Clean Energy Innovations to Boost Rural Incomes

Report I October 2018

SANCHIT WARAY, SASMITA PATNAIK, AND ABHISHEK JAIN

Egg incubators used for hatching eggs in rural poultry farms.

Image: iStock

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Good Energies Foundation is a Swiss-based private foundation. It was established in 2007 as an integral part of Good Energies Inc., a private equity company specialised in investing in the renewable energy and energy-efficiency industries. The foundation's goal is to help prevent climate change and mitigate its harm, especially to people who live in poverty. It focuses on two levers that reverse climate change: clean energy and forest protection. The foundation invests in early-stage market solutions and funds efforts to bring successful approaches to scale.

Council on Energy, Environment and Water (CEEW)
Sanskrit Bhawan, A-10, Qutab Institutional Area
Aruna Asaf Ali Marg, New Delhi - 110067, India

About CEEW

The Council on Energy, Environment and Water (CEEW) is one of South 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. The Council addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with wider public.

In 2018, CEEW once again featured extensively across nine categories in the '2017 Global Go To Think Tank Index Report', including being ranked as South Asia's top think tank (14^{th} globally) with an annual operating budget of less than USD 5 million for the fifth year in a row. In 2016, CEEW was also ranked 2^{nd} in India, 4^{th} outside Europe and North America, and 20^{th} globally out of 240 think tanks as per the ICCG Climate Think Tank's standardised rankings. In 2013 and 2014, CEEW was rated as India's top climate change think-tank as per the ICCG standardised rankings.

In over eight years of operations, The Council has engaged in 200 research projects, published well over 130 peer-reviewed books, policy reports and papers, advised governments around the world nearly 500 times, engaged with industry to encourage investments in clean technologies and improve efficiency in resource use, promoted bilateral and multilateral initiatives between governments on more than 60 occasions, helped state governments with water and irrigation reforms, and organised nearly 250 seminars and conferences.

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The Council's major projects on climate, environment, and resource security include advising and contributing to climate negotiations (COP-23) in Bonn, especially on the formulating guidelines of the Paris Agreement rule-book; pathways for achieving INDCs and mid-century strategies for decarbonisation; assessing global climate risks; heat-health action plans for Indian cities; assessing India's adaptation gap; low-carbon rural development; environmental clearances; modelling HFC emissions; business case for phasing down HFCs; assessing India's critical minerals; geoengineering governance; climate finance; nuclear power and low-carbon pathways; electric rail transport; monitoring air quality; business case for energy efficiency and emissions reductions; India's first report on global governance, submitted to the National Security Adviser; foreign policy implications for resource security; India's power sector reforms; resource nexus, and strategic industries and technologies; and Maharashtra-Guangdong partnership on sustainability.

The Council's major projects on water governance and security include the 584-page National Water Resources Framework Study for India's 12^{th} Five Year Plan; irrigation reform for Bihar; Swachh Bharat; supporting India's National Water Mission; collective action for water security; mapping India's traditional water bodies; modelling water-energy nexus; circular economy of water; participatory irrigation management in South Asia; domestic water conflicts; modelling decision making at the basin-level; rainwater harvesting; and multi-stakeholder initiatives for urban water management.

About the Authors

SANCHIT WARAY | sanchit.waray@ceew.in | @pancakepoet

Sanchit Waray is a Programme Associate in the Energy Access team at the Council on Energy, Environment and Water (CEEW). He has over five years of experience in researching technology and policy aspects of innovation ecosystems, renewable energy systems, sustainable materials, and chemicals, among others. Prior to joining The Council, he was an entrepreneur and had also worked with Saint-Gobain and Battelle. Sanchit received a Master of Science in Energy Science, Technology, and Policy at Carnegie Mellon University and a Bachelor of Technology in Polymer and Surface Engineering from Institute of Chemical Technology (formerly UDCT), Mumbai.

SASMITA PATNAIK | sasmita.patnaik@ceew.in | @sasmitapnaik

Sasmita Patnaik is a Programme Lead in the Energy Access team at The Council. She has over five years of research and consulting experience in rural development, sustainability, and social entrepreneurship. Her work in sustainability involved the assessment of sustainability policies and practices of industries around biodiversity and land use, health and safety, and carbon emissions. Sasmita is a Felix scholar, and holds an M.Sc. in Development Studies from School of Oriental and African Studies (SOAS) and a Post-Graduate Diploma in Rural Management from Xavier Institute of Management, Bhubaneswar (XIMB).

ABHISHEK JAIN | abhishek.jain@ceew.in | @ajainme

Abhishek Jain is a Senior Programme Lead at CEEW. He leads the Energy Access focus area at The Council. His research focuses on energy provision and use for households, community, and productive applications, fossil fuel subsidy reform, and circular economy. With close to seven years of professional experience, Abhishek has worked on multiple issues at the confluence of energy, economics, and environment. He holds an M.Phil. from University of Cambridge and an engineering degree from IIT Roorkee.

Image: Sasmita Patnaik/CEEW

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Abbreviations

CAG	core advisory group
CIAE	Central Institute of Agriculture Engineering
CII	Confederation of Indian Industry
CLEAN	Clean Energy Access Network
CSIR	Council on Scientific and Industrial Research
CSR	corporate social responsibility
DARE	Department of Agricultural Research and Education
DRE	decentralised renewable energy
EE	energy efficiency
ESMAP	Energy Sector Management Assistance Program
FPO	farmer producer organisation
GOGLA	Global Alliance for Clean Cookstoves
GDP	gross domestic product
GOGLA	Global Off-Grid Lighting Association
ICAR	Indian Council for Agricultural Research
I-DESIRE	Initiative for DRE and Efficiency innovations to Support Income in Rural Economy
IFAD	International Fund for Agricultural Development
IP	intellectual property
KVK	Krishi Vigyan Kendras
MGIRI	Mahatma Gandhi Institute for Rural Industrialisation
MSME	micro, small, and medium enterprises
NDP	net domestic product
NGO	non-governmental organisation
NIC	National Industries Classification
NIDHI	National Initiative for Developing and Harnessing Innovations
NSSO	National Sample Survey Office
OGCCC	Off-Grid Cold Chain Challenge
PRAYAS	Promoting and Accelerating Young and Aspiring technology entrepreneurs
R&D	research and development
RET	renewable energy technologies
RIGA	rural income generating activities
RuTAG	Rural Technology Action Group
SAM	segmented addressable market
SDG	Sustainable Development Goal
SHS	solar home systems
TAM	total addressable market
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USD	United States Dollar
VAPW	value add per worker
WWF	World Wildlife Fund

The potter's wheel is a viable source of income for many rural families.

Image: Chandan Singh/flickr

Executive Summary

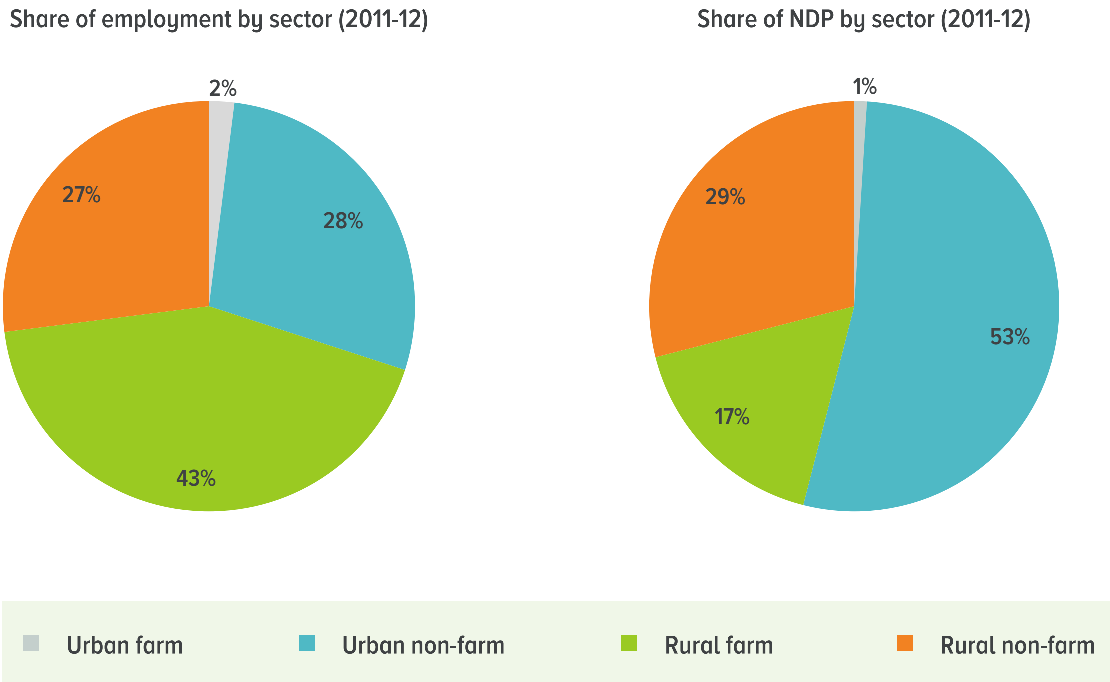
Access to energy has historically been a critical input to economic development. In the current context, access to modern forms of energy is considered indispensable for alleviating poverty, increasing employment, promoting economic growth, and providing social services. Recognising the role of energy in furthering human development, access to energy is listed among the United Nations' 17 Sustainable Development Goals (SDGs). For India, access to modern forms of energy is inextricably tied to economic development.

Energy access in India

While India is home to 18 per cent of the world's population, it uses only six per cent of the world's primary energy. Within India, there is a significant divide between energy consumption in rural and urban India. As of 2015, an estimated 240 million people in India did not have access to electricity, and many more suffered from irregular and poor access. The situation appears even more dire when one considers the case of rural India. Of those without electricity, almost 92 per cent lived in rural areas.

While the Indian economy has witnessed an impressive growth post liberalisation in the 1990s, there continues to remain stark differences in the per capita incomes of urban and rural India. The rural population accounts for 70 per cent of India's workforce and 46 per cent of its national income. It is projected that in 2050, about half of India's population will still be living in rural areas. Clearly, India's economic development is tied to improving rural per capita incomes. Hence, the story of India's economic development is incomplete without improved per capita income in rural areas.

Rural areas in India contribute significantly to the employment in farm and non-farm sectors, but lag in contribution to Net Domestic Product (NDP)



Non-farm includes manufacturing, construction, services, and others

Source: Chand et al. 2017

Energy access and rural economy

The rural economy is broadly divided into two sectors: those whose primary income comes from agriculture (the farm sector), and those whose livelihoods depend on work other than agriculture (the non-farm sector). Agriculture accounts for only 17 per cent of India's GDP, but it constitutes the livelihood of more than 40 per cent of India's 1.3 billion population. The ever-increasing demand for food has put productivity pressure on agriculture, leading to increased mechanisation in the farm sector. While the average farm power availability in India has increased from about 0.30 kW/ha in 1960-61 to about 2.02 kW/ha in 2013-14, it is still far lower than in countries like China (about 6 kW/ha). Overall farm mechanisation in India stands at about 40 to 45 per cent, which presents a stark contrast to countries such as the United States (95 per cent) and Brazil (75 per cent). Lack of energy access remains a significant impediment to improving agricultural productivity and incomes in India.

While agriculture has remained the primary source of income for most of rural India, non-farm employment has grown from 15 per cent in the early 1970s to more than 35 per cent in 2011-12. Further, as productivity improves in the farm sector, people moving away from agriculture will seek employment opportunities in the non-farm sector. This will increase the need to expand and support livelihood opportunities in the non-farm sector. However, this sector is also facing energy access challenges. Based on National Sample Survey of unincorporated non-agricultural enterprises 2015-16, we found that in over 100 districts in India, more than 50 per cent of micro-enterprises mentioned lack of reliable electricity as one of their top two challenges. According to the World Bank Enterprise Survey (Word Bank Group 2014), over 55 per cent of Indian manufacturing and service sector firms (small, medium, and large) are affected by electricity supply interruptions an average of 14 times a month.

Both the farm and non-farm sectors in India are under-served by existing electricity sources and are primarily complemented by diesel. This gap presents an opportunity for decentralised renewable energy (DRE) and energy efficiency (EE) innovations. The Indian government's electrification plans, which predominantly focus on household electrification, need to be complemented in two ways: (i) product innovations for livelihood applications, which can use electricity efficiently and effectively; (ii) DRE-powered innovations that can bridge gaps in the centralised electricity supply system and which can power income-generating activities in rural areas. These innovations are already beginning to transform lives among population deprived of reliable energy access by increasing productivity and product value, reducing input costs, and reducing drudgery. DRE-powered solutions such as sewing machines, milk-chillers, milking machines, motorised pottery wheels, weaving machines, and solar pesticide sprayers are already introduced in rural areas.

To understand whether, where, and how such clean energy innovations can support incomes in rural areas, we carried out a three-part research study with the following objectives.

IN OVER 100 DISTRICTS IN INDIA, MORE THAN 50 PER CENT OF MICRO-ENTERPRISES MENTIONED LACK OF RELIABLE ELECTRICITY AS ONE OF THEIR TOP TWO CHALLENGES

Research objectives

- Characterising and sizing the demand for clean energy innovations in livelihood applications, for both the farm and non-farm sectors;
- Understanding the status of such innovations in terms of their overall number, stage of development, numbers deployed on the ground, and the challenges being faced in scaling up;

- Assessing the current support mechanisms and the gaps, in the entrepreneurial ecosystem for clean energy innovations, focusing particularly on livelihood applications.

Demand for clean energy innovations in livelihood applications

A solar-powered irrigation system in Varanasi district, Uttar Pradesh, installed by Claro Energy.

To estimate the demand for clean energy innovations in livelihood applications, we prioritised rural income-generating activities (RIGAs), in the farm and non-farm sector, using four factors associated with each RIGA: (i) number of livelihoods; (ii) prevailing situation regarding access to energy and mechanisation potential; (iii) value addition or revenue generation; and (iv) energy cost as compared to other input costs for the activity.

Considering these factors and using the latest national survey data for both the farm and non-farm sectors, we have prioritised RIGAs. By breaking down each RIGA to their constituent processes and understanding the current energy sources used for each process and the associated costs, we identified areas where clean energy solutions could contribute towards income generation in rural areas.

One of the key findings, applicable to both farm and non-farm sectors, is that energy efficiency of equipment is critical to the economic viability of DRE-powered appliances. However, energy efficiency is rarely seen as a priority in the design of existing appliances. Rather, they are designed for unreliable and subsidised/flat-priced electricity supply prevalent at present in rural India. With no incentives for energy efficiency, farm and non-farm machinery in India are being designed to cope primarily with an unreliable supply of electricity, through over-sizing or in other ways. Small motors (up to 10 kW), which are particularly popular in micro-enterprises, exhibit high energy consumption as they are currently designed to offer a lower upfront cost rather than being optimised for energy efficiency. Thus, for DRE to be viable, there is a need to support evolution and development of energy-efficient equipment for livelihood applications.

Farm sector

We found several activities in the cultivation process for various crops, which could be mechanised through clean energy solutions, but to estimate the order of magnitude of this market, we considered three particular machines: the reaper binder, knapsack sprayer, and rice transplanter. The total addressable market (TAM)[1] for each is estimated at USD 15.6 billion, 17.1 billion, and 8.2 billion respectively, based on 119 million cultivators in rural India. A realistic market sizing would take into account the potential sharing of equipment between farmers: the sharing of 19 million electric pumps was factored in, and thus 22.76 million cultivators were excluded from the total. The use of electric pumps indicates access to grid electricity at these farms, and hence DRE-powered innovations may not find initial adopters

ENERGY EFFICIENCY IS RARELY SEEN AS A PRIORITY IN THE DESIGN OF EXISTING APPLIANCES. RATHER, THEY ARE DESIGNED FOR UNRELIABLE AND SUBSIDISED/FLAT-PRICED ELECTRICITY SUPPLY

[1] TAM or Total Addressable Market is used to reference the revenue opportunity for a product or service. It is a means of prioritising business opportunities based on the underlying potential of a given opportunity.

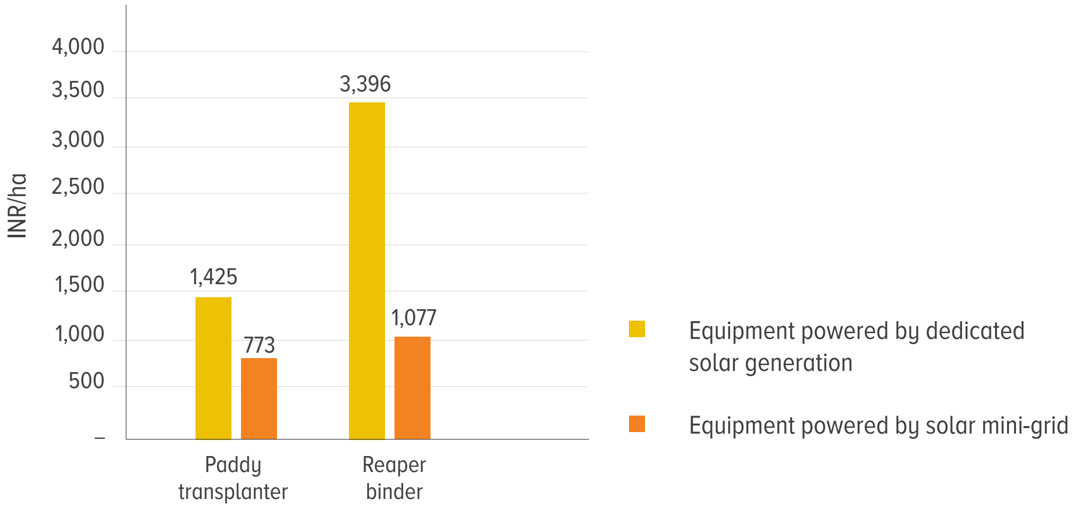
at these locations. The segmented addressable market (SAM)[2] for the three machines combined, based on these considerations, is approximately USD 29.6 billion.

While the market potential seems large, the low utilisation rates of machines in the farm sector presents a significant impediment to capturing the market. Many cultivation processes - including pesticide spraying, fertiliser application, planting of rice, and harvesting of produce - need to be done usually for only 20 to 30 days in a year. Thus, the utilisation rate of farm machinery is so low that standalone solar panels or dedicated batteries for such equipment are not economically viable. A comparison of costs per hectare for different energy sources elucidates this limitation, as seen in the figure below.

WHILE THE MARKET POTENTIAL SEEMS LARGE, THE LOW UTILISATION RATES OF MACHINES IN THE FARM SECTOR PRESENTS A SIGNIFICANT IMPEDIMENT TO CAPTURING THE MARKET

Farming equipment with dedicated solar power are not viable, in most cases, due to very low utilisation

Cost of farming operation (INR/ha) by power source



Source: CEEW analysis, 2017

The second fundamental challenge in capturing the farm sector is the need for mobility of most devices. Since, most cultivation activities (except irrigation) need the equipment to be mobile to cover the field, it necessitates the need for a battery, even if the equipment could be mounted with solar panels. If the energy is coming from a DRE-based mini/micro-grid, even in these instances a battery is necessary to enable mobility, adding to the cost of equipment and thus operation. Thus, **battery costs will have a significant bearing on economic viability of DRE-powered farm implements.**

[2] SAM or Segmented Addressable Market is used to reference that part of TAM that can actually be reached, based on customer segment being targeted.

Non-farm sector

We estimate a total addressable market of about USD 13.2 billion for 14 key rural income-generating activities, which constitute about one-third of the 34 million micro-enterprises in rural India. These RIGAs include custom tailoring, *beedi* manufacturing, restaurants, retail shops, hairdressing, flour milling, furniture manufacturing, jewellery making, poultry raising, sweetmeat making, and vehicle repair. The estimated market size pertains to the value of energy-efficient appliances running with DRE (solar and battery) in these RIGAs. The TAM for energy-efficient appliances alone for these RIGAs is about USD 4.9 billion, without considering the power source. Based on a conservative estimate, the segmented market for the non-farm sector is about USD 1.25 billion, after excluding all the enterprises in those RIGAs that do not mention electricity as the top bottleneck for business.

WE ESTIMATE A TOTAL ADDRESSABLE MARKET OF ABOUT USD 13.2 BILLION FOR 14 KEY RURAL INCOME-GENERATING ACTIVITIES

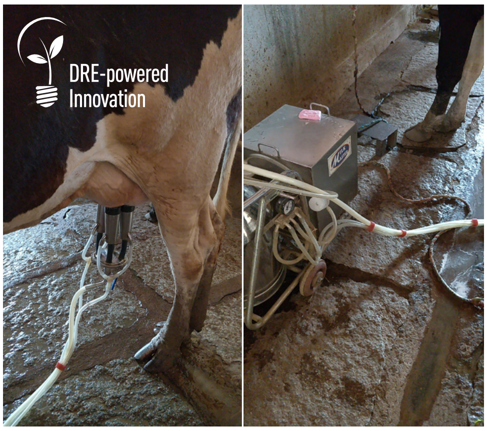
The issue of latent (or potential) demand is worthy to note in estimating market size in the non-farm sector. The lack of reliable electricity discourages potential entrepreneurs from setting up an enterprise. The increase in entrepreneurial activity that could follow the introduction of reliable electricity sources is very difficult to capture in market sizing calculations. This question of latent demand is particularly relevant for the non-farm sector. In the farm sector, activities can still continue without energy input (though with less productivity and dependent only on rainfall), whereas more non-farm activities require electricity to function at all.

A solar-powered dal mill in Wardha district, Maharashtra, installed by Mahatma Gandhi Institute for Rural Industrialization (MGIRI).

Current status of clean energy innovations for livelihood applications

While there are a number of RIGAs where DRE-based innovations could effectively support mechanisation to improve productivity and incomes, we found only 20-odd machines which had been designed or repurposed to run effectively on DRE. The figure below represents the existing innovations along the axis of development. Even among these limited number of innovations, very few have been deployed commercially at a significant scale-only solar pumps have achieved large-scale implementation in the order of 150,000, mainly because of heavy government subsidies.

VERY FEW DRE-POWERED LIVELIHOOD APPLIANCES HAVE BEEN DEPLOYED COMMERCIALLY AT A SIGNIFICANT SCALE. ONLY SOLAR PUMPS HAVE ACHIEVED LARGE-SCALE IMPLEMENTATION IN THE ORDER OF 150,000, MAINLY BECAUSE OF HEAVY GOVERNMENT SUBSIDIES



A solar-powered milking machine in Chitradurga district, Karnatiaka, installed by SELCO India.

Batteries from a Gram Oorja micro-grid, powering a flour mill in Palghar district, Maharashtra.

Very few DRE-powered innovations for livelihood applications have reached commercialisation stage.

DRE-POWERED INNOVATIONS FOR PRODUCTIVE USE, STAGE OF DEVELOPMENT

Concepts	Initial technical & customer validation		Near-commercial
Seed sower	Knapsack sprayer	Cassava grater	Solar pump
Weeder	Rice huller	Dryer	Cold storage
Maize sheller	*Roti* (flat bread) rolling machine	Refrigerator	Sewing machine
	Butter churner	Milling machine	*Charkha* (spinning wheel)
	Cane crusher	Forge blower	
	Egg incubator	Photocopiers and computers	
	Puncture remover	Milking machine	

Source: CEEW analysis, 2017

Assessment of entrepreneurial ecosystem to support innovation and deployment of clean energy solutions in livelihood applications

To understand the ecosystem-level challenges affecting the sector, we conducted semi-structured interviews with 94 stakeholders spanning different backgrounds. We interviewed entrepreneurs, technology experts, business incubators, rural and agricultural economy experts, financiers, impact investors, corporates, multilateral agencies, government representatives, think-tank professionals, and others supporting the ecosystem. Our research revealed major gaps in the entrepreneurial ecosystem with regard to support for, and in particular scaling up of, clean energy and energy efficiency innovations in livelihood applications. While we have categorised the challenges at each stage of the product's life cycle - from concept to prototype to pilot to commercialisation to deployment at scale - most of the challenges span more than one stage of a product's life cycle.

Number and type of stakeholders consulted for semi-structured interviews

4% THINK TANK
16% ENTREPRENEUR
11% TECHNICAL EXPERT
5% INCUBATOR
11% COMMERCIALISATION EXPERT
16% ECOSYSTEM SUPPORTER
17% RURAL ECONOMY EXPERT
6% FINANCIER
5% CORPORATE
6% DONOR AGENCY
3% GOVERNMENT

Source: CEEW analysis, 2017

Challenges in the ecosystem by stage of product development

Concept to prototype

- Lack of very early-stage grant support often stalls potential innovators at the ideas-to-prototype stage;
- The pace of invention is slowed due to limited access to fabrication labs (fablabs) and other such facilities where prototypes could be built and products tested;
- The available fablabs and incubators that support product development are concentrated in urban areas and limited to few cities;
- Lack of policy clarity regarding the role of DRE along with the grid supply leads to business uncertainty for entrepreneurs, which affects the innovation ecosystem and the financial support available for DRE-powered products;
- Emerging sectors such as DRE lack role models and success stories for new innovators to follow. Success stories inspire new entrepreneurs to innovate and help them build networks and access finance;
- Existing ecosystem support mechanisms tend to focus mainly on ambitious entrepreneurs with privileged institutional backgrounds, this leaves out most business owners from the MSME sector.

Prototype to pilot (customer validation)

- The process of technology valuation is not well-developed in government institutions, limiting technology transfer from public research institutions;
- Collaboration between larger businesses and smaller entrepreneurs has been limited. Experts suggest that such collaborations at the right stage can lead to improvements in the design and efficiency of the product, and thus its commercial viability;
- Innovators may have technical expertise but not necessarily the business skills required to get the product off the ground, such as marketing, strategy, or finance.

Pilot to commercial product

- Access to up-to-date market research information is critical for the development of DRE-powered appliances and machinery, but conducting such market research is an expensive exercise for early stage enterprises;
- The high capital expenditure (capex) associated with DRE is the biggest impediment to adoption by customers when compared with low-capex diesel-powered equipment. Micro-enterprise financing mechanisms need to incentivise financing in new capital-intensive technologies;
- Product designs often fail to match customer needs. Product demonstrations and processes to incorporate customer feedback during the design phase is crucial to improve user acceptance;

- Lack of support for large-scale strategic pilots near commercialisation stage makes it difficult for enterprises to move beyond the second 'valley of death'. Such pilots are critical to facilitate product improvements and streamline business models based on customer value proportion assessments. Successful pilots can attract higher investments in commercialising the product, but one-off grants to conduct such pilots do not enable long-term strategic support for enterprises;
- Setting up manufacturing and assembling infrastructure is one of the most significant outlays for enterprises. The investment associated with acquiring the building and machinery (fixed cost) can be a significant drain on the entrepreneur's capacity to invest. Leveraging and partnering with existing small-scale manufacturing set-ups is a more effective solution;
- Subsidies for livelihood products increase adoption in the short-term but affect the long-term sustainability of market-based business models. Performance-linked incentives and interest subsidies could be more conducive to facilitate adoption without skewing market dynamics;
- Lack of access to affordable financing - both for the enterprise as well as the customer - remains one of the biggest impediments to commercialising and scaling up. Unlocking such financing will require addressing bankers' risk perceptions and building their understanding of such products and enterprises;
- Early-stage enterprises promoting energy innovations encounter a fragmented market of rural micro-enterprises, increasing customer acquisition costs. Market aggregation could address the challenges presented by this fragmented customer base, lending important support to early-stage entrepreneurs, thus helping to promote DRE-powered solutions.
- Developing a value chain that is cost effective in terms of manufacturing, distribution, and after-sale service networks is another challenge for enterprises working on DRE products. Strategically developing linkages with existing rural distribution channels (of durable goods) could help enterprises avoid stretching themselves too thin;
- Business models that are only product-based would be difficult to scale up in this sector. Diversifying into energy services, rentals, and pay-as-you-go models, or leveraging village-level entrepreneurs to provide such services, could be a way to enable commercialisation and scaling up.

Commercial product to large-scale deployment

- Inaccessibility of true impact capital - characterised by low expectation of return, high appetite for risk, and patience for longer tenure - limits support to early stage enterprises to move towards growth;
- Energy efficient livelihood appliances, owing to their high price and low volume of sales, are not prioritised by distributors of durable products;
- Lack of collateral on the part of the capital-poor, end-customer creates impediments to accessing loans, which limits the scale of adoption under a direct-purchase model.
- The success of DRE-powered innovations is also dependent on the evolution of individual technology components such as batteries, generation units, and motors. The cost of these components has a direct bearing on the affordability of DRE-powered appliances, and thus on the rate of their adoption.

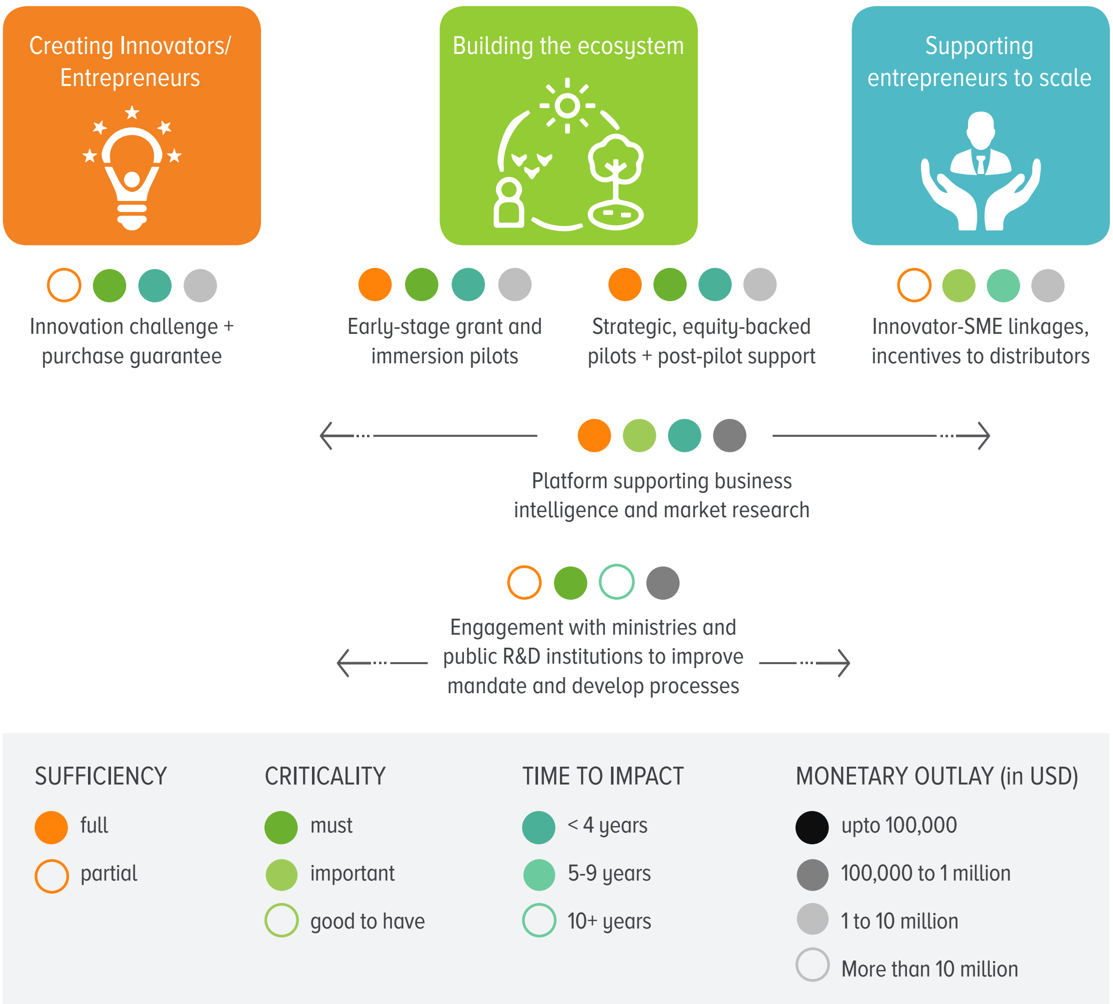
From research to action

Based on engagements with the stakeholders mentioned earlier, we identified a few key areas of intervention to address identified gaps in the ecosystem. To prioritise potential interventions, we used the following four criteria to assess the proposed interventions:

1. **Sufficiency**
   How sufficient is the proposed intervention to address the particular ecosystem gap?
2. **Criticality**
   How critical is the proposed intervention to support the innovation ecosystem for DRE-powered livelihood applications?
3. **Time to impact**
   How long will it take to realise the intended impact through the intervention?
4. **Monetary outlay**
   How much would it cost to undertake the intervention? (this excludes the value created, and includes the outlay directly associated with the intervention)

In the following figure, we discuss the top six interventions that were prioritised on the basis of the above-mentioned criteria from among a long list of proposed interventions.

A snapshot of proposed interventions



Source: CEEW analysis, 2017

A. Creating innovators/entrepreneurs

Innovation challenge with purchase guarantee

Sufficiency: Partial

Criticality: Must

Time to impact: < 4 years

Monetary outlay: USD 1 million - 10 million

A grand challenge that focusses on clean energy innovations for income generation can draw the attention of innovators towards this sector. If an innovator is interested in building a business, a purchase guarantee for the winner(s) will enable them to take the first step towards the same. At present, there are grand challenges that provide grants for product development, but they do not provide any follow-on funding. A purchase guarantee will help winners push prototypes to the product stage using the grant money. Furthermore, committed demand also allows for the deployment of the product at a large-scale (equivalent to a pilot). Hence, customer interest can be validated and the potential market for the product can be tested. Further, the aggregation of demand through a grand challenge could reduce the customer acquisition challenges for the young enterprises.

Grant and immersion programme for early-stage innovations

Sufficiency: Full

Criticality: Must

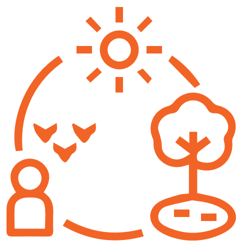
Time to impact: 5-9 years

Monetary outlay: USD 1 million - 10 million

Low-risk capital in the initial stages of growth can help early-stage businesses strengthen their product development. A grant or fellowship programme can incentivise innovators to develop their ideas into prototypes and can help to increase the number of innovators in this space. Since the technical evaluation is only limited to ideas at such an early-stage, the programme could use innovative approaches to monitor performance, such as peer assessments to ensure that there is sincerity of effort and timely course corrections. The programme could also be designed to support entrepreneurs who have achieved a certain degree of sophistication in their ideas.

To help entrepreneurs develop an understanding of the user and usage context, an immersion fellowship programme for innovators could be organised to facilitate co-designing opportunities. This would enable innovators to co-design their products with end users and would allow them to incorporate their feedback during the design and development phase itself.

B. Building the ecosystem



Platform supporting business intelligence and market research

Sufficiency: Partial

Sufficiency: Full

Criticality: Important

Time to impact: < 4 years

Monetary outlay: USD 100k - 1 million

Access to data on markets and consumer segmentation allows enterprises to better understand their customers' needs, target markets, and optimise their communication and distribution. Access to affordable and timely information on markets has been cited as a key challenge by several entrepreneurs. To overcome this challenge, a platform that aggregates various market research and durable product consulting companies to provide pro bono or low bono services to early-stage enterprises in the sector would be useful. The value proposition for market research companies is that it allows them to build their profile, provides them opportunities to understand rural markets and consumers better, and creates potential long-term business opportunities. Companies such as EY, Bain, and Accenture have already been undertaking such initiatives to support non-profits and social enterprises. However, there is a need to create a niche platform for the rural livelihoods space in order to better tap into the resources of international and domestic companies. Further, this kind of collaborative platform would need donor support to develop an open access database of critical market information.

Engagement with ministries and public R&D institutes to modify mandates and develop processes for tech transfer

Sufficiency: Partial

Criticality: Must

Time to impact: 5-9 years

Monetary outlay: USD 100k - 1 million

As discussed earlier, there have been credible innovations to empower agriculture and other non-farm activities through public institutions such as Mahatma Gandhi Institute of Rural Industrialisation and Central Institute of Agricultural Engineering. However, public institutions lack a clear mandate, sufficient focus, and effective operational processes to enable technology transfer. There is a need to strategically engage with these institutions and respective ministries to bring to their attention the importance of technology transfer. In addition, it is necessary to aid in the development of guidelines to enable the same. This would require long-term and persistent engagement over years to first bring attention to the cause, push institutional mandates, and then lay out operational mechanisms to enable greater and faster technology transfer. Ultimately, this could have a significant impact in bringing affordable innovations to end customers.

Facility for large-scale strategic pilots and post-pilot support

Sufficiency: Full

Criticality: Must

Time to impact: 5-9 years

Monetary outlay: USD 1 million - 10 million

Early-stage clean energy enterprises face two major challenges beyond the prototyping stage: (i) difficulty in gathering adequate and strategic financial and technical support to organise a pilot; (ii) absence of post-pilot follow-on support in most cases. While individual enterprises face these challenges, the overall ecosystem lacks a cohesive strategy to support various enterprises during the pilot stage (and beyond). For example, a programme may only support innovations in end applications without taking into account potential improvements in energy efficiency through platform technologies such as cost-effective storage solutions or energy-efficient small-scale motors. Instead of each programme providing a small and inadequate tranche of support to enterprises - which does not allow the pilots to prove the viability of the business model - there is a vital need to pool resources across donors and investors to provide more impactful support for the sector. A facility to pool together philanthropic and impact capital from donors and investors could be instrumental. Such a facility would support enterprises for strategic large-scale pilots and to also provide them with post-pilot support.

The facility could provide post-pilot support for access to networks for follow-on funding, identifying go-to-market strategies, establishing distribution channels, demand aggregation, etc. Several enterprises import a large portion of their products or components from other countries as the costs are lower and production is more convenient. Over the course of the post-pilot period, aggregation efforts could create a network of MSMEs to manufacture and scale products locally. The facility could build such a network in order to reduce the steep learning curve for each enterprise and to collectively optimise the match between the product and the MSME. The collaborative facility could also support enterprises through its core funding and could even act as an enabling platform for donors and investors to support enterprises directly.

C. Supporting entrepreneurs to scale

Strengthening the distribution network for DRE-powered products

Sufficiency: Partial

Criticality: Important

Time to impact: 5-9 years

Monetary outlay: USD 1 million - 10 million

A strong distribution network is essential to promote and scale DRE-powered products. It could also be leveraged to provide timely after-sales services, which is imperative for sustaining the market for a product. A facility, of the kind discussed above, could support enterprises' post-pilot efforts to establish distribution networks, and could also support market aggregators and last-mile distributors. Further, guarantee mechanisms to buy back unsold stock from distributors or finance the interest amounts of their working capital loans could be explored to encourage distributors to stock DRE-powered products in the early phases of market adoption. Options such as buyback could also improve the risk appetite of small- and medium-sized distributors. Currently, most large distributors control the access to credit for rural retailers. However, by easing credit levels for retailers and distributors, the interruption of their cash flow could be prevented, strengthening the distribution network for DRE-powered innovations.

Image: Sasmita Patnaik/CEEW

A solar-powered sewing machine in Chitradurga district, Karnataka, installed by SELCO India.

Conclusion

Acknowledging the energy access barriers for the farm and non-farm sectors in India, The Council aims to move beyond research and support the ecosystem in scaling clean energy solutions to improve livelihood opportunities in rural areas. We envision clean energy to be a catalyst for nurturing income-generating activities through enhanced mechanisation in rural areas. As we move forward, we plan to partner with ecosystem supporters: philanthropic organisations, impact investors, incubators, corporates, and the public sector. We hope to leverage our respective capabilities to provide an enabling environment for many more innovations to get realised, many more products to get commercialised, and many more solutions to get deployed on the ground, to support rural livelihoods.

A solar-powered flour mill in Palghar district, Maharashtra, installed by Gram Oorja.

Woodworking machine, an example of a rural income-generating appliance.

Image: Pixabay

1. Introduction

Access to energy has historically been crucial for economic development. Today, access to modern forms of energy is considered indispensable for alleviating poverty, increasing employment, accelerating economic growth, and providing social services (IIASA 2012). Because of its importance for furthering human development, access to energy was included among the United Nations' 17 Sustainable Development Goals (SDGs) in 2015.

While India is home to 18 per cent of the world's population, it uses only six per cent of the world's primary energy. As of 2015, an estimated 240 million people in India did not have access to electricity, and many more suffered from irregular and poor access. The situation appears even more dire when one considers the case of rural India. Of those without electricity, almost 92 per cent lived in rural areas.

Though the Indian economy has being growing rapidly following the implementation of liberalisation policies in the 1990s, the per capita incomes of urban and rural India remain skewed. In 2011-2012, rural India accounted for 70 per cent of India's workforce but only 46 per cent of the national income (Chand, Ramesh, S.K. Srivastava, and Jaspal Singh, 2017) (Chand et al. 2017). In 2014, World Urbanisation Prospects highlighted that despite rapid urbanisation in India, about half the population will continue to reside in rural areas in 2050 (United Nations 2014). Thus, India will not be able to achieve true economic development without improving the per capita income of rural India. To do so, improving access to energy is key.

Figure 1 (a): Contribution of rural India to Net Domestic Product (NDP) by sector

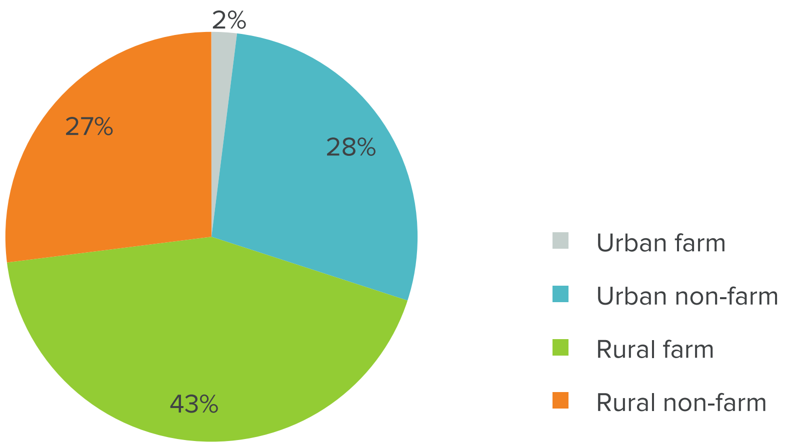
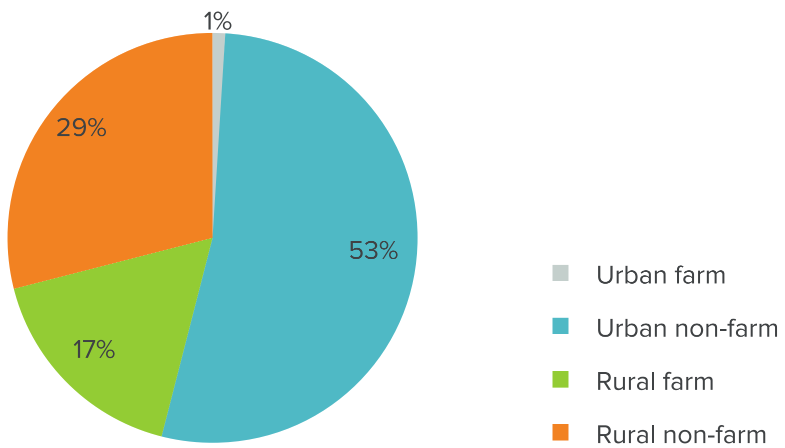


Figure 1 (b): Contribution of rural India to employment by sector



Source: Chand et al. 2017

Mechanisation of the farm and non-farm sectors

Agriculture accounts for only 17 per cent of India's GDP, but it provides a livelihood for almost than half of India's 1.3 billion strong population. Yet, the average annual growth rate of the agriculture sector ranged between one per cent and six per cent between 2004-05 and 2013-14, while during the same period, the overall Indian economy grew at an annual average of at least seven per cent (Central Statistical Organisation 2014; Ministry of Agriculture 2014). Crop yields in India are still only 30 to 60 per cent of the best sustainable crop yields achieved in other parts of the world, including developing countries (Chaudhry 2015). Among the many challenges that plague agriculture in India, one of the most prominent is poor access to affordable and continuous energy supply for mechanisation. In the last 53 years, the average farmpower availability in India has increased from about 0.30 kW/ha in 1960-61 to about 2.02 kW/ha in 2013-14 (Singh 2013). Yet, overall farm mechanisation in India stands at around 40-45 per cent, with some processes such as rice transplanting or weed removal being less mechanised than others (Mehta et al. 2014). In contrast, farm mechanisation in the United States stands at 95 per cent and in Brazil at 75 per cent (ibid.).

Farm mechanisation has furthered agricultural production in developed countries and has contributed to improving labour productivity and reducing drudgery. Studies illustrate that all farmers benefit from improved mechanisation, irrespective of holding size or whether they own equipment (Singh et al. 2014).

According to the Ministry of Agriculture, the share of small (one to two hectare) and marginal (less than one hectare) land holdings in India increased from 70 per cent in 1971 to 85 per cent in 2011 (Department of Agriculture & Cooperation, Agriculture Census Division, 2010-11). Therefore, there is a need to develop innovative technologies, business models, and financial products to encourage small-holder farmers to adopt mechanisation. Further, a study conducted by the Central Institute of Post-Harvest Engineering and Technology, that about 40 per cent of produce in India is wasted post-harvest, translating to a loss of approximately USD 14 billion every year (Sharma, 2017). The non-availability of affordable cold storage facilities at locations convenient to farmers is one of the major reasons for such massive post-harvest losses. However, given the lack of infrastructure, including access to regular electricity, these facilities cannot be expanded to all locations convenient to farmers.

Although agriculture is the main source of income for households in rural India, the share of the non-farm sector in rural household incomes is steadily rising-it increased from 30 per cent in the 1990s to more than 40 per cent in 2010 (Ministry of Statistics & Program Implementation 1993-94/2009-10). Non-farm activities that are high value but have seen only low levels of mechanisation include post-harvest processing of farm produce, custom tailoring, manufacture of textile garments and accessories, and vehicle repair. Further, as productivity improves in the farm sector, people moving away from agriculture will seek employment opportunities in the non-farm sector. This will increase the need to expand and support livelihood opportunities in non-farm sector.

Studies across the world show that improvements in access to electricity directly correlate with increasing incomes. A World Bank (ESMAP 2002) study in the Philippines showed that over 25 per cent of houses in electrified areas operated businesses at home as compared to only 15 per cent in non-electrified areas. Though electrification may not entirely account for the difference, it is indisputable that it helps create business opportunities for communities. A similar study in Nepal by the United Nations Development Programme (UNDP) (Legros et al. 2011) showed that villages powered by micro-hydropower schemes had significantly higher incomes, with access to electricity explaining 30 per cent of the rise in incomes. Micro, small, and medium enterprises (MSMEs) in the service sector in rural Uganda that use solar home systems (SHS) work for approximately one hour longer, attract more customers, and earn monthly profits that are approximately 8 USD higher than a comparable group of businesses in an unelectrified region (Harsdorff and Bamanyaki 2009).

According to the World Bank's 2014 Enterprise Surveys, over 55 per cent of small, medium, and large manufacturing and service sector firms in India are affected by electricity supply interruptions an average of 14 times a month. The survey also suggests that Indian firms lose about four per cent in annual sales due to such interruptions, and that over 21 per cent of firms consider the lack of regular electricity supply a major constraint (World Bank, 2014). Workflow interruptions, and the damage caused to sensitive electrical equipment by power fluctuations, not only limit the productivity of enterprises, but they also hinder the establishing of new enterprises. In the largest energy access survey to date, conducted across six states of India in 2015 by CEEW, only 39 per cent of rural businesses using electricity indicated that they were satisfied with their current electricity supply. Of the businesses not using electricity, about 52 per cent mentioned that access to electricity can contribute to an increase in income (Jain et al. 2015). Our analysis on National Sample Survey Office (NSSO) 73rd round survey of unincorporated non-farm enterprises indicates that owners of 4.4 million enterprises in rural India complained of erratic power supply as one of the top bottlenecks affecting their business (Ministry of Statistics & Programme Implementation 2015-16).

Opportunities for improving mechanisation in rural India through affordable and reliable sources of renewable energy

Decentralised renewable energy (DRE) could bridge gaps in access to energy and increase overall mechanisation. There is growing evidence that DRE-powered innovations can contribute to driving agricultural mechanisation in India. One such estimate showed that replacing five million diesel pumps with solar pumps could result in savings of nearly 18 GW of installed capacity, 23 TWh of electricity, 10 billion litres of diesel, and 26 million tonnes of carbon dioxide emissions (Indian Council on Agricultural Research 2017). Other examples include solar-powered cold storage units and solar-powered sprayers, though these studies examined a relatively small scale of deployment. If rural businesses can effectively leverage existing market linkages to purchase small and innovative machines powered by DRE, this can help improve productivity and lower the operational costs associated with post-harvest processes such as rice milling, flour milling, dal milling, and oil extraction from oilseeds, among others.

Both the farm and non-farm sectors in India are underserved by existing energy sources and hence present enormous potential for the productive use of DRE. Existing distributed generation assets and new DRE capacity can both be leveraged to unlock significant untapped economic opportunities in rural India, such as home-based enterprises and more efficient post-harvest processing. While the government's electrification policy and schemes primarily focus on household electrification (Ministry of Power 2017), this needs to expanded to cover interventions that can boost rural economic activities. Rural lives that have been deprived of equitable energy access are already being transformed by the improved productivity, enhanced product value, reduced inputs cost, and reduced drudgery of innovations such as solar-powered sewing machines, milk-chillers, milking machines, pottery wheels, weaving machines, solar pesticide sprayers, and biomass-based co-generation, among others. Organisations such as SELCO Foundation have been pioneers in innovating, incubating, and commercialising DRE-powered appliances for productive use. However, the product and customer development ecosystem for DRE is still evolving, and to find a large user base, it must overcome significant technical, financial, and policy challenges. Customers - farmer and entrepreneurs - encounter numerous challenges that prevent or delay adoption, such as cash flow problems, high capital costs, lack of familiarity with new technologies, low asset utilisation, and lack of after-sales support. For distributors, there is limited incentive to stock DRE-related products considering weak demand due to these impediments, or because of a lack of awareness on the part of customers. For entrepreneurs involved in the production or distribution of DRE-powered products, the market remains large but highly fragmented, making it difficult for them to capture the same. For innovators, production of new technologies is hampered by the lack of user feedback. Entrepreneurs, financiers, policymakers, and other ecosystem supporters need to leverage synergies to overcome the challenges in achieving their goal of transforming livelihoods in rural India.

This report explores the potential of DRE and energy efficiency (EE) innovations to improve rural electricity access. It maps the existing challenges in the entrepreneurial ecosystem and outlines potential interventions.

Chapter 2 provides an overview of the study and outlines its research methodology and limitations.

Chapter 3 undertakes a demand-side analysis of DRE-powered electricity access for increasing mechanisation in the farm and non-farm sector. This chapter provides information on the economic viability and market potential of DRE for powering key farm and non-farm rural income-generating activities (RIGAs).

Chapter 4 maps existing DRE-powered livelihood applications, from the concept stage to their commercial availability. Through case studies, this chapter presents four innovations that have seen some uptake and that have helped supplement incomes in rural India.

Chapter 5 highlights the challenges inherent to the ecosystem as experienced by stakeholders. This chapter analyses these challenges across all stages of the product ecosystem and elaborates on potential interventions that could partially or sufficiently address some of these challenges.

Sugarcane juicer, an income-generating appliance. Sugarcane juice is a popular drink across urban and rural India.

Image: Lovell D'souza / flickr

2. What is I-DESIRE?

There is now a widely acknowledged need to map existing DRE-powered solutions for rural economic activities and to facilitate evidence-based action to support the growth and sustainability of the sector. The initiative was started as there was a clear need for a common platform that brings together all stakeholders, ranging from innovators and entrepreneurs to impact investors, donors, and the private sector, along with all the ecosystem supporters who are crucial to the process. The Initiative for DRE and Efficiency Innovations to Support Incomes in Rural Economy (I-DESIRE) was conceptualised in order to eliminate barriers to energy access in rural India, and to improve incomes in the farm and non-farm sectors.

The Council for Energy, Environment, and Water (CEEW), with the support of the Good Energies Foundation, conceptualised I-DESIRE to leverage clean energy to mechanise rural India. The objective is to establish a platform that will educate relevant stakeholders of the untapped potential of DRE in the farm and non-farm sectors and which will support the innovation ecosystem for DRE products and services.

2.1 I-DESIRE programme overview

I-DESIRE has adopted a two-phase plan, as discussed below:

Phase 1: Research to understand the existing market and the current challenges in the entrepreneurial ecosystem

We first identified the challenges, opportunities, and gaps in the clean energy ecosystem, with regard to rural income-generating activities (RIGA). We focused on the current incentives and constraints facing customers, entrepreneurs, financiers, and ecosystem supporters, as shown in Figure 2. Our research was aimed at understanding the following:

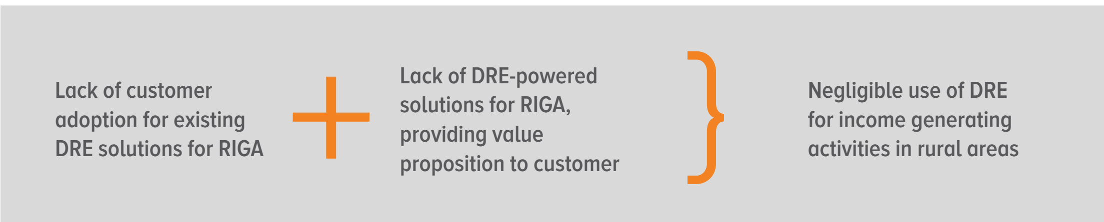
1. The demand-side conundrum: what is the potential demand for DRE-powered solutions for RIGA?

We analysed farm and non-farm RIGA in India to estimate the potential for a DRE intervention. The customer base for innovators and entrepreneurs providing DRE products and services was estimated to be 119 million cultivators and 34 million non-farm unincorporated rural enterprises. This exercise was done to estimate the market size and economic viability of DRE interventions in farm and non-farm RIGA. The key question: is there a lack of customers for existing DRE solutions applied to farm and non-farm RIGA?

2. The supply-side mystery: which DRE-powered solutions exist today that cater to RIGA?

We collected secondary data on current DRE-powered solutions and cross-checked this using primary interviews with sectoral experts. We catalogued our findings on DRE-powered applications catering to the farm and non-farm RIGA sectors, and conducted brief case studies. The key question: is there a lack of DRE-powered products that can be applied to farm and non-farm RIGA?

Figure 2: Demand-side conundrum and supply-side mystery with reference to DRE for RIGA



Source: CEEW analysis, 2017

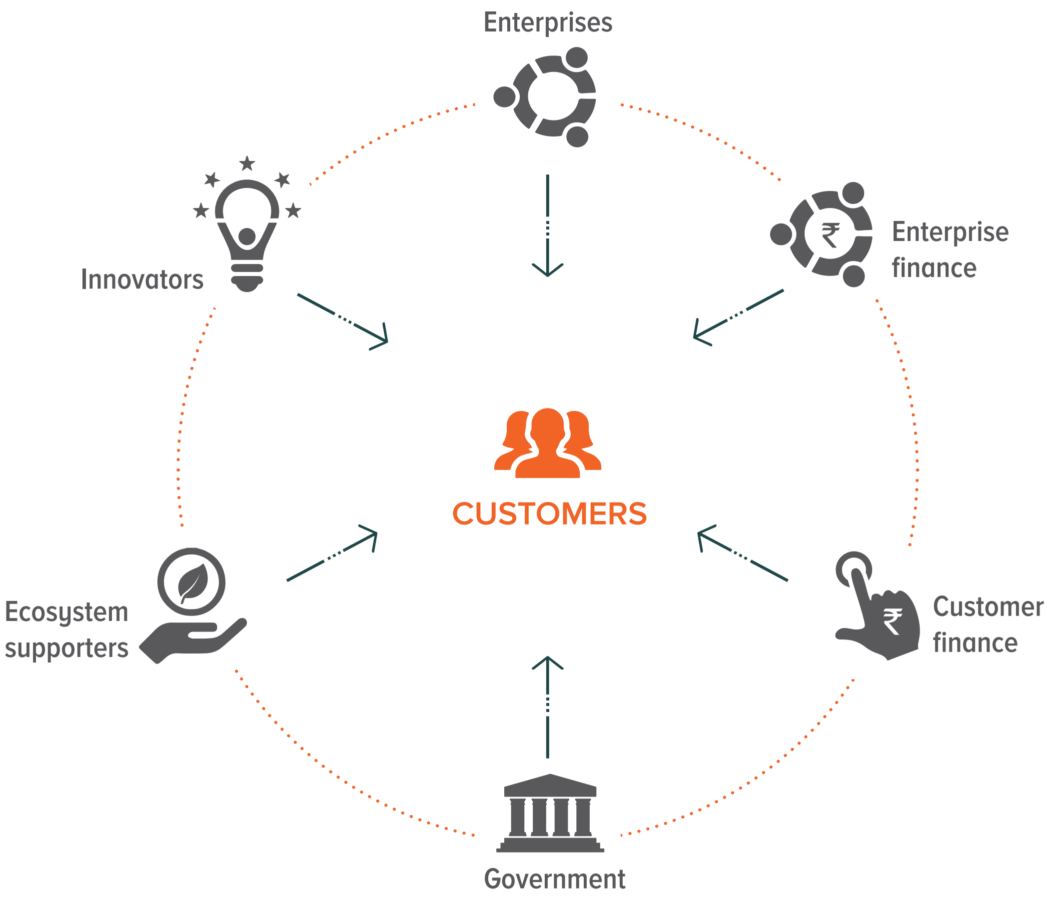
3. The ecosystem of DRE for RIGA: what are the gaps in the existing ecosystem which act as bottlenecks for all stakeholders?

After conducting extensive stakeholder interviews and field visits, we identified more than 30 gaps in the ecosystem for DRE-powered RIGA solutions. We shortlisted the gaps with the help of our Core Advisory Group (CAG), to arrive at the key ecosystem gaps that need to be urgently addressed. Guided by the recommendations of experts, our research and a framework that captures multiple aspects of ecosystem building, we formulated potential interventions that would help fill the identified gaps in the ecosystem, either partially or fully. The framework is discussed in depth in the later chapters, including Figure 20.

Phase 2: Design and execution of an intervention to address an existing challenge or gap in the sector

The research identified interventions that would help plug gaps in the ecosystem for DRE-powered livelihood applications, and thereby unlock the potential of DRE-powered innovations to support RIGA. Based on the research findings, the programme will then conceptualise and design interventions in association with other potential partners such as philanthropic organisations, public sector agencies, impact investors, incubators, and corporates, among others.

Figure 3: Ecosystem approach to DRE-powered solutions for RIGA



Source: CEEW analysis, 2017

2.2 Methods and data

A comprehensive literature review, which included both qualitative and quantitative methods of data collection and analysis, informed the research.

The subsequent points highlight the data sources, methods used, and their purpose in specific aspects of the research:

1. Demand-side: Publicly available data was used to shortlist key farm and non-farm RIGA, and therefore estimate the market potential for DRE-powered livelihood appliances. This data was sourced from i) National Sample Survey: Operational Characteristics of Unincorporated Non-agricultural Enterprises 2010-11 (Ministry of Statistics & P.I., 2010-11); ii) National Sample Survey: Key Indicators of Unincorporated Non-agricultural Enterprises (Excluding Construction) in India 2015-16 (Ministry of Statistics and P.I., 2015-16); iii) Directorate of Economics and Statistics: Ministry of Agriculture; iv) Statewise estimates of Value of Output from Agriculture and Allied Activities (Ministry of Statistics & P.I., 2013); and v) Agriculture Census (Input Survey) 2010-11 (Department of Agriculture & Cooperation, Agriculture Census Division, 2010-11).

2. Supply-side: Survey of literature, including journal publications, internet searches using selective terms, and snow-balling interviews with innovators to identify and collate a list of DRE-powered livelihood appliances in India.

3. Primary interviews were held with stakeholders, including investors, multilateral and bilateral agencies, corporations, DRE and rural economy sector experts, entrepreneurs, representatives from incubators and accelerators, farmer producer organisations (FPOs), scientists, innovators from public R&D institutions, and various ecosystem supporters including NGOs. A semi-structured interview guide was used to identify and understand ecosystem challenges pertaining to product and customer development.

For the FPO interviews, a structured questionnaire was used, which captured information on the wage rates of employees, equipment used for mechanisation, rental cost for use of equipment, etc. For interviews with innovators and entrepreneurs, we designed a semi-structured questionnaire that captured the technical, commercial, and policy dimensions of their product and business. Associated risks (intrinsic or extrinsic) were identified and recorded, as was their strategy to cope with those risks. The stakeholder interviews helped us in multiple ways: mapping ecosystem gaps, developing a deeper understanding of India's farm and non-farm sector, and building a list of existing DRE-powered solutions in the farm and non-farm RIGA sectors. A detailed list of stakeholders interviewed in the process is provided in Annexure 1B.

To guide the research and gather feedback at regular intervals, we created an advisory group comprising experts associated with the broader space of innovation, entrepreneurship, DRE, and market research (see Annexure 1C). The advisory group was also consulted on how to prioritise the shortlisted interventions.

A CEEW researcher taking notes during a field visit to a village in Karnataka, documenting the use of a solar-powered fridge in a shop.

Figure 4: Number and type of stakeholders consulted for semi-structured interviews

4% THINK TANK
16% ENTREPRENEUR
11% TECHNICAL EXPERT
5% INCUBATOR
11% COMMERCIALISATION EXPERT
16% ECOSYSTEM SUPPORTER
17% RURAL ECONOMY EXPERT
6% FINANCIER
5% CORPORATE
6% DONOR AGENCY
3% GOVERNMENT

Source: CEEW analysis, 2017

2.3 Scope of the research

The scope of this research has been determined based on the objectives of I-DESIRE. The following guidelines were followed to determine the focus of the study and arrive at the market potential of DRE in the farm and non-farm sectors.

- Primarily, livelihood applications requiring mechanical or electrical energy inputs are considered. Applications requiring direct thermal energy input, such as brick kilns, activities in food processing with mainly thermal inputs are not considered in the current research, mainly to keep the scope of research manageable.
- Hospitals and schools are classified as community use of energy, and therefore, they are not considered in the current scope of research, which focuses more on livelihood activities.

- Livestock businesses such as dairy, poultry, and pig farms do not feature as part of the framework, since they heavily comprise of processing and manufacturing activities, which are considered to be non-farm activities under National Industrial Classification 2008.
- When considering the gaps in the DRE ecosystem, only concept-level gaps are considered. Implementation-level gaps explaining effectiveness of existing initiatives are not assessed in the research.
- Livelihood activities primarily in rural areas are considered, as per the classification of rural sector by Ministry of Statistics and Programme Implementation.
- One aspect of further research, which is not in the scope of current study, is the issue of latent demand. Improved electricity access can potentially lead to an increase in productivity and incomes along with a reduction in costs for the farmer or rural enterprise. However, access to reliable power in rural areas could lead to evolution of new forms of business and industry that do not exist in those areas today. Such incremental market (or latent demand) is not estimated as part of the demand estimation.

Batteries connected to a microgrid powering productive use activities in a tribal village in Maharashtra, as captured during a field visit.


Image: Sanchit Waray/CEEW

Villagers in a tribal village of Maharashtra wipe off the dust of solar panels in a microgrid that powers local homes and a flour mill.

A solar-powered refrigerator installed in a shop in rural India.

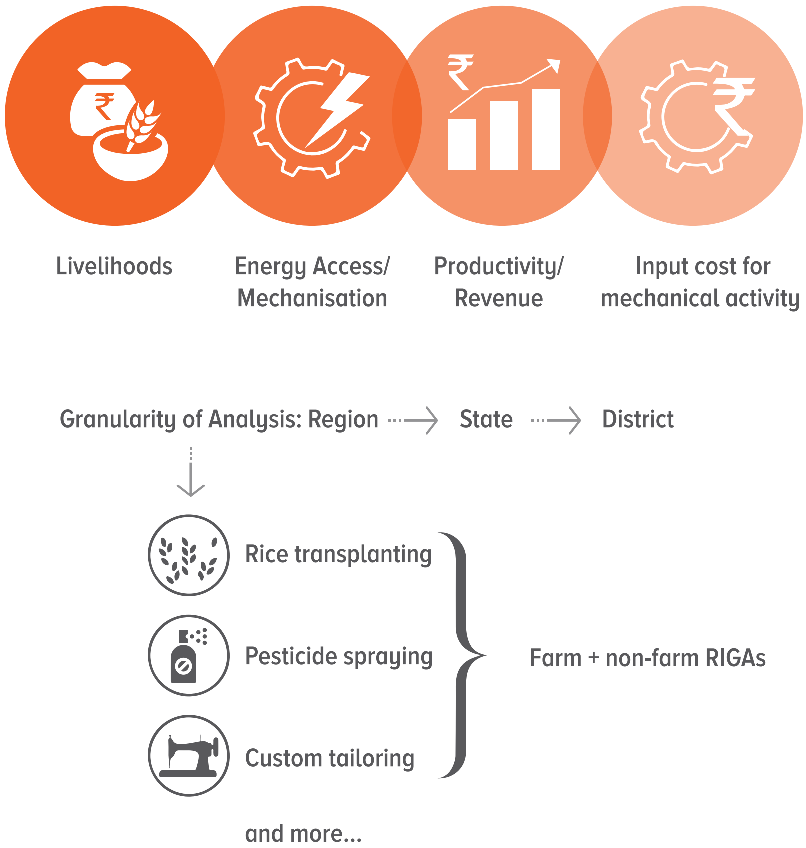
Image: Sasmita Patnaik/CEEW

3. Demand for DRE-powered Mechanisation

Economists and policymakers broadly classify the rural economy into two sectors, the farm and non-farm. While the farm sector accounts for 64 per cent of all livelihoods in rural India, the non-farm sector accounts for the rest, with manufacturing contributing nine per cent, wholesale repair and trade six per cent, and transportation and storage three per cent (Ministry of Statistics & P.I., 2009-10). While the farm sector offers thousands of crop value chains, the non-farm sector comprises as many income-generating activities. To focus our research effort on particular RIGAs, while still covering a substantial portion of the rural economy, we prioritised a few sectors of interest and the corresponding RIGAs using four factors: associated livelihoods, prevailing access to energy, mechanisation potential, productivity and revenue, and the input cost for the activity (see Figure 5).

Further classification was done using data from the National Sample Survey 2010-2011 (67^{th} Round) and using National Industrial Classification (NIC) 2008 codes. Given that a significant share of the rural population relies on farm activities for their livelihoods, the scope for mechanisation in terms of scale is also larger in the farm sector.

Figure 5: Framework for prioritising farm and non-farm RIGAs



Source: CEEW analysis, 2017

3.1 Farm sector

3.1.1 Methodology

For the farm sector, we shortlisted 10 crops using three indicators with predetermined weights, to create a composite score for each crop.

1. Number of operational landholdings cultivating the crop (50 per cent),
2. Value of farm produce per hectare (25 per cent),
3. Ratio of human and animal labour expenses to machine-use expenses (25 per cent).

We assigned weights to these parameters, prioritising scale (determined by the number of farmers cultivating a crop) over the other two parameters. Equal weight was given to the average value of the crop and the mechanisation potential (determined by the ratio of human and animal labour expenses to machine-use expenses). While the former is determined by the economic value of the crop, the latter is determined by the market potential for DRE-powered energy-efficient appliances in the sector.

After multiplying the weighted ratios with the values obtained, the key crops were shortlisted using percentile ranks. A detailed explanation of the normalisation methodology is provided in Annexure 2.

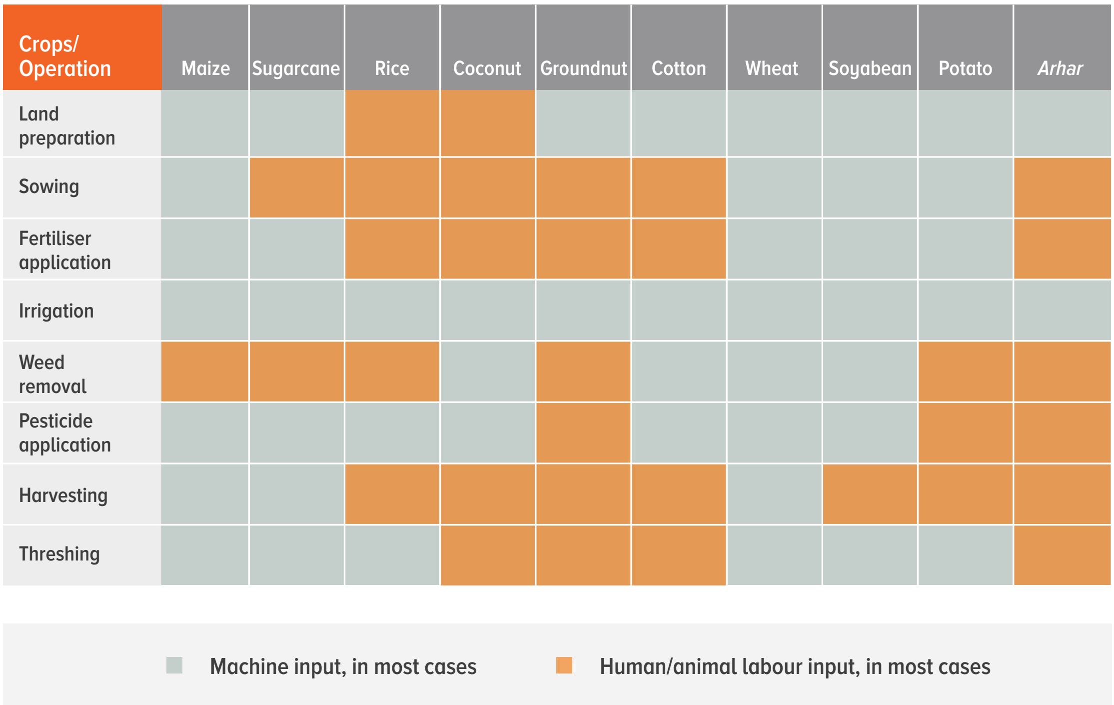
Table 1: Key crops in the farm sector

RIGA	Equipment (for cultivation)
All crops	Power weeder, knapsack sprayer, vertical conveyor reaper, multi-crop thresher, reaper binder
Cotton	Cotton picker
Coconut	Brush cutter
Paddy (rice)	Rice transplanter, paddy thresher
Wheat	Multipurpose grain mill
RIGA	**Equipment (for processing)**
Sugarcane	Sugarcane crusher
Maize	Grain cleaner cum destoner
Arhar (toor dal)	Mini *dal* mill
Groundnut	Groundnut decorticator
Potato	Potato grader

Source: CEEW analysis, 2017; (Directorate of Economics and Statistics 2014; Ministry of Statistics and Programme Implementation 2013; Department of Agriculture Cooperation and Farmers Welfare, Agriculture Census Division 2010-2011)

In the following step, we built a matrix of crops and farm operations to prioritise processes for mechanisation via renewable energy, focussing on operations with a high percentage of human labour. As Figure 6 shows, crops such as rice, coconuts, groundnuts, cotton, and arhar (toor dal) are the least mechanised-mainly due to the low cost of human labour, or the unavailability of suitable machines that can cater to the needs of smallholder farmers. We adopted a value chain approach to identify mechanisation opportunities in the farm sector (for the shortlisted crops), from land preparation to harvesting and threshing.

Figure 6: Level of mechanisation across different crops and farm operations



Source: CEEW analysis, 2017

To perform an in-depth analysis across the value chain of the shortlisted crops, we considered activities that involve high drudgery (such as paddy transplanting) and require small loads of less than 5 kW (such as pesticide spraying). To assess this, semi-structured interviews were conducted with FPOs and agriculture-based businesses to estimate the existing level of mechanisation for each cultivation activity, types of equipment used, and the cost of undertaking the activity using human/animal labour as compared to machines. The types of equipment considered after this analysis were reaper binders, knapsack sprayers, and paddy (rice) transplanters, for which the typical load profiles are listed in Figure 7. The methodology used for the interviews can be found in Annexure 2.

Figure 7: Value chain approach to identifying mechanisation opportunities in farm RIGA

Example: Rice value chain

Main operation	Secondary operation	Farm implement	Typical load
Threshing	Mechanised threshing	Multicrop thresher	7.5 kW
Harvesting	Mechanised harvesting	Reaper binder	5 kW
Crop management	Applying pesticide	Knapsack sprayer	0.5 to 1.5 kW
Nutrition management	Applying fertilisers	UDP applicator	5 to 7.5 kW
Water management	Irrigation	Pump	0.5 to 20 kW
Planting	Seed planting	Transplanter	3 kW
Land preparation	Ploughing	Plough machine	18 kW

Farming activities considered small loads, high drudgery

Source: CEEW analysis, 2017

Figure 7 denotes typical farm operations across the entire crop cultivation value chain, including the implements used and the load profiles of appliances. For instance, in the rice value chain, the operations considered for our analysis are transplanting, pesticide spraying, and the harvesting of grain crops. These operations were chosen as they involve appliances with comparatively small loads while being drudgery heavy, and hence offer a greater market potential for product innovations powered by DRE. As it is more economically viable to create DRE-powered solutions that work with smaller loads,we prioritised activities that require smaller loads (less than 5 kW) for mechanisation. However, the potential impact of machines that use larger loads such as a 7.5 kW multi-crop thresher or urea deep placement applicator cannot be negated. Further, with improvements in energy efficiency, many existing machines can be optimised to operate at lower loads. For estimating market size, we have limited our scope to machines that use loads below 5 kW.

3.1.2 Estimating market potential

We estimated the market size for three DRE-powered farm implements - knapsack sprayer, paddy transplanter, and reaper binder - as these implements satisfied our study criteria (reduced drudgery and loads below 5 kW) and are key components of the value chain of their respective crops. Some important assumptions made during the market sizing exercise include:

- Average cropping intensity for the crops
- Number of days of operational flexibility for each farming activity
- Effectiveness of the sharing of farm implements among cultivators

'Flexibility of farm operation' here refers to the number of days a crop can withstand a delay in a farm operation,without incurring a significant loss. For example, the crop should be harvested within a window of 7-10 days for wheat, once it matures. Similarly, sowing should be finished within a window of 10-15 days for most crops, but it can be delayed or advanced outside of this window. 'Implement-sharing effectiveness' refers to the maximum number of people who can share a particular implement, as dictated by geographical limitations and time constraints with regard to flexibility (as defined above). Our calculation of the market size for DRE-powered appliances only considered farmers with no access to electricity. To estimate the economic viability and test the value proposition of DRE-powered applications, we compared the cost per hectare for farming operations powered by human and animal labour, diesel and kerosene, and standalone solar. Our analysis of the cost per hectare is based on the input costs for each farm operation: energy costs, human labour costs, and depreciation of the machinery. Key assumptions include machine field capacity, rental rates for the machinery, and the daily wage rate for agricultural labourers.

Data and assumptions for market demand estimation:

- For the knapsack sprayer, we assume a sharing effectiveness of only 20 per cent because, based on interviews with FPOs, these are usually owned by farmers. For other equipment, we estimated the sharing effectiveness to be 80 per cent, considering that capex-heavy implements are often rented and shared among farmers.
- Operational flexibility was assumed to be four, five, and seven days respectively for the three farm operations of pesticide spraying, paddy (rice) transplanting, and harvesting of grain crops. This was validated through semi-structured interviews with FPOs.
- We assumed an average cropping intensity of 137 per cent for all crops. This assumption was based on data from the Department of Agriculture Cooperation and Farmers Welfare, Agriculture Census Division 2010-2011.
- The total addressable market (TAM)[3] is calculated as the market for all three farm implements at current market prices.
- The segmented addressable market (SAM)[4] excludes 22.76 million landholdings having access to electricity and, indicated through their use of electric pumps (Department of Agriculture & Cooperation, Agriculture Census Division, 2010-11).
- For human labour, the daily wage rate is taken to be INR 315/day, based on India's average daily wage rate between 2013 and 2015 (Directorate of Economics and Statistics 2014-15; Directorate of Economics and Statistics 2013-14).
- The field capacity of each farm implement is calculated as the number of hectares that can be covered in a given period of time. The field capacity data have been obtained from the Ministry of Agriculture's farm mechanisation portal (Ministry of Agriculture and Farmers Welfare 2017).
- The data on rental rates for machinery was obtained through interviews with FPOs, and from the farm machinery rental note published by the National Bank for Agriculture and Rural Development (2017).
- The current market price of farm implements is as provided by the farm mechanisation portal governed by the Ministry of Agriculture and Farmers Welfare, Government of India.
- Electric motor efficiency is assumed to be 65 per cent and diesel engine efficiency is assumed to be 35 per cent, based on industry estimates.

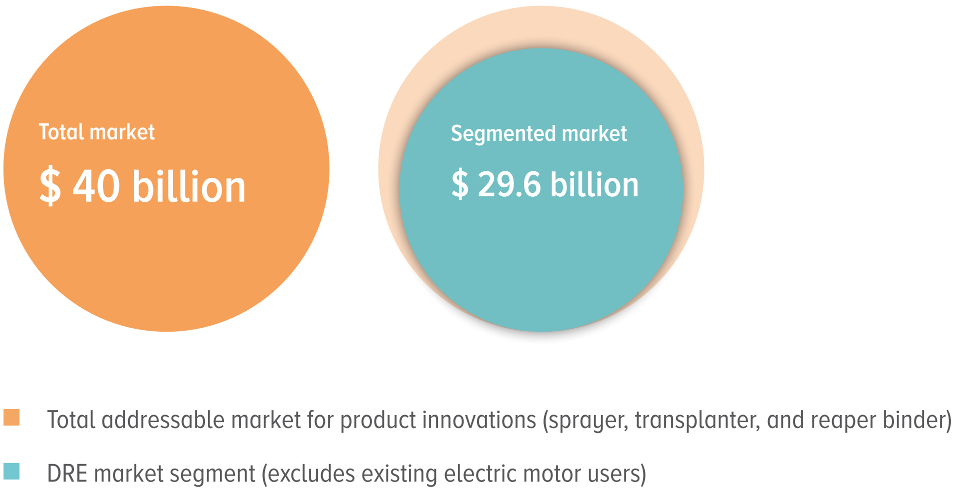
[3] TAM or Total Addressable Market is used to reference the revenue opportunity for a product or service. It is a means of prioritising business opportunities based on the underlying potential of a given opportunity.

[4] SAM or Segmented Addressable Market is used to reference that part of TAM that can actually be reached, based on customer segment being targeted.

Figure 8 represents the market potential for product innovations in select farm operations in the farm sector: paddy transplanting, pesticide spraying, and harvesting of grain crops.

Given the large number of cultivators in India (119 million), the potential TAM for DRE-powered products is estimated to be USD 40.9 billion, based on the current market price of farm implements. The segmented market excludes 22.76 million cultivators who are sharing 19 million electric pumps across India. We assume that farmers who have access to an electricity connection will have limited interest in adopting DRE-powered appliances, particularly as early adopters. As a result, the segmented addressable market (SAM) is approximately USD 29.6 billion.

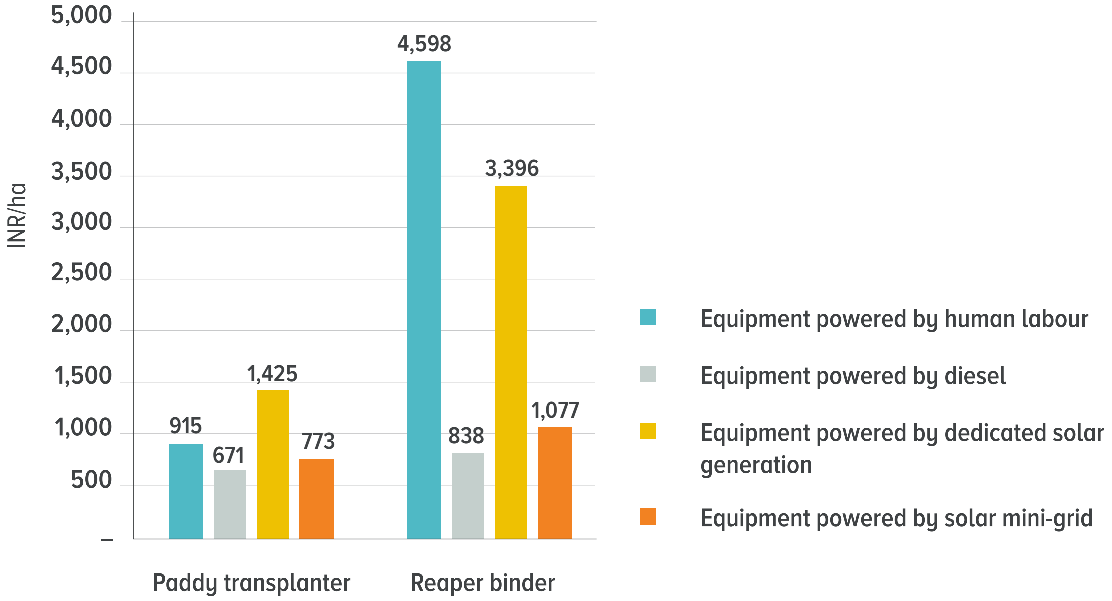
Figure 8: Market segmentation and potential for key farm RIGAs



Source: CEEW analysis, 2017

Considering the per hectare cost of paddy transplanting and harvesting, we find that in most cases, powering these implements with a dedicated source of renewable energy such as solar power is economically unviable. These machines are used for only a few days in the cultivation cycle, and hence fail to recover their cost. However, a more viable alternative is to use the same energy-generating asset to power multiple machines. In such a context, machines powered by mini- or micro-grids would have operational costs similar to kerosene- or diesel-driven farm machinery. However, the economic viability and uptake of DRE-powered livelihood appliances also depends on local factors such as the availability of cheap kerosene and diesel and individual consumer preferences. As human labour is relatively cheap in India, labour costs are almost on par with the costs associated with mechanisation, except in the case of grain harvesting, where the low field capacity of human labour cannot compete with the efficiency of reaper binders.

Figure 9: Per hectare cost comparison for paddy transplanting and harvesting of grain crops, powered by different energy sources



Source: CEEW analysis, 2017

Our interviews with agriculture experts and FPOs representing farmers indicated that as the availability of affordable human labour decreases in rural areas, cultivators are more likely to opt for affordable machinery. Figures 9 compare the cost of powering various agricultural activities using different energy sources. However, it is important to understand the factors that drive operational costs for DRE-powered farm applications, in order to assess the pathways through which DRE can effectively reduce human drudgery and replace diesel-driven implements.

To understand the costs associated with DRE-powered technologies, we undertook a sensitivity analysis of the various parameters which drive up the cost of DRE technologies. Here we take a look at the specific case of a paddy transplanting operation. A key factor was the energy efficiency of the equipment or machinery (see Figures 10a and 10b), followed by the cost of energy (and related build-up factors). Cost of energy is significantly driven by system costs beyond the solar panel costs, including the cost of storage. The trend is applicable for both a standalone system or a mini-grid. Reducing the cost of solar panels will therefore not have a significant impact. Thus, innovators need to focus on improving the energy efficiency of machines and reducing the cost of batteries in order to make DRE-powered applications economically viable. Currently, there is not enough emphasis on energy-efficient livelihood appliances in India, given the prevailing situation where farmers are dependent on unreliable and state-subsidised electricity supply.

Figure 10 (a): Energy efficiency has a significant impact on economic viability of DRE-powered livelihood appliances

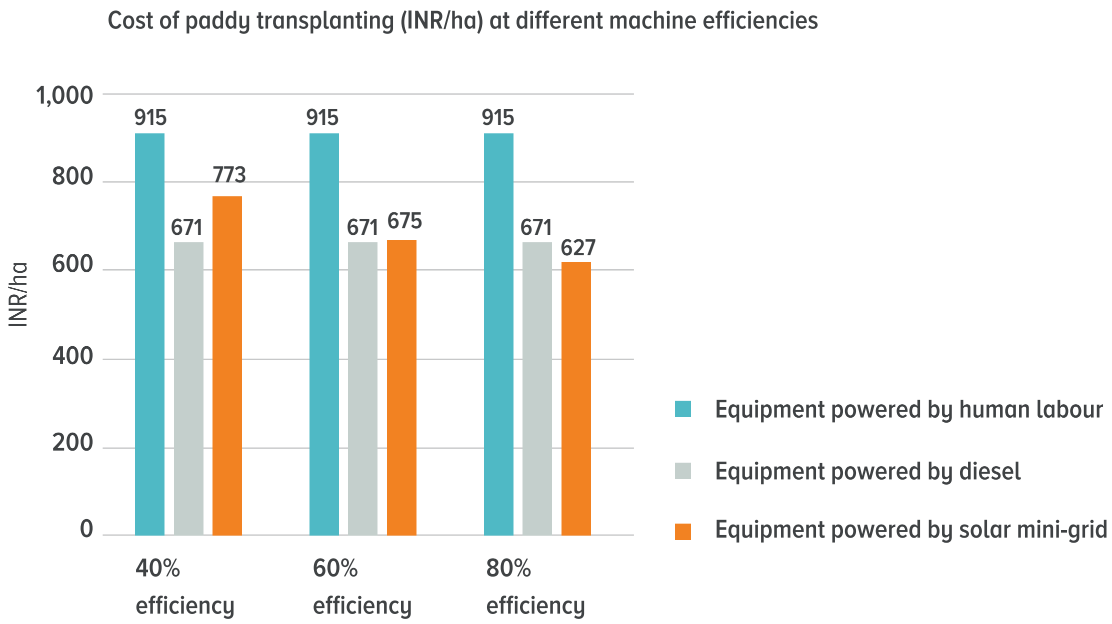
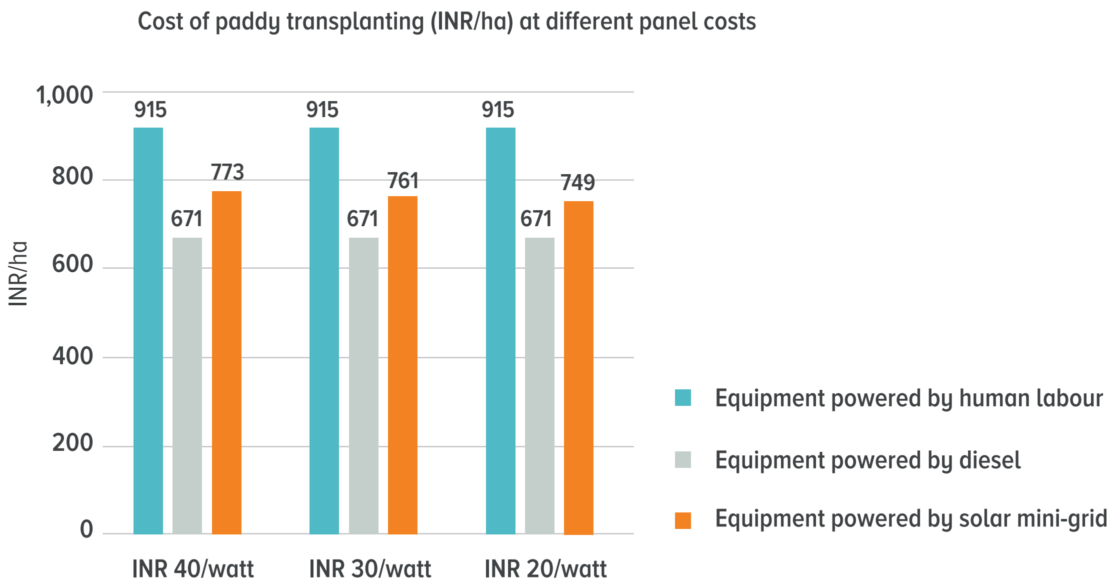


Figure 10 (b): Price of solar panels have negligible impact on economic viability of DRE-powered livelihood appliances



Source: CEEW analysis, 2017

3.2 Non-farm sector

The non-farm sector forms the backbone of India in terms of its contribution to household incomes and the rural GDP. Though its provides lesser employment in rural areas compared to the farm sector, its share has grown significantly - from 15 per cent in the early 1970s to more than 35 per cent in 2011-12 (Chand, Srivastava, and Singh 2017). Thus, it is important to focus on the issues impacting India's non-farm sector in particular, on the lack of opportunity caused by inadequate access to electricity.

3.2.1 Selection of top non-farm RIGAs

To analyse the non-farm sector in India, we used the data from National Sample Survey 2015-2016 (73rd Round) of Unincorporated Non-Agricultural Enterprises (Excluding Construction) (Ministry of Statistics and P.I., 2015-16). This dataset comprises information on 34 million unincorporated non-farm rural enterprises - one of the latest and most comprehensive survey datasets on rural non-farm livelihoods in India. Using this dataset, we shortlisted the top RIGAs based on the following factors:

1. Number of enterprises engaged in a RIGA (50 per cent),
2. Gross value added (GVA) per worker (25 per cent),
3. Ratio of emoluments (i.e. labour costs) to electricity and fuel expenses (15 per cent),
4. Proportion of enterprises reporting electricity access as a key bottleneck (10 per cent).

Similar to our analysis of the farm sector, scale (the number of enterprises engaged in a RIGA) was given the highest weightage, as interventions that targeted the most widely practised RIGAs would have an impact on the largest number of people and their livelihoods. GVA per worker received the second-highest weightage, reflecting the potentially higher gains that can be realised with improved productivity. The ratio of emoluments to electricity and fuel expenses is used as a proxy to estimate the level of mechanisation in the RIGA. Lastly, we considered the proportion of non-farm enterprises in each RIGA which explicitly stated access to electricity as one of their top two bottlenecks.

We estimated the composite score for each RIGA by calculating the weighted average sum of the normalised score across each parameter. (A detailed explanation of the normalisation methodology is provided in Annexure 2.) Finally, we selected for further analysis the 12 RIGAs with the highest overall score (see Table 2).

In addition to the RIGAs shortlisted using the above framework, we also included post-harvest processing as a key non-farm RIGA in our analysis. We chose to do so because (i) some of these RIGAs (and their equipment) are related to the crops we have considered in the farm sector; (ii) value chain losses from 'farm to fork' in India are estimated to be INR 92,000 crores annually (Ministry of Food Processing Industries 2016); (iii) since the feedstock for these activities is produced in rural areas, greater value addition in rural areas before goods are transported to consumer markets would improve rural incomes.

Table 2: Non-farm RIGAs considered for the assessment

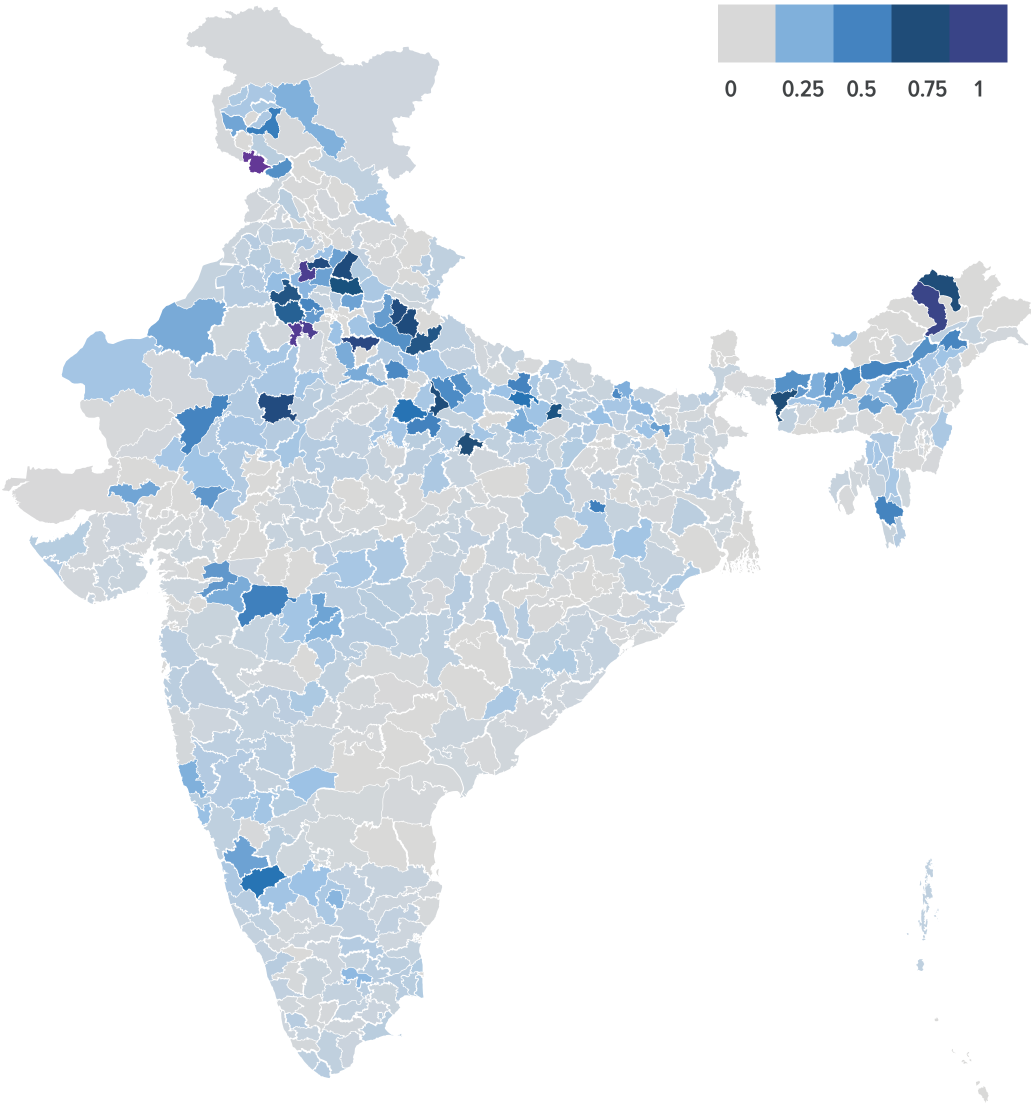
RIGA	Equipment
Post-harvest processing+	Paddy thresher, rice huller, groundnut decorticator, flour mill
Custom tailoring	Sewing machines
Wooden furniture	Wood working machine, wood engraving machine, bamboo slicer
Doors and windows	Various types of equipment
Gold and silver jewellery	Bangle-ring rolling machine, coating machine, bangle sizing machine
Poultry and slaughtering	Portioning machine, egg incubator, stunning unit
Bidi manufacturing	Tobacco packing machine, filter tobacco machine, tobacco mixer
Structural wooden goods	Multiple equipment
Sweetmeat making++	*Paneer* plant, ice cream homogeniser, dairy milk chilling tank
Textile garments	Automatic fusing machine, trouser finishing press
Motor vehicle repair	Air compressor
Hairdressing	Electric hair clipper, hair dryer.
Restaurants (without bars)	Refrigerator
Retail sale in non-specialised stores	Refrigerator

+ Due to its importance, we expanded the original RIGA of flour milling to include all post-harvest processing, as mentioned in the Data and Assumptions for Market Demand Estimation section.

++ Sweetmeat making uses thermal energy, but as mentioned in the section on parameters, we have considered mechanical energy inputs alone.

Source: CEEW analysis, 2017; Ministry of Statistics and Programme Implementation 2017; Indiamart.com including (Industrial Sewing Machines, 2017), (Dairy Equipment, 2017), (Flour mills, 2017), (Jewellery Making Machines, 2017), (Sewing Machines, 2017), (Woodworking Tools and Machines, 2017), (Poultry Equipment, 2017)

Figure 11: Proportion of micro-enterprises reporting electricity access among the top two bottlenecks to their business.



Source: Ministry of Statistics and Programme Implementation (2017) "Key Indicators of Unincorporated Nonagricultural Enterprises (Excluding Construction) in India, 2015-16." New Delhi: Government of India. https://gramener.com/indiamap/

Note: This map depicts districts with rural micro-enterprises reporting unreliable electricity among the top two bottlenecks to their business. The colors in the legend indicate the proportion of such enterprises in a particular district.

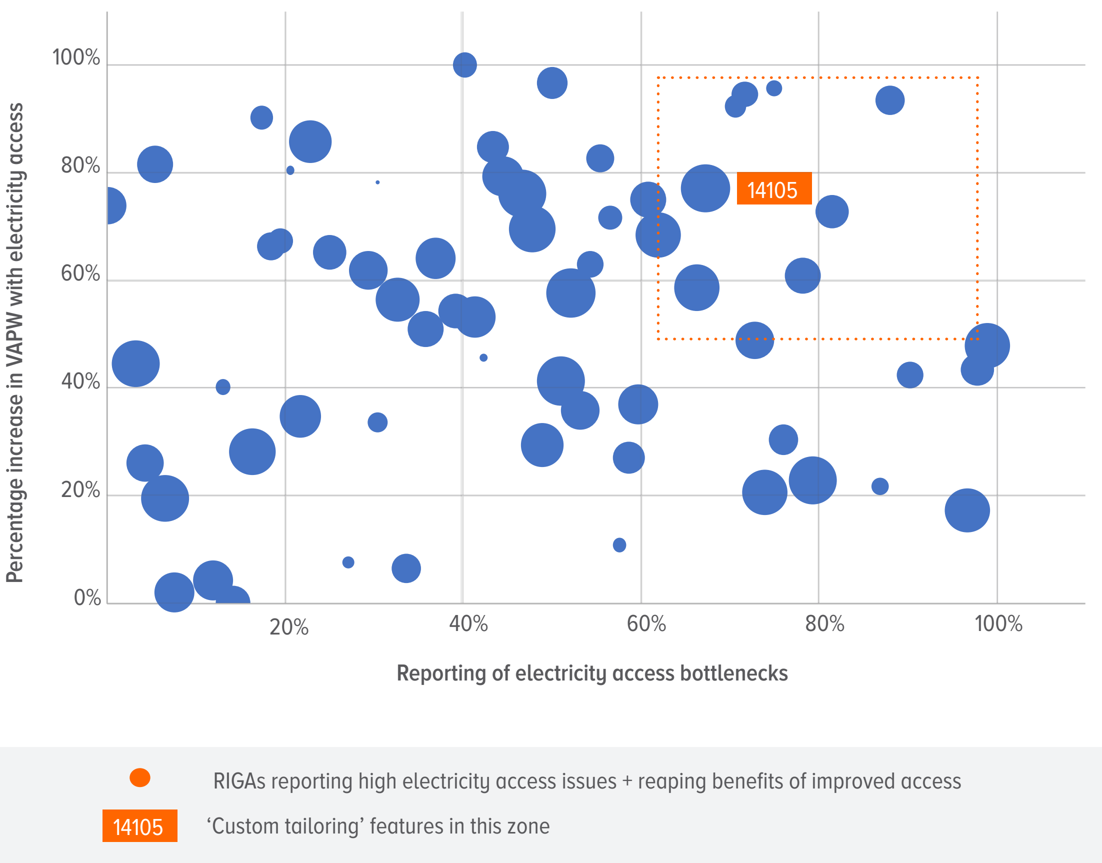
Enterprises not using electricity and using other forms of energy are therefore out of scope for this graph. Additionally, due to the prevalence of latent demand, we see the typically energy-deprived states of north-eastern India not being depicted on this map. Please find a listing of these districts in Annexure 1A.

CORRELATION BETWEEN (LACK OF) ELECTRICITY ACCESS AND VALUE ADDITION IN NON-FARM RIGAS

Using the NSS 73rd Round data, we plotted the RIGAs reporting electricity access bottlenecks against the reported potential benefits derived from correlated with increased electricity access. (The benefit was arrived at by calculating the ratio of It was estimated as ratio of GVA to the number of workers in that enterprise, for each RIGA.) The size of the bubble indicates the number of enterprises present, pertaining to the particular RIGA.

As Figure 12 shows, custom tailoring features in the 'orange box', essentially a cluster of RIGAs where a large proportion of enterprises have reported electricity access to be a bottleneck for doing business, and where increased electricity access has is correlating with improved the value added per worker (VAPW). These RIGAs, including custom tailoring, are an example of how rural micro-enterprises, where electricity access improvement can help could potentially improve rural non-farm incomes. Seven out of ten of these RIGAs are related to retail sales of various goods and services. The other three are related to weaving of cotton products, zari work and custom tailoring. A full list of the RIGA in the orange box is mentioned in Annexure 1A.

Figure 12: Correlation between reporting of electricity access issues and increase in value added per worker (VAPW)



Source: CEEW analysis, 2017

3.2.3 Estimating market potential

One approach to estimating the market potential of DRE in non-farm RIGAs is to consider energy-efficient appliances driven by a standalone DRE source. Figure 13a represents the market for energy-efficient machines in 14 key non-farm RIGAs (as listed in Table 2). The total addressable market for DRE innovations was estimated to be USD 13.2 billion, considering the current market price of the equipment being used in non-farm enterprises in the RIGAs being considered. This market size corresponds to about 11.5 million rural micro enterprises. Further segmentation was done on the basis of data on electricity access bottlenecks, arriving at a segmented market potential of USD 1.25 billion - the early adopter market for DRE-powered appliances in the non-farm sector.

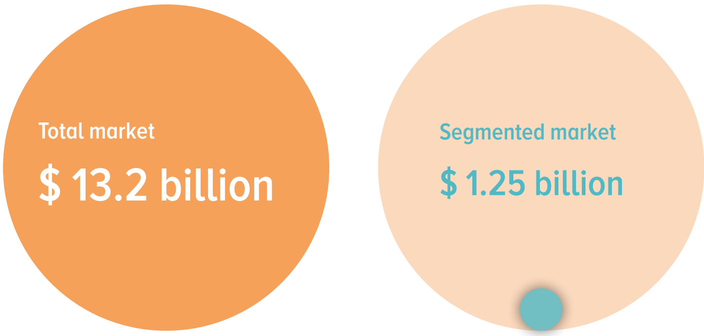
The top 14 RIGAs represent 34 per cent of all 34 million rural micro enterprises in India (Ministry of Statistics and Programme Implementation 2017). We have used a set of assumptions to estimate DRE market potential, such as the number and cost of each appliance in each enterprise for each RIGA. The segmented addressable market (SAM) excludes enterprises not reporting electricity access as a top bottleneck to their business, providing a fairly conservative estimate of the potential market for the 14 RIGAs considered.

An alternative approach of estimating the potential market is to consider the market potential for energy efficient appliances and the corresponding potential for solar mini/micro-grids powering these appliances in non-farm RIGAs. As depicted in Figure 13b, for energy-efficient appliances alone, for 14 key RIGAs, the potential market is USD 4.87 billion, with a segmented market of USD 459 million. The market potential estimation for mini/micro-grids incorporates certain key assumptions, including the hours of utilisation in a year and the factor of investment-required-per-kW of mini-grid installation. We estimate a total micro/mini-grids capacity requirement of 2,369 MW to power these energy-efficient appliances, with a corresponding investment requirement of USD 6.67 billion.

Assumptions

- We assumed the number of machines required per enterprise as per a formula that factors in the nature of the enterprise (whether it is within the household premises or not). Enterprises that are within household premises are assumed to have a single machine, whereas the remainder are assumed to have two machines per enterprise. (The detailed load profiles of all machines being considered are mentioned in Annexure 1A).
- The TAM comprises the all existing enterprises belonging to the key non-farm RIGAs.
- Daily utilisation of appliances is assumed as eight hours per day, year-round.
- To estimate capital investments in mini-grids, we considered a factor of USD 2.82 per watt, based on interviews with existing micro-grid developers.

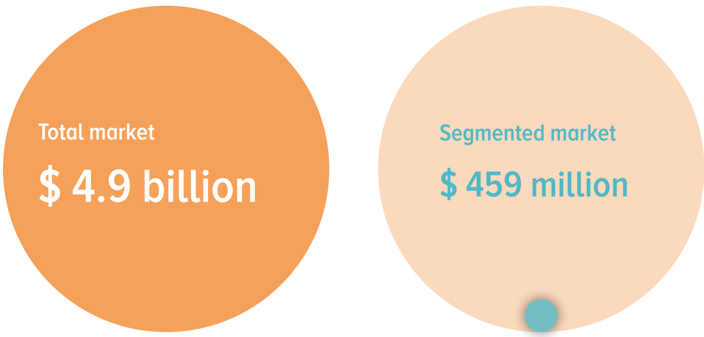
Figure 13 (a): Market segmentation and potential, for key non-farm RIGAs powered by standalone solar



- Total addressable market for clean energy driven EE appliances for 14 key RIGAs
- DRE market segment (considers enterprises reporting electricity access bottlenecks)

Source: CEEW analysis, 2017

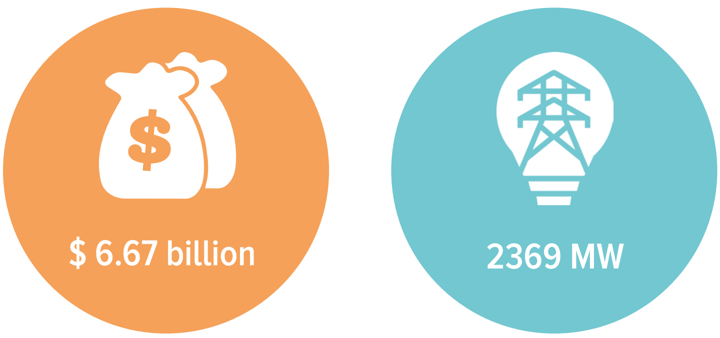
Figure 13 (b): Market segmentation and potential, for key non-farm RIGAs powered by mini-grids



- Total addressable market for clean energy driven EE appliances for 14 key RIGAs
- DRE market segment (considers enterprises reporting electricity access bottlenecks)

Source: CEEW analysis, 2017

Figure 14: Capacity and investment required for DRE mini-grids



- Investment required for powering key RIGAs reporting electricity access issues
- Capacity required for powering key RIGAs reporting electricity access issues

Source: CEEW analysis, 2017

Sewing machine, an income-generating appliance used for custom tailoring in rural India.

Image: iStock

4. DRE-powered Innovations for Productive Use

There are very few DRE-powered appliances available in the market, particularly for rural farm and non-farm income-generating activities. We could identify about 20 such innovations in the course of a comprehensive literature review and through interviews with DRE innovators, entrepreneurs, and sectoral experts. The identified innovations are listed in Table 3.

Table 3: DRE-powered innovations for productive use

Innovation	Innovator(s)
Cold storage	Ecozen, Tessol, Inficold, Central Institute of Agriculture Engineering (CIAE)
Milking machine	Raghav Gowda, Lifeway Solar
Pump	Claro Energy, Atom Solar
Charkha (spinning wheel)	Mahatma Gandhi Institute for Rural Industrialisation (MGIRI), SELCO
Knapsack sprayer	University of Agricultural Sciences Raichur, Jacto
Cassava grater	Project Support Services
Roti (flat bread) rolling machine	SELCO
Rice huller	Project Support Services, Mlinda
Butter churner	SELCO
Milling machine	Seine Tech
Sewing machine	SELCO
Forge blower	SELCO
Photocopy machine	SELCO
Cane crusher	Battighar
Puncture remover	Battighar
Dryer (multiple variants)	Tamil Nadu Agricultural University, CIAE
Maize sheller	College of Agricultural Engineering, Pusa
Weeder	Mohan Kumar
Seed sower	Swetha Sreerangaiah

Source: CEEW analysis, 2017

Note: This is not an exhaustive list, innovators listed here are for representative purposes only.

Figure 15 showcases the existing innovations along the axis of development. It can be observed that very few solutions have been deployed commercially on a large scale. The solar pump is the only innovation that has achieved large-scale deployment, with about 100,000 units deployed, mainly due to heavy government subsidies.

Figure 15: DRE-powered innovations for productive use, stage of development

DRE-POWERED INNOVATIONS FOR PRODUCTIVE USE, STAGE OF DEVELOPMENT			
Concepts	Initial technical & customer validation		Near-commercial
Seed sower	Knapsack sprayer	Cassava grater	Solar pump
Weeder	Rice huller	Dryer	Cold storage
Maize sheller	*Roti* (flat bread) rolling machine	Refrigerator	Sewing machine
	Butter churner	Milling machine	*Charkha* (spinning wheel)
	Cane crusher	Forge blower	
	Egg incubator	Photocopiers and computers	
	Puncture remover	Milking machine	

Source: CEEW analysis, 2017

4.1 Case studies of DRE-powered solutions for RIGAs

These case studies examine the success of various innovations, including milking machines, sewing machines, irrigation systems, and cold storage refrigeration, all powered using distributed solar power. The case studies serve a dual purpose:

a) They act as information dossiers, recording data on the technical aspects of the appliance, its usability, and consumer feedback; and they also provide a measure of the product's economic viability in comparison with other alternatives.

b) They are intended to provide inspiration to innovators and entrepreneurs looking to invent novel and efficient appliances for the rural farm and non-farm market.

Solar-powered milking machines

Milking machines can eliminate the drudgery of milking a cow by hand. In this case study, we consider a solar-powered milking machine with a battery backup and estimate its return on investment vis-à-vis other sources of energy including kerosene and human labour.

Based on interviews with milking machine innovators and manufacturers, including Lifeway Solar and Ksheera Enterprises, it was found that a farmer can recover his or her investment in a solar-powered milking machine in less than two years. The simple payback[5] period is arrived at after considering the initial investment of INR 60,000 for the machine, with 60 per cent of the costs going toward the solar panel and battery. In comparison, a kerosene-powered milking machine of the same capacity would consume one litre of fuel every hour. Figure 16 lists the different payback periods according to the number of cows milked using the machine. It shows that higher utilisation would lead to a further reduction in the operating cost of milking for the enterprise. The machine is interoperable, meaning that it can be operated on grid electricity as well as solar power. Milking cows using a milking machine reduces time by a third compared to manual labour.

[5] Simple payback refers to the time taken to recover initial investments by ignoring the time value of money

Lifeway Solar, a manufacturer of these solar-powered milking machines, aims to install more than a 100 of these machines in two years by partnering with NGOs and other demand aggregators. The technology is developed in-house, and the machine has been tested for comfort and hygiene. After-sales customer support is provided to ensure sustained adoption by the beneficiaries.

At present, there exist a few challenges in the commercialisation of this product, most notably that of generating demand and providing end customers with access to credit. Customers face technical challenges such as low solar power generation during the monsoon season, which make solar power an unattractive option in areas with reliable grid supply.

Figure 16: Simple payback for DRE-powered milking machines

Cows	Simple payback against kerosene (months)	Simple payback against labour (months)
6	24	18
12	12	9
24	6	5

Source: CEEW analysis, 2017 (Refer to Annexure 3 for details)

Solar-powered sewing machines

Solar-powered sewing machines are an alternative to regular sewing machines that are operated by a foot pedal and by hand. SELCO Foundation has retrofitted existing sewing machines with solar panels, so that they can run for eight hours per day, at a cost of INR 25,000.

They have achieved more than 60 installations in one year, with distribution and after-sales support covered by various branches. The sales target for the next year is more than 250 sewing machines, and they are tying up with major banks in the area to enable customers to avail of cheap credit.

Challenges include: the significant effort needed for partnership-building on the ground; generating constant demand; and the need for effective market linkages for longer-term success.

Figure 17: Simple payback for DRE-powered sewing machines

Monthly income using grid (INR)	Monthly income using solar powered DC motor retrofit (INR)	Simple payback (months)
2,000 to 2,500	4,500 to 5,000	10.5

Source: CEEW analysis, 2017 (Refer to Annexure 3 for details)

Solar-powered irrigation systems (SPIS)

Solar-powered irrigation systems have achieved a relatively higher penetration among farmers compared to other DRE-powered innovations. India is the world's leading country in terms of solar pumps deployment with a current deployment of 150,000 (as of December 2017). Individual solar pump prices range from INR 85,000 to INR 100,000 per horsepower, whereas a conventional pump of a similar size can be purchased for ten times less. However, the operating cost of solar pumps is low, and several studies conclude that from a lifecycle cost perspective, solar pumps are better for farmers than diesel pumps (Agrawal and Jain, 2015).

FOR THE ENTERPRISES IN THE SECTOR, ONE OF THE BIGGEST CHALLENGES IS TO DEVELOP AND VALIDATE INNOVATIVE BUSINESS MODELS WITHOUT RELIANCE ON SUBSIDY, WHICH COULD COMPETE WITH SUBSIDISED GRID ELECTRICITY

Some studies have looked at various deployment approaches for SPIS and concluded that multiple business models and novel financial instruments need to be tested in different geographies to arrive at the most cost-optimal and sustainable SPIS solution for every region (Raymond & Jain, 2017). For instance, models such as pumping-as-a-service would allow farmers to overcome the upfront cost. Financial instruments such as interest rate subvention could prove to be more useful in accelerating rapid deployment of pumps as opposed to capital subsidy on upfront cost. Another study in Uttar Pradesh shed light on farmers' perspectives on renting vs owning farming technology, current irrigation practices, solar-based irrigation systems, and sources of financing (Jain and Shahidi 2018). For the enterprises in the sector, one of the biggest challenges is to develop and validate innovative business models without reliance on subsidy, which could compete with subsidised grid electricity.

Solar-powered cold storage

Several companies such as Tessol, Inficold, and Ecozen have made forays into the cold storage business with varying scales of deployment over different geographies. Farmers are mostly using cold storage systems for storing milk and horticultural produce - horticulture includes produce such as potatoes, mangoes, and baby corn, mainly catering to large retailers such as Walmart and Reliance Fresh, or the export market. These units are mainly being used by aggregators of produce, including online retailers, small wholesalers, and FPOs.

The addition of solar increases the cost of cold storage by at least 4 times, which is probably the biggest deterrent to deployment and the adoption of solar-powered cold storage. So far, mostly farmers with strong market linkages have been able to afford these solutions. Like solar pumps, cold storage solutions are also supported by subsidies from various ministries. For instance, the Ministry of Food Processing Industries offers support through open ended credit linked schemes, while the Ministry of New and Renewable Energy provides capital subsidy on the product.

Enterprises in this sector agree that there is a need for longer, more strategic pilot projects to establish the market for DRE-powered cold storage. These pilots need to focus on proving business models by considering factors such as appropriate sizing of the cold storage based on farmers' need, extent of asset sharing, adequate market linkages & demand, willingness to pay from farmers, novel financial instruments for end-user financing, and conducive policy mechanisms that promote end-to-end cold chains.

Transplanter of rice being used in a farm. It is an effective substitute for the tedious task of planting rice saplings manually in the field.

Image: - Jircas/flickr

5. Ecosystem Challenges and Proposed Interventions

5.1 Gaps in the DRE for productive-use ecosystem

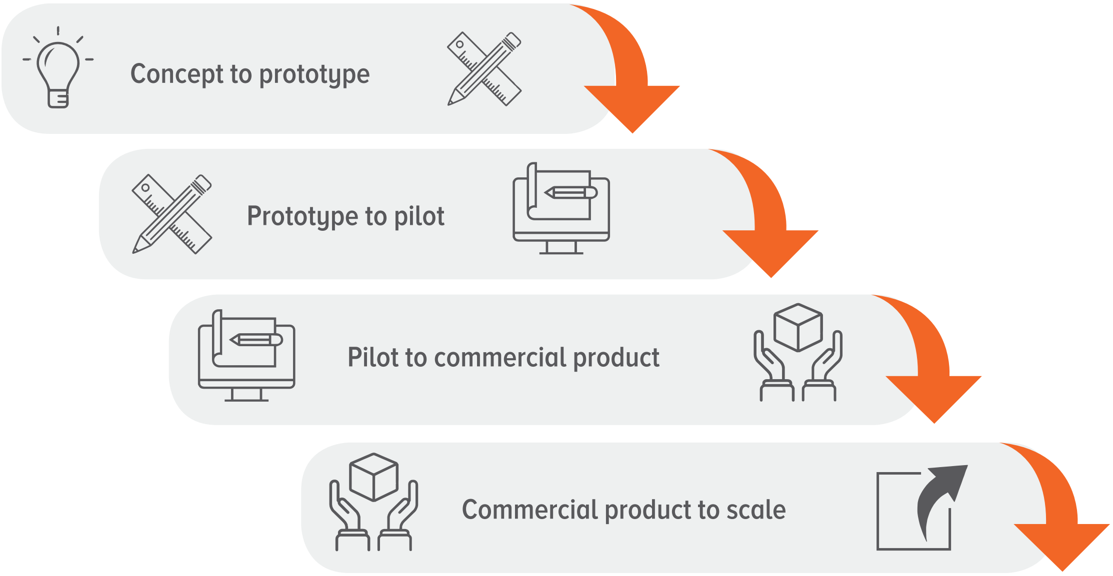
To design context-specific solutions for driving adoption of DRE-powered livelihood appliances, it is necessary to first develop a critical understanding of the current challenges in the DRE entrepreneurial ecosystem. The dearth of comprehensive research on DRE solutions in India has led to the proliferation of solutions that only partially address the challenges faced by entrepreneurs or investors. Further, analysing the challenges from a unidimensional perspective (of entrepreneur, investor, or incubator) does not allow for a holistic understanding of the sector. Therefore, an approach that aims to close the loop of ‘understanding the problem- designing the solution-addressing the challenges in designing the solution’ and is inclusive of all relevant stakeholders could provide for better rigour and a stronger basis for the analysis. Such an approach would also help explain the drivers for specific challenges instead of merely identifying the same.

In order to understand the challenges facing the DRE for productive use ecosystem, we consulted 94 stakeholders, including investors, sector experts, incubators, and enterprises. Through these interviews, we sought to better understand the challenges facing innovations in clean energy for income generation (productive use). Semi-structured interview guides were used to record the opinions of experts. We also conducted a comprehensive literature review to finetune the interview guide, contextualise the discussions, and corroborate the findings.

Sustainable development necessitates a transformative restructuring of socio-technical systems. Such a restructuring entails not just adding new products or replacing old ones, but also upgrading practices, markets, policies, and infrastructure. DRE for income generation (productive use) calls for a similar transformation of the product ecosystem. An in-depth understanding of innovation systems would help assess the support required towards of the entrepreneurial ecosystem for developing sustainable DRE solutions. It is known that as a technology matures, its costs reduce due to technical innovations, improved business practices, and large-scale production (Foxon, et al., 2005). As technologies advance further, the manufacturing process becomes more efficient with economies of scale, and supply chains and business models are optimised to accelerate deployment and reduce costs. Therefore, the analysis in this chapter will be premised on the stages of evolution of product ecosystem to contextualise the challenges and opportunities for the DRE powered applications.

The innovation chain can be grouped into four broad stages: concept to prototype, prototype to pilot, pilot to commercial product, and commercial product to scale. Innovation systems are non-linear and involve multiple interactions across stages (Figure 18), with components such as research, production, and markets. It is also strongly influenced by broader institutional arrangements such as public infrastructure, financial institutions, and national and international policies. Thus, it is critical to develop an understanding of the drivers and barriers to the innovation ecosystem particular to and beyond DRE for productive use in order to transform innovations from concept to scale.

Figure 18: The stages of product development



Source: CEEW analysis, 2017

5.1.1 Concept to prototype

Biggest challenges

Lack of high-risk capital, limited support infrastructure, poor incentives for increasing energy efficiency, lack of policy clarity, and a dearth of role models.

The lack of financial support in the pre-incubation stages for the development of ideas into prototypes is a big deterrent for innovators. Given the high-risk nature of the product development process, there is a dire need for capital grants from philanthropic and public funds. Incubators such as the Centre for Innovation Incubation and Entrepreneurship and Villgro provide support to entrepreneurs from the development stage to formulating marketing strategies. However, very few clean energy entrepreneurs are supported by these incubators given their mandate to support entrepreneurs across sectors. This is because of a preference for entrepreneurs working in established sectors over an underdeveloped sector such as DRE for productive use. Also, the longer gestation period (especially compared to software and internet products) for the realisation of a DRE-powered innovation into a prototype puts off prospective early-stage investors.

The Department of Science and Technology, Government of India, has set up the National Initiative for Developing and Harnessing Innovations (NIDHI) for nurturing an innovation-driven entrepreneurial ecosystem for social development. In order to ameliorate the profound lack of support for early-stage prototyping in India, NIDHI launched a programme in 2016 - PRomoting and Accelerating Young and ASpiring technology entrepreneurs (PRAYAS) - which looks to support young innovators in turning their ideas into proof-of-concepts. The programme is sector-agnostic.

Every year, ten innovators are supported with a grant of INR 10 lakhs (USD 15,600) to develop a prototype of their idea. Our interviews indicate that the key challenge for entrepreneurs is transforming quality products into affordable, economically viable solutions, in order to secure follow-on funding from private investors, including venture capitalists. Further, the long gestation period for product development results in fewer entrepreneurs entering this space.

A dearth of physical infrastructure facilities such as fabrication labs (fablabs) to build prototypes and test products limits the pace of invention. Further, fablabs and incubators that support product development tend to be concentrated in urban areas and in particular cities, making them inaccessible to some innovators. Entrepreneurs have also argued that it is not just the availability of physical infrastructure that is critical, but access to skilled technicians who can design working prototypes is as important.

Lack of policy clarity in establishing the role of DRE vis-à-vis grid supply leads to business uncertainty for entrepreneurs, thereby affecting the innovation ecosystem and the inflow of financial support for DRE-powered products. Small enterprises also have limited incentive to invest in capital expenditure heavy equipment when electricity supply, though unreliable is provided for free or at subsidised rates. Furthermore, policy efforts to promote DRE for livelihood applications have been limited. Our interviews with entrepreneurs reveal that they are reluctant to compete with subsidised sources of electricity in rural areas.

The cost incentives for developing energy-efficient productive use appliances are limited, due to the availability of subsidised and flat-rate electricity in rural areas. However, improving the energy efficiency of appliances will be critical to improving the economic viability of DRE-powered products. Accordingly, the Bureau of Energy Efficiency has already undertaken several initiatives to increase the energy efficiency of household and industrial appliances, which can be leveraged to support innovations in DRE-based products as well, such as developing more energy-efficient motors. While energy-efficient motors that possess a capacity beyond 20 kW are readily available due to high industrial demand, there is a major gap in the availability of sub-20 kW motors that are energy-efficient and cost-friendly.

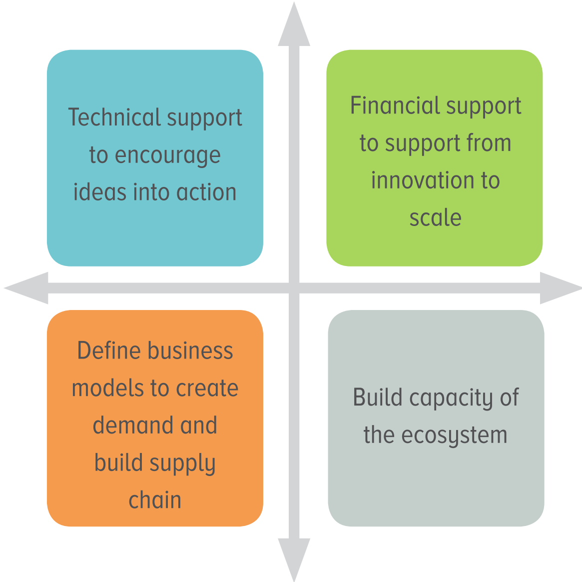
A lack of awareness among innovators regarding the potential market for energy-efficient devices has also been noted as a challenge for innovations that improve the energy efficiency of existing products. Most innovations retrofit existing devices with DRE sources without realising that the efficiency of every product can also be optimised to make the most of its source of energy.

> There is very little incentive to look at energy-efficient appliances/equipment or efficient practices where rural enterprises are not paying or paying very less for electricity
>
> **- Rajat Batra, STENUM Asia**

Emerging sectors such as DRE also lack role models and success stories for new innovators to follow. Success stories inspire new entrepreneurs to innovate, build networks, and access finance. Entrepreneurs developing DRE appliances for productive use face challenges in convincing customers and investors because of the limited number of success stories. This can be partly attributed to the lack of many successful enterprises in this space. But also, there has been a limited effort to learn from past failures. Failure is an evident step in the process of innovation and only a limited number of enterprises with strong products and innovative business models will succeed in scaling their business. Thus, it is necessary to showcase both lessons from failures and stories of success to pave the way for future entrepreneurs.

On the contrary, success stories that gain attention, encourage a particular form of innovation and entrepreneurship, based on experiences in other sectors. While we are yet to figure out what scale of operation could be more relevant and effective for the sector, it is likely that a certain idea of success, which aims solely for the national or global scale, will limit the kinds of products that will enter the market. Appliances with small market potential may not receive enough focus from such entrepreneurs or investors. An alternative system could be to privilege MSMEs that have high penetration within a smaller region and operate with a smaller market size but better suited to capture market for various livelihood appliances.

Figure 19: Structural support essential for DRE innovators for income generation



Source: CEEW analysis, 2017

Some incubators already focussing on this sector have been instrumental in advancing the progress of entrepreneurs through multiple forms of support. Table 4 lists some of the key incubators working in this area and the kind of support that they offer.

Table 4: Some key incubators for renewable energy innovations

Incubator	Support offered	Type of funding
Social Alpha	Prototype, proof of concept, field trials and market research, professional advice (legal, marketing, advertising) and seed capital	▪ Grant ▪ Equity
Villgro	Seedfunding, incubation plan, go-to-market strategy, technical advisory, human resource advisory, financial advisory	▪ Early-stage grant ▪ Quasi-equity ▪ Equity
Factor (e) Ventures	Validate, fund, and de-risk clean technology innovations. Provides technical support through collaborations with MIT Tata Centre and University of Colorado	▪ Equity ▪ Convertible note ▪ Debt
Infuse Ventures	Technical support, access to additional capital through a network of debt and equity investors, networking with leading industry people	▪ Early-stage grant ▪ Equity
Sangam Ventures	Technical support, proof of concept, access to commercial investors	▪ Equity

Source: CEEW analysis, 2017

5.1.2 Prototype to pilot

Biggest challenges

Lack of adequate knowledge of valuation of technology, lack of industry collaboration, lack of skilled professionals.

Entrepreneurs and government institutions lack adequate knowledge of valuation of new products and enterprises. This limits their ability to assess the market potential of an innovation and attract capital from financiers. Early-stage entrepreneurs may not have the skills nor the knowledge to value their innovations appropriately. Valuation is a challenge for many technical institutions in India, when it comes to setting a price for the transfer of technology. Government institutions such as the Rural Technology Action Group (RuTAG), Mahatma Gandhi Institute for Rural Industrialisation (MGIRI), and Central Institute of Agriculture Engineering (CIAE) have developed several innovative products that can help farmers and small businesses to mechanise their operations through renewable energy. However, these institutions face difficulties in commercialising their products on account of two reasons: 1) the lack of a strong mandate and an effective mechanism for technology transfer; 2) lack of guidelines to evaluate potential innovations for technology transfer. These institutions lack the professional capacity to estimate the market potential of a product and to adequately value it. Further, these institutions lack a definitive mandate to facilitate the smooth transfer of technology from innovation to commercialisation. Although Kisan Vigyan Kendras (KVKs) are designed to be the frontline points of contact of agricultural universities and can facilitate the dissemination of viable technology, they lack the ability to estimate the market potential of a product.

Very recently, the International Fund for Agricultural Development (IFAD) proposed a collaboration with the Indian Council for Agricultural Research (ICAR) to scale up the commercialisation of selected renewable energy technologies (RETs) in agriculture for marginal and small farm holders. ICAR was interested in taking existing RET prototypes developed by their institutes and having farmers test them under IFAD-supported projects so that they can be deployed at scale at a later stage. Such collaborations would allow government institutions to get a better sense of the market demand for their innovations and will also enable them to estimate their market potential. Farmers' willingness to adopt and pay for these products could provide a basis to assess the potential demand of similar products in future.

Collaborations with industry has been limited, especially for smaller entrepreneurs. Experts have suggested that collaborating with the manufacturing sector can help in improving the design and efficiency of products, making them more commercially viable. Collaborations between industry associations and innovators and entrepreneurs can also help in building more sustainable business models by allowing for a more accurate estimation of the market potential of the product, as well as by guiding research on the willingness of consumers to pay for these products. However, for entrepreneurs in this space, access to collaborations with industry has been limited. Some notable examples include a partnership between Crompton Greaves with the energy technology company Cygni. The collaboration was incubated at IIT-Madras and aimed to deploy energy-efficient fans compatible with solar home systems. Another example is an MoU signed between the Confederation of Indian Industry and the Council on Scientific and Industrial Research (CSIR) for the commercialisation of more than 640 technology processes and products available with 38 labs across India, under the aegis of CSIR (The Hindu Business Line, 2017).

Innovators are not always skilled at all pertinent business functions. While innovators have the technical expertise, many are not adept at skills such as marketing, strategy, or finance. Incubators do provide support for innovators-turned-entrepreneurs to learn some of these skills. However, in the long run, entrepreneurs must have a strong team with diverse skills to run their business successfully. Hiring people with the right set of skills, who have the expertise to get the business off the ground, is critical and challenging for the entrepreneur. Further, the cost of hiring and training a team, in the absence of adequate funding, has also been highlighted as a barrier.

5.1.3 Pilot to commercial product

Biggest challenges

Limited access to affordable market research, the high capital cost of DRE-powered applications; developing products that are aligned with consumer needs; infrastructural costs; subsidies on products; access to finance; and the lack of large-scale strategic pilots, quality certifications, non-energy inputs, and a cost-effective distribution network.

Access to up-to-date information and market research is critical yet limited for DRE-powered productive appliances. Market research is an expensive investment for early-stage businesses. Information on the rural business-to-business (B2B) market is very limited in India, creating barriers for enterprises in the process of designing their own go-to-market strategies and those targeting potential markets. Insights into which customers to target first in a particular geographical region would enable enterprises to make informed decisions. This is particularly valuable at the early stages of an enterprise when resources are limited and identifying an effective business model is important. It also helps enterprises formulate a targeted communication and marketing approach to generate demand from the bottom-up. This is achieved by improving the awareness of the targeted customers. However, market research services are often prohibitively expensive for smaller enterprises. Hence, making research more affordable and accessible will help in reducing the customer acquisition costs of enterprises.

> It is important to contextualise innovations for a heterogenous market like India, microsegment and micro plan for the specific districts to be covered, and then apply your innovation.
>
> **- Vikas Bali, Intellecap**

The high capital cost of DRE is the biggest bottleneck to adoption by customers. When compared with diesel-powered equipment that have lower capital expenditure costs, DRE-powered appliances struggle to meet customer demands for a lower initial investment, despite having no fuel cost. This is because even the most efficient solutions are relatively expensive as they cannot benefit from economies of scale. This challenge is also intrinsically linked with other needs such as low-cost capital, enterprise finance to reduce the price of products, and the need for economies of scale and improved uptake among early adopters.

Poor access to energy often correlates with poor socio-economic conditions. Hence, the customers who are most likely to find DRE-powered appliances useful are also those who have relatively lower incomes and limited capital compared to their counterparts in economically better-performing states. Thus, enterprise financing is particularly important to enable the adoption of these technologies.

Product designs often fail to match customer needs. Demonstrations of product performance and the incorporation of customer feedback during the design phase is important. While equipment cannot be customised to the needs of each user, it should align with the users' value prioritisation. Even a well-designed product may require significant time and effort to develop a customer base, particularly in the case of new products. Design level challenges also arise when entrepreneurs are pressurised to optimise their design for better protection against duplication while also retaining its simplicity of use. This balance needs to be achieved without compromising the economic viability of the product.

Setting up of manufacturing and assembling infrastructure is one of the most expensive components of the manufacturing process. The investment cost associated with acquiring buildings and machines (fixed cost) can be a significant drain on an entrepreneur's capacity to invest. Additionally, at this stage, external funding may not be enough to cover all costs, and there may not be enough collateral for securing loans from banks. Many entrepreneurs therefore opt to import complete or partially-built products from countries such as China, where manufacturing costs are low. Nonetheless, to sustainably meet market demand in the long term, localised manufacturing may be required.

Subsidies increase adoption temporarily, but they damage the long-term sustainability of business models. Products such as solar pumps and drip irrigation have been promoted through significant subsidies. However, once the subsidy is withdrawn, the market for such products becomes unstable, and the ensuing uncertainty creates challenges in planning, especially for smaller companies. This also means that newer technologies that do not benefit from subsidies are unlikely to witness similar rates of adoption. Subsidies in this context also symbolise the government's endorsement of a product and, therefore, these products are more likely to earn customer trust quickly. This affects the attitude of prospective customers towards new products that do not receive policy support.

Electricity from the grid is often considered to be the benchmark in terms of cost, which affects customers' perception of DRE-powered equipment and, hence, their willingness to invest in the same. DRE offers reliable access to power in areas where grid supply is insufficient or unavailable. However, this preference for grid-based electricity interferes with the customer's willingness to explore and adopt other sources. Hence, policy support for DRE-powered products can provide the impetus required for the sector. For instance, giving a production-based incentive for green products manufactured using DRE can encourage a higher uptake, and can address energy access challenges for productive use. Similarly, demonstrating the effectiveness of the technology can lead to greater awareness among customers and can increase in their willingness to pay for a product or service.

EARLY STAGE SUPPORT TO TEST AND VALIDATE NEW BUSINESS MODELS

1. A study by the Shell Foundation (Desjardins et al. 2014) shows that it can take anywhere from six to ten years for a business with an unproven business model to refine its value proposition, demonstrate demand, and achieve scale with positive cash inflows.

2. The study also reveals that it requires USD 5 million to USD 20 million for innovators to build enough knowledge and capacity to acquire core technical and commercial knowledge to avoid market failure and design scalable solutions.

3. The need to balance affordability, quality, and reliability makes it expensive to invest in technological innovations.

Access to finance remains one of the biggest bottlenecks in the path to commercialisation

- In 2016, the renewable energy sector received funding of USD 242 billion globally. Of this, USD 187 billion went to industrial-sized projects that provided clean power to utilities (BNEF-UNEP, 2017). The funding for small distributed renewable energy was a mere 16.5 per cent of the total investment in the sector.
- According to the YourStory Start-Up Funding Report, 2017 witnessed a surge in investments in Indian start-ups-USD 13.7 billion in 2017 in comparison to USD 4.06 billion in 2016 (YourStory, 2017). However, 70 per cent of the investments went to just 10 established companies. The funding received by early-stage companies has reduced to USD 542 million in 2017 from USD 628 million in 2016 and USD 1.3 billion in 2015.

THE FUNDING RECEIVED BY EARLY-STAGE COMPANIES HAS REDUCED TO USD 542 MILLION IN 2017 FROM USD 628 MILLION IN 2016 AND USD 1.3 BILLION IN 2015. ADDITIONALLY, IN 2017, 70 PER CENT OF THE INVESTMENTS WENT TO JUST 10 ESTABLISHED COMPANIES

- Donors and multilateral organisations offer support to early-stage start-ups through grants for research and market development. However, the value of such grants is pre-determined by the donors, and often, it falls short of the requirements of the entrepreneur. Further, the business stage at which funding is received depends on the priorities of the funders. Some donors such as the United States Agency for International Development (USAID) offer grants to businesses at all stages, to support both product and market development. However, their impact is limited by the size of the grants and the limited accessibility to certain kinds of entrepreneurs. Despite the increasing number of impact investors and venture capital funds in the market, entrepreneurs' access to these funds is limited by the quality of their networks and the stage of their business. Some incubators such as Factor (e) and Social Alpha offer financial linkages and go-to-market strategies to their incubatees; however, not all enterprises can access such networks, and the extent of these linkages are also limited.
- A flexible debt option in the early stages of an enterprise is crucial to cover the initial operational risk. Equity investors look for predictable numbers and operating margins, the lack of which limits an entrepreneur's ability to scale. Some investors have also argued for newer modes of raising private and public capital-hybrid structures-that can offset the financial risk for investors and align risks and returns (Desjardins et al. 2014). De-risking investments in the early stages of an enterprise through grants or other forms of hybrid capital structures could help attract investments in the sector.
- The role of rural financial institutions in providing access to credit for local entrepreneurs is critical. The SELCO Foundation works with regional rural banks, NGOs, and microfinance organisations across Karnataka to provide low interest loans for home-based enterprises operating in rural areas. Home-based enterprises, especially those run by women, often face challenges in accessing loans without collateral. While such collaborations with local financial institutions exist at the enterprise level, there is no policy or industry-wide mechanism to support the credit market for DRE-powered livelihood applications that can improve income generation.
- Corporate social responsibility (CSR) programmes could serve as an anchor for strategic innovation in the country. The increased availability of CSR funds under the Companies Act

- 2013 can be leveraged to promote investments in development innovations. However, very few organisations use their CSR funds to support this cause. As of 2017, Indian companies spent only 6 per cent of their CSR funds on clean energy (Tenneti & Parekh, 2017). Only 39 per cent of the top 100 companies with a CSR budget spent money on programmes that focused on product-based solutions for generating clean energy. Further, states with relatively low energy gaps have a higher proportion of companies implementing an access to energy programmes through CSR, while states which need interventions the most, such as Bihar, remain a nascent space for CSR programmes. Typically, CSR funds are tied to specific causes, and CSR programmes are expected to meet conventional parameters of project efficiency. Hence, CSR programmes are not adequately focused on promoting innovations in DRE owing to their complexity, experimentality, and long gestation periods.
- The need for funding is not limited to first generation or first-time entrepreneurs alone, but also extends to established entrepreneurs who are pursuing small-scale ventures in the energy or other sectors. Given the risks associated with starting a new business, especially one that is product-based, access to low-risk capital can prove to be a key factor in encouraging existing businesses with a stable supply chain to consider investing in this space.

> Grant/soft funding is key to getting started with innovative and high-risk business ideas in the clean tech space. At a later stage when a company is ready to raise Rs 5-10 crore (corresponding to a company valuation of at least Rs 25 crore) then it would get more attention among commercial and institutional investors for follow-on funding
>
> **– Premnath Venugopalan, NCL Venture Centre**

The lack of a large-scale strategic pilot impedes the honing of the product and the streamlining of the business model. Strategic pilots can validate the techno-economic feasibility of a product and the willingness of customers to pay for it. Further, large pilots can demonstrate the viability of the product to customers and can improve customer awareness, as has been well-noted by entrepreneurs. However, even though successful pilots can help attract higher investments in commercialising the product, a lack of funding to conduct such pilots is itself a deterrent during product development. New businesses and products tend to require more time to set up pilots than conventional businesses. This is owing to a lack of precedents in the product and the business model. New products also require innovations in business processes, such as financing, distribution models, etc. (Allen et al. 2012). This makes access to patient and low-risk capital essential for success. At present, most pilots are funded through grants, given that there are such high risks and uncertainties involved. However, donors and public institutions that support these pilots through grants rarely have a strategy in place to support enterprises beyond organising pilots. This strands enterprises and leaves them to figure out the next steps for themselves. Hence, there is a need for a new kind of investment that can weather high risks and is patient with respect to returns. Blended finance, defined as the strategic use of development finance and philanthropic funds, could play an important role in mobilising private capital flows to emerging markets.

> Demonstrative pilots can be hugely impactful, it will encourage few early adopters to come forward
>
> **– Lakshminarayan Kannan, Microspin, Skillveri, Vortex Engineering**

The de-fragmented rural microenterprises market presents customer acquisition challenges for early-stage DRE product enterprises. Market aggregation could address the challenges presented by a de-fragmented customer base, and in turn reduce early-stage enterprises' difficulties in acquiring customers. However, at present, there are no market aggregators operational in this sector. As a result, existing institutions such as farmer producer organisations (FPOs) and NGOs would have to act as market aggregators to develop the initial market. Organisations like Tata Trusts have been aggregating the demand for productive use applications in their areas of intervention. In each region covered by the trust, there has been an initiative framed, according to local conditions. However, the sustainability of this business model is uncertain as the aggregation depends on donor funding and state support, with minimal customer contributions. Further, enterprises become dependent on the subsidy model as opposed to developing their own business and financial models.

Developing cost-effective distribution value chains and after-sale service networks is another challenge for DRE product-based enterprises. Larger corporates and SME players working in the durable goods industry have established distribution networks. Hence, new enterprises can tackle this challenge by learning from the experiences of other SMEs, collaborating with them, and piggy-backing on the distribution channels of larger corporates through strategic collaborations. Further, innovative distribution channels (existing or new) may help accelerate growth. For instance, Dharma Life is a social enterprise that provides last-mile distribution services for products such as cookstoves and solar lamps, by building a network of rural entrepreneurs. Frontier Markets is another company that has established innovative distribution models for its energy products with strong after-sales service networks by focussing on women entrepreneurs.

The economics of a business is determined by both energy and non-energy inputs, this influences the buyer's willingness and/or ability to invest in DRE-powered productive applications. The potential customers for DRE for productive use are businesses and farm holders. This influences the dynamics that are at play. For the buyer, an investment in DRE has to make business sense and should recover its initial costs within a short period. If the scale of the business is small, and the investment required is high, the motivation to purchase the product is low. The decision to invest is not merely a factor of the current energy costs. Nonetheless, business models such as for hire, pay-as-go, or service-based payments can alleviate the burden of upfront costs and improve uptake. EM3 Agri Services offers farming-as-service to about 8,000 farmers in Madhya Pradesh, Rajasthan, and Uttar Pradesh. It is able to do this by enabling a pay-for-use mechanism for all mechanisation equipment from land preparation to post-harvest management. In 2017, the company raised Series B funding from the Global Innovation Foundation (GIF), which proves the merit of its business model (Pani, 2017).

The lack of quality certifications and benchmarking processes for products has also had an impact on the quality of the products that enter the market. Sub-standard products could potentially put off customers, leading to a distrust of the entire product category. Thus, it may be useful to have quality certifications in order to identify good-quality products, particularly to aid the decision-making of financing institutions providing end customer financing.

5.1.4 Commercial product to scale

Biggest challenges

Lack of consumer finance, prohibitive cost of ecosystem building, lack of follow-on funding, lack of distribution network, lack of skilled technicians, and dependence on the economic viability of components.

Low utilisation rates make many standalone DRE-powered products unviable. Given that standalone DRE-powered products require high capital investments, the utilisation rate of the asset is a key determinant of its economic viability. Higher the utilisation, the more attractive is the economic value proposition for the end customer. Low utilisation rates particularly affect the farm sector, as for most cultivation activities, a certain machine is only used for a few days in a year. In such cases, energising various appliances using the same power generation source could help improve economic viability. Other possibilities include improving asset utilisation through enterprise-based or FPO-based rental models that provide farmers with the necessary equipment for a period of time for a fee. Considering that this allows many farmers to share the same equipment, it can significantly improve the utilisation rate in comparison to individual ownership.

In 2012, USAID, along with several partner stakeholders, launched **Powering Agriculture,** a global competition to support clean energy innovations that can improve agricultural productivity and stimulate low carbon economic growth. It provides grants between USD 500,000 to USD 2,000,000 to enterprises to design, pilot, or deploy clean energy innovations in the agricultural value chain. The competition has seen numerous applicants from Africa and Asia. Most businesses supported under the programme are in the early stages. In the future, USAID aims to provide follow-on funding after a certain scale has been achieved. However, access to this programme is limited to a certain pool of entrepreneurs who can leverage their network and communication capabilities to make an effective pitch.

It is prohibitive expensive for early-stage enterprises to invest in the collective needs of the ecosystem, which impedes their ability to scale. To address this challenge, collaborative networks that pool together resources to create the required infrastructure are necessary. Global and national platforms such as Global Off-Grid Lighting Association (GOGLA) or Global Alliance for Clean Cookstoves (GACC) have brought together relevant stakeholders (both government and non-government) and funds to develop the ecosystem for all early-stage enterprises. Whether it is establishing distribution channels, addressing policy uncertainty, or leveraging existing government networks, a platform that integrates all the relevant voices will enable the designing of a coherent strategy to address the challenges faced by entrepreneurs in this sector. In India, the Clean Energy Access Network (CLEAN) is a platform that attempts to address the collective challenges of DRE enterprises with respect to finance, policy, skills, and technology. Such platforms can also be leveraged to generate awareness of DRE innovations for productive use.

Lack of patient follow-on funding after pilots that offer longer repayment tenures and low interest rates affect the ability of enterprises to scale. Acquiring customers for DRE-powered products is expensive and time-consuming, owing to the high upfront costs associated with procuring the product and the lack of awareness of the technology. In such a situation, the relatively low upfront cost of conventional products skews customer preferences towards the same. For instance, the cost of a solar loom is INR 1.6 lakhs (USD 2500), as opposed to INR 60,000 (USD 940) for a conventional power loom.[6] While in terms of operation, there may not be any differences between the two, the solar loom could improve revenues and reduce input cost, owing to the improved productivity from having better access to electricity. This needs to be communicated effectively to customers to help them make informed decisions while making their purchase. Therefore, conventional repayment cycles and interest rates make it economically unviable for enterprises to sustain in the market long enough to build a customer base and communicate the benefits of DRE-powered appliances to prospective customers.

[6] Primary interview with stakeholders.

Technical and commercial skilling of manpower for functions such as distribution and after-sales services is an additional challenge for entrepreneurs. Almost all the entrepreneurs we interviewed cited the lack of trained personnel as a major impediment for the upscaling of business. Training additional manpower is expensive and, most new enterprises struggle to meet this cost. Entrepreneurs also mentioned that as soon as workers gained new skills, they migrated to nearby towns and cities, seeking better remuneration. Rural skilling centres can help meet this demand and aid in building a strong network of on-ground professionals. Strong incentive structures will also be essential to retain skilled staff members. As per government estimates from 2014, around 7 million workers are skilled annually (Ministry of Skill Development and Entrepreneurship, 2015). The National Policy for Skill Development and Entrepreneurship can be leveraged to create skilled professionals for this space.

Energy-efficient livelihood appliances, owing to their high prices and low sales volumes, are not prioritised by durable products distributors. Distributors tend to stock fast-moving products to reduce their working capital requirements. As a result, DRE products are rarely stocked, which in turn affects their uptake and customer awareness. However, the solution is to not only strengthen the distribution network, but to adopt an integrated approach that will build customer awareness and makes the product accessible and affordable for customers. Some organisations, such as Dharma Life and Frontier Markets, have even tried to build alternate rural supply chains for renewable energy products. However, most of their products are still limited to household use, and they are yet to focus on livelihood applications.

The capital-starved end consumer's lack of collateral creates barriers in accessing loans, which limits adoption under the direct purchase model. Access to finance for the end consumer is critical for the realisation of demand. New financial models such as group lending could help improve access to finance for DRE. Equipment rental models can also help address this challenge to a great extent, provided that an adequate number of entrepreneurs are able leverage capital to set up custom hiring centres. In our interviews, organisations[7] had mentioned that customers would be interested in owning an asset, but only if the payback period is two years or less.

> Energy is opportunity. So, what would happen if you could provide 24x7 power to villages in rural India? Imagine how that could transform lives, businesses, rural economies!
>
> **– Paul Needham, Simpa Networks**

The success of DRE-powered innovations is also dependent on the viability of individual components such as batteries. The cost of storage comprises about 45 per cent of the total cost of a motorised machine (e.g., flour mill).[8] For most livelihood appliances, a battery is essential (unless powered through mini-grid/grid), though the capacity requirements differ significantly based on the appliance. However, the high cost of storage increases the cost of the overall product, thereby reducing the demand for the product. Inficold provides cold storage services to farmers. While the cost of an 800 cubic feet cold storage unit is INR 10-12 lakhs (USD 15,600-18,700), an additional investment of INR 9-10 lakhs (USD 14,000-15,600) is required to make it solar compatible. Hence, most cold storage units operated by the company are powered by electricity from the grid. In addition, only farmers that cater to export markets are willing to pay for cold storage, due to the direct value addition. This limits the customer base of the enterprise.

[7] Cold storage services.

[8] Primary interview with entrepreneurs.

UNDP's Scale Up of Access to Clean Energy for Rural Productive Uses project is trying to address challenges in scaling-up, by encouraging local suppliers to opt for DRE products, and mandating a one-year O&M for the product. However, beyond the warranty period, the onus lies with the customer. This is because extending warranties can be expensive for an entrepreneur. But nevertheless, having a skilled technical team in place to provide multiple services at a cost can be also be a win-win as it would help improve the durability of the product and increases employment generation. The scheme provides up to INR 20 lakhs (USD 31,200) to local entrepreneurs in two or more instalments.

5.2 Existing interventions

After discussing the challenges or gaps in the ecosystem for DRE-powered energy-efficient livelihood appliances, we now look at some initiatives that are trying to overcome some of these challenges. We note some of the key interventions in the DRE for livelihood applications market that aim to promote product innovations and their deployment. Donors and government agencies across the world and in India have taken steps to encourage DRE innovations. Most of the initiatives listed below particularly focus on clean energy or livelihood promotion.

Table 5: Existing interventions to promote innovation

Incubator	Support offered
Start-up India	Launched by the Ministry of Commerce and Industry, this initiative provides technical and financial support to start-ups that are less than seven years old. It aims to support innovative start-ups through a credit guarantee fund of INR 2,000 crore, an alternate investment fund of INR 10,000 crore, tax exemptions, and procedural support for the filing of patents, etc. The initiative has already funded 75 start-ups across various sectors.
Agrinnovate India	It is a for profit company owned by the Department of Agricultural Research and Education (DARE), Ministry of Agriculture, Government of India. It aims to utilise the findings of the Indian Council of Agricultural Research to promote R&D and technology transfer through Intellectual Property (IP) protection, commercialisation, and forging partnerships both in the country and outside for public benefit.
Shell E4	Shell India's initiative - Energizing and Enabling Energy Entrepreneurs - works with a select cohort of start-ups in the early, pilot, and post-pilot stages for a period of six months and provides them with access to Shell's resources in the technology development and product commercialisation areas, along with mentorship and up to USD 20,000 in investments. Shell India also runs an accelerator to help businesses build strong value propositions and to provide access to funding to scale.
Global LEAP Off-grid Challenge	CLASP and Energy 4 Impact have partnered to run the Global LEAP Off-Grid Cold Chain Challenge (OGCCC). This programme aims to stimulate the use of off-grid energy and to deploy coldchain infrastructure for smallholders and aggregators in off- and weak-grid areas. It is a global competition that will identify and incentivise the most energy-efficient, sustainable, and affordable technologies that can meet diverse cold storage requirements such as fresh fruits, vegetables, and dairy products. The challenge is yet to expand to other products for productive use.
Climate Solver	Climate Solver is a global initiative by the World Wildlife Fund (WWF) to provide an interface between low carbon technology innovators and industry associations, investors,

Incubator	Support offered
	governments, incubation centres, and the media. After carefully screening and selecting innovative clean technologies developed by small- and medium-sized enterprises, Climate Solver aims to showcase their potential, expand their outreach, generate awareness about the enterprises and their innovations. The innovations could target improved energy access or lowering carbon emissions. In India, the initiative has partnered with the Confederation of Indian Industry (CII), New Ventures India, Centre for Innovation Incubation and Entrepreneurship, Indian Angel Network, and the Department of Science and Technology, Government of India.
Powering Agriculture: An Energy Grand Challenge for Development	Funded by USAID, along with other partners, the grand challenge aims to support the development and deployment of clean energy innovations that increase agricultural productivity and stimulate low carbon economic growth in the agriculture sector of developing countries. The challenge funds enterprises across six stages - concept development, R&D, initial piloting, early adoption/distribution, market growth, wide-scale adoption. It provides grants between USD 500,000 to 2,000,000 to entrepreneurs to design, pilot, and deploy clean energy solutions at different points along the agricultural production cycle.
Rural Innovation Fund (RIF)	RIF is a fund designed by National Bank for Agriculture and Rural Development (NABARD) to support innovative, risk -friendly, and unconventional experiments in the farm, non-farm, and microfinance sectors that would have the potential to promote livelihood opportunities and employment in rural areas. The funding support that is extended for each project goes up to INR 30 lakhs.
PACEsetter Fund	With a fund size of INR 50 crore (USD 7.9 million), this venture is jointly capitalised by the Governments of the Republic of India and the United States of America. It aims to accelerate the commercialisation of innovative off-grid clean energy solutions by providing early-stage grant funding that would allow businesses to develop and test innovative products, business models, and systems. It awards grants to support of innovative technologies, business models, and programmes. It also provides support for product development, research, and capacity building.

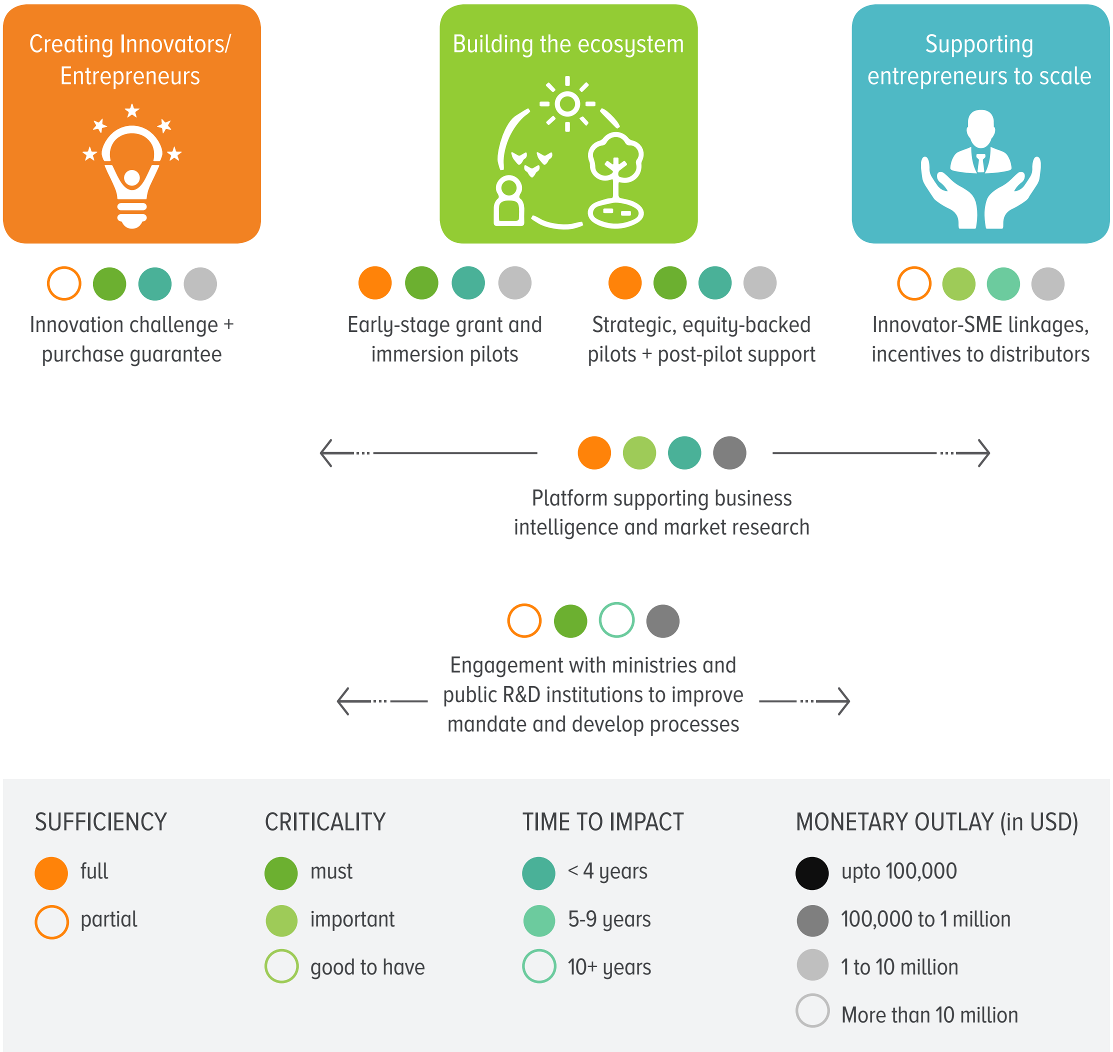
Source: CEEW analysis, 2017

5.3 Proposed interventions

Based on engagements with the stakeholders mentioned earlier, we identified a few key areas of intervention to address identified gaps in the ecosystem. To prioritise potential interventions, we used the following four criteria to assess the proposed interventions:

1. **Sufficiency**
   How sufficient is the proposed intervention to address the particular ecosystem gap?
2. **Criticality**
   How critical is the proposed intervention to support the innovation ecosystem for DRE-powered livelihood applications?
3. **Time to impact**
   How long will it take to realise the intended impact through the intervention?
4. **Monetary outlay**
   How much would it cost to undertake the intervention? (this excludes the value created, and includes the outlay directly associated with the intervention)

Figure 20: Key potential interventions



Source: CEEW analysis, 2017

The figure highlights the prioritised interventions, which if executed, could potentially help sector to move forward, supporting innovation and deployment of DRE powered solutions for livelihood applications. These interventions would support in creating innovators and entrepreneurs, building a strong ecosystem and enabling enterprises to scale their operations. Some interventions, similar to the ones proposed, have seen success in other sectors but need to be adapted for DRE-powered innovations for livelihood activities. Depending upon their interest and capacity, different stakeholders supporting the sector could undertake these proposed interventions.

A. Creating innovators/entrepreneurs

Innovation challenge with purchase guarantee

Sufficiency: Partial

Criticality: Must

Time to impact: < 4 years

Monetary outlay: USD 1 million - 10 million

A grand challenge that focusses on clean energy innovations for income generation can draw the attention of innovators towards this sector. If an innovator is interested in building a business, a purchase guarantee for the winner(s) will enable them to take the first step towards the same. At present, there are grand challenges that provide grants for product development, but they do not provide any follow-on funding. A purchase guarantee will help winners push prototypes to the product stage using the grant money. Furthermore, committed demand also allows for the deployment of the product at a large-scale (equivalent to a pilot). Hence, customer interest can be validated and the potential market for the product can be tested. Further, the aggregation of demand through a grand challenge could reduce the customer acquisition challenges for the young enterprises.

Grant and immersion programme for early-stage innovations

Sufficiency: Full

Criticality: Must

Time to impact: 5-9 years

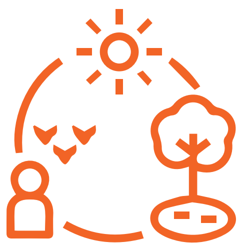
Monetary outlay: USD 1 million - 10 million

Low-risk capital in the initial stages of growth can help early-stage businesses strengthen their product development. A grant or fellowship programme can incentivise innovators to develop their ideas into prototypes and can help to increase the number of innovators in this space. Since the technical evaluation is only limited to ideas at such an early-stage, the programme could use innovative approaches to monitor performance, such as peer assessments to ensure that there is sincerity of effort and timely course corrections. The programme could also be designed to support entrepreneurs who have achieved a certain degree of sophistication in their ideas.

To help entrepreneurs develop an understanding of the user and usage context, an immersion fellowship programme for innovators could be organised to facilitate co-designing opportunities. This would enable innovators to co-design their products with end users and would allow them to incorporate their feedback during the design and development phase itself.

B. Building the ecosystem

Platform supporting business intelligence and market research



Sufficiency: Partial

Sufficiency: Full

Criticality: Important

Time to impact: < 4 years

Monetary outlay: USD 100k - 1 million

Access to data on markets and consumer segmentation allows enterprises to better understand their customers' needs, target markets, and optimise their communication and distribution. Access to affordable and timely information on markets has been cited as a key challenge by several entrepreneurs. To overcome this challenge, a platform that aggregates various market research and durable product consulting companies to provide pro bono or low bono services to early-stage enterprises in the sector would be useful. The value proposition for market research companies is that it allows them to build their profile, provides them opportunities to understand rural markets and consumers better, and creates potential long-term business opportunities. Companies such as EY, Bain, and Accenture have already been undertaking such initiatives to support non-profits and social enterprises. However, there is a need to create a niche platform for the rural livelihoods space in order to better tap into the resources of international and domestic companies. Further, this kind of collaborative platform would need donor support to develop an open access database of critical market information.

Engagement with ministries and public R&D institutes to modify mandates and develop processes for tech transfer

Sufficiency: Partial

Criticality: Must

Time to impact: 5-9 years

Monetary outlay: USD 100k - 1 million

As discussed earlier, there have been credible innovations to empower agriculture and other non-farm activities through public institutions such as Mahatma Gandhi Institute of Rural Industrialisation and Central Institute of Agricultural Engineering. However, public institutions lack a clear mandate, sufficient focus, and effective operational processes to enable technology transfer. There is a need to strategically engage with these institutions and respective ministries to bring to their attention the importance of technology transfer. In addition, it is necessary to aid in the development of guidelines to enable the same. This would require long-term and persistent engagement over years to first bring attention to the cause, push institutional mandates, and then lay out operational mechanisms to enable greater and faster technology transfer. Ultimately, this could have a significant impact in bringing affordable innovations to end customers.

Facility for large-scale strategic pilots and post-pilot support

Sufficiency: Full

Criticality: Must

Time to impact: 5-9 years

Monetary outlay: USD 1 million - 10 million

Early-stage clean energy enterprises face two major challenges beyond the prototyping stage: (i) difficulty in gathering adequate and strategic financial and technical support to organise a pilot; (ii) absence of post-pilot follow-on support in most cases. While individual enterprises face these challenges, the overall ecosystem lacks a cohesive strategy to support various enterprises during the pilot stage (and beyond). For example, a programme may only support innovations in end applications without taking into account potential improvements in energy efficiency through platform technologies such as cost-effective storage solutions or energy-efficient small-scale motors. Instead of each programme providing a small and inadequate tranche of support to enterprises - which does not allow the pilots to prove the viability of the business model - there is a vital need to pool resources across donors and investors to provide more impactful support for the sector. A facility to pool together philanthropic and impact capital from donors and investors could be instrumental. Such a facility would support enterprises for strategic large-scale pilots and to also provide them with post-pilot support.

The facility could provide post-pilot support for access to networks for follow-on funding, identifying go-to-market strategies, establishing distribution channels, demand aggregation, etc. Several enterprises import a large portion of their products or components from other countries as the costs are lower and production is more convenient. Over the course of the post-pilot period, aggregation efforts could create a network of MSMEs to manufacture and scale products locally. The facility could build such a network in order to reduce the steep learning curve for each enterprise and to collectively optimise the match between the product and the MSME. The collaborative facility could also support enterprises through its core funding and could even act as an enabling platform for donors and investors to support enterprises directly.

C. Supporting entrepreneurs to scale

Strengthening the distribution network for DRE-powered products

Sufficiency: Partial

Criticality: Important

Time to impact: 5-9 years

Monetary outlay: USD 1 million - 10 million

A strong distribution network is essential to promote and scale DRE-powered products. It could also be leveraged to provide timely after-sales services, which is imperative for sustaining the market for a product. A facility, of the kind discussed above, could support enterprises' post-pilot efforts to establish distribution networks, and could also support market aggregators and last-mile distributors. Further, guarantee mechanisms to buy back unsold stock from distributors or finance the interest amounts of their working capital loans could be explored to encourage distributors to stock DRE-powered products in the early phases of market adoption. Options such as buyback could also improve the risk appetite of small- and medium-sized distributors. Currently, most large distributors control the access to credit for rural retailers. However, by easing credit levels for retailers and distributors, the interruption of their cash flow could be prevented, strengthening the distribution network for DRE-powered innovations.

Forge blower used by blacksmiths in rural India to make metallic tools that mainly find use in agriculture or construction.

Image: Sanchit Waray/CEEW

6. Conclusion

DRE and energy efficiency innovations can play a pivotal role in replacing existing fossil-fuel-based sources of energy, reducing human and animal drudgery, and contributing to an increase in rural net incomes, thereby making India's villages 'smarter'. Potential DRE solutions to power RIGAs would require technological as well as business model innovations, coupled with access to patient capital investment. This section summarises the key insights from the study, and the interventions needed to promote the mass adoption of DRE-powered livelihood applications.

Improving the asset utilisation and economic viability of DRE by complementing and sharing loads.

One way of improving the utilisation rate of solar energy applications on farms is to also use it to power non-farm productive activities, such as dal or gram mills, parboiling units, rice puffing machines, multipurpose grain mills, or pedal-cum-power-operated wheat cleaners. Load sharing can be done directly between two parties or can be moderated through a third party (e.g., an energy services company). The benefit the farmer accrues from selling additional electricity will depend on the local price of electricity and the revenues that can accrue from the additional productive work. Given the seasonality of the energy demand for agricultural activities, seasonal productive uses of energy (such as post-harvest processing) can help improve asset utilisation and facilitate better incomes for farmers. Energy products and services need to be modified accordingly to meet consumer expectations of quality, reliability, and affordability.

Concerted focus on the product innovation ecosystem will be necessary to develop sustainable markets that cater to all stakeholders.

While there are some innovations that cater to the needs of the farm and non-farm sectors, they are inadequate to mechanise rural India sufficiently to improve incomes and reduce drudgery. There exist more than 200 farm and non-farm RIGAs, and each RIGA has a value chain comprising several processes, while there are only a handful of DRE-powered innovations. The few innovations that do exist are still at an early, pre-commercial stage, with limited revenues and markets.

Markets where energy supply is inadequate to meet market requirements, where fossil fuels are being used, where human and animal drudgery limit productivity and undermine quality of life, or where energy is being used inefficiently thus driving up the price, are potential markets for DRE-powered solutions.

Product innovation in the sector is insufficient and inadequately supported. A product innovation ecosystem is needed to support product development from concept to commercialisation. For a vibrant innovation ecosystem, there need to be design labs, prototyping facilities, incubators and accelerators, angel investors and early-stage venture capital, low-cost manufacturing hubs, and identification of early adopter customers. While some of these services already exist, others are yet to be established. New business models and financial innovations need to be tested and validated to make DRE-powered products economically competitive. There are lessons to be learned on how to create, cultivate, and capture a novel market, from innovation hubs such as Shenzhen and Silicon Valley, as well as Oxbridge and Israel.

Customer development and demand creation will be critical to the success of the product despite an enabled product ecosystem

Industry interviews and a literature review show that there is a dearth of product innovations in DRE-powered livelihood applications. However, product innovations alone would not guarantee adoption on the ground. One of the most vital reasons for poor technology adoption is an inadequate understanding of human behaviour, and the failure to acknowledge its importance for the adoption of new products and business models. Unlike conventional products where customers realise the value proposition of the product, a customer base needs to be developed for DRE products by analysing unmet needs that may indicate potential demand. Access to information on customers' needs, perceptions, and willingness to pay is crucial. To that end, consumer research, design experts catering to consumer utility, and strategic pilots to evaluate consumers' needs and willingness to pay are all essential. Endeavours to design a holistic innovation ecosystem will need to address all these essential aspects of product and consumer development simultaneously.

DRE for productive use can be the catalyst for improving household energy consumption and supporting a better quality of life

Access to energy does not translate into human development unless it is followed by an increase in energy use in line with a higher standard of living (Nordhaus, Trembath and Devi 2016). With the Saubhagya Scheme, the Government of India aims to universalise household electrification, but this will not be enough to increase energy use among rural populations (Ranjan 2018). While establishing energy supply is a first step, affordable energy services need to be made available to encourage a transition to higher energy use. Rural incomes can rise through the increased use of distributed renewable energy powered innovative, energy-efficient products. Higher incomes will not only facilitate the further expansion of productive activities, but it will also improve the affordability of energy for households, thus leading to an increase in energy consumption. I-DESIRE's focus on DRE for livelihood activities would also have the additional benefit of improved and affordable energy consumption among rural households.

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Annexure 1A

1. Machine-use pattern and source of power in India from 1996 to 2012

Agri Census input survey	Farm implement	1996-1997	2001-2002	2006-2007	2011-2012	% increase
Machine-powered	Combine harvester (self-propelled)	209,018	424,506	637,860	1,900,101	809.06
Machine-powered	Agricultural tractors	6,796,960	15,463,421	31,279,048	61,132,951	799.42
Machine-powered	Combine harvester (tractor-powered)	363,569	497,499	1,021,953	2,795,857	669.00
Machine-powered	Power threshers	2,852,995	6,232,545	6,718,998	17,110,640	499.74
Machine-powered	Power-operated sprayer/duster	2,369,862	7,122,613	5,722,480	13,152,231	454.98
Machine-powered	Tractor-drawn leveller	2,135,850	3,550,909	4,642,913	10,425,356	388.11
Machine-powered	Power tiller	1,671,104	3,261,167	2,894,946	7,953,861	375.96
Miscellaneous	Sprinkler used for irrigation purposes	743,344	2,384,098	1,261,748	3,444,127	363.33
Machine-powered	Tractor-drawn seed cum fertiliser drill	2,280,388	3,810,456	5,130,579	9,375,182	311.12
Machine-powered	Power chaff cutter	1,359,671	3,446,015	4,196,245	5,551,421	308.29
Machine-powered	Tractor-drawn board plough	3,736,568	5,960,474	7,648,717	13,649,659	265.30
Machine-powered	Diesel engine pumps	8,889,706	14,261,130	13,179,632	30,081,857	238.39
Machine-powered	Tractor-drawn disc harrow	3,312,997	5,515,237	6,196,946	10,629,945	220.86
Human-powered	Hand seed/fertiliser drill	5,253,652	9,143,222	6,909,518	14,680,907	179.44
Human-powered	Maize sheller	3,064,337	2,299,454	2,534,155	7,701,032	151.31
Machine-powered	Electric pumps	9,159,758	18,447,532	12,713,933	22,760,742	148.49
Machine-powered	Tractor-drawn potato digger	450,789	552,069	487,816	1,082,309	140.09
Animal-powered	Cane crusher	687,065	1,011,426	762,757	1,546,240	125.05

Human-powered	Hand-operated sprayer/duster	15,981,329	24,783,530	20,351,313	34,466,383	115.67
Human-powered	Pedal-operated thresher	5,053,073	7,020,175	4,689,482	10,391,645	105.65

Source: Department of Agriculture Cooperation and Farmers Welfare, Agriculture Census Division 2010-11.

2. Farm power availability

Year	Agricultural worker	Draught animal	Tractor	Power tiller	Diesel engine	Electric motor
1960-61	131.1	80.4	0.037	0	0.23	0.2
1970-71	125.7	82.6	0.168	0.0096	1.7	1.6
1980-81	148	73.4	0.531	0.0162	2.88	3.35
1990-91	185.3	70.9	1.192	0.0323	4.8	8.07
2000-01	234.1	60.3	2.531	0.1147	5.9	13.25
2010-11	263	53.5	4.207	0.321	8.2	16.5
2011-12	266.08	53	4.553	0.362	8.3	16.7
2012-13	269.2	52.8	4.858	0.402	8.35	16.8
2013-14	272	52	5.237	0.4409	8.45	17

Source: (Singh, Singh, and Singh 2014)

3. RIGA in the orange box (Figure 12)

13121 - Weaving, manufacture of cotton and cotton-mixture fabrics

47221 - Retail sale of alcoholic beverages not consumed on the spot

47300 - Retail sale of automotive fuel in specialised stores

45300 - Sale of motor vehicle parts and accessories

13992 - *Zari* work and other ornamental trimmings

14105 - Custom tailoring

47522 - Retail sale of hardware including paints, varnishes, and lacquers

47721 - Retail sale of pharmaceuticals, medical, and orthopaedic goods

47711 - Retail sale of readymade garments, hosiery goods, and other articles of clothing

47594 - Retail sale of refrigerators, washing machines, and other electronics

4. Load profiles of machines considered under key non-farm RIGA

Machine (s)	Typical load (kW)	Hours of utilisation (h/year)
Sewing machine	0.3735	2,891
Woodworking machine	1.494	2,891
Bangle-ring rolling machine	1.494	2,891
Portioning machine	0.3735	2,891
Tobacco-packing machine, filter tobacco machine, tobacco mixer, automatic *kandi* machine	0.747	2,891
Filler cord making machine	0.3735	2,891
Paneer plant, ice cream homogeniser, dairy milkchilling tank, demineralised whey powder plant, liquid milk-processing plant, milk *khoya mawa* machine, etc.	1.494	2,891
Air compressor	3	2,891
Hair cutting machine, dryer, etc.	0.5	2,891
PKV mini *dal* mill	1.49	1,944
Multipurpose grain mill	1.49	1,944
Pedal- and power-operated cleaner	0.37	1,944

Source: Indiamart.com; International Council on Agricultural Research 2015

5. Load profiles of machines considered under farm RIGA

Machine (s)	Typical load (kW)
Self-propelled rice transplanter	3.28
Brush cutter	0.75
Self-propelled power weeder	2.25
Power knapsack sprayer	0.52
Self-propelled vertical conveyor reaper	3.75
Self-propelled reaper binder	5.1
Mini paddy cutter	1.48
Multicrop thresher	5.59

Source: Ministry of Agriculture and Farmers Welfare 2017

6. List of districts having rural non-farm microenterprises reporting electricity access as one of top two bottleneck hampering their business (excludes districts where no enterprises reported electricity access as top two bottlenecks)

State	District	Proportion (%) of enterprises reporting electricity access as one of top two bottlenecks to business
Andaman and Nicobar	North and Middle Andaman	2
Andaman and Nicobar	South Andaman	10
Andhra Pradesh	Adilabad	2
Andhra Pradesh	Anantapur	3
Andhra Pradesh	Chittoor	7
Andhra Pradesh	East Godavari	4
Andhra Pradesh	Guntur	1
Andhra Pradesh	Hyderabad	1
Andhra Pradesh	Karimnagar	6
Andhra Pradesh	Khammam	5
Andhra Pradesh	Krishna	3
Andhra Pradesh	Mahbubnagar	3
Andhra Pradesh	Nalgonda	2
Andhra Pradesh	Nizamabad	1
Andhra Pradesh	Prakasam	1
Andhra Pradesh	Rangareddi	2
Andhra Pradesh	Sri PottiSriramulu Nellore	5
Andhra Pradesh	Srikakulam	3
Andhra Pradesh	Visakhapatnam	4
Andhra Pradesh	Warangal	1
Andhra Pradesh	West Godavari	3
Arunachal Pradesh	Changlang	3
Arunachal Pradesh	Tawang	20
Arunachal Pradesh	Upper Siang	52
Arunachal Pradesh	West Siang	67
Assam	Baksa	7
Assam	Barpeta	29
Assam	Bongaigaon	33
Assam	Cachar	16
Assam	Chirang	25
Assam	Darrang	36
Assam	Dhemaji	11
Assam	Dhubri	50
Assam	Dibrugarh	37

Assam	Dima Hasao	53
Assam	Goalpara	20
Assam	Golaghat	26
Assam	Hailakandi	20
Assam	Jorhat	19
Assam	Kamrup	31
Assam	Kamrup Metropolitan	62
Assam	KarbiAnglong	32
Assam	Karimganj	20
Assam	Kokrajhar	35
Assam	Lakhimpur	35
Assam	Morigaon	6
Assam	Nagaon	19
Assam	Nalbari	37
Assam	Sivasagar	40
Assam	Sonitpur	37
Assam	Tinsukia	8
Assam	Udalguri	38
Bihar	Araria	8
Bihar	Arwal	1
Bihar	Aurangabad	2
Bihar	Banka	25
Bihar	Begusarai	10
Bihar	Bhagalpur	15
Bihar	Bhojpur	13
Bihar	Buxar	27
Bihar	Dharbanga	1
Bihar	Gaya	10
Bihar	Gopalganj	12
Bihar	Jehanabad	5
Bihar	Kaimur (Bhabua)	8
Bihar	Katihar	32
Bihar	Khagaria	14
Bihar	Kishanganj	2
Bihar	Lakhisarai	1
Bihar	Madhopura	8
Bihar	Munger	20
Bihar	Muzaffarpur	10
Bihar	Nalanda	7
Bihar	Nawada	17

Bihar	Paschim Champaran	31
Bihar	Patna	6
Bihar	PurbaChamparan	2
Bihar	Purnia	16
Bihar	Rohtas	6
Bihar	Saharsa	13
Bihar	Samastipur	25
Bihar	Saran	16
Bihar	Sheikhpura	36
Bihar	Sheohar	29
Bihar	Sitamarhi	8
Bihar	Siwan	2
Bihar	Supaul	9
Bihar	Vaishali	50
Chandigarh	Chandigarh	4
Chattisgarh	Bilaspur	7
Chattisgarh	Dhamtari	15
Chattisgarh	Durg	5
Chattisgarh	Janjgir - Champa	1
Chattisgarh	Kabeerdham	5
Chattisgarh	Korba	7
Chattisgarh	Koriya	3
Chattisgarh	Raigarh	8
Chattisgarh	Raipur	2
Chattisgarh	Rajnandgaon	13
Chattisgarh	Surguja	12
Chattisgarh	Uttar BastarKanker	2
Goa	North Goa	14
Goa	South Goa	25
Gujarat	Ahmadabad	1
Gujarat	Amreli	7
Gujarat	Anand	3
Gujarat	Bharuch	1
Gujarat	Bhavnagar	6
Gujarat	Dohad	3
Gujarat	Gandhinagar	1
Gujarat	Jamnagar	14
Gujarat	Junagadh	3
Gujarat	Kachchh	1
Gujarat	Kheda	2

Gujarat	Panch Mahals	2
Gujarat	Porbandar	12
Gujarat	Rajkot	3
Gujarat	Surat	6
Gujarat	Surendranagar	6
Gujarat	Tapi	2
Gujarat	Vadadora	6
Gujarat	Valsad	2
Haryana	Ambala	24
Haryana	Bhiwani	46
Haryana	Faridabad	24
Haryana	Fatehabad	26
Haryana	Gurgaon	2
Haryana	Hisar	48
Haryana	Jhajjar	33
Haryana	Jind	27
Haryana	Kaithal	78
Haryana	Karnal	31
Haryana	Kurukshetra	57
Haryana	Mahendragarh	82
Haryana	Mewat	8
Haryana	Palwal	11
Haryana	Panchkula	3
Haryana	Panipat	37
Haryana	Rewari	78
Haryana	Rohtak	37
Haryana	Sirsa	14
Haryana	Sonipat	7
Haryana	Yamunanagar	32
Himachal Pradesh	Bilaspur	1
Himachal Pradesh	Kangra	1
Himachal Pradesh	Kinnaur	20
Himachal Pradesh	Lahul&Spiti	10
Himachal Pradesh	Mandi	3
Himachal Pradesh	Shimla	3
Himachal Pradesh	Sirmaur	1
Himachal Pradesh	Una	1
Jammu and Kashmir	Anantnag	38
Jammu and Kashmir	Bandipore	13
Jammu and Kashmir	Baramula	19

Jammu and Kashmir	Doda	2
Jammu and Kashmir	Ganderbal	5
Jammu and Kashmir	Jammu	92
Jammu and Kashmir	Kargil	29
Jammu and Kashmir	Kathua	35
Jammu and Kashmir	Kulgam	32
Jammu and Kashmir	Kupwara	17
Jammu and Kashmir	Leh (Ladakh)	5
Jammu and Kashmir	Pulwama	17
Jammu and Kashmir	Punch	31
Jammu and Kashmir	Rajouri	38
Jammu and Kashmir	Reasi	24
Jammu and Kashmir	Samba	58
Jammu and Kashmir	Shupiyan	23
Jammu and Kashmir	Srinagar	18
Jammu and Kashmir	Udhampur	12
Jharkhand	Bokaro	5
Jharkhand	Chatra	11
Jharkhand	Deoghar	1
Jharkhand	Dhanbad	4
Jharkhand	Dumka	4
Jharkhand	Garhwa	17
Jharkhand	Giridih	6
Jharkhand	Godda	12
Jharkhand	Gumla	18
Jharkhand	Hazaribagh	1
Jharkhand	Jamtara	9
Jharkhand	Kodarma	3
Jharkhand	Latehar	14
Jharkhand	Lohardaga	38
Jharkhand	Pakur	5
Jharkhand	Palamu	3
Jharkhand	PaschimiSinghbhum	7
Jharkhand	PurbiSinghbhum	4
Jharkhand	Ramgarh	10
Jharkhand	Ranchi	8
Jharkhand	Sahibganj	2
Karnataka	Bagalkot	8
Karnataka	Bangalore	28
Karnataka	Bangalore Rural	18

Karnataka	Belgaum	15
Karnataka	Bellary	6
Karnataka	Bidar	3
Karnataka	Bijapur	12
Karnataka	Chamarajanagar	5
Karnataka	Chikkaballapura	6
Karnataka	Chikmagalur	40
Karnataka	Chitradurga	4
Karnataka	Dakshina Kannada	13
Karnataka	Davanagere	12
Karnataka	Dharwad	20
Karnataka	Gadag	21
Karnataka	Gulbarga	6
Karnataka	Hassan	22
Karnataka	Haveri	1
Karnataka	Kodagu	10
Karnataka	Kolar	9
Karnataka	Koppal	14
Karnataka	Mandya	5
Karnataka	Mysore	4
Karnataka	Raichur	24
Karnataka	Ramanagara	23
Karnataka	Shimoga	31
Karnataka	Tumkur	24
Karnataka	Udupi	17
Karnataka	Uttara Kannada	10
Kerala	Alappuzha	5
Kerala	Ernakulam	4
Kerala	Idukki	2
Kerala	Kannur	8
Kerala	Kasargod	8
Kerala	Kollam	2
Kerala	Kottayam	13
Kerala	Kozhikode	9
Kerala	Malappuram	13
Kerala	Palakkad	2
Kerala	Pathanarothitta	4
Kerala	Thiruvananthapuram	10
Kerala	Thrissur	9
Kerala	Wayanad	3

Madhya Pradesh	Alirajpur	6
Madhya Pradesh	Anuppur	6
Madhya Pradesh	Balaghat	7
Madhya Pradesh	Barwani	5
Madhya Pradesh	Betul	19
Madhya Pradesh	Bhind	2
Madhya Pradesh	Bhopal	3
Madhya Pradesh	Chhatarpur	11
Madhya Pradesh	Chhindwara	17
Madhya Pradesh	Damoh	1
Madhya Pradesh	Datia	14
Madhya Pradesh	Dewas	6
Madhya Pradesh	Dindori	9
Madhya Pradesh	East Nimar	11
Madhya Pradesh	Guna	3
Madhya Pradesh	Gwalior	11
Madhya Pradesh	Harda	8
Madhya Pradesh	Hoshangabad	7
Madhya Pradesh	Indore	4
Madhya Pradesh	Jhabua	1
Madhya Pradesh	Katni	10
Madhya Pradesh	Mandla	8
Madhya Pradesh	Mandsaur	6
Madhya Pradesh	Narsimhapur	4
Madhya Pradesh	Raisen	1
Madhya Pradesh	Rajgarh	2
Madhya Pradesh	Ratlam	10
Madhya Pradesh	Sagar	4
Madhya Pradesh	Satna	2
Madhya Pradesh	Sehore	7
Madhya Pradesh	Seoni	4
Madhya Pradesh	Shahdol	2
Madhya Pradesh	Shajapur	1
Madhya Pradesh	Sheopur	9
Madhya Pradesh	Shivpuri	5
Madhya Pradesh	Sidhi	9
Madhya Pradesh	Tikamgarh	1
Madhya Pradesh	Ujjain	2
Madhya Pradesh	Umaria	4
Madhya Pradesh	Vidisha	6

Maharashtra	Ahmadnagar	4
Maharashtra	Akola	31
Maharashtra	Amravati	11
Maharashtra	Aurangabad	8
Maharashtra	Bhandara	6
Maharashtra	Bid	3
Maharashtra	Buldana	21
Maharashtra	Chandrapur	9
Maharashtra	Dhule	29
Maharashtra	Gadchiroli	10
Maharashtra	Gondiya	2
Maharashtra	Hingoli	17
Maharashtra	Jaina	38
Maharashtra	Jalgaon	9
Maharashtra	Kolhapur	15
Maharashtra	Latur	18
Maharashtra	Mumbai	12
Maharashtra	Mumbai Suburban	10
Maharashtra	Nagpur	33
Maharashtra	Nanded	6
Maharashtra	Nandurbar	17
Maharashtra	Nashik	6
Maharashtra	Osmanabad	10
Maharashtra	Parbhani	12
Maharashtra	Pune	3
Maharashtra	Raigarh	11
Maharashtra	Ratnagiri	5
Maharashtra	Sangli	29
Maharashtra	Satara	8
Maharashtra	Sindhugurg	11
Maharashtra	Solapur	12
Maharashtra	Thane	28
Maharashtra	Wardha	13
Maharashtra	Yavatmal	67
Manipur	Bishnupur	3
Manipur	Chandel	2
Manipur	Churachandpur	1
Manipur	Imphal East	7
Manipur	Senapati	3
Manipur	Tamenglong	4

Manipur	Ukhrul	18
Meghalaya	East Garo Hills	4
Meghalaya	East Khasi Hills	5
Meghalaya	Jaintia Hills	1
Meghalaya	Ri Bhoi	3
Meghalaya	West Garo Hills	10
Mizoram	Aizawl	19
Mizoram	Champhai	4
Mizoram	Kolasib	13
Mizoram	Lawngtlai	7
Mizoram	Lunglei	37
Mizoram	Mamit	7
Mizoram	Saiha	14
Mizoram	Serchhip	17
Nagaland	Dimapur	24
Nagaland	Kohima	15
Nagaland	Longleng	7
Nagaland	Mokokchung	6
Nagaland	Mon	7
Nagaland	Peren	53
Nagaland	Phek	3
Nagaland	Tuensang	2
Nagaland	Wokha	7
Nagaland	Zunheboto	5
Orissa	Anugul	3
Orissa	Balangir	1
Orissa	Baleshwar	17
Orissa	Bargarh	1
Orissa	Baudh	5
Orissa	Bhadrak	6
Orissa	Cuttack	9
Orissa	Dhenkanal	1
Orissa	Gajapati	7
Orissa	Ganjam	9
Orissa	Jagatsinghapur	1
Orissa	Jajapur	11
Orissa	Jharsuguda	5
Orissa	Kalahandi	8
Orissa	Kandhamal	7
Orissa	Kendrapara	5

Orissa	Kendujhar	10
Orissa	Khordha	2
Orissa	Koraput	10
Orissa	Malkangiri	18
Orissa	Mayurbhanj	7
Orissa	Nabarangapur	5
Orissa	Nayagarh	2
Orissa	Nuapada	14
Orissa	Puri	2
Orissa	Rayagada	16
Orissa	Subarnapur	2
Orissa	Sundargarh	3
Puducherry	Pondicherry	2
Punjab	Amritsar	3
Punjab	Barnala	9
Punjab	Bathinda	12
Punjab	Faridkot	14
Punjab	Fatehgarh Sahib	15
Punjab	Firozpur	1
Punjab	Gurdaspur	5
Punjab	Hoshiarpur	5
Punjab	Jalandhar	12
Punjab	Kapurthala	5
Punjab	Ludhiana	1
Punjab	Mansa	12
Punjab	Moga	16
Punjab	Muktsar	8
Punjab	Patiala	8
Punjab	Rupnagar	11
Punjab	SAS Nagar	21
Punjab	SBS Nagar	2
Punjab	Sangrur	9
Punjab	Tarn Taran	3
Rajasthan	Ajmer	16
Rajasthan	Alwar	5
Rajasthan	Banswara	17
Rajasthan	Baran	14
Rajasthan	Barmer	1
Rajasthan	Bharatpur	4
Rajasthan	Bhilwara	19

Rajasthan	Bikaner	30
Rajasthan	Bundi	14
Rajasthan	Chittaurgarh	15
Rajasthan	Churu	4
Rajasthan	Dausa	21
Rajasthan	Dhaulpur	6
Rajasthan	Dungarpur	33
Rajasthan	Ganganagar	8
Rajasthan	Hanumangarh	13
Rajasthan	Jaipur	19
Rajasthan	Jaisalmer	21
Rajasthan	Jalor	3
Rajasthan	Jhalawar	4
Rajasthan	Jhunhjunun	4
Rajasthan	Jodhpur	3
Rajasthan	Karauli	10
Rajasthan	Kota	20
Rajasthan	Nagaru	14
Rajasthan	Pali	11
Rajasthan	Pratapgarh	10
Rajasthan	Rajsamand	14
Rajasthan	Sawai Madhopur	11
Rajasthan	Sikar	20
Rajasthan	Sirohi	20
Rajasthan	Tonk	57
Rajasthan	Udaipur	23
Sikkim	South District	2
Sikkim	West District	7
Tamil Nadu	Ariyalur	8
Tamil Nadu	Chennai	7
Tamil Nadu	Coimbatore	8
Tamil Nadu	Cuddalore	9
Tamil Nadu	Dharmapuri	8
Tamil Nadu	Dingugul	5
Tamil Nadu	Erode	1
Tamil Nadu	Kancheepuram	13
Tamil Nadu	Kanniyakumari	27
Tamil Nadu	Karur	4
Tamil Nadu	Krishnagiri	8
Tamil Nadu	Madurai	16

Tamil Nadu	Nagapattinam	8
Tamil Nadu	Namakkal	7
Tamil Nadu	Perambalur	6
Tamil Nadu	Pudukkottai	12
Tamil Nadu	Ramanathapuram	15
Tamil Nadu	Salem	6
Tamil Nadu	Sivagangai	13
Tamil Nadu	The Nilgiris	2
Tamil Nadu	Theni	3
Tamil Nadu	Thiruvallur	12
Tamil Nadu	Thiruvarur	6
Tamil Nadu	Thoothukkudi	13
Tamil Nadu	Tiruchinappalli	10
Tamil Nadu	Tirunelveli	6
Tamil Nadu	Tiruppur	9
Tamil Nadu	Tiruvannamalai	5
Tamil Nadu	Vellore	5
Tamil Nadu	Viluppuram	4
Tripura	Dhalai	3
Tripura	North Tripura	4
Tripura	South Tripura	1
Tripura	West Tripura	7
Uttar Pradesh	Agra	29
Uttar Pradesh	Aligarh	62
Uttar Pradesh	Allahabad	10
Uttar Pradesh	Ambedkar Nagar	40
Uttar Pradesh	Azamgarh	23
Uttar Pradesh	Baghpat	14
Uttar Pradesh	Bahraich	3
Uttar Pradesh	Ballia	13
Uttar Pradesh	Balrampur	7
Uttar Pradesh	Banda	16
Uttar Pradesh	Bara Banki	17
Uttar Pradesh	Bareilly	54
Uttar Pradesh	Basti	37
Uttar Pradesh	Bijnor	18
Uttar Pradesh	Budaun	35
Uttar Pradesh	Bulandshahr	22
Uttar Pradesh	Chandraili	10
Uttar Pradesh	Chitrakoot	50

Uttar Pradesh	Deoria	12
Uttar Pradesh	Etah	16
Uttar Pradesh	Etawah	3
Uttar Pradesh	Faizabad	25
Uttar Pradesh	Farrukhabad	26
Uttar Pradesh	Fatehpur	8
Uttar Pradesh	Firozabad	7
Uttar Pradesh	GBN Faridabad	3
Uttar Pradesh	Ghaziabad	3
Uttar Pradesh	Ghazipur	7
Uttar Pradesh	Gonda	38
Uttar Pradesh	Gorakhpur	21
Uttar Pradesh	Hamirpur	40
Uttar Pradesh	Hardoi	29
Uttar Pradesh	Jalaun	21
Uttar Pradesh	Jaunpur	14
Uttar Pradesh	Jhansi	3
Uttar Pradesh	Jyotiba Nagar	19
Uttar Pradesh	Kannauj	52
Uttar Pradesh	Kanpur Nagar	21
Uttar Pradesh	Kanshiram Nagar	11
Uttar Pradesh	Kaushambi	9
Uttar Pradesh	Kheri	7
Uttar Pradesh	Kushinagar	35
Uttar Pradesh	Lalitpur	17
Uttar Pradesh	Lucknow	12
Uttar Pradesh	Mahamaya Nagar	16
Uttar Pradesh	Mahoba	36
Uttar Pradesh	Mahraganj	29
Uttar Pradesh	Mainpuri	48
Uttar Pradesh	Mathura	31
Uttar Pradesh	Mau	9
Uttar Pradesh	Meerut	32
Uttar Pradesh	Mirzapur	49
Uttar Pradesh	Muzaffarnagar	15
Uttar Pradesh	Phule	22
Uttar Pradesh	Pilibhit	56
Uttar Pradesh	Pratapgarh	55
Uttar Pradesh	Rae Bareli	18
Uttar Pradesh	Rampur	17

Uttar Pradesh	SKN	48
Uttar Pradesh	SRNB	5
Uttar Pradesh	Saharanpur	1
Uttar Pradesh	Shahjahanpur	9
Uttar Pradesh	Shrawasti	11
Uttar Pradesh	Siddharthnagar	8
Uttar Pradesh	Sitapur	36
Uttar Pradesh	Sonbhadra	18
Uttar Pradesh	Sultanpur	60
Uttar Pradesh	Unnao	75
Uttar Pradesh	Varanasi	33
Uttarakhand	Bageshwar	14
Uttarakhand	Champawat	16
Uttarakhand	Dehradun	9
Uttarakhand	Garhwal	2
Uttarakhand	Hardwar	16
Uttarakhand	Nainital	6
Uttarakhand	Pithoragarh	2
Uttarakhand	Rudraprayag	2
Uttarakhand	Tehri Garhwal	1
Uttarakhand	Udham Singh Nagar	5
Uttarakhand	Uttarakshi	1
West Bengal	Bankura	12
West Bengal	Barddhaman	1
West Bengal	Birbhum	11
West Bengal	Dakshin Dinajpur	1
West Bengal	Darjiling	8
West Bengal	Haora	5
West Bengal	Hugli	4
West Bengal	Jalpaiguri	1
West Bengal	Koch Bihar	4
West Bengal	Kolkata	5
West Bengal	Maldah	11
West Bengal	Murshidabad	4
West Bengal	Nadia	5
West Bengal	North Twenty Four Parganas	6
West Bengal	Paschim Medinipur	9
West Bengal	PurbaMedinipur	2
West Bengal	Puruliya	7
West Bengal	South Twenty Four Parganas	1

Annexure 1B

1. Stakeholders interviewed in the study

Stakeholder	Organisation(s)/role
P. Pradeep	Aavishkaar Venture Management
Sandip Sinha	ABB
Charu Jain/Chandramouli Chandrasekaran	Advit Foundation
Lalit Koradia	AKRSP-India
Surendra Singh	AMMA-India
Sahil Kini	Aspada Investments
Nilesh Jain	Basix
Prasanta Biswal	BattiGhar
Ashish Gawade	BOPEEI, Jeevtronics
Mukesh Shrivastava	CAE, Pusa
Sonal Adlakha	Claro Energy
Asif Hassan/Jeff Stottlemyer/Aditi Ahuja	CLASP
Elisa Lai, Aditi Ahuja, Matt Jordan	CLASP
Yang	CLASP
Nitin Akhade	CLEAN
Hari Natarajan and Surabhi Rajagopal	CLEAN/SELCO
Venkat Rajaraman	Cygni
Adwitiya Mal	EM3
Ashish Bhosale	ex-MH SLPC
Satyajit Suri	Factor[e] Ventures
Alessandro Flammini	FAO
Srikanth Prabhu	FISE/Social Alpha
Hari Harikumar	former CTO USHA
Sangeeta Agasty	Foundation for MSME Clusters (FMC)
Shefali Kothari	Frontier Markets/Freelancer
Diego Senoner and Nilanjan Ghose	GIZ India
Seema Tiwari	Godrej CSR
Abhilash Thirupati	Gold Farm
Stephanie Jones	Good Energies Foundation
Anshuman Lath	Gram Oorja
Kuldeep Solanki	Gujpro - GJ SLPC
Anil Gupta	Honey Bee Network, IIM-A
Devinder Dhingra	ICAR
C.R. Mehta	ICAR-CIAE
K.C. Pandey	ICAR-CIAE
Alagusundaram	ICAR-IARI
Rasha Omar	IFAD
Ashok Jhunjhunwala	IIT-M
Gaurav Vats	Indian Society of Agribusiness Professionals (ISAP)
Pradip Kumar	Indian Society of Agribusiness Professionals (ISAP)
Nitin Goel	Inficold
Ambar Maheswari	Infuse Ventures
Sanjay Khazanchi and Hasna Khan	Institute for Transformative Technologies

Shambu Prasad	Institute of Rural Management, Anand (IRMA)
S. Murthy Sreedhara	Integrated Welding Automation and Controls (IWAC)
Vikas Bali	Intellecap
Raghav Gowda	Ksheera Enterprises
Georgekutty Kariyanappally	Lifeway Solar Devices
S. Mohankumar	MCE, VTU, Belgaum
P.B. Kale	Mahatma Gandhi Institute for Rural Industrialisation (MGIRI)
Deep Varma	Mahatma Gandhi Institute for Rural Industrialization (MGIRI)
Anirban Ghosh	Mahindra CSR/Strategy
Amit and Pratik Shitole	Mahindra Susten
Sunil Kumar Tiwari	Makita Tools India Pvt. Ltd. (Indian subsidiary of Makita Tools)
Ralph Sims	Massey University
Kannan Lakshminarayan	Microspin, Vortex Engineering, Skillveri
Vijay Bhaskar	Mlinda Foundation
Manjula Menon	MSSRF
Tushar Garg	National Innovation Foundation (NIF)
Premnath Venugopalan	NCL Innovation Park/Venture Center
Piyush Joshi	NIDHI-PRAYAS/NCL Venture Center
Mudit Narain	NITI Aayog
Antara Dey Bhowmik	ONergy
Kainat Ahmed	POWERED (Zone Startups, DFID, and Shell Foundation Initiative)
Pratap Raju	PR Climate Studio
Dinesh Kumar	Progressive farmer from Haryana
Prashant Katar	Progressive farmer from Haryana
Susmita Bhattacharjee	Pushan
Ketaki Bapat	RuTAG
Sabyasachi Chatterjee	RuTAG
Karthik Chandrasekhar	Sangam Ventures
Starlene Sharma	Sangam Ventures
Vaibhav Tidke	Science for Society
Harish Hande	SELCO Foundation
Niraj Sabnani	SELCO Foundation
Paul Needham	Simpa Networks
Rajat Batra	Stenum Asia
Swetha S	Acharya Institute of Technology
Ganesh Neelam	Tata Trusts/CINI
Debajit Palit/Bigsna Gill	TERI
Rajat Gupta	Tessol
D. Suresh Kumar	TNAU
K.B. Umesh	UAS Bangalore
Durlav Dhadumia	UNDP
S.N. Srinivas	UNDP
Shailaja Fennel	University of Cambridge
Augusta Abrahamse	USAID
Priya Somaiya	USHA Silai Schools
Ranjit Bobade	Vikasganga
P.R. Ganapathy	Villgro
Ananth Aravamudan	Villgro
Mukesh Parmar	Vimal Electronics
Jessica Seddon	World Resources Institute
T.S. Panwar	WWF-India

2. Semi-structured interview guide

The following questions were asked during the semi-structured interviews. The actual questions asked varied on a case-by-case basis.

1. Entrepreneur/technical expert/incubator: What innovations have taken place in the decentralised renewable energy (DRE) space in the last five years in India or globally? What are the technology readiness levels (TRL) of these innovations? Which of them would be regarded as having widespread application (platform technologies)?

2. Rural economy expert: What are the pressing energy needs of a rural manufacturing enterprise or business? Which existing DRE technologies can be used to power an appliance or process in a rural manufacturing enterprise or business? What are the negative effects of deploying technologies in rural settings? What are the aspirations of rural entrepreneurs?

3. Commercialisation expert: Alternatively, what are the challenges in commercialising DRE technologies for productive use? How do you make these technologies affordable and aspirational for rural enterprises?

4. Financier: What is the market potential of DRE technologies, specifically in powering agriculture, livestock, and micro-enterprises? Which parameters affect the funding for DRE technologies at each stage:

- At the initial ideation/business plan stage?
- At the proof of concept stage, when working on a prototype in a lab?
- When the product is fully developed, and the initial sales pitch is being made to early adopters?
- When establishing sustained revenue, widespread adoption, and exponential user growth?

Are the impediments internal (fund mandate, philosophy, returns) or external (unproven tech, uncertain market, inexperienced team)? What would have to change in order to obtain more funding for DRE technologies at all of these stages?

5. Channel partner: In what ways would collaboration help scale up DRE technologies and enable market penetration? How would such partnerships help products and services reach end users? For instance, what would you do to deploy a DRE product in all rural micro-enterprises in India?

6. Corporate partner: Large corporations can often provide useful resources for research and development, manufacturing, testing and certification, marketing and advertising, distribution and sales, and they may finally choose to acquire the product vertical of the startup. Which DRE technologies are of interest to large corporations and how would they identify them?

7. Incubator, accelerator, university: What are the missing links in the support received by DRE technologies at an early-stage (ideation/business plan on paper, or proof of concept/working prototype in a lab)? In what ways could entrepreneurs be incentivised to take up R&D in DRE technologies or, alternatively, what problems need to be solved in this sector?

8. Research agency: What role would be played by organisations that research policy aspects of DRE technologies? What incentivising mechanism would you create so that more DRE technologies get incepted and commercialised?

Annexure 1C

Core advisory group members

CAG member	Organisation(s) or role
Ashok Jhunjhunwala	Advisor to Piyush Goyal
Ananth Aravamudan	Villgro
Harish Hande	SELCO Foundation
Jessica Seddon	World Resources Institute
Kannan Lakshminarayan	Microspin, Skillveri, Vortex

Annexure 2

1. Methodology for collection of data on mechanisation across crops

For data collection, ten crops were chosen on the basis of a number of cultivatorsrepresentative of the number of livelihoods supported, the value of produce, and ratio of total labour cost to machine-operational cost. The ten crops were:

1. Wheat
2. Rice
3. Cotton
4. Coconuts
5. Sugarcane
6. Soybeans
7. Maize
8. *Arhar (toor) dal*
9. Groundnuts
10. Potatoes

The normalisation methodology used for selecting the top crops in the farm sector and the top RIGA in the non-farm sector was percentile rank, which was applied to the weighted sum of the respective indicators being considered. We did not apply a Z-score normalisation because the data was not a normal distribution, whereas our calculations showed the existence of an outlier effect for at least one indicator, because of which the min-max method of normalisation was deemed unusable.

Three states were chosen on the basis of the gross cropped area for these select crops: Tamil Nadu for coconuts, maize, rice, and sugarcane; Gujarat for cotton; Madhya Pradesh for soybeans and potatoes; Uttar Pradesh for wheat, groundnuts, and arhar. The stakeholders for the study were:

- Small Farmers' Agribusiness Consortium (SFAC)
- State Level Producer Company (SLPC)
- Farmer Producer Organisations (FPO)

According to SFAC, as of July 2017, 741 FPOs existed, out of which 318 were of interest because they were associated with the selected crops. Data was collected through telephonic conversations, with the best data obtained from organisations experienced in cultivating specific crops. A semi-structured questionnaire was prepared to collect information from FPOs on the different steps involved in the cultivation of the selected crops, and the extent and types of farm mechanisation involved. The semi-structured interviews posed questions related to:

- The area and the district to which an FPO belongs, the number of farmers being served by the organisation, and the area of land holdings
- The major crops grown in the region, and the cropping cycle (including the different cultivation steps)
- The level of mechanisation and how labour intensive the cultivation process is, along with the cost of operation and energy for each crop

- The input costs for different power sources (animal, human, diesel, and electricity), as well as field capacities and hours of usage for all the equipment used with each power source.
- The availability of different power sources, hiring costs, wage rates (in the case of human labour), and costs of animal labour, and the different challenges related to the usage of each.
- The quantity harvested in one cycle, post-harvest technologies, the availability of market or the produce, the availability of packaging, cold storage, and transportation to markets.
- Farmers' perspectives on the kind of machines they need which are not available, the challenges in employing agricultural labour, farmers' opinions on the adoption and diffusion of technology, the lack of adoption of machines, the availability of non-tractor machinery, ecosystem challenges like the effect of various government policies and schemes, the availability of financing schemes, the role of clean energy, farmers' understanding of clean energy solutions, and any best practices taken up by farmers that improved production.

2. Methodology for data collection for existing DRE-powered livelihood applications

A separate questionnaire was designed to interview DRE entrepreneurs, farm machinery manufacturers, financiers, venture capitalists and seed funders, ecosystem supporters such as government bodies and solar engineering agencies, as well as providers of engineering, procurement, and construction (EPC) solution. The questionnaire covered the following areas:

- The specifics of product/prototype/innovation and what problems they are addressing in the farm space
- Challenges faced during product development, and how to tackle those challenges
- Assess the customer base, revenues, business model, target markets, and sectors in which the enterprise has a presence - questions were included which focused on products, prototypes, and innovations
- Challenges faced during customer development, and steps taken to address those challenges
- Challenges faced in the search for seed funding, and the availability of financial schemes to support the setting up of business models in the farm sector
- Competition in the market, if information is available, and the related selling price
- External and ecosystem-level risks that may impact the company's growth or the growth of the sector, and what measures are taken to address these risks
- The internal risks that can be foreseen, and what measures can be taken to prepare for them
- The ecosystem support that is expected in order to help establish the model in the market

A literature review of various reported and published materials was conducted to find entrepreneurs who offered DRE-powered innovations in the farm sector. Through an extensive online search, the contact details for these entrepreneurs and other stakeholders were gathered, and semi-structured interviews were conducted with them. A snowball sampling strategy was also used to get new respondents from the stakeholders' list. Around 20 DRE-powered innovations were captured from various sources. Various data points were gathered, such as materials used, power and load profiles, production or operational capacity, the capacity of the solar panels, storage options, inverter capacity, electricity/diesel consumption, and the price of the product.

Annexure 3

1. Calculations for case studies on DRE-powered applications for livelihoods

Simple payback for solar-powered milking machines

Cows	Simple payback against kerosene (months)	Simple payback against labour (months)
6	24	18
12	12	9
24	6	5

A typical entrepreneur in Karnataka, India, may have about 10 to 12 cows, and therefore our calculation considers a range of 6 to 24 cows. As the number of cows increases, the number of machines required increases; a single-cluster machine can milk up to 10 or 12 cows.

Simple payback against kerosene is calculated based on the DRE system cost against the operating cost of the machine every month, based on kerosene consumption. Simple payback against human labour considers the overall system costs as the basis for the calculation, against the monthly wages of employees for milking the cows. The DRE system cost, including battery costs, is considered to be INR 36,000, and the overall system cost, including the single-cluster machine, is considered to be INR 60,000. The system cost for a double-cluster machine are considered to be INR 72,000.

Simple payback for solar-powered sewing machines

Monthly income using grid (INR)	Monthly income using solar powered DC motor retrofit (INR)	Simple payback (months)
2,000 to 2,500	4,500 to 5,000	10.5

A typical entrepreneur in Karnataka, India, earns approximately double the amount of income using the DC-motor retrofitted sewing machine. Simple payback was calculated by considering the time taken to recover the initial investment of INR 25,000.

Image: iStock

Image: Pixabay

Council on Energy, Environment and Water (CEEW)
Sanskrit Bhawan, A-10, Qutab Institutional Area
Aruna Asaf Ali Marg, New Delhi - 110067, India
T: +91 (0) 11 40733300
info@ceew.in | ceew.in | @CEEWIndia