Risk preparedness	Prepares the user and business for any potential risks that could affect the technology's performance (e.g. bad weather)	**Prepare for weather or equipment issues** Have backup options such as batteries or a contingency plan for bad weather. Save a portion of earnings for emergency repairs or weather-related disruptions.

Source: Authors' analysis

4.2 Pragmatic strategies to catalyse end-user financing in the DRE sector

Many of the challenges and risks associated with financing DRE technologies for livelihoods are similar to those of any other technology adoption, lending to micro/nano enterprises and farmers. The following table identifies key challenges/risks and outlines strategies to mitigate them.

Table 40. Flexible repayment terms, variable loan products, and hypothecation of the DRE asset can mitigate the challenges/risks associated with financing end users of DRE livelihood technologies

Challenges/Risks	Mitigation strategies
Cash flow disruptions due to income seasonality, technology breakdowns, and supply chain disruptions	**a. Design flexible repayment structures** Implement repayment schedules and amounts that align with the income cycles of DRE technology users. **b. Adjust terms during disruptions** Offer flexible financing terms such as grace periods, and allow for adjustments in repayment terms in case of supply chain disruptions to help users manage cash flow issues.
Providing a fixed loan product for a DRE livelihood technology without accounting for differences in use cases can increase the risk of default	**a. Design two to three kinds of loan products for various DRE technologies based on use-case categorisation** The same DRE solution can have very different income-generating potential depending upon the use case. Develop loan repayment structures based on the income potential of different use cases. Offer longer tenures and smaller EMIs to users with low-income-generating use cases (e.g. a solar-powered refrigerator in a grocery store) and shorter tenures with larger EMIs to those engaged in higher-income-generating use cases (e.g. solar-powered refrigerator in a fishery).
Lack of collateral among low-income and asset-poor users of DRE livelihood technologies can pose a credit risk	**a. Hypothecation of the DRE asset with a buy-back arrangement with the manufacturer** To enhance the bankability of end users, the DRE technology itself can be treated as collateral. Depending on its condition, the financing institution can recover the asset at a pre-negotiated buy-back rate with the enterprise. **b. Leverage social capital as collateral** Develop lending programmes that rely on social collateral and collective guarantees instead of traditional assets. Explore community guarantees, group lending structures, and lending to FPOs and SHGs to mitigate credit risk.

Source: Authors' analysis

Besides these, some of the potential risks and challenges that financiers should account for include market uncertainties and absent or weak market linkages. Financial interventions such as FLDGs, interest subvention, business correspondents, and pay-as-you-go models have already proven efficacious in enhancing loan serviceability for clean technologies. Such models can be scaled further while exploring other innovative mechanisms to minimise risk of default.

Flexible repayment terms, variable loan products, and hypothecation of the DRE asset can mitigate the challenges/risks associated with financing end users.

4.3 Conclusion

Scaling decentralised renewable energy–based livelihood technologies requires moving beyond grant and subsidy-led deployment towards a financing ecosystem grounded in evidence, confidence, and contextual understanding. By introducing the *DRE Livelihoods Financial Assessment Toolkit* and consolidating technology-specific insights, this report seeks to support financiers in making informed lending decisions and enables stakeholders to better guide end users in adoption and business planning. In doing so, it seeks to strengthen the foundations for commercially viable, inclusive, and sustainable scale-up of DRE-powered livelihoods in India.

Women DRE users report a significant enhancement in their agency to make decisions through the adoption and use of these technologies.

Acronyms

BIRD	Bankers Institute of Rural Development
CAPEX	capital expenditure
CEEW	Council on Energy, Environment and Water
DRE	decentralised renewable energy
EMI	equated monthly instalment
FI	financing institution
FLDG	first loss default guarantee
FPO	farmer producer organisation
GST	Goods and Services Tax
INR	Indian Rupee
kg	kilogram(s)
KVK	Krishi Vigyan Kendra
L	litre(s)
MFI	microfinance institution
MSME	micro, small and medium enterprises
MT	metric tonne(s)
NABARD	National Bank for Agriculture and Rural Development
NBFC	non-banking financial companies
NGO	non-governmental organisation
NIBM	National Institute of Bank Management
OPEX	operating expenses
POC	point of contact
SFB	small finance bank
SHG	self-help group
SOP	standard operating procedure
SRLM	State Rural Livelihood Mission
UV	ultraviolet
VLE	village-level entrepreneur

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