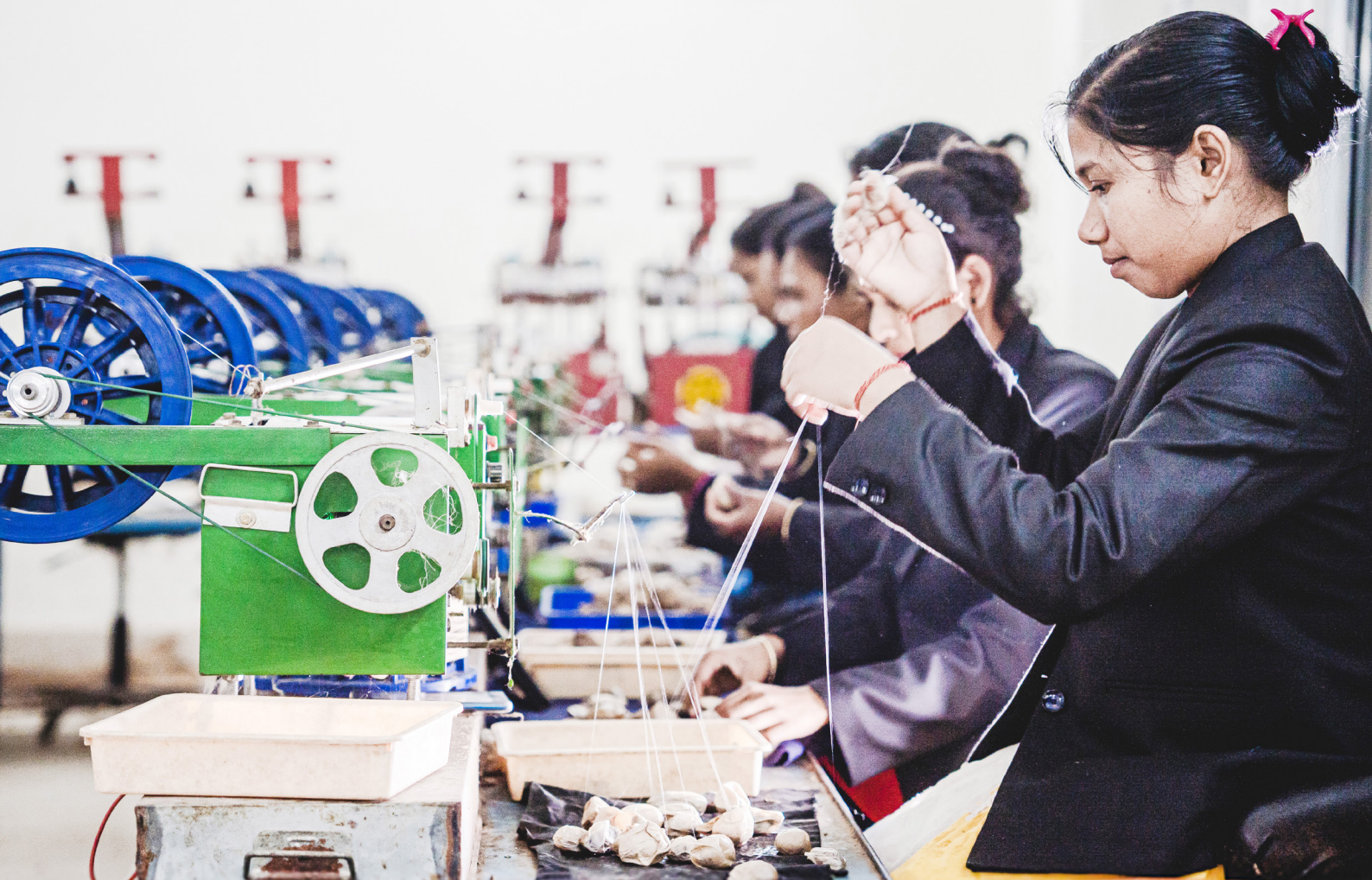


How Decentralised Renewable Energy-powered Technologies Impact Sustainable Livelihoods

Findings from the Ground (2025)

Priyatam Yasaswi, Divya Gaur, and Abhishek Jain

Executive Summary | April 2025





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Organisation:	<p>The Council on Energy, Environment and Water (CEEW) — a homegrown institution with headquarters in New Delhi — is among the world's leading climate think tanks. The Council is also often ranked among the world's best-managed and independent think tanks. It uses data, integrated analysis, and strategic outreach to explain — and change — the use, reuse, and misuse of resources. It prides itself on the independence of its high-quality research and strives to impact sustainable development at scale in India and the Global South. In over fourteen years of operation, CEEW has impacted over 400 million lives and engaged with over 20 state governments. Follow us on LinkedIn and X (formerly Twitter) for the latest updates.</p> <p>Villgro Innovations Foundation is India's foremost impact first incubator. Established in 2001, Villgro's mission is to make innovative, impactful businesses succeed in Health, Agribusiness, and Climate Action. We believe that innovation and for-profit business models are the sustainable route to solving critical social and environmental problems in India. Since 2001, we have worked with over 350 enterprises which have impacted over 20 million lives. Villgro was awarded the Top Incubator Award by the Department of Promotion of Industry and Internal Trade (Gol) in 2020 and the DivHERsity Awards in 2023.</p> <p>COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW) ISID Campus, 4 Vasant Kunj Institutional Area New Delhi – 110070, India +91 11 4073 3300 info@ceew.in ceew.in X@CEEWIndia ceewindia</p> <p>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 74103 info@villgro.org villgro.org X@Villgro</p>



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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 social impact enterprises deploying RE-powered livelihood equipment
- 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-livelihoods
- supporting national and sub-national policy frameworks to mainstream DRE-livelihoods to positively impact rural incomes, especially of women.

Solar refrigerators, energy-efficient food processors, solar reeling machines, 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. As of March 2025, through the PL supported enterprises, more than 32,000 livelihoods have been positively impacted, with around 50 per cent being women, driven by over 16,000 technology deployments.

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Enabling reliable cooling solutions can empower fisherwomen by minimising spoilage and maximising profits.

Image: CEEW/Emotive Lens

Executive summary

Agriculture continues to employ nearly half (45.8 per cent) of India's workforce, mainly in rural areas. However, the rural economy's contribution to India's GDP remains limited due to the impacts of climate change, water shortages, reverse migration and low productivity. (Ministry of Finance 2024). Evidence shows that lack of access to affordable and reliable energy hinders agricultural productivity and the growth of agribusinesses, thereby curbing the overall rural economy (Ringler et al. 2022). Therefore, enabling access to reliable energy, ideally through clean energy, is important in realising the potential of the rural economy. A decentralised renewable energy (DRE) system that generates and distributes energy independently of a centralised grid to power lighting, space heating, and consumer and productive appliances presents a cost-effective solution for ensuring reliable energy access at the last mile (Jain, Ghosh, and Chhabra 2021). These decentralised solutions help meet rural communities' electricity loads and requirements, which are often unmet by centralised grids (IRENA and SELCO Foundation 2022). Consequently, documenting and understanding the social, economic, and environmental impact of DRE systems is crucial, as these technologies could potentially impact livelihoods of 37 million people in India (Jain, Khalid, and Jindal 2023). In 2020, CEEW and Villgro launched the Powering Livelihoods programme to promote DRE-powered solutions in rural India. It aims to foster a supportive ecosystem for mainstreaming clean energy livelihood solutions. Through impact assessment research, it seeks to inform sectoral stakeholders by generating nuanced evidence on the social, economic, and environmental impacts of DRE livelihood solutions deployed across the country.

This impact assessment research is an ongoing effort that will take place over multiple rounds, with new technologies being added in each round and cross-sectional data collected. In our previous study (Gaur, Yasaswi, and Jain 2023), we examined the impact of six DRE livelihood technologies on users' livelihoods and highlighted the factors that constrained the usage of these solutions and the steps stakeholders must take to address them. In Round 2, the present study, we examine eight DRE technologies. To do so, we interviewed 889 users across 18 states and union territories. These technologies primarily support livelihoods in the agricultural, textile, and food processing sectors. These technologies are a) solar silk reeling and spinning machines, b) small horticulture processors, c) solar refrigerators, d) vertical fodder grow units, e) micro solar pumps, f) solar dryers, g) solar dehydrators, and h) biomass-powered cold storage.

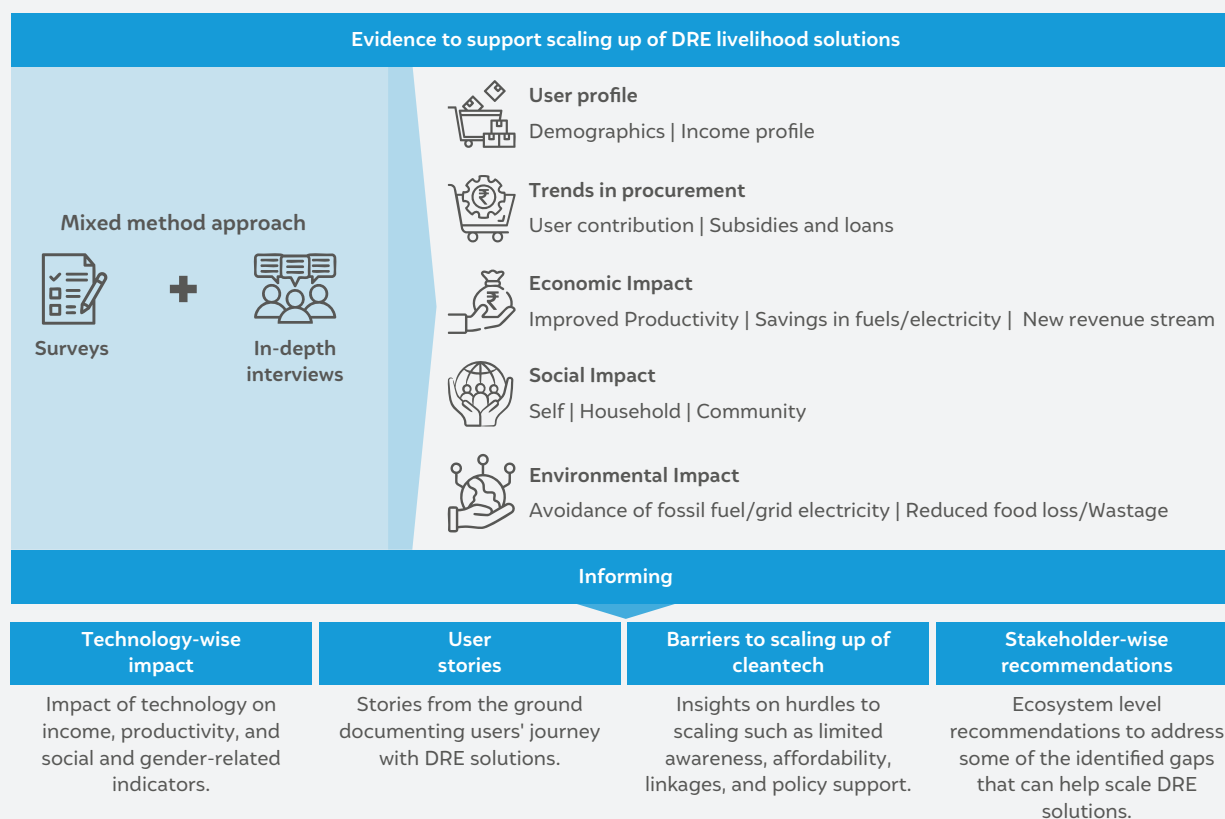
This study through a nationally representative survey aims to provide evidence on the following questions (Figure ES1):

- Who are the users of DRE livelihood solutions in India and how are they purchasing these solutions?
- What is the impact of DRE livelihood solutions on users' incomes?
- How do users engage with the solutions, and what barriers limit their usage?
- How significantly do DRE solutions impact aspects of users' lives other than their incomes?
- How is clean tech in rural livelihoods reducing carbon emissions?



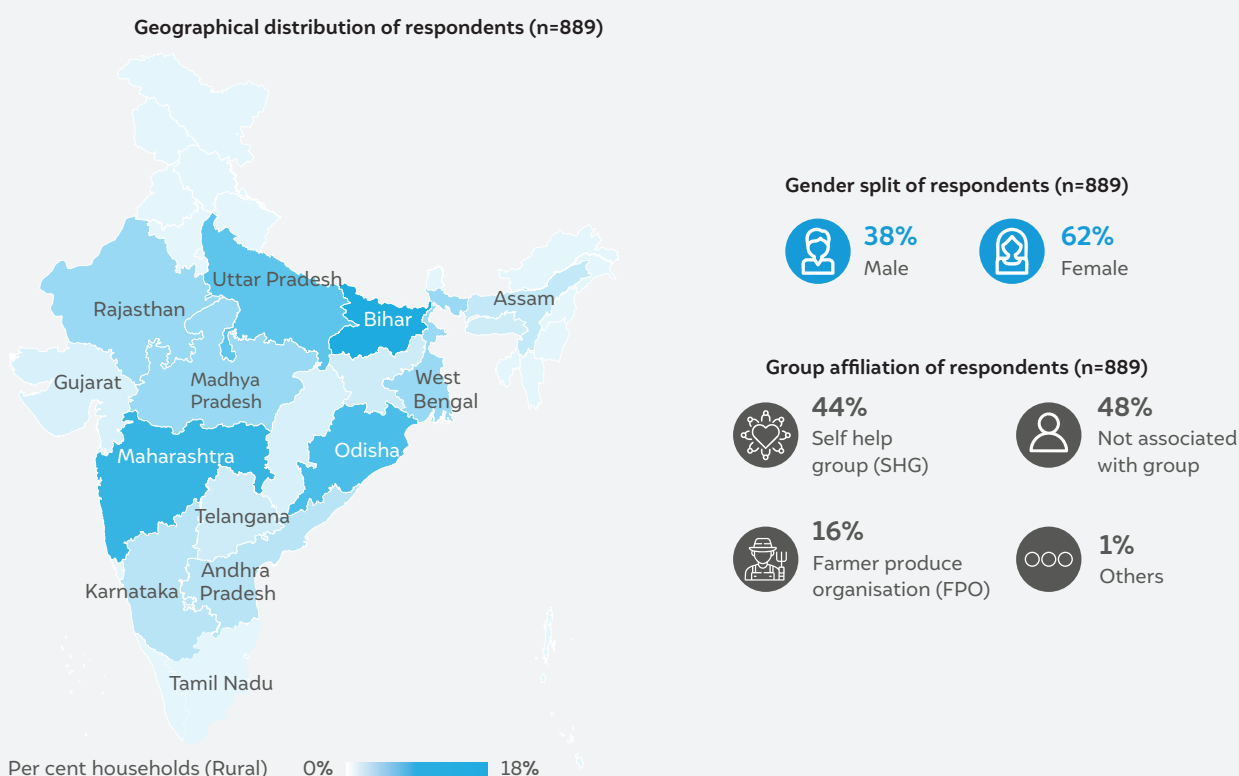
Mainstreaming DRE-powered livelihood solutions, especially in rural and remote areas, can help enhance incomes, improve productivity, and enhance demand for consumer goods, leading to rural prosperity

Figure ES1 Aspects covered under this impact assessment research

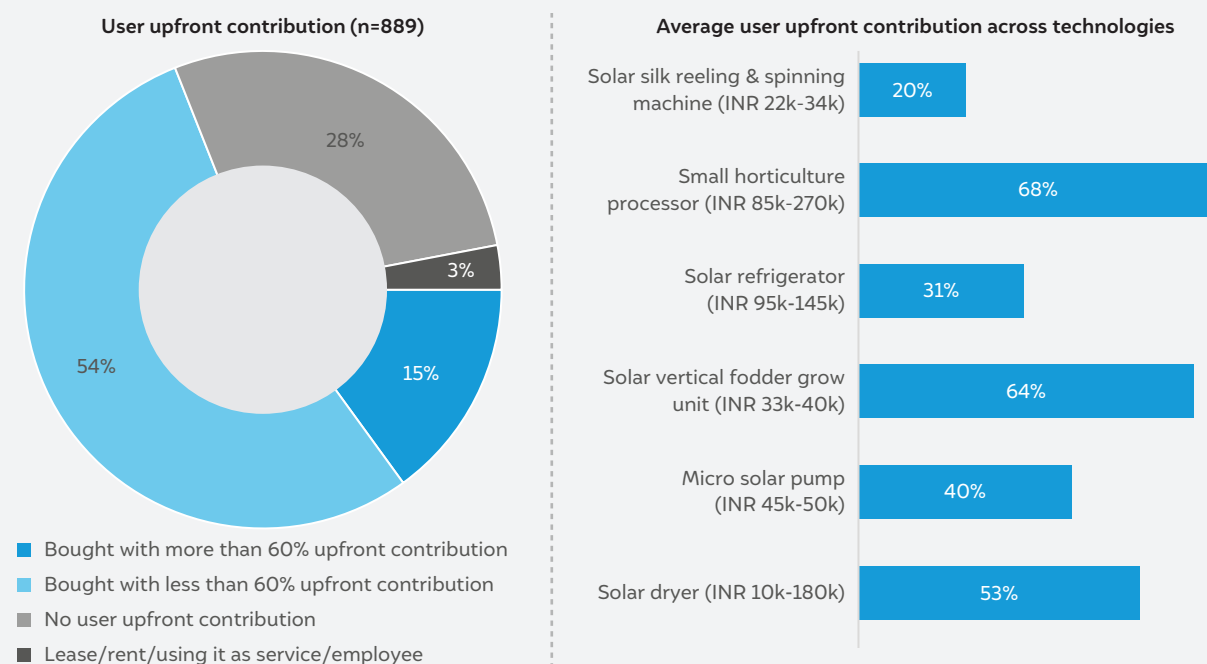
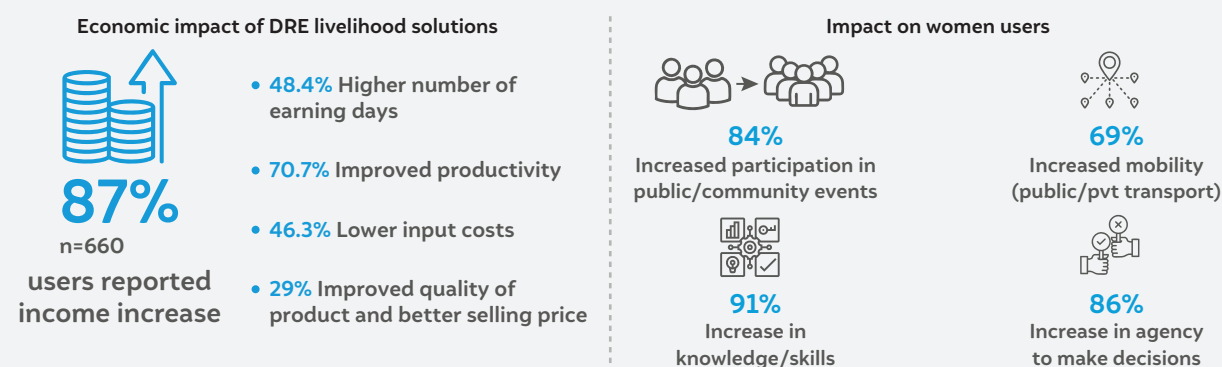
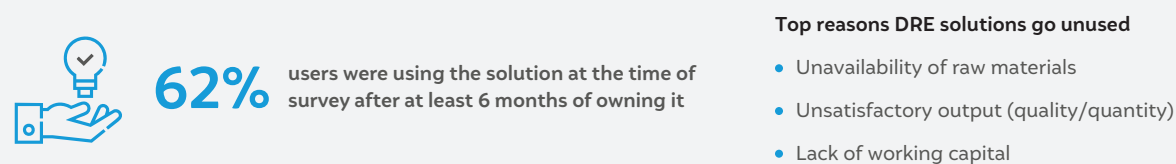


Source: Authors' compilation

Figure ES2 A typical respondent is a 30-45 year old female, part of a collective and residing in the central or eastern regions of India.



Source: Authors' analysis

Figure ES3 Most users contribute upfront but dependent on subsidy to procure the technology**Figure ES4** DRE adoption increased incomes for almost 90%, while also enabling positive social impact, especially among women**Figure ES5** Availability of market linkages, working capital and satisfactory output are crucial for long term usage of DRE solutions.

SOLAR SILK REELING AND SPINNING MACHINES

Energy-efficient, solar-powered silk reeling and spinning machines enable users (usually women) to reel high-quality silk. The machine reduces the drudgery of traditional manual thigh reeling, increases productivity, and promises increased incomes.



Image: CEEW/Emotive Lens

Kuni Dehury, a master silk reeler and trainer, successfully oversees operations at the Tassar Silk Park which houses more than 250 solar silk reeling machines in Bhagamunda, Keonjhar, Odisha.

States surveyed	Respondents		Primary income
56% 22% 13% 9%	277 97%	68% OBC	69% 31%
Bihar West Others Assam	Total Females	26% SC/ST	Non-farm Farm
Bengal		6% General	

Source: CEEW analysis 2024

INCOME IMPACT

Users experiencing income increase



74%



100%



₹ 44,000

increase in annual income for a typical user from a baseline income of ₹ 1,26,000



120%

Increase in the average selling price of yarn

Source: CEEW analysis 2024

USERS' EXPERIENCE



2x

increased in productivity, compared to earlier reeling practices (Manual & Grid based machine)



97%

of users reported an increase in the quality of reeled silk



10 months

of usage reported in a year on average

ENVIRONMENTAL IMPACT



1.1 MT

CO₂e abatement*

*For every 100 units of Unnati (Silk Reeling) machine used for 5 hours for 250 days a year.

SMALL HORTICULTURE PROCESSORS

A multi-purpose food processor that extracts juices, pulp and essential oil from various vegetables, fruits, herbs and flowers. It can be also used to make jams, candies and squashes, etc. It enables value addition for otherwise perishable horticulture produce, increasing the users' income.



Image: Manish Singh/CEEW

Shiv Kumar, an entrepreneur from the Gonda district of Uttar Pradesh, uses the small horticulture processor to manufacture over fifteen varieties of products from fruits, vegetables and herbs, which he then markets through local retailers.

States surveyed				Respondents			Primary income	
38%	25%	25%	12%	32	16%	66% General	50%	50%
Rajasthan	Uttar Pradesh	Others	Uttarakhand	Total	Females	31% SC/ST	Non-farm	Farm
						3% OBC		

Source: CEEW analysis 2024

INCOME IMPACT

Users experiencing income increase



80%



50%



₹ 59,000

increase in annual income for a typical user from a baseline income of ₹ 2,12,000

Source: CEEW analysis 2024

USERS' EXPERIENCE



88%

users reported decrease in the wastage of produce



100%

users reported no physical strain in operating the machine



88%

respondents use the small horticulture processor to make fruit, vegetable and herbal juice products

ENVIRONMENTAL IMPACT



11.6 MT

of CO₂e abatement*

* For every 100 units of solar powered small horticulture processor used for 3 hours daily for 180 days a year.

SOLAR REFRIGERATORS

The energy-efficient and solar-powered DC refrigerator provides reliable cooling for a wide range of commodities (dairy products, fish, cold drinks, vaccines). It decreases spoilage of perishables and provides savings on users’ electricity bills.



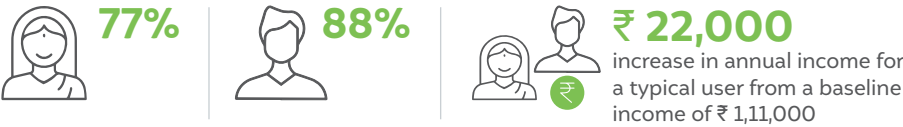
In the fisheries value chain, solar refrigerators serve as an effective solution, replacing the expensive ice boxes used for storing fish produce.

States surveyed			Respondents		Primary income	
60%	29%	11%	169	31%	60%	40%
Uttar Pradesh	Rajasthan	Karnataka	Total	Females	Non-farm	Farm
					40%	SC/ST
					36%	OBC
					23%	General
					1%	No data

Source: CEEW analysis 2024

INCOME IMPACT

Users experiencing income increase



Source: CEEW analysis 2024

USERS' EXPERIENCE



Source: CEEW analysis 2024

ENVIRONMENTAL IMPACT



*For every 100 units of solar refrigerators used for 21 hours daily for 250 days a year.

SOLAR VERTICAL FODDER GROW UNIT

A solar-powered, microclimate-controlled, hydroponics unit enables users to harvest about 25 kgs of fresh green fodder daily with less than a bucket of water. This solution promises an increase in the milk and meat yield of animals, thereby helping animal rearers realise better incomes while reducing the time and drudgery involved in fodder procurement and preparation.



Image: Selva Prakash Lakshmanan / Swiss Re Foundation / Fairpicture

Solar vertical fodder grow unit can reduce the time involved for women in rural areas for fodder collection and management.

States surveyed				Respondents			Primary income	
38%	28%	26%	8%	39	62%	62%	79%	21%
Karnataka	Andhra Pradesh	Telangana	Others	Total	Females	OBC	Farm	Non-farm
						28%		
						10%		
						General		
						SC/ST		

Source: CEEW analysis 2024

INCOME IMPACT

Users experienced income increase



67%



60%



₹ 59,000

increase in annual income for a typical user from a baseline income of ₹ 2,19,000

Source: CEEW analysis 2024

USERS' EXPERIENCE



59%

users reported reduced physical effort with fodder collection and preparation



47%

users reported reduced concentrate feed purchase



2 hours

average reported time saved in fodder collection and feed preparation



₹ 2/litre

average reported increase in the price of milk

Source: CEEW analysis 2024

ENVIRONMENTAL IMPACT



15.4 MT

of CO₂e abatement*

*For using 100 units of solar vertical fodder grow units for 225 days a year.

MICRO SOLAR PUMPS

A hyper-efficient, portable, open-well submersible pump system, designed for small farmers with a land holding of up to two acres. The pump increases income by expanding the irrigated area, increasing cropping cycles and displacing diesel use. It also reduces the overall effort that typically goes into starting and operating diesel pumps for irrigation.



A micro solar pump enables small and marginal farmers to provide timely irrigation for their crops without relying on costly diesel or kerosene-operated pumps in rural areas.

States surveyed	Respondents	Primary income
55% Odisha 35% Madhya Pradesh 10% Jharkhand	159 Total 60% Females	92% Farm 8% Non-farm
	79% SC/ST 16% OBC 4% General 1% No data	

Source: CEEW analysis 2024

INCOME IMPACT

Users experienced income increase



96%



100%

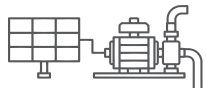


₹ 28,000

increase in annual income for a typical user from a baseline income of ₹ 63,000

Source: CEEW analysis 2024

USERS' EXPERIENCE



81%

users reported an increase in irrigated area post the adoption of micro solar pump



84%

users reported reduced cost of irrigation post the adoption of micro solar pump



₹ 14,600

average reported annual savings in irrigation costs



82%

users mention the water discharge quality as 'very good'

ENVIRONMENTAL IMPACT



11.4 MT

of CO₂e abatement*

*For every 100 units of micro solar pump used for irrigating 2 acres on average across 6 months of a year.

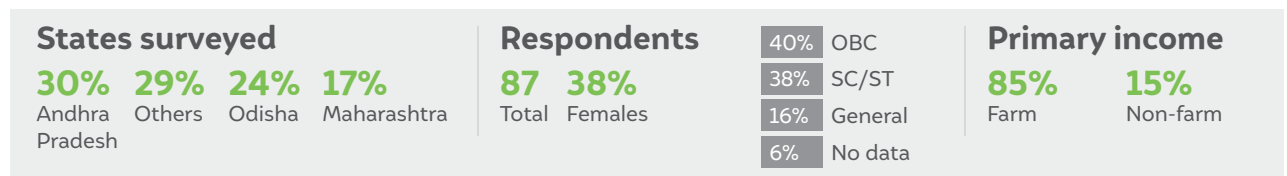
SOLAR DRYER

A portable solar dryer helps farmers increase the shelf life of perishable agricultural produce, thereby enabling savings from food loss and better value for farmers. Solar dryers are commonly used for drying fruits, vegetables, spices and grains in bulk.



Image: CEEW/Emotive Lens

Solar dryers are a viable solution for mitigating produce loss and price volatility in commodities such as tomatoes.



Source: CEEW analysis 2024

INCOME IMPACT

Users experienced income increase



91%



77%



₹ 46,000

increase in annual income for a typical user from a baseline income of ₹ 89,000

Source: CEEW analysis 2024

USERS' EXPERIENCE



91%

users mentioned that they had no prior experience with dryers as they relied on open sun drying



88%

users experienced an increase in the quality of dried produce



₹ 700

average reported price realised for dried spices and flowers (per kg)



52%

users process fruits in the solar dryer, 35% process vegetables

ENVIRONMENTAL IMPACT



20.3 MT

of CO₂e abatement*

*Through drying 60 batches per year in ten units of 100 kg solar dryers

SOLAR DEHYDRATOR

A portable solar dehydrator helps farmers increase the shelf life of perishable agricultural produce, thereby enabling savings from food loss and better value for farmers. Designed for small-scale use, solar dehydrators effectively remove moisture from food items to ensure preservation.



Image: S4S

Solar dehydrator-based village processing centres offer women viable livelihood opportunities, reducing the physical effort and drudgery associated with traditional farm-based work.

States surveyed

100%
Maharashtra

Respondents

75 **96%**
Total Females

67%	General
27%	SC/ST
3%	OBC
3%	No data

Primary income

40% **60%**
Farm Non-farm

Source: CEEW analysis 2024

INCOME IMPACT

Users experienced income increase



82%



33%



₹ 74,000

increase in annual income for a typical user from a baseline income of ₹ 1,53,000

Source: CEEW analysis 2024

USERS' EXPERIENCE



6 hours

average reported time spent per day on dehydrator



92%

users reported a **decrease in physical effort** from earlier livelihood activities



53%

users mention confidence from assured buyback of dried produce

ENVIRONMENTAL IMPACT



20.3 MT

of CO₂e abatement*

*Through drying 60 batches per year in ten units of 100 kg solar dryers

BIOMASS-POWERED COLD STORAGE

The biomass-powered cold storage offers reliable cooling to farmers for storing their agricultural products at minimal running cost. It utilises the waste biomass available at the farm gate.



Image: CEEW/Emotive Lens

Biomass-powered cold storage offers a cost-effective means for farmers and farmer collectives to store produce like lemons and tomatoes, helping mitigate price volatility.

States surveyed

100%

Maharashtra

Respondents

51

Total Females

8%

53% SC/ST

35% General

12% OBC

Primary income

100%

Farm

Source: CEEW analysis 2024

INCOME IMPACT

Users experienced income increase



100%



100%



₹ 60,000

increase in annual income for a typical user storing produce in the cold storage from a baseline income of ₹ 81,000

Source: CEEW analysis 2024

USERS' EXPERIENCE



72%

of users were first-time users of cold storage



84%

users reported improved price realisation for commodities with the use of cold storage



73%

users store fruits in cold storage on average for 73 days, 23% store vegetables



30%

users mention 'low price during harvest' as one of the reason for adopting the biomass cold storage

ENVIRONMENTAL IMPACT



94 MT

of CO₂e abatement*

*By one biomass cold storage unit through avoiding 15% food loss per batch for 15 batches in a year

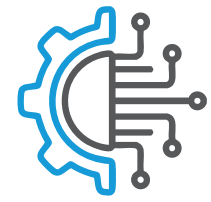
Key recommendations for scaling up of DRE livelihood solutions

This impact assessment study is the first of its kind effort to generate evidence at scale on the social, economic, and environmental impacts of DRE livelihood solutions on its users in India. The insights provide broader implications for the scaling up of these solutions in the DRE sector in the Global South. Notably, 87 per cent of users reported an income increase after adopting DRE solutions, in addition to enhancing productivity, reducing drudgery, and contributing to carbon emission reduction.

This study offers actionable recommendations to accelerate the scaling of these technologies on the ground. These recommendations are informed by both research findings (quantitative and qualitative) and experiences from the Powering Livelihoods programme, emphasising evidence-based strategies to overcome adoption barriers and maximise impact.

- **DRE livelihood technologies can be targeted towards SHGs and FPOs, to enable group ownership and creation of micro/nano-enterprises.** Our data reveals that 60 per cent of self-selected DRE technology adopters are members of Self-Help Groups (SHGs) or Farmer Producer Organisations (FPOs). Leveraging group lending preferences of financiers and government revolving funds is key to scaling these enterprises and unlocking economic activity.
- **Commercial scale up of technologies should be incentivised to reduce subsidy-heavy deployments for long-term usage.** Our regression analysis shows a strong and statistically significant relationship between user upfront contribution and usage of the solution ($p\text{-value}=0.00$). Therefore, user contribution is crucial to ensure long-term usage and hence, commercial models of deployments should be advanced.
- **Facilitate sustained use of DRE solutions by strengthening market linkages and ensuring access to working capital to maximise user benefits.** Consistent utilisation of DRE solutions is essential for securing reliable incomes for users. Our findings indicate that approximately 18 per cent of users have never used the solution, while about 5 per cent have discontinued its use. Although the reasons for non-usage may vary across different technologies, we found that a lack of working capital is the primary barrier for 86 per cent of respondents who have never used the solution. Additionally, 30 per cent of those who stopped using the solution cited the unavailability of raw materials or inputs as a significant constraint.

Enhancing the targeting of DRE solutions through SHGs and FPOs, incentivising user upfront contribution, policy alignment, and streamlined value chain linkages is crucial to mainstream DRE livelihood solutions. This study provides evidence to stakeholders for informed decision making to materialise these actions.



Targeting of DRE solutions through SHGs and FPOs, incentivising user upfront contribution, policy alignment, and streamlined value chain linkages is crucial to mainstream DRE livelihood solutions

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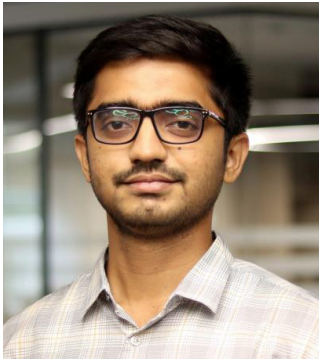
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Workers using solar-powered silk reeling machines at the Tasar Silk Park in Keonjhar, Odisha.

Image: CEEW/Emotive Lens

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