# Decentralised Renewable Energy Technologies for Sustainable Livelihoods

## Market, Viability, and Impact Potential in India

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*Context, Rationale, and Methodology*

# 1. Context and rationale - Decentralised Renewable Energy (DRE) Livelihood Technologies for Farmers and Microenterprises

India needs to create at least 90 million new non-farm jobs by 2030 (Sankhe et al. 2020). As it fulfils the employment and development aspirations of millions, India's resource footprint will also expand. Even with its very low per capita energy consumption, India is the world's third-largest carbon-emitting country (Durba et al. 2021), and it has committed to reach net zero by 2070. Therefore, it is imperative to align India's climate ambition with the need to generate millions of new livelihoods and jobs.

## 1.1 Sustainable livelihoods: Why is promoting DRE livelihood technologies important in India?

While the deployment of large-scale renewables and transition to green hydrogen will generate more jobs, these are not sufficient to productively engage the million additional youth getting added to our workforce every month (Mallapur 2018). We need much more entrepreneurship, livelihood opportunities, and jobs that are economically rewarding, environmentally sustainable, and socially equitable. One solution to improve livelihoods across India is to power them using decentralised renewable energy (DRE) sources, which offer clean and sustainable energy options. Energy-efficient technologies powered by decentralised renewables can help enhance the incomes and resilience of tens of millions of microenterprises nationwide while fostering climate action. Recognising the unique opportunity that such DRE-based livelihoods pose, in early 2022, the Ministry of New and Renewable Energy, Government of India, released a dedicated policy framework titled *Framework for Promotion of Decentralised Renewable Energy Livelihood Applications* (MNRE 2022).

In recent years, India has achieved almost 100 per cent coverage of electricity connections to households. However, a substantial proportion of the population, especially in rural areas, faces issues of unreliable electricity. CEEW's 'State of Electricity Access in India' report estimates that, on average, households in rural areas face daily power outages of at least four hours (Agrawal et al. 2020). Additionally, some states, such as Uttar Pradesh, Jharkhand, Haryana, Assam, and Bihar, experience an average of six or more hours of daily power outages (Agarwal et al. 2020). Without reliable electricity, rural microenterprises resort to diesel engines to power their businesses. Decentralised energy sources that power income-generating activities can eliminate diesel use and supplement electricity (MNRE 2022). In recent years, many livelihood technologies have emerged that are highly energy efficient and are designed to run with DRE sources, including solar water pumps, solar-powered looms, solar-powered charkhas, solar/biomass-powered cold storages, solar dryers, and solar-powered vertical fodder stations. DRE livelihood technologies offer a few distinctive advantages, as discussed here:

- **They are economically lucrative for rural microenterprises.**
  Manufacturers of DRE livelihood technologies have focused on developing energy-efficient technologies and optimising solar and battery system sizes. Such optimised designs often make DRE livelihood variant more viable than grid variants over the product's lifetime. With economies of scale, DRE livelihood technologies would be even more economically attractive to rural microenterprises.

- **They enable productive applications in remote and mobile settings.**
  Most DRE livelihood technologies are portable, enabling productive activities such as irrigation, storage, and processing in rural settings where farms are often split into multiple plots and households are not near the farms.

- **DRE livelihood technologies for perishables can help avoid food loss.**
  The limited post-harvest infrastructure in rural areas results in significant spoilage of perishable products. Farm-level processing and storage facilities powered through DRE can help avoid food losses, which were as high as USD 15.2 billion (INR 92,651 crore) in FY2014 (Jha et al. 2015).

- **They improve climate resilience.**
  With the increased frequency of climate change-induced extreme events such as floods, cyclones, cloud bursts, etc., there is a need to provide climate-resilient systems in rural areas. DRE livelihood technologies could help provide continuity in operations to enable communities to bounce back in the aftermath of disaster events. DRE technologies can be designed to withstand extreme events like high heat and high-speed winds (Ginoya et al. 2021).

## 1.2. What does this report aim to answer?

As a nascent yet rapidly evolving sector, the potential of using DRE to transform the rural economy through livelihood technologies is being recognised by various stakeholders, including governments, philanthropic funders, investors, financiers, think tanks, incubators, entrepreneurs, and end users. As these stakeholders engage with the DRE livelihood technologies, they often come across a set of questions. For instance:

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

As part of the Powering Livelihoods initiative, this report attempts to answer all these questions, such that insights on the market, viability, and impact potential of DRE livelihood technologies can help the stakeholders make more informed choices.

While the report analyses DRE livelihood technologies in the Indian context, there are a set of transferable lessons that could be useful for stakeholders from other developing nations with similar economic and geographic contexts to India.

# 2. Methodology: The Impact-Feasibility Framework

To assess the market, viability, and impact potential of DRE livelihood technologies and answer the key questions posed by the sector stakeholders, we use an **'impact-feasibility'** framework. It would help stakeholders navigate the DRE livelihoods landscape even as technology and markets evolve over time.

**Impact-feasibility framework**

We have designed the 'impact-feasibility' framework to understand how big the impact opportunity would be and how easy it would be to realise that impact. Using this framework, we analyse and compare the mature DRE livelihood technologies.

We define the impact potential as the total number of new or existing livelihoods that could be positively impacted using the respective DRE livelihood technologies. It essentially pertains to the '**scale of impact**'.

By contrast, we define feasibility as **the likelihood of realising the impact**. It is essentially a measure of how feasible it is to realise the impact that the DRE technology promises. We assess feasibility through a combination of indicators (not every indicator is relevant in every context, but many are in most settings). Most of these indicators are essentially reflecting the likelihood of the adoption of a DRE livelihood technology considering the economic and financial viability.

### 2.1 Estimating impact

To estimate the impact potential for each of these technologies, we have adopted a tailored approach as described here:

- For small solar refrigerators/deep freezers, grain-milling machines, looms, cold storages and bulk milk chillers:
  Dataset: We use the microenterprise data from the NSSO 73rd round survey (NSSO 2018) that captures the economic and operational characteristics of 64 million unincorporated non-agricultural enterprises.
  Approach: We first identified the relevant livelihood activities (linked to a NIC code[1]) in which the microenterprises are engaging where there is a possibility of using the respective DRE livelihood technology. We further segregated livelihood activities relevant to each DRE technology as **'direct use'[2]** and **'indirect use'[4]**.
  For 'direct use' activities, we have considered all the microenterprises engaged in the activity to arrive at the market potential for each DRE application.
  For 'indirect activities', we consider only enterprises reporting electricity as a bottleneck, as, from the dataset to arrive at the market potential for each DRE application.
  (Note: The complete list of activities and the associated microenterprise count are included in Annexure 1.)

[1] The National Industrial Classification Code ("NIC Code") is a statistical standard for developing and maintaining a comparable data base for various economic activities.

[2] Under 'direct use' the DRE livelihood technologies are relevant for all microenterprises engaged in the activities. Whereas, under 'indirect use' the DRE livelihood technologies might be relevant to only a certain group of microenterprises engaged in the activities.

- For solar dryers:
  Dataset: We used the microenterprise data from the NSSO 73rd round survey (NSSO 2018) and the state-level data on horticulture production from the Department of Agriculture and Farmers Welfare (DAC&FW 2020).
  Approach: First, from the NSSO 73rd round survey, we identified the existing microenterprises engaged in drying activities. We also estimated the further drying potential – to avoid food loss – in each state, using the horticulture production data. We combined the two estimates to arrive at the total market potential for solar drying.

- For solar-powered higher capacity pumps:
  Dataset: We used the data on holdings, irrigation, and diesel pump set usage from the Agricultural Census 2016 (DAC&FW 2021). We also considered the water permeability index and the groundwater index, using data from the Central Ground Water Board reports and publications (CGWB 2021).
  Approach: Using the data mentioned prior, we first estimated the number of farmers who are using diesel pumps for irrigating large-scale land holdings in non-critical groundwater regions that can adopt solar pumps for irrigation. Next, we estimated the number of farmers with large-scale, non-irrigated land holdings cropping once a year in regions with non-critical groundwater levels and water-permeable terrains. We combined these two estimates to determine the total market potential for higher-capacity solar pumps.

- For solar-powered silk reeling machines[3], micro water pumps[4], charkhas[5], small horticulture processors[6], and vertical fodder grow units[7]:
  We used the market potential estimates published by CEEW for the respective DRE livelihood technologies. The dataset and approach used to estimate market potential are discussed in the referenced reports.

[3] Sahdev, Garvit, Shruti Jindal and Abhishek Jain. 2021. *Energy-Efficient Silk Spinning and Reeling Machines: How Big is the Opportunity?* New Delhi: Council on Energy, Environment and Water.
[4] Khalid, Wase, Abhishek Jain, Shruti Jindal and Arpan Thacker. 2022. *Mainstreaming Micro Solar Pumps to Improve Incomes of Marginal Farmers*. New Delhi: Council on Energy, Environment and Water.
[5] Sahdev, Garvit, Shruti Jindal, Abhishek Jain. 2021. *Solarvastra: Is Renewable Energy-powered Sustainable Fashion a Real Market Opportunity?* New Delhi: Council on Energy, Environment and Water.
[6] Khalid Wase, Shruti Jindal and Abhishek Jain. 2022. *Can Small Horticulture Processors Enhance Rural Incomes?* New Delhi: Council on Energy, Environment and Water.
[7] Khalid, Wase, Shruti Jindal, Abhishek Jain, Richa Ahuja. 2021. *Enhancing India's Milk and Meat Production: Is Hydroponics Green Fodder the Probable Answer - Market Opportunity Analysis.* New Delhi: Council on Energy, Environment and Water.

### 2.2 Assessing feasibility

We assessed the feasibility of impact realisation for each technology by considering the product cost, the discounted payback period, and whether a market linkage is required. We also compare the total cost of ownership of DRE products with similar capacity grid-connected and diesel-powered variants, considering long-term (10 years) usage. Below, we detail out the **estimation method and rationale of consideration** for all factors being assessed.

A. Product cost

Rationale:
The higher the product cost, the more difficult it is for end users to either buy it outright or get financing, and hence the lower the likelihood of adoption, *ceteris paribus*.

Method:
The product cost accounts for all the associated capital costs, including the equipment, solar panel, batteries, controllers, etc.

- **Equipment/Technology cost:**
  We consider the cost of equipment (including taxes) based on the quotations shared by manufacturers or the price quoted on their websites or online portals.

- **Solar panel, batteries, and backup cost for the DRE variant:**
  Wherever applicable, we estimate the costs of the solar panel, batteries, and other backups as per the daily hours of usage; thus, the higher the usage hours, the larger the size of these components and the higher the cost. We arrived at typical daily usage hours through our end-user surveys and interactions with technology manufacturers. We have detailed the considerations and assumptions made for estimating the cost of these components below.

  Note: For the DRE livelihood technologies with cooling functions, while the cooling functions for 24 hours a day, daily usage accounts for duty cycles ranging from 33–100 per cent for cold storage, 60–100 per cent for refrigerators, and 25–100 per cent for bulk milk chillers. The costs for different components have been estimated accordingly.

  Assumptions made for solar panel, battery, and inverter selection:

  - We assume 5.5 hours of average peak sun in India.
  - We assume photovoltaic losses at 20 per cent.
  - We consider the inverter size to be 1.5 times (VA) the required power rating or the maximum connected load.
  - We assume a 75 per cent depth of discharge to size the battery.
  - We have used the next higher available battery and inverter size wherever the estimated size of the battery and inverter was not standard and hence were unavailable.

- **Inverter, battery, and diesel genset cost for grid-variants of the technology:**
  For grid-based variant, in scenarios of unreliable or no supply,[8] we considered backups (such as diesel gensets or inverters and batteries) based on the kW rating of the equipment. The backup is sized based on the typical usage of the equipment and sizing norms specified by the backup solution providers.

  Assumptions made for inverter and battery selection:

  - We consider inverter and battery backup for equipment up to 1 kW of rated power consumption.
  - We consider the inverter size to be 1.5 times (VA) the required power rating or the maximum connected load.
  - We assume a 75 per cent depth of discharge to size the battery.
  - We have used the next higher available battery and inverter size wherever the estimated size of the battery and inverter was not standard and hence were unavailable.

  Assumptions made for diesel genset selection:

  - We consider diesel-genset backup for equipment with more than 1 kW of rated power capacity.
  - We consider the genset size to be 1.25 times (VA) the required power rating.
  - We have used the next larger available diesel generator size wherever the estimated size of the genset was not standard and hence not available.

**B. Discounted payback period**

Rationale:

The shorter the discounted payback period, the higher the likelihood of availability of financing for adopting such technologies and of an end customer investing in such a technology.

Method:

We estimate the discounted payback period for DRE livelihood technologies considering an annual discounting rate of 10 per cent and a financing interest rate of 16 per cent. The typical annual income values used for estimation are based on the end-user surveys and interviews with the manufacturers (where end-user survey data is unavailable).

[8] These scenarios are discussed later in this chapter.

**C. Long-term 'total cost of ownership'**

Rationale:

The lower the Total Cost of Ownership (TCO) of a DRE livelihood technology compared to a grid-connected or a diesel-powered alternative, the higher the likelihood of a potential customer adopting the DRE variant over the diesel or grid variant. We use the Net Present Value (NPV) of the TCO across all analyses.

Method:

While operating the product, an end user incurs expenditures such as EMIs[9] (to repay the loan for product adoption), maintenance costs, and other recurring expenses. We account for each of these expenses over the 10 years of operation to arrive at the '**TCO for 10 years of operation**' for all 3 variants (DRE, grid, and diesel) for each technology analysed.

Further, as the output capacity of all three variants (DRE, grid, and diesel) is the same, we assume that both the raw material cost (or input cost) and the income from selling the output are the same in all three cases. Thus, the cost of operation analysis does not account for the income but focuses on the present value of the expenditure. We detail these expenditures here:

- Product EMI: An end user may have to pay EMIs if a loan has been taken to adopt a technology. The EMI duration depends on the loan tenure, which is typically a function of the loan size. We assume a relatively high financing interest rate of 16 per cent. As the products become mainstream and the interest rates come down (as banks start lending), the DRE variant having a higher capex than the grid or diesel variants would become more competitive with lowering interest rates.
- Maintenance and component replacement: Over the ten years of product usage, we consider the cost of maintenance and component replacement for all the variants. We consider the replacement or maintenance costs at 20 per cent of the equipment cost every five years; battery replacement costs at 75 per cent once every five years; other components such as wiring, controller, and generator or inverter replacement costs at 100 per cent of the cost of these components once every ten years.
- Recurring costs: Grid- and diesel-based variants incur the recurring costs of electricity and diesel, respectively. The electricity consumption varies for each product depending upon their capacity and usage. We consider the electricity cost as INR 6.15 per kWh, which was the average cost of supply across India in 2019–20 (PFC 2021). We assume a two per cent annual increase in the electricity tariff. We consider the diesel price as INR 95.9 per litre, which was the average diesel price in India as of June 2022[10] (global petrol prices). We consider an annual increase of two per cent in diesel prices.

[9] EMI: equated monthly instalment

[10] https://www.globalpetrolprices.com/India/diesel_prices/, as of June 2022

**D. Whether a market linkage is required**

Rationale:
Several DRE livelihood technologies generate products that do not necessarily have a sufficient local market, such as yarn produced on a solar-powered spinning machine, fabric produced on a solar-powered loom, products dried in a solar-powered dryer, etc. However, other categories of DRE livelihood technologies primarily cater to the local demand, such as small solar refrigerators in grocery shops, solar-powered fodder growing units to feed cattle, solar pumps, etc. The technologies catering to local demand have a higher likelihood of adoption, as the impact realisation is immediate, and the effort to establish market linkages is not required.

Method:
We have considered the market linkage requirements for mature DRE livelihood technologies based on the authors' on-field experience and inputs shared by the technology manufacturers and users.

### 2.3. Scenario analysis for economic viability

We compare the Total Cost of Ownership (TCO) of the DRE livelihood variant with the grid-based and diesel-based variants under different scenarios. These scenarios are governed by three factors: reliability of grid electricity, product utilisation rate, and business horizon. The scenario analysis helps identify the economically preferable product variant under different contexts. These factors are described as follows:

- Grid reliability:
  **No access to grid power.** In this scenario, we assume the use of a diesel generator to run the off-the-shelf grid variant of the product. This assumption is made as direct diesel engine-run equipment, which used to be prevalent in a few categories, is no longer readily available in India. The capital cost includes the cost of the generator and equipment, and the operational cost includes the cost of diesel required for the product's usage.

  **Erratic electricity** (at least four hours of power backup is required to operate the grid-connected product). Here, the capital cost includes the cost of the backup (diesel genset or battery plus inverter), and the operational cost includes the electricity and diesel costs (in case of genset backup).

  **Reliable electricity** (such that no power backup is required). In this case, we do not consider any backup cost as part of the capital cost for the grid-connected variant. Operation cost includes the cost of electricity usage.

- Product utilisation: For each product, the daily/annual product utilisation may vary based on various external factors such as raw material availability, market linkage, individual or shared usage, etc. Therefore, we compare the product variants by evaluating their cost of operations considering 4–24 hours of daily usage and respective number of days in a year that the product would get used.

- Investment/business horizon: For this analysis, we have estimated financial viability for a business horizon of 5, 10, 15 and 20 years. Since DRE livelihood technologies are capital-intensive, it is imperative to understand the financial viability over different business horizons. Technology adopters and financiers can use these insights to assess the viability/bankability of these technologies.

**To access the full report, Decentralised Renewable Energy Technologies for Sustainable Livelihoods: Market, Viability, and Impact Potential in India, please scan the following QR code or visit** https://www.ceew.in/publications/decentralised-renewable-energy-technologies-for-sustainable-livelihoods-india

# Annexure 1 - Market potential estimation

Using NSSO survey – India – unincorporated non-agricultural enterprises (excluding construction), July 2015–June 2016, 73rd round.

**Table A1: Market: Number of unincorporated non-agricultural enterprises**

| Activity | NIC code | NIC code description | Total number of micro enterprises | Enterprises reporting erratic electricity as a bottleneck | Comments |
|---|---|---|---|---|---|
| Bulk milk chiller | 46302 | Wholesale of raw milk & dairy products | 90,223 | 7,220 | Direct |
| Solar cold storage | 52101 | Warehousing of refrigerated (cold storage) | 902 | 221 | Direct |
| | 46301 | Wholesale of fruits & vegetables | 108,576 | 819 | Direct |
| | 46303 | Wholesale of meat, fish, & eggs | 32,506 | 29 | Direct |
| Solar dryer | 10504 | Manufacture of cream, butter, cheese, curd, ghee, khoya, etc. | 52,930 | 359 | Direct |
| | 10201 | Sun-drying of fish | 7,707 | 0 | Direct |
| | 10202 | Artificial dehydration of fish and seafood | 5 | 0 | Direct |
| | 10205 | Processing and canning of fish | 4,428 | 0 | Direct |
| | 10301 | Sun-drying of fruit and vegetables | 3,726 | 0 | Direct |
| | 10302 | Artificial dehydration of fruit and vegetables | 845 | 0 | Direct |
| | 10502 | Manufacture of milk-powder, ice-cream powder, and condensed milk (except baby milk food) | 5,521 | 68 | Direct |
| | 10796 | Manufacture of papads, appalam, and similar food products | 125,458 | 539 | Direct |
| Grain milling | 10614 | Grain milling other than wheat, rice, and dal | 12,883 | 4,033 | Indirect |
| | 10619 | Other grain milling and processing | 19,799 | 512 | Indirect |
| | 10611 | Flour milling | 771,356 | 206,726 | Indirect |
| | 10612 | Rice milling | 163,815 | 30,866 | Direct |
| | 10613 | Dal (pulses) milling | 6,964 | 451 | Direct |
| Solar loom | 13121 | Weaving, manufacture of cotton and cotton-mixture fabrics. | 415,200 | 46,201 | Direct |
| | 13122 | Weaving, manufacture of silk and silk-mixture fabrics. | 205,714 | 32,033 | Direct |

| | | | | | |
|---|---|---|---|---|---|
| Solar refrigerator | 10504 | Manufacture of cream, butter, cheese, curd, ghee, khoya, etc. | 52,930 | 359 | Direct |
| | 10505 | Manufacture of ice-cream, kulfi, etc. | 15,390 | 1,289 | Direct |
| | 47215 | Retail sale of sugar confectionery and sweetmeat | 458,411 | 7,092 | Indirect |
| | 47810 | Retail sale via stalls and markets of food, beverages, and tobacco products | 99,385 | 191 | Indirect |
| | 10712 | Manufacture of biscuits, cakes, pastries, rusks, etc. | 25,724 | 3,516 | Indirect |
| | 46304 | Wholesale of confectionery, bakery products, and beverages other than intoxicants | 47,013 | 313 | Indirect |
| | 47110 | Retail sale in non-specialised stores with food, beverages, or tobacco predominating | 2,534,654 | 100,311 | Indirect |
| | 56101 | Restaurants without bars | 1,477,128 | 44,287 | Indirect |
| | 56292 | Operation of canteens or (e.g., for factories, offices, and hospitals or schools) on a concession basis | 17,325 | 589 | Indirect |
| | 10509 | Manufacture of other dairy products | 7,092 | 253 | Direct |
| | 10734 | Manufacture sweetmeats, including dairy-based sweetmeats | 120,389 | 5,224 | Direct |
| | 47213 | Retail sale of meat, meat products, poultry products, fish, other seafood and products thereof | 437,678 | 3,171 | Direct |
| | 47214 | Retail sale of bakery products, dairy products, and eggs | 599,319 | 13,581 | Indirect |
| | 47222 | Retail sale of non-alcoholic beverages including ice cream not for consumption on the premises | 178,015 | 7,584 | Direct |
| | 56102 | Cafeterias, fast-food restaurants, and other food preparation in market stalls | 321,856 | 6,295 | Indirect |
| | 56103 | Ice cream mobile vendors, mobile food carts | 161,391 | 477 | Direct |
| | 56301 | Bars and restaurants with bars | 45,876 | 1,200 | Direct |
| | 56303 | Fruit juice bars | 19,928 | 712 | Direct |
| | 56304 | Mobile beverage vendors | 17,501 | 89 | Direct |

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# Acronyms

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

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Cover image: CEEW/Emotive lens

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*The serviceable addressable market for energy-efficient silk spinning and reeling machines is USD 25.9 million. It can impact ~81,500 livelihoods improving incomes and reducing drudgery.*

*Source: CEEW analysis*

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