2017/18

STATE OF THE DECENTRALIZED RENEWABLE ENERGY SECTOR IN INDIA

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Disclaimer

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FOREWORD

Decentralized renewable energy has the potential to address social, environmental, and economic goals while meeting poverty alleviation and gender welfare objectives. It deserves its rightful place in India's clean energy narrative.

CLEAN recognizes Government of India's actions and concerted efforts to upscale access to energy. As the representative body of enterprises and other NGOs working in the DRE sector, we believe that our members can support the government in meeting the larger targets for electrification, clean cooking, and livelihoods, while at the same time contributing to large-scale impacts on the ground.

In the fourth year of its establishment, CLEAN has evolved from a small entity with 45 members and has more than tripled its membership base to 150 members in 2018. It is also well positioned to becoming a credible voice for the DRE sector in India. However, at the same time, it realizes that the journey has just begun and there remains a lot of ground to cover in achieving the overarching objective of sustainable and clean energy access. Our members and other energy enterprises working in the DRE sector also recognize that while improvements have happened over the past few years in terms of business environment as well as an increase in private investment, the DRE potential is waiting to be tapped.

To sustain the momentum in the sector, energy enterprises require a facilitative policy environment and importantly low-cost, long-tenor financing in the form of equity, patient capital, and grants. To signal investment into DRE, the government can play an important role by fortifying its commitment to energy access through appropriate policy measures. The practitioners in turn, also have the responsibility to deliver quality products and systems, ensure reliable customer support and service delivery.

This edition of the State of Sector report presents the current landscape of DRE in India and highlights the areas that require policy attention. At the same time, it also provides relevant information on key trends that drive the sector. We hope this publication will be useful for all the stakeholders to reflect on their aspirations for the sector given the realities that shape the present DRE landscape.

Svati Bhogle
Chairperson, CLEAN

PREFACE

The Government of India is committed to the goal of providing 24 x 7 power for all by 2022 and ensuring access to clean cooking solutions. The commitment is evident through the launch and the initial success of the Saubhagya and Pradhan Mantri Ujjwala Yojana programmes.

We firmly believe Decentralized Renewable Energy (DRE) solutions have an important role to play in achieving universal energy access and going beyond basic access to energizing livelihoods. DRE solutions are rapidly emerging as promising solutions for rural livelihoods and enterprises, for instance charkhas, dryers, cold storage, sewing machines, egg incubators etc. However, many of the DRE applications are still not commercialized at scale and require capital for expansion.

India has an estimated market potential of more than INR 6.71 lakh crores (USD 103.3 billion) for DRE with around INR 4.27 lakh crores (USD 65 billion) potential in the solar pumps and solar thermal segments alone. While the DRE sector as a whole has grown and is poised for further growth, it requires a facilitative policy framework and infusion of capital, particularly availability of affordable finance to scale up at a faster pace.

This second edition of CLEAN's *State of the Decentralized Renewable Energy Sector in India* – 2017/18 aims to provide the current landscape of the DRE sector in India in terms of deployment, market potential across key technologies. It also offers insights on the new and emerging innovations that some of CLEAN's member enterprises have implemented.

We are sure all stakeholders in the sector, including policy-makers, energy enterprises, financiers and donors will find this report useful and practical to inform their decisions. We are hopeful that it will generate sufficient interest resulting in accelerating investment and policy support to DRE projects in India to achieve national energy access goals.

S N Srinivas, PhD
Chief Executive Officer, CLEAN

Anurag Mishra
Energy Team Leader, USAID

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Core team

S N Srinivas, Krithika P R, Prerna Sharma, Sandhya Naik (Intern)

Contributors

Srinivas Krishnaswamy & Rishabh Jain (Consultants to Oxford Policy Management); Bhaskar Deol (Mynergy Renewables Pvt. Ltd.); Nitin Akhade & Prabhat Singh (Intern) (CLEAN) and Ashwin Gambhir (Prayas Energy Group)

GLOSSARY

Anchor Business Model (ABC)	A model where the mini-grids provide bulk of their power to the telecom tower who are called 'anchor' clients
Below Poverty Line (BPL)	A BPL household in rural areas is one which has a monthly expenditure below INR 4,860. In urban areas, household with a monthly expenditure below INR 7,035 is considered BPL as per the recommendation of Rangarajan Committee Report on Poverty.
Build Own Operate Maintain (BOOM)	In this model, the organization is itself engaged in setting up plants, procurement of feedstock, and management of affairs, in the entire chain of project development.
Decentralized Renewable Energy (DRE)	DRE generally refer to any system that uses renewable energy to generate, store (in some cases), and distribute energy in a localized way. It includes off-grid solar systems (pico-solar and solar home systems [SHS]), mini and micro-grids powered by solar, biomass, hydro or a combination of these sources, improved biomass cookstoves, biogas and solar cookers, and productive applications.
Direct benefits Transfer (DBT)	The Direct Benefits Transfer simply involves transferring the subsidy amount and other benefits (called transfers) directly to the beneficiaries' bank accounts instead of providing it through government office.
Energy Service Companies (ESCOs)	An ESCO is defined as a company that would install, own, and operate RE systems, and provide energy services to consumers. Such companies are characterized by the following features: • It guarantees the energy savings and/or provision of the same level of energy service at lower cost. • Its remuneration is directly tied to the energy savings achieved. • It can either finance or assist in arranging financing for the installation of an energy project they implement by providing a savings guarantee.
Feed-in-tariff (FiT)	The tariff offered for purchase of the renewable power generated from such plants.
Force draft stove	In a forced draft cook stove, an external fan is attached to it, which runs on external power from mains/battery/thermoelectric generator for proper circulation of air for combustion.

Islanding	Islanding is the condition in which a distributed generator (DG) continues to power a location even though electrical grid power is no longer present.
Micro and Mini grid	A 'Micro Grid' system is defined as a system having an RE-based generation capacity of below 10 kW. Micro grids generally operate in isolation to the electricity networks of the DISCOM grid (standalone) but can also interconnect with the grid to exchange power. A 'Mini Grid' is defined as a system having an RE-based electricity generator (with capacity of 10 kW and above) and supplying electricity to a target set of consumers (residents for household usage, commercial, productive, industrial and institutional set-ups, etc.) through a Public Distribution Network (PDN).
ESCO	A person, a group of persons, local authority, panchayat institution, users' association, co-operative societies, non-governmental organizations, a company that builds, commissions, operates, and maintains the Mini-Grid Project within the state for generation and supply of electricity to consumers and/or sale to the distribution licensee in the mini-grid areas.
Natural draft stove	In natural draft cook stove, the air required for combustion is circulated naturally.
Pay-As-You-Go Model (PAYG)	In PAYG model, customers usually make a small deposit for the installation of the system and then pay regular instalments through mobile payment systems. PAYG has two main approaches: energy as a service approach whereby the customer pays for the electricity provided and does not own the system, and the lease-to-own model whereby the customer becomes the owner of the system after a period of time. The lease-to-own model is the most prominent one.
Productive applications for DRE	Productive applications for DRE constitute decentralized distributed renewable energy system that can contribute to the enhancement of rural sustainability and improvements in the quality of rural life.
Public Distribution network (PDN)	The distribution infrastructure owned by the mini-grid operator for supplying electricity generated from the mini-grid renewable energy system to the consumers in the mini-grid area.
Stacking (in cooking)	The use of multiple fuels and stoves, known as fuel stacking, is a common phenomenon where households tend to use a primary fuel such as LPG only for selected cooking activities while also using other fuels for cooking.

ABBREVIATIONS

ABC	Anchor-Business-Consumer
AC	Alternating current
ACS	Average cost of supply
AHEC	Alternate Hydro Energy Centre
ARR	Average revenue realized
B2B	Business-to-Business
B2C	Business-to-Consumer
B2G	Business-to-Government
BHKGS	Bihar Harit Khadi Gramodaya Sansthan
BIS	Bureau of Indian Standards
BOOM	Build own operate maintain
BPCL	Bharat Petroleum Corporation Limited
BPL	Below poverty line
CAGR	Compound annual growth rate
CEA	Central Electricity Authority
CEEW	Council on Energy, Environment and Water
CFA	Central financial assistance
Cr	Crore (10 million)
CRISIL	Credit Rating Information Services of India Limited
CSE	Centre for Science and Environment
DBT	Direct benefit transfer
DC	Direct current
DDG	Decentralized distributed generation
DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana
DFA	Distribution franchisee agreement
DISCOM	Distribution company
DRE	Decentralized renewable energy
EESL	Energy Efficiency Services Limited
ELVDC	Extra Low Voltage Direct Current
EPC	Engineering, Procurement and Construction
ESCOs	Energy Service Companies
FiT	Feed in tariff
FY	Financial year
GIZ	Gesellschaft für Internationale Zusammenarbeit
GoI	Government of India
GPS	Global Positioning System
GST	Goods and Services Tax
HP	Horsepower
HPCL	Hindustan Petroleum Corporation Limited
IEA	International Energy Agency
IEC	International Electro technical Standards
INR	Indian National Rupee
ISO	International Organization for Standardization

ABBREVIATIONS

JNNSM	Jawaharlal Nehru National Solar Mission
kg	Kilogram
KUSUM	Kisan Urja Suraksha Evam Utthaan Mahaabhiyan
kW	Kilowatt
LED	Light emitting diode
LPG	Liquefied petroleum gas
LT	Low tension
LWE	Left wing extremism
MFIs	Micro-finance institutions
ESCO	Energy Service Company
MNRE	Ministry of New and Renewable Energy
MP	Madhya Pradesh
MSME	Ministry of Small and Medium Enterprises
MToE	Million tonnes of oil equivalent
NABARD	National Bank for Agriculture and Rural Development
NGO	Non-Government Organization
NISE	National Institute of Solar Energy
NIWE	National Institute of Wind Energy
OMCs	Oil marketing companies
PAYG	Pay-as-you-go
PHC	Primary health centre
PMUY	Pradhan Mantri Ujjwala Yojana
PPA	Power purchase agreement
PPAC	Petroleum Planning and Analysis Cell
PV	Photovoltaic
R&D	Research and Development
REEEP	Renewable Energy and Efficiency Partnership
RESCO	Renewable Energy Service Company
RMS	Remote monitoring system
SC	Sub-entres
SDGs	Sustainable Development Goals
SECC	Socio Economic and Caste Census
SHG	Self-Help Group
SHS	Solar home system
SNA	State Nodal Agency
SPI	Smart Power India
SSS-NIBE	Sardar Swaran Singh National Institute of Bio Energy
TPM	Total particulate matter
TV	Television
UP	Uttar Pradesh
UPNEDA	Uttar Pradesh New and Renewable Energy Agency
USAID	United States Agency for International Development
USD	United States Dollar
UTs	Union Territories
V	Voltage
W	Watt

SUMMARY

Access to energy continues to be a challenge for India, with over 118 million people without access to electricity and 819 million people (IEA, 2016) without access to clean cooking fuels. However, the Government of India is committed to the goal of providing 24 x 7 electricity for all by 2022 and ensuring access to clean cooking energy through schemes such as Saubhagya and Pradhan Mantri Ujjwala Yojana (PMUY). Decentralized Renewable Energy (DRE) has an important role to play in complementing and supplementing the current energy provisioning approaches for households and enterprises. The stakeholders in the DRE sector are committed to meeting the Sustainable Development Goal (SDG) goal 7: Affordable access to clean energy and Government of India's mandate of energy for all.

This edition of the state of the sector report presents the landscape of DRE in India and captures overarching trends and developments that have shaped the sector in 2017/18. The report highlights the following key facts.

1. Increasing access to energy is critical to supporting human and economic development, through the direct provision of energy services for basic needs, by supporting productive uses, and by creating jobs. DRE technologies have immense potential to achieve all these goals. By a conservative estimate, at least 41,868 new jobs were created in 2017/18 in India in the DRE sector.

2. The estimated overall market potential for DRE in India is around INR 6.71 lakh crores (USD 103.3 billion). Solar thermal applications are an untapped segment, which have a significant potential of INR 1.95 lakh crores (USD 30 billion).

3. At the global level, DRE systems have experienced a three-fold increase from under 2 GW in 2008 to over 6.5 GW in 2017. A vast majority (83%) was deployed for industrial (co-generation), commercial, and public end-uses, while the rest supported household electrification. DRE systems represented about 6% of new electricity connections between 2012 and 2016, mainly in rural areas.

4. As on 31st July 2018, the cumulative achievement of off-grid solar systems under government programmes in India accounted to 762 MW. Of this, 104 MWp of capacity of off-grid solar PV systems was added in 2017/18.

5. There has been a spurt in the growth of private-sector-driven sales over the last few years, particularly in the off-grid solar and mini-grids segment. The estimated sales in the off-grid solar products (pico-solar products and solar home systems in India)

is about 6.7 million units in 2017/18. Further, based on our discussion with CLEAN members deploying mini-grids, the rough estimate of mini-grids deployed in 2017/18 is about 1.8 MW.

6. Business models have evolved in the DRE sector over the past few years with mini-grids focussing on demand generation and productive loads for financial viability. In solar pumps segment, the emphasis is on net-metered grid-connected solar pumps providing additional income generation opportunity for farmers. Several states such as Karnataka and Gujarat have introduced schemes for grid-connected solar pumps. Solarization of feeders is another model being piloted in Maharashtra. The preliminary economic analysis shows that installation of 2000 MW of tail end solar power plants under the solarized feeder model, implies savings of INR 250 crore (USD 38.5 million) per year in terms of subsidy support.

7. Productive applications of DRE reduce drudgery, increase productivity and income for rural consumers. Solar charkha is one such example of productive applications of DRE, which has created jobs and increased income for rural households. Solar charkhas are likely to come up in multiple clusters across India under the Solar Charkha Mission. Pilots undertaken by Khadi and Village Industries have demonstrated an increase in income of weavers by more than 200% a month. Solar charkha pilots in Bihar have demonstrated income generation potential of INR 6,000–10,000 per month for weavers, primarily women.

8. On the technology front, data analytics is playing a key role in energy access, enabled by smart meters and GPS enabled smart control panels in case of solar pumps.

9. On the cooking and heating front, high dependence on firewood for cooking and heating in India and the resultant biomass burning has found to be responsible for around 2,67,700 deaths in India, or nearly 25% of the deaths attributable to $PM_{2.5}$, making it the single-most important anthropogenic source related to mortality in 2015. While the Government has made efforts to provide LPG connections to poor households under the PMUY scheme, the cost of refills continues to be a significant barrier for households to use LPG. There is a renewed focus on promotion of induction stoves and solar cooking solutions by the government.

10. Government is focused on grid extension and promotion of LPG for energy access. While this is helpful in the short run in reaching the remote segments, it would be helpful to tap cleaner energy resources such as DRE solutions for ensuring energy access. With KUSUM scheme launched under Union Budget, earmarking INR 48,000 crores (USD 7.4 billion) for the scheme), solar pumps, in particular, solar PV,

got significant fillip. Similarly, policies are needed to encourage the untapped solar thermal market. Renewable energy based clean cooking solutions such as biogas, solar cooking, clean cooking biomass can play an important role in complementing the Ujjwala scheme.

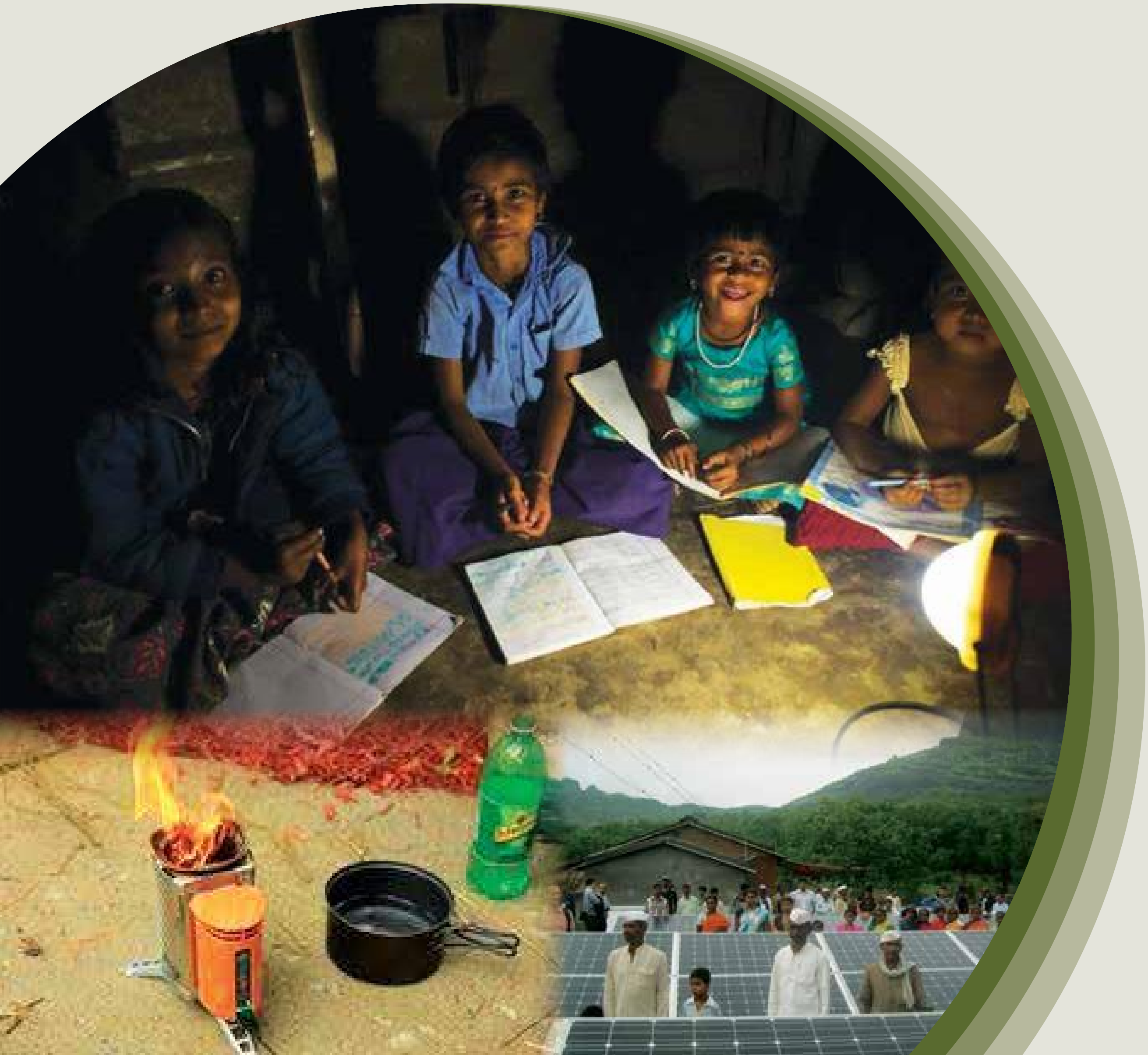
11. On the financing front, unlike utility-scale solar, where Indian commercial banks are now comfortable lending, off-grid solar and DRE continue to remain a lukewarm area for banks. Investment in the DRE sector has been significantly driven by development finance institutions and impact investors. Corporate social responsibility (CSR) and crowd-funding are emerging avenues for financing for the DRE companies. However, technical know-how of grant-making corporates in the case of CSR remain challenges impeding the flow of finance to DRE projects.

13. The DRE sector contributed to avoiding emissions of 2,84,685 tonnes of CO_2 in 2017-18.

Finally, in addition to the direct benefits to beneficiaries, a scale up in DRE systems could also benefit the overall economy. For instance, imports of diesel can be reduced through promotion of DRE applications. Around INR 40,000 crores (USD 6.1 billion) of oil imports can be saved through the replacement of solar pumps with existing conventional pumps in India. In summary, a dual focus on increasing access to energy services and promoting clean sources of energy through DRE is a win-win scenario for India from a developmental and environmental perspective.

CHAPTER

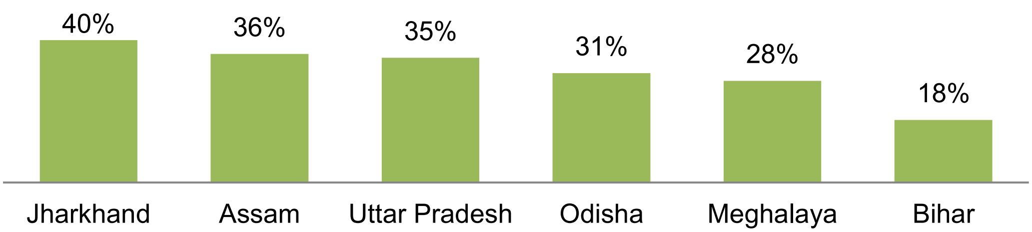
1 INTRODUCTION



1 Introduction

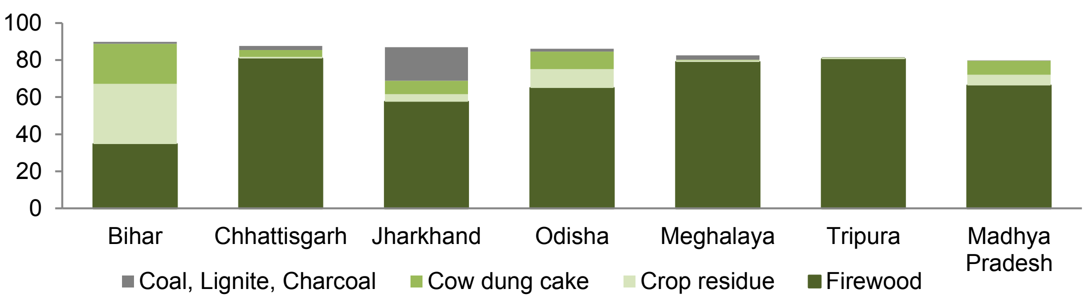
Access to energy continues to be a daunting global challenge with 14% (approximately 1.06 billion people) of the population living without access to electricity, and 38% (approximately 2.8 billion people) lacking clean cooking facilities (REN21, 2018). In the case of India, over 118 million[1] people are without access to electricity and 819 million without access to clean cooking fuels (IEA, 2016). Majority of the unelectrified population belongs to six states – Jharkhand, Uttar Pradesh, Bihar, Odisha, Assam, and Meghalaya (Figure 1). With regard to cooking, the dependence on firewood is found to be consistently high across the states with predominant usage of biomass fuels (Figure 2). In fact, residential biomass burning has been found to be responsible for about 2,67,700 deaths in India, or nearly 25% of the deaths attributable to $PM_{2.5}$, making it the single-most important anthropogenic source related to mortality in 2015 (GBD MAPS Working Group, 2018).

***FIGURE 1** States with highest share of unelectrified households in India*



Source: Saubhagya Dashboard (as on 29th June 2018)

***FIGURE 2** States with highest percentage distribution of households using solid biomass fuels for cooking*



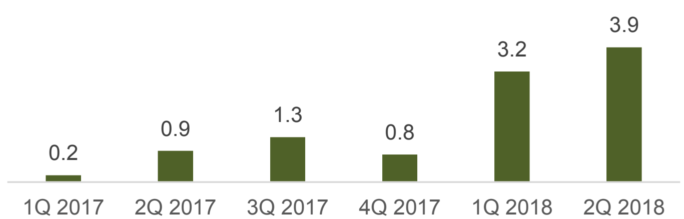
Source: Census 2011

[1] 23.5 million households are yet to be electrified (Source: http://saubhagya.gov.in/). Considering average household size as 5 persons

Recognizing these challenges, the Government of India (GoI) is making targeted efforts to increase universal energy access. India being one of the 193 United Nations member states to adopt the Sustainable Development Goals (SDGs) has also committed itself as a stakeholder to meet the 2030 agenda for sustainable development. Goal 7 of the SDGs aims to ensure access to affordable, reliable, sustainable, and modern energy for all by 2030.

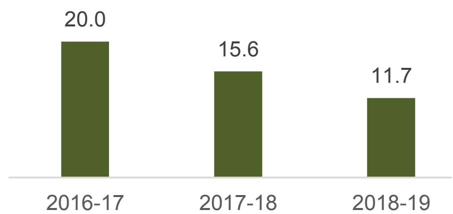
GoI has intensified efforts to provide 24 x 7 power for all. India achieved 100% village electrification in April 2018 when the last remaining unelectrified village, Leisang located in Manipur, was connected – an important milestone in development. Two recent flagship schemes for energy access are ***Saubhagya*** for electrification and ***Pradhan Mantri Ujjwala Yojana (PMUY)*** for clean cooking. Both these schemes mark a significant shift in the government's approach of providing energy access. Saubhagya scheme is focused on household grid connections and not just on village electrification. As per the International Energy Agency (IEA), household electrification in India grew from 43% in 2000 to 82% in 2016, representing about half a billion people. The progress has increased further post the announcement of Saubhagya. The pace of electrification has more than quadrupled (Figure 3). Similarly, under PMUY, GoI is actively promoting the use of liquified petroleum gas (LPG) for domestic use. A brief snapshot of these schemes is provided in Boxes 1 and 2. A snapshot of the progress since the launch of these two schemes is also presented in Figures 3 and 4).

FIGURE 3 *Number of households electrified in each quarter under Saubhagya (in millions)*



Source: Saubhagya Dashboard (as on 29th June 2018)

FIGURE 4 *LPG connections released under PMUY (in millions)*



Source: (Ministry of Petroleum and Natural Gas, 2018)

BOX 1

Sahaj Bijli Har Ghar Yojana – Saubhagya

Launched on 25th September 2017, the scheme aims to provide last-mile connectivity and electricity connections to all households in rural and urban areas through grid extension. At the time of announcement, there were about 40 million unelectrified households in India.

In addition to grid connections, un-electrified households in remote and inaccessible areas are provided with power packs of 200–300 Wp (with battery bank) and 5 LED lamps (maximum), 1 DC fan, 1 DC power plug along with repair and maintenance for 5 years.

Andrew Milligan ©

Salient Features

- **Subsidy:** Subsidized connections are provided to households. INR 500 is deducted from the monthly bills of the household over 10 equal instalments
- **Target:** Electrify all 219 million households (rural and urban)
- **Timeline:** Complete household electrification by March 2019
- **Achievements:** 7.5 million electrified households (as on 18th June 2018).

Source: (Government of India, 2017) & Saubhagya Dashboard last accessed on 18th June 2018

1.1 Decentralized Renewable Energy Sector (DRE) in India: an overview

Complementing the centralized grid extension for electricity access and LPG for cooking, Decentralized Renewable Energy (DRE) systems have a definite role in ensuring universal energy access and accelerating livelihoods in India. DRE generally refers to any system that uses renewable energy to generate, store (in some cases), and distribute energy in a localized way. DRE generally refers to any system that uses renewable energy to generate, store (in some cases), and distribute energy in a localized way. These systems cater to **electricity, thermal and motive power needs** of various segments including domestic, productive, commercial establishments and institutions. Under electrification, it includes off-grid solar systems (pico-solar and solar home systems [SHS]), mini and micro-grids powered by solar, biomass, hydro or a combination of these sources. Thermal includes cooking and process heat applications, while motive power includes energy to power motors or machinery.

BOX 2

Pradhan Mantri Ujjwala Yojana (PMUY)

The PMUY scheme aims to provide LPG connections to Below Poverty Line (BPL) households, which do not have prior connections to LPG. The beneficiary bears the cost of hot plate and purchase of first refill. The beneficiary also has the option to take hot plate (cookstove) or the first refill or both on loan basis, from Public Sector Oil Marketing Companies (OMCs) at zero interest rate and the same is recovered through subsidy received by the beneficiary as and when refill is purchased. In April 2018, OMCs decided to defer the recovery of loans up to 6 (six) refills. All PMUY customers with outstanding loan as on 31st March 2018 will have deferred loan recovery for up to six refills.

Business Today ©

Salient Features

- **Subsidy:** Cash assistance of INR 1600 is provided for releasing a new LPG connection
- **Target:** 80 Million LPG connections
- **Timeline:** 2020
- **Achievements:** As on August 2018, around 52 million connections have already been released.

Source: PMUY website, last accessed on 20th August 2018

DRE systems can be deployed faster, are cheaper compared to centralized grids, considering their life cycle costs, eliminate inefficiencies associated with long-distance transmission since they generate electricity in proximity to the load. In addition, DRE systems also offer economic, environmental, and social impacts in terms of reduced emissions, increased productivity, and income generation opportunities.

In most cases, upfront costs of DRE systems are higher than the conventional sources of energy. Hence, the DRE sector in India has been historically driven by government and NGO-led programmes. Table 1 provides a snapshot of the DRE systems deployed under the government programmes in India. The cumulative achievement of off-grid solar systems deployed by government is about 762 MW[2] (as on 31st July 2018). The table clearly shows that capacity additions in the government-driven off-grid sector are increasing across all segments. Biogas plants have seen a slow-paced growth over the

2 *This represents total of all off-grid solar systems deployed till date (lamps, home lighting systems, pumps, standalone power plants etc.)*

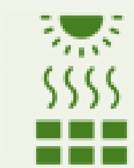
past few years and much of the deployment has been in a few states such as Maharashtra, Andhra Pradesh, Karnataka, Uttar Pradesh, and Gujarat.[3]

At the same time, the sector has evolved over the past few years with private enterprises across different segments trying and testing new business models and applications for meeting domestic and productive needs. The sector has seen a spurt of growth in the private-sector-led off-grid deployment in India. There are about 400 recognized energy enterprises spanning all the segments listed above, of which 80 are CLEAN members.[4]

TABLE 1 Off-grid systems deployed under Government schemes (cumulative till 31st December of that year)

	Technology	2015	2016	2017
	Off-grid solar			
	Lamps (million)	0.98	1.00	2.33
	SHS (million)	1.25	1.40	1.48
	Streetlights (million)	0.38	0.44	0.47
	Pumps (million)	0.04	0.10	0.15
	Standalone power plants (MW)	129.00	172.46	182.00
	Biogas plants (million)	4.87	4.95	4.99

Source: MNRE Annual reports

	Technology	2015/16	2016/17	2017/18
	Concentrating solar thermal (million square metres)	0.045	0.05	0.05
	Solar water heaters (million square metres)	12	*	*

*Source: MNRE Annual reports *data not available*

Off-grid solar and mini-grids sector has been primarily driven by the private sector. Table 2 shows the estimated number of off-grid solar products sold in the market mode by private energy enterprises. The data for the overall capacity addition in 2017/18 was not available for mini-grids in India. The capacity addition in 2017/18 reported by three of the largest ESCOs in India (also CLEAN members) was about 1.4 MW and about 383 kW of

[3] *Based on state-wise installations data from MNRE annual report.*

[4] *Includes enterprises in off-grid solar, solar pumps, micro-grids, and clean cooking segments. CLEAN 2017; Estimation based on disparate data sources.*

micro-grids were added by other CLEAN members, bringing the cumulative capacity to about 1.8 MW.

TABLE 2 Estimated number of off-grid products sold in market mode[5]

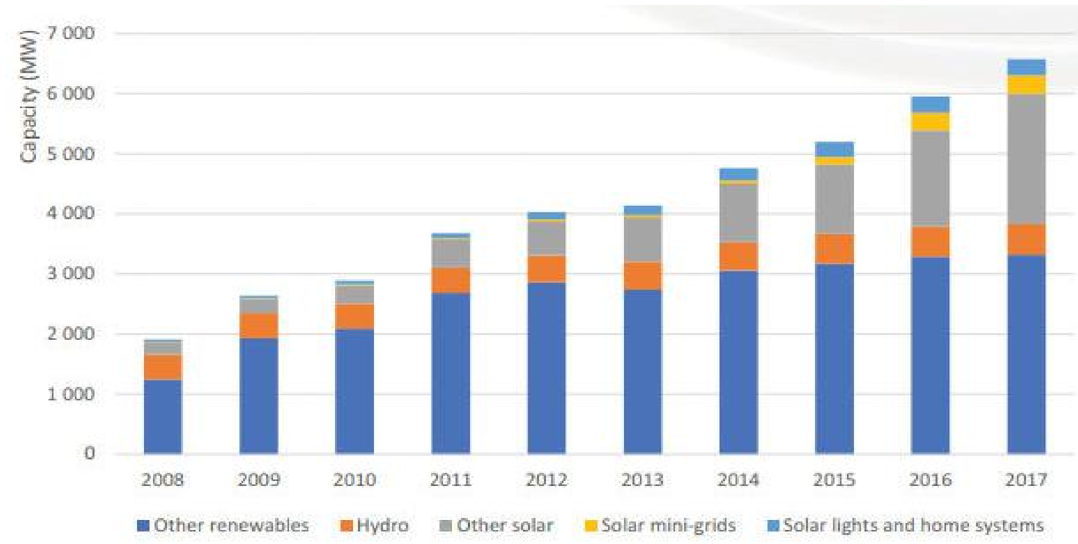
Technology	2017/18
Off-grid solar (Pico-solar products + SHS) (in million)	5.29

Source: CLEAN analysis

1.2 DRE: a brief global overview[6]

At a global level, DRE systems have experienced a three-fold increase from under 2 GW in 2008 to over 6.5 GW in 2017 (Figure 5). A vast majority (83%) was deployed for industrial (co-generation), commercial, and public end-uses, while the rest supported household electrification. DRE systems represented about 6% of new electricity connections between 2012 and 2016, mainly in rural areas. About INR 1,846 crores (USD 284 million) was invested in the off-grid solar sector globally in 2017.

FIGURE 5 *Global off-grid capacity (2008–17)*



Source: IRENA, 2018
Other renewables: primarily industrial bioenergy. Other solar: comprises off-grid power capacity in end-use sectors as industry and commercial/public.

5 *Refer to Chapter 4 for estimated sales of off-grid solar products. The number reported in the table 2 is the difference of the overall sales and the sales under the government programmes in 2017-18 (Table 1)*

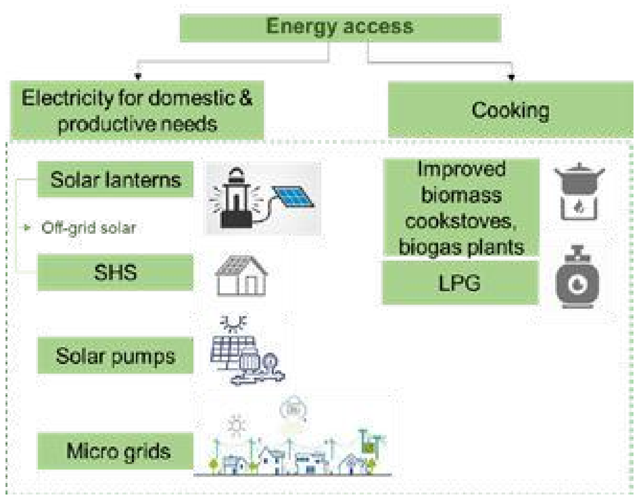
6 *IRENA, 2018*

In terms of growth by segment, off-grid solar systems experienced negative growth (–14%) in 2017 owing to localized shocks and market restructuring in major markets such as India, Kenya, Nigeria, and Tanzania. East Africa and South Asia are two major markets for off-grid solar representing over two-thirds of the total sales. Further, end-user financing approaches such as PAYG solutions have been gaining significant momentum. About 80% of the off-grid PV sales during 2015–17 were PAYG. About 9 million clean cookstoves (excluding LPG) were distributed in 2016. Deployment in the mini-grids sector was driven by installations in East Africa and South Asia.

1.3 Objectives and Scope

The objective of this report is to present the current state of the DRE sector in India and capture overarching trends and developments. The report aims to serve policymakers, private sector and other stakeholders in the DRE sector by providing up-to-date information and insights with the aim of accelerating investment in the sector. While DRE encompasses all the technologies listed in the previous section, the report primarily focuses on electrification and clean cooking sector catering to the energy needs of domestic, agriculture, and small businesses as depicted in Figure 6.

FIGURE 6 *Sectoral focus of the report*



Chapter 1 of the report provides the introduction, national and global overview of the DRE sector. **Chapter 2** highlights the immense potential of DRE solutions in India and establishes its case as complementary and supplementary to the current energy provisioning approaches. **Chapter 3** captures the market evolution in terms of sales, market drivers, and key technology trends. **Chapter 4** presents the policy framework underpinning the growth of DRE in India. **Chapter 5** discusses different business models, financing of DRE and case studies of best practices. **Chapter 6** concludes the way forward for the sector in India.

1.4 Methodology

The report was prepared by conducting a combination of primary and secondary desk research comprising published reports, information from company websites, and annual reports of companies (wherever available). An online survey was conducted in association with GOGLA for CLEAN member enterprises on their sales data and business operations.[7] Further, interviews were conducted with 15 energy enterprises across all the segments. Inputs and feedback were also obtained from an Advisory Group consisting of technical experts with different sectoral knowledge from Gesellschaft für Internationale Zusammenarbeit (GIZ), Global Alliance on Clean Cookstoves, Shakti Sustainable Energy Foundation, and the United States Agency for International Development (USAID).

1.5 Limitations of the Report

It is important to acknowledge that the availability of market data on DRE continues to be a critical challenge. The quantitative analysis is based on the survey of the sales and operational data reported by CLEAN member enterprises. The companies from off-grid solar and micro-grids segment that participated in our survey are leading players and likely to be indicative of wider industry trends. However, leading private enterprises from the improved biomass cookstoves segment did not share sales data, therefore the anal-ysis for that segment has relied on available secondary information. Of the 40 CLEAN member enterprises who responded to the data request (comprising about 50% of total CLEAN member enterprises), only 22 enterprises provided full details on sales and operations while remaining 18 provided only partial data. Further, while the report has attempted to capture major DRE sub-segments on the key developments, an exhaustive coverage of each sub-segment is outside the scope of this report.

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[7] *In the report, 1 USD = INR 65, has been used for conversion. Installations and number of units sold have been presented in millions and all monetary values are depicted in both INR and USD.*

CHAPTER

2 DRE Market Potential in India

2 DRE Market Potential in India

This chapter highlights the untapped DRE market potential in India and the possible role DRE solutions could play in supplementing the current energy provisioning approaches.

2.1 Untapped Potential for DRE Solutions

DRE solutions have a variety of applications in segments beyond lighting and cooking. The estimated overall DRE market potential is as high as INR 6.71 lakh crores (USD 103 billion), much of which is yet to be tapped. The segment-wise estimated potential is given in Table 3.

TABLE 3 Estimated overall DRE market potential in India

Technology	Potential	Market potential (USD billion)	Market potential (INR crores)	Source/Assumptions
Off-grid solar PV[1]				
Solar PV lanterns	0.9 GW	5.3	34,450	(UNDP, 2015)
Solar pumps	16.3 GW	33	2,14,500	(UNDP, 2015)
Solar-powered telecom towers	3.5 GW	12.5	81,250	(UNDP, 2015)
Street lighting	3.5 GW	15	97,500	(UNDP, 2015)
Total off-grid solar PV		**65.8**	**4,27,700**	
Solar thermal[2] (Solar water heaters+ solar concentrators+ solar cookers+ dryers+ air heaters)	100 GWth	30	1,95,000	(UNDP, 2015)
Clean cooking systems[2]				
Family-size biogas plants	7.4 million	3.4	22,200	Total potential for biogas has been estimated at 12.4 million of which ~5 million has been installed. Average unit cost for a 2 m^3 plant is assumed to be INR 30,000 (USD 462)
Improved biomass cookstoves	55 million	2.1	13,813	Estimated, considering 167.8 million rural households (Census 2011) of which 55 million will not be covered under LPG and biogas schemes. Considering an average price of INR 2,500 (USD 38) per cookstove
Productive applications for rural livelihoods	1 million	2	13,000	Estimated, by assuming that at least 1 million MSME enterprises have potential for DRE by 2032, each costing INR 1.3 lakh (USD 2,000).
Total market potential		**USD 103.3**	**INR 6,71,713**	

1 – Potential till 2022, 2 – Potential till 2032, 1 USD = 65 INR.
Sources: (UNDP, 2015), CLEAN Analysis

2.1.1 Off-grid solar PV

2.1.1.1 Lighting

While significant advances have been made to electrify households, rural households continue to depend on kerosene as a primary source of lighting or as back-up option during outages. About 176 million households depend on kerosene lamps and lanterns for lighting, although there is a declining trend over the past 3–4 years.[8] If these kerosene lamps/lanterns are to be replaced by solar lamps/lanterns, the required investment is to the tune of about INR 34,450 crores (USD 5.3 billion). Street lighting in villages, towns, and cities is another high potential segment. It is estimated that nearly 3.5 GW equivalent streetlights can be solarized and the estimated investment potential is INR 97,500 crores (USD 15 billion).

2.1.1.2 Solar pumps

Solar pumps are set for a significant growth in the Indian market, given the recent announcement of KUSUM. Given the targets set under KUSUM, the market is estimated to be about INR 56,875 crores (USD 8.75 billion).[9] However, the potential is significantly higher (INR 2.1 lakh crores), assuming the replacement of existing pumpsets in a phased manner with solar pumpsets, addition of new solar pumps, innovations in financing and service delivery models. A recent analysis points out that the replacement of current stock of conventional (electric and diesel) pumps with solar pumps of average of 3 HP capacity has the potential to save agriculture electricity subsidy of INR 22,800 crores (USD 3.5 billion) per year and forex savings of oil to the tune of INR 40,000 crores (USD 6.1 billion) per year (Garg, 2018).

2.1.2 Solar thermal applications

The proportion of heating applications in the overall share of India's primary energy consumption was significantly high at about 57% (Figure 7).[10] Solar heating applications for industrial processes and household uses are some key areas where DRE-based systems can be promoted. Solar thermal segment is yet to be tapped fully in India. In particular, solar water heaters have a high potential as compared to other solar applications and it is estimated that about 98% of the investment will be on solar water heaters (UNDP, 2015). Further, India has a large number of industries that require medium-to-high thermal energy for heating fluids and generation of hot air for their processes.

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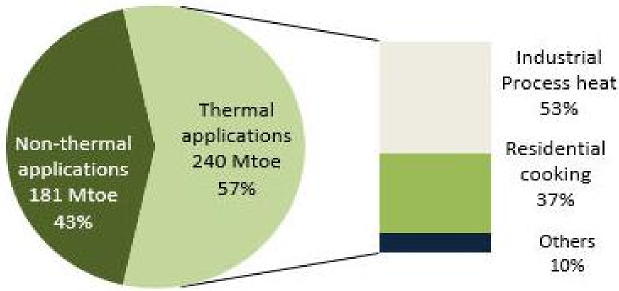
[8] *Kerosene consumption has declined 18.5% from 7949 thousand tonnes in 2012/13 to 6649 thousand tonnes in 2015/16. Source: TERI Energy Data Directory and Yearbook (2016/17)*

[9] *Taking 1.75 million off-grid pumps target at benchmark cost of INR 65,000 for an average 5 HP AC pump (MNRE 2018-19)*

[10] *As per the most recent data available from India Energy Security Scenarios, 2047*

***FIGURE 7** Final energy consumption in 2012 (421 Mtoe)*



Source: (UNDP, 2015)

2.1.3 Clean cooking solutions

As stated in Table 3, traditional biomass stoves will continue to be used in rural areas given the prevalence of fuel stacking. Two distinct opportunities emerge here: (1) there is scope to fast-track construction of biogas plants to tap the remaining potential of about 7.4 million and (2) until LPG fully penetrates the rural segment, there is scope for replacing existing biomass stoves with energy-efficient, smokeless stoves. The investment potential, thus, in biogas plants translates to about INR 22,200 crores (USD 3.3 billion), while in improved cookstoves, it is estimated to be about INR 13,813 crores (USD 2.1 billion).

2.1.4 Productive applications

India has about 63 million micro, small, and medium enterprises (MSMEs) (MSMEs, 2017), of which assuming even 1 million have the potential to deploy DRE-based applications, provides an opportunity of INR 13,000 crore (USD 2 billion).

2.2 Complementary and Supplementary Solutions for Energy Provisioning

The energy access narrative in India is evolving rapidly, through grid extension (in case of electricity) and promotion of LPG connections (in the case of cooking). While these are noteworthy, there are some gaps in the implementation of the current approaches, which can be addressed by DRE solutions.

2.2.1 Electrification

Electricity access through centralized grid, while being an important means of increasing access, may not always be the desirable solution. The main reasons are as listed below.

(i) Economically less feasible for discoms

a) It is not financially viable for discoms to extend the grid to certain regions/areas owing to the remoteness of terrain and low demand density. Further, the cost of electricity supplied through centralized grid when compared to DRE alternatives such as mini-grids, while being the lowest, does not accurately reflect the total lifecycle costs. Alternatives such as mini-grids provide quality and reliable power supply, which is available 24 x 7. However, to achieve similar performance levels, discoms would have to undertake significant network investments, which will increase the overall cost of delivered power. Recent research indicates that the cost of grid extension is about INR 2 lakh (USD 3,077) per km (single phase LT line and 1–2 distribution poles) (Tongia, 2018). Adding costs of distribution pole (INR 25,000) and costs of wiring a rural household (INR 5,000–10,000) increases the total costs of grid connections significantly.

b) The gap between the average cost of supply (ACS) of electricity and the average revenue realized (ARR) by discoms varies between INR 2.15 and INR 0.1[11] across all the states, largely due to low tariffs set to serve rural and agricultural consumers. Further, technical and commercial losses are as high as 36% for states like Bihar. This essentially means that the extension of discom grid to service rural area can further exacerbate their losses.[12]

(ii) Quality and reliability of power

A village or a household connected to a grid may not always guarantee electricity access. The definition of village electrification, as is known, is a limiting factor.[13] Availability of quality and reliable power, when needed, continues to be a challenge in rural areas. While, with the initiative of 24 x 7 Power for All, states are reporting an increase in the duration of power supply, many rural areas continue to report frequent outages and voltage fluctuations. As per a recent study conducted by CSE, power supply in some rural villages of Uttar Pradesh in districts such as Sitapur, Unnao, and Kushinagar is as low as 3–4 hour (Bhati & Singh, 2018) This is, in fact, one of the most critical drivers for the growth of mini-grids in India.

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[11] *Except Himachal Pradesh, Chhattisgarh and Gujarat, Source: Lok Sabha Question 2782, Loss of Discoms*

[12] *The total loss incurred by all discoms in FY 2016-17 in India was INR 36,905 crore.*

[13] *A village is considered electrified if 10% of the households, public institutions such as Panchayat office, health centres etc. are electrified and there is basic distribution infrastructure present in that village.*

Husk Power, one of the leading mini-grid developers, also a CLEAN member, has reported cases of consumers continuing to use mini-grid power supply in villages of Uttar Pradesh even when the grid is present, owing to frequent power supply interruptions. Consumers of Husk Power in Bihar, who also have grid connections, have reported voltage levels falling to 140 V in peak summer months, as against the 220-240V.

There is a need for alternative affordable solutions for energy access that can complement and supplement grid extension, provide quality and reliable power as and when needed by the consumers.

2.2.2 Cooking

Cooking on LPG stoves is something which rural consumers aspire for, however LPG promotion as the main fuel for cooking has certain limitations.

a) **Cost of re-fills:** The cost[14] of re-fills after getting LPG connection is a significant barrier for households, as affirmed by a CRISIL study (CRISIL, 2016). It has been seen that re-fills for cylinders are not happening regularly among the PMUY beneficiaries. The average per capita consumption as reported by GoI is 4.32 cylinders. The energy expenditure for the given level of LPG consumption comes roughly to about INR 30,270 (USD 466), which is about 44% of the total annual expenditure of a BPL household, prohibitively high for such households.

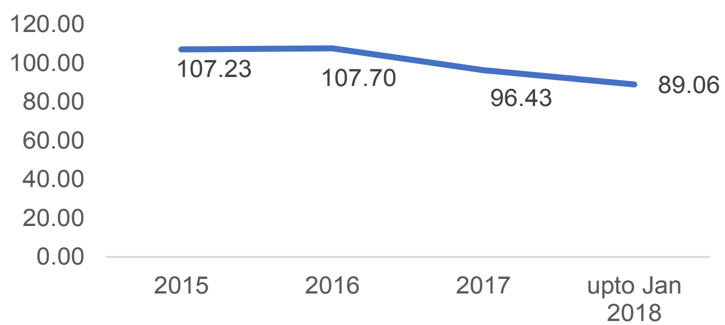
b) **Fuel stacking:** Fuel stacking is a reality in rural areas, where consumers often use a combination of stoves for cooking such as mud stoves and LPG. The sole use of LPG is seldom the case, which essentially means that households will still continue using traditional forms of fuel. This has also been acknowledged in the Draft National Energy Policy, where the analysis for Energy Security Scenarios predicts that 35% of rural households will be reliant on biomass for cooking by 2032 and 20% of households will be reliant on biomass by 2047.

   Further, the national average LPG consumption per consumer was 7.3 cylinders in 2015/16. This when measured against the normative expectation of 12 cylinders, if all of LPG was consumed for cooking, indicates that LPG is utilized to only 60%–70% of cooking (Dabadge, Sreenivas & Josey, 2018). This means that PMUY consumers are consuming less LPG compared to other users. The objective of providing LPG to induce a behavioural shift to LPG is well-intentioned, but yet to address practical issues.

[14] *Cost of subsidized 14.2 kg cylinder in Delhi was INR 495.69 in January 2018.Source: Indian Oil Corporation Ltd*

c) **Inadequate distribution system:** The Petroleum Planning and Analysis Cell (PPAC) data show that the average number of distributors per 1 million consumers has continuously declined since 2015 (Figure 8). It is also found that there are 80 distributors for 1 million households in urban areas, while there are only 65 distributors per 1 million households in rural areas (PPAC,2018). It is also important to note that the distribution business has to be viable for them to set up the business, which essentially depends on the density of consumers and the cost of delivering cylinders to them. Distributors usually serve consumers within a distance of 20–25 km;[15] therefore, rural consumers who live in interior areas are not accorded priority. This also leads to malpractices and diversions by distributors to make up for viability.

FIGURE 8 *Average number of distributors per 1 million consumers*



Source: PPAC 2018

Wide prevalence of stove stacking along with challenges in converting connections to sustained use of LPG necessitates the need for holistic access to modern energy. There is a strong need for solutions beyond LPG.

2.2.3 Productive applications

As per the World Bank Enterprises Survey Report 2014, lack of reliable supply of electricity was one of the key obstacles hampering enterprises in undertaking business in India. Further, a FICCI study pegged the revenue losses to INR 40,000 (USD 615) per day for small and medium firms in some states of India (FICCI, 2012). While rural livelihoods have a smaller scale of operations, the concern persists. In addition to quality, reliability, and availability of power, rural livelihoods also face fluctuations in energy input costs (diesel prices) and involve drudgery.

[15] *Interviews*

Going beyond electrification and cooking, DRE options energize rural livelihoods and provide benefits in terms of reduction in drudgery, reduction of input costs, and increase in productivity (Section 3.4). They also provide environmental, social, and economic impacts by reducing carbon emissions, contributing to jobs and increasing welfare of the rural community (Section 3.5).

CHAPTER

3 DRE Market Evolution

3 DRE Market Evolution

The market for DRE has evolved over the past few years with the emergence of new business models and technology trends. This chapter captures the market evolution and the trends that drive various segments.

3.1 Off-grid solar (Pico Solar and SHS)

Pico-solar (solar lanterns) are lower wattage systems ranging from 0 to 10 W and can power 1–3 LEDs, and one mobile charging point. SHS can range from 10 to 200 W and a standard system (40–60 W) can power 1–3 lights, appliances such as DC fan and TV. The price range of products in the lantern segment varies from INR 260 to 3,250 (USD 4 to 50) while that of SHS varies from INR 3,250 to 32,500 (USD 50 to 500) (Figure 9).

FIGURE 9 *Examples of off-grid solar products*

Greenlight Planet – Sun King Charge Solar Lantern
- Price – INR 1362
- Capacity – 2.5 W
- Max. brightness – 50 lumens
- Battery runtime – 72 hours
- Other features – Multiple phone adapters and multi-use stand

Simpa – Solar Home System with Magic TV
- Price – INR 25,000
- Capacity – 80 W
- Backup time – 5–8 hours
- Features – 20'' energy-efficient LED Television, battery, charge controller, and 3 LED lights

Source: Company websites

3.1.1 Off-grid solar sales

India represents one of the largest markets for off-grid solar globally. There are about 70 established players in the off-grid solar market and several more exist in the unorganized market (Bloomberg New Energy Finance, 2016). The off-grid solar market in India is divided into commercial market (sales to consumers through distributors and other partners) and sales to government through tenders released by state nodal agencies (SNAs). Under the government programme, subsidies are provided on off-grid solar products, based on benchmark cost (See Section 3.6.1).

Table 4 provides the estimated number of off-grid products sold in 2017/18[16].

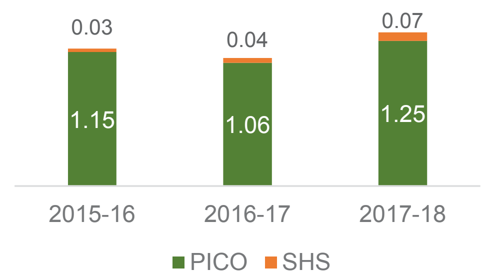
TABLE 4 Estimated total volume of off-grid product sales in 2017/18

Off-grid solar (Pico-solar + SHS)	Sales in 2017/18
Number of products sold (million)	6.7

This estimated volume is inclusive of component-based systems and the sales under government programmes.

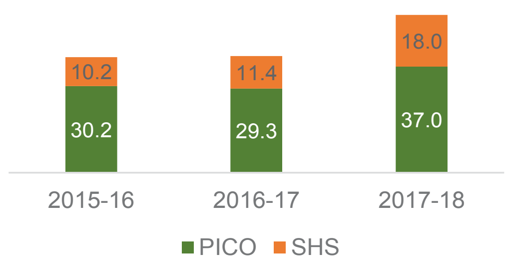
As per the survey of only the CLEAN members,[17] 1.32 million off-grid solar products were sold in 2017/18 (Figure 10). Further, the trend in CLEAN member sales indicates a dip in 2016/17 owing to demonetization; however, as the economy stabilized from the impact, sales picked up in 2017/18. Interestingly, the share of SHS in volume and value is seen to rise consistently indicating consumer preference for higher wattage systems. Further, in terms of revenue,[18] about INR 357.5 crores (USD 55 million) worth of products were sold in 2017/18.

***FIGURE 10** CLEAN member sales - off-grid solar products (million units)*



Source: CLEAN-GOGLA survey

***FIGURE 11** CLEAN member sales - off-grid solar products (USD million)*



Source: CLEAN-GOGLA survey

16 *Total sales for off-grid products in India has been estimated by taking sales data of GOGLA affiliates as reported in their off-grid solar market report for H1 and H2 2017 for India. While the data given is for January–December 2017, it is assumed that the sales volume will be reflective of the sales in FY 2017/18 also. It is further assumed that the calculated sales represent 35% of the total sales in India, given the market share of GOGLA affiliates in the pico PV segment (GOGLA, 2018). As over 95% of the sales volumes are in pico-PV, the overall market size has been calculated taking this figure.*

17 *Data of 9 CLEAN members*

18 *Revenue has been calculated by summing up the retail price of products sold by members. Retail price = FOB price*1.8, as per GOGLA methodology*

3.1.2 Market drivers

- The off-grid solar market in India is witnessing changes in the preferences of consumers towards higher capacity systems. This is indicated by the rise in the sales of SHS.
- Though current penetration of PAYG models in India is low, PAYG sales are expected to increase with the use of digital wallets and digital transactions (Box 3). Some players who have experimented with PAYG in other Asian markets are planning to test models in India.

3.1.3 Key challenges

- The recent imposition of 25% import duty on solar modules in July 2018 is expected to have a negative impact only on component-based sales, though products with integrated panels (solar panels with luminaries) are not expected to have a significant impact (See section 3.6).
- Imported off-grid products in India are expected to conform to BIS standards as per the MNRE order in 2017. However, industry players have pointed out issues in compliance with the order, as the order appears to be applicable to higher capacity systems (Section 3.6.2). Further, there are limited number of labs in India (4)[19] to test pico-solar products (less than 5 Wp) as reported by industry players. The waiting time for testing (30–45 days) for solar lanterns in some labs is also seen as a constraining factor.

3.2 Technology Trends: energy-efficient DC appliances

As rural consumers are heterogeneous and have evolving needs, enterprises are also changing their product offerings to beyond lighting and mobile charging, catering to a range of their energy needs. Some leading enterprises in this segment have introduced or announced plans for solar-powered appliances such as TVs and refrigerators for the rural domestic markets. For instance, Simpa introduced 'Magic TV' in 2017 (Figure 9), which is available to the consumer through point of sale financing options over time through 12, 24 or 36 months financing (Simpa Networks, 2017). d.light is also increasing its product range to fans, refrigerators, and TVs. DC appliances are being provided in the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY)and Saubhagya schemes of the government.

As per a study conducted by Global Lighting and Energy Access Partnership (Global LEAP), there is a wide market opportunity for off-grid appliances in India (Table 5). Further, a recent survey undertaken by Global LEAP indicated that the top 5 products

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[19] *Accredited test centres as per MNRE off-grid programme*

BOX 3

Pay-as-you-go models in India

Pay-as-you-go (PAYG) models, which allow consumers to pay for the product in small increments using mobile phones, have not gained much traction in India, while they are immensely popular in other regions such as Africa. Though the penetration of smart phones and internet is increasing, the current data indicates that only 7% of the population owns smart phones (Mckinsey Global Institute, 2016). Further, mobile money and digital wallets are not widely used in rural areas in India. India is a cash-based economy and less than 1% of the total transactions by volume are through digital payments. Secondly, the implementation of PAYG solutions are capital-intensive in nature and complicated to operationalize on the ground (Wells, 2017). The consumer awareness of digital transaction is also low in rural areas. Consequently, there are very few players providing these solutions.

Simpa customer recharging her PAY G meter, Simpa©

Simpa Networks is the only leading PAYG solar company in India, which has sold about 20,000 units (GSMA, 2017). A recent entrant in this market is Greenlight Planet, which is piloting some PAYG models. Greenlight Planet's model 'EasyBuy' is operational in Asia (Direct channel in Myanmar since 2017 and other Asia pacific countries through partnerships) and is currently being implemented in India via two distribution channels – Partnerships and Direct distribution channels. It is partnering with key developmental agencies and payment partners who offer Easybuy-enabled Sun King products (flagship product) to end-customers through their distribution networks. Under their direct distribution channel, they recruit village-level entrepreneurs working as energy officers in their community. These energy officers go door to door to educate customers, sell products, and collect the instalments.

as per the anticipated consumer demand in India are household refrigerators, TVs, fans, refrigeration for small medium enterprises (SME), and agricultural cold chains (Global LEAP, 2017). While manufacturers primarily offer fans and TVs with standard SHS, there are a number of other DC appliances available (GIZ, 2016). These appliances are super-efficient and enable greater levels of energy access, e.g., 40 Wp solar module and a 70 Ampere hour (Ah) battery – can power a 25 W incandescent bulb for 5 hours each day, but the same system can power a super-efficient 21" flat panel TV, two high-quality LEDs.

TABLE 5 Addressable market for off-grid appliances India

Appliances	Addressable market[20] (millions)
Fans	100.4
TVs	57.5
Refrigerators	13.1

Source: Global LEAP, 2017

Key innovations in DC appliances include Permanent Magnet Brushless DC (BLDC) motors for fans, which have higher efficiency,[21] longer lifetimes, compact design (lightness), and programmable controls. However, they are 50%–100% more expensive as compared to brushed motors. Despite the immense potential of DC appliances, the industry is sceptical about the current manufacturing eco-system of DC appliances. Even in the global market, BLDCs currently constitute less than 1% of the total sales because of its high upfront costs (Global LEAP, 2017a). Lack of scale and the need for customization and right sizing of BLDCs for off-grid sector, is a challenge.

There are limited DC appliance manufacturers in India manufacturing DC products for the off-grid sector. Most of them are unwilling/hesitant to take orders for a smaller consignment for the rural off-grid market. Initiatives such as the 'E-merge' Alliance in India, led by IIT Madras and Cygni Energy, having around 14 manufacturers for lighting, BLDCs and TVs, are seen as welcome first steps in creating a supply chain for DC appliances. CLEAN has also pilot-tested DC motors for mixer-grinders (See Box 4). Several CLEAN members such as Simpa, Greenlight Planet, SELCO, d.light, and Cygni are offering DC appliances integrated with their products. Further, BIS has also announced guidelines for 48 V extra low voltage DC (ELVDC) distribution system. These guidelines specify 48V as the distribution voltage for DC considering safety and distribution losses. (Bureau of Indian Standards, 2017).

BOX 4

CLEAN energy-efficient DC mixer grinder

CLEAN – Energy-efficient direct current mixer grinder

CLEAN, GSH Technologies, and EmSys Electronics have developed a prototype of DC-run mixer grinder that uses a 200-W, energy-efficient DC-powered motor instead of the conventional 750-W motor. This new mixer requires only 0.3 kWh of electricity costing about INR 1.80 (at INR 6 per kWh) to make a litre of juice. Laboratory testing has been completed. An added advantage is the lesser sound/noise level of a DC product compared to a conventional AC mixer/grinder.

CLEAN©

[20] *Addressable market is estimated considering household electrification status, annual consumption pattern, household energy and appliance spend*

[21] *BLDC motors are 85%–90% efficient while brushed motor efficiency ranges between 75% and 80%*

Case study 1: Cygni Energy

Eliminating losses through solar DC solutions

Cygni Energy Pvt. Ltd, an IIT Madras incubatee and a B2B enterprise founded in 2014, is deploying solutions such as solar DC inverterless controllers, which eliminate the need for DC–AC and AC–DC conversions. As a result of high efficiency and low losses, a household benefits from savings in power and hence cost in per unit of power. These solutions are primarily targeted towards rural and peri-urban areas, which face long hours of load shedding and unreliable power supply. For a household connected to the grid (AC) and having a back-up solar home system, the following situation can arise. Solar PV panels produce DC power and require conversion to AC to power the load. The problem is further compounded when AC power needs conversion to DC before it charges the battery, and the battery output needs conversion from DC to AC before it powers appliances. All the modern appliances (Light Emitting Diode (LED), LCD (Liquid Crystal Display), laptops, computers, etc.) are run on DC power and hence there is one more AC to DC conversion at the final appliances end. The entire process of conversion leads to losses of about 45%.

Cygni has innovated a battery-based inverterless system that runs on solar power and fully DC-powered without any conversions from solar or from batteries. In the absence of solar, it is powered either by batteries or main power supply (Figure 12). Eliminating a series of conversions, there is a single high efficiency conversion from AC to DC to power DC appliances. The system comes with DC appliances. Given that most of the appliances such as TVs, laptops, electronic gadgets, set top boxes, and computers use DC power and are best powered by DC, this solution has a good potential to scale in off-grid or unreliable grid areas. Power can be remotely monitored with data logged on to a server using bluetooth and a mobile handset or via Global system for mobile communications (GSM)/General Packet Radio Services (GPRS) network. Cygni has deployed these solutions in about 4,000 off-grid homes in Rajasthan under the DDUGJY programme and about 22,000 till July 2018 (Picture shown below).

Cygni Energy Pvt. Ltd ©

System cost – INR 23,000 (USD 354) (exclusive of DC appliances)

1. Solar Panel (125 W)
2. Controller + Integrated Li-Ion Battery
3. DC appliances – 1 Tubelight, 1 Fan, Two LED bulbs, 1 mobile charger and 1 DC socket – INR 5,000

FIGURE 12 DC inverterless system implemented by Cygni

Cygni Energy Pvt. Ltd©

3.2.1 Mini and micro-grids

Micro (<10 kW) and mini-grids (>10 kW) are categorized further into those deployed by private sector and those installed under government programmes. As per industry interviews, there are about 350 private sector mini-grids (above 10 kW capacity) operating in the country. The estimated total number of all micro and mini-grids in India is more than 4000 (including government-owned and operated mini-grids). Most of the mini-grids installed by the private sector in Uttar Pradesh and Bihar. Uttar Pradesh alone has 1850 mini-grid installations, of which 90% are pico grids (1 kW or less) (Bhati & Singh, 2018). It is further estimated that these two states have about 6.5 million households that can be economically served by mini-grids (Tkacik & Smith, 2017). The estimated installed capacity of micro and mini-grids in India deployed by the private sector is about 6 MW.

TABLE 6 Mini-grids in India

Particular	Units / Capacity
No. of private mini-grids (>10 kW)	350
Total number of mini-grids	>4000
Estimated capacity (Till 2017/18)	~6 MW

Source: Interviews

Unlike the off-grid solar segment, there are only a few established players in the private mini-grid sector. It is estimated that there are about 30 private mini-grid operators in India, also known as Energy Service Companies (ESCOs)[22]. Among the private mini-grids, OMC is the largest developer in India with 99 mini-grids deployed in Uttar Pradesh. Smart Power India (SPI), affiliated with the Rockefeller Foundation, has supported about 150 private mini-grids in the states of Uttar Pradesh, Bihar, and Jharkhand.

3.2.2 Technology trends

3.2.2.1 Falling storage costs (Li-ion)

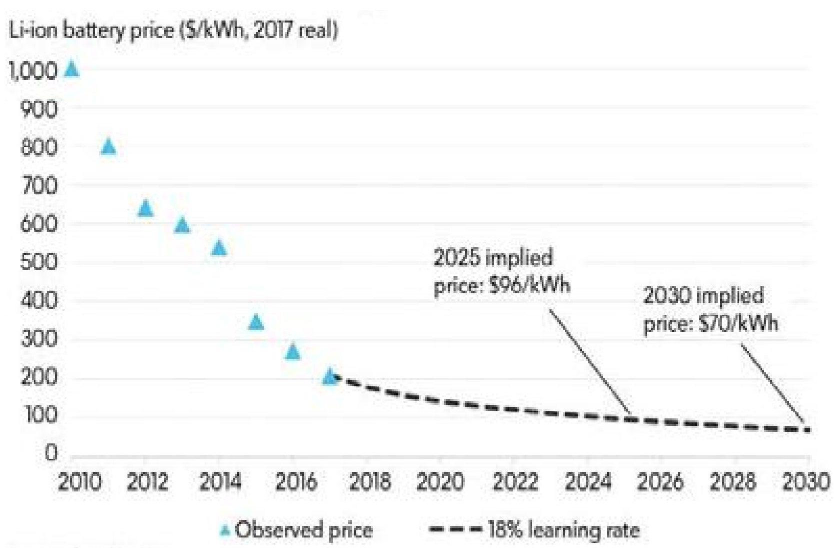
Of the total 57 GW energy storage market potential for India, 2% (~1.1 GW) has been estimated for rural micro-grids (Ragupathy, 2018). Though a range of technologies are used in off-grid energy storage, lead-acid and lithium-ion (Li-ion) are the most dominant storage technologies for micro-grids. Each is different in terms of cost, cycle life, charge/discharge rate, and environmental impact. A comparative table of assessment of different energy storage technologies is provided in the Annexure 3.

Lead-acid batteries, which are more standard for micro-grids, are seen to perform poorly in Indian conditions owing to the exposure to high ambient temperature conditions in India and if they are discharged below 50%, they tend to remain in the state of partial discharge for prolonged periods (Buluswar, Khan, Hansen, & Friedman, 2016). Li-ion batteries are preferred over lead-acid batteries for high energy, power density, and higher cycle life. However, they are expensive compared to lead-acid batteries. Lead-acid batteries cost about INR 16,250-32,500/kWh (USD 250-500/kWh) as compared to INR 16,250- INR 32,500 (USD 250–500) for Li-ion batteries. Added to this are the additional costs and complications of imports. Though driven by a global surge in demand for electric vehicles (EVs), Li-ion batteries are experiencing rapid cost reductions and prices will begin to plateau out beginning 2020 (Figure 13). As of 2017, Li-ion batteries are not manufactured in India. The manufacturing of Li-ion batteries is restricted to a few countries (Japan, South Korea, China). With an increasing focus on EVs, it is expected

[22] *BNEF, 2016*

that some well-known brands may consider manufacturing in India or start bulk shipping, leading to affordable alternative options.

***FIGURE 13** Lithium ion battery prices trend*



Source: (Bloomberg New Energy Finance, 2018)

CLEAN is undertaking two projects in Jharkhand and Chhattisgarh in collaboration with Panasonic India and Amplus Solar for demonstration of lithium-ion battery technology for mini grids.

At the same time, lead-acid battery technologies such as 'Advanced Lead-Acid' batteries are available, which have better longevity and performance, but they are still new and currently too expensive for mini-grids. Larger mini-grid players are not sure of Li-ion batteries in the medium term; however, they are keenly watching the trends in cost reduction. One of the other proposed solutions is hybrid mini-grids (Li-ion and lead-acid hybrid), which can combine the cost-effectiveness of lead-acid batteries and resilience of lithium batteries. (ITT, 2016)

FIGURE 14 *Utility in a box*

Institute for Transformative Technologies©

CLEAN member, Oorja Solutions, has piloted such a hybrid battery storage for a micro-grid in Uttar Pradesh. Other new innovations such as 'Utility in a Box' models are also being trial-tested in India.

BOX 5 Utility in a Box

'Utility in a Box' pioneered by Institute for Transformative Technologies (ITT)

Mini-grids deployed in India are usually an assembly of various components which are non-standardized, leading to sub-optimal performance and operational leakages. The problem has been addressed to some extent by the recent Solar DC Micro-grid Guidelines, 2017, which specifies voltage level, selection of cables, and specification of BIS standards for various components. However, mini-grid developers often choose affordable but sub-par components.

ITT has tried to address this problem by 'productizing' a system, which they have termed as 'Utility in a box (UiB)', where the most important components (batteries, charge controller and inverter optimized for the battery chemistry, metering, assembly fixtures) are combined to form an integrated system. The UiB mini-grids will have complete metering and load management system along with a full revenue management system with features like on-bill financing and mobile money gateway integration. All customer and revenue operations can be remotely monitored and controlled. Such an integrated system is expected to bring the capital cost down by 10%–20% and deliver higher performance. The cost reduction occurs due to elimination or simplification of components, economies of scale and bulk procurement. The performance is enhanced by adding new functionalities. Prototypes of an integrated, standardized UiB were first deployed in rural India in June 2017. The first UiB prototype caters to 10 kW load comprising about 200 households/commercial loads and 10–12 micro-enterprises. UiB prototypes underwent field trials between June and October 2017, under strict performance monitoring by three energy service companies - TARA Urja, Mlinda, and OMC Power.

Source: ITT, 2016

3.2.2.2 Smart meters

Smart meters,[23] while being ubiquitous at grid scale, have seen moderate level of deployment in micro-grids. Few ESCOs have deployed smart meters with full range of features (custom tariffs, load limiting, remote monitoring, cloud software, loss detection, etc.) for micro-grids, owing to high cost. Most of the smart meters deployed by ESCOs enable certain essential functionalities such as custom tariffs, remote monitoring, and load limiting. The average cost per consumer for a smart meter presently ranges between INR 2500–3000 (USD 39-46), while the load limiters offer a much cheaper alternative at INR 500 (USD 8 or less).[24] The cost of smart meters can come down if procured in bulk (greater than 100,000 units); however, many of ESCOs feel the returns of deploying smart meters for rural consumers are not commensurate with the costs. Those micro-grids providing 24 x 7 power necessarily deploy smart meters to monitor consumption patterns. Some ESCOs such as Mlinda have migrated from a post-paid system to a pre-paid smart metering system. All 17 villages where Mlinda is operational have smart meters installed.

3.3 Solar Pumps for Irrigation

Solar pumps are a combination of solar PV panels, pumps, and associated electronics (Figure 15). Solar pumps are further categorized into Alternating current (AC) and DC pumps. While DC pumps are primarily imported, AC pumps are locally manufactured in India. The pump capacity ranges from 0.2 HP to 10 HP. Further, as a general thumb rule, if the depth of the water table is up to 10 m, surface pumps are used and for a depth greater than 10 m, submersible pumps are used. The break-up of a typical 5 HP AC pump is indicated in Figure 16. Bulk of the costs are constituted by solar PV panels and installation.

Solar pumps industry has primarily been Business to Government, with most of the installation happening under the state tenders issued by the SNA or the Department of Agriculture. The solar pumps market is also regulated with only those players able to participate in the tendering process, who have been empanelled by MNRE and SNAs.

3.3.1 Solar pump installations in India

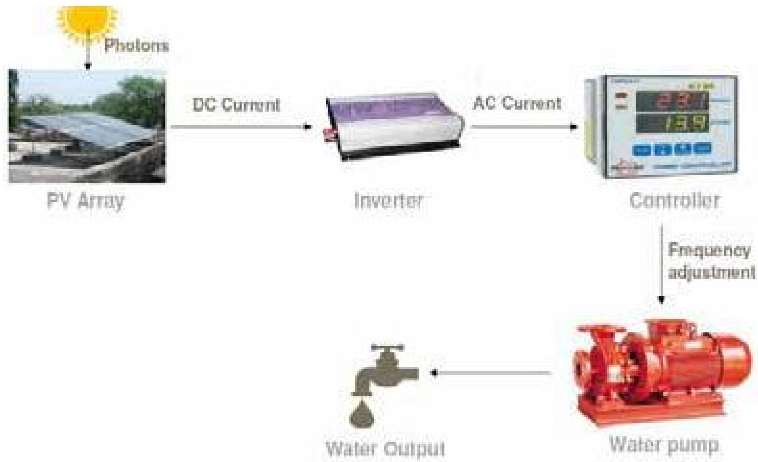
Solar pumps market is dominated by two or three large players who make up 70%–80% of the market share. Pump manufacturers supply pumps to the system integrators. System

[23] *Smart meters are wireless and allow micro-grid operators to control and incentivize customer loads by monitoring their consumption patterns remotely, on a real-time basis*

[24] *Interviews*

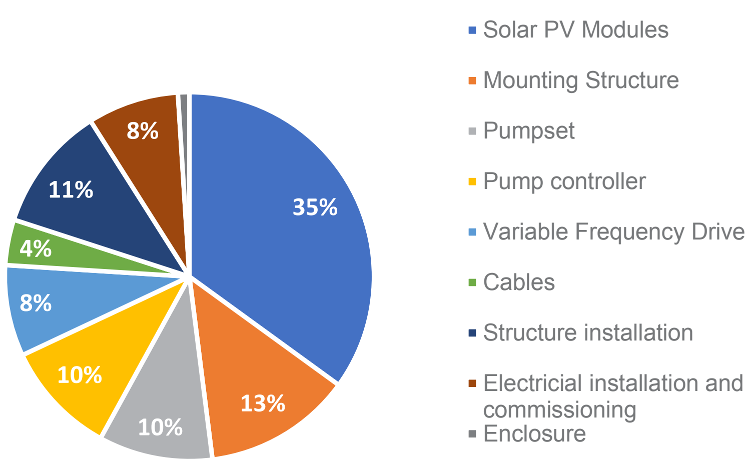
integrators procure panels, pumps, and other electronics and assemble the components together. Dealers who are appointed by system integrators execute installation, sales, and after-sales support (Figure 17).

FIGURE 15 *Components of an AC solar pump*



Source: (Ghosh, 2017)

FIGURE 16 *Break-up of cost of a 5 HP solar pump*



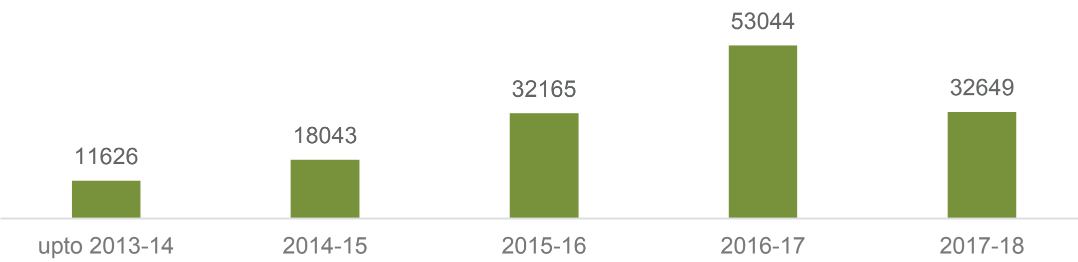
Source: (Ghosh, 2017)

***FIGURE 17** Value chain of solar pumps*

Source: (KPMG, 2014)

There are about 0.14 million solar pumps cumulatively installed in the country as on 31st December 2017 (Figure 18). In contrast, there are about 19 million electric pumps and 9 million diesel pumps in the country (Jain & Shahidi, 2018). Majority of the solar pumps have been deployed in three states – Rajasthan, Chhattisgarh, and Andhra Pradesh. While at present solar pumps constitute only 1% of the total agricultural pumps installed in the country they are expected to form around 6% of the total market by 2022.[25] The growth will be driven by the recently announced KUSUM programme, which aims to deploy around 2.75 million pumps in the country of which 1.75 million will be off-grid pumps. Details of the scheme are provided in the following section.

***FIGURE 18** Year-wise installation of solar pumps*



Source: MNRE Annual Report 2017-18

3.3.2 Market drivers

- Solar pumps have been given a boost by the recent policy initiatives of the government. Solar pumps are heavily subsidized and subsidies range from 40% to 90% across different states. With the KUSUM scheme in place, there is an increasing focus on grid-connected pumps.

[25] *It is assumed that 10% of the diesel pumps will be replaced by off-grid solar pumps under KUSUM scheme. Another 1.75 million solar pumps will be deployed by 2022*

***FIGURE 19** Agriculture pumps market (2018)*

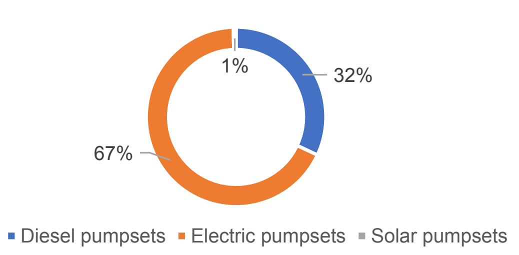


***FIGURE 20** Agriculture pumps market (2022)*

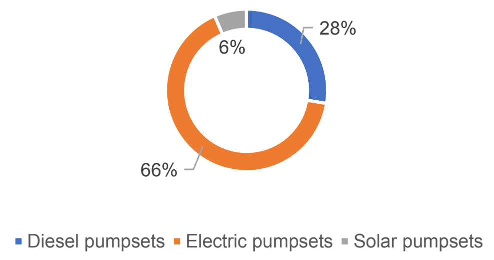
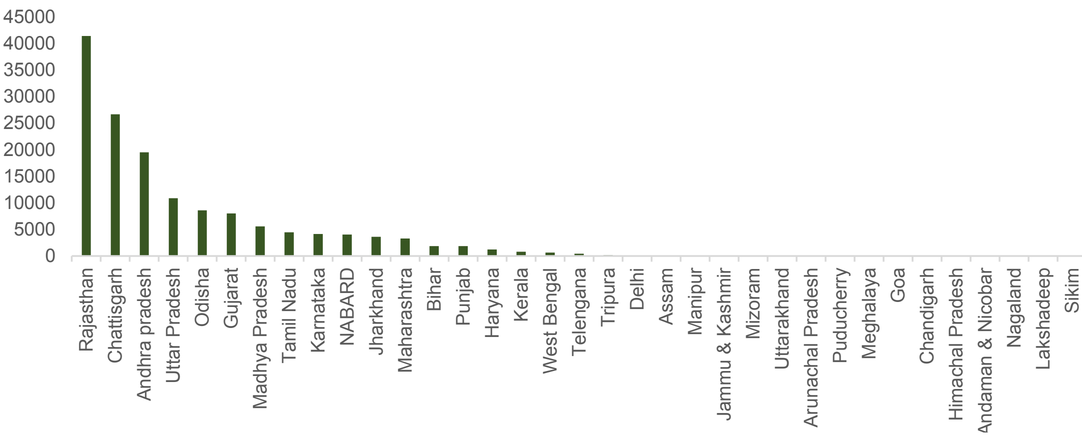


***FIGURE 21** State-wise installations of pumps (numbers)*



Source: MNRE Annual Report 2017-18

- The tender expected from International Solar Alliance for 500,000 solar pumps aggregating demand from India, Bangladesh, and Mauritius is also expected the drive the market further. (Climatescope, 2017)
- Monitoring, and communication systems are expected to make pumps more versatile (See case study 2).
- Income generation model under KUSUM scheme is also bound to increase the viability of systems.

3.3.3 Key challenges

The viability of solar pumps depends on a host of parameters, including depth of water table, type of crop irrigated, climatic conditions, water use efficiency, financing support, etc. Solar pumps are presently viable for farmers with subsidies and under specific conditions such as subsidies, multiple cropping patterns with remunerative crops (vegetables), and higher asset utilization (greater or equal to 200 days) (See Table 7).

TABLE 7 Payback period under different financing models

State	Financing mechanism	Farmer operational land holdings/ major crops grown	Average cost of solar pump (USD)	Price paid by user (USD)	Annual savings in energy costs per ha (USD)	Payback on subsidized system (Years)	Payback on unsubsidized system (Years)
Bihar	100% subsidy	8 ha (paddy, wheat, maize, lentils	2583	Irrigation charges of 9.5 per ha	102	0	19
Haryana	60% subsidy on total cost	8 ha (Paddy, wheat, vegetables)	2506	7366 per system (post subsidy)	132	4	11

Source: FAO, 2018

Discussion on different business models of solar pumps is provided in Chapter 4.

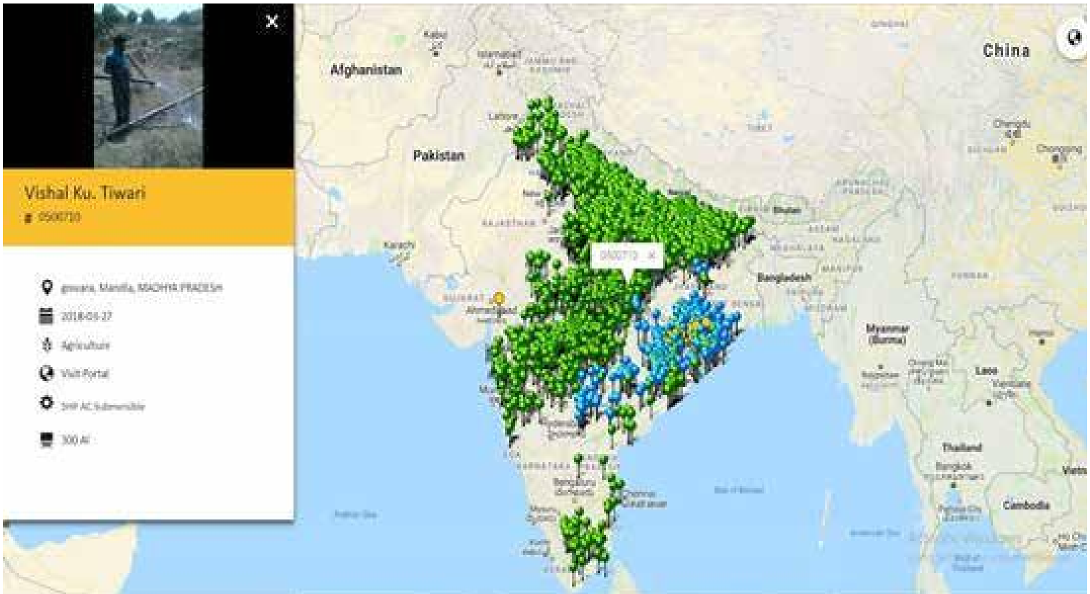
Case study 2: Claro Energy

Remote monitoring of pumps

Remote monitoring of solar pumps has been necessitated by MNRE for solar pumps in controllers or inverters either through an integral arrangement or through an externally fitted arrangement. Claro Energy, established in 2010, is a leading system integrator of solar pumps in India, providing purchase, financing, sourcing, installation, and maintenance of solar pumps. Claro Energy's pumps are installed with RMS (Remote Monitoring System), which provide live status of the pumps and are tracked through the data acquired through the field force management tool of Claro Energy. Farmer and live pump details/status can be seen just by selecting any pump in the interface. It provides details on Global Positioning System (GPS) coordinates, pump type (submersible/surface), pump capacity, energy consumed, land area irrigated, and CO_2 emissions off-set. The RMS helps in multiple ways:

- Live tracking of pumps
- Workforce management
- Supports and facilitates immediate maintenance and service network
- Data management

FIGURE 22 GPS monitoring of pumps – Claro Energy



Claro Energy©

BOX 6 Portable sub-HP pumps

Pumps of below 1 HP capacity, which are cycle- or trolley-mounted, are making a mark in rural areas. Investment required to acquire them INR 30,000–40,000 as compared to conventional 5–8 HP pumps.

- Lighter, portable, can be carried at the back or cycle to serve several land parcels. Moreover, they are beneficial for women farmers as they are convenient to use.
- Water discharge rate is such that does not cause topsoil erosion.
- They can be run on domestic single-phase connections available far more easily than 3-phase high-tension connections needed for larger pumps.
- Applied for growing vegetables or flower crops yielding greater income per drop of water.
- They cause lower water depletion in aquifers as they operate on lower heads.

Tata Trusts ©

3.4. Clean cooking systems

3.4.1 Improved biomass cookstoves

Government programmes have driven Improved biomass cookstoves sector to a large extent. The number of cookstoves sold under the Unnat Chulha Abhiyan is given in Table 8. In terms of sales in the open market, around 1.7 lakh stoves were distributed in 2015/16 in India by two of the biggest manufacturers in India, as reported by Global Alliance on Clean Cookstoves (GACC).[26] A few enterprises highlighted that Goods and Services Tax levy of 12% and increase in steel as well as aluminium prices (10%–15%) over the past one year have impacted sales on the ground. Sales have also been impacted by the penetration of PMUY across several districts of India.

TABLE 8 Cookstoves distributed under Unnat Chulha Abhiyan

Unnat Chulha Abhiyan	No. of cookstoves distributed
Domestic cookstoves	36,940
Community cookstoves	849

Source: MNRE website

There are 22 cookstove manufacturers listed with MNRE whose models have been approved by them and there are several more in the unorganized sector (local artisans). However, in terms of scale, only 2–3 enterprises dominate the market.[27] Most of the cookstoves sold by the private sector enterprises in India are natural draft stoves primarily using traditional biomass fuels. A few enterprises in this segment are vertically integrated in the value chain, undertaking design, manufacturing, distribution, and after-sales service inhouse. For example, Envirofit has an inhouse manufacturing facility in Pune, India, which can manufacture about 15,000 cookstoves a month (Envirofit, 2015).

Some of the stove enterprises have shifted from a Business to Consumer (B2C) to a Business to Business (B2B) model owing to limited consumer demand and the high costs of customer acquisition. For instance, Envirofit, which started out with a B2C model, has shifted to a model whereby it sells cookstoves to various retailers including private companies, Micro Finance Institutions (MFIs), corporates under corporate social responsibility (CSR), and NGOs. Envirofit has partnered with Infosys to distribute 37,200 stoves in India under their CSR programme. It also partnered with GoI in 2017 to imple-

[26] *GACC did not undertake data collection in India for 2016/17 and 2017/18. In the last survey undertaken by CLEAN,1.2 lakh stoves were reported by members. Though this year only six CLEAN members responded to the survey and have reported cumulative sales of 6500–7000 stoves between 2015/16 and 2017/18.*

[27] *Interviews; CLEAN, 2017*

ment community/institutional stoves in schools under their mid-day meal programme. It has sold around 500, 000 cookstoves in India since 2010.The improved biomass cookstoves sector urgently requires policy attention, given that the sector has thrived largely because of government support. Induction cookstoves have been piloted by various agencies such as TERI and Tata Trusts in various states (Himachal Pradesh, Uttar Pradesh and Gujarat), however, at a much smaller scale and have not gained traction yet.

Supernova Technologies Private Limited - Natural Draft Smokeless Chulha
- Price - INR 1,700
- Thermal efficiency - 27%
- Fuel used - Cow dung, wood, pellets

Supernova Technologies Pvt Ltd ©

Nevertheless, there is a renewed focus on induction cookstoves as well as solar cooking technologies. GoI is aiming to promote induction cookstoves while increasing connections under Saubhagya programme (Mint, 2018). Induction cookstoves, which are often seen as "lifestyle products", are still considerably expensive (upfront costs[28]) and also have usability challenges where specific cookware is required for cooking. At the same time, pilots by distribution companies such Dharma Life indicate that with consumer financing options, people have the propensity to adopt induction stoves. It also reduces the cooking time drastically without effecting the taste and texture of food. Further, on a recurring expenditure basis, induction cookstoves are comparable with LPG (~INR 540 or USD 8.3 per month) (Patnaik and Tripathy, 2017).

Biogas plants are being implemented under government programmes and with support under Gobardhan and the new biogas programme, installations are expected to increase across states.

Case study 3: Mysore Zila Panchayat Mould model biogas plants

Deenbandhu biogas plants are approved models under the government programme and are being propagated in various states. However, increase in price of materials such as cement and sand, has resulted in escalation of cost of Deenbandhu plants. At present, the cost of a 2 m^3 Deenbandhu plant ranges from INR 30,000- 35,000 (USD 462-538). A Zila Panchayat engineer from Mysore, Murtaza Ali, has developed an innovative model

[28] *Induction cookstoves fall in the price range of INR 1,800-2,400.*

using a mould with mild steel. The intervention has (a) eliminated the need for bricks and sand, (b) reduced the construction time to 2 days as opposed to 6-8 weeks for Deenbandhu plants and (c) made the whole construction process easier and considerably faster. Further, masons are required to learn only to assemble and disassemble the steel moulds. This is in contrast to highly skilled masons required for construction of the traditional plants. At present, INR 15,000 (USD 231) is available as subsidy from central and state government. With this level of subsidy, mould model requires the farmers to bear only INR 7,500 (USD 115) and provide labour support during construction.

Mould model biogas plant (CLEAN©)

3.5 Productive and Institutional Applications of DRE

The market for productive applications of DRE has still not been tapped in India and there are immense opportunities in that segment. A snapshot of the potential in some of the livelihood sectors is given in Table 9. The case of solar charkhas for weaving is discussed in the section below. Various other DRE applications for livelihoods (particularly for Self-Help Groups) are discussed in the CLEAN publication, titled *Livelihoods for Self Help Groups through Solar Applications.*

TABLE 9 Potential for DRE in select livelihood sectors

Livelihood sector	Potential
Horticulture[1]	10 million tonnes of cold storage required
Dairy[2]	0.16 million dairy cooperative societies
Weaving[3]	1 million manual charkhas

Sources: 1 - Assocham, 2017; 2 - NDDB, 2018; 3 – Interview with Shakti Pumps

3.5.1 Solar Charkhas

There are about 1 million charkhas operational in India. Converting these manual charkhas to solar charkhas offers a great opportunity to enhance and improve livelihoods. Mahatma Gandhi Institute for Rural Industrialization (MGIRI), along with Khadi Village Industries Commission (KVIC), in India has been at the forefront of promoting solar charkhas. Solar charkhas have been designated as village industry by the Ministry of Small and Medium Enterprises. To promote charkhas on a large scale, ***Solar Charkha Mission*** was announced on 27th June 2018. The mission aims to create 50 'Solar charkha clusters' across the country and provide direct employment to 0.1 million persons. It aims to provide capital subsidy, interest subvention, and training support to spinners, weavers, and artisans (GoI, 2018). The details of the financial assistance are provided in the Annexure 7.

During MGIRI pilots, spinners working on regular charkha used to earn INR 30–40 (USD 0.4 - 0.6) per day. However, after adoption of solar charkhas, the daily wage of the spinners increased to more than INR 100 (USD 1.5) per solar charkha due to increase in productivity (Table 10). This translates to increase in incomes of more than 200% per month[29]. Usage of solar charkhas also improved the quality of the product, where the yarn is stronger than that obtained from the manual charkha; it was more uniform and freer from knots. The standard type is the 10-spindle charkha, while there are other variants available (16, 24, and 32 spindle charkhas). A 10-spindle charkha costs about INR 45,000 (USD 692).

TABLE 10 Solar charkha pilots in Tamil Nadu and Gujarat

S no.	Name of cluster	Hanks[30]	Average production/ day	Average working hours/ day	Projected hanks/8 hours	Total wages/ day (INR)
1	Karaikudi (Kandanur, Tamil Nadu)	30	28	5.07	44	132
2	Limbdi (Rajkot, Gujarat)	40	23	5.01	37	103

Source: MGIRI

[29] *Considering 22 working days in a month*

[30] *A hank is a coiled or wrapped unit of yarn*

***FIGURE 23** Solar charkha pilots*

At Karaikudi, Tamil Nadu — At Limbdi, Gujarat

MGIRI©

Case study 4: Bhartiya Khadi Gramodaya Sansthan

Empowering women through solar charkhas

Solar charkha mission has attempted to scale up the successful model of Bhartiya Harit Khadi Gramodaya Sansthan (BHKGS), which has implemented solar charkhas in Khanwan village, Bihar. BHKGS provides solar charkhas to women such that they can earn a monthly income of INR 6,000 (USD 92) while working at home. The distribution of raw material and collection of finished goods happens at their doorstep through a nearby 'Training-cum-Production Centre' (TPC), which is set up in the village (Figure 24). The TPC acts as a facilitator of training and production of value-added activities such as dyeing, printing, weaving, stitching, and embroidery. One spindle creates one job (e.g., one 10-spindle solar charkha provides jobs to 10 artisans). Apparel brand W has tied up with BHKGS to launch a new line of *Harit Khadi* products.

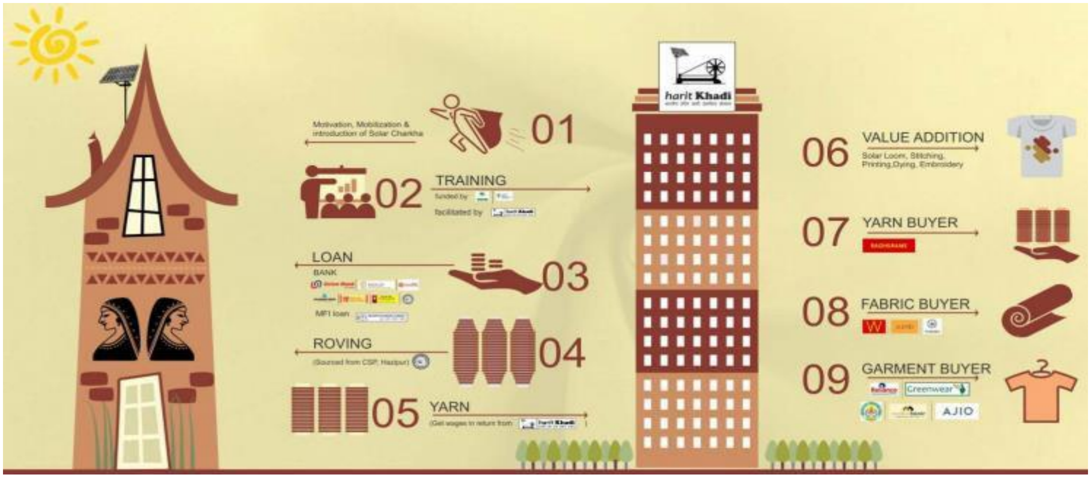
Women earning INR 6,000-10,000 (USD 92 – 154) per month

1012 women trained

3.5.2 DRE for institutions (Health Care)

Several states have started implementing solar PV rooftop solutions for electrifying their health-care facilities. For instance, Chhattisgarh Renewable Energy Development Agency (CREDA) installed off-grid PV systems in 570 out of 800 primary health centres (PHCs) in the state between 2012 and 2016. These systems were primarily connected to support critical functions when there was no constant supply of power. The success of this venture has led to similar initiatives in Maharashtra, Tripura, and Andhra Pradesh. Surat, in fact, became the first district in the country to have 100 percent solar-powered PHCs. Other innovative solutions such as mobile solar-powered health-care facilities are also being deployed. One such solution – 'Boat Clinic' – has been solarized by a CLEAN member, Eastern Envo in Assam (Case study 3).

***FIGURE 24** BHKGS solar charkha model*



Source: (NAWADA, 2018)

Case study 5: Eastern Envo

Solar-powered boat clinics

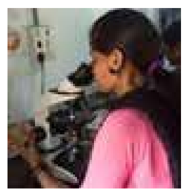
A vast network of shifting islands characterizes the River Brahmaputra, in its 891-km course through Assam in North East India. These islands are home to nearly 2.5 million people. People risk the weather and flooding rivers, and make long journeys in difficult terrains to get basic health services such as vaccination, mother and child care, medicines, and minor operations.

The Centre for North East Studies and Policy Research (C-NES), in partnership with the National Health Mission, Government of Assam, has been operating Boat Clinics providing primary health care to the remote island populace in the Brahmaputra since 2005. These boat clinics, and the equipment on them, were initially operated using diesel as the fuel. The use of diesel was highly polluting, expensive, and noisy, which made it difficult for doctors and medical practitioners on board to carry out their work.

In April 2017, with technical support from SELCO Foundation and Envo Business Solutions Pvt. Ltd, the first solar-powered boat clinic, named S. B. Nahor, was commissioned in Jorhat district of Assam. The boat's 5 kW solar system powers all the equipment on the boat that used to run on diesel earlier. This also means the boat itself has more diesel available to be able to stay on the river longer and thus serve more people. The boat has installed a refrigerator – doing away with the unreliable system of using ice – to store vaccines, speed up laboratory tests, and started making announcements via loudspeaker. Most importantly, it is now lit up at night. In the past year, S.B. Nahor has treated nearly 11,000 people, provided care to 600 pregnant women, and immunized 580 children living on the island. Till now, a total of four boats have been solarized. The cost of solarizing a large boat – as measured by its size and load requirement – is about INR 7 lakhs (USD 10,769) while that of a small boat is INR 5 lakhs (USD 7,692).

Retrofitting a boat with solar presents certain challenges. Panels and batteries add over 500 kg, which needs to be balanced across the span—this is more a concern for smaller boats than for larger ones. A water-proof space is needed for batteries, panel-mounting structures preferably made from aluminium to prevent rusting and sturdy enough to withstand high wind speeds. To reduce the size of the solar system, every watt makes a difference—low energy, high efficiency portable medical equipment will address these problems.

Refrigerator powered by solar energy



Solar poweted Boat clinic- S B Nahor Guwahati (Eastern Envo©)

Testing equipment

3.6 Impact

There are significant environmental and economic impacts that are generated from DRE systems. Table 11 provides the carbon emissions offset by each segment and the cumulative impact. In 2017/18, DRE systems enabled carbon emission offsets of 2,84,685 tonnes of CO_2. We also estimated that at least new 41,868 jobs were created in 2017/18 in the sector (Table 12). The methodology for estimation of GHG emissions offset and jobs has been provided in Annexure 4.

TABLE 11 GHG emissions offset in each DRE sub-segment

Technology	GHG emissions offset (tonnes of CO_2 per annum)
Off-grid solar	40,535
Solar pumps	1,69,775
Mini-grids	919
Biogas	73,456
Total	**2,84,685**

TABLE 12 Number of jobs created in each DRE sub-segment in 2017/18

Technology	Jobs
Off-grid solar	40,334
Solar pumps	457
Mini-grids	850
Biogas	227
Total	**41,868**

BOX 7

Impact created by energizing remote Himalayan communities

Global Himalayan Expedition (GHE): Energizing off-grid Himalayan communities

This is a unique initiative leveraging tourism and technology to provide energy access to remote off-grid Himalayan communities. Such villages are searched through contacts and word of mouth due to lack of any database or survey owing to remoteness and inaccessibility and un-motorable roads. The team from GHE treks for 5–6 days to reach such villages, educate communities, and get their buy-in for provision of electricity from solar DC micro-grid. A committee is formed for the upkeep and maintenance of the micro-grid. Each villager contributes a monthly rental, which is deposited in a joint account opened by the villagers. The capital cost of micro-grids is supported by CSR funds and grants while the community contribution is utilized for the operation and maintenance of the micro-grids. Electrification has resulted in additional income through homestays and sale of Pashmina and other woollen artefacts. It has also enabled digital education in the village for children. Villages that were electrified in 2014 are witnessing a surge in demand for higher levels of access, where people have bought TVs through income generation from sale of woollens and homestays.

Impact created by GHE ***(Bansal, 2017)***

- Overall 20,000 lives impacted
- 500 tonnes of CO_2 eliminated
- 20 women entrepreneurs
- 1,500 student lives impacted

1500-year-old village electrified in Ladakh (Global Himalayan Expedition©)

Grid material transportation in Ladakh (Global Himalayan Expedition©)

CHAPTER

4 Policy Framework

4 Policy Framework for DRE

The policy framework for DRE has witnessed several changes over the past few years. Figure 25 showcases the policy developments, which have impacted the DRE sector over the past five years. In 2010, when the government announced the National Solar Mission, the targets also included off-grid and solar thermal. The off-grid solar was allocated a target of 2 GW by 2022, i.e., 10% of the 20 GW allocated to grid-connected solar power plants. The government through Deen Dayal Upadhyay Grameen Jyoti Yojana (DDUGJY) electrified all the villages and through Saubhagya it plans to electrify all the un-electrified households. However, in 2014, when the targets were ramped up to 100 GW, off-grid solar did not see a mention in the revised targets.

Recently, solar pumps, have seen a favourable policy environment as compared to all other DRE segments with the announcement of the KUSUM Scheme. Recently, the government also announced some schemes for productive applications such as solar charkhas and solar power looms. Similarly, policies such as draft national policy on mini-grids and revival of micro/mini grids and draft national small hydro mission[31] can be also be taken up on priority. In addition to these, schemes are also required for improved biomass cook-stoves.

It is notable a few state governments have taken initiatives and laid down a policy framework for DRE. Energy storage forms a major component of energy access systems like micro grid or solar home lighting systems. Government can capitalise on decreasing prices of storage globally, can formulate more conducive policies. The CFA earlier provided to entrepreneurs to set up micro/mini grids may be continued to improve the viability.

Key policy updates for each specific sub-segment have been briefly described below.

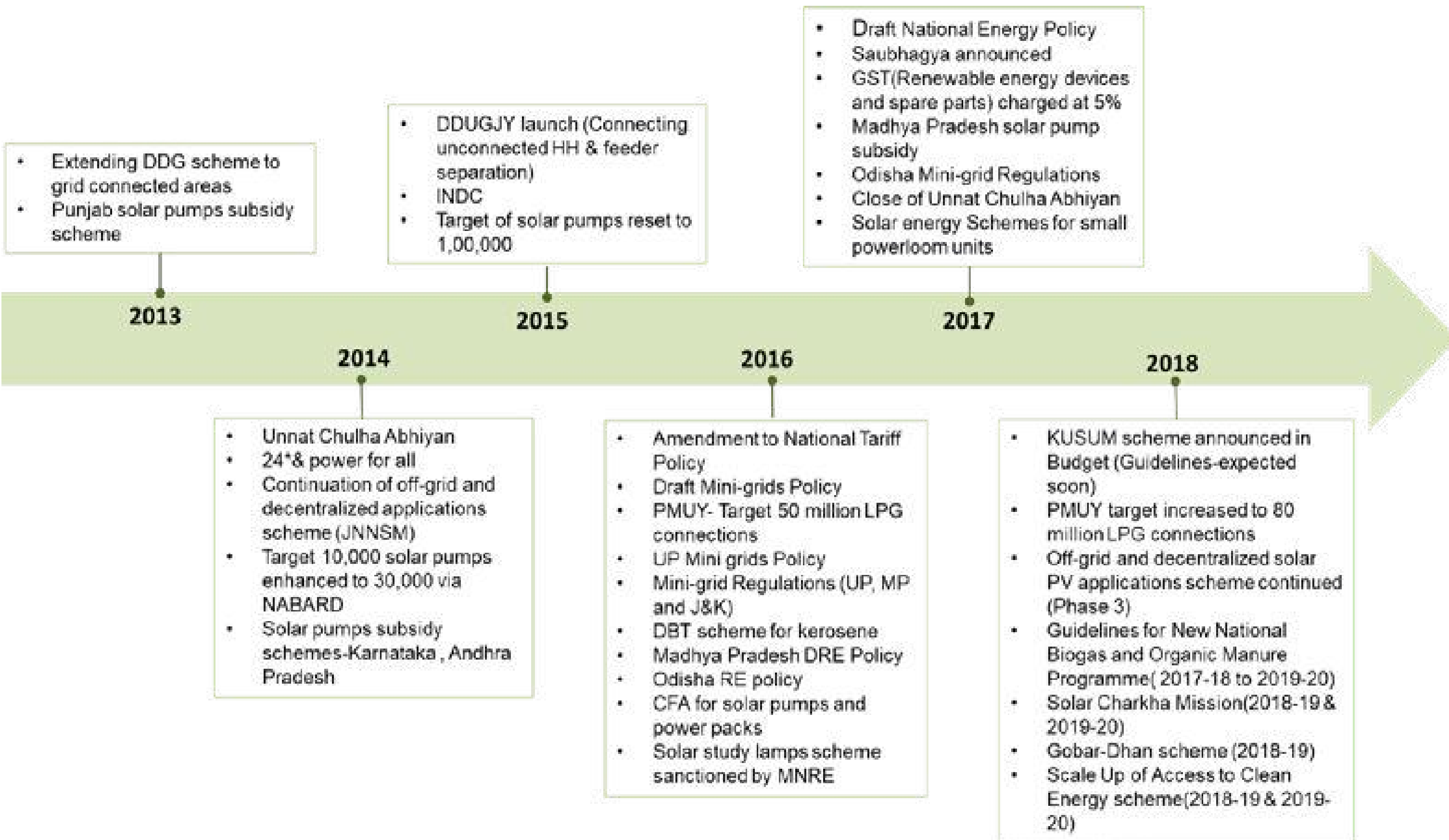
4.1 Policies and government programmes: updates

4.1.1 Off-grid solar

The Cabinet Committee on Economic Affairs, GoI, has provided approval for implementing off-grid and decentralized PV applications programme (Phase III), setting a target of 118 MWp capacity by 2020. Residential lighting (under off-grid solar home lighting) has been discontinued for provision of subsidy support. The focus of the current scheme is primarily on community institutions. The total project cost of the

[31] *The mission has been dropped. The capacity addition in SHP has been on the decline since 2014/15 viz. 252 MW, 219 MW and 106 MW in 2014/15, 2015/16, and 2016/17, respectively (GoI. (2018 b).*

FIGURE 25 *Key policy developments impacting DRE sector in India (2013–18)*



programme is INR 1,895 crores (USD 292 million), of which INR 637 crores (USD 98 million) will be available as CFA. Table 13 provides the details of the scheme. The benchmark costs[32] for the off-grid solar including pumps, solar lighting systems, and standalone solar power plants were announced by MNRE in 2018. Details are provided in Annexure 2.

TABLE 13 Details of off-grid and decentralized PV applications programme (Phase III)

Type of application	Target	Subsidy	Focus areas
Solar streetlights	0.3 million	30% of benchmark cost; 90% in North-Eastern states	North-Eastern states, Left Wing Extremism (LWE) affected districts, areas with no grid power
Stand-alone solar power plants	Individual size – (up to) 25 kWp Cumulative capacity - 100 MWp	30% of benchmark cost; 90% in North-Eastern states	Unelectrified, under-electrified regions. Mainly for schools, hostels, panchayats, police stations, and other public service institutions.
Solar study lamps	2.5 million	15% of lamp cost to be borne by user; 85% subsidy to be provided by the state government	Schools in North-Eastern and LWE-affected districts

Source: (MNRE, 2018)

BOX 8

Seven million solar lamps scheme

One million solar study lamps programme implemented by IIT Bombay in 2014–16 is currently being upscaled through the 7 million solar lamps scheme launched in 2017. It will cover five states – Assam, Bihar, Jharkhand, Odisha, and Uttar Pradesh. All enrolled school students (Class 1 to Class 12) in the intervention blocks will have an opportunity to buy the solar lamp at a discounted price of INR 100 (USD 1.5) per lamp. IIT Bombay is the central agency for overall coordination, strategizing, and implementation, while Energy Efficiency Services Limited (EESL) is responsible for procuring and providing the lamp kits, spares, etc. in the intervention blocks.

Saur Energy ©

[32] *Benchmark costs for various technologies are standardized capital costs for providing subsidies to the end users.*

BOX 9

Discontinuation of Akshay Urja Shops Programme

MNRE has discontinued the Akshay Urja Shops with effect from June 2017. The programme supported the establishment of at least one shop per district for selling subsidized solar-powered technologies and providing easy after-sales service. The closure comes in light of the fact that there were issues such as lack of in-home service, increasing competition from the grid, and many of these shops were reported to be facing survival issues.

BOX 10

Safeguard duty on solar cells and modules with effect from 2018

Imposition of 25% safeguard duty on solar cells and modules

A safeguard duty of 25% on solar cells and modules imported from China and Malaysia imposed by the Ministry of Finance was supposed to come into effect from 30th July 2018. As per the notification issued by the Ministry of Finance, a 25% safeguard duty has been imposed between 30th July 2018 and 29th July 2019. It will gradually come down to 20% between 30th July 2019 and 29th January 2020, and 15% from 30th January 2020 to 29th July 2020. GoI has temporarily suspended the 25% duty in response to the opposition from solar project developers. While this duty will have a definite impact on utility-scale projects, in the off-grid sector, as reported by industry players, this import duty would not be levied on panels that were a part of the product packaging as the import duty is applicable only on the panel's Harmonized System of Nomenclature (HSN) codes. However, the levy will adversely impact component-based sales in India.

4.1.2 Solar pumps

The deployment of solar pumps in India is backed by policy push provided by the central and state governments. About 13 states in India provide subsidies for solar pumps ranging from 60% to 90%. (Details provided in Annexure 6.) More recently, a new scheme for the promotion of solar pumps ***Kisan Urja Suraksha Evam Utthaan Mahaabhiyan (KUSUM)*** was launched in the Union Budget 2018/19. Table 14 provides the salient features of the scheme. The official guidelines of the scheme providing details of funds and mode of implementation are expected to be announced shortly.

State-level schemes

Maharashtra has launched a scheme for solarization of agricultural feeders in 2018, while Karnataka has net metering scheme for grid connected solar pumps. Following Karnataka, Gujarat has also launched a scheme for grid-connected solar pumps in June 2018. Table 15 provides the key features of the schemes.

TABLE 14 Salient features of KUSUM scheme announced in Union Budget 2018

Salient features	Target	Financial assistance
1. Installation of grid-connected solar power plants each of capacity up to 2 MW in the rural areas	1 million grid-connected pumps	Total cost of scheme - INR 1.4 lakh crore (USD 22 billion)
2. Installation of standalone off-grid solar water pumps to fulfil irrigation needs of farmers not connected to grid 3. Solarization of existing grid-connected agriculture pumps to make farmers independent of grid supply and also enable them to sell surplus solar power generated to DISCOM and get extra income	1.75 million standalone pumps **Total – 2.75 million solar pumps**	Financial assistance from MNRE - INR 48,000 crores (USD 7.4 billion) Capital subsidy - 60% shared equally by Centre and State Government - 30% financing through bank - 10% to be borne by farmer
4. Solarization of tube-wells and lift irrigation projects of Government sector.		

Source: (The Economic Times, 2018)

TABLE 15 State solar pumps schemes – Karnataka and Maharashtra

State	Highlights
Maharashtra Chief Minister's Solar Agriculture Feeder Policy (Saur Krushi Vahini Yojana)[1]	• Procurement of power from 2 MW to 10 MW capacity solar projects totalling 1000 MW • To provide uninterrupted 8 hours supply to farmers through dedicated agricultural feeders • State Govt's revenue land near substations where projects are feasible will be leased to the generation utility, Mahagenco for a period of 30 years. Farmers can also lease their land for such projects. • Developers to be selected through a transparent competitive bidding process
Karnataka Surya Raitha Yojana[2]	• Applicable to pumps of up to 10 HP rating • Farmers can set up an onsite solar installation, under the net-metering scheme, and would be compensated for excess energy pumped into the grid • Scheme financed by the Government of Karnataka, MNRE, farmer's upfront investment and interest-free loan from BESCOM

[1] Source: (India Filings, n.d.) , [2] Source: (KREDL, 2014)

4.1.3 Mini-grids

The framework conditions for deployment of mini-grids were laid down in the Amendment to National Tariff Policy in 2016. It stipulates that an appropriate regulatory framework should be put in place to mandate compulsory purchase of surplus power generated by the mini-grid into the national grid. A fillip was provided to the segment with the issuance of the Draft National Mini-grids Policy in June 2016; however, it has not been finalized so far. Further, mini-grids have not been considered for CFA in 2017/18 and 2018/19.

State Policies and Regulations

Uttar Pradesh: Leading progress

Uttar Pradesh was the first state in India to bring forth a Mini-grids Policy in 2016. The policy provides for two kinds of options to developers – with and without state government subsidy (to the tune of 30%). Projects with subsidy will have to charge INR 60 per month for a load of 50 W, INR 120 for a load of 100 W, and beyond 100 W, the tariff will be on mutual consent between consumer and developer. Further, those availing state subsidy will operate in areas notified by the SNA.

Projects without subsidy, on the other hand, can charge tariffs based on mutual consent. A number of incentives have also been provided to the developers in terms of exemption from stamp duty, exemption from electricity duty, reimbursement of land conversion fees, interest subvention, etc. The mini-grid regulations of the state also highlight different business models and exit options for the mini-grid in case grid arrives in their areas of operations. Uttar Pradesh is also progressive in terms of bringing better clarity for operations of mini-grids by developing technical guidelines, implementation guidelines, and also developing the model documents for Power Purchase Agreement (PPA) and Distribution Franchisee Agreement (DFA).[33] It is understood that these guidelines are under development.

Other States

Following Uttar Pradesh, a few other states have brought forth state-specific policies and regulations for mini-grids (Figure 26). One of the main objectives of the policies and regulations has been to ensure the sustainability of the micro-grid upon the arrival of discom grid. As of June 2018, there is no grid-interactive mini-grid yet in India. In Uttar Pradesh, pilot projects for grid-interactivity have been identified for mini-grids operated by OMC and TaraUrja. Discussions with regulatory commission and discoms are under way to pilot-test these projects.

The policies and regulations outline various business models possible for an ESCO (See Chapter 4). Most of the mini-grid regulations of other states are similar to UP Regulations. Madhya Pradesh has a slightly different model upon grid arrival. The entire power

[33] *Shakti Sustainable Energy Foundation is supporting UPERC in framing Technical Guidelines and DFA, which are currently under development. Inputs from Shakti Foundation.*

is sold to the discom and the ESCO becomes only a distribution franchisee by selling its assets to discom.

Bihar has set target of 100 MW for mini-grids in unserved and under-served areas. The cap on individual project capacity is 500 kW. All the projects whether availing state subsidy or without subsidy will operate on Build Own Operate Maintain (BOOM) mode.

FIGURE 26 *States with Mini-grid Policies and Regulations*

1 Odisha and Bihar have RE policies which have provisions for mini grids

2 Bihar and Odisha have formulated draft regulations for mini grids

4.1.4 Clean cooking

Since the close of Unnat Chulha Abhiyan in 2017, there have been no new programmes or schemes announced for improved biomass cookstoves in India. The Draft National Energy Policy, 2017 mentioned launching a National Mission on Clean Cooking, to promote efficient biomass cookstoves and induction cooktops. Further, as per recent media reports[34], the government is planning to distribute induction cookstoves in a large scale with the progress of Saubhagya. Recently, Oil and Natural Gas Corporation (ONGC) and Startup India launched a competition to create a "Solar Chulha" meeting a set of criteria[35]. IIT Bombay was selected as the winner, which has developed a solar PV cook-stove that works on the principle of induction. The cook-stove has been designed to provide 3 units of electricity every day, sufficient for cooking three meals daily for a family of five members. The cook-stove has two induction cook-tops and a back-up time of 1 day from batteries. The cook stove is designed to work on 48V DC which is safe to operate.

[34] *https://www.livemint.com/Politics/oIEugpSDg9MPh5BPucxVIP/After-Saubhagya-govt-plans-induction-stoves-for-the-poor.html, last accessed on 29th August 2018*

[35] *1) Cooks both at night and during the day 2) Can be used for all cooking processes (boiling, steaming, frying) 3) Is safe and easy to use 4) Is built with materials that are available easily and can be disposed of safely 5) can be mass produced to achieve good quality control and economies of scale, and 6) can be used independently or in conjunction with some power from the grid*

New programmes for deployment of biogas plants have also been launched, details of which are given below.

New National Biogas and Organic Manure Programme (2017/18 to 2019/20) (MNRE, 2018)

New National Biogas and Organic Manure Programme (NNBOMP) is a continuation scheme of the earlier biogas programme and is effective from 1st April 2018. The programme aims to implement at least 0.25 million biogas plants equivalent to generation of about 8.40 lakh cubic metre (m^3) of biogas per day by the end of 2019/20 of capacity ranging from 1 m^3 to 25 m^3 per day. It mainly aims to provide clean cooking fuel for kitchens, lighting, and meeting other thermal and small power needs of farmers and individual households. The CFA for biogas plants sized 1–25 m^3 per day ranges from INR 7,500 to INR 35,000 (USD 115 – USD 538) depending on the state category. There is additional subsidy of INR 1,600 (USD 25) per day for cattle dung-based biogas plants if linked with sanitary toilets (only for individual households). This scheme will also provide support for communication and publicity, training courses, setting up biogas development and training centres, incentive for saving fossil fuels.

Gobardhan Yojana

GOBAR (Galvanizing Organic Bio-Agro Resources) - DHAN scheme launched in April 2018 aims to improve village cleanliness and generate wealth and energy from cattle and organic waste. The scheme envisages the implementation of 700 biogas units in different states of the country in 2018/19. The programme will be funded under the solid liquid waste management component Swachh Bharat Mission. The total assistance for projects is on the basis of total number of households in each Gram Panchayat. Funding will be provided by the Central and State Government in the ratio of 60:40. The programme recommends four models of operation and provides different incentives depending on the type of model – (1) Gram Panchayat, (2) SHG Federation, (3) Entrepreneur, and (4) any eligible enterprise

TABLE 16 Funding assistance for biogas plants under Gobardhan

No. of households in Gram Panchayat	Maximum funding
150	INR 7 lakhs (USD 10,769)
300	INR 12 lakhs (USD 18,462)
500	INR 15 lakhs (USD 23,077)
> 500	INR 20 lakhs (USD 30,769)

Source: GoI, 2018 a

4.1.5 Productive applications

MNRE has initiated a scheme for productive uses of DRE in Assam, Odisha, and Madhya Pradesh known as ***Scale up of Access to Clean Energy Scheme***. The scheme will be operational in 2018/19 and 2019/20. It aims to provide thrust in poultry, horticulture, fisheries, dairy, biomass-based local business and cottage industries through DRE-based applications such as solar dryers, solar PV bulk milk chilling units, and biogas plants based on poultry litter among others. The project has four key components and will be implemented by inviting tenders.

1. Develop key RE-based rural applications
2. Develop supply chain of RE technology providers
3. Policy and regulatory support for RE-based rural livelihoods
4. Financial support

Subsidy to the tune of 30% of benchmark cost or tender cost (whichever is lower) will be provided to the project developer. It aims to support 30,000 rural enterprises using renewable energy in three states namely, Assam, Madhya Pradesh and Orissa.

In addition to this scheme, there are schemes for solar charkhas and solar looms, which aim at income generation through subsidizing DRE applications. However, there are many other productive applications at different scales of maturity and require support (e.g., knapsack sprayer, roti rolling machines etc.)

4.2 Technical, performance standards, and specifications for DRE in India

Standards can be categorized into quality and performance standards. Quality standards set a baseline level of quality that needs to be met by an off-grid device or a system. For instance, Lighting Global quality standards for off-grid solar products cover aspects such as quality, durability, truth in advertising, lumen, maintenance, and warranty to protect consumers. Performance standards detail out how a component or components together should perform, for example, what should the lux-lumen output be in the case of off-grid solar products. For cook-stoves, it is based on thermal efficiency, CO and CO_2, and particulate matter emissions, etc. It is necessary that quality standards are harmonized with performance standards under local climatic conditions and over the life of product. In India, systems and system components for off-grid products and systems are required to conform to International Electrotechnical Standards (IEC) or Bureau of Indian Standards (BIS). There are standards defined for system components and (light emitting diode [LED] bulbs, solar panels, pumps, etc.) and integrated systems (off-grid

TABLE 17 Summary of policy environment for DRE

Segment	Current outlook	Policy environment
Off-grid solar	• Residential lighting has been left out from the current scheme on off-grid for subsidy allocation • Imposition of safeguard duty of 25% on solar panels is expected to negatively impact the sector	Marginally favourable
Solar pumps	• State specific programmes on solar pumps with high capital subsidies makes the segment attractive for investors • Launch of KUSUM has provided fillip to the segment	Highly favourable
Micro and mini-grids	• Draft National Mini-grids policy stalled, though a few states have come out with mini-grid regulations. • Mini-grids have not been considered for CFA	Neither favourable nor unfavourable
Clean cooking	• PMUY has shifted the focus to LPG • New Biogas programme and Gobardhan Yojana expected to increase deployment of clean cooking systems • Increasing focus on induction and solar PV based cookstoves • No new schemes for improved biomass cookstoves	Moderately favourable
Productive applications	• New scheme for productive applications launched by MNRE for 2018/19 and 2019/20 for three states in select livelihood sectors • Solar Charkha Mission announced with incentives such as capital subsidy and interest subvention • Solar looms scheme provides capital subsidies	Marginally favourable

Source: CLEAN Analysis

power packs, solar pumps, etc.). The relevant technical standards for off-grid systems are given in Annexure 8.

Despite existing national and international performance standards, many off-grid product manufacturers and system integrators in India face several challenges as discussed below.

- **Clarity on Solar Photovoltaics, Systems, Devices and Components Goods (Requirements for Compulsory Registration) Order, 2017:** This order was issued by the Central Government to ensure entry of only quality verified solar PV systems and components into India. However, based on feedback from CLEAN members, it is understood that the standards mentioned in the said order appear to be applicable to larger sized systems and components and not to smaller category of decentralized solar lighting products (less than 50 W module capacity). The specified order states that PV panels need to adhere to the IS 14286: 2010, IS 16077: 2013 or IS/IEC 61730 standards, which are meant for cells and modules of larger size. These standards are not meant to test smaller PV modules, which manufacturers use for small decentralized solar lighting products. Additionally, the IS 16270 standard for batteries does not cover lithium-based batteries.

- **Testing procedure of solar pumps:** In an office memorandum issued by MNRE (MNRE, 2018 a) for testing procedure of solar water pumps, it is specified that the test certificate should be in the name of the manufacturer or system integrator who participates in the bidding process. The procedure is found to be cumbersome, when multiple players have to test the same configuration to participate in the tender; for instance, a system integrator who has procured the same configuration of a pump from a solar pump manufacturer who already has the test certificate for that configuration/specifications of the pump.
- **Standards set for improved biomass cookstoves are not reflective of field conditions:** At present, there is no protocol designed for chimney-based stove. The BIS (draft) standards for Portable Solid Bio-Mass Cookstove (Chulha) Part 1 [First revision of 13152(Part 1):1991] was designed on one single chulha and was not representative of many chulhas, which existed at that point of time. Similarly, the Water Boiling Test (WBT) is also not a criterion to judge the performance of the stove as the stove may be 'perfect' while boiling water but may not be best for cooking a staple food. Regional-level tests have to be designed for stoves, which are presently lacking.
- **Testing of Tier 4 pellet based improved biomass cookstoves:** As highlighted by GACC, there is a need for functional standards and testing centres which conform with the global ISO lab standards in India, so that in country certification of Tier 4 cookstoves is made possible. Tier 4 stoves have the lowest emissions and highest performance as per the International Workshop Agreement (IWA 11:2012). The first international standard for lab testing of cookstoves has been published in June 2018 which has replaced ISO International Workshop Agreement from 2012.

CHAPTER

5 Business Models and Financing

5 Business Models

Business models in the sector have evolved and are expected to get refined further with the extension of grid and integration of DRE systems with the grid. This chapter discusses various business models in some key DRE segments such as mini-grids and solar pumps which have witnessed changes over the last one year.

5.1 Micro and Mini-grids

5.1.1 Operational models

Current scenario

Build Own Operate Maintain (BOOM) model is the most prevalent model of mini-grid deployment in India. Most ESCOs serve community load including a mix of domestic and productive loads that comprise shops, micro enterprises, agriculture pumps, petrol pumps, etc. The other model is where bulk of their power supply is to telecom towers who are called 'anchor' clients. OMC is in fact the first mini-grid to propagate the ABC model (Anchor-Business-Consumer model). A classification of different mini-grid business models is provided in Annexure 8. Mini-grids are found to be financially viable, only above a certain threshold of demand – pegged at 40 kWp[36]. Further, financially viable ESCOs are ones who have a payback period of 8-10 years and project returns of 10% or more over their lifetimes[37]. The operational performance of ESCOs has increased over the last two years[38] in terms of increase in operating margins (35%-non-anchor plants, 49%- anchor plants). There has also been reduction in operating costs as well as increase in consumption of electricity in the communities served.

Focus on productive and commercial loads

Mini-grids set up by private developers are increasingly focusing on serving commercial and productive loads for financial viability in addition to servicing domestic consumers. For instance, several of the ESCOs supported by SPI have seen the growth of micro-enterprises in the areas served by them, in terms of quantity, type, and scale. SPI has supported 7 ESCOs serving 6,000 households and 3,000 small businesses. Enterprises supported by such ESCOs have reported an average increase of 13% in their monthly revenues (Sambodhi, 2017).

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[36] *Smart Power India, 2017, Expanding Opportunities for Renewable Energy based Mini-Grids in Rural India*

[37] *ESCOs financed by SPI are seen to have payback periods ranging from 7-9 years*

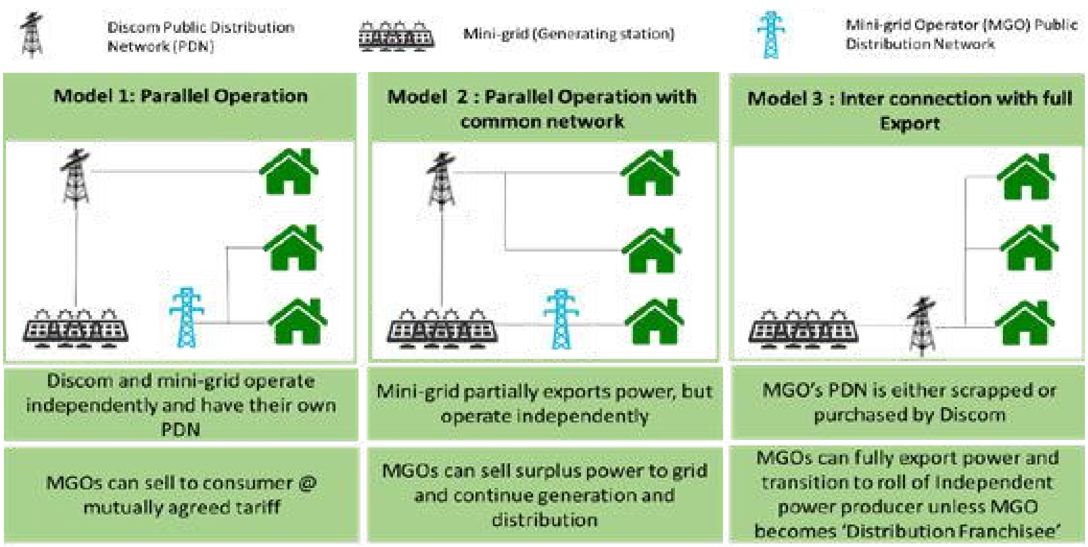
[38] *2016 and 2017*

Going forward, ESCOs will continue to focus on adding new segments of productive loads, improving operations (pruning costs such as manpower and fuel costs (in case of solar diesel hybrids), increasing hook-up rates and improving services (providing energy efficient DC appliance), customer management and monitoring through smart metering systems.

Future scenario

With government's plans of extended electrification of all areas, business models of mini-grids will undergo a change. The policies at the state level have explicitly recognized the possibility of grid extending to the current areas where mini-grids are operational and have provided for different options for migration. For instance, the Uttar Pradesh (UP) Mini-grid Regulations provide the following three options (Figure 27).

FIGURE 27 *Business models under UP Mini-grid Regulations, 2016*



CLEAN©

The UP Mini-grid Regulations outline business models for two scenarios: (1) Grid pre-exists and (2) Grid eventually arrives. Both these scenarios allow the ESCO to migrate to any of the options listed above. These models include options ranging from operating in isolated mode to becoming a distribution franchisee of the discom. The last two models broadly follow the construct of Public- Private-Partnerships, ranging from simple options of power purchase by discom to ESCOs becoming distribution franchisees or micro-utilities having a formal agreement with the former. Though these options have been formulated, there is a lack of clarity on the commercial arrangements for grid interactivity. Once a mini-grid interconnects with the main grid, it will be subject to regulatory purview and hence the tariffs charged by the ESCO and feed-in-tariff for an ESCO will be determined by regulatory commission.

Following are the main areas that still require clarity.

- **Feed-in-tariff to the ESCO:** The feed-in-tariff to the ESCO should be such that it justifies the cost of generation and the cost of interconnection to the grid. The cost of generation is significantly higher for mini-grids as the costs include distribution infrastructure and operational costs. It is a concern among many ESCOs that feed-in-tariff may be decided based on other solar/biomass generators operating in the region or average power purchase cost, both of which may not be financially viable for a discom. (Bhati & Singh, 2018)
- **Islanding:** Mini-grids serving in load-shedding-prone areas should be able to continue supply to its customers (islanding). However, the CEA (Technical Standards for connectivity of the Distributed Generation Resources) Regulations, 2013, do not specifically address this (Okapi, 2017).

Given there are no grid-connected models as yet, and no proof of concept exists, there is a need for detailed technical and implementation guidelines, which provide greater clarity on the roles, responsibilities, and processes related to grid interconnection. Shakti Sustainable Energy Foundation is pilot testing some models for grid interactivity in Uttar Pradesh, the lessons of which will be useful in understanding and redefining aspects of grid interconnection.

5.1.2 Mini-grids under government programmes

Mini-grids under government programmes have been installed under the Decentralized Distributed Generation (DDG) programme of Deen Dayal Upadhyay Gram Jyoti Yojana (DDUGJY) and other programmes of the states. Uttar Pradesh, for instance, has 16 mini-grids set up by the state nodal agency all of which are above 30 kWp. The biggest mini-grid set up by UPNEDA is 250 kWp in Kannauj, which supplies electricity to about 350 consumers round the clock.

As per MNRE data, solar PV mini-grids of aggregate capacity of 1.9 MW have been installed in India, which have availed support from MNRE.[39] Further, under the Saubhagya scheme, while mini-grids have not been explicitly stated for electrification of remote communities, states like Chhattisgarh and Bihar have sought approvals for installing mini-

39 *Lok Sabha Unstarred Question number 2124 : Access to Solar Microgrids*

BOX 11

Conditions for mini-grids under Saubhagya

- Cost per household shall not exceed cost for standalone systems – INR 50,000 (USD 769) per set
- Equipment used under standalone systems (5 LEDs, 1 DC fan, DC power plug and provision for mobile charging) shall be provided to beneficiaries of mini-grids
- System shall be operated and maintained by developer for a period of 5 years
- Electrification through off-grid applicable for only villages which are electrified through standalone/mini-grid

grids for remote communities. The Monitoring Committee of Saubhagya has approved installation of mini-grids for remote communities, subject to certain conditions (Box 11).[40]

5.2 Solar Pumps

On a broader level, solar pumps can be configured as either off-grid and grid-connected. Apart from irrigating their own fields, farmers can also sell water to other farmers in lieu of a fee. Majority of solar pumps in India presently are standalone, however, with the launch of the KUSUM scheme, the emphasis is on grid-connected solar pumps. In the grid-connected model, the farmer sells the surplus electricity to the grid at a pre-determined Feed-in-Tariff (FiT). This model has been piloted in Dhundi village of Gujarat (Case study 6). The Energy Efficiency Services Limited (EESL), a joint venture company of the Ministry of Power and the Government of India, has also tendered for 300 MW of solar for installing grid-connected pumps. The power generated will be utilized to power 20,000 agricultural pumps in Uttar Pradesh and Andhra Pradesh.

In addition to these models, an emerging model of solarization of agriculture feeders to provide electricity for irrigation is being piloted.

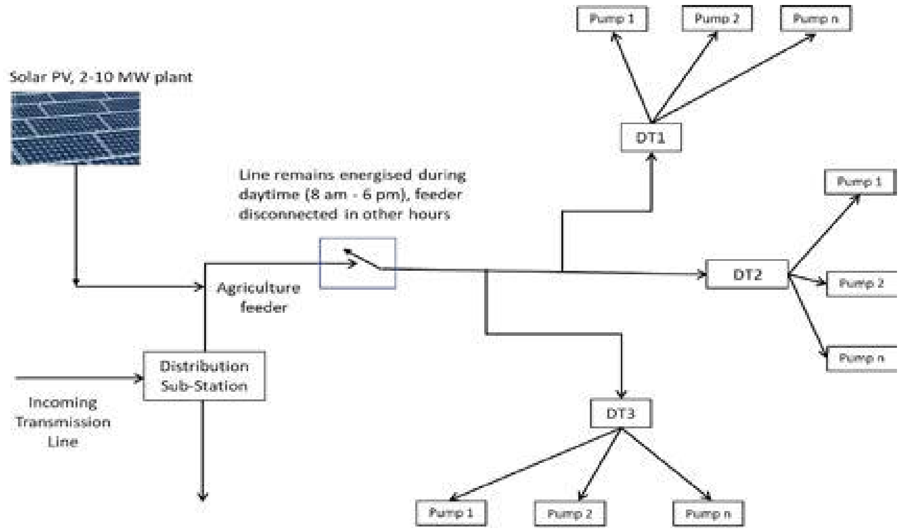
Maharashtra Solar Feeder Model

Under this model, tail-end grid connected MW scale solar PV projects of size (2-10 MWs) will be connected to be the 11/33 kV sub-stations and the power would be supplied to separated agriculture feeders (See Figure 28).

Two pilot projects in Ahmednagar and Yavatmal districts have been successfully undertaken. Projects would be either implemented by Maharashtra State Power Generation Company Ltd (MSPGCL) or Maharashtra State Electricity Distribution Company Ltd (MSEDCL) whereas developers would be selected through a competitive bidding route

[40] *Government of India, 2018*

***FIGURE 28** Solarized feeder model*



DT-Distribution Transformer
Source: (Gambhir, 2018)

with a ceiling tariff of INR 3.15-3.3 per kWh (USD 0.05/kWh). Regulatory approval for tendering as well as changing the agriculture supply timing to such feeders for 8 hours between 8 am – 6 pm has been obtained. The solar feeder approach is significantly more cost effective than conventional grid supply (due to rising power procurement costs) as well as in comparison to standalone off-grid solar pumps (Refer to analysis given in Table 18, Table 19 and Table 20 below).

In addition, the solar feeder approach requires no subsidies from the government and can be rapidly scaled across states within the existing regulatory framework while additionally qualifying for the discoms RPO. Further, it requires no behavioral changes or undertakings by the farmers and ensures reliable day-time power for agriculture.

TABLE 18 Comparison of grid connected electricity pumps and solarized feeder model -Assumptions

One 11 kV feeder	Assumptions
No. of pumps connected	500
Average capacity of pump	5 HP
Operating hours per year	1250
Losses (11 kV+ LT line)	4.5%
Discount rate	10%
Annual escalation	1%
Calculated annual feeder input	2.471 million units (MU)

Source: (Gambhir, 2018)

TABLE 19 Comparison of grid connected electricity pumps and solarized feeder model

Parameters	Existing supply scenario (Grid power)	Solar feeder scenario
APPC (INR/kWh)	4.00	
Transmission charges (INR/ kWh)	0.41	
Total cost (including losses)	4.61	
FiT (INR/ kWh)	-	3.15
Annual landed energy cost (INR crore/ year) (Year -1)	1.14 (2.471*4.61)	0.78 (2.471*3.15)
Total cost of supply over 20 years (NPV discounted at 10%) (INR crore)	10.36	6.63
Total savings per feeder over 20 years		**INR 3.73 crores (USD 0.5 million)**

Source: (Gambhir, 2018)

TABLE 20 Cost of replacing existing pumps with standalone off-grid solar pumps

Parameters	Cost
Benchmark cost of 3-5 HP AC solar pump as per MNRE (2018-19)	INR 65,000
Cost of each solar pump	INR 3,25,000
Total cost of standalone solar pumps	INR 16.25 crores (USD 2.5 million)

** There will be some additional cost savings on metering and billing can be saved with off-grid solar pumps (not quantified)*
Source: (Gambhir, 2018)

If 2,000 MW are installed in Maharashtra under this program, it implies a consumption of roughly 2,800 MUs. This is equivalent to supplying power to **0.6 million pumps** (of 5 HP each) for 1,300 hours per year. i.e. ~15% of electric pumps in Maharashtra. Considering a price discovery of INR 3.15/kWh (USD 0.05), there is a saving INR ~250 crore (USD 38.5 million) per year in terms of subsidy support. If over 25 years, Average power purchase cost (APPC) at INR 4 per kWh and assumed to be rising at a conservative 1% per year, **the Net Present Value (NPV) of savings is INR 2,800 crore (USD 431 million)**.

Table 21 below summarizes the different models for solar pumps

TABLE 21 Solar pumps models

S no.	Type of pumps	Purpose	Mode of usage
1	Off-grid/Standalone	Irrigation, livelihoods (sale of water)	Single user/Multiple users
2	a) Grid-connected (Net metered)	Irrigation, other livelihoods and injection to the grid	Single user/Multiple users
	b) Grid-connected (Solarized feeder)	Irrigation, other livelihoods	Single user/Multiple users

Source: CLEAN Analysis

5.2.1 Service delivery models

At the end-user level, solar pumps have been installed using three kinds of service delivery models in India (Table 22). Given the significant upfront cost of the asset, solar pumps are increasingly being promoted under the community ownership models, as they help in increasing the asset utilization and the payback period. In the community model, the solar pump is shared between a group of farmers who have land adjacent to each other or within the catchment area that can be served by the pump. An operator is selected from the group who keeps track of the usage of solar pumps by members and a service charge is levied based on the quantum of water delivered to members ('water-as-a-service' model). This model has been experimented by GIZ in the Vaishali district of Bihar.

TABLE 22 Solar pumps service delivery models in India

S no.	Type of model	Details
1	Co-operative Model	The water is shared between a larger group of 15–20 farmers and the ownership lies with the farmer co-operative. The cooperative is a legal and registered entity (See Case study 6)
2	Joint Liability Group Model	A group of 4–10 farmers come together for availing bank loan on individual basis while the asset ownership lies with the group. This is an informal group of members in contrast to a registered cooperative.
3	Entrepreneurship Model	Individual farmer owns the asset, bears the capital cost of installing the pump, and supplies water to other farmers in lieu of a service fee based on consumption of water.

Source: Based on discussion with GIZ

Case study 6: Dhundi Solar Pump Irrigators' Cooperative Enterprise Model

Grid-connected solar pumps

The International Water Management Institute (IWMI) implemented a pilot project in Dhundi village, Kheda district of Gujarat, in 2016, which brought together a group of six farmers to form a cooperative model for solar pumps. Three farmers were provided 5 HP pumps, while three were given 7.5 HP pumps and they paid roughly 20% of the price of pump. The rest was contributed from the research grant of IWMI. The discom, Madhya Gujarat Vij Company Ltd, offered a Feed-in-Tariff (FiT) of INR 4.63/kWh (USD 0.07/kWh) and in addition they were also provided with incentives such as green energy bonus and water conservation bonus[41] taking the effective FiT to INR 7.13/kWh (USD 0.1/ kWh).

[41] *Green energy bonus and water conservation bonus of INR 1.25/kWh each*

Flicker/ India Water Portal ©

Farmers consumed a part of the electricity and sold the rest to discom (Table 23). The net income increased 46% from INR 6.9 lakhs (USD 10,615) in 2015/16 to INR 10.1 lakhs (USD 15,538) in 2016/17. They also earned additional income by selling water to neighbouring farms at INR 250/bigha (USD 3.8)[42]. Prior to the Dhundi cooperative, neighbouring farms used to buy diesel at INR 500/bigha (USD 7.7). At the same time, the discom has also benefitted by eliminating the subsidized electricity given to farmers. The solar power purchased will also count towards their Renewable Purchase Obligation (RPO). The model is being replicated across 137 feeders in Gujarat.

TABLE 23 Details of energy consumption (2015/16 and 2016/17) - Dhundi model

Total generated Energy	97,500 kWh
Self-consumption	43,350 kWh
Injection to grid	52,150 kWh
Effective FiT	INR 7.13/kWh (USD 0.1/kWh)

Source: (Shah, Durga, Verma, & Rathod, 2016)

5.3 Financing DRE

Financing challenges have persisted for DRE in the absence of policy and regulatory signals, creating uncertainty about the long-term viability of investments. Financing for off-grid solar systems has remained difficult and inefficient with less than 1% of the entire national solar financing provided to the off-grid sector (TFE Consulting, 2017). Within this, most of the funding has been dedicated to solar water pumps and government-driven tendered projects with little support for enterprise-based models.

5.3.1 Current state of financing for DRE in India

Financing for DRE continues to be sustained by international donor grants, debt from international development finance institutions, and owner equity, which have been

[42] *One bigha is equal to 17, 424 square feet*

primary drivers for early stage funding (Anand, 2016). As per a recent study undertaken by GIZ, the overall demand for debt products for MSMEs in DRE sector ranges between USD 30-90 billion. The overall equity demand on the other hand, is higher than demand for debt and is around USD 50-115 million (GIZ,India, 2017)

Unlike utility-scale solar, a sector where Indian commercial banks are now comfortable lending, off-grid solar and DRE continues to remain a lukewarm area for banks. Challenges presented by short track record of companies, new and evolving business models, income security of off-grid consumers, high-risk profile and lack of assets to offer as collateral, hinder the availability of financing for enterprises and consumers.

With regard to consumer finance for energy products such as lanterns and home systems, local bank officials have been risk-averse to lend, and further discouraged by the small loan sizes sought by customers. Companies in Uttar Pradesh, which earlier had one of the highest consumer loans portfolios for solar home systems complain of a complete stoppage of last-mile consumer debt.[43] The banks in these areas complain of defaults and consider grid expansion as a competitive threat. Government subsidy has also decreased in this segment as compared to earlier scheme (from NABARD where 40% of the consumer loan for a home system was subsidized by the government).

In the area of microfinance, there have been developments in recent years, and as DRE product companies have evolved, most have sought to offer financing solutions to end consumers, either directly or through partnerships with banks or MFIs.

Table 24 summarizes key programmes including debt, equity, and grants currently available to the DRE sector.

Recent years have shown a trend of maturing enterprises that are achieving scale, despite policy and market headwinds. There has been an increase in availability of earmarked equity and concessional finance for companies operating in this sector, but availability continues to significantly lag the total capital requirements, stifling growth.

Three significant equity transactions that took place between 2017 and 2018 highlight a positive trend, where conventional investors and large-scale utilities have taken up stake in DRE companies.

- USD 9 million investment by Japanese company Mitsui in mini-grid operator OMC Power, an enterprise focused on solar-power for telecoms (Bhaskar, 2017).

[43] *Interviews with select companies in Uttar Pradesh*

TABLE 24 Type of financing facilities available for DRE

Type of finance	Fund	Proponent(s)
Debt	Responsibility Energy Access Fund (USD 30 million)	International Finance Corporation (IFC), Shell Foundation
	Off Grid Access to Clean Energy Program Corpus (USD 28 million)	KfW, Indian Renewable Energy Development Agency (IREDA)
	Loan Guarantee for Clean Energy Projects (USD 75 million)	USAID, Ratnakar Bank Limited (RBL)
	Solar Rooftop Credit Line (USD 500 million)	Asian Development Bank (ADB), Punjab National Bank (PNB)
	Solar Rooftop Credit Line (USD 625 million)	World Bank, State Bank of India
	Line of credit for commercial, industrial and residential solar rooftop (USD 100 million)	Green Climate Fund, NABARD, TATA Cleantech
Equity	Equity Fund (USD 18 million)	Infuse Ventures
	Microgrid Investment Accelerator (USD 50 million)*	Allotrope Partners, Electric Capital Management
Grant	USAID PACEsetter Fund (USD 8 million)	US Embassy, Government of India
	US-India Clean Energy Finance Grant funding to obtain long-term debt (USD 20 million)	OPIC, Climate Policy Initiative, Government of India
	GCF Grant for Energy and Energy Efficiency	NABARD, Small Industries Development Bank of India (SIDBI)

*Source: (CLEAN, 2017) & (Intellecap, 2016) *Microgrid Investment Accelerator was proposed as a 50 million USD fund for equity and debt investment in microgrids in India, Tanzania, and South Asia.*

- USD 20 million investment by Shell, European utility ENGIE, and the Swedish government in Husk Power Systems, a rural distributed utility with operations in India and Africa (Colthorpe, 2018). The investment will enable the ESCO to enable expansion in 300 villages in India and Africa.
- USD 6.4 million raised by Cygni Energy through a combination of debt and equity for expansion and growth. (Business Standard, 2018)

These investments indicate that DRE deal sizes have reached the threshold levels for conventional equity investors, a welcome trend that can pave the way for more investment. However, there continues to be a gap between equity fund availability and requirement.

5.3.2 Corporate social responsibility (CSR) and crowdfunding

Given CSR's overall potential to unlock funding from around 16,000 eligible companies, it presents a historic opportunity to tap funding for DRE. A survey of corporate donors highlighted persistent challenges, with technical know-how and long gestation periods of energy projects resulting in 60% companies omitting energy as part of their CSR contributions.

In 2014, India announced the corporate social responsibility (CSR) law, mandating large firms to spend 2% of their net profits on CSR projects (Karnani, 2016) and in 2016, Indian companies spent INR 9,309 crores (USD 1.4 billion) on CSR projects promoting a range of activities (Naik, et al., 2016). A number of companies have dedicated CSR funding on projects related to energy access and improvement of livelihoods and training-related activities, which directly or indirectly support DRE. For example, CSR projects have included set-up of solar microgrids, smart classrooms powered by solar energy, solar irrigation, and drinking water (Tenneti & Parekh, 2017). Other examples include solar pump systems in Odisha by Claro Energy supported by ITC, and community solar power plants installed by Barefoot College funded by the Coca-Cola Foundation.

Another emerging avenue for financing for DRE companies is crowdfunding. A handful of microgrid companies have financed systems using funds raised through domestic and international crowdfunding platforms. Mlinda worked with platform Milaap, to raise INR 50-55 lakhs (USD 76,923 – 84,615) in funds at interest rates of 4%–5% for debt financing. As debt is repaid by the village-level Joint Liability Group, the collateral is freed and returned to the project for scaling further. Similarly, Mera Gao Power, Boond and Mynergy have worked with Frankfurt-based Bettervest to raise larger tranches of INR 1.5 crore (USD 0.2 million) collateral-free debt funding for microgrids at 4%–5%.

TABLE 25 Availability of capital for DRE sectors

	Availability of debt	Availability of equity	Availability of grants/ subsidies	Observations
Solar Home Systems and Lanterns	● (orange)	● (green)	● (red)	• Primarily debt from MFI, bank or companies to help consumer finance • A small number of companies have gained access to significant equity investments, but the larger market of players continues to struggle • Lack of clear policy and subsidy support has stalled regional rural bank support (as it was happening earlier under the NABARD scheme)

	Availability of debt	Availability of equity	Availability of grants/ subsidies	Observations
Micro- and Mini-grids	● (red)	● (orange)	● (red)	• Three new equity funding rounds in the last one year have been the first few major equity investments in the DRE sector. • Policy uncertainty about grid expansion has had a chilling effect on investment • Banks continue to be highly sceptical about the business model, debt remains highly challenging • Current market growth has been donor-driven, and there are few purely commercial models globally. • The UP Mini-grids policy envisioned an exclusive viability-gap funding assistance of up to 30%, which was widely seen as an attractive proposal, however, the policy is not expected fructify in near term • Grid connected minigrids are still in experimental stage and hence dependent on research capital or grants
Solar Pumps	● (orange)	● (orange)	● (orange)	• Solar pumping is expected to get a boost from the newly announced KUSUM scheme, but market remains highly driven by subsidies • Debt remains challenging, further exacerbated by working capital requirements needed to match subsidy payout schedules
Cooking Systems	● (orange)	● (orange)	● (red)	• Debt through MFIs and bank finance channels is present but is difficult and low • Lack of CDM or carbon exchange linked clean cookstove industry growth due to global fall in price of carbon
Solar Heating	● (green)	● (green)		• Debt availability primarily on customers' balance sheet through conventional bank channels • Some established players have developed a presence leveraging equity investments • Market remains highly driven by subsidies.

● (red) *Limited financing available*
● (orange) *Finance is available with some challenges*
● (green) *Finance is available*

WAY FORWARD

On the 28th April 2018, when Leisang, a small village in Manipur was connected to the grid, India had officially connected the last of the 18,452 villages, which had been identified as not connected to the grid.

On the 29th April 2018, the Prime Minister of India tweeted and to quote from his tweet:

> *28th April 2018 will be remembered as a historic day in the development journey of India. Yesterday, we fulfilled a commitment due to which the lives of several Indians will be transformed forever! I am delighted that every single village of India now has access to electricity.*

While this is definitely a milestone for India as far as electrification is concerned, it needs to be recognized that, over 118 million people still lack access to electricity and the numbers are significantly higher, if we consider the current definition of electrification. 819 million continue to depend on traditional biomass to meet their cooking and heating requirements. Therefore, India, is far from achieving the 24 x 7 electricity for all, a target set for 2022 by the Government as well as access to modern and clean cooking fuels.

In addition to the above, the issue of quality and reliability of electricity supply remains unaddressed. Uninterrupted supply of electricity for all energy needs of households and enterprises, round the clock, and all through the year should be the overarching goal.

At the same time, GoI is yet to firmly address on a mission mode, non-electricity use of energy (thermal energy), which contributes to 57% of our primary energy consumption. Of this, 37% is utilized for cooking energy (in the form of biomass), 53% for industrial process heat. Unlike for electricity where there are focused programmes such as electricity for all households through Saubhagya, there are no focused programmes for thermal energy. 175 GW target of renewable energy (RE) appears to be primarily set for electricity generation. PMUY is the lone programme, which is aiming to meet clean cooking energy needs.

As explained in the report, as many as over 62 million households require clean cooking solutions, which can be met through RE-based cooking solution.

Further, from the foregoing sections of report, it is clear that DRE has a clear role to play and it goes beyond electricity and lighting. It needs to be recognized as a sector that can address the issue of improving access and ensure reliability of energy supply through clean and sustainable energy sources.

The overall market potential for DRE in India in our estimate is around INR 6.71 lakh crores (USD 103.3 billion), almost 5 times the budget of KUSUM scheme announced by the government. However, to realize this potential, a facilitative policy framework for scaling up DRE in India is needed.

Following are some recommendations to strengthen the DRE sector.

- **Stronger policy backing for DRE:** DRE requires a strong policy push and endorsement from the central and state governments. This has been the unanimous sentiment of majority of industry players (CLEAN members and non-members).
    a. Policy support should also be extended to other segments such as improved biomass cookstoves and other non-solar segments. A technology agnostic mission on clean cooking fuels should be prioritized and implemented, where regional diversities on multiple fronts (agro-climatic zones, distribution infrastructure, livestock population, user tastes and preferences, etc.) are considered before deciding the choice of cooking fuel and technology.

    b. India has already submitted its voluntary commitments to the United Nations Framework Convention on Climate Change (UNFCCC), through its Nationally Determined Contribution (NDC). Therefore, the country also needs to fulfil its obligation of ensuring reduction of its emissions intensity of its GDP by 33%–35% by 2030 from 2005 levels, which will include amongst others, India's share of non-fossil fuel in the total installed capacity to change from 30% in 2015 to 40% by 2030. The government should ensure that adequate and appropriate targets are also fixed to the DRE sector to contribute to its commitments to the UNFCCC. It has been observed that a number of states are currently revising its State Action Plan on Climate Change, in line with India's NDC. It should be ensured that DRE also has a dedicated space and responsibility to contribute to India's NDC.

- **Resolve regulatory issues for grid-interactivity of mini-grids:** Issues around grid interactivity such as islanding and feed-in-tariff determination for mini-grid operators (if they enter into a PPA with discom) need to be resolved by regulatory commissions.

- **Nurture rural livelihoods and enterprises to build demand for productive uses:** The current approach of the Government seems to be 'electricity focused' rather than 'energy services focused', as it rightly should be. Energy access should also address all energy needs for livelihoods and productive needs. Nurturing enterprises run by SHGs and other rural livelihoods can build demand for energy. Nurturing could be in the form of incubation support to such enterprises, provision of subsidies, training, and mentoring.

- **Industry support for data collection:** Given that the DRE sector is outside the regulatory purview, obtaining accurate market data for different sub-sectors is a challenge. Wider support to systematic data collection exercise from the industry is required. The lack of available market data limits the investment made in enterprises, which has also been highlighted in the recently released report by Global Alliance on Clean Cookstoves on financing clean cookstoves. CLEAN has initiated the collection of market data (sales, financial, and operational) from energy enterprises. The first such exercise through online data platform has been undertaken for this report in partnership with GOGLA, and subsequent exercises will be recalibrated, considering the lessons and feedback from members.

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Annexure 1: List of organizations interviewed

Name of organization	Person interviewed
Claro Energy	Rajesh Mishra
Cygni Energy Pvt Ltd	Venkat Rajaraman
Eastern Envo	Fazle Ilahi
Envirofit	KP Ravi
Gautam Solar	Shubhra Mohanka
Greenlight Planet	Manasi Dev Suryadevara (through email)
Husk Power	Subhendu Goswami
Mlinda	Sudeshna Mukherjee
OMC	DVS Rajan, S N Rao
Oorja	Amit Saraogi, Clementine Chambon
Orb Energy	N Ramesh
SELCO	Sudipta Ghosh
Shakti Pumps	Manu Sharma
Simpa Networks	Piyush Mathur
TIDE	Svati Bhogle

Annexure 2: Benchmark Costs for off-grid solar system

1. Solar Pumps

Pumps Capacity (HP)	Benchmark Costs (INR/HP)	
	General Category States	North Eastern States/ Hill States/Island UTs
Up to 3 HP DC	85,000	93,500
>3 HP–5 HP DC	77,000	84,700
Up to 3 HP AC	80,000	88,000
> 3 HP–5 HP AC	65,000	71,500

2. Solar lamps

System	Benchmark Cost (INR/Wp)	
	General Category States	North Eastern States/Hill States/ Island UTs
Solar lamps	250	275
Solar street lights		
i. With lead–acid battery	300	330
ii. With Li-ion battery	435	475

3. Standalone solar power plants/solar power packs

Capacity (kW)	Battery Back-up (hours)	Benchmark Costs (INR/Wp)	
		General Category States	North Eastern States/Hill States/Island UTs
Up to 10	6	100	110
	3	80	88
	1	68	75
Above 10 and up to 25	6	90	99
	3	72	79
	1	61	67

Annexure 3: Comparative assessment of different battery technologies

	Lead-acid batteries (Pb-acid)	Lithium-ion batteries (Li-ion)	Nickel batteries (Ni-Cd; Ni-MH)	Sodium batteries
Capital cost	USD 65–150/kWh	USD 250–500/kWh	USD 600–800/kWh	USD 200–500/kWh
Life cycle (number)	500–2000	100–5000	3000	4500
Life time	5–25 years (depending on temp. and charging model)	5–15 years (depending on temp. and charging model)	5–25 years	10+ years
Efficiency	70%–75%	80%–90%	90%	95%
Self discharge	3%–5%/month	3%–5%/month	N.A.	N.A.
Recycling efficiency	>95%	50%	75%	N.A.
Advantages	• Mature technology • Low investment costs	• High energy density • Long life expectations • No requirements at installation site • Low maintenance efforts	• Mature, robust, and very versatile technology • Insensitive towards extreme temperature • Resistance to overcharging and deep discharge	• Insensitive towards Extreme temperature
Disadvantages	• Short cycle life • Slow charging • Maintenance requirements • Pb on disposal	• High costs • Little experience • Safety: danger of fire • Limited storage time • Self discharging-> reload required	• Maintenance requirements • Relatively high cost • For Ni-Cd: Cd on disposal	• Limited life cycle

	Lead-acid batteries (Pb-acid)	Lithium-ion batteries (Li-ion)	Nickel batteries (Ni-Cd; Ni-MH)	Sodium batteries
Off-grid applications	• Solar home system • Electric transport like motorcycles a car • In productive uses like irrigation and food cooling • In micro and nano grids systems	• Solar lantern • Solar charger • Solar home system • In productive uses like irrigation and food cooling • Electric transport like motorcycles and car • In micro and nano grids systems	• Solar torches* • Solar garden lights*	• In Nano-grid systems

Annexure 4: Estimated GHG emissions off-set by DRE technologies in 2017-18

	Parameter	Units	Methodology	Source
			OFF-GRID SOLAR	
	GHG Emission by one kerosene lamp	kg CO_2/annum	The average annual emission for one light source is estimated to be: Average annual emissions per baseline light source = 365 (d/a) x 3 (h/d) x 0.005 (emission factor) kg CO_2/h = 5.5 kg CO_2/annum	https://www.reeep.org/sites/default/files/BGFZ%20emission%20reductions%20calculation%20model.pdf
	Total no of Solar lanterns	Nos	6,36,5000	
	Total number of SHS	Nos	1,00,5000	
A	**GHG off set (replacement of kerosene lamp with solar lanterns & SHS)** **(Assuming 1 SHS = 3 solar lanterns)**	**kg CO_2/annum**	**4,05,35,000**	
			SOLAR PUMPS	
	Total no of Solar Pumps	Nos	32649	
	GHG emission offset per pump	kg CO_2/annum	5 million solar pumps can save 23 billion kilowatt-hours of electricity, or 10 billion litres of diesel translating emissions reduction of nearly 26 million tonnes of carbon dioxide. 1 pump can reduce 5200 kgs of carbon dioxide	www.energetica-india.net/download.php?seccion=articles&archivo...pdf
B	**GHG off set (replacement of diesel and/or electric pump with solar pump)**	**kg CO_2/annum**	**16,97,74,800**	
			MINI-GRIDS	
	GHG Emission offset by oneunit generation	kg CO_2/kWh	The emissions per unit of electricity are estimated to be in the range of 0.91 to 0.95 kg/kWh for CO_2	https://www3.epa.gov/ttnchie1/conference/ei20/session5/mmittal.pdf

	Total standalone plants installed capacity	kW	1800	
	Parameter	**Units**	**Methodology**	**Source**
	Electricity generation through standalone plant (Capacity*8 hours* Capacity utilization factor (19%)*365)	kWh	998640	
C	**GHG off set**	**kg CO_2/kWh**	**9,18,748.8**	
			BIOGAS	
	Total no of biogas plant	No.s	20125	
	GHG emission offset per plant (2 m^3)	kg CO_2/annum	10 kg cow dung is daily requirement of a 2 m^3 biogas plant.10 kg dry cow dung can recycle 10 kg of CO_2 so annually 10 * 365 days 3650 kg/annum of CO_2 is recycle per annum	http://inseda.org/wordpress/wp-content/uploads/2014/07/Env-Impact-of-Biogas-plants.pdf
D	**GHG off set (replacement of wood with biogas)**	**kg CO_2/annum**	**7,34,56,250**	
	Total GHG off-set (A+B+C+D)		**28, 46,84, 798.8 kg/CO_2 per annum**	

Annexure 5: Estimated number of jobs created in the DRE sector in FY 2017-18 in India

Technology	Sales	Assumption	Jobs created
Off-grid solar • Lanterns/ Pico-solar • SHS	Lanterns- 63,65,000 SHS- 3,35,000	Solar lanterns- Every 1 million increase in unit sales capacity requires 5600 jobs SHS- Every 200,000 increase in unit sales capacity requires 2800 jobs	40334
Solar pumps	32645	Every 200,000 increase in unit sales capacity requires 2800 jobs	457
Biogas plants	20125	For every 1,00,000 biogas units, 1130 jobs are created	227
Mini-grids	1.8 MW / 250 projects	3400 jobs are created for every 1000 mini-grid projects	850
Total jobs created in FY 2017-18			**41868**

Methodology source: Skill solutions for off-grid clean energy, CLEAN strategy series, April 2015

Annexure 6: State subsidies for solar pumps

State	Subsidy	Links
Haryana	90% subsidy for installation of 2HP, 5HP and 10 HP solar pumps with a target of 3050 pump sets	Haryana Solar Water Pumping Scheme http://hareda.gov.in//writereaddata/document/hareda218569796.pdf
Uttar Pradesh	Grants in the range of 60%–90% being provided by central and state government for solar pump installation	UPNEDA Solar Pump Policy http://upneda.org.n/?q=solar- photo-voltaic-pump-water
Rajasthan	Target to install 10,000 solar pumps in 2017/18 with 86% combined MNRE and state government subsidy	Directorate of Horticulture, Govt. of Rajasthan http://www.agriculture.rajasthan.gov.in/c ontent/dam/agriculture/Direc-torate%20of%20H orticulture/Statics/Scheme/Solar/solar_gi_2017_18.pdf
Gujarat	75%–80% subsidy for the farmers; provision of selling surplus power to state discoms	Gujarat Energy Development Agency https://geda.gujarat.gov.in/policy_files/gu jarat_solar_power_policy_2015.pdf
Maharashtra	Target of 10,000 solar pump sets with 95% subsidy	Maharashtra Energy Development Agency https://www.mahaurja.com/meda/data/off_grid_solar/RE%20Solar%20Policies%20and%20GRs/State%20Policy/Off- grid%20State%20Policy%20(11%20February%202016).pdf
Bihar	50% subsidy provided to farmers for installing 2 HP DC pumps; target of installing 2,85,000 pumps.85 lakhs solar pumps	Bihar Saur Kranti Sichai Yojana http://energy.bih.nic.in/docs/Schemes- SolarRevolution.pdf
Madhya Pradesh	90% subsidy provided to farmers for installation of solar pump sets ranging from 1 HP to 10 HP	Mukhyamantri Solar Pump Yojana http://mpcmsolarpump.com/wp-content/uploads/2017/04/About_schemes.pdf

State	Subsidy	Links
Chhattisgarh	Target of 51,000 solar pump sets by 2019; subsidy to the tune of 95%–98% is being provided	Saur Sujala Yojana http://www.creda.in/guidelines-saur-sujala-yojana-fy2016-17
Andhra Pradesh	89% subsidy for the farmers with MNRE contributing 33% and state discom 56%; target of 10,000 solar pump units	New & Renewable Energy Development Corporation of Andhra Pradesh Limited http://nredcap.in/Solar_PV_Water_Pump ing_Programme.aspx
Tamil Nadu	The state government is giving 1000 solar pump sets of 5, 7.5, and 10 HP with 90% subsidy	Agriculture Engineering Department http://www.aed.tn.gov.in/English/solar_sc h.html

Annexure 7: Financial assistance for solar charkhas

Maximum subsidy for a single cluster- INR 9.599 crore

CAPITAL SUBSIDY

Particulars	Subsidy per unit (in %)	Subsidy per unit (in INR)
2,000 Solar Charkhas for 1,000 spinners (Rs 45,000/- per charkha)	35%	INR 15,750/- per charkha (Cumulative- INR 3.15 crore)
500 Solar Looms for 2,000 Charkhas (Rs 1,10,000/- per loom)	35%	INR 38,500/- per loom (cumulative- INR 1.93 crore)
Workshed (min. space of 20,000 sq. ft)	100%	maximum rate up to INR 1.20 crore per cluster for the Special Purpose Vehicle (SPV)
Solar Grid (50 kW capacity)	100%	maximum rate up to INR.0.40 crore per cluster for the SPV
Purchase of twisting machines, dying machines and stitching machines (500 in number)	35%	maximum of Rs.0.75 crore per Cluster for the SPV

INTEREST SUBVENTION ON WORKING CAPITAL

Celling of 8% irrespective of the interest charged by the banks/financial institution for a period of 6 months (equals to INR 1.584 crore for one cluster including cost of roving, wages of spinners and weavers)

CAPACITY BUILDING

Cost of courses for spinners /weavers per cluster for a period of 2 years is INR 0.595 crore

Annexure 8: Technical standards for off-grid systems

OFF-GRID SOLAR

MNRE Technical Specifications for Solar Photovoltaic Lighting Systems & Power Packs

(Off-Grid Solar Applications Scheme 2016-17) (issued on September 20, 2016)[44]: - Technical specifications, details and broad performance specifications for White LED (W-LED) Based Solar Lantern, Solar Home Lighting Systems with and without battery type luminary, Solar Street Lighting System, Solar Study Lamp, PV Integrated Micro Solar Dome (Pvi Msd), Solar Home Systems (AC and DC Models).

SOLAR PUMPS

MNRE Solar Photovoltaic Water Pumping Systems for Micro Pumping Applications (2016-17) (issued on August 30, 2018)[45]: - Performance specifications and requirements for 6 Models specifying- capacity of solar panel ranging from 300-500 Wp, Motor capacity ranging from 0.25-0.5 hp, Shut Off Dynamic Head and Water output.

MINI/MICRO-GRID

BIS Draft Guidelines For 48 V ELVDC Distribution System (ETD50 (11294))[46]:-

- 48V is chosen as the distribution voltage for DC considering safety, distribution losses, re-use of existing 230/110V ac utility eco-system, local sourcing capability, and its recognition as a DC primary voltage according to IS 12360:1988/ IEC60038.
- Applicability
  - Dwelling units and commercial units, hotels, motels or similar occupancies, mobile homes, and in building, Off-grid RE based.
- Essential requirements and precautions regarding wiring installations and equipment powered by DC sources.
- Safety requirements for the installations
- Does not address the needs of a collective system where power delivery over a large area is required

MNRE Guidelines for solar DC systems for off-grid and grid connection applications[47].

- Developers can select AC-DC system based on village size and transmission feasibility
- For DC microgrid, 60 V is the voltage limit for safety at distribution.
- BIS/International standards should be specified for equipment specifying their technical parameters
- System voltage and cable thickness (recommended less than 10 sq. mm) should be compatible.

44 *https://mnre.gov.in/file-manager/UserFiles/spls-pp-2016-17.pdf*

45 *https://mnre.gov.in/file-manager/UserFiles/micropump-specs-030817.pdf*

46 *http://www.bis.org.in/sf/etd/ETD50(11294)_27012017.pdf*

47 *https://mnre.gov.in/file-manager/UserFiles/OM-Solar-DC-Guidelines.pdf*

IMPROVED BIOMASS COOKSTOVES

BIS (draft) standards for Portable Solid Bio-Mass Cookstove (Chulha) Part 1 [First revision of 13152(Part 1):1991][48]:- Standard covers requirements of different designs and types of solid bio-mass portable cookstove (chulha) for domestic and community/commercial applications.

- The size of cookstove (chulha) will be based on the corresponding heat and power output rating (0.5 kW – 10 kW)
- Specified performance parameters: -
  - Thermal efficiency- Natural Draft- > 25 %; Force Draft – > 35%
  - Emissions- CO and CO_2 should not exceed 5 g/MJd
  - Total Particulate Matter (TPM)- Natural Draft- <350 mg/MJd; Forced Draft- <150 mg/MJd

ISO 19867-1:2018- Clean cookstoves and clean cooking solutions - Harmonized laboratory test protocols - Part 1: Standard test sequence for emissions and performance, safety and durability[49]- The standard is applicable to cookstoves used primarily for cooking or water heating in domestic, small-scale enterprise, and institutional applications, typically with firepower less than 20 kW and cooking vessel volume less than 150 l, excluding cookstoves used primarily for space heating.

It specifies laboratory measurement and evaluation methods for:

- Particulate and gaseous air pollutant emission;
- Energy efficiency;
- Safety;
- Durability of cookstoves.

[48] *http://www.bis.org.in/sf/med/MED04_1157C.pdf*

[49] *https://www.iso.org/standard/66519.html*

Annexure 9: Classification of mini-grids

Specifications	Pico-grids (<1 kW)	Micro-grids (1– 10 kW)	Mini-grids (>10 kW)
Service offered	Lights, Mobile charging	Lights, mobile charging, TV, fan	Different kinds of appliances (Domestic, commercial and productive load)
Supply hours	6– 7 hours	7– 24 hours	24 x 7
Business model	BOOM	BOOM	BOOM
Payment cycle	Weekly	Monthly	Monthly
Payment mode	• Post paid • Manual collection by agents	• Post paid	• Post paid • Manual collection for domestic and business consumers • Electronic payment for anchor consumers
Target consumers	Domestic	Domestic, productive (agriculture and small shops) and institutional (schools, health centres, etc.)	Domestic, anchor (Telecom towers) and productive (agriculture and small shops)
Tariff	20 Watt – INR 120 (Domestic tariff)	A fixed monthly charge of INR 60– 100 for up to 10 units a month, beyond that INR 10/unit	• 15 Watt – INR 110 (Domestic Tariff) • INR 22– 24/ unit (Commercial consumers)
Examples	Mera Gaon Power	Nature tech Infra	OMC

Source: Interviews

For more details, please contact:

Clean Energy Access Network
2nd floor, A-23, Near Green Park Church, Aurobindo Marg, New Delhi – 110 016
p: +91-11-41601543
w: www.thecleannetwork.org, e-mail: info@thecleannetwork.org