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Powering Livelihoods
A CEEW-VILLGRO INITIATIVE

How Decentralised Renewable Energy-powered Technologies Impact Livelihoods

Findings from the Ground

Divya Gaur, Priyatam Yasaswi, and Abhishek Jain

Issue Brief | May 2023

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The **Council on Energy, Environment and Water (CEEW)** is one of Asia's leading not-for-profit policy research institutions. The Council 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, develops partnerships with public and private institutions, and engages with wider public. In 2021, CEEW once again featured extensively across ten categories in the *2020 Global Go To Think Tank Index Report*. The Council has also been consistently ranked among the world's top climate change think tanks. Follow us on Twitter @CEEWIndia for the latest updates.

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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 storage, 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.

Supporters

We thank the following organisations whose users have been surveyed in this study. Deployment of micro solar pump, small solar refrigerator, and solar vertical fodder grow units were supported by Sustain Plus Energy Foundation and implemented by Collectives for Integrated Livelihood Initiatives (CInI) and SELCO Foundation. We also extend our gratitude to Market Xcel Private Ltd., our data collection partner who supported us in quantitative data collection for the study.

Contents

Gayathri Suthar, a member of the Ashapura Self Help Group, Udaipur district, Rajasthan with the small solar refrigerator that helped the group cut down milk losses in their business significantly.

Image: CEEW/Emotive Lens

Executive summary

In India, about half of the population (47 per cent) depends on agriculture (Ministry of Finance 2023). The average annual income of a farmer is INR 122,616 (USD 1,495)[1] (Ministry of Agriculture and Farmers Welfare 2022). Most of the employment in rural areas is informal, with low levels of productivity and low wages. Over the past two decades, the country has witnessed significant labour migration and a substantial employment shift away from agriculture (Choithani, Jan van Duijne, and Nijman 2021, 2). India needs to create at least 90 million (9 crore) new non-farm jobs by 2030 (Sankhe et al. 2020) to meet the aspirations of millions of youths who will enter the workforce. Significant investment in infrastructure and an enabling policy environment are needed to create this volume of highly productive jobs. On the other hand, India has committed to becoming net zero by 2070. This means that India needs to build millions of resilient and sustainable livelihoods while ensuring that its economic growth does not get hampered by the various climate risks, and helps achieve its climate goals (Ghosh and Raha 2020).

Alongside India's commitment to net zero by 2070, it has to create at least 90 million new non-farm jobs by 2030

Decentralised renewable energy (DRE)–powered livelihood technologies will help generate these resilient and sustainable livelihoods. However, currently the deployment of these technologies on the ground is limited, and it is a challenge to scale at the pace required to address the needs of rural and peri-urban communities. Further, a lack of evidence on the commercial viability of such solutions makes it challenging to garner support from investors, financiers, policymakers, and market enablers.

Therefore, Powering Livelihoods (PL) planned an impact assessment study with two phases to adequately capture the impact of the technologies in the PL portfolio, which represent more than 80 per cent of the sector in terms of revenue. In 2022, we undertook Phase I of the impact assessment study, involving end-users of six different DRE-livelihood technologies (Table 1).

Table ES1 Details of the technologies covered in the impact assessment study

Technology	Image	Power Rating	Price Range (INR)	Livelihoods Supported	Dominant Deployment States
Solar Silk Reeling and Spinning Machine		15 W	15,000–30,000	Silk reelers and weavers	Chhattisgarh, Odisha
Small Horticulture Processor		0.5–2 HP	70,000–225,000	Small and medium food processing enterprises	Haryana, Punjab, Uttarakhand
Small Solar Refrigerator		65–155 W	80,000–145,000	Departmental/ kirana/medical store owners	Uttar Pradesh, Rajasthan, Karnataka

1 Conversion rate: USD 1 = INR 82.

Technology	Image	Power Rating	Price Range (INR)	Livelihoods Supported	Dominant Deployment States
Solar Vertical Fodder Grow Unit		30 W	40,000–45,000	Small dairy farmers	Rajasthan, Andhra Pradesh, Karnataka
Micro Solar Pump		0.3 HP	45,000–50,000	Small and marginal farmers	Odisha, Jharkhand, Madhya Pradesh

Source: PL-supported enterprises

Phase I of the study covered 767 end-users across 19 Indian states. The research covered users who had had access to and used the technologies for at least six months. A cross-sectional study with a mixed-method approach, consisting of quantitative and qualitative research methods, was conducted. The aim was to gauge the impact of these technologies on end-users' livelihoods.Phase II will consider more technologies, more users, and include revisiting some users from Phase I.

The findings in this brief would help stakeholders make informed decisions about promoting DRE-livelihood technologies. The various stakeholders include livelihood-focused state departments (state rural livelihood missions [SRLMs], animal husbandry, horticulture, textile, khadi and village industries commissions etc.), state renewable energy agencies, central ministries (Ministry of Rural Development, Ministry of Micro, Small and Medium Enterprises, Ministry of Food Processing Industries, Ministry of Textiles, Ministry of New and Renewable Energy etc.), end-user financiers (microfinance institutions, small finance banks, regional rural banks), and small cooperative banks, investors, donors, and enterprises.

Image: CEEW/EmotiveLens

SHG members from Udaipur district, Rajasthan attended a hyper local event to understand the benefits of small solar refrigerators.

The objective of this impact assessment study is to understand the socio-economic and environmental impact of DRE-powered livelihood technologies on its users

A. Key findings

Majority of users were females, employing the silk reeling and spinning technology

Around 74 per cent of respondents were female, while male users made up the remaining 26 per cent. This is because technologies like solar silk reeling and spinning as well as solar vertical fodder grow units have significantly higher shares of female users.

About 45 per cent of users were engaged in farm-based activities for their primary income, which is in line with government data on the percentage of people dependent on agriculture (Ministry of Finance 2023). Around 49 per cent had non-farm livelihoods (own businesses, informal daily wage work etc.), salaries, and pensions, and the remaining mentioned miscellaneous sources.

Government and philanthropic capital support drove the deployment of these technologies on the ground

Almost 90 per cent of users had access to the technologies through some capital support from government and civil society organisations, which subsidised the cost. Still, the majority of the users were not aware that they had availed a subsidy to access the technology.

Table ES2 Major impacts enabled by DRE livelihood technologies

Economic impact	**71%** of end-users experienced an increase in income. **35%** increase in annual income was experienced by a typical user.	**Social impact**	**86%** end users had improved confidence to earn and work. **88%** end-users experienced increased support of family members/spouses
Impact on productivity	**2X increase** in productivity of silk reeling users compared to earlier reeling practices. **0.7 litres** of average increase in milk yield per day per animal on using solar vertical fodder grow unit	**Impact on women**	**89%** women users reported increased participation in events. **93%** women users reported having gained relevant knowledge and skills.

Source: Authors' analysis

After using a DRE-livelihood technology, the annual income of 71% end-users increased, typically by 35%

The technologies enabled income increases for 71 per cent of the surveyed users. The solutions generated this additional income by improving productivity, increasing savings on operational costs, and enhancing the value of processed products. Among those whose income increased following the use of DRE-livelihood technologies, many (39 per cent) reported having increased their investment in their children's educations and in better nutritional and dietary intake.

Increased incomes can pay for product financing with longer repayment tenures and lower interest rates, thereby making commercial deployments feasible

There was minimal uptake of technologies through formal sources of financing – indeed, almost 95 per cent of users did not take out a loan. We analysed the ability of end-users to repay loans from the reported increase in incomes. As many as 81 per cent of silk reeling machine users would be able to repay loans from the income increase following the adoption of the technology. Longer loan tenures and lower interest rates could increase the viability of the solution for even more users across technologies.

Poor market linkage — both backward and forward — and lack of service support constrain continuous usage of technologies

Users continue to employ technologies until constrained by raw material unavailability, limited earnings due to poor market linkages, and a lack of service support

About 70 per cent of users were using the solution at the time of the survey. Raw material unavailability (28 per cent) and earnings being lower than expected (14 per cent) were the two major reasons for end-users not using the technology at the time of the survey. Further, since the majority of deployments were done with philanthropic and government support, users had difficulty reaching manufacturers for prompt support, in cases where the technology was not functioning due to technical issues. However, for users who had procured the technology on their own, initial contact and conversations with the manufacturers during the procurement helps in raising issues on non-functioning in a timely manner.

Certain DRE-livelihood technologies create final products that do not have sufficient local market demand, underlining the criticality of forward market linkages to ensure sustained use of the technology. Similarly, for technologies that depend on raw material that might not be easily available locally, enabling backward market linkages is equally critical.

Capacity building on economic benefits and operational features of the technologies is essential to build the trust of stakeholders

Overall, we found gaps in people's understanding of DRE-livelihood technologies, their operations, and economic benefits. Such gaps can contribute to a mismatch between the assess needs of a particular user or community and the solution deployed. Such a mismatch could lead to reduced use or non-use of the technologies, thus misleading prospective users and other stakeholders about the efficacy of the DRE-livelihood technologies.

Image: CEEW/EmotiveLens

Users being given demonstration of small solar refrigerators in Udaipur, Rajasthan.

B. Way forward

We highlight some ways forward based on early findings of this research on the impacts of DRE-livelihood technologies. This information can help stakeholders address the identified challenges associated with scaling up.

Convergence is required among ecosystem stakeholders to enable market linkages

Given the criticality of forward and backward linkages, it is necessary for implementing organisations and technology manufacturers to work collaboratively with relevant government and private stakeholders. This would ensure establishment of the linkages so that the technologies can be deployed at scale.

Affordable financing should be accessible through innovative financial instruments

The capital that many philanthropic organisations and government departments are actively contributing to this sector could be directed towards enabling financing mechanisms that facilitate effective and wider adoption of these technologies.

After-sales support and timely check-ins are essential to ensure sustained use of DRE-livelihood technologies

To address unresolved technical issues, it is necessary for technology manufacturers to train and engage youth from local communities on a fee-based model, especially where there are a sizable number of deployments. These youths can then provide support to end-users looking to resolve issues.

Currently, training programmes conducted by ground-level organisations and government departments target many sections of the rural population. In addition, dedicated training and holistic capacity building for all stakeholders involved, as well as appropriate expectation setting for users, could go a long way in the process of realising and sustaining the impact of these technologies.

A user setting up the solar silk reeling machine before her day's work at the Tasar silk park in Keonjhar, Odisha.

Image: CEEW/Emotive Lens

1. Introduction

1.1 DRE-livelihood technologies and sectoral context

Enabling decentralised renewable energy (DRE) to power productive use applications can increase livelihood opportunities, improve incomes, and build resilience for climate change–vulnerable communities to continue their livelihood activities (Jain, Ghosh, and Chhabra 2021). According to a study by CEEW, there is a market opportunity of approximately USD 50 billion (INR 4.08 lakh crore) for clean energy innovations to power livelihoods in India (Waray, Patnaik, and Jain 2018).

In India alone, DRE-powered livelihood technologies have a market potential of approximately USD 50 billion+

In recent years, multitudes of livelihood technologies have emerged. These are highly energy-efficient and designed to run on DRE sources. Examples include solar water pumps, looms and charkhas, biomass-powered cold storages, solar dryers, solar vertical fodder grow units and many more. DRE-livelihoods offer a few distinct advantages, such as being economically lucrative for microenterprises and often more viable than their grid-based or diesel counterparts. Further, these applications are portable and do not depend on the availability of a grid electricity connection at the point of use. DRE applications for post-harvest processing and storage also help avoid food losses, which amounted to as much as USD 15.2 billion (INR 92,651 crore) in FY2014 (Jha et al. 2015). The technologies can be designed to withstand extreme heat and high-speed winds (Ginoya et al. 2021), thereby enabling climate-resilient livelihoods in rural areas.

There have been various initiatives to promote DRE in India by governments and the private sector. Specifically, for livelihoods, however, most of the work is being done by individual entities. Organisations like Sustain Plus Energy Foundation, SELCO Foundation, Collectives for Integrated Livelihood Initiatives (CInI), and Rajiv Gandhi Foundation have been at the forefront of deploying DRE-livelihood technologies on the ground for marginalised communities.

The Government of India's *Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan (PM KUSUM)* scheme promotes the installation of solar water pumps by providing upfront capital support. It is among the major government initiatives which offers clean energy-powered solutions. On the other hand, the private sector has deployed solutions such as solar lanterns, home systems and mini-grids, funded by philanthropic and international developmental organisations. Some of the key technological enterprises working and enabling deployments in this sector include Husk Power Systems, OMC Power, SELCO Foundation, Simpa Networks, Greenlight, D.light, Frontier Markets and Dharma Life.

The Government of India, through its Ministry of New and Renewable Energy (MNRE), released a framework for promoting **DRE-livelihood** applications in February 2022 (MNRE 2022). This framework, the first of its kind in the world, is intended to facilitate the development of an enabling ecosystem for the widespread adoption of DRE-based livelihood applications in India.

1.2 Major stakeholders in scaling up DRE-livelihood technologies

End-users of these solutions; primarily low-income households in rural and peri-urban areas.

Enterprises deploying clean energy solutions for livelihoods, who are receiving capital and enterprise support from various startups and innovation programmes.

Ecosystem actors such as policymakers, financiers, impact investors, non-governmental organisations, civil society organisations and funders.

1.3 Need for evidence at scale

Key stakeholders – investors, financiers, policymakers, and market enablers – often seek meaningful evidence on the viability of clean energy–based livelihood solutions. But the lack of thorough research/transparent data restricts stakeholders from taking informed decisions. Therefore, Powering Livelihoods (PL) is undertaking such research, and intends to publish evidence on the market potential, viability, and impact of these DRE-livelihood technologies. We believe that the ecosystem stakeholders can use such transparent and data-based evidence to make decisions in future. This issue brief presents findings from the impact assessment study of DRE-livelihood technologies, supported by PL.

2. Scope of the research

Image: CEEW

CEEW's DIVYA GAUR (R) and WASE KHALID (C) conducting an impact assessment of the PL programme in Gumla, Jharkhand.

This section has details on the objective of the study, methodology and approach adopted for sampling, data collection as well as limitations that were identified during the process.

2.1 Research objectives

The aim was to generate evidence at scale on the socio-economic impact of DRE applications for livelihoods, based on the following factors:

- Changes in the income of users.
- Changes in the productivity of users.
- Perceived changes in social and gender-related norms/behaviours.
- Amount of emissions mitigated.

2.2 Types of DRE-livelihood technologies

The research evaluates the impact of the technologies currently supported by the PL initiative listed in Table 1. The technologies supported under the PL programme span sectors such as agriculture, animal husbandry, textile and food processing. They facilitate livelihoods that are cutting across sectors in villages across the country.

Table 1 Distribution of respondents according to the technology

Technology	Male respondents	Female respondents	Total number of respondents
Solar Silk Reeling and Spinning Machine	40	454	494
Small Horticulture Processor	41	4**	45
Small Solar Refrigerator	44	9**	53
Solar Vertical Fodder Grow Unit	36	35	71
Micro Solar Pump	26	48	74
Solar-run textile manufacturing unit	14	16	30*
Total	**201**	**566**	**767**

Source: Authors' analysis

Notes: *This sample consisted of people who work with solar charkhas, solar looms, and electrical sewing machines in solar-run textile manufacturing units that are supported by PL. The low population could not ensure a significant sample for the solar charkha and solar loom. However, we also provide qualitative insights into the user experience of solar charkhas and solar looms to strengthen the quantitative findings.

**As per the sales data received and the respondents we were able to contact.

2.3 Geographical coverage and timelines

The study was undertaken during February–September 2022. It covered users in areas (19 Indian states) where the PL programme enterprises have outreach or a customer base.

2.4 Methodology

A mixed-method approach was adopted for the study, with quantitative (surveys) and qualitative (in-depth interviews). A lean questionnaire was designed for the survey to make the data collection exercise efficient.

2.5 Sampling

The population for the study was drawn from the end-user data obtained from the PL-supported enterprises. For the survey, sample of end-users for each technology was calculated using a 95 per cent confidence interval and 5 per cent margin of error approach as per the data received from the PL-supported enterprises. Further, given the limited availability of the details on the end-users, and challenges of reaching them at the last mile, a convenient sampling approach was employed to select end-users for the survey. While this approach could lead to sample selection bias, it was ensured that there is an adequate representation of male and female respondents, technologies, and geographies, as per the end-user data available. The sample distribution across technologies is given in Table 1.

As the deployments have been highest for the silk spinning and reeling machine, relevant end-users make up the greatest proportion of the overall study sample. For in-depth interviews, a saturation approach[2] was undertaken to select the number of respondents. For each technology, at least five end-users were interviewed across various geographies. A total of 40 in-depth interviews were conducted for the current phase of the study.

2.6 End-user description

Survey respondents were end-users who own the machine or operate it as an employee/daily wage worker. The end-users for this research had used the machine for at least six months before the time of data collection.

2 The saturation approach refers to selecting respondents for qualitative interviews when new respondents do not offer new information/insights.

2.7 Data collection

Data collection for the research was conducted in phases. Initially, telephonic interviews were planned and conducted due to COVID-19 and related lockdowns. However, the success rate of computer-assisted telephone interviewing (CATI) was quite low (<20 per cent). Further, as end-users were located in remote areas with limited access to phones, it was challenging to speak for longer than 10 minutes. Therefore, on-ground data collection was started in March 2022 after some stabilisation of the COVID-19 crisis. About 13 per cent of the data was collected via telephonic interviews, and the remaining 87 per cent through in-person surveys. We onboarded a survey agency for data collection, with personnel engaged in all states where end-users were located. The enumerators conducted interviews and collected responses through a mobile-based application, collecting both quantitative and qualitative responses.

This research covers 767 end-users across 19 Indian states. It uses a mixed method approach to capture in-depth impact of the technologies

2.8 Research framework and key indicators

The research aims to capture the direct and indirect impacts of the technologies on end-users. Beyond the economic, social, and environmental impacts, we also determine the accessibility of financial subsidies and credit. A detailed list of indicators for each outcome is given in Table 2.

Table 2 List of impact indicators

Outcome	Indicators
Economic impact 	Income enhanced (INR/annum) as a result of using the product. End-users who have started engaging with the activity as a new livelihood/income-generating initiative. Creation or purchase of additional assets. New livelihood generation for users who do not own the technology.
Social impact 	Reduction in physical effort because of mechanisation. Reduction in overall time engaged in a livelihood. Change in confidence to buy assets and save money. Change in confidence in ability to earn and work. Change in support of family member/spouse. Increased spending on healthcare and children's education.
Environmental impact 	CO_2e emissions abatement through deployed DRE-livelihood technologies.
End-user monetary contribution for the technology (more than 60%) 	Number of end-users who contributed more than the benchmark. Number of end-users who availed subsidy. Number of end-users who availed loan. Number of end-users who availed neither of loan or subsidy.
Product efficiency 	Change in quantity of production with same number of working hours of earlier practice. Change in quality of production with same number of working hours of earlier practice.

Source: Authors' analysis

To establish the environmental impact of DRE-livelihood technologies covered by the study, the following baseline conditions were assumed:

- Silk reeling machines, solar charkhas, and micro food processors running on grid electricity generate certain emissions. These emissions can be mitigated if the machines are powered by clean energy sources.
- A diesel water pump discharging 10,000 litres per day (the typical water requirement of one acre farms covered in this study) creates CO_2 emissions during its operations. A micro solar pump replacing such a diesel pump would abate these emissions.
- A typical grid-powered 100 litre capacity refrigerator used for 275 days would consume about 357 units of electricity per year. A small solar refrigerator would replace this electricity consumption from grid and effectively abate the emissions resulting from the operation of a grid-powered refrigerator.

The environmental impact of DRE livelihood technologies was established through their usage data with similar grid/ diesel-powered technologies acting as benchmarks

All the calculations were done considering the CO_2 emissions factor (tCO_2/MWh) published by the Central Electricity Authority. The latest release in December 2022 establishes the emissions factor (tCO_2/MWh) at 0.81. This figure has been consistently applied in this research to arrive at the final emissions abated.

Concerning the environmental impact calculations, the following are some limitations:

- Challenges were identified in determining the environmental impact of hydroponically grown fodder replacing the conventional fodder grown on agricultural lands and the concentrate feed available in the market. Given that there are variations in the types of seeds used and the feed requirements with geography, establishing a benchmark and defining the boundary within which emission generating activities would be considered has been difficult. We intend to consult experts and researchers working in the animal husbandry and cattle feed production fields to reach a consensus on the best approach. Hence, we have not covered the environmental impact of this technology in this publication, but will incorporate any relevant findings into our final report.
- Similarly, for other technologies considered in this study, data was collected on a) usage of the DRE-livelihood technology, from the respondents, and b) specifications of the technology that the DRE-livelihood technology was replacing, from secondary sources. As we did not collect data on what variant of the technology respondents were using, we assumed a typical use case. We then calculated the emissions abatement for the technology's most deployed variant/capacity from this typical use case data.

Image: CEEW/Emotive Lens

Members of Sri Gayathri FPO led by Malleswaramma (C) setting up solar dryers in YSR Kadapa district, Andhra Pradesh.

2.9 Limitations

Research approach

In an ideal scenario, the impact of technologies would be derived using treatment and control groups. However, given the reality of self-selection of technologies by end-users, and the nature of the PL programme, it was challenging to conduct such experimental research, that is, to define control and treatment groups. Thus, the study has been limited to descriptive findings, and evaluating the impact of DRE-livelihood technologies along defined indicators.

Income increase attribution

Ascertaining people's income through surveys is always challenging (Kuhn 2019). Moreover, when households have multiple sources of income, it becomes even more difficult to accurately estimate changes to each income stream. To keep the data collection process simple for end-users, we only asked for total annual household income before and after the adoption of the DRE-livelihood product. This means that in some cases, the net change in income may be due to factors other than DRE-livelihood technologies. A typical way to address this would be to have a control group. But, as discussed earlier, this was not possible.

We consider the income impact on end-users in two ways. For end-users who reported the use of the DRE-livelihood product as their primary source of income (including end-users who reported not having earned an income before), the income increase was wholly attributed to the DRE-livelihood product.Some end-users mentioned that their use of the DRE-livelihood product was a secondary source of income; in these cases, the income increase was attributed to the technology, but not entirely. For such end-users, the data on the number of days of usage and reported output of the technology was used to validate the income increase.

Gross income vs net income

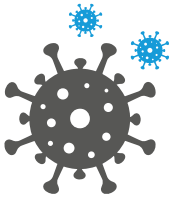
Calculating net income for end-users has been a challenge. The question we asked during the survey was, "What is your annual income after using the DRE-livelihood product?". We could not determine whether responses referred to gross or net income. In Phase II of the survey, which is planned for 2023, our learnings from Phase I will be incorporated. Therefore, questions on gross vs net income and relevant specifics (income and expenses) will be added to ensure accurate reporting.

Understanding income gains across different use cases

Some products, such as multipurpose food processors and small solar refrigerators, can have wide variations in income gains depending on the use case and/or value chain within which the product is being used. For example, storing fish, dairy products, or cold drinks in a refrigerator may lead to different income gains. Given the limited number of respondents across each individual use case, we could not establish business category–wise income impacts.

Impact of COVID-19

Most rural communities were hugely impacted by COVID-19, starting in March 2020. Their livelihoods were affected by supply chain disruptions, limited demand for discretionary products, and minimal government support. Therefore, usage patterns, income changes, and overall feedback may not be entirely representative of usual times.



COVID-19 may have impacted the usage patterns of technologies, income changes and overall feedback from the users

2.10 Ethical considerations

CEEW complies with the highest ethical standards and ensures that the rights of human research subjects are protected. It ensures a strict due diligence process, including institutional review board (IRB) clearance for all primary surveys. This process was followed for this impact assessment study, and an IRB certification was issued.

CEEW follows a data-sharing protocol to minimise the sharing of identifiable information of users to maintain the privacy of respondents. Consent was taken from every end-user before surveying or photographing them during interactions on field.

Image: Wase Khalid/CEEW

A user working on Ghani based oil extraction machine for sesame seeds in Rajkot, Gujarat.

3. Impact assessment findings

Image: CEEW/Emotive Lens

Neetu Tandon, a micro- entrepreneur uses a multi-purpose micro-food processing machine in Agra, Uttar Pradesh to manufacture various products.

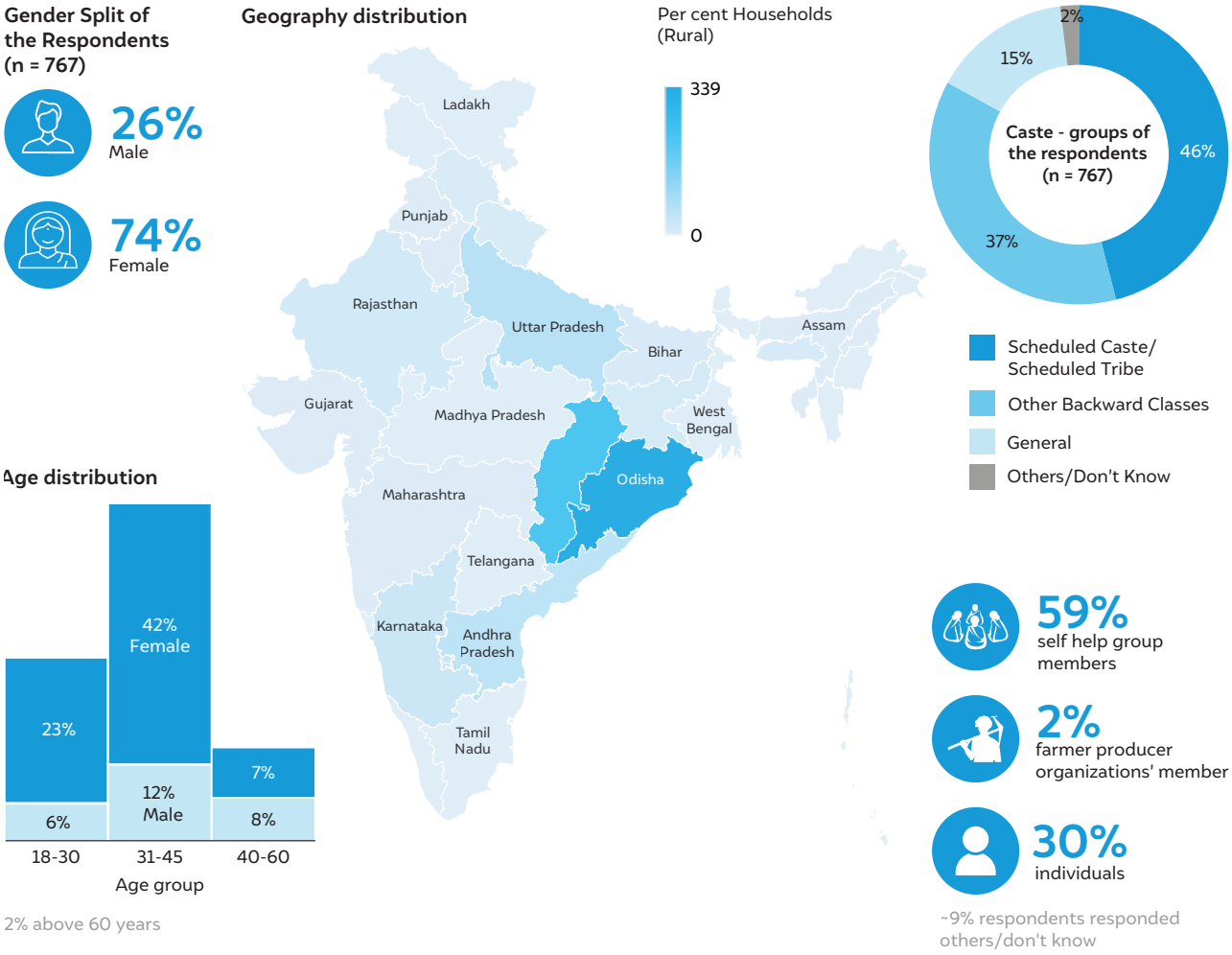
This section summarises the economic, social, and environmental impacts that DRE-livelihood technologies have on users. It also presents insights from the field to highlight the perspectives of end-users.

3.1 Respondent profiles

End-user demographics

This section presents findings from the study and the profile of a typical end-user. The survey was conducted in 19 states and union territories across the country. Most respondents were from the Indian states of Odisha and Chhattisgarh, comprising a combined share of 73 per cent. The rest were from Uttar Pradesh, Andhra Pradesh, Karnataka, and Rajasthan. The geographical distribution is representative of the adopters of technologies in these regions.

Figure 1 A typical respondent is a female, aged aged 30-45 years, located largely in the central and eastern India belt, belonging to an SHG



Source: Authors' analysis

Almost 60 per cent of respondents belonged to the 30–45 age group, followed by 24 per cent from the 18–29 age group, and the remaining 16 per cent from the 46–70 age group. With almost 25 per cent of users being younger than 30 years, there is a significant opportunity to build the capacities of youth entrepreneurs using DRE-livelihood products. This would enable them to have sustainable sources of income. Solutions such as solar silk reeling machine and solar charkhas, in particular, had many young users. This indicates the inclination of youths at the village level to earn secure incomes through such technologies that improve productivity.

The majority (>80 per cent) of end-users belonged to marginalised castes (Scheduled Castes, Scheduled Tribes, and Other Backward Classes). More than 50 per cent were members of collectives such as self-help groups (SHGs) and farmer producer organisations.

There were more female than male respondents because technologies like solar silk reeling machines, micro solar pumps, and solar charkhas are mostly adopted by women.

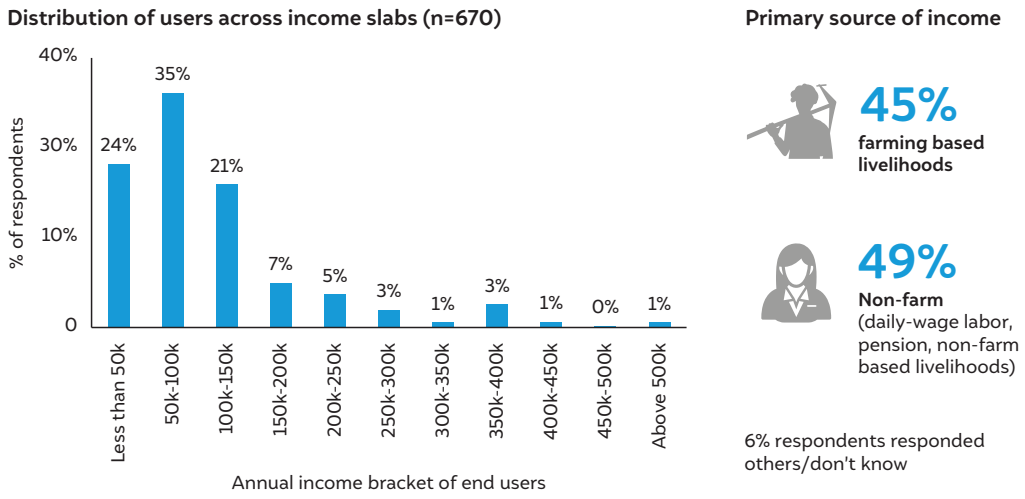
Economic background of the respondents

About 75 per cent of users had an annual income of less than INR 150,000 (USD 1,829; USD 1 = INR 82) before adopting the DRE-livelihood technology. About 45 per cent of respondents were earning their primary income from agriculture and associated activities. Almost 50 per cent of respondents earned their income from non-farm livelihoods such as daily wage labour, pensions, and other sources (Refer Figure 2).

Procurement of technology

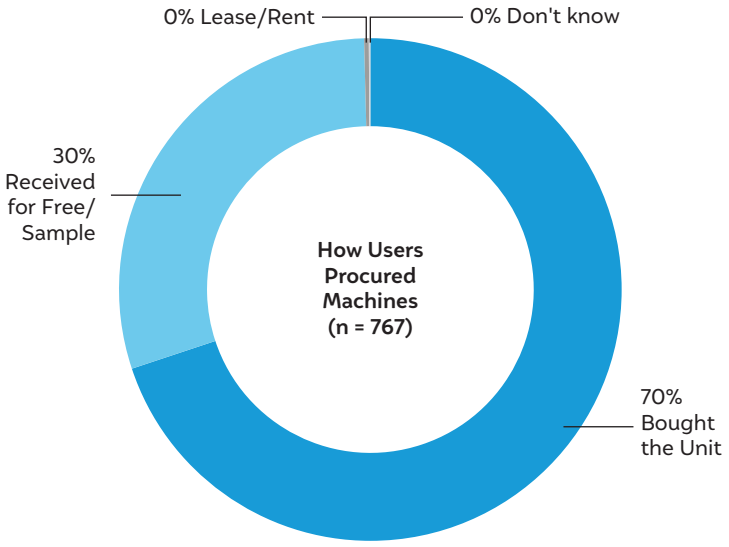
Around 70 per cent of users bought the DRE-livelihood machine or technology by themselves. This included individual and group ownership. The remaining end-users had the machine because the government, an NGO, or philanthropic organisations deployed the technology free of cost to them. In some cases, the end-user rented/leased the technology for some time before returning it to the owner (Refer Figure 3).

Figure 2 Most users adopting the DRE solution, had an annual income of INR 50,000–100,000



Source: Authors' analysis

Figure 3 70% users bought the unit, while some got it free of cost or on lease



Source: Authors' analysis

Users who had bought the unit were further asked if they had purchased it on their own, as a group (a registered entity), or in partnership with someone else. Around 79 per cent of the total users who bought the unit had bought the unit on their own, while group and partnership purchases were 10 per cent and 11 per cent, respectively. During our interactions with users, we learnt that users preferred to procure the units on their own so that they can use it at their convenience, without worrying about sharing it with others.

Users were largely unaware that they had availed of a subsidy while procuring the solution

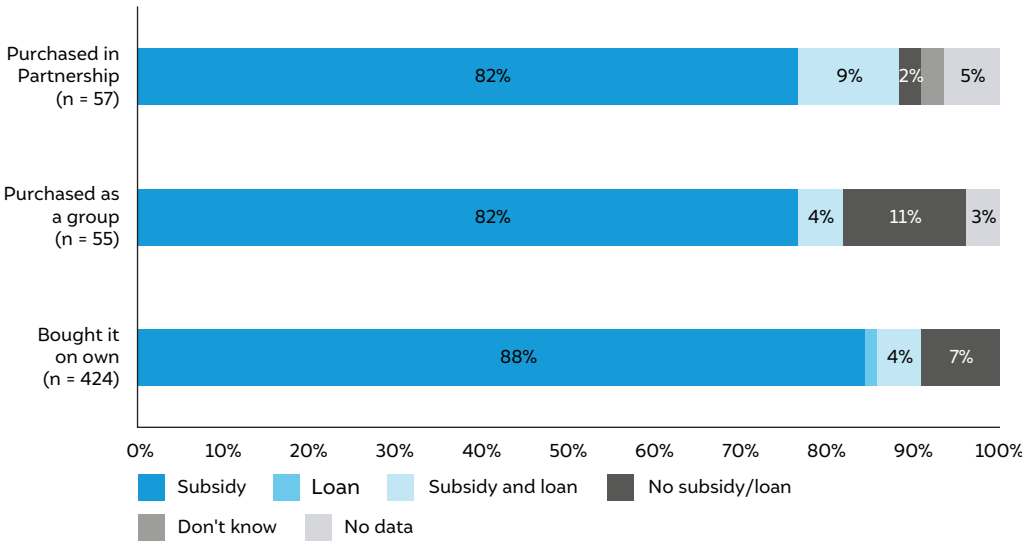
More than 80 per cent of users who had bought the unit independently were not aware that they had availed of some subsidy (Refer figure 4). We inferred the existence of a subsidy by deducting the price they paid from the market price of the technology. Users contributing less than 60 per cent of the market price of the technology were considered to have availed subsidy. Subsidies are provided by government departments, NGOs, and philanthropic organisations. Some technologies, such as solar silk reeling machines, have been institutionally supported at scale by government departments (Refer figure 5).

Technology adoption through financing has been minimal

Only three per cent of users reported availing of a loan to procure the DRE-livelihood equipment. For them, banks and SHGs were popular sources of loans, disbursing 88 per cent of the loans reported. Other sources like microfinance institutions (MFIs) and local moneylenders made up the rest. While women end-users preferred SHGs to secure loans, male end-users preferred banks. We found that 88 per cent of users who availed of a loan also availed of a subsidy. On the other hand, a few users reported that they did not need to take out a loan, as they had had sufficient savings; since the unit was subsidised, they were able to cover the remaining cost. Overall, about five per cent of users procured the solution with neither a subsidy nor a loan.

Figure 4 Most users who bought the unit themselves, availed some subsidy

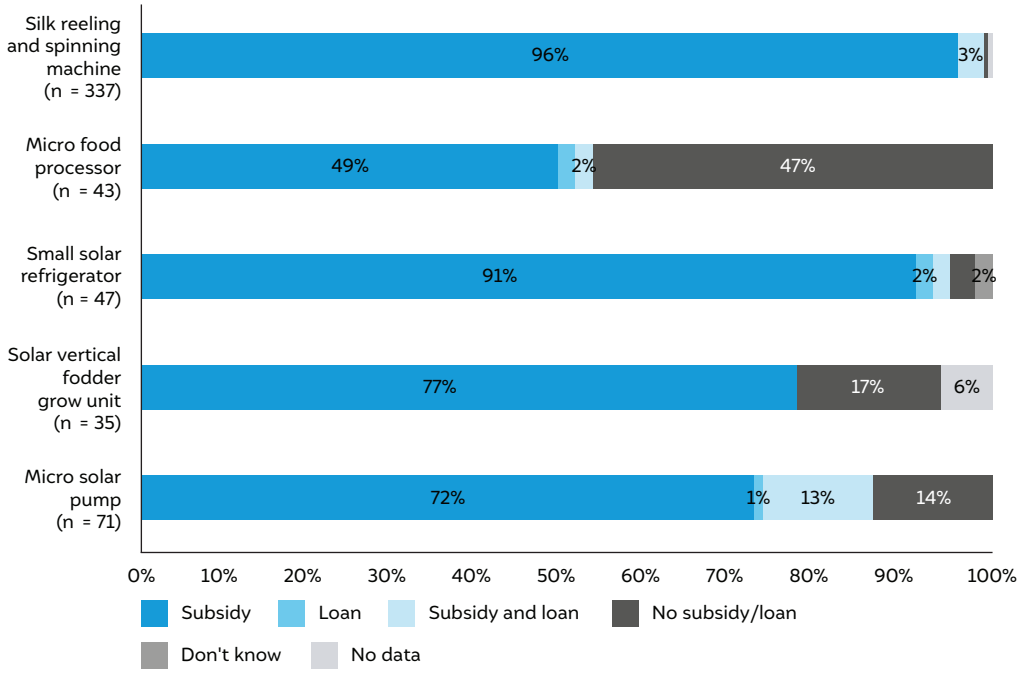
Share of users availing different capital resources beyond their contribution



Source: Authors' analysis

Figure 5 ~95% of silk reeling machine users got some subsidy

Share of users availing different capital resources beyond their contribution



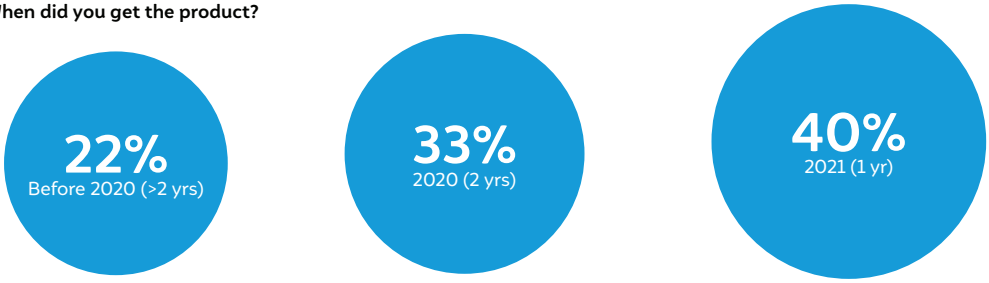
Source: Authors' analysis

About 40% of end-users procured the product at least one year ago and have been using it for more than a year

Many end-users had had the product for at least one year (40 per cent). More than half the respondents had procured the product at least two years prior. We deliberately sampled users so that we could understand the impact of the DRE-livelihood technologies over a reasonable amount of time.

Figure 6 About 25% of the total users had had the product for more than two years

When did you get the product?

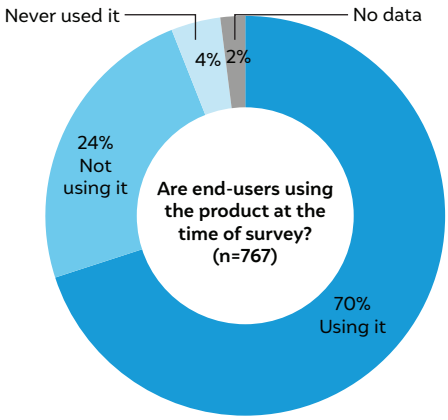


~5% respondents did not respond

Source: Authors' analysis

Most end-users were using the product at the time of survey

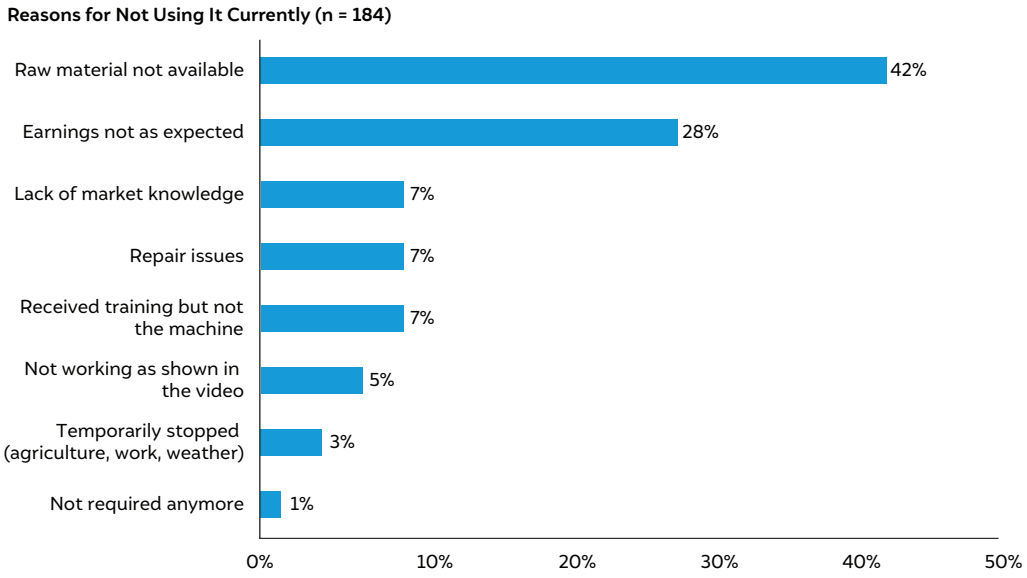
Figure 7 ~70% of respondents were using the DRE-livelihood technology at the time of the survey



Source: Authors' analysis

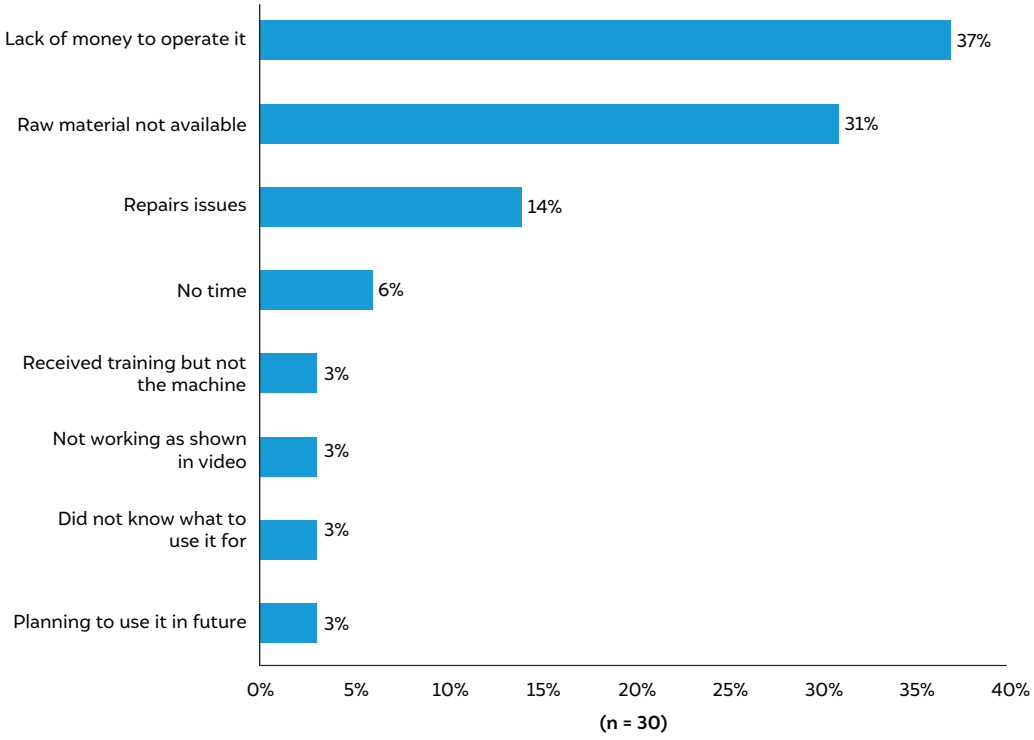
We found that of the end-users who were not using the product, 70 per cent had purchased **the product on their own**. Of those who had received the product free of cost, 36 per cent were not using it, eight per cent had never used it, while the remaining 55 per cent were using it. On the other hand, among users who had bought the product on their own, 30 per cent were not using it, four per cent had never used it, while the remaining 66 per cent were using it. One reason for not using the product was that raw material was not available. For instance, users of solar silk reeling machines reported that they were not able to use the product due to the non-availability of cocoons. About 28 per cent of end-users who were not using the product at the time of the survey mentioned lower earnings than expected as the reason for the discontinuation.

Figure 8 Raw material unavailability and lower-than-expected earnings influenced people's use of the technology



Source: Authors' analysis

Figure 9 Users who never used the product mentioned a lack of working capital and raw material unavailability as their top concerns



Source: Authors' analysis

There were a few cases of repair-related issues, users not having received the machine after being trained in how to use it, and the machine not working as shown in the training videos. About three per cent of users had stopped using the product temporarily due to cultivation work or weather-related reasons such as summers for micro solar pump, or, in some cases such as fodder stations, because of cyclones/storms. For users who had never used the machine, the top reasons were a lack of adequate working capital followed by raw material unavailability (Refer figure 9).

DRE-powered technologies positively change income for more than 70% of its users. Further, 11% of women end-users started earning for the first time through the usage of DRE-powered technologies

3.2 Economic impact

The economic impact of the technologies has been evaluated by considering the change in people's income after they adopted the technology. As such, users were asked to declare their income before and after beginning to use the product. Further, questions about how users spent the increased income helped us understand the consequential economic impacts.

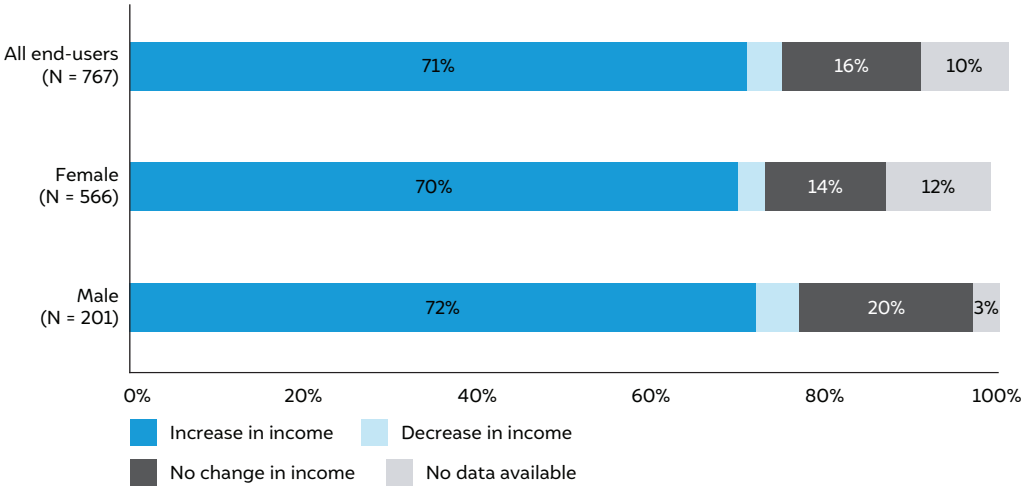
~20% of end-users relied on the DRE-livelihood product as their primary source of income

~11 per cent of end-users started earning an income for the first time since starting to use the DRE-livelihood technology. Most of these end-users were women working on solar charkhas and solar silk reeling machines. These technologies enable the women to work in their households or in nearby clusters. This helps them overcome the challenges of mobility and social barriers.

~21 per cent of end-users moved to DRE-livelihood technologies such as solar silk reeling machines, solar charkhas and micro food processors, which became their primary sources of income. For the most part, end-users were previously engaged in agriculture and allied activities such as cattle rearing.

Majority of users experienced an increase in income after using the DRE-livelihood technology

Figure 10 More than 70% of users reported an increase in their annual income after adopting the DRE-livelihood product



Source: Authors' analysis

The study, owing to challenges associated with collecting accurate data on the income and expenditures of users, considered only the responses of end-users for the analysis.

Among those who had experienced an increase in income, the median income increased by INR 28,000 (USD 341),[3] from a baseline annual income of INR 80,000 (USD 975)

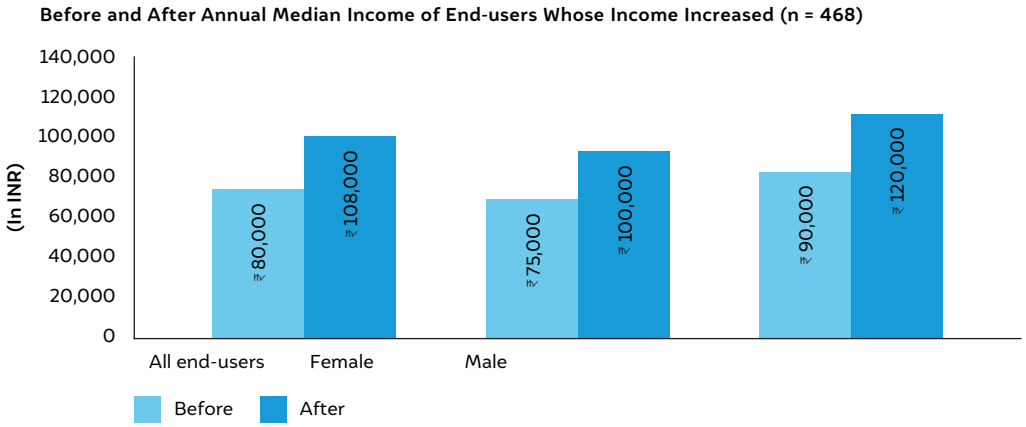
For those who were earning an income before, the median annual income increased by 35 per cent. End-users who were not previously making started earning INR 36,000 ($ 439) annually from the DRE-livelihood solution. As these are self-reported values, there could be errors that we cannot rule out. Further, end-users who made DRE-livelihood solutions their primary source of income reported a higher median income increase (55 per cent) than others (25 per cent).

Image: Selvaprakash Lakshmanan/Swiss Re Foundation/Fairpicture

Rugaram Goyal, aged 50, selects a tray of hydroponic fodder to buy at a vertical farming station in Ghantiyali, Rajasthan, India.

3 Conversion rate USD 1 = INR 82.

Figure 11 Users with an income before the intervention experienced a 35% increase in their annual income



Source: Authors' analysis

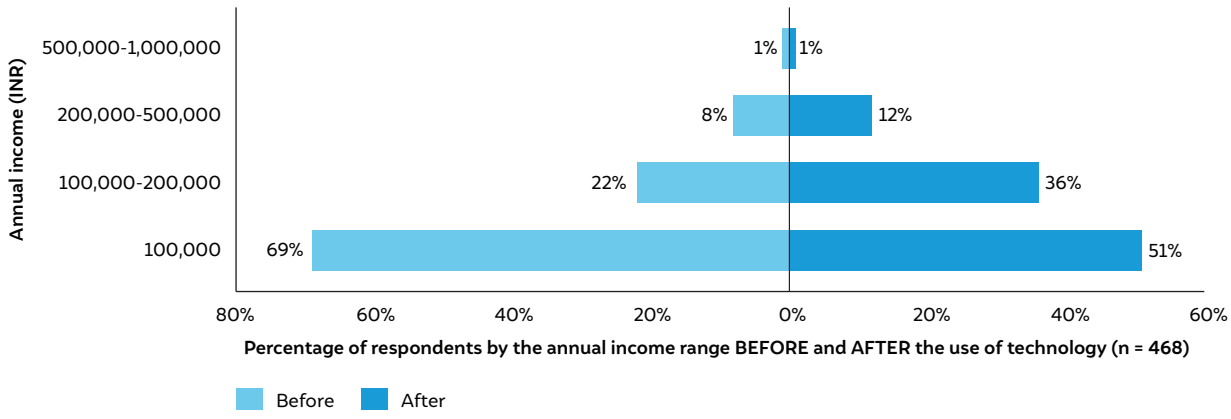
End-users moved to a higher income group after using the product

Of the end-users who reported their income, most earned less than INR 100,00 annually (69 per cent), followed by those who earned in the range of INR 100,000–200,000 (22 per cent), and INR 200,000–500,000 (8 per cent). Following their usage of the DRE-livelihood technology, many users moved up the income ladder (Refere figure 12). This was clear from the sharp reduction of those who earned less than INR 100,000 (18 percentage points) and the increase in the share of users who earned between INR 100,000–200,000 (over 10 percentage points).

End-users reported additional savings from reduced diesel and electricity usage

End-users, specifically for technologies such as micro solar pumps and small solar refrigerators, reported savings on diesel and electricity, respectively. From our conversation with micro solar pump users in Odisha, we found that farmers are able to save approximately INR 13,000 - 16,000 annually due to reduced usage of diesel. While it was not possible for this study, for the next phase of the survey, distinction would be made in the savings from diesel and the incomes reported by the users. The market price of the pump is about INR 45,000, necessitating a payback period of two or three years, without accounting for the additional income earned through more cropping cycles. Similarly, for those who switched from grid-based refrigerators to small solar refrigerators, savings on electricity amounted to at least INR 500 per month.

Figure 12 Adopting DRE-livelihood technologies can help users move to higher income brackets



Source: Authors' analysis

Box 1 Stories from the ground

Kuni Dehury is a master silk reeler from Keonjhar, Odisha. She had to stop studying early on earn for her family. With her experience in silk reeling from a very young age, she has now has setup a small centre in her village where she trains women in silk reeling. She has, so far, successfully trained more than 500 women on solar silk reeling machines at the Tassar Silk Park. The center has more than 250 solar silk reeling machines. She says these machines help the women increase their monthly incomes from ~INR 1500 to ~INR 6000, and also helps the centre cut down on electricity costs.

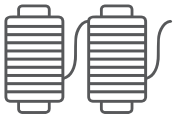
Source: CEEW

At least 25% users can pay for their respective technologies with increased incomes

To understand the viability of a few DRE-livelihood technologies, we analysed end-users' ability to repay loans only from the additional income generated from using these technologies. For viability calculations, these technologies were assumed to have been procured with the end-user contributing 10 per cent and the remaining 90 per cent being funded by a loan with a two-year tenure and a 16 per cent annual interest rate. Here, the technology would be considered viable if the user were able to repay the loan just from the income earned by using the DRE-livelihood technology.

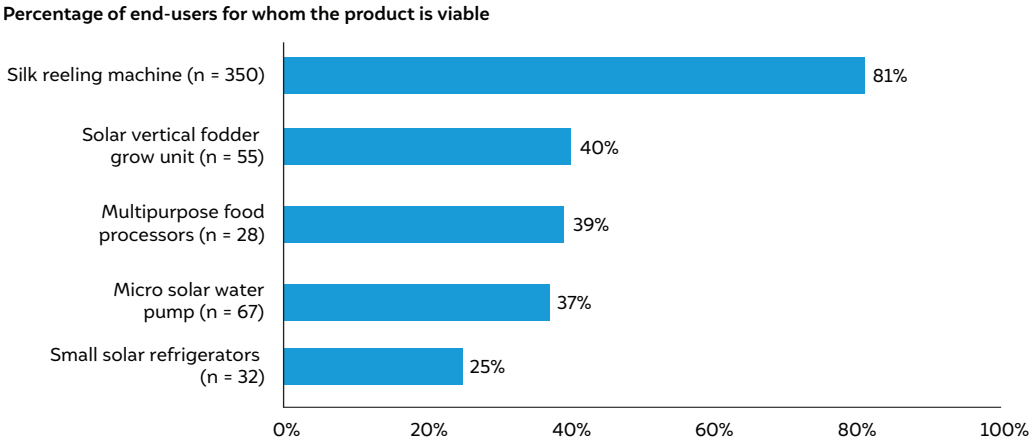
Besides silk reeling machines, which about 80 per cent of users found viable, at least one-fourth of users for each of the remaining technologies found them viable. This could be crucial information for

- policymakers to understand the types of financial and loan models that work best for such end-users in rural areas
- banks and financing institutions, especially when there is a significant difference in the cost of credit disbursement and maintenance between rural and urban areas.



81% users of the silk reeling machine can repay loan for the technology, only through increased incomes

Figure 13 More than 33% of users can pay for the solution without a subsidy for 4/5 technologies



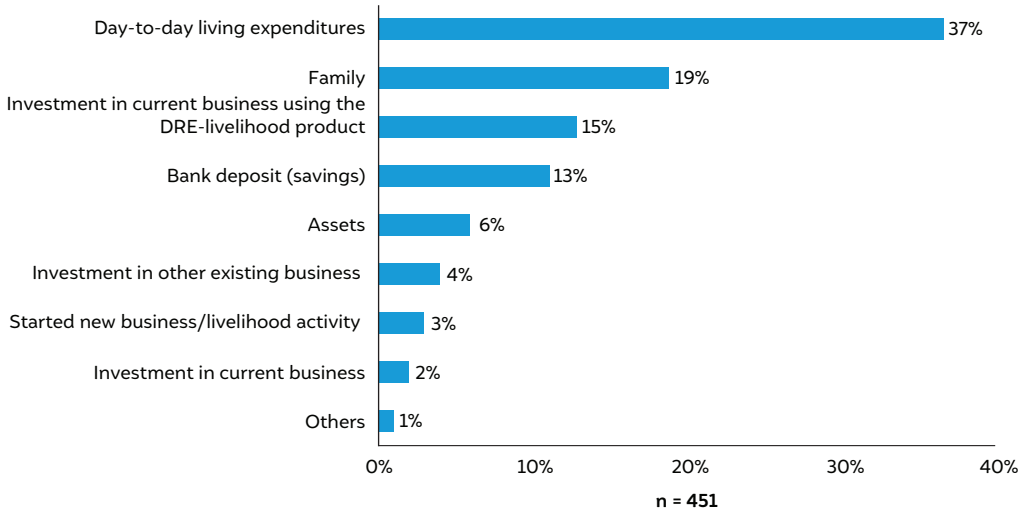
Source: Authors' analysis

How do households spend the additional income?

We tried to understand how users spent their additional income. Most respondents mentioned spending the money on day-to-day living expenditures, on their families, and on expanding their businesses/livelihoods.

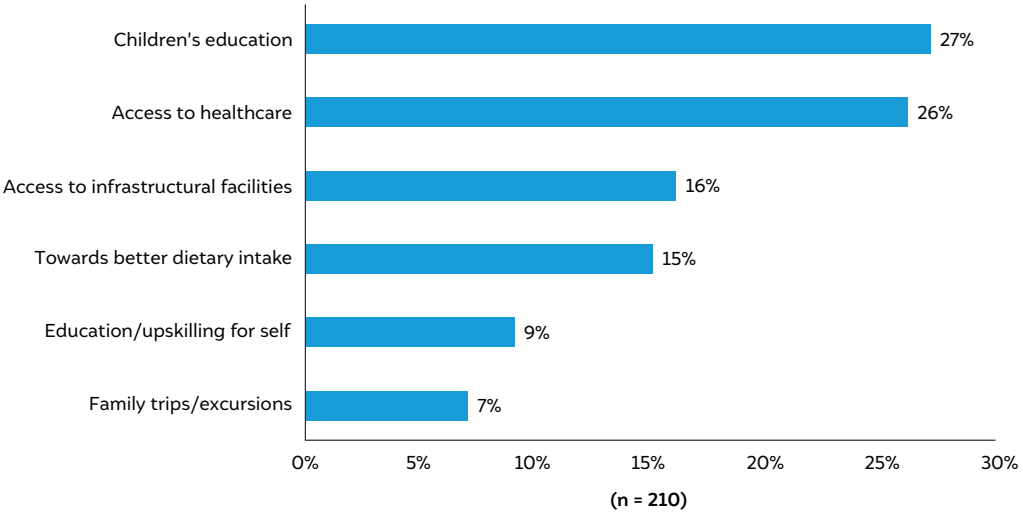
Notably, more than 15 per cent of users who experienced an increase in their income mentioned having invested a part of those funds back in the DRE-operated business. Meanwhile, end-users who had invested in their families mostly spent the money on their children's education and on improving their access to healthcare.

Figure 14 Typically, users preferred to spend the increased income on daily expenses



Source: Authors' analysis

Figure 15 More than 50% respondents invested in their children's education and healthcare



Source: Authors' analysis

Box 2 Stories from the ground

Image: Khethworks

Bahuri Devi, 36, is a smallholder tribal farmer from Gumla, Jharkhand, with 0.63-acre farmland where she primarily grows vegetables. Previously, Devi was dependent on diesel and grid-run water pumps for her irrigation requirements. Through the use of the micro solar pump in the last year and a half, Devi has been able to save up to INR 12,000 annually on the fuel costs of running a conventional pump.

Further, she has also been able to increase the number of cropping seasons to two.

"Pehle 10 decimal mei kheti karte the, ab 20 decimal mei karte hain. Pehle kheti ka kaam December tak chalta tha, ab agle saal March tak chalega"

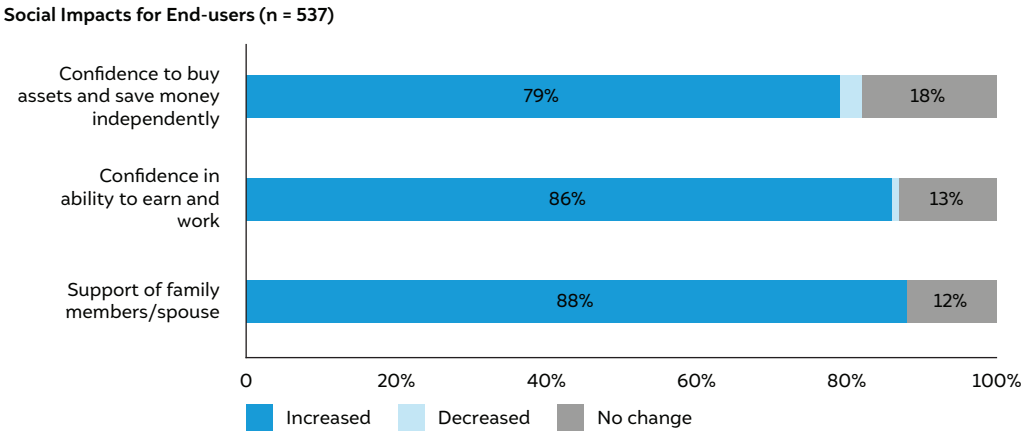
(With the solar pump, I have been able to increase the area under cultivation from 10 decimal to 20 decimal. Similarly, I could work on my farm only till December earlier, but now I'm able to work till March.)

Source - Authors' compilation

3.3 Social impact

We wanted to understand whether DRE-livelihood products have any social impacts beyond improving the income of users. We measured social impact through perception-based questions on changes in these factors: i) end-users' confidence in their ability to earn and work, ii) availability of support from family members/spouse, and iii) end-users' confidence to independently buy assets and save money after using the technology. While these are typically long-term impacts, responses were recorded based on end-users' understanding of the benefits that using the technology had on these social aspects in the first 6 months to 1 year.

Figure 16 Improved livelihoods enhance social aspects of life



Source: Authors' analysis

We found that the technologies successfully helped improve the general confidence of end-users and the level of support they received from their families. About 86 per cent of respondents reported greater confidence in their ability to earn and work. During the in-depth interviews, most of the women end-users mentioned that the machines reduced the time and effort required to manually produce the same output. This increased their motivation and capacity to work while managing household-related tasks. Also, the ability to work in their homes or nearby played a significant role in improving their confidence in their ability to earn and work. This helped them get support from their families while continuing to work.

Drudgery reduction

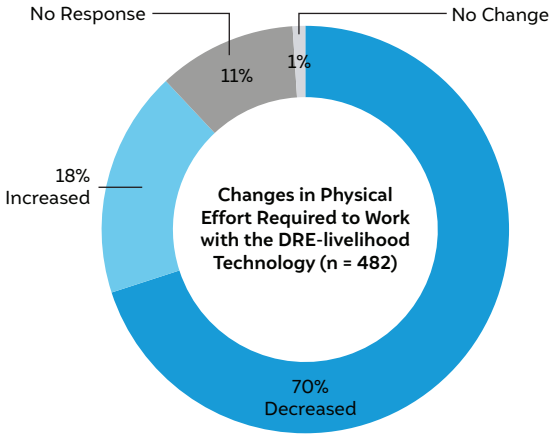
Most users (70 per cent) reported a reduction in the necessary physical effort compared to their earlier practices – working manually or using conventional appliances – especially for technologies such as silk reeling machines, vertical fodder grow units and micro solar pumps (Refer figure 17).

3.4 Impact on women

With a gender-focused approach, the PL programme has several initiatives that integrate women into clean energy-powered livelihoods. Therefore, we wanted to understand the impact of the DRE-livelihood products on gender-related norms for women end-users. Most women end-users reported positive changes in their participation in community events (89 per cent), increased knowledge and skills that made them more relevant in the workforce (92 per cent), enhanced mobility (72 per cent), and more agency to make decisions (76 per cent) (Refer figure 18).

DRE livelihood technologies improve women's agency, mobility and social life while earning sustainable incomes

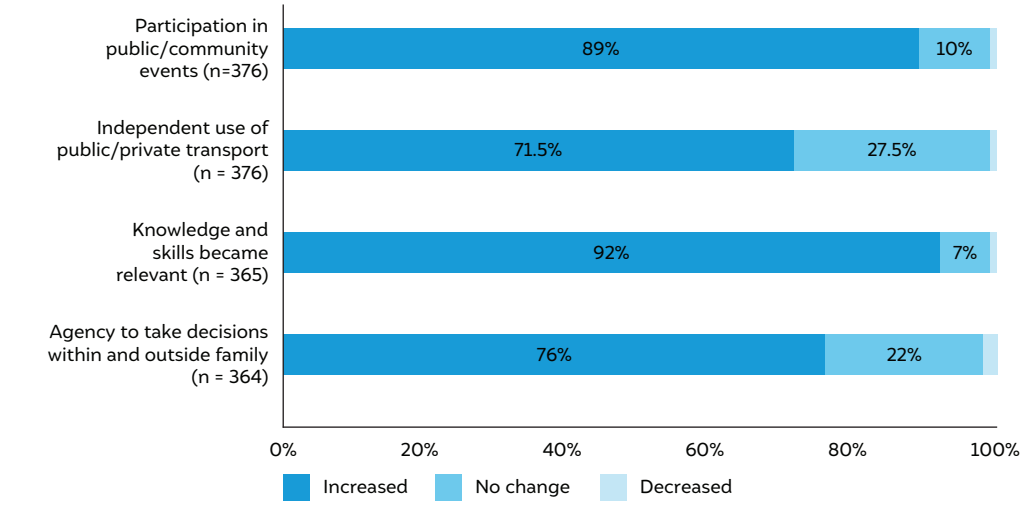
Figure 17 About 70 per cent of the respondents felt that DRE-livelihood technologies reduced their physical effort/drudgery



Source: Authors' analysis

Figure 18 Women end-users gained agency over their decisions across scenarios

Perceived social impacts on women end-users



Source: Authors' analysis

Box 3 Stories from the Ground

Image: DD Solar

Maitree Mahila Dairy and Agriculture Producer Company, one of the many farmer producer groups which adopted the small solar refrigerator in Rajasthan, is managed and run entirely by rural women in the Duni village of Tonk district. It is promoted by Self-reliant Initiatives through Joint Action (SRIJAN).

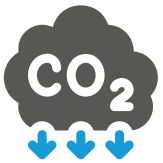
The group is involved in processing of goat milk and preparation of milk products from it. Through SRIJAN, they had installed solar DC refrigerators in 2020. This intervention helped to triple the processing capacity of the unit, and increased revenue by significantly reducing the cost of electricity.

Now the women are planning to increase the variety of products that they manufacture and expand the area in which they market the product. They also intend to procure more refrigerators to cater to their business expansion plan. This group exemplifies what a women's collective with a clear objective and support from the system can achieve.

Source - Authors' compilation

3.5 Environmental impact

Apart from helping improve income and productivity among end-users, DRE-powered livelihood technologies may also mitigate potential GHG emissions compared to a business-as-usual scenario in which conventional, inefficient, and fossil fuel-powered technologies are used. A huge section of the rural population – especially those involved in agriculture – is rising up the productivity ladder, with mechanisation occurring across the value chain. This has the potential to significantly influence the energy and emissions intensity of the country as a whole. DRE-livelihood technologies can play a critical role here in mitigating these emissions, thus helping to preserve natural ecosystems.



660 metric tonnes of CO2e were the cumulative emissions mitigated from over 7,000 clean energy technologies during the PL programme between June 2020 – April 2022

We collected data on people's use of these technologies – such as the number of hours of use per day and number of days in a month – to establish the amount of CO_2 emissions abated. The detailed analysis approach along with limitations of the calculations in the case of each technology has been explained in section 2.8. We find that the cumulative emissions mitigated from over 7,000 deployments of the 6 technologies (Table 1) in June 2020–April 2022 is around 660 metric tonnes of CO2 emissions. While these technologies are primarily slated to decrease emissions that would arise from the use of conventional livelihood appliances, there are cases where emissions abatement can happen across the value chain and not just at the user level such as in the case of solar vertical fodder grow unit. The solar vertical fodder grow unit, unlike other technologies, does not just abate emission that would arise if it were to be used on grid electricity. Through hydroponically grown fodder, it also helps mitigate emissions from fodder that would be grown using conventional cultivation practices. To establish the environmental impact in these cases, a consensus on approach could be arrived at, through collaboration between sector experts and researchers.

4. Technology-wise findings

In this section we present findings according to each technology covered in the assessment. We intend to highlight the impact of the technologies on income, productivity, as well as social and gender-related indicators.

4.1 SOLAR SILK REELING AND SPINNING MACHINES

Image: Reshamsutra

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. Till date, approximately 14,000 solar-powered silk reeling machines have been deployed in India.

The findings below are from a primary survey conducted through in-person and telephonic interviews between February - September 2022.

States surveyed
(share of respondents)
55% Odisha
45% Chhattisgarh

Respondents*
494 Total
92% Females
49% OBC
45% SC/ST
6% General

Users
73% First-time silk reelers
71% SHG members

**All respondents procured the machines for at least one year before the survey, with 61% using them for more than one year.*

INCOME IMPACT

Users experiencing income increase

70%

83%

₹ 36,000 increase in annual income for a typical user from a baseline income of ₹ 60,000.

13% female users earn for the first time.

Source: CEEW analysis 2022

Top five spends of increased income

36% use it for day-to-day expenditure

18% invested in the livelihood activity of silk reeling

17% invested in family

14% deposited in the bank as saving

6% bought assets

Source: CEEW analysis 2022

PRODUCTIVITY IMPACT

2x
increased productivity compared to earlier reeling practices (manual and grid-powered machines)

63%
users experienced an **improvement in yarn quality**

2 hours
a day, average time **saved on silk reeling**

72%
users reported **no physical strain/reduced effort** with the machine

Source: CEEW analysis 2022

Technology usage at the time of survey

65% Using it	31% Not using it	4% Never used it

Top five reasons for not using it

36%	17%	16%	9%	8%
Raw material unavailability	Earnings not as expected	Produce/output not as expected	Machine unavailability (wage earners)	Lack of marketing knowledge

Source: CEEW analysis 2022

SOCIAL IMPACT

94%
users experienced **increased support from family members/spouse**

93%
users reported improvement in **confidence to earn and work**

87%
users now have a better ability to **buy assets and save on own**

Source: CEEW analysis 2022

IMPACT ON WOMEN

94%
believe they have the relevant **knowledge & skills to become self-reliant**

87%
report increased participation in **public/ community events**

74%
believe they have better agency to **take decisions in family**

73%
more confident about using **public/private transport on own**

Source: CEEW analysis 2022

ENVIRONMENTAL IMPACT

1.1 MT
CO_2 abatement*

**For every 100 units of Unnati (silk reeling) machine used for 5 hrs for 192 days a year.*
Source: CEEW analysis 2022

4.2 SMALL HORTICULTURE PROCESSORS

Image: CEEW/Emotive Lens

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. Till date, approximately 600 small horticulture processors- have been deployed in India.

The findings below are from a primary survey conducted through in-person and telephone interviews between February - September 2022.

States surveyed (share of respondents)

31% Uttar Pradesh	20% Uttarakhand	11% Himachal Pradesh	9% Rajasthan	
7% Haryana	7% Maharashtra	7% Punjab	2% Gujarat	2% Delhi

Respondents*

45 Total

91% Males

9% Females

80%	General
7%	SC/ST
7%	OBC
6%	Don't know

Users

78% processing for the first time

36% own/ involved in a business

**71% respondents procured the machine for at least six months before the survey, with 67% using it for at least six months.*

INCOME IMPACT

62% users experienced income increase

₹ 60,000 increase in annual income for a typical user from a baseline income of ₹ 220,000

24% users experienced an increase of more than ₹ 1 lakh in their annual income

Source: CEEW analysis 2022

Top five spends of increased income

- **36%** used it for day-to-day expenditure
- **36%** reinvested in current business
- **9%** invested in family
- **9%** began new business/ livelihood
- **9%** invested in another existing business

Source: CEEW analysis 2022

PRODUCTIVITY IMPACT

88%
users reported **no physical strain** involved in the operation of the technology.

84%
users reported **satisfaction with the multi-purpose** food processor.

73%
users **process more than one commodity** with the food processor.

6
different kinds of commodities were typically processed using the machine.

Source: CEEW analysis 2022

Machine usage at the time of survey

80%	11%	9%
Using it	Not using it	Never used it

Image: CEEW/Emotive Lens

ENVIRONMENTAL IMPACT

54 MT
CO_2e abatement per year*

** For every 100 units of small horticulture processor used on clean energy for 7 hours daily for about 173 days a year,Source: CEEW analysis 2022*

4.3 SMALL SOLAR REFRIGERATORS

Image: CEEW/Emotive Lens

The energy-efficient and solar-powered DC refrigerator provides reliable cooling for a wide range of commodities (dairy products, fish, cold drinks, vaccines) with ozone-friendly refrigerant (Ozone depletion potential - 0). It decreases spoilage of perishables and provides savings on users' electricity bills. Till date, approximately 500 small solar DC refrigerators have been deployed in India.

The findings below are from a primary survey conducted through in-person and telephone interviews between February - September 2022.

States surveyed
(share of respondents)

- 32% Uttar Pradesh
- 32% Karnataka
- 19% Meghalaya
- 13% Odisha
- 4% Rajasthan

Respondents*

- 53 Total
- 83% Males
- 17% Females

55%	General
37%	SC/ST
8%	OBC

Users

- 76% using it for businesses
- 15% using it only for household use
- 9% using it for both

**85% respondents procured the machine at least six months before the survey, with 87% using it for at least six months.*

INCOME IMPACT

60% users experienced income increase

₹ 24,000 increase in annual income for a typical user from a baseline income of ₹ 60,000

₹ 2,100 of average savings from electricity bills in a year (assuming unit electricity price of ₹ 6).

**29% users had no change in their income (50% of these are household users)*
Source: CEEW analysis 2022

Top five spends of increased income

- **33%** used it for day-to-day expenditure
- **25%** invested in family
- **25%** reinvested in current business
- **15%** deposited in the bank as saving
- **1%** invested in another existing business

Source: CEEW analysis 2022

PRODUCTIVITY IMPACT

41%
users saw a **decrease in spoilage of products/goods**

34%
users reported **savings on electricity bill**

37%
users report an **increase in the quantity of products** that can be stored

31%
users with income **increase experienced more than one benefit**

Source: CEEW analysis 2022

Technology usage at the time of survey

94% Using it	2% Not using it	4% Never used it

Top three business use cases

28% Dairy | **22%** Frozen food items | **17%** Beverages

Source: CEEW analysis 2022

Image: CEEW/Emotive Lens

ENVIRONMENTAL IMPACT

29 MT
CO_2e abatement per year*

**For every 100 Units of Solar DC refrigerator used for 24 hrs for 275 days a year.*
Source: CEEW analysis 2022

4.4 SOLAR VERTICAL FODDER GROW UNIT

Image: Hydrogreens

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. Till date, approximately 210 solar-powered vertical fodder grow units have been deployed in India.

The findings below are from a primary survey conducted through in-person and telephone interviews between February - September 2022.

States surveyed
(share of respondents)

69% Andhra Pradesh
16% Karnataka
14% Rajasthan
1% Bihar

Respondents*

71 Total
49% Females

56% SC/ST
31% OBC
13% General

Users

65% rear cattle for primary income
75% SHG members

**79% respondents procured the machines for at least one year before the survey, with 98% using them for at least six months.*

INCOME IMPACT

Users experienced income increase

86%

69%

₹ 24,000 increase in annual income for a typical user from a baseline income of ₹ 96,000

66% users also realise better milk prices with an average increase of ₹ 2 per litre

Source: CEEW analysis 2022

Top five spends of increased income

44% use it for day-to-day expenditure

21% invested in family

20% bought assets

11% deposited in the bank as saving

2% began a new business/ livelihood activity

Source: CEEW analysis 2022

PRODUCTIVITY IMPACT

69%
users reported a **decrease in time spent** around fodder collection.

71%
of users experienced a **decrease in physical effort**

2 hours
a day, average **time saved on feeding cattle**

0.7 ltrs
average **increase in daily milk yield** per animal, with a farmer typically owning 4 cows.

Source: CEEW analysis 2022

Technology usage at the time of survey

61% Using it	38% Not using it	1% Never used it

Top five reasons for not using it

35%	23%	23%	12%	6%
Produce/ output not as expected	Faults in the unit that need repair	Miscellaneous	Have some issues in the unit	Earnings not as expected

Source: CEEW analysis 2022

SOCIAL IMPACT

97%
of users experienced **increased support from family members/spouse**

91%
of users reported improvement in **confidence to earn and work**

53%
of users now have a better ability to **buy assets and save on own**

Source: CEEW analysis 2022

IMPACT ON WOMEN

91%
report increased participation in **public/community events**

87%
believe they have **better agency to take decisions in family**

75%
believe they have the relevant **knowledge & skills to become self-reliant**

66%
more confident about using **public/private transport on own**

Source: CEEW analysis 2022

Image: Hydrogreens

4.5 MICRO SOLAR PUMPS

Image: Khethworks

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. Till date, approximately 1,500 micro solar pumps have been deployed in India.

The findings below are from a primary survey conducted through in-person and telephone interviews between February - September 2022.

States surveyed
(share of respondents)

83% Odisha
16% Jharkhand
1% Assam

Respondents*

74 Total
65% Females

86% SC/ST
8% OBC
3% General

Users

84% users have agriculture as their primary income
61% SHG members

*85% respondents procured the machines for at least six months before the survey, with 48% using it for at least six months,

Income impact

Users experienced income increase

94%

96%

₹ 12,500 increase in annual income for a typical user from a baseline income of ₹ 50,000

Source: CEEW analysis 2022

Top five spends of increased income

34% day-to-day expenditure

22% invested in family

17% reinvested in agriculture

16% deposited in the bank as saving

5% invested in another existing business

Source: CEEW analysis 2022

PRODUCTIVITY IMPACT

96%
users **reported satisfaction** with the micro solar pump

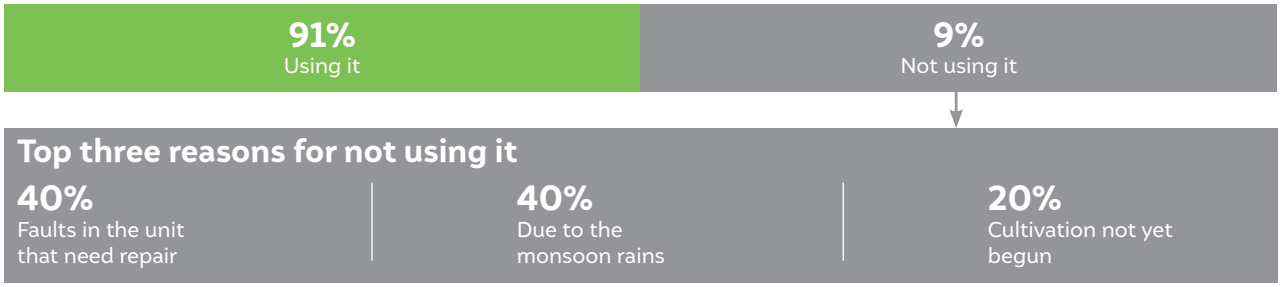
91%
users **increased the annual cropping cycles** after adopting the pump

70%
of users reported an **increase in the total irrigated area**

41%
of users reported a **reduction in effort involved in irrigation**

Source: CEEW analysis 2022

Technology usage at the time of survey



Source: CEEW analysis 2022

SOCIAL IMPACT

99%
users reported improvement in **confidence to earn and work**

99%
users experienced **Increased support from family members/spouse**

97%
users now have a better ability to **buy assets and save on own**

Source: CEEW analysis 2022

IMPACT ON WOMEN

98%
report increased **participation in public/community events**

96%
believe they have the **relevant knowledge and skills** to become self-reliant

80%
more **confident about using public/private transport on own**

76%
believe they have **better agency to take decisions in family**

Source: CEEW analysis 2022

ENVIRONMENTAL IMPACT

11 MT
of CO_2e abatement per year*

**For every 100 units of solar pump unit used for 4 hours daily for about 110 days a year.*
Source: CEEW analysis 2022

Users working on solar silk reeling machines to reel silk at the Tasar silk park in Keonjhar, Odisha.

Image: CEEW/Emotive Lens

5. Learnings from conducting the research: Study design and data collection

5.1 Design

Defining hypotheses, indicators, and stakeholder mapping prior to the research

Given the variation in use cases of the products – with respect to ownership, usage time, and procurement – and to capture the impacts holistically, it was crucial to define clear hypotheses and indicators prior to the research. Stakeholder mapping was also vital.

This research focused on the impact of DRE-livelihood technologies on women end-users, especially differences in incomes earned and drudgery reduction

Sample selection and availability of KYC data

In this research, we had to reach out to more than twice (~1500) the end-users to meet the sample size requirement. The response rate was low among users because of the low-touch model where we were not directly connected with the end-users before the survey, especially among individuals who got the product on their own. Hence, when conducting an assessment of technologies, we recommend making twice the end-user know your customer (KYC) data available to your data collection partner or impact assessment partner.

A mixed-method approach, i.e., quantitative and qualitative research, is vital to getting a full picture on the impacts

The quantitative approach shed light on variables such as income and productivity. Meanwhile, qualitative data consolidated from in-depth interviews was immensely helpful in validating the quantitative data and capturing nuances by end-user type. Further, to understand the nuances of perception-based questions on social and gender-related indicators, it was important to conduct in-depth interviews, especially with women users.

Gender-focused evaluations

Gender-focused evaluations help with collecting data that is disaggregated by gender. This research, in line with the PL programme, focused on the impact of DRE-livelihood technologies on women end-users, especially differences in incomes earned and drudgery reduction. With such a focus, interventions can be inclusive of women.

A lean questionnaire facilitates asking the most relevant questions and keeps end-users interested

We started out with a long questionnaire for the research. However, from our experience of conducting telephonic and in-person surveys, we learnt that users could not devote more than 20 minutes to the process. Thus, we reduced the length of the questionnaire to fit in 15–20 minutes. In the process, we also realised that determining the hypotheses and indicators could help us stick to the most relevant and pointed questions.

Measuring income gains is tricky, especially among people with diverse sources of income

The major challenge in measuring income was to calculate the net income attributable only to the DRE-livelihood technologies. This was especially true for users with diverse livelihoods, medium-scale businesses, and those involved only partly in the value chain of making end-products (in the input stage). The most critical learning was the need to differentiate between household and individual income. This was followed by the need to classify income sources into primary and secondary. The third takeaway was to understand the price points of inputs required for people to use the technology. Finally, we had to consider the case of a person who had availed of credit. In this case, their net income should reflect their EMI expenditure.

5.2 Survey

On-ground surveys are more effective than telephonic ones

Conducting multiple pilots along with rigorous training to the field staff is the key to get quality data from ground

Telephonic surveys are cost-effective means of establishing contact with end-users located in remote locations. However, beyond establishing initial contact, getting users to agree to take part in the interviews and the quality of documented responses was subpar at best. This could be due to multiple factors on the part of respondents or enumerators. We realised that respondents often do not have the complete context for surveys and feel apprehensive about participating. Further, enumerators face difficulties in explaining the questions and getting relevant responses. Therefore, we moved to a focus on in-person interviews for both the qualitative and quantitative surveys. We strongly believe that impact data collection for DRE-livelihood technologies is more effective when done in person.

Rigorous training on technology to enumerators

As DRE-powered livelihood technologies are fairly niche, it was challenging to train enumerators to capture responses from users on the nuances of the technologies. Enumerators were given detailed descriptions of the technologies, along with operating models, and benefits for them to conduct the survey. Further, female end-users, especially in rural areas, are more likely to respond to questions from a female enumerator than a male one. This has to be factored in while planning surveys and training enumerators.

Pilot surveys are important to capture the gaps in your survey

In addition to training sessions, pilot surveys were critical for highlighting the gaps in the survey data being documented, especially on various use cases of the technologies. This allowed the research team to predict which survey sections might prompt ambiguous entries and focus on training enumerators to address such issues.

Getting the right data for income and usage – questionnaire needs to be designed in a way that it cross-validates the data

During the analysis, we noticed that a few users' responses on annual income and technology usage did not tally. This was after accounting for the fact that respondents usually underreport their incomes. While we anticipated diverse usage data across technologies, with a wide range of applications, ownership and financing models, and geographic influences, the extent of diversity was significant. This made attributing trends in income change to the usage of the technologies difficult. Therefore, we made an effort to cross-check usage data with respondents, where there were discrepancies, in order to arrive at accurate estimates. The key takeaways are to incorporate calculations and conditions in the survey so that responses are validated against each other, and ideally add up.

6. Conclusion

DRE-livelihood technologies can play a crucial role in creating sustainable and resilient livelihoods, especially in rural India. This research, on assessing the economic, social, and environmental impacts of these technologies, is an effort towards creating evidence at scale. Our brief also highlights findings from qualitative research to capture the experiences of end-users and in-depth feedback.

This brief presents findings from the initial phase of the impact assessment study, which had a cross-sectional design. CEEW will conduct the next phase of the study in 2023. In this next phase, researchers will re-interview some respondents from the current phase to capture the long-term impact of the technologies. Further, the next phase of the study will cover other technologies, such as solar dryers and cold storage, to gain insight into their economic, social, and environmental impacts.

Overall, DRE-livelihood technologies increase the incomes of users and positively impact social and gender-related indicators, especially for women. However, a concerted effort is required by stakeholders towards the commercialisation of these technologies, through enhanced capital support to manufacturers and affordable credit to end-users. Enhanced capital support could help manufacturers and enterprises focus on enabling robust after-sales services and leverage digital technology for awareness generation at scale. Affordable credit and support to strengthen backward and forward linkages would enable sustained use of these technologies, thereby increasing the incomes of users. Using innovative financing mechanisms, implementing and funding organisations should actively help users access these technologies.

India's plan to achieve its climate goals should actively consider these technologies and promote their widespread adoption. This would require the government to drive collaborations and convergence among various stakeholders at different levels of the livelihood development ecosystem. We believe that the learnings from the ground presented in this brief will help researchers, implementers, and policymakers design targeted interventions involving DRE-livelihood technologies.

References

Ghosh, Arunabha, and Shuva Raha. 2020. "Jobs, Growth and Sustainability: A New Social Contract for India's Recovery." New Delhi: CEEW. https://www.ceew.in/sites/default/files/CEEW-Jobs-Growth-Sustainability-Report-2020-web.pdf.

Ginoya, Namrata, Harsha Meenawat, Amala Devi, Pamli Deka, and Bharath Jairaj. 2021. "Powering Development in Climate Vulnerable Areas: The Role of Decentralized Solar Solutions in India." New Delhi: World Resources Institute. https://www.wri.org/research/powering-development-climate-vulnerable-areas-role-decentralized-solar-solutions-india.

Jain, Abhishek, Arunabha Ghosh, and Sanjana Chhabra. 2021. "Powering Livelihoods Globally through Clean Energy." New Delhi: CEEW. https://www.ceew.in/sites/default/files/ceew-study-on-powering-livelihoods-with-distributed-renewable-energy-systems.pdf.

Jha, Shyam Narayan, Rajesh Kumar Vishwakarma, Tauqueer Ahmad, and Anil Rai. 2015. "Assessment of Quantitative Harvest and Post-harvest Losses of Major Crops/Commodities in India." Ludhiana: MoFPI. https://doi.org/10.13140/RG.2.1.3024.3924.

Kuhn, Ursina. 2019. "Measurement of Income in Surveys." *FORS Guide Nº 02*, no. 1 (January). Lausanne: Swiss Centre of Expertise in the Social Sciences FORS. https://doi.org/10.24449/FG-2019-00002.

Ministry of Finance. 2023. "Economic Survey Highlights Thrust on Rural Development." *Press Information Bureau*. https://pib.gov.in/PressReleasePage.aspx?PRID=1894901#:~:text=The%20Survey%20notes%20that%2065,on%20rural%20development%20is%20imperative.

Ministry of New and Renewable Energy. 2022. "Framework for Promotion of Decentralised Renewable Energy Livelihood Applications." New Delhi: MNRE.

Sankhe, Shirish, Anu Madgavkar, Gautam Kumra, Jonathan Woetzel, Sven Smit, and Kanmani Chockalingam. 2020. "India's Turning Point." McKinsey Global Institute. https://www.mckinsey.com/featured-insights/india/indias-turning-point-an-economic-agenda-to-spur-growth-and-jobs#/.

Waray, Sanchit, Sasmita Patnaik, and Abhishek Jain. 2018. "Clean Energy Innovations to Boost Rural Incomes." New Delhi: CEEW. https://www.ceew.in/sites/default/files/CEEW_Clean_energy_innovations_to_boost_rural_incomes_15Oct18.pdf.

Choithani, Chetan, Robbin Jan van Duijne, and Jan Nijman. "Changing Livelihoods at India's Rural–Urban Transition." *World Development* 146 (October 2021): 105617. https://doi.org/10.1016/j.worlddev.2021.105617.

Acronyms

SHG	Self-help group
CInI	Collectives for Integrated Livelihood Initiatives
DC	Direct current
DRE	Decentralised renewable energy
PL	Powering Livelihoods
HP	Horse power
MNRE	Ministry of New and Renewable Energy
MFI	Microfinance institutions
MWh	Megawatt hour
SELCO	Solar Energy Lighting Company
COVID-19	Coronavirus disease
NGO	Non-governmental organisation
KYC	Know your customer
W	Watts
GHG	Greenhouse Gases

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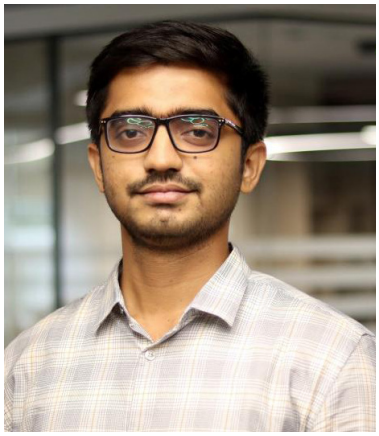
Divya leads the work of impact measurement of DRE livelihood technologies at the Council along with supporting gender inclusivity within the Powering Livelihoods initiative. Previously, she worked in the impact measurement consulting sector where she worked on various development projects.

"The 50 billion dollar market of DRE-powered livelihood technologies has a significant potential to impact more than 30 crore livelihoods in India. The path to leveraging this huge opportunity ought be evidence-backed and to bring out the end-users' perspective to channelise the sectoral ecosystem and its efforts in the right direction."



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Priyatam is a research analyst at the Council, and his work aims to maximise the impact of clean energy technologies. He focuses on establishing the impact of various clean energy technologies supported under the Powering Livelihoods initiative.

"India can become a global leader in creating sustainable livelihoods through DRE technologies; however it needs to focus on developing holistic ecosystem models to achieve this."

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Abhishek Jain is the Director of the Powering Livelihoods initiative at the Council. His work involves research on various issues including decentralised renewable energy, energy access, LPG for cooking, fossil fuel subsidies, power sector, rural livelihoods, and sustainable agriculture. He works very closely with decision makers to action recommendations from the research.

"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."

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