Decentralised Renewable Energy Technologies for Sustainable Livelihoods

Market, Viability, and Impact Potential in India

Abhishek Jain, Wase Khalid, and Shruti Jindal

Report | May 2023

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Publications team: Kartikeya Jain (CEEW); Alina Sen (CEEW); The Clean Copy; MADRE Designs; and FRIENDS Digital Colour Solutions.

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Council on Energy, Environment and Water (CEEW)
ISID Campus, 4 Vasant Kunj Institutional Area,
New Delhi – 110070, India
T: +91 (0) 11 4073 3300
info@ceew.in | ceew.in | @CEEWIndia | ceewindia

Villgro Innovations Foundation
3rd Floor, IIT Madras Research Park, Kanagam Road, Taramani,
(Behind Tidel Park, on Old Mahabalipuram Road),
Chennai – 600113
T: +91 (0) 44 4005 7410
info@villgro.org | villgro.org | @Villgro

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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.

The scale of these deployments is large enough to demonstrate the commercial viability and make the key stakeholders take notice. By collecting and disseminating the evidence on enterprises' commercial growth, the economic viability of the products for end-users, their cash-flows, etc., in a standardised way, the programme unlocks enterprise investments, end-user financing, and a conducive policy environment to enable sectoral growth.

Small solar refrigerators, solar-powered small horticulture processors, solar-powered silk reeling machines, solar-powered cold storage, solar dryers, etc., are some of the technologies we support under the programme.

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Rajasthan Grameen Aajeevika Vikas Parishad (Rajeevika) is providing end-user financing support in Rajasthan. This has allowed for women to purchase a DRE refrigerator using a 50% subsidy and 50% credit support from Rajeevika in the first two months of the support programme.

Image: CEEW/EmotiveLens

Executive summary

India needs to generate 90 million jobs by 2030 (Sankhe et al. 2020). Simultaneously, it needs to rapidly transition its economy to a low-carbon and resilient one, in line with the national commitments on climate action. While deploying large-scale renewables and transitioning to green hydrogen will create more jobs, these will not be sufficient to productively engage the more-than-a-million additional youth reaching employable age every month (Mallapur 2018). We need much more entrepreneurship, livelihood opportunities, and jobs that are economically rewarding, environmentally sustainable, and socially equitable.

The Government of India has released a dedicated policy framework to promote DRE livelihood technologies

A. Why should India promote decentralised renewable energy (DRE) livelihood technologies?

One solution to increase livelihood opportunities is to power microenterprises across India through clean energy. Energy-efficient technologies powered by decentralised renewables can help enhance the incomes and resilience of many of India's more than 60 million microenterprises while fostering climate action (MoMSME 2022). Recognising the unique opportunity that such DRE–based livelihood technologies pose, the Ministry of New and Renewable Energy, Government of India, released a dedicated policy framework titled *Framework for Promotion of Decentralised Renewable Energy Livelihood Applications* (MNRE 2022).

In recent years, many livelihood technologies have emerged that are highly energy efficient and designed to run with DRE sources, from solar-powered looms and charkhas to solar-powered cold storages, solar dryers, and solar-powered vertical fodder grow units (SELCO 2021). While many of these technologies are already being sold commercially, some are being supported via grants and philanthropy to enable adoption among end customers. Others are in development or being tested under technical pilots. Based on our mapping of these technologies, Table ES1 presents the broad landscape of DRE livelihood technologies in the country. The aim is not to be exhaustive but to indicate the broad spectrum of technologies and their commercial maturity.

Box 1 Why DRE-livelihood technologies are beyond merely solarising the off-the-shelf livelihood equipment?

Stakeholders often ask why DRE livelihood technologies are referred to as a unique technology category, why can't we just add solar (and battery) to off-the-shelf livelihood technologies that are otherwise meant to run on the grid – be it a milling machine, oil expeller, or anything else. Waray et al. (2018) explain that **most of the existing off-the-self livelihood technologies are not energy-efficient, as they are designed to run with a grid supply that is often subsidised – creating limited incentives for customers to demand energy-efficient solutions.** Moreover, these technologies are often over-designed to take care of the unreliable supply – enabling a day's worth of throughput in a few hours when electricity is available. **Both the poor efficiency and over-designing mean that the prevailing technologies need much bigger solar systems or battery back-ups to run them effectively. It significantly adds to the overall cost of the solution, often making it economically unviable.** Only in instances where the existing off-the-shelf equipment is energy efficient, directly solarising them is economically viable. Such existing technologies are limited, and hence innovators have been focusing on developing highly-efficient DRE-compatible solutions that could be economically viable.

Source: Authors' Analysis

Table ES1 Few DRE livelihood technologies have scaled to reach thousands of users.

Deployment scale of DRE livelihood technologies				
Less than 50	**51-100**	**In '00s**	**In '000s**	**In '00,000s**
Carpentry machineries (wood lathe machine, power drill, side-planer)	Animal repeller	Blacksmith machineries (fan-blower, power hammer, angle-grinder)	Charkha	Water pump
Integrated energy centres	Bulk milk-chiller	Cold storage	Dryer	
Oil extractor	Butter churner	Food processors	Poultry machineries (incubators, lighting, brooders)	
Puffed rice processor	Grain-milling machine	Milking machinery	Silk-reeling machine	
Vaccine freezer	Loom	Pottery machineries (pottery wheel, blunger, pugmill)	Sewing machine	
		Small refrigerator		
		Sugarcane Juicer		
		Vertical fodder grow unit		

Source: Authors' compilation

Image: CEEW

Maitree Mahila Mandal Samiti, a dairy and agriculture producer company (PC), employs over 8,000 rural women from Dooni village in Rajasthan. The purchase of solar refrigerators gave them a consistent electricity supply, which helped increase the shelf life of dairy and other perishable products as well as save on electricity bills.

B. What do stakeholders ask about DRE livelihood technologies?

As a rapidly evolving sector that is still in its early stages, stakeholders who are trying to engage, support, or promote these DRE livelihood technologies – including policymakers, bankers, financiers, donor, enterprises, incubators, and development sector professionals – are often confronted with the following questions:

There are many DRE livelihood technologies out there. Across different contexts, which technologies should we support and why?	**Are these DRE livelihood technologies economically viable? Are they worth financing? How long is their payback period?**	**Should DRE technologies be promoted when/ where there is reliable grid supply?**	**Which technologies are relevant in my state or region?**

Our report answers these questions. In the process, we propose a framework that can help us navigate the DRE livelihoods landscape, even as technologies and markets evolve over time.

C. How are we answering the key questions to help stakeholders navigate the DRE technologies landscape?

To answer these emerging questions, we use an **impact-feasibility framework.**

Impact

We define impact as the **number of livelihoods a DRE livelihood technology can positively impact in a given region**. In some ways, it pertains to the '**scale of impact**'.

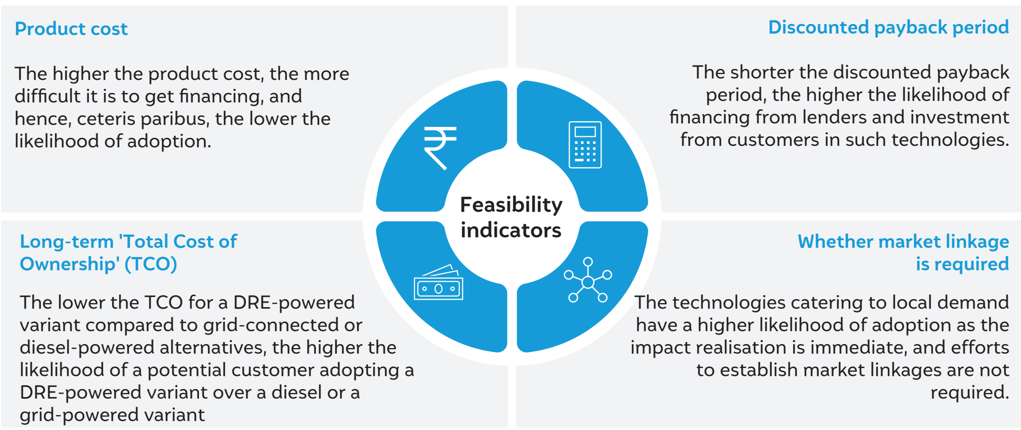
Feasibility

We define feasibility as **the likelihood of realising the impact**. It is essentially a measure of how feasible it is to realise the impact that the DRE livelihood technology promises. We assess feasibility through a combination of indicators.

Based on this framework, we undertook a comparative assessment of the DRE livelihood technologies that have achieved commercial maturity (in the agriculture and textile sectors). The findings around these 12 commercially-mature technologies are discussed below.

The 12 mature DRE livelihood technologies collectively have the potential to impact 37 million livelihoods

Figure ES1 Feasibility assessment indicators



Source: Authors' compilation

D. Key findings

Impact potential of different DRE livelihood technologies

The twelve mature DRE livelihood technologies collectively have the potential to impact **37 million livelihoods** This livelihood impact potential translates into a revenue opportunity worth **USD 48 billion** for enterprises deploying and commercialising such technologies. The number of current deployments of these technologies and associative livelihood impact are also summarised in the Table ES2.

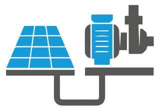
Table ES2 **The 12 mature DRE livelihood technologies have already impacted more than 566,000 livelihoods across India**

DRE-powered technology	Existing installations (numbers)	Estimated livelihood impacted
Higher capacity pump	520,000	520,000
Silk-reeling machine	14,000	14,000
Dryer	8,000	16,000
Charkha	2,000	2,000
Micro pump	1,500	1,500
Small horticulture processor	600	1,200
Small refrigerator/deep freezer	500	500
Cold storage	350	10,500
Vertical fodder grow unit	210	737
Grain-milling machine	100	200
Loom	70	140
Bulk milk chiller	50	50
Total	**547,380**	**566,827**

Source: Authors' compilation

Solar-powered pumps—higher capacity and micro-pumps— have the maximum deployment potential, followed by solar-powered vertical fodder growing units and solar dryers. Collectively, these four technologies alone can impact around 27 million livelihoods. Unsurprisingly, solar pumps are the most mature among these technologies due to the government subsidy programmes supporting them since 2015. We summarise the estimated livelihood potential of each such technology in Table ES3.

The DRE livelihood technologies have the greatest impact opportunity in Uttar Pradesh, the state with the highest population in the country. It is followed by West Bengal, Bihar, Gujarat, Maharashtra, Madhya Pradesh, and Karnataka. Table ES4 shows the distribution of market potential and livelihood impact potential among Indian states.



Solar-powered pumps have the maximum deployment potential, followed by solar-powered vertical fodder growing units and solar dryers

Table ES3 **The 12 mature DRE livelihood technologies have the potential to impact 37 million livelihoods across India**

DRE livelihood technology	# of livelihoods that can be impacted (in million)	Market potential (in billion USD)
Vertical fodder grow unit	11.9	1.8
Higher capacity pump	8.2	26
Cold storage	4.3	2.5
Micro pump	3.4	2.0
Dryer	3.4	2.3
Grain milling	1.9	8.7
Loom	1.2	1.2
Small refrigerator/deep freezer	1.2	1.5
Small horticulture processors	1.1	0.8
Charkha	0.4	0.2
Bulk milk chiller	0.1	0.8
Silk reeling machines	0.1	0.03
Total	**37**	**48**

Source: Authors' compilation

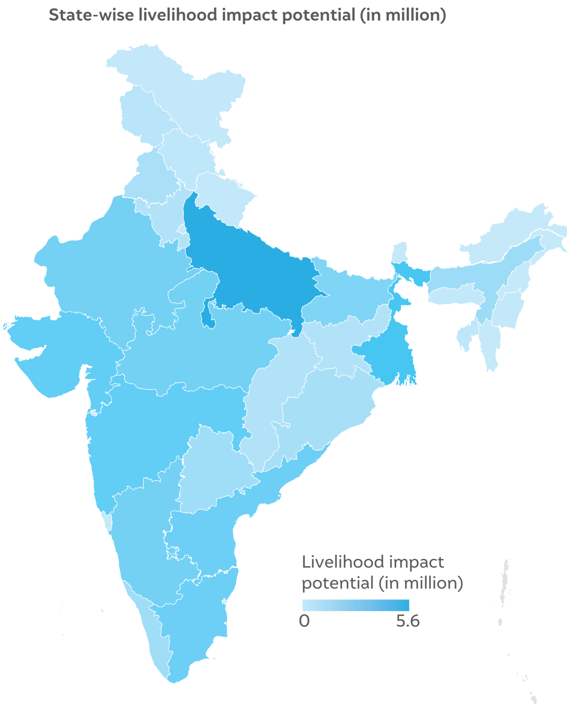
Table ES4 **State-wise distribution of market and impact potential**

State	No. of livelihoods that can be impacted	Market potential	
		in INR crore	in USD million
A & N Islands	12,056	158	20
Andhra Pradesh	2,453,414	18,217	2,306
Arunachal Pradesh	21,462	362	46
Assam	1,235,600	18,346	2,322
Bihar	1,997,070	20,012	2,533
Chandigarh	4,618	15	2
Chhattisgarh	590,388	10,655	1,349
Dadra and Nagar Haveli	1,083	20	3
Daman and Diu	1,808	15	2
Delhi	41,932	532	67
Goa	35,748	377	48
Gujarat	2,825,884	34,413	4,356
Haryana	630,906	3,555	450
Himachal Pradesh	173,229	1,921	243
Jammu & Kashmir	433,207	3,519	445
Jharkhand	569,507	7,352	931
Karnataka	2,267,444	14,113	1,786
Kerala	1,054,177	6,535	827
Lakshadweep	856	14	2
Madhya Pradesh	2,409,300	38,367	4,857
Maharashtra	2,803,541	30,751	3,893
Manipur	110,469	1,306	165
Meghalaya	63,304	603	76
Mizoram	28,318	350	44
Nagaland	47,685	806	102
Odisha	884,670	14,471	1,832
Puducherry	8,010	80	10
Punjab	832,594	6,036	764
Rajasthan	2,339,375	18,928	2,396
Sikkim	10,251	108	14
Tamil Nadu	2,464,889	15,331	1,941
Telangana	1,115,238	6,639	840
Tripura	183,359	1,697	215
Uttar Pradesh	5,587,759	68,113	8,622
Uttarakhand	143,557	2,141	271
West Bengal	3,735,555	32,719	4,142
Total	**37,118,260**	**378,576**	**47,921**

Source: Authors' compilation

Additionally, the relative market for each DRE livelihood technology varies across states. For example, micro solar pumps have the highest market in West Bengal, whereas solar dryers have the highest market in Maharashtra. The relative impact potential of these DRE livelihood technologies across Indian states is shown in Figure ES2.

Figure ES2 Uttar Pradesh has the greatest impact opportunity for DRE livelihood technologies



Source: Authors' compilation

Note: State-wise market potential estimates for DRE livelihood technologies is available here

Image: CEEW

Shivraj Singh Chouhan from Kanpur Dehat, Uttar Pradesh, earns a monthly income of INR 5 lakh through drying flowers using solar dryers. He sources flowers from more than 100 farmers to dry them in solar dryers.

Costlier DRE livelihood technologies have longer payback periods except solar-powered looms and small horticulture processors

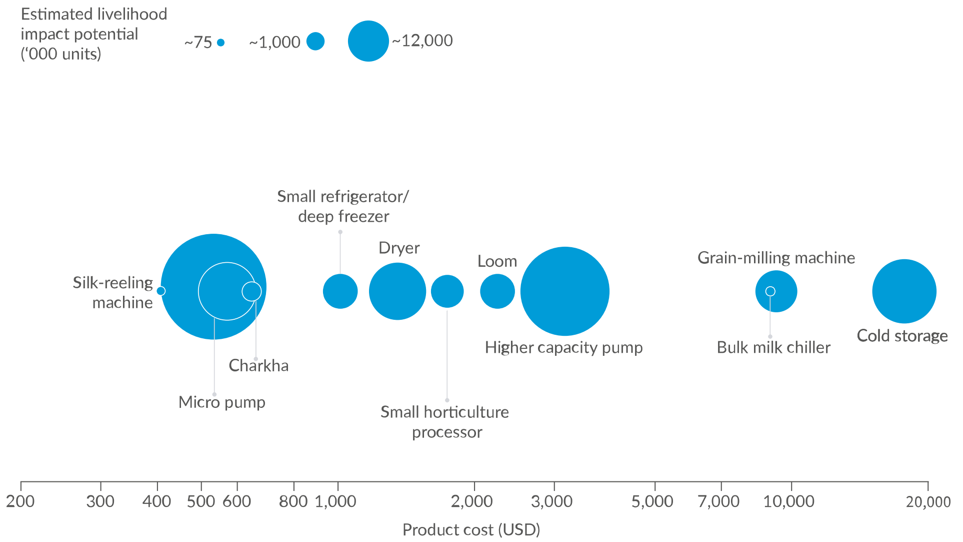
Feasibility of impact realisation

Next, we add our feasibility indicators to the impact potential to understand the relative ease of enabling the adoption of such technologies among potential customers. First, we plot the livelihood impact potential against the typical product cost[1] (Figure ES3). Please note that the product-cost axis is in the log scale and that we are considering the product costs of the most

1 For the cost and analysis of grain-milling machines, we only consider rice-milling machines. Going forward, we plan to expand our analysis to include other grain-milling machines.

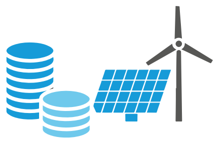
popular variants of these technologies. Of course, the product costs vary across product capacities and different manufacturers, but the broader order of magnitude and the relative cost trends among technologies remain, as shown in Figure ES3. Products on the left end of the spectrum, such as solar-powered silk-reeling machines and micro solar pumps, would have a relatively higher likelihood of adoption than those on the other end, such as solar-powered bulk milk chillers and solar-powered cold storages. We understand this is a broad generalisation, and there could be several exceptions; we add nuances as we proceed further in the discussion.

Figure ES3 DRE livelihood technologies cost between INR 25,000 - INR 1,400,000



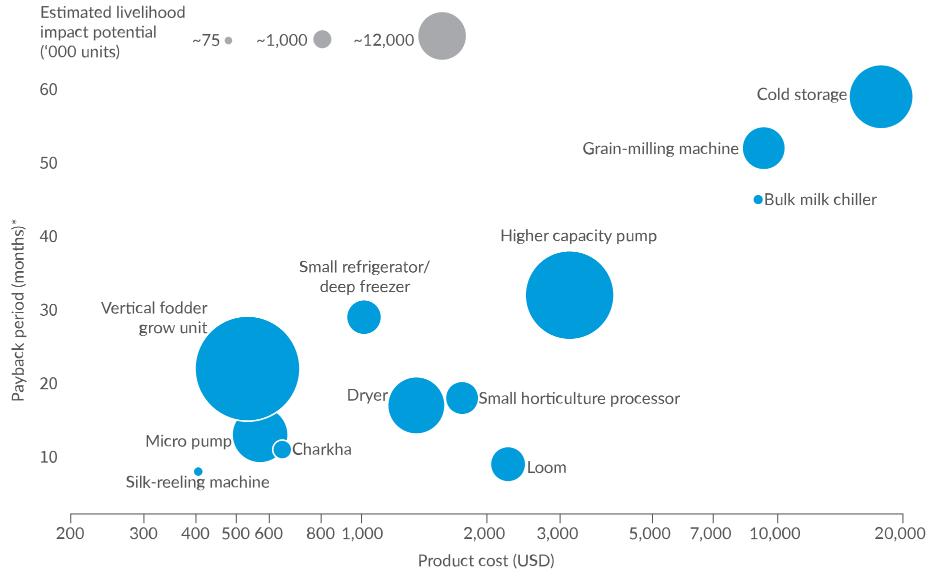
Source: Authors' compilation

Next, on the same plot, we add another dimension to assess the feasibility aspect – the typical discounted payback periods of the respective DRE livelihood technologies. The relative location of each technology bubble along the Y-axis is now determined by its typical discounted payback period, as shown in Figure ES4. The products lower on the Y-axis, i.e., having shorter discounted payback periods, are more likely to find traction among the end-users and financiers. We also observe a broad positive association between the product's unit cost and the discounted payback period. Costlier DRE livelihood technologies have longer payback periods. However, there are notable exceptions, such as solar-powered looms and solar-powered small horticulture processors. It is worth noting that the payback periods are estimated based on the typical (median) reported income increase by the end-users of these technologies through impact assessment surveys and customer interviews conducted by CEEW. The income increase itself has significant variation based on the context of use. For instance, solar-powered cold storage used to store potatoes would generate a very different income profile than one used to store high-value commodities such as lemons. So, the payback periods are indicative and used to broadly understand the relative trends across technologies.



Over a 15-year investment horizon, the DRE variants become more attractive than their grid alternatives

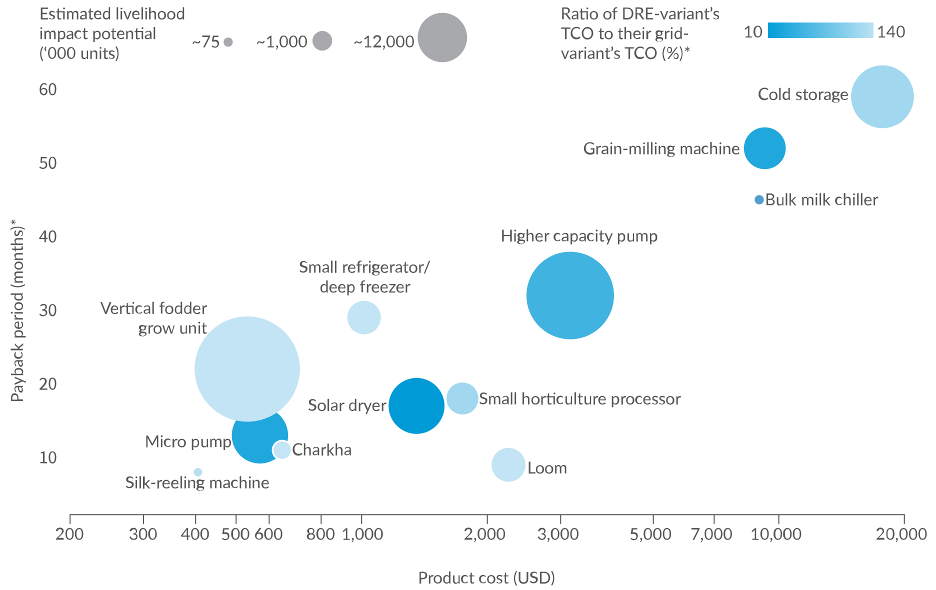
Figure ES4 **Technologies with shorter payback periods may find more traction among users and financiers**



Source: Authors' compilation

Next, we add another feasibility dimension to the same plot: the TCO for ten years of operations compared to grid alternative[2], represented by the colour of the bubbles in Figure ES5. The darker the bubble's shade, the lower the long-term cost of the DRE variant compared to the grid alternative. It indicates that DRE livelihood technologies such as solar dryers, and solar-powered looms are highly attractive economically, even in areas with reliable grid supply. By contrast, for technologies such as small solar refrigerators, solar-powered horticulture processors, or solar-powered cold storages, their DRE variant saves costs only marginally over a 10-year period as compared to their grid alternative. However, over a 15-year investment horizon, the DRE variants of such technologies become much more attractive than their grid alternatives. So, if an end user is considering a business horizon of 10+ years, the DRE livelihood technologies could be economically more attractive, even if the grid is reliable.

Figure ES5 **Solar dryers, fodder-growing units, and looms are highly economically attractive than their grid variants**

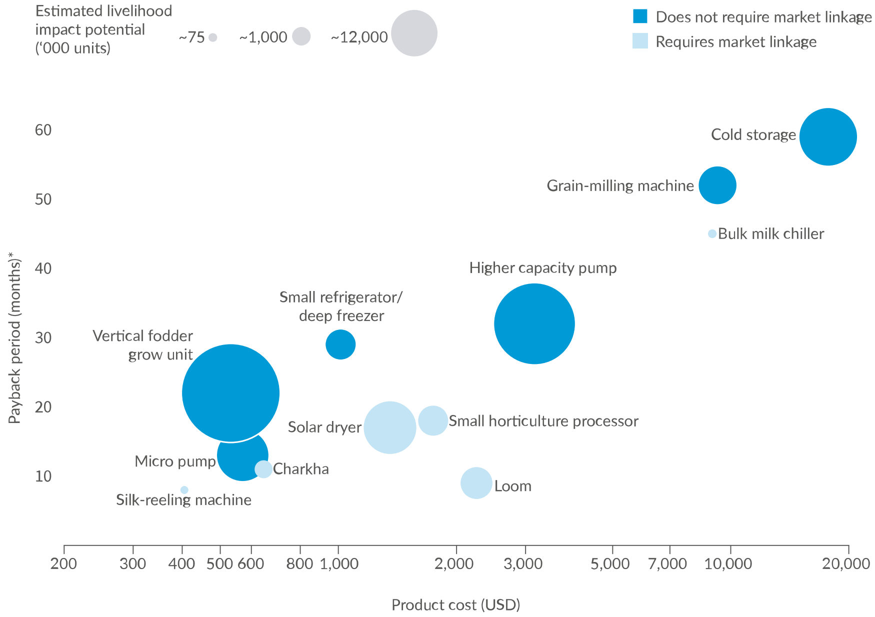


Source: Authors' compilation

2 Except in the case of pumps, where we compare the DRE variant with the diesel alternative.

Finally, instead of colouring the bubbles with the comparative costs of the grid alternatives, we colour the bubbles based on whether the DRE livelihood technologies need an explicit market linkage to be viable. As shown in Figure ES6, the products with the darker shade (i.e., which do not need a market linkage) would have lower barriers to adoption, *ceteris paribus*.

Figure ES6 DRE livelihood technologies for local demands may experience better adoption

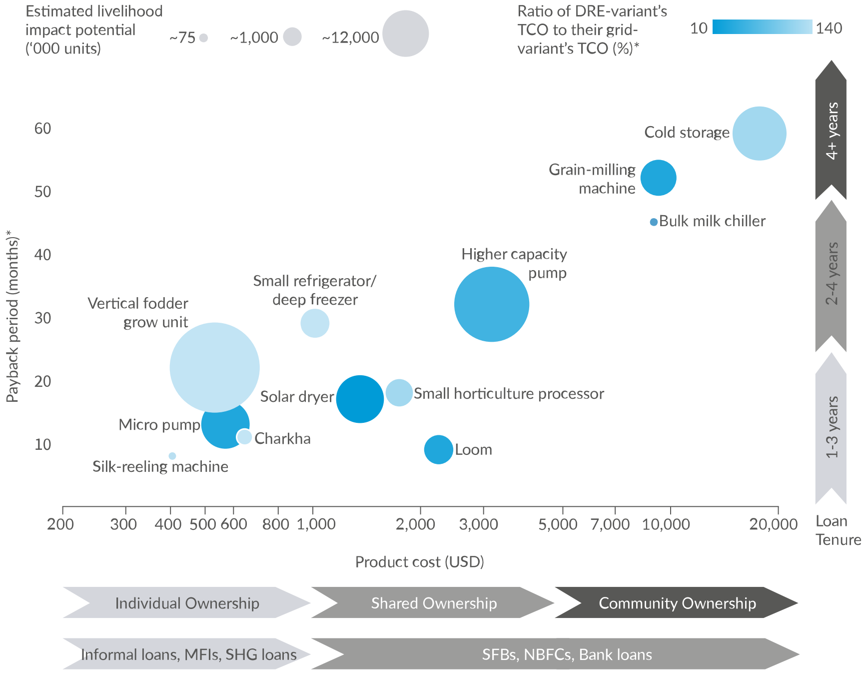


Source: Authors' compilation

Image: CEEW/Emotive Lens

Kuni Dehury from Keonjhar, Odisha has enhanced here monthly income from INR 1,500 to 6,000 using solar-powered silk reeling machines. Additionally, she has trained more than 500 women on using solar-powered silk reeling machines.

Figure ES7 **The product cost and payback period can help guide ownership models, source of financing, and loan tenures**



Source: Authors' compilation

Guiding the business, financing and stakeholder engagement models

Apart from identifying technologies with high impact potential and feasibility, the impact-feasibility framework also helps to strategise the business, financing, and stakeholder-engagement models for these DRE livelihood technologies. For instance, as shown in Figure ES7, as the value of the products increases, the ownership model for these technologies would likely shift from individual users to community/farmer groups. Similarly, the financiers for such technologies would change from Microfinance institutions (MFIs) and Small Finance Banks (SFBs) on the left end of the spectrum to larger Non-Banking Financial Companies (NBFCs) and banks on the right. Similarly, the location of these bubbles on the Y-axis (i.e., the typical discounted-payback periods) can help financiers devise relevant financial products with appropriate loan tenures to match the typical payback periods, as the technologies move up the Y-axis, longer tenure loans are needed to make the financing viable.

E. A final note on impact feasibility (i.e., economic viability)

The analysis and key findings that emerge would generally help sector stakeholders make more informed decisions about which products to support in different contexts. They would also help the stakeholders appreciate the relative impact potential and the feasibility of the various DRE livelihood technologies. However, it is important to reiterate that this broad sector-wide analysis does not conclude the viability of each individual installation in its particular context. The factors that would play an important role in determining the context-specific viability of these technologies are:

- **The utilisation of the asset**, i.e., the number of hours a year for which the DRE livelihood technologies are used. For example, a solar pump is generally much more economically attractive than a diesel pump, but if a pump would only be used for 20 days a year, then a diesel pump – despite its very-high running costs – would be economically more attractive than a solar pump.

DRE livelihoods technologies presents a market opportunity of ~USD 50 billion

- **The value of the commodity being processed/stored in these technologies:** What is being stored in a biomass-powered cold storage or what is being processed in a solar-powered horticulture processor will strongly influence the income the end user could generate from it. For instance, processing aloe vera and mangoes to create value-added products would generate higher income than processing tomatoes and carrots.
- **The investment/business horizon of the end user/microenterprise:** those with longer investment horizons would find DRE livelihood technologies to be more economically attractive compared to grid alternatives.
- **For some technologies, the prevailing and future reliability of the grid.** For certain technologies (as discussed prior), DRE variants may not be as economically attractive if the grid is highly reliable in an area.

The results of the scenario/sensitivity analysis around these factors for each of the twelve mature DRE livelihood technologies are discussed in the section below. It may help stakeholders make more informed choices based on the specific contexts in which they plan to support the deployment of DRE livelihood technologies.

F. Conclusion

DRE livelihood technologies provide a significant opportunity to impact tens of millions of livelihoods across the country. Sector stakeholders – policymakers, financiers, investors, technology distributors, and manufacturers – must extend context-specific support to mainstream DRE livelihoods while appreciating the relative impact potential and the factors guiding the financing, business, and stakeholder-engagement models.

To access the detailed analysis, please scan the following QR code

or visit https://www.ceew.in/publications/decentralised-renewable-energy-technologies-for-sustainable-livelihoods-india

1. Higher capacity solar pumps

Higher capacity solar pumps (which are 2 hp and above) can provide irrigation facilities for non-marginal farmers with land holdings of more than 2 acres.

They are available in capacities ranging from 2–7 hp. The cost of a solar-powered 5 hp water pump is INR 2,50,000 (USD 3,165).[1]

Image: iStock

Economics of a typical* higher capacity solar pump

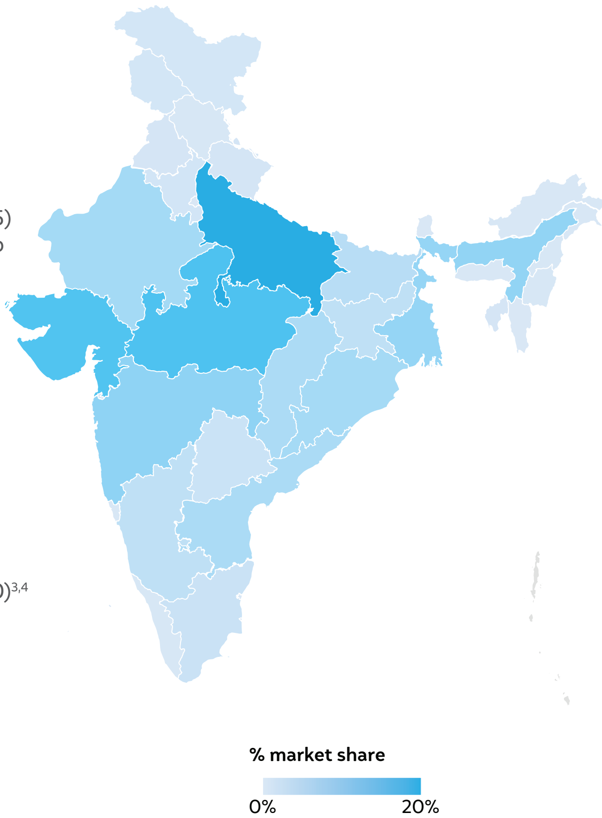
Cost
INR 2,50,000 (USD 3,165) for a 5 hp capacity pump

Typical usage
1,280[#] hours annually[4]

Incremental annual income
INR 1,02,000 (USD 1,290)[3,4]

Discounted payback period[†]
32 months[3]

State-wise distribution of market potential



Market overview

~5,20,000
products installed in 26 states[2]

8,195,000
units is the market potential[3]

8.2 million
livelihoods can be impacted[3]

Source: Authors' analysis

The incremental income and associated payback period are based on the average or median values. Incremental income through higher capacity solar pumps varies from INR 72,000 to INR 1,56,000, depending on savings in fuel costs and an increase in the number of cropping cycles and cropped area. Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of higher capacity pump variants

Equipment cost (INR)	DRE-powered[‡]	Grid-connected[§]	Diesel-powered[§]
5 hp capacity pump	80,000	46,800	30,000
Solar PV unit (including battery backup)	170,985	-	-
Total capex	**250,985**	**46,800**	**30,000**

Source: Authors' analysis

‡ The power rating of the 5 hp DRE-powered pump is 3.75 kW. Details considered are sourced from the manufacturers.

§ A 5 hp electric and diesel pump has a typical power rating of 3.75 kW. Details listed are as indicated on IndiaMART (last accessed in August 2022).

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for ten years with 1,280 hours of annual usage is

1.6x higher than a grid-connected product

2.1x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO[††] of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Reliable electricity			
		5	10	15	20	5	10	15	20
Annual usage (hours)	DRE variant: 640; non-DRE variant: 400	144%	90%	73%	65%	322%	241%	210%	195%
	DRE variant: 960 ; non-DRE variant: 600	96%	62%	50%	45%	252%	191%	163%	150%
	DRE variant: 1280; non-DRE variant: 800	74%	48%	38%	34%	216%	159%	134%	122%

DRE-powered | Grid-connected | Diesel-powered

Source: Authors' analysis

The comparative analysis of TCO shows that the DRE variant is financially more attractive than the other product variant in regions with no or erratic electricity. Grid-connected variant is financially preferable in regions with reliable electricity.

1280 hours of annual operation of the DRE variant is equivalent to 800 hours of annual operation of the non-DRE variants.
* For the most popular variant, as quoted by the appliance manufacturers.
† At an incremental annual income of INR 1,02,000 (USD 1,290), USD 1 = INR 79.
†† We use the Net Present Value of TCO across all analyses
1 As per the quotations shared by higher capacity solar pump manufacturers.
2 Stakeholder consultation.
3 Authors' analysis.
4 Based on the consultations with higher capacity solar pump manufacturers and users.

2. Micro solar pumps

Sub-hp or micro solar pumps provide irrigation access to marginal farmers (with 1–2 acres of land).

They are available from 0.1-hp capacity to 0.75-hp capacity, with a daily water output capacity ranging from 5,000 litres to 30,000 litres. The cost of a micro solar pump (of around 0.5-hp capacity) with an output of 20,000 litres per day is ~INR 45,000 (USD 570).[1]

Image: CEEW

Economics of a typical* micro solar pump

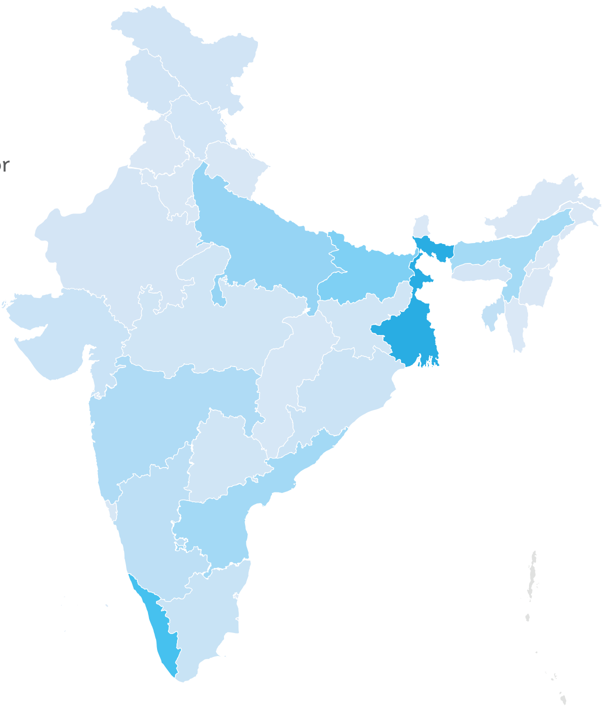
Cost
INR 45,000 (USD 570) for a 0.5 hp capacity pump

Typical usage
1,280[#] hours annually[4]

Incremental annual income
INR 45,000 (USD 570)[4,5]

Discounted payback period[†]
13 months[5]

State-wise distribution of market potential



Market overview

~1500
products installed in 9 states[2]

3,425,000
units is the market potential[3]

3.4 million
livelihoods can be impacted[3]

Source: Authors' analysis

The incremental income and associated payback period are based on the average or median values. Incremental income through micro solar pumps varies from INR 30,000 to INR 55,000, depending on savings in fuel costs and an increase in the number of cropping cycles and cropped area. Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of micro pump variants

Equipment cost (INR)	DRE-powered[§]	Grid-connected[§§]	Diesel-powered[§§]
0.5[‡] hp capacity pump	31,000	10,740	26,000
Solar PV unit (including battery backup)	14,000	-	-
Total Capex	**45,000**	**10,740**	**26,000**

Source: Authors' analysis

‡ A 2 hp diesel pump has been considered for comparison with the 0.5 hp DRE-powered and electric pumps.

§ The power rating of the 0.5 hp DRE-powered and grid-connected product is 0.375 kW. Details considered are sourced from the manufacturers for the DREpowered product, and from IndiaMART for grid-connected product.

§§ A 2 hp diesel pump has a typical power rating of 1.4 kW. Details listed are as indicated on IndiaMART (last accessed in August 2022).

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for 10 years with 1,280 hours of annual usage is

2.1x higher than a grid-connected product

5.5x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO[††] of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Reliable electricity			
		5	10	15	20	5	10	15	20
Annual usage (hours)	DRE variant: 640; non-DRE variant: 400	48%	33%	27%	25%	322%	272%	250%	238%
	DRE variant: 960 ; non-DRE variant: 600	34%	23%	19%	17%	279%	235%	211%	199%
	DRE variant: 1280; non-DRE variant: 800	27%	18%	15%	13%	253%	206%	183%	172%

DRE-powered | Grid-connected | Diesel-powered

Source: Authors' analysis

The comparative analysis of TCO shows that the DRE variant is financially more attractive than the other product variant in regions with no or erratic electricity. Grid-connected variant is financially preferable in regions with reliable electricity.

* For the most popular variant, as quoted by the appliance manufacturers.
# 1280 hours of annual operation of the DRE variant is equivalent to 800 hours of annual operation of the non-DRE variants.
† At an incremental annual income of INR 45,000 (USD 570), USD 1 = INR 79.
†† We use the Net Present Value of TCO across all analyses.
1 As per the quotations shared by micro solar pump manufacturers.
2 As reported by the micro solar pump manufacturers.
3 Khalid, Wase, Abhishek Jain, Shruti Jindal and Arpan Thacker. 2022. Mainstreaming Micro Solar Pumps to Improve Incomes of Marginal Farmers. New Delhi: Council on Energy, Environment and Water.
4 Based on the consultations with micro solar pump manufacturers and users.
5 Authors' analysis.

3. Small solar refrigerators (or deep freezers)

Small solar refrigerators (or deep freezers) are energy efficient and can be used to store processed food, dairy products, fishery products, beverages, and vaccines.

They are available in storage capacities ranging from 100 litres at INR 80,000 (USD 1,013) to 250 litres at INR 145,000 (USD 1,835).[1]

Image: CEEW

Economics of a typical* small solar refrigerator

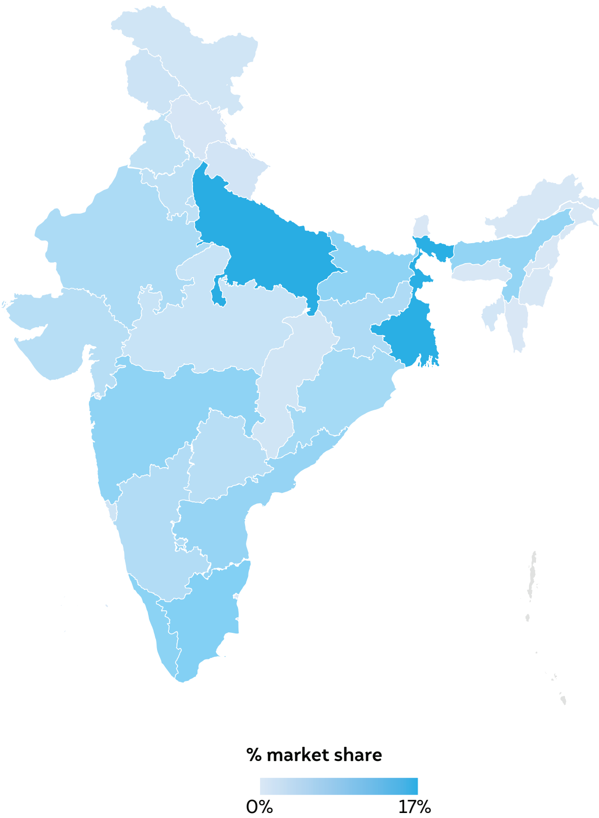
Cost
INR 80,000 (USD 1,013) for 100 litres storage capacity deep freezers.

Typical usage
24-hours per day (60 per cent duty cycle) for ~330 days/year[4]

Incremental annual income
INR 35,000 (USD 443)[3,4]

Discounted payback period†
29 months[3]

State-wise distribution of market potential



Market overview

~500
products installed in 14 states[2]

1,232,000
units is the market potential[3]

1.23 million
livelihoods can be impacted[3]

Source: Authors' analysis

The incremental income and associated payback period are based on the average or median values. A user can annually earn anywhere between INR 27,500 for bakery or retail to INR 71,500 for fishery. Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of small refrigerator variants

Equipment cost (INR)	DRE-powered[‡]	Grid-connected[§]	Grid-connected with 4-hour backup[§]	Diesel-powered[§]
100-litre storage capacity refrigerator (or deep freezer)	38,864	18,500	18,500	18,500
Solar PV unit (including battery backup)	41,200	-	-	-
Inverter and battery backup	-	-	29,900	-
Diesel genset	-	-	-	28,910
Total capex	**80,064**	**18,500**	**48,400**	**47,410**

Source: Authors' analysis

‡ The power rating of the DRE-powered small deep freezer is 0.085 kW. Details considered are sourced from the manufacturers.

§ A 100-litre storage capacity electric deep freezer has a typical power rating of 0.132 kW. Details listed are as indicated on IndiaMART (last accessed in August 2022).

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for 10 years with 330 days of annual usage is

1.6x higher than a grid-connected product

1.1x lower than a grid-connected product with a 4-hour backup

22.7x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO[††] of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

Erratic electricity

Under this scenario, we compare the DRE-powered product's TCO with the grid-connected equipment requiring a 4-hour backup.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Erratic electricity				Reliable electricity			
		5	10	15	20	5	10	15	20	5	10	15	20
Annual usage (days)	240	9%	6%	5%	4%	116%	99%	91%	87%	238%	191%	170%	159%
	270	8%	5%	4%	4%	113%	95%	87%	83%	225%	179%	158%	147%
	300	7%	5%	4%	4%	110%	92%	84%	79%	213%	167%	147%	137%
	330	7%	4%	4%	3%	107%	89%	81%	76%	202%	157%	138%	128%

DRE-powered | Grid-connected | Grid-connected with 4-hour backup | Diesel-powered

Source: Authors' analysis

The comparative analysis of Total Cost of Ownership (TCO) shows that the DRE variant is financially more attractive than the other product variant in regions with no access to electricity. In regions of erratic electricity, the DRE variant is financially more attractive than the other product variant for an investment horizon of ten years and more. Grid-connected variant is financially preferable in regions with reliable electricity.

* For the most popular variant, as quoted by the appliance manufacturers.
† At an incremental annual income of INR 35,000 (USD 443), USD 1 = INR 79.
†† We use the Net Present Value of TCO across all analyses.
1 As per the quotations shared by small solar refrigerator manufacturers.
2 As reported by the small solar refrigerator manufacturers.
3 Authors' analysis.
4 Based on the consultations with small solar refrigerator manufacturers.

4. Solar dryers

Solar dryers (also called dehydrators) use solar energy to dry and extend the shelf-life of otherwise perishable fruits, vegetables, flowers, and seafood. The dryer supplies controlled and optimised heat to the products and protect the products from UV radiation, dust, dirt, insects and pollution.

Their variants are available in capacities that can process inputs ranging from 5 kgs at INR 8,925 (USD 113) to 500 kgs at INR 170,100 (USD 2,153) per batch.[1]

Image: CEEW

Economics of a typical* solar dryer

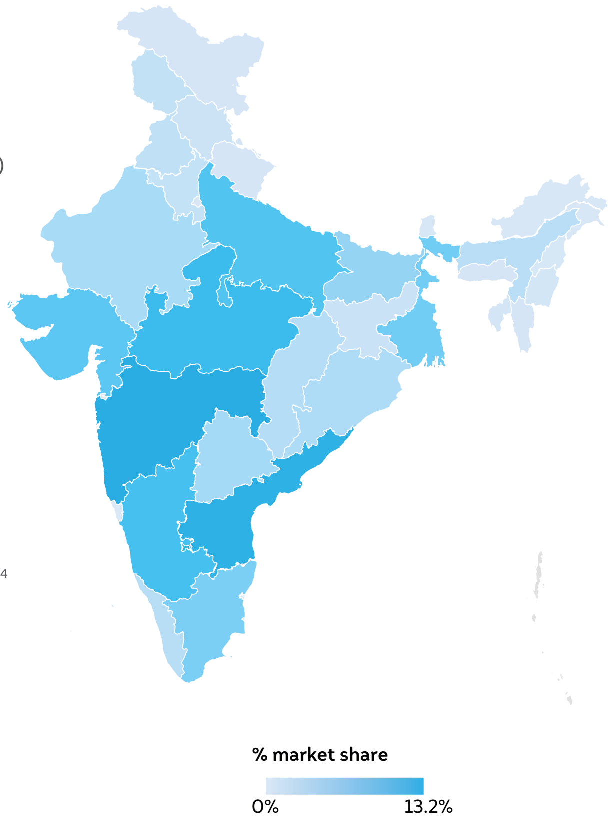
Cost
INR 107,000 (USD 1,354) for a 100 kg input capacity dryer

Typical usage
6 hours/day for ~240 days/year[3]

Incremental annual income
INR 80,950 (USD 1025)[3,4]

Discounted payback period[†]
17 months[4]

State-wise distribution of market potential



Market overview

~8,000
products installed in 26 states[2,3]

1.7 million
units is the market potential[4]

3.4 million
livelihoods can be impacted[4]

Source: Authors' analysis

The incremental income and associated payback period are based on the average or median values. The incremental annual income from the dried commodity varies from INR 48,000 for low-value commodities such as spinach to INR 105,000 for high-value commodities such as black grapes and mangoes. Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of dryer variants

Equipment cost (INR)	DRE-powered[‡]	Grid-connected[§]	Grid-connected with 4-hour backup[§]	Diesel-powered[§]
100 kg input capacity dehydrator	102,325	206,500	206,500	206,500
Solar PV unit (including battery backup)	4,675	-	-	-
Diesel genset	-	-	37,760	37,760
Total Capex	**107,000**	**206,500**	**244,260**	**244,260**

Source: Authors' analysis

‡ The power rating of the DRE-powered product is 0.04 kW, only to run small DC fans. Details considered are sourced from the manufacturers.

§ A 100 kg electric dehydrator has a typical power rating of 6 kW. Details listed are as indicated on IndiaMART (last accessed in August 2022).

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for 10 years with six hours of daily usage is

5x lower than a grid-connected product

10x lower than a grid-connected product with a 4-hour backup

12x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO[††] of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

Erratic electricity

Under this scenario, we compare the DRE-powered product's TCO with the grid-connected equipment requiring a 4-hour backup.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Erratic electricity				Reliable electricity			
		5	10	15	20	5	10	15	20	5	10	15	20
Daily usage (hours)	4	15%	11%	10%	9%	15%	11%	10%	9%	31%	26%	23%	22%
	6	12%	8%	7%	6%	14%	10%	9%	8%	27%	21%	19%	17%
	8	10%	7%	6%	5%	13%	9%	8%	7%	23%	18%	16%	14%
	12	7%	5%	4%	3%	12%	8%	7%	6%	19%	14%	12%	11%

DRE-powered | Grid-connected | Grid-connected with 4-hour backup | Diesel-powered

Source: Authors' analysis

The comparative analysis of TCO shows that the solar dryer/dehydrator is financially more attractive than the other product variant across all power availability and usage scenarios.

* For the most popular variant, as quoted by the technology manufacturer.
† At an incremental annual income of INR 80,950 (USD 1025), USD 1 = INR 79.
†† We use the Net Present Value of TCO across all analyses.
1 Raheja Solar. Available at http://www.rsfp.in/our-products/
2 Saini, Ananya, Amittosh Kumar Pandey, Rajni Jain, Gopala Krishnan, Sankara Subramanian, Kritika Kumar, and Chhavi Arora. 2021. State of the Decentralised Renewable Energy Sector in India – Insights from CLEAN 2021. New Delhi: CLEAN.
3 Based on the consultations with solar dryer manufacturers and users.
4 Authors' analysis.

5. Solar-powered bulk milk chillers

Solar-powered bulk milk chilling systems offer an affordable and reliable solution for preserving large quantities of milk, minimising milk spoilage and extending the shelf-life of the product.

They are available in capacities ranging from 500 litres per day at INR 709,015 (USD 8,975) to 5,000 litres per day at INR 2,500,000 (USD 31,646).[1]

Image: Inficold

Economics of a typical* solar-powered bulk milk chiller

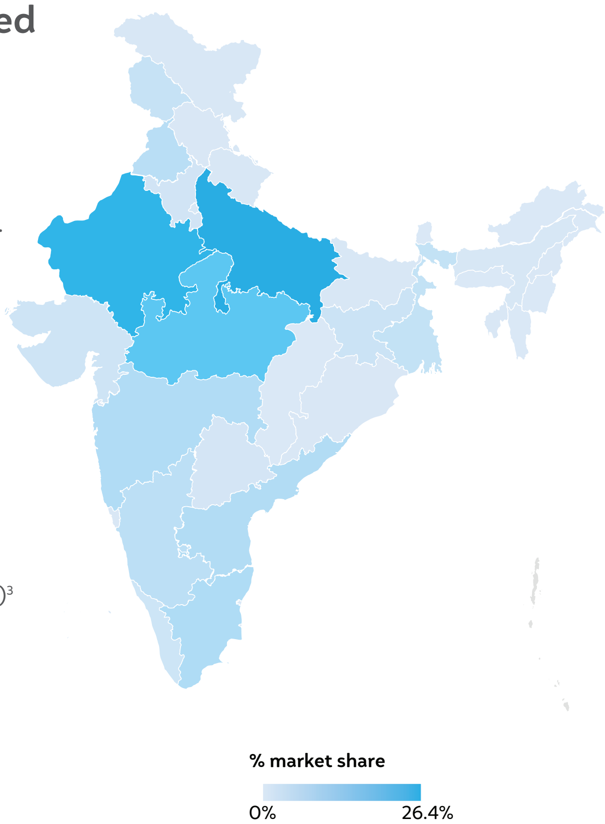
Cost
INR 709,015 (USD 8,975) for 500 litres per day storage capacity chillers.

Typical usage
24-hours per day (25 per cent duty cycle) for ~330 days/year[4]

Incremental annual income
INR 210,000 (USD 2,662)[3]

Discounted payback period[†]
45 months[3]

State-wise distribution of market potential



Market overview

~50
products installed in 4 states[2]

90,000
units is the market potential[3]

90,000
livelihoods can be impacted[3]

Source: Authors' analysis

The incremental income and associated payback period are based on the average or median values. An entrepreneur with a bulk milk chiller has an annual income potential of INR 173,000–247,500 depending on the utilisation of the milk chiller throughout the year (varying from 70–100 per cent). Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of bulk milk-chiller variants

Equipment cost (INR)	DRE-powered[‡]	Grid-connected[§]	Grid-connected with 4-hour backup[§]	Diesel-powered[§]
500 litres per day storage capacity milk-chiller	400,000	171,100	171,100	171,100
Solar PV unit (including battery backup)	309,015	-	-	-
Diesel genset	-	-	35,400	35,400
Total Capex	**709,015**	**171,100**	**206,500**	**206,500**

Source: Authors' analysis

‡ The power rating of the DRE-powered milk chiller is 2.66 kW. Details considered are sourced from the manufacturers.

§ A 500 litre storage capacity electric milk-chiller has a typical power rating of 1.68 kW. Details listed are as indicated on IndiaMART (last accessed in August 2022).

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for 10 years with 330 days of annual usage is

1.2x higher than a grid-connected product

1.6x lower than a grid-connected product with a 4-hour backup

5.3x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO[††] of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

Erratic electricity

Under this scenario, we compare the DRE-powered product's TCO with the grid-connected equipment requiring a 4-hour backup.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Erratic electricity				Reliable electricity			
		5	10	15	20	5	10	15	20	5	10	15	20
Annual usage (days)	240	38%	25%	21%	19%	111%	79%	67%	60%	193%	148%	128%	118%
	270	34%	23%	19%	17%	102%	72%	60%	55%	181%	137%	118%	108%
	300	31%	20%	17%	15%	94%	66%	55%	50%	170%	127%	109%	100%
	330	29%	19%	15%	14%	88%	61%	51%	46%	161%	119%	101%	93%

DRE-powered | Grid-connected | Grid-connected with 4-hour backup | Diesel-powered

Source: Authors' analysis

The comparative analysis of TCO shows that the DRE variant is financially more attractive than the other product variant in regions with no or erratic electricity. Grid-connected variant is financially preferable in regions with reliable electricity.

* For the most popular variant, as quoted by the appliance manufacturers.
† At an incremental annual income of INR 210,000 (USD 2,662), USD 1 = INR 79.
†† We use the Net Present Value of TCO across all analyses.
1 As per the quotations shared by solar-powered bulk milk-chiller manufacturers.
2 As reported by the bulk milk-chiller manufacturers.
3 Authors' analysis.

6. Solar-powered charkhas

A solar-powered charkha produces uniform, solid, and knot-free yarn. Its 10-spindle setup can make 40 hanks (2 kgs) of the yarn compared to the 25 hanks (1 kg) made by a traditional charkha.

They are available as 8-spindle setups at INR 40,059 (USD 507) and 10-spindle setups at INR 50,950 (USD 645).[1]

Image: CEEW

Economics of a typical* solar-powered charkha

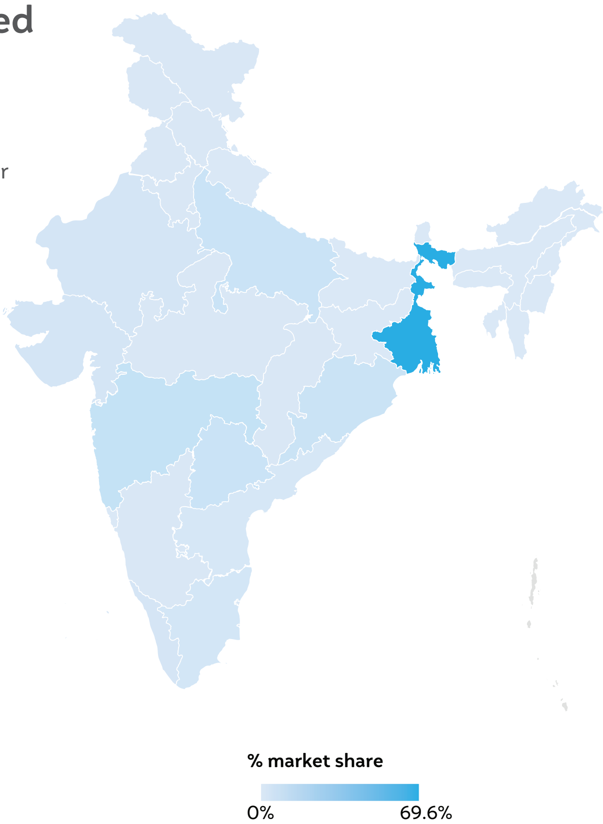
Cost
INR 50,950 (USD 645) for a 10-spindle charkha.

Typical usage
8 hours/day for ~250 days/year[4]

Incremental annual income
INR 50,000 (USD 633)[4,5]

Discounted payback period†
11 months[3]

State-wise distribution of market potential



Market overview

~2,000
products installed in 4 states[2]

387,000
units is the market potential[3]

387,000
livelihoods can be impacted[3]

Source: Authors' analysis

The incremental income and associated payback period are based on the average or median values. The income potential for charkha users varies from INR 25,000 to INR 75,000, depending upon the raw material's cost and quality. Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of charkha variants

Equipment cost (INR)	DRE-powered[‡]	Grid-connected[‡]	Grid-connected with 4-hour backup[‡]	Diesel-powered[‡]
10-spindle charkha	26,900	26,900	26,900	26,900
Solar PV unit (including battery backup)	24,040	-	-	-
Inverter and battery backup	-	-	8,325	-
Diesel genset	-	-	-	28,910
Total Capex	**50,950**	**26,900**	**35,225**	**55,810**

Source: Authors' analysis

‡ The power rating of both DRE-powered and electric charkha is 0.07 kW. Details considered are sourced from the manufacturers.

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for 10 years with eight hours of daily usage is

1.8x higher than a grid-connected product

1.4x higher than a grid-connected product with a 4-hour backup

9.5x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO[††] of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

Erratic electricity

Under this scenario, we compare the DRE-powered product's TCO with the grid-connected equipment requiring a 4-hour backup.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Erratic electricity				Reliable electricity			
		5	10	15	20	5	10	15	20	5	10	15	20
Daily usage (hours)	4	21%	15%	13%	12%	116%	114%	114%	114%	150%	149%	148%	148%
	6	18%	12%	10%	9%	128%	125%	124%	123%	164%	162%	160%	158%
	8	15%	11%	9%	8%	140%	137%	136%	134%	180%	176%	173%	171%
	12	14%	9%	8%	7%	175%	166%	162%	159%	222%	210%	203%	198%

DRE-powered | Grid-connected | Grid-connected with 4-hour backup | Diesel-powered

Source: Authors' analysis

The comparative analysis of TCO shows that the DRE variant is financially more attractive than the other product variant in regions with no access to electricity. Grid-connected variant is financially preferable in regions with reliable or erratic electricity.

* For the most popular variant, as quoted by the appliance manufacturers.
† At an incremental annual income of INR 50,000 (USD 633),USD 1 = INR 79.
†† We use the Net Present Value of TCO across all analyses.
1 As per the quotations shared by the solar-powered charkha manufacturers.
2 As reported by the solar-powered charkha manufacturers.
3 Sahdev, Garvit, Shruti Jindal, Abhishek Jain. 2021. Solarvastra: Is Renewable Energy-powered Sustainable Fashion a Real Market Opportunity? New Delhi: Council on Energy, Environment and Water.
4 Based on the consultations with the solar-powered charkha manufacturers.
5 Authors' analysis.

7. Solar-powered cold storages

Solar-powered cold storages are energy-efficient, portable, and modular appliances that can help reduce food loss by storing perishable food commodities. With predictive market analytics for farmers, farmer co-operatives, entrepreneurs and aggregators, they disrupt the way perishables are handled across the value chain.

Their variants are available in storage capacities ranging from 2 MT at INR 767,200 (USD 9,711) to 10 MT at INR 2,464,000 (USD 31,190).[1]

Image: CEEW

Economics of a typical* solar-powered cold storage

Cost
INR 1,400,000 (USD 17,722) for a 5 MT capacity cold storage

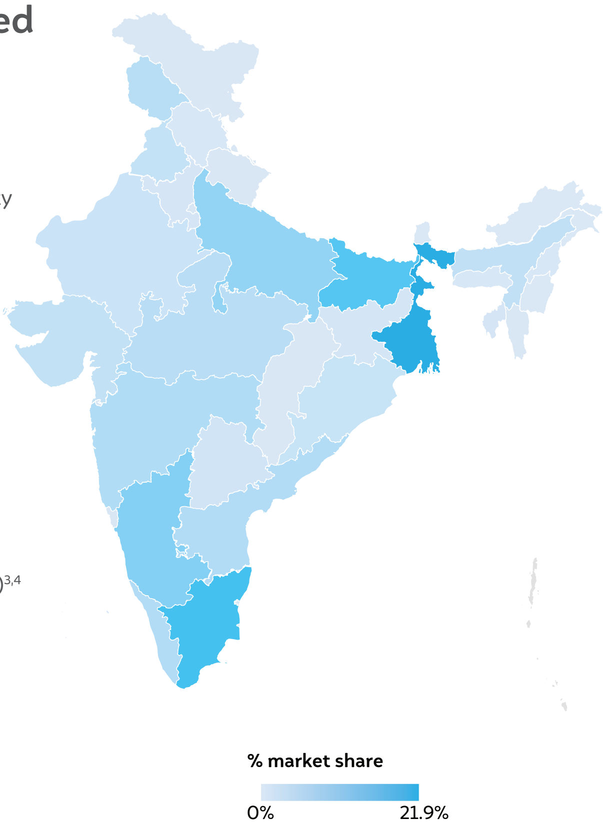
Typical usage
24-hours per day (33 per cent duty cycle) for ~330 days/year[4]

Incremental annual income
INR 319,400 (USD 4,043)[3,4]

Discounted payback period[†]
59 months[3]

Source: Authors' analysis

State-wise distribution of market potential



Market overview

~350
products installed in 12 states[2]

142,000
units is the market potential[3]

4.3 million
livelihoods can be impacted[3]

The incremental income and associated payback period are based on the average or median values. Cold storage operators can potentially earn an annual income of INR 273,750–365,500 depending on the utilisation of the cold storage throughout the year (varying from 60–80 per cent). Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of cold storage variants

Equipment cost (INR)	DRE-powered[‡]	Grid-connected[§]	Grid-connected with 4-hour backup[§]	Diesel-powered[§]
5 MT storage capacity cold storage	637,650	500,000	500,000	500,000
Solar PV unit (including battery backup)	780,000	-	-	-
Diesel genset	-	-	37,760	37,760
Total Capex	**1,400,000**	**500,000**	**537,760**	**537,760**

Source: Authors' analysis

‡ The power rating of the DRE-powered cold storage is 7 kW. Details considered are sourced from the manufacturers.

§ A 5 MT electric cold storage has a typical power rating of 2.5 kW. Details listed are as indicated on IndiaMART (last accessed in August 2022).

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for 10 years with 330 days of annual usage is

1.2x higher than a grid-connected product

1.4x lower than a grid-connected product with a 4-hour backup

4.3x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO[††] of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

Erratic electricity

Under this scenario, we compare the DRE-powered product's TCO with the grid-connected equipment requiring a 4-hour backup.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Erratic electricity				Reliable electricity			
		5	10	15	20	5	10	15	20	5	10	15	20
Annual usage (days)	240	46%	31%	26%	23%	117%	88%	76%	70%	175%	144%	129%	122%
	270	42%	28%	23%	21%	109%	81%	70%	64%	167%	136%	121%	114%
	300	38%	26%	21%	19%	103%	75%	65%	59%	160%	129%	114%	107%
	330	35%	23%	19%	17%	97%	70%	60%	55%	154%	122%	108%	100%

DRE-powered | Grid-connected | Grid-connected with 4-hour backup | Diesel-powered

Source: Authors' analysis

The comparative analysis of TCO shows that the DRE variant is financially more attractive than the other product variant in regions with no access to electricity. In regions of erratic electricity, the DRE variant is financially more attractive than the other product variant for an investment horizon of ten years and more. Grid-connected variant is financially preferable in regions with reliable electricity.

* For the most popular variant, as quoted by the appliance manufacturers.
† At an incremental annual income of INR 319,400 (USD 4,043), USD 1 = INR 79.
†† We use the Net Present Value of TCO across all analyses.
1 As per the quotations shared by solar-powered cold storage manufacturers.
2 As reported by the solar-powered cold storage manufacturers.
3 Authors' analysis.
4 Based on the consultations with solar-powered cold storage manufacturers.

8. Solar-powered grain milling machines

Efficient solar-powered grain milling machines can be used for rice, wheat, and other grains and pulses for value addition closer to production locations.

They are setups that combine some or all of the following: a pre-cleaner, huller, polisher, and grader. While this can be customised based on the user's requirements, a standard setup to process 100–150 kgs of grain per hour is available at INR 730,986 (USD 9,253).[1]

Image: CEEW

Economics of a typical* solar-powered grain milling machine[#]

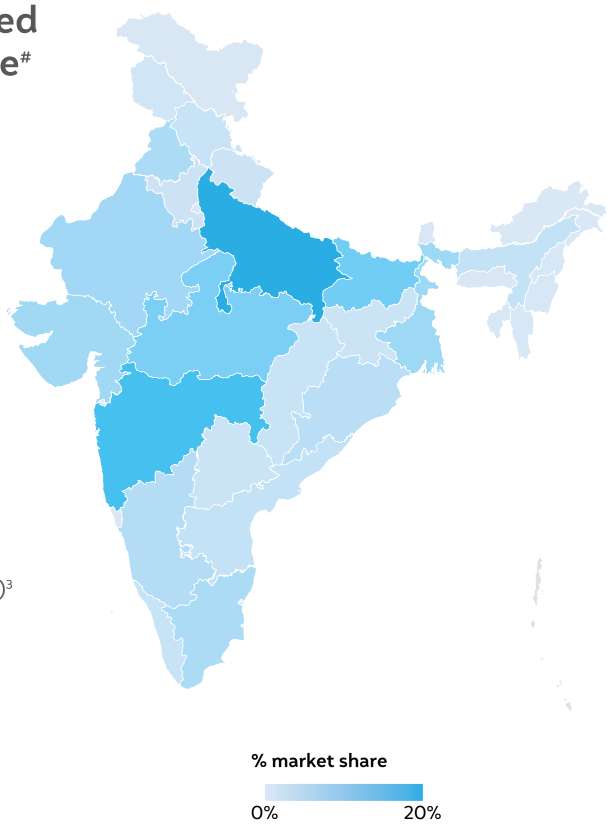
Cost
INR 730,986 (USD 9,253) for a 100 kg per hour output capacity grain mill.

Typical usage
6 hours/day for ~240 days/year[4]

Incremental annual income
INR 188,000 (USD 2380)[3]

Discounted payback period[†]
52 months[3]

State-wise distribution of market potential



Market overview

~100
products installed in 4 states[2]

946,000
units is the market potential[3]

1.9 million
livelihoods can be impacted[3]

Source: Authors' analysis

The incremental income and associated payback period are based on the average or median values. Income potential from a grain mill varies from INR 38,400 in a 100-household village to INR 480,000 in a 1,250-household village. Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of grain milling machine variants

Equipment cost (INR)	DRE-powered‡	Grid-connected§	Grid-connected with 4-hour backup§	Diesel-powered§
100 kg per hour output capacity grain mill	382,556	232,000	232,000	232,000
Solar PV unit (including battery backup)	348,430	-	-	-
Diesel genset	-	-	120,000	120,000
Total Capex	**730,986**	**232,000**	**352,000**	**352,000**

Source: Authors' analysis

‡ The power rating of the DRE-powered rice milling machine is 2.66 kW. Details considered are sourced from the manufacturers.

§ A 100 kg per hour output electric rice milling machine has a typical power rating of 8.19 kW. Details listed are as indicated on IndiaMART (last accessed in August 2022).

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for 10 years with six hours of daily usage is

1.3x higher than a grid-connected product

2.4x lower than a grid-connected product with a 4-hour backup

3.1x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO†† of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

Erratic electricity

Under this scenario, we compare the DRE-powered product's TCO with the grid-connected equipment requiring a 4-hour backup.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Erratic electricity				Reliable electricity			
		5	10	15	20	5	10	15	20	5	10	15	20
Daily usage (hours)	4	53%	38%	32%	29%	53%	38%	32%	29%	171%	141%	127%	120%
	6	46%	32%	27%	25%	59%	42%	36%	33%	166%	132%	117%	109%
	8	42%	29%	25%	22%	65%	46%	39%	36%	166%	129%	113%	105%
	12	38%	26%	22%	20%	75%	53%	45%	41%	164%	123%	107%	98%

DRE-powered | Grid-connected | Grid-connected with 4-hour backup | Diesel-powered

Source: Authors' analysis

The comparative analysis of TCO shows that the DRE variant is financially more attractive than the other product variant in regions with no or erratic electricity. Grid-connected variant is financially preferable in regions with reliable electricity.

* For the most popular variant of a rice huller, as quoted by the technology manufacturers.
# For the analysis of grain-milling machines, we only
consider rice-milling machines. Going forward, we plan to expand our analysis to include other grain-milling machines.
† At an incremental annual
income of INR 188,000 (USD 2380), USD 1 = INR 79.
†† We use the Net Present Value of TCO across all analyses.
1 As per the quotations shared by solar-powered grain-mill manufacturers.
2 As reported by the solar-powered grain mill manufacturer, includes sales of both solar and energy efficient product variants.
3 Authors' analysis.
4 Based on the consultations with solar-powered grain mill manufacturers and users.

9. Solar-powered looms

Solar-powered looms increase productivity by two to three times over traditional hand/paddle looms. They are ideal for the production of stripes and plain fabric.

Their reed space of fabric width can be customised from 36 inch to 72 inch, and the average cost of a solar-powered loom is INR 177,600 (USD 2,248).[1]

Image: CEEW

Economics of a typical* solar-powered loom

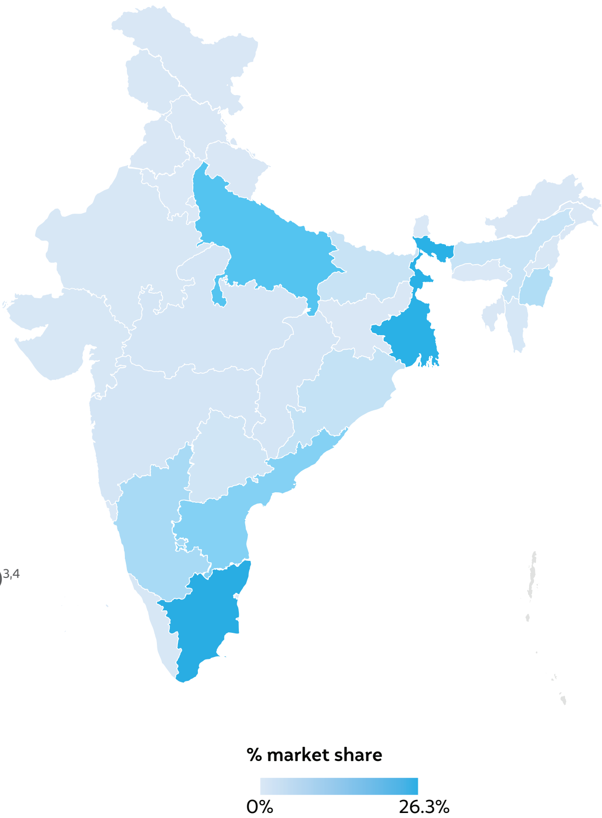
Cost
INR 177,600 (USD 2,248) for a 36" – 72" weaving width loom.

Typical usage
8 hours/day for ~300 days/year[4]

Incremental annual income
INR 261,500 (USD 3,309)[3,4]

Discounted payback period[†]
9 months[3]

State-wise distribution of market potential



Market overview

~70
products installed in 14 states[2]

621,000
units is the market potential[3]

1.2 million
livelihoods can be impacted[3]

Source: Authors' analysis

The incremental income and associated payback period are based on the average or median values. The income potential for the solar-powered loom users varies from INR 193,000 to INR 334,000 depending upon the raw material's cost and quality. Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of loom variants

Equipment cost (INR)	DRE-powered[‡]	Grid-connected[§]	Grid-connected with 4-hour backup[§]	Diesel-powered[§]
36"–-72" weaving width loom	102,660	96,760	96,760	96,760
Solar PV unit (including battery backup)	74,940	-	-	-
Diesel genset	-	-	28,910	28,910
Total Capex	**177,600**	**96,760**	**125,670**	**125,670**

Source: Authors' analysis

‡ The power rating of the DRE-powered loom is 0.2 kW. Details considered are sourced from the manufacturers.

§ A 36"–-72" weaving width power loom has a typical power rating of 1.5 kW. Details listed are as indicated on IndiaMART (last accessed in August 2022).

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for 10 years with eight hours of daily usage is

1.1x higher than a grid-connected product

2.4x lower than a grid-connected product with a 4-hour backup

3.5x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO[††] of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

Erratic electricity

Under this scenario, we compare the DRE-powered product's TCO with the grid-connected equipment requiring a 4-hour backup.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Erratic electricity				Reliable electricity			
		5	10	15	20	5	10	15	20	5	10	15	20
Daily usage (hours)	4	49%	36%	32%	29%	49%	36%	32%	29%	109%	96%	89%	85%
	6	43%	31%	27%	25%	53%	39%	34%	31%	109%	92%	84%	79%
	8	40%	29%	25%	22%	57%	42%	37%	34%	111%	92%	82%	78%
	12	34%	23%	20%	18%	58%	43%	37%	34%	104%	82%	73%	68%

DRE-powered | Grid-connected | Grid-connected with 4-hour backup | Diesel-powered

Source: Authors' analysis

The comparative analysis of TCO shows that the DRE variant is financially more attractive than the other product variant in regions with no or erratic electricity. In regions of reliable electricity, the DRE variant is financially more attractive than the other product variant for an investment horizon of ten years and more.

* For the most popular variant, as quoted by the appliance manufacturers.
† At an incremental annual income of INR 261,500 (USD 3,309), USD 1 = INR 79.
†† We use the Net Present Value of TCO across all analyses.
1 As per the quotations shared by the solar-powered loom manufacturers.
2 As reported by the solar-powered loom manufacturers.
3 Authors' analysis.
4 Based on the consultations with the solar-powered loom manufacturers.

10. Solar-powered silk reeling machines

Compact and portable solar-powered silk-yarn reeling, twisting, and spinning machines are useful for Tassar, Eri, and Muga silk yarns.

They are available with processing capacities ranging from 250 g per day at INR 19,080 (USD 242) to 350 g per day at INR 32,000 (USD 405).[1]

Image: CEEW

Economics of a typical* solar-powered silk reeling machine

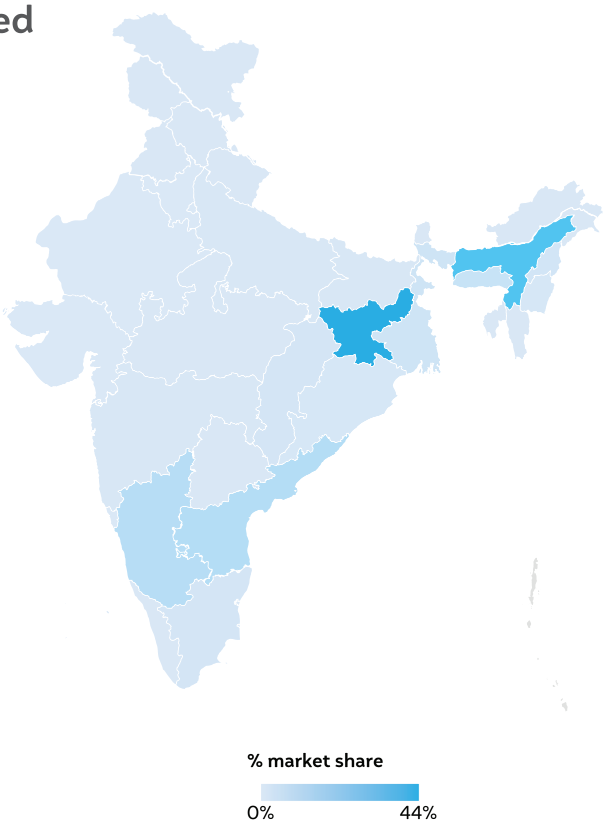
Cost
INR 32,000 (USD 405) for 350 gms per day processing capacity machine.

Typical usage
8 hours/day for ~300 days/year4[4]

Incremental annual income
INR 53,500 (USD 677)[4,5]

Discounted payback period[†]
8 months[5]

State-wise distribution of market potential



Market overview

~14,000
products installed in 16 states[2]

78,000
units is the market potential[3]

78,000
livelihoods can be impacted[3]

Source: Authors' analysis

The incremental income and associated payback period are based on the average or median values. The income potential for silk reelers varies from INR 30,000 to INR 90,000 depending upon the raw material's cost and quality. Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of silk-reeling machine variants

Equipment cost (INR)	DRE-powered‡	Grid-connected‡	Grid-connected with 4-hour backup‡	Diesel-powered‡
350 gms per day processing capacity machine	18,592	19,588	19,588	19,588
Solar PV unit (including battery backup)	13,470	-	-	-
Inverter and battery backup	-	-	3,478	-
Diesel genset	-	-	-	28,910
Total Capex	**32,062**	**19,588**	**23,066**	**48,498**

Source: Authors' analysis

‡ The power rating of both DRE-powered and electric silk-reeling machine is 0.02 kW. Details considered are sourced from the manufacturers.

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for 10 years with eight hours of daily usage is

1.5x higher than a grid-connected product

1.3x higher than a grid-connected product with a 4-hour backup

19.1x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO†† of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

Erratic electricity

Under this scenario, we compare the DRE-powered product's TCO with the grid-connected equipment requiring a 4-hour backup.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Erratic electricity				Reliable electricity			
		5	10	15	20	5	10	15	20	5	10	15	20
Daily usage (hours)	4	11%	8%	6%	6%	106%	105%	106%	105%	124%	124%	124%	124%
	6	9%	6%	5%	5%	117%	117%	117%	117%	136%	137%	137%	137%
	8	8%	5%	4%	4%	130%	130%	130%	129%	152%	152%	151%	151%
	12	6%	4%	3%	3%	140%	138%	138%	137%	162%	161%	159%	159%

DRE-powered | Grid-connected | Grid-connected with 4-hour backup | Diesel-powered

Source: Authors' analysis

The comparative analysis of TCO shows that the DRE variant is financially more attractive than the other product variant in regions with no access to electricity. Grid-connected variant is financially preferable in regions with reliable or erratic electricity.

* For the most popular variant, as quoted by the appliance manufacturers.
† At an incremental annual income of INR 53,500 (USD 677), USD 1 = INR 79.
†† We use the Net Present Value of TCO across all analyses.
1 As per the quotations shared by the solar-powered silk reeling machine manufacturers.
2 As reported by the solar-powered silk reeling machine manufacturers.
3 Sahdev, Garvit, Shruti Jindal and Abhishek Jain. 2021. Energy-Efficient Silk Spinning and Reeling Machines: How Big is the Opportunity? New Delhi: Council on Energy, Environment and Water.
4 Based on the consultations with the solar-powered silk reeling machine manufacturers.
5 Authors' analysis.

11. Solar-powered small horticulture processors

Energy-efficient solar-powered small (or micro) horticulture processors can reduce spoilage of perishable fruits, vegetables, herbs and flowers while enhancing their value by extracting juices, pulp, and essential oils.

They are available with outputs ranging from 40 litres per hour at INR 137,780 (USD 1,744) to 200 litres per hour at INR 408,390 (USD 5,169).[1]

Image: CEEW

Economics of a typical* solar-powered small horticulture processor

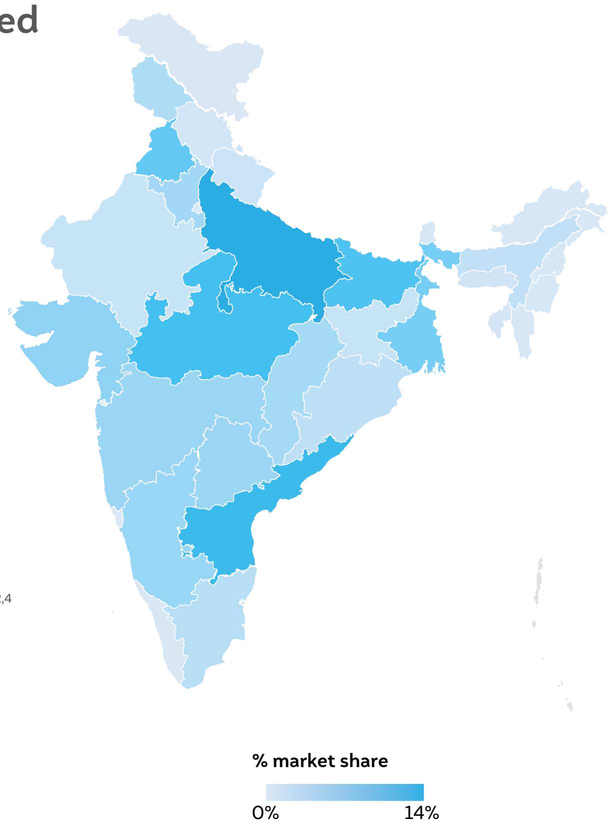
Cost
INR 137,780 (USD 1,744) for a 40 litres per hour output capacity processor.

Typical usage
4 hours/day for ~175 days/year[2]

Incremental annual income
INR 96,000 (USD 1,215)[2,4]

Discounted payback period[†]
18 months[4]

State-wise distribution of market potential



Market overview

~600
products installed in 18 states[2]

547,000
units is the market potential[3]

1.1 million
livelihoods can be impacted[3]

Source: Authors' analysis

The incremental income and associated payback period are based on the average or median values. Incremental annual income from the processed commodity varies from INR 30,000 for commodities such as peaches and goes up to INR 200,000 for commodities such as aloe vera. Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of small horticulture processor variants

Equipment cost (INR)	DRE-powered[‡]	Grid-connected[§]	Grid-connected with 4-hour backup[§]	Diesel-powered[§]
40 litres per hour output capacity processor	70,800	64,900	64,900	64,900
Solar PV unit (including battery backup)	62,780	-	-	-
Diesel genset	-	-	28,910	28,910
Total Capex	**137,780**	**64,900**	**93,810**	**93,810**

Source: Authors' analysis

‡ The power rating of the DRE-powered product is 0.375 kW. Details considered are sourced from the manufacturers.

§ A 40 litre per hour output electric juicer has a typical power rating of 2.25 kW. Details listed are as indicated on IndiaMART (last accessed in August 2022).

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for 10 years with four hours of daily usage is

1.3x higher than a grid-connected product

1.4x lower than a grid-connected product with a 4-hour backup

1.8x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO[††] of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

Erratic electricity

Under this scenario, we compare the DRE-powered product's TCO with the grid-connected equipment requiring a 4-hour backup.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Erratic electricity				Reliable electricity			
		5	10	15	20	5	10	15	20	5	10	15	20
Daily usage (hours)	4	74%	57%	51%	47%	101%	72%	76%	72%	147%	127%	117%	111%
	6	74%	55%	48%	45%	115%	92%	84%	79%	159%	132%	119%	113%
	8	70%	51%	45%	41%	119%	94%	85%	79%	159%	129%	115%	107%
	12	77%	55%	47%	43%	148%	113%	101%	93%	187%	145%	127%	118%

DRE-powered | Grid-connected | Grid-connected with 4-hour backup | Diesel-powered

Source: Authors' analysis

The comparative analysis of Total Cost of Ownership (TCO) shows that the DRE variant is financially more attractive than the other product variant in regions with no access to electricity. In regions of erratic electricity, the DRE variant is financially more attractive than the other product variant for an investment horizon of ten years and more. Grid-connected variant is financially preferable in regions with reliable electricity.

* For the most popular variant, as quoted by the technology manufacturers.
† At an incremental annual income of INR 96,000 (USD 1,215), USD 1 = INR 79.
†† We use the Net Present Value of TCO across all analyses.
1 Kissan Dharambir. Available at kissandharambir.com/shop/
2 Based on the consultations with small horticulture processor manufacturers and users
3 Khalid Wase, Shruti Jindal and Abhishek Jain. 2022. Can Small Horticulture Processors Enhance Rural Incomes? New Delhi: Council on Energy, Environment and Water.
4 Authors' analysis.

12. Solar-powered vertical fodder grow units

A low-cost, climate-controlled grow house can address the green fodder deficit in livestock feed and improve their milk yield.

They are available in two versions – those with 10–15 kgs output per day at INR 28,000 (USD 354) and those with 25–30 kgs output per day at INR 42,000 (USD 532).[1]

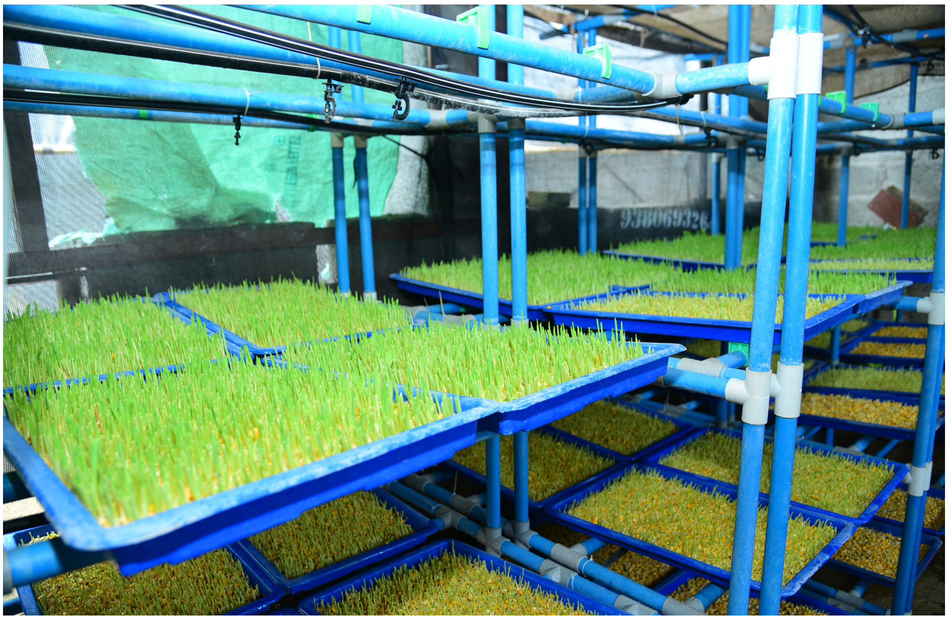


Image: Hydrogreens

Economics of a typical* solar-powered vertical fodder grow unit

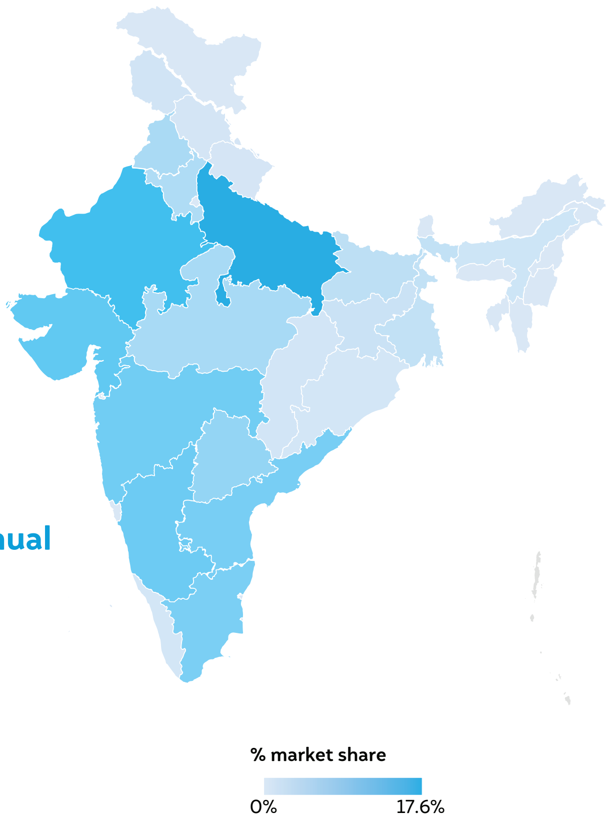
Cost
INR 42,000 (USD 532) for a 25–30 kgs per day output capacity vertical fodder units.

Typical usage
12-24 hours/day for ~240 days/year[4]

Incremental annual income
INR 24,000 (USD 304)[4,5]

Discounted payback period†
22 months[5]

State-wise distribution of market potential



Market overview

~210
products installed in 10 states[2]

3,380,000
units is the market potential[3]

11.9 million
livelihoods can be impacted[3]

Source: Authors' analysis

The incremental income and associated payback period are based on the average or median values. A vertical fodder grow unit may result in an increase of milk yield varying from 1–3 litre per cattle . Therefore, an animal husbandry farmer with four cattle can earn an incremental income of INR 9,600–57,600. Many users with incomes lower than average or median income would have much longer payback periods. Accordingly, such users may need support through product subsidies or longer-tenure loans.

Cost of vertical fodder grow unit variants

Equipment cost (INR)	DRE-powered[‡]	Grid-connected[§]	Grid-connected with 4-hour backup[§]	Diesel-powered[§]
25–30 kgs per day output capacity vertical fodder unit	32,600	30,000	30,000	30,000
Solar PV unit (including battery backup)	9412	-	-	-
Inverter and battery backup	-	-	6,722	-
Diesel genset	-	-	-	28,910
Total Capex	**42,012**	**30,000**	**36,722**	**58,910**

Source: Authors' analysis

‡ The power rating of the DRE-powered product is 0.375 kW. Details are sourced from the manufacturers.

§ A 25—30 kg per day output electric vertical fodder grow unit has a typical power rating of 0.375 kW. Details listed are as indicated on IndiaMART (last accessed in August 2022).

How does this DRE product's long-term TCO compare to other variants?

This product's TCO for 10 years with typical (12-24 hours) daily usage is

1.2x higher than a grid-connected product

Almost equal to a grid-connected product with a 4-hour backup

4x lower than a diesel-powered product

Source: Authors' analysis

When is this DRE-powered product financially preferable?

We compare the TCO[††] of DRE-powered products with that of other variants under different scenarios of power availability and daily usage durations for various investment horizons.

No access to grid power

Under this scenario, we compare the DRE-powered product's TCO with the diesel-run product's TCO.

Reliable electricity

Under this scenario, we compare the DRE-powered product's TCO with a grid-connected product's TCO.

Erratic electricity

Under this scenario, we compare the DRE-powered product's TCO with the grid-connected equipment requiring a 4-hour backup.

In the table below, the cell's colour represents the financially-preferable product variant. Whereas, the cell values denote the ratio of DRE-powered product's TCO compared to the other product variant's TCO in percentage terms.

Years of operations/ Investment Horizon(years)		No access to grid power				Erratic electricity				Reliable electricity			
		5	10	15	20	5	10	15	20	5	10	15	20
Annual usage (days)	180	40%	30%	27%	24%	107%	101%	99%	96%	130%	126%	123%	121%
	210	37%	27%	24%	22%	106%	99%	97%	94%	129%	123%	120%	118%
	240	34%	25%	22%	20%	104%	97%	95%	92%	127%	121%	117%	114%
	270	32%	23%	20%	18%	103%	96%	93%	90%	125%	118%	114%	111%

DRE-powered | Grid-connected | Grid-connected with 4-hour backup | Diesel-powered

Source: Authors' analysis

The comparative analysis of Total Cost of Ownership (TCO) shows that the DRE variant is financially more attractive than the other product variant in regions with no access to electricity. In regions of erratic electricity, the DRE variant is financially more attractive than the other product variant for an investment horizon of ten years and more. Grid-connected variant is financially preferable in regions with reliable electricity.

† At an incremental annual income of INR 24,000 (USD 304), USD 1 = INR 79.

†† We use the Net Present Value of TCO across all analyses.

1 As per the quotations shared by solar-powered vertical fodder grow unit manufacturers.

2 As reported by the vertical fodder grow unit manufacturers.

3 Khalid, Wase, Shruti Jindal, Abhishek Jain, Richa Ahuja. 2021. Enhancing India's Milk and Meat Production: Is Hydroponics Green Fodder the Probable Answer - Market Opportunity Analysis. New Delhi: Council on Energy, Environment and Water.

4 Based on the consultations with solar-powered vertical fodder grow unit manufacturers and users.

5 Authors' analysis.

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Acronyms

AC	alternating current
CEEW	Council on Energy, Environment and Water
CGWB	Central Ground Water Board
DC	direct current
EMI	equated monthly instalments
DAC&FW	Department of Agriculture, Co-operation and Farmers Welfare
DRE	decentralised renewable energy
HP	horsepower
INR	Indian Rupee
kW	kilowatt
MFI	microfinance institutions
MNRE	Ministry of New and Renewable Energy
MoMSME	Ministry of Micro, Small and Medium Enterprises
MSME	Micro, Small and Medium Enterprises
NBFC	non-banking financial companies
NIC	National Industrial Classification
NSS	National Sample Survey
NSSO	National Sample Survey Office
PL	Powering Livelihoods
SHGs	self-help groups
TCO	total cost of ownership
USD	United States dollar
VA	volt-ampere

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The authors

Abhishek Jain
abhishek.jain@ceew.in
@ajainme

As a fellow at CEEW, Abhishek built and leads its practices on energy access, rural livelihoods, and sustainable food systems. He also directs 'Powering Livelihoods', a USD 3 million initiative. He co-conceptualised and leads CEEW's flagship research, 'Access to Clean Cooking Energy and Electricity – Survey of States'. With more than 10 years of experience, Abhishek has worked on multiple issues at the confluence of energy, development, and the environment. He is a Chevening Fellow and an alumnus of the University of Cambridge and IIT Roorkee.

"DRE livelihoods pose a massive impact and market opportunity, but a difficult one to realise. The report's discerning view will help financiers, investors, entrepreneurs, and impact seekers prioritise high-impact and highly-feasible opportunities."

Wase Khalid
wase.khalid@ceew.in
@wase_khalid

As a programme associate at CEEW, Khalid's work focuses on energy access at the intersection of rural livelihoods under 'Powering Livelihoods', a CEEW–Villgro initiative. He is engaged in programmes that support the commercialisation of clean-energy innovations for livelihoods. He is helping enterprises undertake commercial deployment of decentralised renewable energy (DRE) technologies and generating on-ground evidence at a meaningful scale.

"There has been growing interest amongst the sector stakeholders in understanding the market, impact potential, viability and feasibility of DRE livelihoods technologies. Through this report we attempt the address their questions and help them make informed decisions about investing in, scaling, and promoting DRE livelihood technologies."

Shruti Jindal
shruti.jindal@iiml.org
Shruti_Jindal_

Shruti is a development professional who worked as a Programme Associate at CEEW. Her research expertise and interests include livelihoods, clean energy, and digital literacy. She has completed the Post-graduate Diploma in Sustainable Management from IIM Lucknow and her Bachelor of Technology from IIT Roorkee.

"High capital cost is often a barrier to adopting DRE for productive use. Through this report we have established the viability of these appliances through actual implementation examples and identified payback periods under different scenarios. I hope this report brings the promise of DRE appliances to the attention of policymakers and the financing ecosystem to enable millions of livelihoods."

COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW)

ISID Campus, 4 Vasant Kunj Institutional Area
New Delhi - 110070, India
T: +91 11 4073 3300

info@ceew.in | ceew.in | @CEEWIndia | ceewIndia