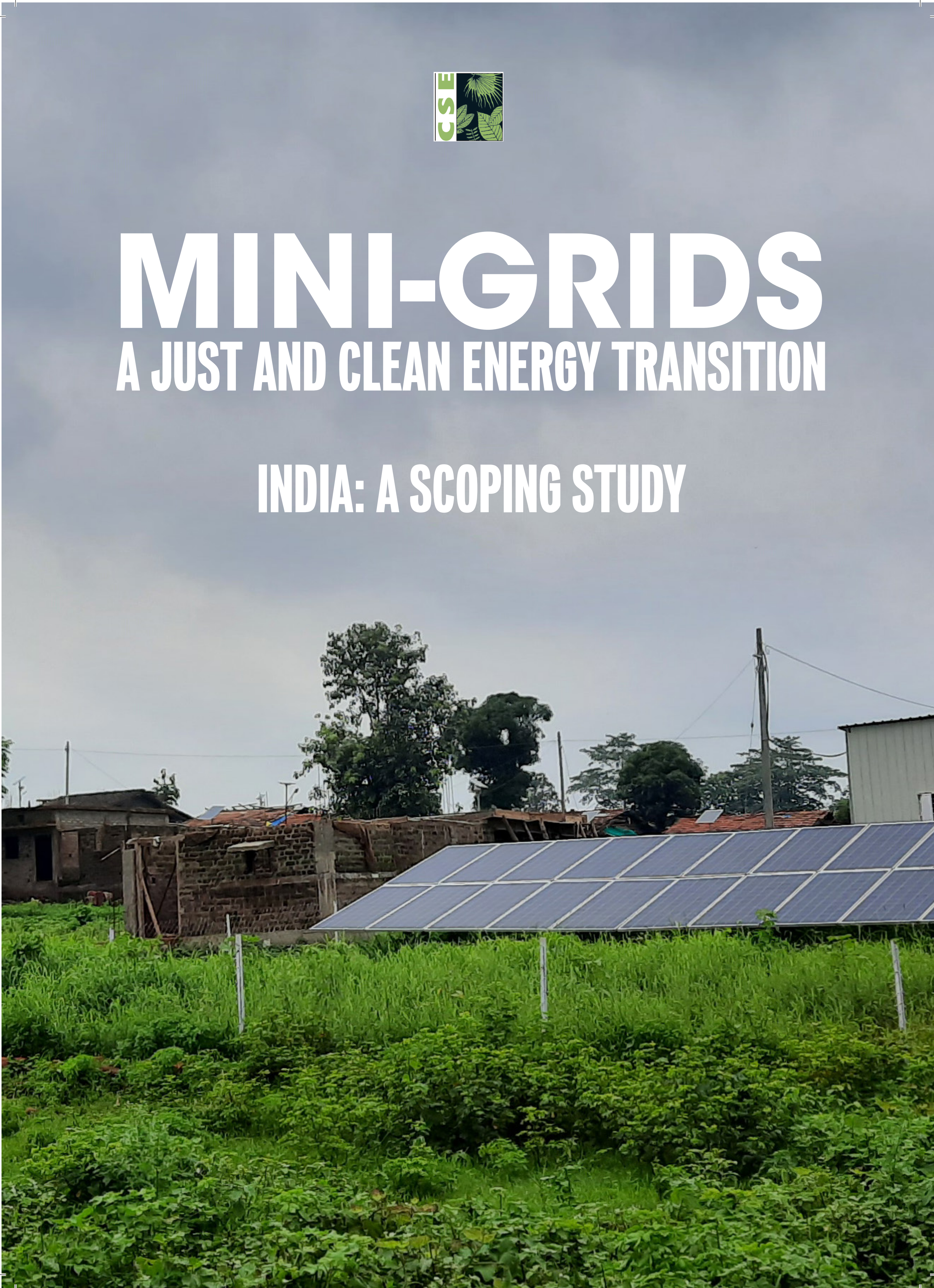

MINI-GRIDS
A JUST AND CLEAN ENERGY TRANSITION

INDIA: A SCOPING STUDY

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Research direction: **Sunita Narain**

Writers: **Binit Das, Aditya Batra and Jasleen Bhatti**

Reviewer: **Koshy Cherail**

Editors: **Souparno Banerjee and Aditya Batra**

Design: **Ajit Bajaj**

Production: **Rakesh Kumar Shrivastava and Gundhar Das**

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Published by
Centre for Science and Environment
41, Tughlakabad Institutional Area
New Delhi 110 062
Phones: 91-11-40616000
Fax: 91-11-29955879
Website: www.cseindia.org

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PART 1

A PATHWAY TO DECENTRALISED POWER

A PATHWAY TO DECENTRALISED POWER

A mini-grid refers to decentralised electricity generation systems with capacities above 10 kW to a few MW, serving residential, commercial, institutional and small industrial loads. As opposed to this, micro-grids are systems with capacities less than 10 kW.

Currently, households in India use diesel or biomass as sources of decentralised energy. These fuels are polluting, but convenient. The aim is to shift households from direct use of diesel and biomass to electricity produced from solar, biomass and wind. This can then become the key source for last-mile connectivity, reaching households that still do not have access to electricity; or, and most critically, can become the supply for cooking energy needs of households. It will then displace all the dirty fuels which are used today, and can be a win-win proposition for the world's energy-insecure poor.

As of March 31, 2021, some 216 MW capacity of standalone power plants (off-grid power plants) had been set up in the country. In addition, there are 10 million off-grid solar-based lighting systems (street lights, home lights and solar lanterns) and 286,830 solar water pumps in the country. All these totaled to 1,467 MW of installed capacity by January 31, 2022, according to the Ministry of New and Renewable Energy (MNRE).

ACCORDING TO THE MNRE, INDIA HAD 1,467 MW OF INSTALLED CAPACITY TILL JANUARY 31, 2022

In the past decade, there was interest in setting up mini-grids till policy focus shifted to all-India grid-connectivity. Mini-grids were promoted by MNRE as components of the `Off-grid and Decentralised

Applications Programme', implemented under the National Solar Mission with a provision of Central Financial Assistance. In 2016, the Indian government came up with a Draft National Policy on Mini and Micro-grids with a target of deploying at least 10,000 renewable energy-based micro/mini-grids with minimum capacities of 500 MW within five years in under-served and un-served locations of the country. But this policy has not been finalised yet.

INDIA'S 2016 DRAFT NATIONAL POLICY ON MINI AND MICRO-GRIDS ENCOURAGES STATES TO PREPARE THEIR OWN POLICIES

The draft policy encouraged states to use the enlisted guidelines to prepare their own policies. Uttar Pradesh, following this, has framed its own mini-grid policy, while states like Odisha and Bihar have included the component of mini-grids in their wider renewable energy policies (*see Table 1*).

Table 1: State mini-grid policies and their features

States	Salient features of mini-grid policy
Uttar Pradesh (Uttar Pradesh Mini-grid Policy, 2016)	• To ensure power supply to 20 million households of the state for minimum need (daily three hours in the morning and five hours in the evening with a total of at least eight hours) • To create a conducive environment for stimulating private sector participation through 30 per cent subsidy. Developers to establish projects on Build Own Operate & Maintain (BOOM) basis and guarantee 10 years of Operation and Management (O&M) services. • To enhance skills and create employment opportunities at the local level. • To promote establishment of local manufacturing facilities and socio-economic development of backward areas.
Odisha (A component under Odisha Renewable Energy Policy, 2016)	The Odisha Electricity Regulatory Commission notified the Mini-grid Renewable Energy Generation and Supply Regulations in June 2019. Two models for business operations are discussed—one each for where the grid pre-exists and the grid is non-existent.
Bihar (A component under Policy of Promotion of Bihar New and Renewable Energy Sources, 2017)	• Promotion of mini-grids as a solution to provide 24x7 reliable energy to all by FY 18-19. • State government targets to achieve deployment of 100 MW of RE capacity equivalent through mini-grids. • Projects to be constructed on the BOOM model. • The government to facilitate the development of mechanisms to streamline project aspects such as single window clearance etc.

A PATHWAY TO DECENTRALISED POWER

THE DEFINITION OF 'ELECTRIFICATION' IS PROBLEMATIC. TILL RECENTLY, IT MEANT THAT THERE WAS MORE THAN A SINGLE WIRE IN A VILLAGE CONNECTED TO A GRID

By 2017, the government's focus had shifted to providing electricity access to all households by extending the grid. The Pradhan Mantri Sahaj Bijli HarGhar Yojana—also known as the `Saubhagya' scheme—was launched with the aim to electrify the whole country. As of 2019, there were some 19,679 villages that remained to be electrified. As of 2022, even these have been reached with the grid. India, therefore, can claim 100 per cent electrification, says the government. This is no mean achievement.

However, the definition of `electrified households' remains problematic. Till recently, `electrification' meant that there was more than just a single wire in the village connected to the grid. The 2004 definition says if at least 10 per cent of the households are electrified, the village can be declared as electrified.

There is also a lack of data to show if this electrification has led to electricity reaching households, if it is reliable, and if electricity supply is continuous given that distribution companies are mostly cash- strapped and households are often unable to pay. In such a situation, mini-grids, which can generate and supply energy close to the households, could well be the answer.

The 2019 report called *Rural Electrification in India—Customer Behaviour and Demand*, published by Smart Power India, a subsidiary of The Rockefeller Foundation and the Initiative for Sustainable Energy Policy (ISEP), had found households mixing and matching both grid and off-grid energy sources for their needs. The study, based on data collected from

10,000 households and 2,000 rural enterprises in Bihar, Uttar Pradesh, Odisha and Rajasthan, found that 16 per cent of the households and 40 per cent of the enterprises used non-grid sources—diesel generators, but also solar home systems. It also found that one in two grid-users faced a power cut at least eight hours daily. Besides the inconvenience, an undependable electricity supply forced customers to bear additional expenses on power back-ups.

Therefore, the requirement of mini-grids cannot be ruled out—particularly for energy access to meet the needs of the poorest. The country is still facing a major challenge in providing reliable and quality electricity supply. The supply during the evening peak hours (5-11 pm) is a serious issue, especially in villages. According to Prayas (Energy Group)'s Electricity Supply Monitoring Initiative, 27 per cent of the monitored locations experienced an average daily outage of 30 minutes or more during evening hours in September 2019. For the same month, only 7 per cent of rural areas received the entire six hours of evening supply.

These frequent interruptions and variability in voltage strengthen the case of mini-grids. Localised mini-grids are efficient and have high accountability. Supplying 24x7 electricity through a centralised grid is both costly and technically challenging. The transmission and distribution losses are also high as the distance from the generation end increases. Therefore, mini-grids can play a grid-balancing role. These are also helpful in generating employment in rural areas.

MINI-GRIDS CAN PLAY A GRID BALANCING ROLE AND ALSO GENERATE EMPLOYMENT IN RURAL AREAS

A PATHWAY TO DECENTRALISED POWER

THE POTENTIAL OF MINI-GRIDS IN INDIA HAS BEEN ESTIMATED AT ABOUT 4 GW IN THE VILLAGES WHICH HAVE AN INADEQUATE POWER SUPPLY

RELEVANT FOR CLEAN ENERGY ACCESS

The CEA acknowledges the importance of mini-grids in meeting the target of 175 GW of renewable energy by 2022. The potential of mini-grids in India has been estimated at about 4 GW in the villages which have an inadequate power supply. It is also clear that energy is critical for economic and livelihood growth. This energy access would ensure that not only are domestic needs taken care of but that it is used to make small businesses sustainable and make villages viable for economic growth.

The key will be to develop mini-grid systems and policies that integrate with the grid, so that the surplus power generated can be exported out; and in times of need also imported into the system for supply. The modern mini-grid must be as easy to install as the local distributor for other supplies—it should provide last-mile connectivity.

COOKING FOOD WITH ELECTRICITY

The advantage is that the solar energy distributor knows the customer and this means that there can be on-demand energy available at low cost. It is a sustainable business model and if it can be made affordable, it can allow households to meet basic livelihood and economic needs.

Energy access is still a key issue. In addition, over 70 per cent of Indian households in rural India continue to cook food on biomass-based fuels (cowdung, wood, twigs), which are polluting and harmful for health, particularly of women working the stoves. The Central government's Ujjwala programme—which provides subsidised LPG to meet cooking needs—has reached over 80 million households. But what is now well recognised is that affordability remains the key issue and even the refills of LPG are 50 per cent below full utilisation.

It is also clear that electricity could be a viable option for meeting the needs of cooking in households. It is cheaper than LPG—even at the cost of Rs 8/unit—and efficiency is higher. The problem is that cooking energy costs remain unmonetised in households—the time taken by women to collect fuelwood or cowdung is discounted. And therefore, households do not want to pay for this energy—even though now there is a better understanding of the health impacts of using dirty fuel. Then there is the cultural problem of using electricity for cooking—as it would require changes in utensils and may be even certain culinary practices.

But the potential of this leapfrog—moving the poor in the world to clean energy—without going through the fossil fuel trajectory is enormous and powerful (*see Box on next page*).

ECONOMICS OF THE SMALL

The problem with this decentralised source of energy is that it remains more expensive than the conventional grid-based energy supply. This is partly to do with the scale of operations as setting up solar systems, particularly with battery back-ups to meet night time usage, is expensive—more so than solar energy supplied through grid-based large systems. It is also because the system operator has to set up the entire distribution network to reach each household and this comes at a high cost. It is also a

ELECTRICITY COULD BE A VIABLE OPTION FOR MEETING COOKING NEEDS IN HOUSEHOLDS; IT IS CHEAPER THAN LPG AND HAS HIGHER EFFICIENCY

A PATHWAY TO DECENTRALISED POWER

CLEAN COOKING

A status report from India, Africa, Nepal and Bangladesh

In developing countries, solid (and polluting) fuels like wood, biomass, kerosene and coal are often used in traditional inefficient stoves for cooking. This results in household/indoor air pollution, leading to respiratory illnesses, heart problems and even death. In fact, indoor air pollution causes more than four million premature deaths every year in the world—50 per cent of which are of children under the age of five.

Despite three decades of efforts, access to clean cooking fuel and technologies has continued to be a concern. CSE has carried out virtual stakeholder consultations on this subject—the result is this bank of case studies from various parts of the world, each different from the other in size, technologies being used, funding methods, operating models, and ownership.

CASE STUDIES FROM INDIA

KHANDWA, Madhya Pradesh: Mumbai-based Smokeless Cookstove Foundation (SCF), a non-profit working to curb the problem of household air pollution, trains rural, migrant and tribal populations on making a "virtually zero-cost, efficient and improved cookstove" that has a reduced smoke output. The stove uses less fuel than traditional chulhas, reducing the cooking time, and can be made from locally available materials such as mud, dry grass, cowdung, etc. Metal moulds are used to make the base for the chulha; a mould can be manufactured for under Rs 500 and thereafter, can be used to make several hundred stoves.

In 2018, the SCF conducted three training sessions in 30 villages of Khandwa. Surveys were conducted in 16 villages in the region, from 49 respondents who were using the SCF chulha. The gains were impressive: cooking time was found to have reduced in the 49 households by 33 per cent, and there was lesser use of firewood. A majority of the users reported an easing of their health problems such as watering of eyes during cooking, coughing, and respiratory issues.

SHIRDI, Maharashtra: The Saibaba temple in Shirdi has installed a solar steam cooking system capable of cooking 40,000-50,000 meals per day. The system is comprised of 73 rooftop-mounted Scheffler reflectors of 16 square meter each. The dishes concentrate sunlight on receivers that contain water, generating steam that is piped down to the kitchen for cooking purposes. To maintain constant focus with the sun, the dishes automatically rotate throughout the day after being manually aligned once each morning.

The system has been retrofitted to existing LPG-powered steam boilers that are used in the evenings and during periods of inclement weather. Though the system cost nearly US $300,000, government subsidies reduced the temple's portion to about US $170,000. It has helped cut LPG use by roughly 100,000 kg each year, for an annual savings of approximately US $45,000.

Though the solar steam cooking technology was developed in Germany, the equipment does not contain imported components, and has been manufactured with local machinery and labour.

CHOULDHARI, Andaman Islands: Energy Efficiency Services Limited (EESL), a joint venture of public sector undertakings under the Union ministry of power, has implemented a solar PV induction cookstove project for tsunami shelters and homes at Chouldhari, Andaman Islands. About 100 cookstoves have been installed and commissioned at Badmaspahad in Chouldhari, at an approximate project cost of Rs 1.6 crore.

The current status of the project is unknown. EESL has tried handing over the responsibility to the Andaman administration; however, no department had taken charge till the time of the CSE survey.

EESL has also been involved in an initiative in Ladakh's Zanskar valley. Convergence Energy Services Limited (CESL), a wholly owned subsidiary of EESL, has signed a memorandum of understanding with the Ladakh administration for implementing various clean energy and energy efficiency programmes. The pilot in Zanskar will take up solar mini and micro-grid solutions, energy-efficient lighting, energy storage-based solutions, efficient cooking stoves and electric mobility solutions.

METHAN, Patan, Gujarat: Methan village in Patan is home to India's largest biogas plant, run by Silver Jubilee Biogas Producers and Distributors Cooperative Society Limited. The plant has been running since April 1987, and produces gas from cowdung for the villagers.

The plant has eight digesters with a total capacity of 630 cubic metre (cu m). The digesters are used on a daily rotation basis. Every day, one digester is filled with a trolley of cowdung that has been mixed with water in a mixer-well. The temperature inside a sealed digester is maintained at 35 to 55°C; microorganisms in the cowdung get metabolised at this temperature.

The end products of the process are biogas and digested substrate. Methan, with its high cattle population, is never short of cowdung. One trolley of cowdung weighs two and a half tonnes, and costs Rs 125. Dry waste and the digested substrate from the biogas plant is used in the fields as manure. This manure is sold at Rs 300 per trolley.

The biogas is transported from the plant to individual households through underground pipelines. Supply timings are fixed: 6-8 AM, and 6-8 PM. In case households need to cook in between, they use kerosene or LPG. All households that have biogas connection pay Rs 50 a month. Apart from the monthly charge, every household pays one-time charges: Rs 100 for connection and Rs 200 for maintenance. At the time of the CSE survey, 320 of the 500 households in the village were covered by biogas.

All connected households are members of a cooperative society. A management committee, which has women representatives as well, looks into the management and monitoring of the biogas plant.

CHIKBALLAPUR, Karnataka: Chikballapur is an underdeveloped district. During the time of the CSE survey, over 70 per cent of its rural households were dependent on fuelwood for cooking. Women spent almost 16 hours a week gathering firewood, and cooked indoors on open wood fires, which generate harmful smoke.

In 2009, FairClimateFund, a social enterprise, initiated a project to supply biogas to 12,000 farming families in Chikballapur. These families were members of the Bagepalli Coolie Sangha (BCS), which was given ownership of the project; the BCS is entitled to the revenues resulting from the sale of carbon credits. This income is sufficient to cover all costs of the project and the biogas installations. The surplus goes directly in cash to the farming families.

The biogas plants in Chikballapur consist of an underground biodigester in which organic waste, mainly cowdung, is converted into methane gas and bioslurry. The gas is led into the houses through a plastic hose, where it is connected to a two-burner gas stove. The bioslurry, a residual product, is used as fertiliser. About two cows are needed to provide an average household with sufficient gas for cooking on a daily basis.

With 11,633 biogas installations in use, the project claims to have cut down 203,361 tonne of CO_2 emissions, and saved 436,837 trees (from being burnt as fuel).

A PATHWAY TO DECENTRALISED POWER

CHIPIYA, Madhya Pradesh: Chipiya village, with 275 households, is located in a backward region; the main sources of income for villagers is agriculture, supplemented by manual labour, artisanal work, and small-time businesses. In 2019, the community – with the help of Sistema.bio, a biogas solution provider — installed and started operating a small flexi biogas plant, with a daily generation capacity of 70 cubic metre. The plant is fed with cowdung generated by cows in the village's cow shelter.

The community manages to convert three tonne of cowdung into clean biogas for 68 households – it provides clean on-demand fuel, replaces about 50 tonne of wood fuel every month, produces 200,000 litre of biofertilisers every month, and ensures a projected revenue of about Rs 20,000-25,000 per month for the cow shelter. Villagers can also avail of the opportunity to train themselves in operating the plant.

The dried slurry from the plant is being used for vermicompositing by the cow shelter. Using this dried slurry has significantly reduced the number of days needed for vermicompositing — it generally takes 60 days with raw cow manure; with the dried slurry, it takes only 25. The cow shelter sells the vermicompost manure in the market. The cow count has increased at the cow shelter from 700 to 950 cows now due to availability of green fodder.

DIBRUGARH, Assam: Between December 2014 and November 2015, a clean cookstove pilot project was funded by the tea marketing company, Twinings, in Dibrugarh. With a budget of £47,000 (about US $61,650), the project was implemented by Socio Education Welfare Association (SEWA) and aimed at promoting clean cookstoves among tea estate workers.

In this region, a typical household requires three stacks of firewood every year to cook daily meals. One stack is supplied by the management; the remaining two are bought or collected by the households, with children and women spending a disproportionate amount of their time on this.

Over the course of the project, 807 households adopted the clean cookstove. Some community members were trained as master stove makers. The clean cookstoves were estimated to have reduced indoor air pollution by 60 per cent in the single pot user households, and by 90 per cent in the double pot user households, according to the project implementors. The stoves were also 30-35 per cent fuel-efficient.

HIMACHAL PRADESH: The New Delhi-based think tank The Energy and Resources Institute (TERI) has initiated an induction stove pilot programme for rural households in Himachal Pradesh. The aim was to find out what alternative cleaner solutions were available to households that rely on traditional cookstoves (using firewood, cowdung cake, and agricultural residue).

A total of 4,000 electric induction hotplates were distributed to households in Himachal Pradesh. An analysis of primary usage information from 1,000 households indicates that electricity has replaced LPG as a cooking mode, but this has not significantly influenced the primary cooking technology of mud stoves.

The analysis noted that only 5 per cent of the households surveyed moved from firewood to electricity as a primary cooking fuel. Rural households in the lower monthly per capita expenditure classes have less access to electricity and clean cooking options than those in the higher classes. Among rural households with high levels of electrification in India, only three states reported induction stove usage results exceeding 82 kWh per month (the estimated average).

Overall, the results of the study indicated that induction stoves will have limited potential in reducing the consumption of firewood and LPG if included in energy access programmes — that too only in regions where high levels of electrification exist.

JHABUA, Madhya Pradesh: In a scenario where 90 per cent of biogas plants set up by the government of India between 1981 and 2019 have become defunct, the project in Jhabua focuses on operational innovation through community mobilisation, awareness building and providing door-to-door technical support. Operationalised with the help of the global non-profit Enactus, the project has facilitated the construction of fixed dome household-level biogas plants, costing Rs 23,000 — Rs 13,000 of this amount can be reimbursed through government subsidies; Rs 3,000 is borne by the farmer; and the rest is transacted by Enactus. The subsidy availing process has been simplified by minimising the involvement of farmers in it. Enactus has installed 12 household-level plants and revived over 35 existing fixed dome plants that had been set up by the government.

Door-to-door technical assistance is provided for gas and stove connections to ensure safety; explanatory workshops are held for feeding inputs in the right proportion and right way. Each plant produces adequate gas for cooking twice a day for a family of 10-12 people.

Additional cemented structures have been built in every household to process the bioslurry into vermicompost and vermiwash. Monthly training sessions are held on this aspect as well. In collaboration with Jhabua Naturals, a local FPO, the community is provided free organic farming training. The vermicompost is sold under two categories – to larger organic farmers, nurseries and schools at Rs 12/kg through B2B sales, and to kitchen gardens and societies in cities at Rs 25/kg through e-commerce platforms.

About 55 per cent of the profits is used to sustain the operations, while 45 per cent goes to the farmer — thus creating an additional source of income for him. Women of the community have been trained in handling operations of biogas and processing vermicompost out of bioslurry.

In terms of estimated benefits, the project is expected to reduce firewood use for each family from 5.2 kg/day to 1.4 kg/day; 462 trees would be saved every year. The total reduction of carbon footprint is estimated to be 239,878 tonne/year. Use of the bioslurry will enhance soil quality and increase the total produce. Elimination of indoor smoke could result in a 36 per cent decrease in respiratory disorders, and add 1.7 years to life expectancy. A woman could save up to 70 minutes/day with biogas as the cooking fuel, and annual income of households could increase by Rs 75,000 (from vermicompost sales).

CASE STUDIES FROM OTHER PARTS OF THE WORLD

SUB-SAHARAN AFRICA: Here, Modern Energy Cooking Services (MECS), a programme funded by UK Aid, has introduced electric pressure cookers (EPCs) along with e-cookbooks. The EPCs consist of an electric hotplate, a pressure cooker, insulation and an automatic control system. These offer significant benefits in terms of time saving in cooking, cleaner indoor air, safety and convenience (they can be safely programmed and automated), and versatility, as they can be used as a traditional hotplate as well as a pressure cooker.

The families who received the EPCs have been highly satisfied by them. The e-cookbook offered along with the EPCs has been an added attraction – they have been developed in consultation with local populations and cooks, and provide recipes that can be prepared in an EPC, as also the relative cost and cost-saving potential of these cookers compared to traditional cooking methods.

PERI-URBAN NEPAL: In 2019, with support from the Norwegian Agency for Development Cooperation, the Clean Cooking Alliance successfully completed a two-year demonstration project titled 'Maximizing the Health Benefits of Clean Household Energy in Peri-Urban Nepal'. This was designed to support the Government of Nepal's objective to establish smoke-free kitchen communities and improve health outcomes through clean cooking.

Between May 2018 and October 2019, the project studied 1,533 households in Panchkhal and Mandandeupur municipalities. Over the course of the project, 338 cooking solutions – induction cookstoves, LPG connections, biogas digestors etc — were purchased by the households in the intervention area. The focus was on increasing access to and use of clean cooking solutions through behaviour change, demand creation, market strengthening, and household repairs/ upgrades.

An Android-based 'Smart Bhanchha App' was developed to enable induction stove users to monitor their energy consumption and cost of cooking in real time.

The project resulted in some key findings: one, that induction stoves can bring down the use of both LPG and traditional stoves. Families that bought an induction stove managed to bring down their use of traditional stoves by 35 minutes/ day. Secondly, it was realised that adopting induction stoves and other efficient electrical appliances can save consumers money, but energy supply constraints and knowledge gaps need to be addressed. Thirdly, the existing infrastructure in a majority of the homes was incapable of meeting modern electrical cooking appliance requirements – they required upgradation.

DHAKA, Bangladesh: In Dhaka, Modern Energy Cooking Services (MECS) funded a research project titled 'A solar PV based low-cost inverter less grid integrated cooking solution' to investigate the possibility of low-cost solution for grid integrated solar PV based electric cooking system for households using rooftop solar PV.

The project was completed in April 2020 and the findings indicate that such a cooking solution could be highly efficient and cost-effective, with a more than 60 per cent reduction in consumption of grid energy compared to the conventional electric cooking systems.

Under the project, three households were connected to 400-Wp solar PV arrays, and offered a curry cooker and multi-cooker over a period of 18 months. Among commercial establishments, two tea stalls were connected to 400-Wp solar PV, over 18 and 10 weeks; each received kettles. A small restaurant was connected to 800-Wp solar PV array for seven weeks; it was handed out an EPC and a rice cooker.

fact that while many of these costs are underwritten in conventional electricity projects as development charges, the developer of the stand-alone clean energy system has to bear these charges.

A survey done by CSE of the different models of mini-grids in the country found that the cost of generation per unit could range from Rs 6-28 depending on the size of the system and its configuration. The supplied energy costs are high and unaffordable for general use in many cases. But it has been observed that people 'buy' higher cost energy for productive purposes—village-based industry or even to power their irrigation pumps. It is important that the cost of energy is reduced so that it can be used for all purposes, including cooking, in households. Only then will we address the issue of energy poverty.

A SURVEY OF DIFFERENT MODELS OF MINI-GRIDS IN THE COUNTRY HAS FOUND THAT THE COST OF GENERATION PER UNIT COULD RANGE FROM RS 6-28, DEPENDING ON THE SIZE OF THE SYSTEM AND ITS CONFIGURATION

MODELS OF MINI-GRIDS

A CSE study of solar-biomass hybrid-based mini-grid model at Chanpatia village in Pashchim Champaran district in Bihar found that the system is effectively handling the load during power outages as well as ensuring stable and uninterrupted supply for customers. Customers have a higher willingness to pay to the mini-grid-based energy suppliers for their service steadfastness, operational efficiency and tailored solutions, despite the power being costlier than that from grid-based supply. Small commercial customers were found to shift from diesel generators to mini-grid connections.

Some private sector firms—including TP Renewable Micro-grid, a joint venture of Tata Power, The

Rockefeller Foundation and Husk Power Systems—are installing mini-grids to provide quality energy in rural areas.

Tata Power (mini-grid), for instance, has a growing programme as it finds that as a power utility it can provide an integrated service of 24x7 power to all. In this case, mini-grids can be an option even in those places where power supply has reached but is not reliable.

CSE is documenting case studies of mini-grids to review functioning, costs and possible models for scaling up. What is emerging is that while the potential exists, it will be the affordability of energy that will make or break this decentralised clean source of power.

Annexures: Mini-grid projects surveyed in this study

Based on field visits and documentation by CSE

Project location	Technology used	Implemented by	Year	Capacity	Cost-CAPEX (Rs)	Cost-OPEX (Rs)	Tariff	No. of consumers
Raimongol Kumirmari Island, Sundarbans, West Bengal 2021 case study update	Solar PV with storage	WWF India, IndusInd Bank Schneider Electric India Foundation	2016 and completion 2021	22.5 kW: Marichjhapi 23.6 kW: Raimongol	80 lakh for each plant	85,000/ month	Up to 3 kWh: Rs 50/month Above Rs 12/ kWh	400 households
Madavchandra Satjelia Island, Sundarbans, West Bengal 2021 case study update	Solar PV with storage	WWF, Tata Power Solar and CAT international	2010	9.6 kW	80 lakh	40,000/ month	Fixed charge of Rs 50/ month for usage up to 3 kWh Above this Rs 12/kWh	70 households With grid coming to village, usage has dropped
Jargatoli Gumla, Jharkhand 2021 case study update	Solar PV with storage	Mlinda Sustainable Environment Pvt Ltd (India)	2016 Completion by 2018	23.5 kW	91 lakh Fee of Rs 1700–2700 paid for connection		Pre-paid meter for Rs 100 for 2 LED bulbs and 1 mobile charger for 28 days Rs 20/hour for ½ Hp pump Rs 78/hour for 5 HP pump	124 households 19 small pumps, 3 rice hullers, 2 flour mills and 2 shops
Basua, Gumla Jharkhand Grid in village 2021 case study update	Solar PV with lithium-ion batteries for storage Grid connected	Mlinda Sustainable Environment Private Limited (India)	2018	33.3 kW	1.2 crore Fee of Rs 1700–2700 paid for connection		Domestic consumers: Rs 20–30/kWh Commercial: Rs 40–50/ kWh Rs 20/ hour for ½ -HP water pump; Rs 78/hour for a 5-HP water pump	230 households 20 small pumps, 1 rice huller, and 1 welding workshop
Chopan, Amravati, Maharashtra Grid in village 2021 case study update	Solar PV with storage	Maharashtra Energy Development Agency (MEDA)	2019	24 kW	42.5 lakh Deposit of Rs 60 for electricity meter		Rs 7/kWh	124 households

A PATHWAY TO DECENTRALISED POWER

Project location	Technology used	Implemented by	Year	Capacity	Cost-CAPEX (Rs)	Cost-OPEX (Rs)	Tariff	No. of consumers
Fughala and Anghanwadi, Thane district, Maharashtra 2016 case study, published in CSE report, Minigrids for All	Solar PV with storage	Solarisis and Grand Lodge of India (GLI)		3.6 kW x2	5 lakh x 2		Nil	80 households x2
5 villages in Kandhara Reserve Forest, Dhenkanal, Odisha 2016 case study, published in CSE report, Minigrids for All	Solar PV with storage AC/DC system	The Energy and Resources Institute (TERI) and Institute for Research and Action on Development Alternatives (IRADA), funded by Off- Grid Access System for South Asia (OASYS)	2014	13.8 kWp Rajanga (6 kWp) Kanaka (5 kWp) Baguli (2.4kWp) Rajanga hamlet (400 Wp) Chadoi (400 Wp)	60 lakh for 5 plants		Rs 50/ month	140 households
Darewada, Pune, Maharashtra 2016 case study, published in CSE report, Minigrids for All	Solar PV with storage	Gram Oorja, with CSE fund from Bosch Solar	2012	9.36 kW	30 lakh (land was donated by village)		Fixed Rs 90/ month per connection Rs 20/unit (prepaid meter)	36 households + street lights and pumps
Neechli Babhan, Pali district, Rajasthan 2016 case study, published in CSE report, Minigrids for All	Solar PV with pre-paid smart meters	Gram Power With funding from MNRE	2013	5.5 kW	25 lakh Connection fee of Rs 2.8 collected from households		Rs 31.25/ unit (pre-paid meter)	80 households

Project location	Technology used	Implemented by	Year	Capacity	Cost-CAPEX (Rs)	Cost-OPEX (Rs)	Tariff	No. of consumers
Chanpatia, West Champaran, district, Bihar CSE field report 2020	Biomass (husk)-solar with battery storage plant	Husk Power Energies	2017	40 kW solar and 25 kW biomass (for evening and night time)				100 customers, of which 30 per cent domestic, 10 per cent industrial and 60 per cent commercial
Odanthurai Tamil Nadu CSE field report 2021	Wind energy	Panchayat with partial funding from Central Bank of India	2006	350 kW Suzlon windmill	1.55 crore Rs 40 lakh from villagers and rest as commercial bank loan		6.75 lakh units generated each year Self-use is 4–5 lakh units/year. Remaining 2.25 lakh units sold at Rs 2.90/ unit to TN Electricity Board, generating Rs 19.6 lakh/ year which is used to pay back bank loan.	

PART 2

THE CASE STUDIES

THE CASE STUDIES

The research team from Center for Science and Environment (CSE) has visited mini-grid sites to understand and study the various models in use. These models differed in terms of their size, the type of renewable sources being used, funding methods, operating systems, and ownership. This work has been done over a period of past few years – we have documented cases, which have now been compiled in this publication. The year of the case study indicates how updated the information is.

We documented mini-grids as small as 1.5 kW capacity that were using solar PV technology, as well as large 32-kW units, using biomass and solar PV. A solar mini-grid's advantage is its modular nature and scalability, which means it can be as small as a few kiloWatts capacity, or large enough to range in megaWatts. The majority of solar mini-grids in India are small and only serve basic lighting requirements.

We found that most mini-grids are funded through grants from governments, multilateral funding agencies, or corporate houses through their CSR initiatives. There is a wide variety of operating models, depending on who owns and operates them. A government-owned mini-grid charges a small amount for energy use, which is not sufficient to cover operational expenses; a trust-owned mini-grid charges much higher amounts to cover all operational expenses and to build a corpus as well. Some mini-grids are funded by private investors with a profit motive; the power produced by these mini-grids is expensive.

SUNDARBANS, WEST BENGAL, 2021

RAIMONGOL KUMIRMARI ISLAND

The Sundarban Biosphere Reserve (SBR), a fragile ecosystem covering more than 10,000 km^2 of islands, is located in the vast delta of two great rivers, the Brahmaputra and the Ganga. The region comprises of mangrove forests, swamps and islands, all interconnected through a dense network of smaller rivers and streams that eventually flow into the Bay of Bengal, and is frequently affected by extreme weather events (floods, cyclones and storms). Between 2019 and 2021, Sundarbans was battered by four severe tropical cyclones — Fani, Bulbul, Amphan and Yaas.

In this area, boats are the primary modes for travel; to commute within an island, one must walk or ride a bicycle. The region's population of 4.5 million relies heavily on kerosene, candles, and forest biomass for lighting and cooking. The national grid arrived at these remote and isolated islands in mid-2012. But the distribution and transmission networks are often disrupted by weather events, resulting in long power cuts that may take a week or more to restore.

Most of the region's villagers rely on DC batteries as their main energy source. Amidst this rather dismal scenario, the islands of Kumirmari (and Satjelia, covered later in the book) have stood apart with their successful forays into solar micro-grid.

DRIVEN BY SAHASRA JYOTI

In 2016, the World Wide Fund for Nature-India (WWF-India) initiated an energy access project in the Sundabans, called 'Sahasra Jyoti' (literally, a thousand lights). The project aimed at lighting up 1,000 households in the region using solar-powered energy access solutions. The idea was to ensure that communities had access to affordable, reliable and modern energy services that would deliver socio-economic benefits to the forest fringe communities; conservation benefits were also expected from the project. Schneider Electric, the global energy giant, was selected as the technology partner.

WWF-India took over the responsibility of mobilising the community, even as Schneider Electric India Foundation focused on providing technical and knowledge support. During the first phase of the project, 69 households and 25 shops participated in the project.

Under the initiative, Kumirmari has installed two micro-grids — a 22.5-kW one in Marichjhapi and a 23.6-kW project at Raimongol. Plans to install these in 2020 got delayed due to the Amphan and Yaas cyclones; installation was completed in early 2021.

For the operation, maintenance and fund management, Village Energy Committees have been formed. Bank accounts have been opened for these committees, and they are being encouraged to secure common land and land donated by individuals for installing solar panels.

“Around 400 households directly benefit from the project, and there are indirect beneficiaries as well since the local grids illuminate streets, schools, markets, relief shelters and primary health centers. It consists of 120 battery storage units with a capacity of 775 Ah. The micro-grid is beneficial to the communities of the island since the grid power is erratic. Each household has been equipped with a metre to monitor consumption and a changeover to switch power sources between the local grid and the national grid,” elaborates a member of the village energy committee.

A household with a usage of up to 3 kWh is charged Rs 50 per month; the per unit charge for anything above that is Rs 12/kWh.

Today, Sahasra Jyoti is providing reliable, safe solar-powered electricity and energy-efficient LEDs and street lighting to more than 10,000 village households and local businesses in the Sundarbans.

THE IMPACTS

Sundarbans is not a stranger to renewable energy projects: The West Bengal Renewable Energy Development Agency (WBREDA) has been experimenting with introducing different types of RE systems in the islands. But its initiatives have not had the desired results. For instance, the Agency has advocated the use of individual solar home systems (SHS); these systems have been distributed to households. But since they need maintenance of individual batteries and panels and technical knowledge, households have abandoned them and gone back to using kerosene.

The geographical location and climatic conditions of the region pose serious challenges. Ringed by tidal rivers that are almost a kilometer wide in some places, Kumirmari was denied the grid because it is extremely difficult to extend transmission lines from the mainland across the river to these islands: there are technical limitations and prohibitive costs.

Project Sahasra Jyoti has eased the lives of the people, opening up new sustainable socio-economic development opportunities and delivering safe, reliable, affordable, emissions-free and environmentally friendly electricity. With access to lighting after darkness falls, children now have more time to study in the evenings. With well-lit settlements, the risk of human-wildlife interactions has gone down significantly – this has meant led to more community support for environment and wildlife conservation. It has helped increase the average lifespan of inhabitants as deaths due to snake bites and tiger attacks have gone down.

One of the more positive impacts has been in terms of skill development. Capacity building of community-based organisations is enabling them to manage and operate the clean energy infrastructure themselves. This project has also witnessed increased women's participation in the village energy committees. It has also led to the development of local entrepreneurship, home-run business opportunities and wealth creation.

SUNDARBANS, WEST BENGAL, 2021
MADHAVCHANDRA SATJELIA ISLAND

Satjelia island, located in Gosaba block of South 24 Parganas, is one of the 54 human-inhabited islands of Indian Sundarbans, with seven hamlets spread over the two gram panchayets of Satjelia and Lahiripur. Residents in the island depended on biomass and kerosene for meeting the majority of their energy needs. But kerosene is an expensive proposition and unaffordable. Also, the supply of kerosene from fair price shops is limited and did not suffice for cooking as well as for lighting lamps.

COMMUNITY-DRIVEN AND SUCCESSFUL

In 2010, Satjelia set up the Madavchandra Gramin Bidyut Samabay Samity Ltd, which was entrusted with the task of taking forward the island's efforts for getting electricity. In 2011, as a pilot project, Satjelia installed a 9.6-kW solar-powered micro-grid with help from WWF-India, Tata Power Solar, and the Centre for Appropriate Technology (CAT) Projects, Australia, using the 'Bushlight India Model' (see box). The Samity was made responsible for billing, collection and operation and maintenance.

"When this micro-grid project was installed, we used to pay Rs 250 as a monthly fixed charge. On arrival of the grid, the demand for power from the micro-grid dipped. Metres were then installed in the households and the monthly fixed charge was revised to Rs 50 with usage up to 3 kWh; anything above that was charged at a per unit rate of Rs 12/kWh," says Amal Mondol, secretary of the Samity.

For operating sustainably, the micro-grid requires approximately Rs 40,000 a month. It is currently supplying uninterrupted grid quality power to 50 homes, 13 businesses and three community buildings.

Energy service delivery is based on a pre-paid model, akin to telecom services. The premise is that the revenue collected should cover the operating expenses and the cost of the annual maintenance contract (AMC). Cost of the AMC for the first five years and the cost of battery replacement has been capitalised in the project cost. The Samity has set the tariff based on energy slabs opted for by the consumers and has taken into account the life cycle cost of the project.

THE IMPACTS

Local communities say their living standards have improved as compared to other villages. Children can now study at night, and villagers can organise functions like marriages and meetings and keep their shops and businesses open after dark. The installation of street lights has reduced the possibilities of conflict between villagers and wildlife, a common feature in this region, especially after dark.

In accordance with the annual maintenance contract with the developers (WWF India, Tata Power Solar, and CAT International), all the 60 batteries of

THE BUSHLIGHT INDIA MODEL

This model is a comprehensive process for planning and implementing off-grid, centralised renewable energy systems for rural villages – one that is technically and financially sustainable. It is based on the highly successful Bushlight project of Australia, which has provided reliable renewable energy services to remote indigenous communities there since 2002. It is a scalable solution that can provide access to safe and clean energy in the form of grid quality electricity in remote areas.

The 'Bushlight' model involves a comprehensive community engagement and energy planning framework. At Rajat Jubilee island in the Sundarbans, for instance, local residents have been given energy efficiency education and training, which has enabled them to draw up energy budgets for 24-hour cycles. The energy budgets have led to system design allowing provisioning of a pre-determined, assured amount of daily energy to all consumers and providing the community with the information to use this energy to complement and build their livelihoods as they need and choose on a day-to-day basis.

This has been made possible through the installation of a unique demand side management hardware – a programmable energy meter called Urja Bandhu. It is individually programmed to limit the total daily amount of energy used by each consumer to the daily energy budget selected during energy budgeting.

the project have been replaced after seven years. "The cooperative replaces the 800Ah batteries on a rotational basis with the collected fund, so that it is not burdened to replace all 60 batteries at the same time," says Tapan Mondol, who is in charge of maintenance of the micro-grid.

The decision to not bring the grid to Satjelia until 2019 was because of the difficult terrain — the grid would have had to cross a number of rivers. In addition to that, the region is constantly buffeted by high density cyclonic events, which lead to snapping of transmission and distribution lines.

In the event of a cyclone, the delta can go completely dark; micro-grids, therefore, are an important investment. Satjelia (and Kumirmari, covered earlier) have convinced several islands to set up solar micro-grid systems operated, managed, and owned by their communities.

GUMLA, JHARKHAND, 2021
JARGATOLI AND BASUA

JARGATOLI: A WIN-WIN OPTION

The village is connected to grid supply of Jharkhand Bidyut Vitaram Nigam Limited (JBVNL) but people were suffering with long power outages and poor voltage issue. Local ward member Sudarshan Gope says that the villagers could not depend on grid power supply as many appliances wouldn't run on low voltage and since there was no certainty of power supply, villagers did not think of 'wasting money' on buying electrical appliances. "Children faced huge problem in studies, especially during night and some of the villagers had purchased solar lamps to ease the burden," Gope said.

In case of faults in power distribution line, the villagers could not expect any respite immediately as repairs would often take more than a week. Power supply with proper voltage was rare and like an occasion for the villagers but they were never sure how long the households are going to remain lighted. There was no arrangement for street lighting.

Charging mobile phones was a big challenge whenever there was a power outage for more than a week. The villagers would collect their mobile phones and give it to some shopkeeper, who usually went to the town for purchasing goods so that he can get a few mobile phones charged there.

Since the agrarian village takes two-three crops from the field they have to arrange irrigation on the fields instead of depending upon monsoon. Earlier the arrangement for irrigation was through diesel operated water pumps for which they had to face double-trouble in form of spending huge amount on purchasing diesel and transporting the diesel on motorbikes to the village which is nearly 8 Kms from the nearest fuel station.

Due to irregular power supply none in the village dared to open rice haulers or wheat grinding machines as a result of which they were dependent on neighboring villages where these facilities were available.

Ward member Sudarshan Gope remembers that in 2016, they started hearing about solar plant coming up in some village and the fact that if solar grid is installed, it can provide power supply round the clock. "I tried collecting information and was told that if villagers raised a demand, such an arrangement would be provided to our village as well," he said.

Gope met a person named Chhatrapal who was instrumental in 'bringing' solar power to some distant village by bringing in a foreign company named Mlinda. Soon after, Baiju Pahan, field officer of Mlinda (Sustainable Environment Private Limited-

India & Mlinda Charitable Trust-India) asked Gope to arrange a meeting with the villagers. The community meeting was addressed by Pahan in which he explained to the villagers, the benefit of having uninterrupted power supply through solar powered micro grid. "As many as 40-45 people had agreed to take power connection, even after being told that they have to pay an upfront amount of Rs.1700," Gope remembers.

Once the villagers agreed for a solar plant, next challenge was arrangement of land for installation of the project. A plot of land measuring around 35 decimal, belonging to one Mangaldev Oraon was identified. At a monthly rental of Rs.1200 Oraon agreed to give his plot on lease for a period of 20 years. Based on the power requirement, which depended directly on the number of households agreeing to take connection, Mlinda decided to install a 20kWp plant for which installation of solar panels and other equipment began.

An integrated 23.5-kW mini-grid was installed, aimed at providing round-the-clock power supply to the connected households; coupled with a diesel generator as a back-up, this system was envisaged as a dependable and independent distribution network for the villagers. The system became fully operational by February 2018. Over 80 per cent of Jargatoli's households are now connected to it.

Villagers believe that apart from quality power supply, it has helped them in irrigation. A teacher Ajay Kishore Mishra says that though the supply is costlier than government supply, their expenditure on diesel for irrigating the fields has reduced considerably. “We have to pay a minimal fixed rental for the government grid supply line but we cannot depend on it whereas the solar power, even if costly, is dependable,” he said.

The solar powered plant located at the centre of the village covers households within a 2-km radius. The power lines are permanently taken through poles erected by the company. However, temporary connection is extended to farmers’ fields for connecting water pumps for irrigation. For this purpose, adequate extra wire is available with the plant office.

During installation, a booking amount of Rs 1,700 was taken from each household. For this price they were provided with two points for LED bulb and one socket (for charging mobile or using any other appliance). The meter, wire and pole arrangement was done by the power suppliers. Rs 500 credit was given in form of pre-paid token in their meters.

According to villagers, two LED bulbs and one socket, if used every evening, costs around Rs 100 in a month. Villagers are not aware of the unit cost of power. Pre-paid meters one for each household are fixed outside houses on the nearest electrical pole. They get their meters recharged and use the power till the time it supports. “We can see our balance (in terms of money left) in the meter and accordingly either reduce consumption, if we don’t have enough to re-charge our balance, or get it topped up immediately to continue using the power," said Ajay Mishra, a teacher.

Villagers have understood that private power is expensive than government supply but since the quality of power outsmarts grid power they have no complaints. "We are not going to disconnect grid supply because for a fixed amount we are assured of getting power, whatever quality it may be but the private power gets disconnected immediately when we do not have cash to recharge," added Mishra.

After initial investment on erection of the plant, the only expenditure that the power producers have to meet is on humanpower and maintenance of the infrastructure. This makes their business model depend on higher consumption to draw bigger revenue. So, apart from round-the-clock power supply, the company officials gave away electrical appliances to the villagers at subsidised rates, a move aimed at increasing their power consumption threshold. Refrigerators, TV sets, mixer grinders and induction stoves were distributed at 30-50 per cent subsidised rates. It was a win-win situation for both the consumers and the power producers. Today, at least 50 per cent of the households have LED TVs; many of have induction stoves, ceiling fans, coolers and other electrical appliances.

"When you start using appliances without any checks and balances, the monthly expense can reach up to Rs 3,000 or even more — the power is costly," says a villager who has been a customer since the beginning.

FINANCIAL SUSTAINABILITY

The mini-grids provide 24-hour, seven days a week energy for productive agricultural and commercial needs as well as domestic night-time use. Part-time engineers and one full-time operator stay in each village and work with the communities – individual entrepreneurs, women's self-help groups and farmer groups – to shift to devices powered by the mini-grid supply. They also work to improve consumption. These ties ensure that the company builds relations of trust with the community and that quality service is provided.

Local operators are also trained in maintenance and repair of the mini-grids. The grids are designed to increase in capacity as demand grows. Once a grid reaches 95 per cent capacity utilisation, an additional 5 kW array is installed to enable the community to meet its growing demand.

The company's charges are pay-per-hour for commercial usage, and irrigation is a common use. Almost every family uses the solar-powered electricity for irrigation. For a half-HP water pump, the charge is Rs 20 per hour; the amount goes up to Rs 78 per hour for a 5-HP water pump. In case a farmer does not have a water pump, the power company provides him or her with a free pump. "We don't have to spend a single penny for the water pump or wire for connection. Mlinda officials get it fitted to our fields for free and we only pay for the power consumed," says Sudarshan Gope, ward council member who encourages villagers to avail this facility and save money from wasting on buying diesel for diesel-operated water pumps.

The power supply has helped villagers set up one wheat grinding facility, one rice hauler and an oil spiller. The rice hauler and oil spiller were established by the Mlinda office on the premises of its plant, where villagers would bring oilseeds or rice for processing. The model functions on a pay-per-hour basis.

During marriages and other functions, villagers can now arrange DJs from nearby cities. Thanks to the availability of power, they do not hesitate in booking power supply for few hours during the night.

BASUA: 50 PER CENT CONNECTED

The community of Basua is connected to the grid supply of Jharkhand Bidyut Vitaram Nigam Limited (JBVNL); but the supply suffers from long power outages and low voltage. In the past, students would study under kerosene lamps. But over time, kerosene became unaffordable, costing Rs 80 per litre in the open market. The supply of kerosene from fair price shops was limited and did not suffice for cooking as well as for lighting lamps. It was a challenging task to charge emergency batteries and mobile phones; every time there was an extended power outage, villagers travelling to the nearest town would take the mobile phones of other residents to get them charged.

Many residents of Basua are farmers and need power to irrigate their fields — diesel-powered water pumps was what they relied on. These pumps could be hired at a rent of Rs 60-80 per hour of operation; coupled with Rs 90 per litre of diesel, irrigation proved a costly exercise.

Then there are those residents who work in cities. Dharmendra, Basua resident, says that whenever his brothers would come from Mumbai (where one of them works), he would be aghast at the power condition. “I purchased a battery-operated emergency light so that our children could study at night, but the light would hardly function because it was difficult to charge it on the low voltage that we received,” he says.

As in the case of Jargatoli, the villagers of Basua reached out to Mlinda for establishing another plant. The company was already well-known in the Ghaghra and Gumla blocks. As of February 2018, it had set up mini-grids in Jargatoli, Gunia, Tigra, Patia and Pandariya villages. At a community meeting organised in Basua, over 50 families readily agreed to apply for solar mini-grid services at an upfront fee of Rs 1,700; those who failed to apply in this initial meeting, had to shell out Rs 2,700 for a connection later.

Initially, Basua got a 23.6-kW mini-grid integrated with lithium-ion batteries. Synchronised with diesel generators, it provides round-the-clock power supply to the connected households through its own distribution network. The system became fully operational in June 2018; more than 50 per cent of the village’s households are now connected to it. The mini-grid's capacity was increased to 33.3 kW due to a rise in demand.

The Basua mini-grid provides power for agricultural, commercial and domestic use. Consumers pay a connection charge, and a regular cost for the energy used, based on readings rendered by pre-paid metres. Domestic consumers are expected to pay between Rs. 20-30/kWh, while commercial users must pay Rs 40-50/kWh.

Commercial use is billed by the company on a per hour basis, and irrigation is a common use. The village has up to 20 small irrigation pumps, one rice hauling machine, and one welding shop. Water pumps (1/2 HP) are charged at Rs 20 per hour, while 5-HP pumps are billed Rs 78 an hour. A water pump is provided by the power company to farmers who do not have one. The cost of renting the pump has been eliminated, as with diesel water pumps.

A standard connection of one socket with two LED bulbs was not proving to be viable for the power generators, with a household, on an average, billing not more than Rs 500 worth of power every month. To increase consumption, the company provided electrical appliances at subsidised prices. An engineer from Mlinda works with the community to maintain and run the system, local operators have also been trained to maintain and repair it when necessary.

THE IMPACTS

Residents of both villages claim that their living standards have improved, compared to similar villages elsewhere. Children can now study at night. Villagers can organise functions like marriages and meetings — for doing this, they no longer have to give up on their day's work in their crop fields. Using a solar water pumping system, farmers can also irrigate their fields thrice a year. In the villages, the main thoroughfares are now illuminated, making life more secure for women and girls who leave for work or school at night. Indu Oraon plays with her friends until late evening at the village quadrangle, which is illuminated these days.

In fact, all this has now led to a demand for better schools and coaching centers for the children and youth of Jargatoli and Basua.

AMRAVATI, MAHARASHTRA, 2021

CHOPAN

Chopan is a tribal village located in the core forest area of Melghat. The people of Chopan, which is under the Chaurakund Gram Panchayat, belong to the Korku community. The residents speak Korku and Hindi; a few who travel outside the village can understand basic Marathi, but they cannot speak it fluently.

Surrounded by hills and valleys on all sides, Chopan is situated on a slightly elevated ground. Lata Jolle, anganwadi worker of Chopan, says the total population of the village is 530, residing in 124 houses. The villagers are subsistence farmers or daily wage agricultural workers. When they were asked by CSE researchers about alternative sources of income such dairy or poultry farming etc, their reply was that the Gawli community of Chaurakund had a monopoly on these businesses, and Korkus were not welcome in them.

The literacy rate among adults in the village is low – only three to four people between the ages of 35 and 40 are literate. According to Ramdas Dhikar, husband of the Chpan sarpanch, most of the children in the village used to go to the local school – till the pandemic struck and the school shut down. Many parents do not agree to send their children to the local school after the 5th standard, as they have to be sent to the Ashram School for tribal children located outside the village.

The people of the village cook using biomass as fuel in their chulhas. Solar power has come, but electric stoves have not arrived yet. In fact, the villagers have started recognising electrical appliances only recently, after electricity reached Chopan. In December 2019, single plate (12 Watt) connections were provided to each household in the village under the 'Saubhagya' scheme. But it did not provide enough light.

Currently, while 30 to 35 households in Chopan have received gas connections, the families do not know how to use it! A gas cylinder accident in the sarpanch's house has queered the pitch further – fearful, people have gone back to cooking on chulhas.

Ramdas Dhikar says: "There was nothing in our village 20 to 25 years ago. We had no acquaintance with the outside world. The forest was our world."

CHANGE COMES

Chaurakund village was included in the Village Social Transformation Foundation (VSTF) scheme of the Maharashtra Government. A meeting was organised in Chaurakund village to implement various development schemes under VSTF. The issue of household electricity for Chopan was raised in the meeting and after discussion with the sarpanch and village elders, it was decided to provide solar electricity to Chopan village.

The Maharashtra Energy Development Agency (MEDA) decided to install the solar grid in Chopan. The solar micro-grid installed by MEDA has been set up on the village common land.

This 24-kW micro-grid has been installed at a cost of Rs 42,44,490. Expenses have been borne by the MEDA — maintenance will be done by the concerned solar company for five years. Lalchand Dhikar, a young man from the village, has been trained to maintain the solar grid in the village on a daily basis. For this, he is paid Rs 3,000 per month from the money collected from the villagers towards electricity bills. Lalchand is also entrusted with cleaning the panels and other parts of the system..

Villagers use the electricity for running fans, TVs and charging mobile phones. A committee of 13 villagers has been formed which decides on the electricity billing. Each customer (villager) has been given a free electricity meter; a fixed deposit of Rs 60 has been taken from each one. Electricity is supplied to the customers at the rate of Rs 7 per unit and consumption ranges from 5 to 30-35 units per month. The electricity bill amount ranges from Rs 35 to Rs 400-500. The total collection of the village ranges from Rs 6,000 to Rs 16,000.

Some 25 street lights with LED bulbs have been installed in the village. Electricity lasts for about eight to 10 hours, which is used for agricultural work.

WHAT HAS CHANGED?

With the arrival of electricity in the village, doors to the outside world have opened up to the villagers. One by one, 10 to 15 TVs and fans have come into the village. Villagers can now view government schemes and news. “We didn’t know who are our district collector and chief minister. In just two months, about 40 to 50 Android phones came to the village. However, the villagers have to climb a hill five kilometres away to access the network.”

THANE, MAHARASHTRA, 2016
FUGALE AND ANGHANWADI

Fugale village in Kasara taluka of Thane district is approximately 105 km from Mumbai, located off the Mumbai-Nashik highway. The village has a total population of 1,018, distributed across 168 dwellings. As per 2009 statistics, Fugale has a gram panchayat. About a kilometre from this village lies the hamlet of Anghanwadi. Both the villages are in a valley connected by a kachcha (unpaved) road to the rest of the world.

A majority of the communities in these villages are dependent on agriculture for their livelihoods. Till 2011, the villagers did not have any access to electricity due to the remote terrain and sparse population.

POWERED BY SOLARIS

In June 2011, solar power plants of 3.6 kW each were commissioned at Fugale and Anghanwadi by Solaris, the solar energy solution provider. The project cost of Rs 10 lakh for both the projects was funded by the Grand Lodge of India (GLI), an association of freemasons called 'Jyotirgamaya'. This was focused on lighting up 80 villages in remote areas of the country by setting up solar systems. GLI coordinated with local communities to identify the villages that could be targeted, the demand, and the load study of the households. Funds for the project were collected through donations.

The power from the plants feeds one 11-Watt CFL lamp to provide the basic lighting needs for each connected household; additionally, each village has been given four streetlights. There are 15 panels of 245 Watt each, arranged in three arrays. Lines have been drawn from each of these arrays to connect 25-35 households in each village. The power provided to the households is free of charge.

A villager in each village has been trained by Solaris to operate the plants. "I was only taught the basics of how to turn off a particular line in case of an overload. I can also turn off a line if the batteries are not charged properly and can turn it back on later," Sitaram, the operator in Anghanwadi, told CSE researchers. Sitaram is a taxi driver. He checks the plant daily before he leaves for work (at 10 AM), and after he returns.

Sitaram can also identify faults in wiring and minor external troubles. When the charge controllers or the batteries fail, he has to call engineers from Solaris for a maintenance check. He has a mobile phone — villagers can inform him in case of problems.

NOT A PLEASANT EXPERIENCE

There are complaints about Solaris. "The maintenance provided by Solaris is very poor," says Sitaram. "It takes them at least a month to respond to any complaint; sometimes, we have to make do ourselves, especially with respect to the CFLs. About seven months ago, two of the three lines in Anghanwadi stopped working. At first, I thought there was a problem with the inverter and tried to fix it myself as the company technician did not turn up. Now I feel there is a problem with the wiring. I have tried to check and fix it, but could not. The lines have not been working since then. The problem worsened when children got access into the power plant when I was away, and now it is a complete mess," he adds.

Technicians from Solaris have not showed up even once in the last seven months. Due to lack of support, the entire system in Fugale has stopped working and the villagers have had to go back to kerosene lamps and lanterns. In Anghanwadi, one of the lines is still working and powering about 27 households. Solaris is obviously not interested in operation and maintenance of these solar micro-grids, since there is neither a revenue mechanism in place nor a clear ownership of the projects. This has made these solar plants virtually non-operational.

In 2016, both the villages were electrified under the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) scheme; villages have welcomed the coming of grid-based power. The solar power plant remains unused except for the single line in Anghanwadi which acts as a back-up (for a few households only) when grid power fails. A resident of Anghanwadi complains that the light from the solar power plant "has become much dimmer these days. It flickers a lot and we have to turn it off; light from a kerosene lamp is better."

Grid power is scheduled for eight hours a day; consumers are charged Rs 5 per unit. According to Sitaram, households generally consume about nine to 10 units per month if they have TVs and other appliances; otherwise, consumption does not cross five units.

But the grid power is erratic. "Power cuts in both villages are common," says Ekanath, the operator of the solar power plant in Fughala. Some months, the villages have to go without grid power. Villagers rely on kerosene for their lighting and cooking needs. "We end up spending about Rs 150 per month on kerosene," says Dadu Chendar Agan, a resident of Anghanwadi. The TVs and other gadgets purchased by villagers become useless without power.

Source: This case study was first published by CSE in a 2016 report, Mini-Grids: Electricity for all?

DHENKANAL, ODISHA, 2016
RAJANGA AND OTHER VILLAGES

Rajanga is one among a cluster of five villages inside the Kandhara Reserve Forest in Odisha's Dhenkanal district (one of the most backward districts in India). The total population of these villages – which comprise around 140 households — is a little more than 550. As these villages are located inside a reserve forest, they have remained out of the ambit of all electrification programmes of the government.

THE POWER OF 'MANY'

In 2014, the New Delhi-based The Energy and Resources Institute (TERI), along with its grassroots partner, the Institute for Research and Action on Development Alternatives (IRADA), implemented an AC/DC mini-grid project in this cluster of five villages. The project was funded under Off-grid Access System for South Asia (OASYS South Asia) and Rural Electrification Corporation (REC) in a ratio of 80:20.

OASYS is a research association led by the UK-based De Montfort University to identify techno-economically viable, institutionally feasible, sociopolitically acceptable and environmentally sound solutions for decentralised off-grid electricity generation in South Asia. OASYS aims to conduct systematic analysis to develop an off-grid delivery model framework and implement it through demonstration projects in un-electrified villages in different parts of India. These projects include mini-grids, micro-grids and pico-grids, providing either AC or DC power to households and shops/ micro-enterprises.

The project's unique selling proposition was its advocacy of a cluster-based approach for decentralisation. In every identified cluster, it helped establish a Village Energy Committee (VEC), a single institutional entity, having representatives from all the villages, for operating and managing multiple power plants installed in each village.

In Rajanga and its neighbouring villages, the total project cost was around Rs 60 lakh for five mini-grids — Rajanga (6 kW), Kanaka (5 kW), Baguli (2.4 kW), Rajanga Hamlet (400 W) and Chadoi (400 W). The cost included the building of a community hall for villagers. The developers estimate that the cost of the project would be reduced by Rs 8-10 lakh if the building cost was excluded.

As one of the models under OASYS South Asia, this project was designed to ensure the community is an integral part of it. The idea was not just to provide lighting services to the community, but also to generate new activities for livelihood of the inhabitants. Thus, in addition to lighting and facility for charging mobile phones, the project also aims at providing livelihood opportunities by providing power for occupations and activities like spices grinding, packaging, sal leaf plate-making, irrigation, and installation of fans and street lamps in community areas and institutions.

To make sure that the community was involved at every step of the development of the project, a Village Energy Committee (VEC) was formed. This committee was responsible for the operation and management of the project.

THE IMPACTS

The people living in the villages and hamlets in Kandhara Reserve Forest have never had access to electricity. According to Debajit Palit of TERI: "Since the villagers had never interacted with power before, you have to give them some time. Demand projections in these instances become next to impossible." Lalita Pradhan, member of Rajanga's Village Energy Committee, says: "We were living on roots and fruits from the forest and didn't know what 'electric light' was. Now my children are able to study at school in the daytime and at home in the evening. They even take tuitions in the evening. I am really grateful for the light."

The Rajanga project raises the question of whether a single mini-grid of a higher capacity should be considered, rather than smaller distributed mini-grids. A single system makes more operational sense, but the cost of distribution would have been too large as these five hamlets are scattered and far

GRID-READY IN RAJANGA

What can be deemed as a grid-ready mini-grid project? In terms of distribution infrastructure, the Rajanga project uses insulated cables for distribution lines and standard 30-feet concrete poles. These are based on the prescribed norms of the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY). They are technically sound and follow all the safety measurements defined by RGGVY. The project was designed so that when the actual grid reached the village and a transformer or supporting capacity is set up for the supply of power, the distribution lines would be capable enough to carry power to the villagers without any damage to the infrastructure. These distribution lines have been checked by the electrical inspector authorised by the state electrical licensing agency as well.

A mini-grid that is grid-interactive would have an inverter that would draw power from the grid in case there is a deficit, and supply any excess generation back to the grid. The inverter that we use in our homes to supply electricity while there is a power outage, in contrast, only charges the battery with power from the grid and supplies electricity to homes when required. It cannot transport excess electricity back to the grid.

In the case of this project, an SMA inverter has been used in one of the three villages based on AC mini-grid. This has the capability of not just drawing power from the grid, but also exporting power back to the grid. SMA inverters are 30 per cent more expensive than regular inverters in the market because of their dual function of drawing and exporting.

way from each other. A better-designed model that does not need frequent maintenance made more sense than a centrally located system.

However, for the management of the system, a single entity was formed covering the group of five villages. Every household pays about Rs 50 per month for the use of five to six hours of electricity in a day. If consumers use the livelihood services, they pay a service charge for each activity as well.

Of the project's five mini-grids, three are based on AC and two on DC systems. The hamlets where DC mini-grids have been set up are very small villages, with just 12-15 households; for these villages, the

DC mini-grid made more sense for power supply for lighting needs as well as for rationalising the costs of transmission lines. The two DC mini-grids have been operating without any problems for one and a half years. Those with AC mini-grids need comparatively more maintenance of the inverters.

PUNE, MAHARASHTRA, 2016
DAREWADA

Darewada, in Khed taluka, is a picturesque hamlet nestling in the Sahyadri mountains in Maharashtra. Located about 140 km from Pune (even the nearest motorable road is two km away!), this remote village has only 39 households, inhabited by 220 people of the Mahadev Koli tribe. Till 2012, Darewada had no access to electricity, depended solely on kerosene for lighting, and existed in its own world, disconnected from the rest of the country.

A SUCCESSFUL PILOT

In early 2012, Bosch Solar Energy AG and Gram Oorja Renewable Energy Solutions, both based in Pune, entered a partnership to provide basic electricity requirement to the village with a solar-based micro-grid. Bosch was persuaded to fund this as a pilot project to establish a business model that works efficiently, and is sustainable as well. Shakti Foundation was the nodal NGO that provided consultation and guidance.

Gram Oorja Renewable Energy Solutions was founded by four graduates with diversified backgrounds and a keen interest in approaching the problem of energy access in rural areas by creating a local micro-grid based on renewable energy sources (solar, biogas, biomass, small wind, micro-hydel etc). Bosch Solar Energy AG is a German solar wafer and solar cell manufacturer.

The Darewada micro-grid has been independently managed and maintained by the village energy committee formed at the time of its installation. In order to ensure that villagers have a sense of ownership of the project, Gram Oorja encouraged them to participate in setting up the unit and managing it every day. The village energy committee is responsible not only for supplying power to households and collect bills every month, but also for depositing the revenues in a bank account as a corpus fund.

Anshuman Lath, co-founder and head of Gram Oorja, says, 'Villagers pay a fee for the use of the energy, which in most cases is enough only for the operations and maintenance (O&M) of the system. Therefore, the capital expenditure for setting up the micro-grids is entirely dependent on grants or subsidies."

The power plant provides lighting to all 36 households in the hamlet, with 17 poles erected to help provide power distribution. 'Due to the solid rock foundation in most areas in the hamlet, they had to be blasted in order to fix the poles, and these measures were adhering to Maharashtra State Pollution Control Board standards,' Lath says. Every household has a basic connection of one 2-Watt (W) LED light and two 4-W LED lights. “Some of us could afford a TV set, and there are currently seven TV sets in the village,” says Vijaya Borhade, a resident of the village. Apart from these, there are 10 street lights with a 12-W LED light each.

Residents of the village have now asked for a 2-HP water pump, according to Gram Oorja. The entire distribution system is designed at 230 volts AC, 50 Hz frequency, and single phase. Twenty-four Amaron batteries of 600 Ah, 48 V are placed in the control room right next to the power plant to provide power during the night.

The entire cost of the project, including equipments – Rs 30 lakh — has been borne by Bosch Solar. The land for the project (about 50 x 30 feet) was donated, free of cost, by a resident, Shivaji Shelke. This is the first pilot for both the parties and learning from the project will help reduce the cost at least by 5 per cent in the projects that will follow, provided land is free (see Table: Costs).

Darewada is getting 24x7 electricity, but at a high tariff; the electricity generated is currently being used for residential as well as commercial applications. Power for residential applications is available throughout the day, while that for commercial applications has a time restriction and can be used only between 11 AM and 4 PM under peak condition.

Electricity tariff has two components—fixed and variable. The fixed component is the same for both domestic and commercial connections at Rs 90 per month per connection. The variable component is charged at Rs 20 per unit. However, due to small consumption levels and high per unit cost, 0.1 kWh is considered as one unit for which Rs 2 is charged. An energy metre is installed against each connection.

Most residents pay an average monthly bill of Rs 100-140. Those with a TV pay more, depending on usage. To prevent overdrawing of power, a protection unit or load checker has been installed with each energy metre. Anil Lau, a resident of the village and the trained operator of the power plant, is responsible for collecting bill payments.

Table: The costs — break-up of Rs 30 lakh for a 9.36 kWh plant

Capacity (kWh)	9.36
Panel cost (Rs lakh)	6.75
Battery cost (Rs lakh)	2.65
Inverter cost (Rs lakh)	6.5
Cost of fencing (Rs lakh)	0
Cost of PDS (Rs lakh)	5
Other costs (Rs lakh)	9.1
Total project cost (Rs lakh)	30
Net cost per Watt (Rs)	320.51
Benchmark per Watt cost (Rs) of MNRE	300

Source: Interview with Gram Oorja executive, 2016

THE IMPACTS

Having completed nearly a year of operation at the time of the CSE visit in 2013-14, the Darewada plant had generated about 3,230 kWh – at an average daily generation of around 9.7 kWh per day. This means the company is able to generate at least Rs 70,000 in revenues per year, excluding the fixed costs. Adding the fixed cost of Rs 90 per connection per month for 36 households, the annual revenue collection goes up to Rs 1.38 lakh per year.

What this basically means is that the company would be able generate enough revenues for all the O&M expenditure, including replacement of batteries in a cycle of four to five years. The plant was currently operating at a very low plant load factor and had the ability to cater to a larger demand and earn more revenue. The collected revenue is currently deposited in a trust bank account—Vandev Gramodyog Nyas—which has been opened in order to take care of the O&M expenditure of the project.

The plant operator (Anil) is primarily a farmer. "As an operator, I am being paid a very small sum of Rs 300 per month due to the few hours of work required," he says. The plant has withstood its first exposure to monsoons. Villagers note that there has been only one occasion when the plant did not function for little over a day because the battery had been completely drained owing to a local function where speakers and amplifiers were used. Loads were disconnected from the system and the batteries were allowed to get charged for a day.

The residents are upbeat about the solar power system, which, they say, has impacted their lifestyle positively. The television sets are used almost every day. "We feel connected to the rest of the world as we follow the news and the cricket matches," says Sudhatai Lande, deputy sarpanch of the village. Says

UPDATE: 2021

In 2021, the micro-grid, which had served the community for nearly a decade, was replaced by the national grid which is unreliable and offers poor quality energy. In spite of replacing the battery bank in 2019, the micro-grid shut down due to an absence of tariff regulations to charge consumers and feed power to the grid.

Borhade, a resident: "I am happy for the younger generation. They can now study under electric lights." Another resident, Bhimabai, adds: "We can cook comfortably at night. My children can play outside freely in the evenings."

Having successfully implemented this pilot project, Gram Oorja plans to execute 10 more micro-grids in the next year, providing 24/7 electricity. The target is reaching 1,000 villages after satisfactory demonstration of the commercial viability of the pilot projects in another three to four years. The company is in discussion with villages in several parts of central India, mainly Bundelkhand and Madhya Pradesh, to educate the people about this non-conventional method of electrification. Initial surveys have also been completed in several villages in North Kanara district of Karnataka, where the company has identified the design, resource for power generation and demand, and estimated the funds required for each village. However, nothing much has happened on the ground due to lack of funding support.

PALI, RAJASTHAN, 2016
NEECHLI BABHAN

Neechli Babhan is a village in Pali district, in the desert state of Rajasthan. It has a population 1,047, living on an area of around 15 sq km. The otherwise non-descript village has emerged as an important example in any study on mini- and micro-grids in the country.

USING TECHNOLOGY TO MOVE AHEAD

It looks like a regular electricity metre, but an innovative version is changing the way people use electricity and pay for it. Neechli Babhan, a small village in Rajasthan's Pali district, has a 'smart metre' installed in 80 of its 150 houses. The metre forces people to use electricity judiciously.

Gram Power, an energy technology company founded out of University of California Berkeley by two engineering graduates, invented the device. Mohan Singh, a daily wager, says it displays real-time credit information just as prepaid mobile phones do. Additionally, it shows the amount of time an appliance can be used. "We have only Rs 30 left," says Singh's 10-year-old daughter. As she shows off how well she can read a metre, she asks Singh to get the metre recharged before the credit runs out. Mohan calls Udai Singh, who recharges smart metres in the villages and hamlets.

Udai Singh arrives within 10 minutes at Mohan's house with an instrument, a dongle the size of a mobile phone. He puts 100 on it for the Rs 100 that

Mohan pays him, puts it close to the smart metre, and presses a button. A clicking sound is heard and Rs 130 is indicated on the metre's screen. Mohan can light an 8-Watt CFL for 400 hours with a Rs 100 recharge.

A 5.5 kW solar micro-grid has been installed on the roof of a local school to provide electricity to the village. Neechli Babhan is off the main grid due to its rocky terrain. The electricity is stored in batteries and is available 24 hours a day. Until September 2013, the plant generated 4,600 units at a capacity utilisation factor of 16 per cent.

The system has checks against power theft. The smart metres in the village are connected wirelessly and can be controlled online. They can detect a wire attached to a distribution line, and the line is shut down immediately.

THE CHALLENGES AND IMPACTS

As long as people use electricity only to illuminate their houses, smart micro-grids work very well. As soon as they increase its use, the costs rise. A CFL of 8 Watt costs 25 paise for one hour of use. Using two CFLs for six hours a day would cost Rs 90 per month for a family of four. However, if they wish to run a ceiling fan or a television, the cost of electricity goes up.

Think about it: a 70-Watt ceiling fan costs Rs 2.50 to run for an hour. It would cost a family of four Rs 450 a month just to sleep comfortably at night and use a fan for six hours, an amount that can cause sleepless nights for the people of Neechli Babhan, who are mostly daily wage earners. In order to avoid this expense, women of the village gather under a big neem tree during the day. “We save money, so that we can use a fan in the evening when our children study,” says Savita Rawat, a resident.

Another challenge is the service and maintenance. “We have trained vendors to address small problems. The head office sends people to deal with major issues,” Yashraj Khaitan, founder, Gram Power, explains.

Including power storage, the cost of power generation in micro-grids below 10 kW is Rs 28 per unit. CSE’s research in 2016 showed consumers in Neechli Babhan paid about Rs 3.25 per unit. “That is why we have developed a pre-paid system. People can budget their power usage. We can do no better than this, otherwise the model will be financially unviable for the company,” Khaitan says. In five years, he hopes to recover the cost of installing the micro-grid.

Capital cost for the smart micro-grid was Rs 25 lakh. The Ministry of New and Renewable Energy (MNRE) provided Gram Power with a 30 per cent subsidy on capital costs for off-grid systems. A connection fee of Rs 2.8 lakh was collected from households by Gram Power. The rest was raised from private investors.

Khaitan explains that low government subsidies make it difficult to make financially viable projects while maintaining a low electricity rate. “Better funding mechanisms are needed. Banks should provide low interest loans to developers working in off-grid areas," he suggested to CSE in this field report.

SARAN, BIHAR, 2020
JALALPUR

Jalalpur village is connected to the grid supply of the North Bihar Power Distribution Company Ltd (NBPDC). As in any other rural area, erratic supply, power cuts for long hours and poor voltage were common problems here – when local residents heard of a 'unique power solution' being offered by a solar power mini-grid plant in neighbouring districts, they were naturally curious. Some of them approached the company in question — Husk Power Systems — and persuaded them to install a similar plant in Jalalpur.

The 30-kW solar mini-grid based on tubular gel battery (TGL) battery with diesel genset back-up provides uninterrupted power supply with its own distribution network. Customers include shops in the local market and a few households (over 75). The site identification and consultations had begun in 2016-17, and the plant was finally commissioned in 2018 by Husk Power.

Md Kalamuddin, who runs a bicycle showroom at Jalalpur market, says that earlier, most of the shopkeepers were fully dependent on diesel generator sets or rechargeable emergency lamps for lighting. A similar view is expressed by Sujit Kumar, owner of a grocery shop: "For a commercial enterprise, reliable power is a must. The diesel generator was providing power for only a few hours. It was not possible to maintain a fridge to keep cold drinks, butter and chocolate."

About 70 yards away from his shop is a saw mill. The mill owner, Joginder Sharma, says: "We were not able to work for more than four to five hours due to frequent power cuts and low voltage. Our business was badly affected due to this situation."

Jeevan Kumar Rai, electrician-cum-operator of the mini-grid, says most of the local people were not aware that power could be generated from a solar plant. Others were not sure that solar power would be reliable and round-the-clock. "Initially, a team of Husk Power System officials visited several times and met owners of commercial enterprises and local villagers to plan for setting up the plant. Later, the officials also hold a series of meetings with potential micro-enterprise customers and finally took a decision," says Rai.

According to a local community leader, one of the villagers agreed to lease out his 10 katha of land for setting up the plant at Rs 15,000 rent annually. Based on the power requirement, which depended directly on the number of households agreeing to take a connection, Husk Power Systems formally started installation work.

The Jalalpur mini-grid is funded fully by Husk, which has an international shareholder base. Households are provided with pre-paid metres as per a monthly package design. For commercial connections, pre-paid and post-paid meters are provided, one for each connection, fixed outside shops or workshops on the nearest electrical pole. All meters connected to an online system and a customer has access to monitor it any time.

The power lines are permanent, taken through poles erected by the company. However, temporary connections can be extended to commercial users or those who want to use during functions like marriages. For this purpose, adequate extra wire is available with the plant office. The power supply has helped villagers run saw mills, an iron grill workshop, a wheat grinding facility, and a rice hauler.

FINANCIALLY SUSTAINABLE

Officials of Husk Power Systems refused to share financial data or other specifications for individual mini-grids with the CSE researchers who travelled to Jalalpur for a site visit. "Our customers have the option and flexibility to choose an electricity package that suits their needs, similar to how we recharge our phones. Electricity usage is based on prepayment basis and the customers can use the Husk app on their mobile phones to recharge their electricity package," a company release says.

Some information could be gathered from local residents, mostly customers of the solar plant. "I pay Rs 350 per month for lighting two bulbs. There is no system of a per unit charge," Kalamuddin says. But his neighbouring shopowner Sujit has been paying Rs 780 per month. He explains: "I have been consuming more, so I have to pay more. But I am getting power 24 hours — this is an advantage and a benefit." Sharma, the sawmill owner, has a monthly charge that is one of the highest. He says: "We are paying Rs 12,000 to 15,000 per month, depending on our working hours."

Rai says that round-the-clock power is a major attraction for all in this rural belt.

SARAN, BIHAR, 2020
GARKHA

As in the case of Jalalpur, Garkha too was encountering power troubles till a 30-kW solar mini-grid made its appearance in the village. Connected to grid supply of the North Bihar Power Distribution Company Ltd (NBPDC), the erratic service had forced residents into public protests – but things failed to improve. Diesel and kerosene generators, rechargeable emergency lights, battery-operated LED bulbs, and kerosene oil lamps were the options.

In 2018, Tata Urja, an energy services company (ESCO), commissioned a solar mini-grid of 30 kW based on absorbed glass mat (AGM) battery with a diesel genset back-up and its own distribution network. The system provides uninterrupted power supply, mostly to the local market and over 125 households in the village.

Tailoring shops, school, bank, hotels, shops and a shopping mall – all can now run their businesses from 9 AM to 7 PM. Vivek Kumar, a young trader, says that initially, people were not convinced that power could be generated from the sun, and that a private company would provide it to them.

Dharam Raj Singh, head of Tara Urja in Bihar, who was the man behind setting up the solar mini-grid in Garkha, recalls that in 2015-16, he was told by the locals that they were not comfortable with the extremely noisy and highly polluting diesel and kerosene generators – but they did not have any other option. Says Singh: “I put forward before them our plan to set up a solar mini-grid that will provide 24 hours of power supply with no smoke, no sound and no pollution. They agreed to take connections once the plant started its operation. Initially, the number was small, but it slowly increased.”

Tara Urja officials leased a plot of land measuring nearly 40 decimals for 20 years from a resident, at a monthly rental of Rs 2,000. Based on the power requirement, which depended directly on the number of households agreeing to take a connection, Tara Urja decided to install a 30-kW plant.

The company offers smart metres as per a monthly package design; the system functions on an auto mode. For commercial connections, pre-paid and post-paid meters (one for each connection) are fixed outside the establishment on the nearest electrical pole. All meters are connected to an online system and a customer has the facility to monitor the meter round-the-clock.

The plant, located at one end of the village, covers households within a three to four kilometre radius. The power lines are permanent, taken through poles erected by the company. Temporary connections can be extended to commercial users or those who want power during functions like marriages.

THE ECONOMICS AND SUSTAINABILITY

During installation, a booking amount of Rs 500 was taken from each consumer. For this price, they were provided with two points for LED bulbs and one socket for charging a mobile or using any other appliance. The meters, wires and poles were arranged by the power supplier.

Pardom Kumar Singh, who works as a customer service agent, said a common package of two bulbs round-the-clock costs Rs 300 per month. It is cheap, as earlier, businesspeople used to pay Rs 250 to Rs 300 for a bulb for four hours only. Even for commercial use, the charge is not very high.

Muskan Kumari, who runs a shop, is happy paying Rs 300 for reliable power supply during her business hours. Similarly, Ranju Devi, who owns a grocery store, has no problems paying Rs 200 for a monthly package of two bulbs. “Earlier, power cuts badly hit our business and we were helpless. We used to fully depend on recharging emergency lamps. Thanks to power from the solar plant, our life has become easy,” she says.

This Tara Urja solar mini-grid provides round-the-clock, seven days a week energy for domestic and commercial use. The consumers pay a small amount as an upfront connection fees, and then pay a fixed monthly charge. Some of them think that solar power is little costlier than power from the grid, but the quality of power is definitely better.

As per official communication from the company, the plant was funded by a grant from Rockefeller Foundation. Tara Urja worked in consultation of an EPC provider to design the project with the guidance of Smart Power India. Dharam Raj Singh says the company has been providing employment opportunities for local youth: "Among them are one security guard for the solar plant, two customer service agents, and a full-time operator-cum-technician."

Operation and maintenance (O&M) is the critical element for long-term sustainability of any mini-grid system. "We plan well in advance about this at the start of operations. Our O&M partners have the required skill, motivation, integrity and relationship with the community which ensures smooth operations," says Singh.

The customers are charged via affordable pre-paid packages. The revenue earned pays for the humanpower involved in O&M. Focus group interviews are conducted with the community to assess existing and future demand for power. The grid is designed to increase in capacity as demand grows. Once the grid reaches 95 per cent of its capacity utilisation, an additional 5 kW array is installed to meet the growing demand.

THE IMPACT

Life is no more what it was used to be in Garkha. In the day time, the local banks, the school and commercial units function smoothly, thanks to a regular power supply. In the evenings, shops can stay open more hours. "All the polluting diesel and kerosene generators have gone and are replaced by green energy. In view of the increasing demand, Tara Urja is working to upgrade the plant to 45 kW soon," informs Pardom Kumar Singh.

WEST CHAMPARAN, BIHAR, 2020
CHANPATIA

With the solar revolution, an optimum combination of solar-biomass-storage is turning out to be an effective mini-grid based solution for smaller areas and villages in the country – locations that often face electricity outages or blackouts.

The government has managed to make electricity available to almost every household in India. This household electrification process began in September 2017 under the Pradhan Mantri Sahaj Bijli Har Ghar Yojana – the 'Saubhagya' scheme. As per the scheme's dashboard, 99.99 per cent of households have been electrified in India.

About 32,59,041 households in Bihar were electrified under the scheme by January 31, 2019, giving the state the coveted status of '100 per cent electrified state'. But round-the-clock supply of reliable electricity by the government is still a far-fetched dream. Ranjesh Kumar, owner of an independent house in Chanpatia village in West Champaran district complains that despite all this, households get a supply of only 18-20 hours a day during winters; the situation worsens in the summers. The supply is not dependable and at low voltages, it is difficult to use electrical appliances.

This forces villagers to become dependent on diesel generators that are expensive and polluting.

BIOMASS AND SOLAR COMBO WINS THE DAY

However, some villagers of Chanpatia tell a different story: an affordable back-up system. This has come with renewable energy supply from Husk Power Energies in the village through its biomass-cum-solar-storage plant. The incorporation of battery in the system ensures an uninterrupted supply of power with constant voltage. The power generated during the daytime (from 10 AM to 4 PM) from solar has been rated (costs?) 20 per cent less. It is a win-win situation for both industrial and commercial customers, as well as Husk Power.

Aman Kumar, a welding shop owner, is a new customer who subscribed in February 2020. Earlier, he used to run his shop with a diesel generator set, at a cost of Rs. 5,000 a month. With Husk Power, his one month's electricity bill has come down by 38 per cent to just Rs 3,200. Kumar says there are no charges to get a commercial connection from Husk, whereas the public provider has put high charges; moreover, getting a public connection is time-consuming and the supply is still unreliable.

Husk Power commissioned its Chanpatia plant in April 2017. Customer numbers have seen a gradual rise. The installed capacity of the plant is 40 kW solar and 25 kW biogas. Husk has around 100 customers in Chanpatia: 30 per cent are domestic, 10 per cent industrial, and 60 per cent are commercial connections. All the commercial connections are on a 5-kW load.

Vivekananda Academy, a primary school in Chanpatia, is a commercial consumer. Nikhil Kumar Pandey, its caretaker, says: “We have both the government and Husk connections, but Husk is our major source of power. We do not experience voltage drops, unlike the public distributor, and no power shortages during the worst monsoon season.”

The use of smart pre-paid meters has enhanced the experience of customers. “We recharge once or twice in a month depending upon our usage. The support staff of Husk are more responsive than those of other providers,” adds Pandey.

The supply during the evening peak hours (5-11 PM) is a serious issue, especially in villages. According to Prayas (Energy Group) Electricity Supply Monitoring Initiative, 27 per cent of the monitored locations experienced an average daily outage of 30 minutes or more during evening hours in September 2019. For the same month, only 7 per cent of the rural areas received the entire six hours of evening supply.

The biomass part kicks in for the supply of power during evenings and night time. It becomes all the more important during the outages. The biomass feed is supplied by the local threshers. The price ranges anywhere between Rs 1 to 4 depending upon the season and availability of rice husk. Since, rice is grown twice a year in the area, availability is not a major issue. Dry feed like rice husk maintains the moisture and avoids corrosion.

Husk Power has also tried other dry feeds and it has been observed that with little changes in the system, it is possible to use granular feed. The biomass plant can provide reliable power as it gives a stable output whenever required and can play a balancing role, and reduces the requirement of storage.

Vijith, a young entrepreneur from Chanpatia owns a clothing shop is one of the new commercial customers of husk. He highlights the importance of power during the evening time when the maximum customers flock in. Before his relationship with husk, he used to rely on diesel generators as backup power. He used to pay around Rs. 80 per day for the diesel generator and the prices have gone up to Rs. 100 per day recently.

Now, he spends only Rs. 2,200 per month which is slightly less than the diesel connection. “Our customers come at distinct times in a day, there are many unanticipated power cuts and low voltages of supply in this region. Because of this, our day to day business was affected", he says. He also said Husk's connection helps running the business smoothly as there are no power cuts.

Chanda Devi, one of the household consumers of husk power, said that they have three sets of options when it comes to power including – supply from government, husk power, and diesel generator. She has rented property to Uttar Grameen Bank and has a contract for supplying uninterrupted power at the fixed cost. With automatic meters, the connection switches from government supply to husk and at last diesel generator if required. With Husk's supply, it is affordable and easy.

Husk started its first plant in 2007, back then it was just a small company that aimed at providing power to the countryside of India. It has over 75 plants across UP and Bihar. Around 10 plants were being set up in Tanzania and more in the planning phase in the African continent.

These decentralised solutions play a great role in bridging the gap between the government supply of electricity and customer demand. A study published by Initiative for Sustainable Energy Policy (ISEP) suggests that rural households relying on decentralised renewables are more likely to give up on their connection than those with grid electricity. The observation could be extrapolated to the Husk's type mini-grids, where customers are ready to pay higher charges (than government supply) for the reliable power and even find it easier to deal with the local operators.

COIMBATORE, TAMIL NADU
ODANTHURAI

Located in Tamil Nadu's Karamadai block, Odanthurai is an 11-village panchayat 40 km from Coimbatore city. Only 1,500 people lived in Odanthurai in 1996, but today its population numbers 8,000. The panchayat boasts of paved roads, schools and a housing infrastructure which attracts hordes of tribal migrants from the hinterlands. Naturally, it has been faced with the dire challenge of providing public services and facilities to this burgeoning population.

POWERED BY THE WIND

In the past, with each new housing project in Odanthurai came higher public electricity bills, as clusters of mud and stick huts changed to brick and cement buildings with new water systems and electricity connections. In 1999, the then panchayat president commissioned a financial analysis of his administration's expenditures and found that 50 to 60 per cent of the money was being spent on paying public electricity bills. The annual bill ate up all the revenues from the panchayat's businesses (Rs 6.75 lakh), as well as some of the grant that Odanthurai received from the state government (Tamil Nadu allocates around 9 per cent of the state's developmental budget to panchayats).

These funds are intended for development projects such as roads, housing or water and sanitation. Public electricity – which involved 575 streetlights, 15 water distribution pumping motors and one borewell motor — was the single largest expenditure for the Odanthurai panchayat for which no grants were offered. Odanthurai decided to take matters in its own hands.

The Panchayat bought a 350-kW Suzlon windmill for Rs 1.55 crore. It pooled in Rs 40 lakh, and the rest was obtained as a commercial loan from the Central Bank of India.

The Panchayat's windmill produces about 0.67 million units of electricity a year. This power is purchased by the Tamil Nadu Electricity Board at a cost of Rs 2.90 per unit. Thus, the revenue generated from the sale of power is about Rs 19.6 lakh per annum. The state electricity board allows banking of the power produced by the windmill, which is fed into the grid and credited to the power producer's account (which can be availed later). The Odanthurai Panchayat can avail its banked power as per its requirement.

The remaining unutilised power can be sold to the grid. The Panchayat estimates that it can repay the bank loan in six-seven years, using the earnings from sale of electricity to the Tamil Nadu Electricity Board. After paying back the loan, Odanthurai Panchayat can earn close to Rs 8 lakh per year after meeting its own public electricity requirements.

Today, Odanthurai is a role model of self-sustained development, attracting the attention of policymakers and renewable energy enthusiasts — but it is a model yet to be emulated by others.

PART 3

POLICIES IN INDIA

POLICIES IN INDIA AND THE WAY AHEAD

The Indian government has two broad options in trying to meet the 100 per cent reliable electrification target:

- Grid extension to un-electrified households, while also ensuring reliable electricity supply
- Distributed electricity solutions, which would include
  - Off-grid (for example solar lanterns, home lighting systems, solar pumps and mini-grids)
  - Grid-interactive (solar pumps, mini-grids)

THE MNRE RELEASED A DRAFT MINI-GRID POLICY IN 2016, WITH A GOAL OF INSTALLING 10,000 MICRO- AND MINI-GRIDS BY 2021, WITH A TOTAL CAPACITY OF 500 MW

The MNRE released a draft mini-grid policy in 2016, with a goal of installing 10,000 micro- and mini-grids by 2021, with a total capacity of 500 MW. The draft policy states:

"Decentralized RE solutions are being deployed to address the last mile access challenge in rural areas in many parts of the country and with improving costs and increasing efficiencies of RE technologies, RE based Micro and Mini grids solutions are being perceived as a durable solution – able to provide reliable and cost-effective energy service, cater to productive and commercial loads, accommodate future loads, and connect with grid and feed surplus power if needed."

If finalised, this policy can serve as a framework for state policies and a roadmap for future growth.
Grid extension and small grids can also be reconciled by allowing tiny grids to serve as effective last mile

entities within a "24x7 Power for All" framework. Mini-grid operators are classified as "rural utilities" and can be uniquely positioned to assist discoms and provide a variety of services. These services could include the addressing ongoing challenges of bridging peak hour deficits, reducing AT&C losses, better management of consumer behavior with existing government programmes, and assuring requisite technical expertise for sustained O&M of village-level infrastructure.

Existing mini-grid operators' last-mile performance will increase dramatically and sustainably if they are properly equipped as rural utilities. To make this happen, mini-grid operators would have to not only meet the required performance standards, but also be monitored for their service quality. To guarantee that adequate services are given to the rural population, regulators would need to develop suitable performance requirements for these operators, as well as a transparent measuring and verification (M&V) method.

CSE has proposed the Renewable Energy and Energy Access Transformation (GREEAT) model for the global South, to strengthen energy access through clean energy for all. GREEAT is designed to enable modern, distributed, people-centred and decentralized renewable energy power generation from a large range of sources and developers. The proposed model's financial support included feed-in tariffs and other money-against-performance schemes that are linked with climate finance for

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DESPITE EARLY IDENTIFICATION OF SMALL GRIDS AS A VIABLE SOLUTION TO ADDRESSING THE ENERGY ACCESS DIVIDE, PROGRESS ON MINI-GRID POLICY AT THE NATIONAL LEVEL HAS BEEN MODEST

establishing distribution infrastructure that fulfils grid rules and standards.

Bringing mini-grids under regulation and supporting projects through FiT will boost project bankability under the paradigm. It would also assist to ensure the long-term viability of projects since they would be required to supply power on a continual basis in order to obtain the incentive.

GAPS IN POLICY AND BARRIERS FOR IMPLEMENTATION

Despite early identification of small grids as a viable solution to addressing the energy access divide, progress on mini-grid policy at the national level has been modest. Some states have enacted their own legislation. However, state rules have not piqued the attention of small grid project developers for a variety of reasons, including:

- **Unviable tariff rates**: Rural households have been unable to obtain inexpensive and dependable energy as a result of policies. Terms and conditions apply only to initiatives that receive state government money; other projects can negotiate a fee with consumers. No projects have been built as a result of the rules, which have failed to encourage developers to set up ventures with state subsidies[1]. Mini grid developers are continuing to operate as they did before the regulation was established, charging residential

1 http://cdn.cseindia.org/attachments/0.58005500_1530179433_Mini-grid-in-UP-report.pdf

consumers a high fee for a restricted number of hours each day, while companies and telecom towers remain the principal clients.

- **Uncertain exit options**: When the grid arrives, you have two options: feed electricity into the grid or sell the project to the discom. The rate at which mini-grid developers would sell power to the grid would be at the time of exit/integration with the grid, however no details on how this will be done have been released. Similarly, in the case of the second exit option, no guidelines for determining the project's purchase price have been established.[2]

- **Metering**: Further standardisation efforts are required, especially for metering in DC mini-grids. The accuracy of consumption metering in DC mode has to be exactly right when a utility looks to charge and bill customers

- **Protections:** DC mini-grids require protection standards and overall design guidelines and standards as faults in DC system is more difficult to interrupt with fuses and circuit breakers. For AC mini-grids there is still a need for comprehensive documents that can assist equipment vendors, utilities, microgrid developers and owners to specify and configure protection systems for mini-grids of all types

MINI GRID DEVELOPERS ARE CONTINUING TO OPERATE AS THEY DID BEFORE THE REGULATION WAS ESTABLISHED, CHARGING RESIDENTIAL CONSUMERS A HIGH FEE FOR A RESTRICTED NUMBER OF HOURS EACH DAY, WHILE COMPANIES AND TELECOM TOWERS REMAIN THE PRINCIPAL CLIENTS

2 http://cdn.cseindia.org/attachments/0.58005500_1530179433_Mini-grid-in-UP-report.pdf

OPERATIONAL MODELS

Various business models for commercial minigrid operations have arisen, based on the company's goals and local requirements/conditions.

OMC POWER WAS ONE OF THE FIRST FIRMS IN INDIA TO DESIGN THE ANCHOR–COMMERCIAL–COMMUNITY (ABC) MODEL, WHICH IS A BUSINESS MODEL FOR MINI-GRIDS

- OMC Power was one of the first firms in India to design the Anchor–Commercial–Community (ABC) model, which is a business model for mini-grids. A solar producing unit's electricity is prioritised for an anchor load of commercial and industrial customers (usually one or two telecom towers), followed by companies (small firms, stores, banks, and fuel stations), and finally residences. The size of the generator unit in this type is mostly determined by the anchor load required. The strategy is less hazardous since the anchor consumer's known load provides a guaranteed source of revenue. These systems are usually built in big settlements with a high demand for commercial and industrial power. In rural areas with insufficient power supply, their distribution networks are frequently put up parallel to the discoms' infrastructure.

- To make mini-grids financially feasible, TARA Urja's approach also relies on commercial loads. However, via a programme dubbed Community Engagement, Load Acquisition, and Micro-enterprise Development, the corporation focuses on increasing demand for the generated electricity by supporting local industries and enterprises (CELAMeD).

- Husk Power System's mini-grids are positioned in rural communities where rice husks are plentiful.

Electrical wires stretched between bamboo poles provide power generated by biomass gasification. Built-own-operate-maintain (BOOM) and built-maintain (BM) are HPS's two principal revenue models (BM). HPS constructs and maintains mini-grids on the BM model, but local entrepreneurs own and run them.

THE WAY AHEAD

Mini-grids are still needed in spite of grid connections; either because of unreliable power or high cost. People today have to use kerosene or other dirty sources of power which have high health costs. It would be important to find ways to leapfrog households using dirty energy to cleanest energy. India needs a policy to support the growth of mini-grids (standalone clean energy systems).

In February 2022, MNRE released a draft policy framework for Decentralised Renewable Energy (DRE) livelihood applications. The ministry says this is intended to achieve its objective of decentralized and distributed renewable energy supply in the country, particularly for rural populations with little or no access to power.

The main objectives outlined in the new framework are:

1. Enabling a market-oriented ecosystem

2. Increasing the adoption of DRE-based livelihood solutions by enabling easy finance for the end-user Encouraging development and management of high-quality products

IN FEBRUARY 2022, MNRE RELEASED A DRAFT POLICY FRAMEWORK FOR DECENTRALISED RENEWABLE ENERGY (DRE) LIVELIHOOD APPLICATIONS. THE MINISTRY SAYS THIS IS INTENDED TO ACHIEVE ITS OBJECTIVE OF DECENTRALIZED AND DISTRIBUTED RENEWABLE ENERGY SUPPLY IN THE COUNTRY

POLICIES IN INDIA

3. Developing effective DRE livelihood applications through innovation as well as research and development

4. Establishing energy-efficiency standards for high-potential livelihood products

5. Using applications powered by mini/micro-grids operating in hybrid mode along with the main grid

THIS SOURCE OF ENERGY MUST BE SEEN AS KILLING TWO BIRDS WITH ONE STONE— POVERTY REDUCTION AND MEETING THE CLIMATE GOALS OF THE WORLD. IT NEEDS FINANCIAL SUPPORT TO MEET THE NEEDS OF THE POOREST

But this will not be enough. The draft mini-grid policy needs to be finalised and issued so that there is policy coherence and direction on how these standalone systems can be scaled up. The Rwandan government's policy on mini-grids provides for interaction between grid and mini-grids and transfer when grid is available; it standardizes tariffs and provides funding for capital investment.

Financial support is essential. This source of energy must be seen as killing two birds with one stone— poverty reduction and meeting the climate goals of the world. It needs financial support to meet the needs of the poorest— those who are unconnected to conventional energy systems. A scheme needs to be made which under- writes capital investment to reduce energy costs or subsidizes every unit of energy supplied to households for domestic and livelihood purposes. If the government gives subsidy on tariff, then mini- grids could be more affordable for households to use and would displace the consumption of biomass or diesel.

Table: State mini-grid policies, their features, targets and status

States	Salient features of mini-grid policy	Target, Status
Uttar Pradesh (Uttar Pradesh Mini-grid Policy, 2016)	To ensure power supply to 20 million households of the state for minimum need (daily three hours in the morning and five hours in the evening – with a total of at least eight hours) To create a conducive environment for stimulating private sector participation through 30 per cent subsidy. Developers to establish projects on Build Own Operate & Maintain (BOOM) basis and guarantee 10 years of Operation and Management (O&M) services. To enhance skills and create employment opportunities at the local level. To promote establishment of local manufacturing facilities and socio-economic development of backward areas.	Target – To supply power to nearly 02 crore households in the state. Status - Electricity services being provided in almost 1,900 settlements (villages and hamlets); about 37,000 connections provided (as on May 2021)
Bihar (A component under Policy of Promotion of Bihar New and Renewable Energy Sources, 2017)	Promotion of mini-grids as a solution to provide 24x7 reliable energy to all by FY18-19. State government targets to achieve deployment of 100 MW of RE capacity equivalent through mini-grids. Projects to be constructed on the BOOM model. The government to facilitate the development of mechanisms to streamline project aspects such as single window clearance etc.	Target – To build 100 MW of sub 500kW renewable-based mini- grids
Odisha (A component under Odisha Renewable Energy Policy, 2016)	The Odisha Electricity Regulatory Commission notified the Mini-grid Renewable Energy Generation and Supply Regulations in June 2019. Two models for business operations are discussed – one each for where the grid pre-exists and the grid is non-existent.	Target by 31st March 2022 Solar - 2,200 MW Wind - 200 MW Small-hydro - 150 MW Biomass - 180 MW WTE (Waste to Energy)- 20 MW
Jharkhand (2022)	As per an estimate, the demand of power in Jharkhand is all set to reach 6000 MW in the next four-five years. To keep pace with increasing demand, the State Energy Department and JREDA are exploring various avenues and cleaner means of energy sources. Mini-grids will be deployed in villages with intermittent supply or no supply. A total of 110 MW earmarked for this. 1,000 model solar villages would be developed. Special attention would be given to solarizing sectors like healthcare, education and agriculture, and to promoting productive use of solar power for livelihoods. Supporting adoption with financial assistance (capital subsidy) and innovative business models like community solar subscription, pay-as-you-go, revenue-linked EMI schemes etc have also been mooted to target rural demand for residential and farming needs. The JREDA may unveil a separate programme that deals with the issue of providing energy access to households that are yet to be electrified or aren't feasible to electrify by conventional means through mini- and micro-grids.	Policy released as of March 2022

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phones: 91-11-40616000 Fax: 91-11-29955879
Website: www.cseindia.org