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Solar mini-grids in Chhattisgarh State, India

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Abstract

Conventional grid extension has been the predominant mode of electrification in India. However, solar photovoltaic technology has also been used for providing electricity access in remote, forested habitations and islands. Under Remote Village Electrification Programme of Government of India, around 12,000 villages and hamlets have been electrified using renewable energy. Chhattisgarh state in central India has alone been able to electrify around 1400 remote and forested villages through solar mini-grids. This paper makes a modest attempt to examine the development and operation of the solar mini-grid model for enhancing electricity access in India, with special focus on the state of Chhattisgarh. The paper, based on extensive literature review, interview with key stakeholders and field visit to selected remote forested villages in the state of Chhattisgarh, shares the experiences and lessons of the solar mini-grid programmes for rural electrification in the state by comprehensively analyzing multiple dimensions of the programme such as coverage and trend, technical designs, institutional arrangements, financial mechanism and operation and maintenance aspects, which were key to the success of the solar mini-grids. We observe that robust institutional arrangements, strong policy support and an effective maintenance and oversight mechanism have been the key contributing factors for the success of this initiative.

Key words

Off-grid, rural electrification, solar mini-grids, business model, electricity access

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1.0 Introduction

1. Introduction

Having the largest rural population in the world, India confronts a huge challenge of rural electrification, especially electrifying the remote, forested and tribal habitations located in far off places. Despite conscious efforts undertaken by central and state (provincial) governments since 1951, the level of household electrification and power availability in India remains far below the global average. As per the Census of India 2011 figures, electricity as a source of lighting energy in India (both rural and urban) is limited to 67% households, whereas world average stands at about 81.5% [1]. In rural areas, the electrification coverage scenario is further bleak where around 59%, constituting about 72.4 million rural households, still rely on kerosene or other traditional fuel for lighting. Despite various policy and programme specific thrusts (refer [2] for detailed discussion of various rural electrification programmes), energy access challenges, especially in the rural areas, continue to derail the overall development process of the country.

While the centralized grid based electrification has been the most common approach¹, decentralized renewable energy options especially, solar PV (photovoltaic) systems have also been adopted and being increasingly considered as an cost effective mode of electrification, especially for areas where it is techno-economically not feasible to extend the electricity grid or in areas where electricity supply from the grid is inadequate to meet the demand [4, 5]. These off-grid communities are usually small, consisting of low-income households and often characterized by scattered settlements, thus economically unattractive for electricity distribution companies (discoms) to extend the grid. While extending the grid to such areas might be economically unattractive for the discoms, they have also not attempted to cover the off-grid areas with decentralised distributed generation systems, though they are the licensees to provide electricity services in all areas. The vacuum has been largely fulfilled in many cases by NGOs, through pilot projects by raising funding support from donor agencies and support received through funds from corporate social responsibility initiatives, and by the state renewable energy development agencies, established in the different states by the state governments, which work under the aegis of the Indian Ministry of New and Renewable Energy (MNRE).

¹ Currently about 94% of the inhabited areas in India are covered through grid electrification [3].

Statistics from the Ministry of New and Renewable Energy (MNRE) indicate that more than 12,000 villages in India have been covered through renewable energy based mini-grids and solar home systems (SHSs), especially under the Remote Village Electrification Programme (RVEP). Solar PV projects (>1 kWp capacity) which includes solar mini-grids with capacity ranging from 1 to 500 kWp, have been installed in the country with a cumulative capacity of 96.61 MWp (as of August 31, 2012). Though the off-grid village electrification coverage may be only around 1.5% of the total village electrification coverage in the country [4], the benefits and impact by bringing about social and economic upliftment of communities in India, through incremental livelihoods to better facility for health and education has been immense [6,7,8,9]. At the same time, literature also shares that many of the renewable energy based projects in India have met with limited success because of technical, institutional, financial and regulatory issues [10, 11, 12, 13].

While there exists ample literature analyzing the solar PV programs for rural electrification at the country level and also the impact of solar based electrification projects (4, 8, 9, 12, 14, 15, 16, 17, 18], there are limited literature that has comprehensively examined the solar mini-grids delivery model(s) as a means to enhance rural electricity access. The solar mini-grid model, however, has been receiving lot of attention both in South and South East Asia as well as in Africa to achieve the energy access objectives of the Sustainable Energy for All by 2030. This paper makes an attempt to examine the development and operation of the solar mini-grid model for enhancing electricity access in India, with special focus on Chhattisgarh, a state in the central region of India.

India has been implementing solar mini-grids since the nineties as part of the technology demonstration programme of the Ministry of New and Renewable Energy (earlier Ministry of Non-conventional Energy Sources). The state of Chhattisgarh, which is the study focus, has reportedly implemented the highest number of solar mini-grids in India, providing electricity to more than 57,000 households, spread across 1439 villages and hamlets in the state [19]. Despite the state having such as large number of operational mini-grids in India and possibly also globally, it has not received adequate attention in the literature, barring a select few [20, 21, 22]. Millinger et al. [20] carried out a socio-technical bottom up assessment to study two important dimensions of project i.e. technical and maintenance factor and impact on beneficiary, more specifically on the women groups while Malviya [21] briefly provided the status and implementation model. Buragohain [22] carried out an impact evaluation study of

the remote village electrification programme in six states which also covered the Chhattisgarh state.

This paper first briefly describes the solar mini-grids implementation in India focusing on technology, delivery models, financing and policy architecture and then attempts a comprehensive assessment of the solar based mini-grids deployed in Chhattisgarh state by examining multiple dimensions such as coverage and trend, technical design, institutional arrangements, financial mechanism, functionality and performance, operation and maintenance aspects, system of monitoring and oversight and impacts.

1.1 Study Methodology

This study applies a triangulation of research methods to comprehensively assess the solar mini-grid village projects in Chhattisgarh. Review of secondary literature has been supplemented by visit to selected field sites and interview with key stakeholders to gather relevant information for the study. While secondary information has also been collected from Chhattisgarh State Renewable Energy Development Agency (CREDA), the nodal agency implementing the mini-grids in the state, primary data were obtained by visiting eight mini-grid project sites across two different districts - Raipur and Korba - in the state. The field visits was limited to villages in only two districts because of logistical constraints and security concerns². However, these districts and the villages were so selected that a representative sample of solar mini-grids of the entire state is obtained. The secondary data on status of implementation of the mini-grids, technical design and cost parameters for more than 600 mini-grids were collected from CREDA head quarter at Raipur and detailed information on solar power plant wise number of connections, month-wise and annual energy generation and consumption, operation and maintenance details etc. was obtained from the CREDA regional offices at Raipur and Korba districts. The field visits consisted of focus group discussions (FGDs) and semi-structured interviews with key stakeholders such as mini-grid consumers, village energy committee (VEC) members, local health centre staffs, tribal hostels, school teachers, mini-grid plant technicians, plant operators and cluster managers. In addition, some quantitative information was also obtained during the FGDs with mini-grid consumers and VECs to assess the impact of the programme. This was also supplemented by interviews with technology suppliers and CREDA officials. Further, some of the private

² The districts affected by severe left wing extremism were not considered for field study due to security concerns.

sector players in other states as well as WBREDA officials were also interviewed to draw a comparison of mini-grid deployment in Chhattisgarh and other parts of India for cross-learnings.

Based on the interactions and field surveys, a critical analysis of the mini-grid model and its performance was carried out to understand what has worked, what has not worked and why. The section “Solar PV mini-grids in India” attempts to capture the development of mini-grid models and the current status of implementation including the institutional model, and financial aspects and policy architecture instrumental in their promotion. Thereafter, the section “Solar mini-grids in Chhattisgarh” comprehensively captures the dissemination of mini-grids in the state and analyzes the programme based on various parameters such as technical design, delivery model, financing aspects, policy and regulatory architecture, impacts etc. Section four discusses key aspects of mini-grid development that have contributed to the success of the model in Chhattisgarh. Finally, the concluding remarks section summarizes the study.

2. Solar PV mini-grids in India

The concept of the solar PV mini-grids in India was pioneered way back in the 1990s in the Sunderban delta region in the state of West Bengal and in the tribal region of Chhattisgarh state (then part of Madhya Pradesh state). A solar PV power plant of 25 kWp capacity installed in 1995-96 by West Bengal Renewable Energy Development Agency (WBREDA) in Kamalpur Village of Sagar Island continues to provide electricity to its consumers till today. In Chhattisgarh, the first solar power plant was installed at village Lamni in Bilaspur district which is also reportedly operational. Thereafter, solar mini-grids, standalone or in hybrid mode, have been implemented in various states, notably, Andaman & Nicobar Islands, Bihar, Chhattisgarh, Lakshadweep, Madhya Pradesh, Meghalaya, Odisha, Uttar Pradesh and West Bengal.

Solar mini-grids in India have evolved with time and changing priorities. The evolution has not only been limited to technical dimensions of project development, but also to other dimensions such as new and innovative delivery and financial models. Putting it in a chronological order, the first phase of deployment of mini-grids happened during early nineties till early 2000 and focused on developing pilots, technology demonstration and testing of the institutional models. The second phase focused on deployment of these models

as an effective vehicle of electrification of remote and far flung villages primarily under the government sponsored remote village electrification programme, which was initiated in 2001. This phase also experimented in deploying larger capacity mini-grids as well as hybrid mini-grids (e.g. case of solar mini-grids in Sunderban). This was also the phase when the Electricity Act 2003 was enacted and mini-grids as decentralised distributed generation was included as a means for providing rural electricity supply. The current phase of mini-grid development, since the last few years, is experiencing the entry of private sector developers thereby also bringing in technical and institutional innovations and also the development of smart mini-grids for better supply and demand side management.

2.1 Solar mini-grid coverage in India

The solar mini-grids in India have been predominantly deployed under the Remote Village Electrification Programme (RVEP) or lately as part of Jawarlal Nehru National Solar Mission (JNNSM) of the Ministry of New and Renewable Energy. Specifically, WBREDA has set up more than 20 solar mini-grids with an aggregated capacity of around 1 MWp, thereby benefitting around 10,000 households. The CREDA, another key proponent of the model, has electrified 57,968 households with electricity supply from low capacity (2–6 kWp) solar mini-grids [19]. Figure 1 presents a comparative position of states in deploying off-grid Solar PV plants in India.

Apart from government led initiatives, some NGOs and private companies have also implemented solar mini-grids. SCATEC Solar, a Norwegian solar manufacturer has electrified thirty villages in Uttar Pradesh, Jharkhand and Madhya Pradesh. Mera Gao Micro-grid Power, a start-up company is setting up solar DC micro-grids in Sitapur and Barabanki districts of Uttar Pradesh to provide lighting services by using energy efficient LEDs. Husk Power Systems, which is more famous for its biomass gasifier based electricity supply systems, has also reportedly ventured into solar DC micro-grid space and is connecting un-electrified households in their existing operational areas. Other private sector companies who have recently initiated extending electricity services to poorly electrified villages either through solar AC or DC mini-grids are Sun Edison, Kuvam Energy, Minda NextGen technologies, Gram Power etc. [23].

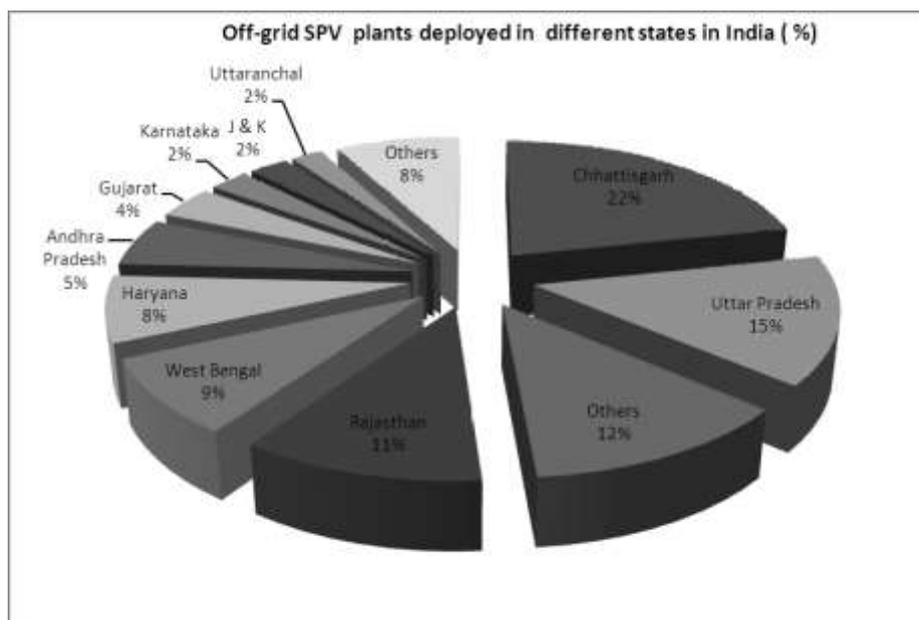


Figure 1: Off-grid Solar PV plants deployed in different states in India (Source: MoSPI, 2012)

2.2 Technical features

The solar mini-grids are designed to generate electricity centrally and distribute the same for various applications to households and small businesses spread within a particular area³. These mini-grids vary in capacity and size, typically in the range of 1–200 kWp, with different states adopting different sizing and models depending on their local requirements. While mini-grids in the state of Chhattisgarh are mostly smaller in capacity (< 6 kWp capacity), the ones in Sunderban region and Lakshadweep are of higher capacities (more than 100 kWp solar PV). These solar mini-grids have also been using state-of-the-art inverters and storage systems, available at the time of installation, to ensure long life and reliable field performance. Innovations have also been brought in depending on technological development and communities' need with change in time. Till 2000, solar mini-grids in the capacity range of 25– 26 kWp were mostly implemented by WBREDA. Larger capacity schemes were not commissioned as the acceptance of concept and technology was not yet proven. However, observing the strong growth in interest and demand from community, WBREDA also started building power plants with higher capacities (>100 kWp) and in some locations also installed

³ In the Indian context, solar mini-grids are designed to generate electricity centrally and distribute the same for various applications to households and small businesses spread within a particular area. They usually supply 220 V 50 Hz 3-phase or single phase AC electricity (depending on the installed capacity) through distribution network. They consist of (i) Solar PV array for generating electricity, (ii) a battery bank for storage of electricity, (iii) power conditioning unit consisting of charge controllers, inverters, AC/DC distribution boards and necessary cabling, etc. and (iv) local low-tension power distribution network [18].

additional generation units using other forms of renewable energy such as small wind-generators and biomass gasifiers to meet the incremental power requirements [18].

The solar DC micro-grids, promoted mainly by private sector companies, generate DC electricity using one or more solar panels and are distributed over a short distance from the battery banks to the cluster of households or shops within the village. They usually supply at 12V or 24V DC for providing lighting services for 5-7 hours using LED lamps of 2-3watt per households. These micro-grids typically cover around 20 to 100 households, providing lighting and mobile charging facilities, generating energy using 100-500 Wp solar panels/array. While the DC micro-grids operated by Mera Gao Power has central storage system, Husk Power Systems on the other hand, are reportedly implementing micro-grids using decentralised storage battery in the consumers' households connected smartly from a centralised solar PV systems. In addition, smart technologies have also been used to conduct remote monitoring and pre-paid payment to keep a track on the daily performance of the plant. Gram Power, another, private initiative, has designed smart stackable batteries having modular features which is called 'MPOWER'. These batteries have inbuilt designs to keep control on the misuse of storage device thereby enhancing their life [18].

2.3 Service delivery model

Most of the solar mini-grids that have been implemented in India are structured around the community i.e. they follow the Village Energy Committee (VEC) approach for management of local generation and supply. In such model, the VEC, formed by members from the community, plays the role of power producer, distributor and supplier of electricity, though they may not have any legal status. They collect payments from users for the electricity and also resolve disputes in the case of a disruption in power supply [4].

In addition to the above community led mini-grid models, the projects implemented by private sector are based on a commercial approach. For instance, Mera Gao Power is implementing using a micro-utility approach, whereas Husk Power System has evolved a franchisee based business model for deployment of mini-grids. Gram power has been operationalizing a model known as 'pay as you go'. These models by private operators are purely service driven, however, to some extent; they also involve local stakeholders to tackle issues like mobilizing people at the local scale, dealing with social problems, and realizing better community responses. Many pertinent matters of plant operation and management are,

however, resolved by the private operators without directly engaging village committees or stakeholders.

2.4 Financing Approach

A major component of capital costs in case of mini-grids implemented under the RVEP came as subsidy from MNRE. For remote areas, the subsidy has been used to cover up to 90% of the project cost, up to a predefined maximum of Rs 18,000 per household. The balance 10% cost of projects could be financed through sources such as state government funds, contributions from local Member of Parliament or Legislatures and corporate sector as part of their social responsibilities. The individual consumers own the internal wiring and appliances and pay for the services they use. However, in case of BPL households, internal wirings and service connections are also taken care of from the subsidy funds. JNNSM, which now is the apex scheme for dissemination of solar, provides capital subsidy for off-grid solar products and mini-grids either to meet unmet community demand for electricity or in un-electrified rural areas. On the other hand, the DDG program of RGGVY considers technology with the lowest marginal cost for a given area and extends subsidy of 90 % of the project cost and some operational subsidies. The subsidy is released on annuitized basis based on performance of the system for five years.

In case of private sector initiatives, a major part of the project cost is borne through financing from banks/investors and equity from the company. Wherever, subsidy can be availed, these companies also avail such funds subject to the norms of the government. The entire cost is recovered through retail tariff, resulting in high tariffs, as compared to the negotiated tariffs for projects implemented by state renewable energy development agencies or electricity retail tariff set by regulators in case of grid electrified villages. Moreover, the projects by private investors are usually in 'not so remote' areas where paying capacity by consumers is high and in the absence of any off-grid regulation, the tariff is based on negotiation between the private service provider and the consumers.

Tariff structures for consumers in different solar mini-grid projects also do not follow a uniform pattern. The tariff is usually based on flat rate such as INR 30 – 200 per connection per month. Since, the number of light points and time of supply in the solar mini-grids are fixed and the socio-economic profiles are usually similar in remote villages, the fixed tariff is much easier to administer as compared to metered tariff for such low consumption. However,

a disadvantage of the system has been inability to keep control on the overdrawl by some households thereby putting extra pressure on the system.

2.5 Policy and regulatory landscape

The initial renewable energy based mini-grids in India, especially based on solar PV, were set up as part of the technology demonstration programme of MNRE during the nineties. The launch of RVEP by MNRE in 2001 and Rural Electricity Supply Technology (REST) Mission in 2002 saw a programmatic approach for deploying mini-grids. Under the REST Mission, the renewable energy based decentralised generation technologies including mini-grids were considered for the first time under the mainstream rural electrification efforts. The Mission, designed to ensure an integrated approach, attempted to change the legal and institutional framework by promoting, financing and facilitating alternative approaches in rural electrification. During the same time, the first focused attempt by the Government of India to look into issues related to decentralised generation, particularly in the context of off-grid electrification also happened through the Gokak Committee⁴.

Thereafter, the Electricity Act 2003⁵, enacted with the overall objective of developing the electricity industry and provide electricity access to all areas, envisaged a two pronged approach for improving rural electricity access - a national policy for rural electrification to extend the reach of grid-connected supply together with enlistment of local initiatives in bulk purchase and distribution of electricity in rural areas and a national electricity policy to encourage additional generation and distribution of electricity through renewable sources of energy including mini-grids [24]. It also opened the door to off-grid generation to a much greater extent than it existed before. Under Section 4, it made the Central Government responsible to prepare and notify a national policy, permitting stand-alone systems⁶ (including those based on renewable sources of energy) as a mode for rural electrification. Section 14 also exempts a person intending to ‘generate and distribute electricity’ in a rural

⁴ The Committee recommended decentralized generation (especially mini-grid mode) may be considered for remote area electrification and the decisions between grid connection and decentralized generation should be made on the basis of technical, managerial and economic issues, viz., distance from existing grid; load density, system losses, and load management.

⁵ The EA 2003 made the government (both state and central) obligated to supply electricity to rural areas including villages and hamlets. Section 6 of the act mandates the hitherto implied Universal Service Obligation by stating that the government shall endeavour to supply electricity to all areas including villages and hamlets.

⁶ Section 2(63) under Electricity Act 2003 defines stand- alone system as the electricity system set up to generate power and distribute electricity in a specified area without connection to the grid;

area, notified by the State Government, from obtaining any license from the regulator⁷. However, Section 53 of the same Act also mandates that such persons shall have to conform to the provisions relating to safety and electricity supply from appropriate authority for supply without license in notified rural areas. The National Electricity Policy and Rural Electrification Policy also state that wherever grid based electrification is not feasible, decentralised generation together with local distribution network would be provided. The policy development made inclusion of decentralised generation also a part of the RGGVY, which was a great step forward in mainstreaming off-grid technologies within the ambit of the national rural electrification strategy.

3. Solar Mini-grids in Chhattisgarh

3.1 Demographic and socio-economic profile of the state

Before elaborating the nuances of rural electrification process in Chhattisgarh, it merits highlighting some of the key demographic and socio-economic characteristics of the state in order to better comprehend the context within which remote rural electrification has been carried out in Chhattisgarh. About 44% of the total area in the state is covered with forests, more than double the national average, and this has important bearings on the rural electrification access in the state. Many of the remote villages are located within the forested areas, out of reach of the centralized grid, therefore, requires alternative energy supply systems such as mini-grids or solar home systems (SHSs) to electrify these far flung areas. Social stratification statistics reveal that out of 25.55 million total population of the state [25], scheduled caste (SC) and scheduled tribe (ST) population constitute around 43.4% compared to the national average of 25%. The latest poverty estimates in India indicate that about 48% of total population in Chhattisgarh lives below the national poverty line. The Multi-dimensional poverty index of Alkire et al. ranks Chhattisgarh as the fourth poorest state in India with 70% of the population being multi-dimensionally poor [20]. Moreover, poverty levels among SCs and STs are also higher than other social groups with more than 2/3rd of SCs and STs in the state are below poverty line [26]. In addition, presence of social problems

⁷ While there is no requirement to obtain a license to generate and distribute electricity in rural areas, this also implicitly means that off-grid operators do not get the benefit of cross-subsidization that are normally extended to rural electricity consumers. Absence of regulatory interventions though have helped in setting up of off-grid projects by different proponents, at the same time, most of these projects set up in remote areas with low paying capacity of consumers become operationally unviable [28]. Further, in absence of off-grid regulation, many projects are also set up without following necessary electrical safety standards (such as using bamboo poles for distribution line) to keep their installation cost low. And in some cases, the tariff is negotiated at much higher price than the prevailing rural electricity tariff.

such as left wing extremism in as many as 16 districts in the state (out of 27 districts in the state) also poses a severe challenge to extend electrification efforts in the state [27].

3.2 Status of electrification in Chhattisgarh

Creation of Chhattisgarh in the year 2000 led to a major institutional and organizational overhaul especially for electricity provisioning. Two new institutions were created i.e. Chhattisgarh State Electricity Board (CSEB)⁸ and Chhattisgarh State Renewable Energy Development Agency (CREDA). While CSEB was entrusted to provide electricity through grid electrification, CREDA was made responsible for promoting renewable energy sources including off-grid/decentralized energy systems. Though this state is one of the few states in India having electrification coverage better than the national average and also have surplus power supply, a large chunk of rural people continue to be out of coverage of the centralized grid electricity supply as they inhabit in difficult terrains within the forested areas. Therefore, despite having surplus power with abundant coal supply in the state, the socio-economically challenged sections in the state seems to face the unique dilemma of “energy poverty in the midst of plenty”.

In order to get a macro picture of the electrification status in the State, it merits dwelling on some recent electrification statistics. The overall percentage of households connected to the grid electricity in the state is around 75.3% whereas the village level electrification stands at 97.1% [29]. Around 563 villages (out of the total 19744 inhabited villages) in the state remain to be electrified, with most of these un-electrified villages being in the tribal dominated districts of Sukma, Dantewada, Narayanpur and Bijapur⁹. Some interesting insights about the use of various source of energy for lighting across districts¹⁰ in Chhattisgarh could be drawn from the Indian Census 2011 figures. In case of lighting, huge disparities exist among districts and social classes in the use of modern sources of energy for lighting (Figure 2 & Figure 3). The districts with poor electrification status are also the same districts which have predominantly poor population and are also affected by left wing extremism [27]. However there is also a positive trend that some of these districts such as Koriya, Jashpur, Korba, Bijapur are utilizing solar energy to electrify their households. Almost 1% of the total households in the state are using solar energy as a source for lighting,

⁸ CSEB which was functioning as a vertically integrated power utility was unbundled into five companies in with effect from January 1, 2009.

⁹ The electrification of all villages in the state is planned to be completed by 2014.

¹⁰ At the time of Census survey, Chhattisgarh, there were only 18 districts, which increased to 27 in 2012 only.

which is 2nd highest (after West Bengal at 1.2%) among the larger states in India and more than double of the national average (~ 0.4%).

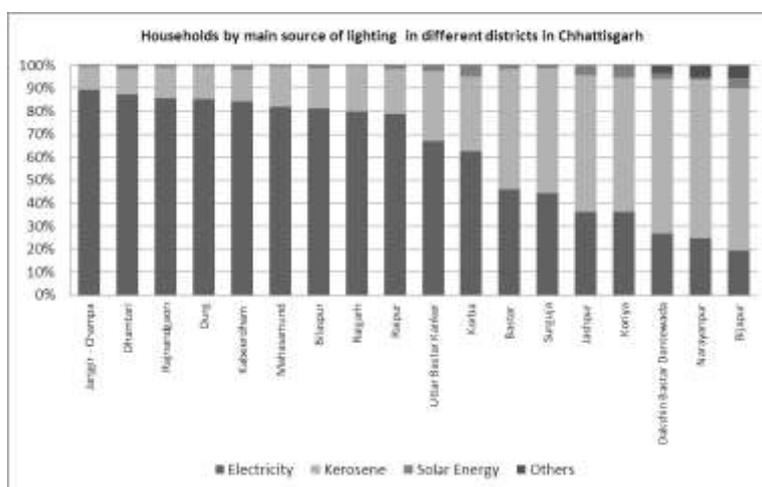


Figure 2: Households by main source of lighting in Chhattisgarh (Source: Census of India, 2011)

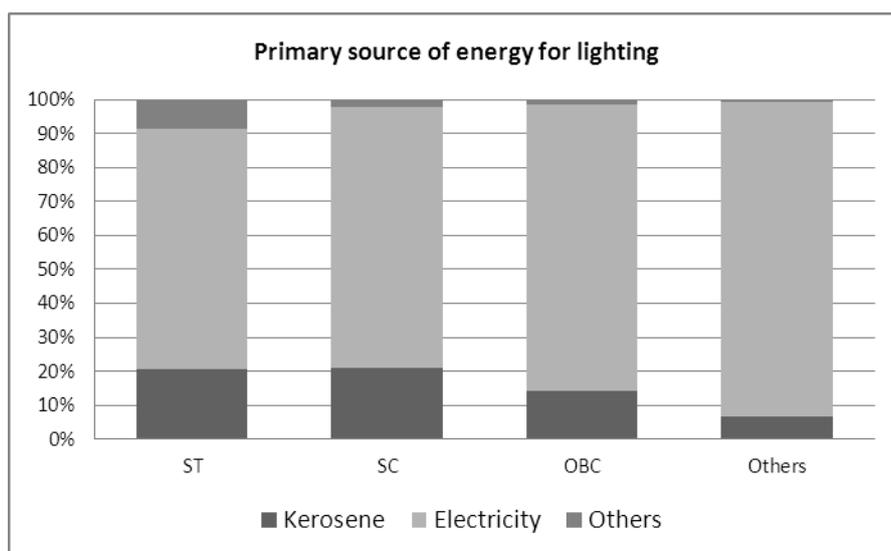


Figure 3: Primary source of energy for lighting among social classes in Chhattisgarh (Source : NSSO, 66 Round Survey, 2009-10)

While Chhattisgarh is abundantly blessed with sunshine, it was not the sole reason for the promotion of solar mini-grids in the state. CREDA had also implemented biomass gasification technology and bio-fuel gensets under RVEP and VESP. However, these projects were reportedly not successful due to technological management and fuel collection issues. The lack of operation and maintenance of biomass based plants and unavailability of qualified manpower were found to be the key factors responsible for the limited success of

biomass based electrification. In addition, the availability of only standard capacities of biomass projects irrespective of load demand has also been a constraint for their use. All such projects were eventually converted into solar energy based projects by CREDA. The solar home systems deployed in the state has their own set of problems. While CREDA implemented solar home systems as early as 2003, the effort did not result in visible success primarily because of two major reasons. First, the beneficiaries did not realize the value of these systems as it was heavily subsidized thereby resulted in mortgaging of the system at a low price by the owner of the system whenever they face any financial crunch. Secondly, social problems like large scale prevalence of theft negated the very purpose of the deployment [21]. Realizing this, CREDA started exploring the option of installing solar mini-grids and the first mini-grid, after the creation of the state, was commissioned in 2004. However, solar home systems as an option have not been discarded altogether. Rather, solar based electrification in remote areas is carried out in two different ways. Larger villages with concentrated settlements are electrified through solar mini-grids whereas hamlets and villages with scattered households are provided with stand-alone solar home systems.

The following section provides a detailed analysis of the delivery model of CREDA including the details of projects deployed, technical contours of the model, institutional arrangement, financial mechanism, functionality and performance, operation and management aspects, system of monitoring and oversight and the observed impacts of off-grid electrification carried out using solar PV technology in the state. As mentioned in the Section 1.1, TERI team carried out field surveys in eight villages of Raipur and Korba districts to understand the multiple dimensions of project impact on communities. Table 2 shows the profile of the villages surveyed. The focus has been on these two districts as they have the highest capacity of solar mini-grids (Figure 4). These districts also represent different physiographical and socio-economic profiles. While in Raipur, both urban and rural population is almost equal as the state capital is in the Raipur district, the major population in Korba lives in rural areas. Korba is also heavily forested [30] and is designated as tribal (Adivasi) district whereas Raipur represents the plain region in the state.

Table 2: Profile of the villages surveyed in Chhattisgarh

	Raipur district	Korba district
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Village	Kouhabehra	Rawan	Mohda	Latadadar	Murumdeeh	Surkha	Sapalwa	Raha
Year of commissioning	2003	2004	2004	2004	2003	2007	2005	2007
Capacity of the plant (kWp)	3	7	4	3	5	4	5	6
Total number of households	50	72	72	45	46	50	83	75

Source: Authors' Field survey, 2012

3.3 Coverage & trend of solar mini-grids

Chhattisgarh has a cumulative capacity of around 3.5 MWp of solar power plants covering 1439 villages (as on June, 2012) spread across different districts in the state [19]. Figure 4 provides the district wise installed capacity and Figure 5 provides the year wise installation and dismantlement by CREDA. Most of the power plants have been installed in Raipur, Korba, Jashpur and Korlia districts, which accounts for around two-thirds of the total installed capacity. These districts are under dense forest cover, especially districts such as Korba, Korlia and parts of Raipur and thus traditionally have higher number of un-electrified villages¹¹.

Of the total installed capacity, around 45 kWp capacity was also found to be dismantled by CREDA mainly during the last five years. While in select few cases, the power plants have to be dismantled due to panel theft and poor management by villagers, in most other cases, dismantling were deliberate owing the grid extension by the CSEB. While CSEB and CREDA are well co-ordinated while taking up of a village for solar based electrification, with CREDA taking up the off-grid route only after CSEB's concurrence, often political compulsions lead to grid extension to village where solar min-grid also exists. However, the dismantled systems have also been utilized mainly in two ways - (1) those villages which are facing an increasing demand for solar power and need capacity augmentation were provided with new capacities using the dismantled systems, (2) the systems are retrofitted in those power plants which have some mal-functioning components such as faulty battery, panels etc. Further, the annual installed capacity figure also portrays a reverse U shape, indicating that annual incremental increase in the installed capacity up to the year 2007 and declining thereafter (Figure 5). This gradual decline in annual installation capacities is primarily due to

¹¹ Grid extension through forests is not permitted in India as they may require the uprooting of forest trees for which necessary permission is required to be taken from the central government [31].

increasing annual electrification rates thereby reducing the leftover villages for electrification.

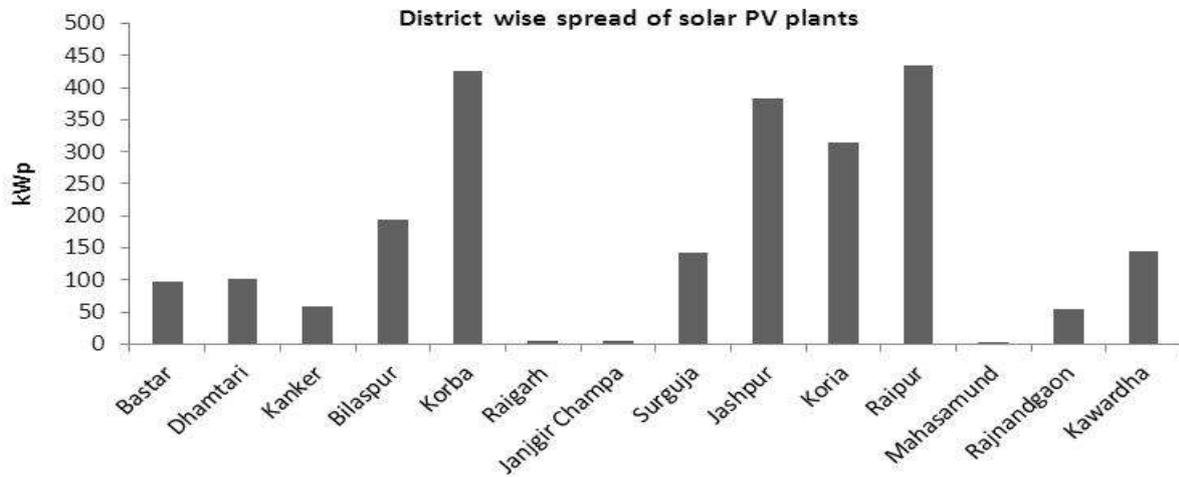


Figure 4: District wise spread of solar PV plants (Source: CREDA, 2012)

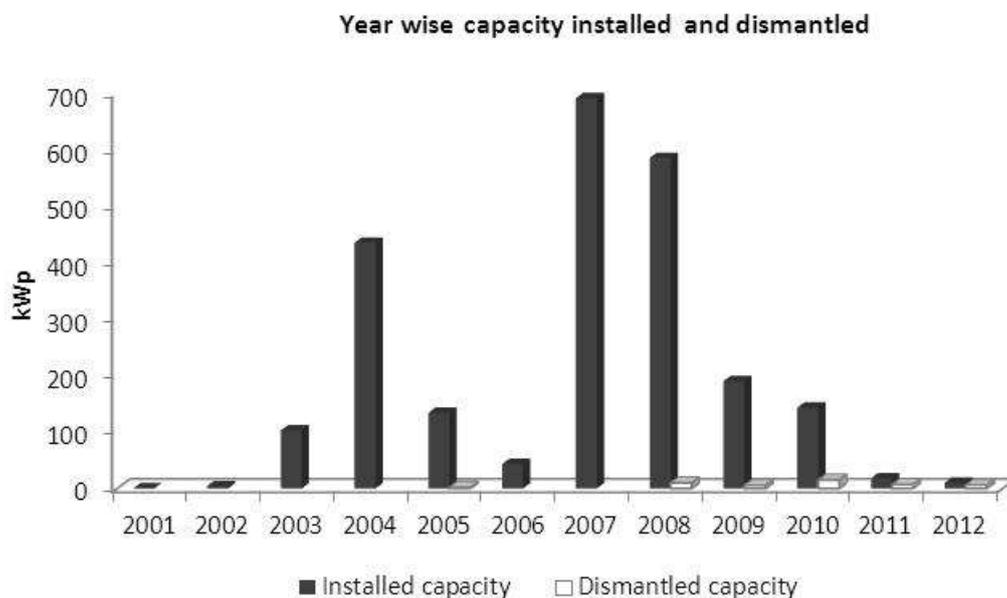


Figure 5: Year wise solar PV plants installation and dismantlement in Chhattisgarh (Source: CREDA, 2012)

3.4 Technical contours of the model

As mentioned in Section 2.2, the solar mini-grid essentially consists of a centralized solar power plant and a power distribution network that distributes the electricity to the households (Figure 6 & Figure 7). It was found that in Chhattisgarh, capacity of the installed systems ranges between 2-6 kWp and supply electricity in single phase. The lower capacity of installed systems is because of the smaller habitation size in terms of population (mostly 50-75 households per village or hamlets) and also because the projects were implemented mainly to provide lighting access either for residential needs or community load such as street lighting, lighting for schools, health centres and community hall, and do not included any productive load. Typically, 4 kWp plant capacity was found to be the most preferred across the different districts. This is mainly due to the fact that the tribal inhabited remote villages in Chhattisgarh are small with typical population of less than 100 households. It was also observed that on an average around 12-14 beneficiaries are connected to solar power plant per kWp capacity across the different districts in Chhattisgarh, with average load (in terms of



per household) being 73 watt (Figure 8).

Figure 6: Solar power plant in village Murumdeeh, district Raipur



Figure 7: View of distribution grid from the solar power plant, village Kauwabhara, Raipur district

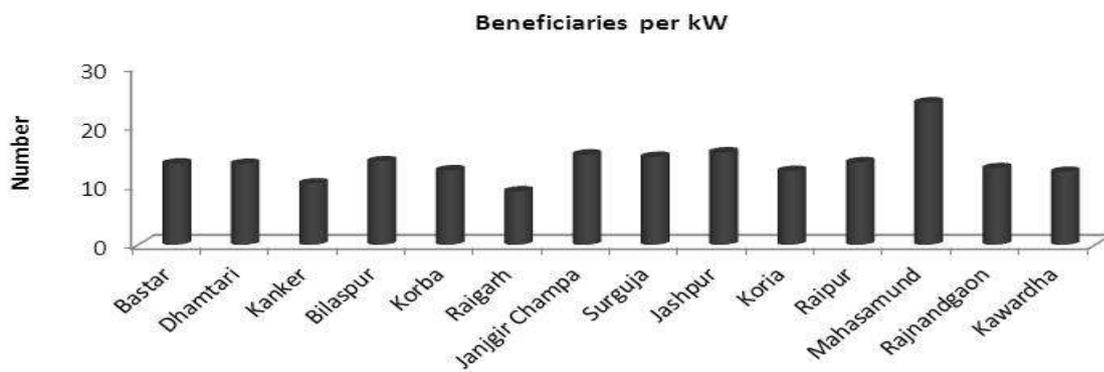


Figure 8: District wise average number of beneficiaries connected per kWp (Source: CREDA, 2012)

Every village is provided with household as well as streetlight connections. A household connection consists of two 11 W CFLs and the supply is given for 6 hours per day in most of the villages – 2 hours in the morning from 4-6 AM and 4 hours in the evening from 6-10 PM. The street lights are mandatorily provided in all the villages mainly for ensuring security in the night and operate for the same time as the domestic connections. Since the solar mini-grids are designed to cater only the lighting requirements, duration of supply is thus designed for the optimal use of the system. However, the systems have been designed such that it generates 10-20% incremental power to meet possible future demand. At present the power plant is not automated through load limiter and is switched on and off by the operator who stays in the village. In fact the primarily responsibility assigned to the operator is to do this job. There is, however, a battery protection panel, which is a switching device meant for isolating the battery bank.

A key feature of the model implemented in Chhattisgarh is the technical standardization which contributed to the ease of operation & maintenance and minimization of cost. While the systems with installed capacity of 1-3 kWp have a battery-bank of 48V and inverter rating of 3 kVA, the systems with 4 to 6 kWp installed capacity have 96V battery bank and inverter rating of 5kVA respectively. While in the beginning of the programme, solar panels were mounted on the ground and fencing provided around the same, for all later installations the civil structure has also been standardized with panel mounted in the rooftop and inverter and battery kept in the room. The height of the room is designed at a little height than usual room height, which reportedly helped in prevention of theft of the panels. Also, roof mounting reduced the cost of maintenance which otherwise is incurred for ground mounted panel on expenses such as fencing, theft, damage during monsoon etc.

Further, the battery bank in most power plants was found to have a last for around 8-10 years, much higher than the usual battery life of 4-5 years prevalent in most others states such as in Sunderban region where solar mini-grids have been implemented extensively [8]. The longer battery life has been ensured by CREDA by keeping a tab on the quality of battery purchased and by controlling the damage through misuse or overloading of battery capacity through routine monitoring (mandatory installation of ampere-hour meter to check the battery health) and maintenance, using the three-tier model of operation and maintenance (discussed in Section 3.8).

3.5 Institutional arrangements

In Chhattisgarh, off-grid electrification through solar mini-grids is mainly a state-led programme by CREDA in partnership with the private sector. While this is essentially a top-down approach, there are several actors involved in the process including state, private as well as local actors imbibing the essence of a Pro-poor Public Private Partnership model. The state and central government provide policy support and financial assistance to set up and operate the power plants, while the private sector is responsible for installation, operation and maintenance of the power plant and the mini-grids.

As a first step in mini-grid installation, CREDA, which can be regarded as the off-grid electricity utility in the state, carries out an extensive survey in the village and builds consensus among villagers about setting up of the plant. One of the important initial steps for selection of a village is to get consent from CSEB regarding the future target of CSEB for grid electrification of that village. Once CSEB gives a green signal that the village is not going to be electrified through centralized grid system, then CREDA takes up the village to electrify through off-grid mode. The next step is to carry out surveys, which are aimed at estimating the demand, decide on the potential size of the plant, keeping in mind the short-term to medium term energy demand in the villages. Consensus is built by convincing village people about the utility of solar lights and the benefits it brings to rural people. Limitations of the proposed plant such as limited application of electrical appliances, limited hours of supply etc. are also informed to the potential beneficiaries of the plant. As a symbolic gesture and to build in sense of ownership, the villagers are also asked to hand over a piece of community land identified for setting up the plant. A village energy committee is also formed to facilitate the project implementation and management. Often, these activities are carried out through direct supervision of CREDA. Survey is followed by cost estimation for installation of the plant and power distribution network (PDN). After the completion of the estimation exercise, it is then sent to the state government and MNRE for necessary approval and release of fund for actual installation.

CREDA then floats tenders inviting technical and financial proposals from solar PV companies and private service providers known as “system integrators”, for setting up the power plant and also for maintaining it. A critical requirement for participation in the tender is that the solar companies or the system integrators are having their offices in the state. This is done to ensure that fly-by-night operators and non-serious bidders cannot take part in the bidding process. One or several companies are then chosen to implement the projects, under

supervision of CREDA. In addition, CREDA also enter into an annual maintenance contract (AMC) with selected contractor for operation and maintenance of the plant. In some cases, both AMC contractor and, system integrator are the same entity; however, in most cases they are different.

At the last rung of the institutional hierarchy, lies the village energy committee (VEC), which acts as an interface between consumers, CREDA and private service providers and also acts as a local monitoring body. A local youth, selected by the VEC, is provided the responsibility by CREDA to operate the power plants and take care of minor maintenance (details on roles and responsibilities are highlighted in Section 3.8). The entire process of implementing this model, selection of service provider and monitoring and supervision of service providers post implementation, communicating with VEC for feedback, lies with CREDA which spearheads off-grid rural electrification process in the state.

3.6 Financing mechanism

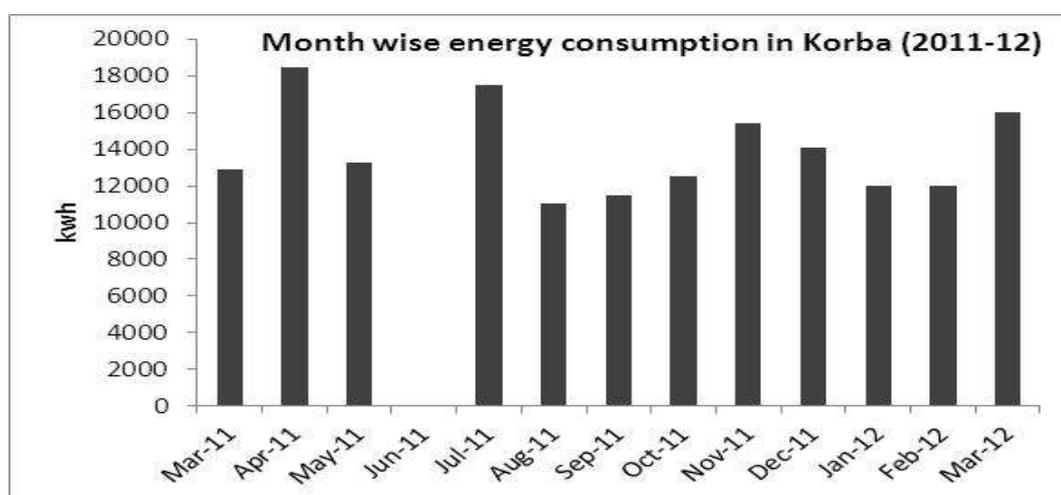
Since a majority of the mini-grids have been deployed under the RVEP, installation costs were taken care of through the capital subsidies by Government of India supplemented by support from the State Government. On an average, the cost incurred to set up a solar power plant in the remote areas in the state has been INR 350,000 to INR 400,000 per kWp. In addition, civil construction costs were INR 150,000 to INR 400,000 depending on the capacity of the power plants and type of civil construction. Similarly, INR 150,000 is the average cost of power distribution network per kWp of solar power plant including household connectivity. Typically the cost of connecting a household through solar mini-grids is INR 25,000/-[21]. Initially, connection charges were not imposed and were provided free of cost. However, lately CREDA has started charging for electricity connection. CREDA records show that these cost for implementing the power plant, civil construction, PDN and electricity connection to households was shared between the MNRE and state government, with MNRE's varying between 38% to and 48% during various years (2002-03, 2003-04 and 2004-05) [32]. The difference of MNRE's share is due to the fact that MNRE's share is dependent on their benchmark cost while the actual cost may be different for different power plants based on remote ness of the site and distance covered by the distribution line in the village.

Tariff structures have been devised keeping the socio-economic profiles of the beneficiaries under considerations. The tariff is INR 30/- per household per month per connection. Out of

which INR 25/- is from the state government as operational subsidy and the balance is collected from the beneficiaries. After meeting the expenses towards operators and cluster technicians, the balance amount is also utilized to buy spares and other incidental maintenance activities. It must be mentioned here that contribution per beneficiary has been decided in line with the existing subsidy schemes under grid electricity supply for the BPL households. Under this scheme, known as ‘*ekalbatti yojana*’, a tariff subsidy is provided for single point connection for below poverty line households.

3.7 Aspects of functionality and performance

During the survey in the eight villages, it was observed that almost all the plants were functioning and more than 90% of the home light connections were in working order. However, for street lights the functional status was found lower at around 70%. The faults were mainly related to CFL blackening or loose connections. The power plants mainly serve the domestic load of the village and cater to the lighting needs of the community (Figure 9, 10, 11 and 12). Thus, in terms of energy consumption pattern, the consumption per month for Raipur was found at 3.34 kWh/household while that for Korba it was found at 2.57 kWh/household. Based on these figures for energy consumption, it can be said that the power plants are operational for around 4-5 hours as against the designed 6 hours of operation. Further, the statistics of March 2012 reveals that in Raipur, a cumulative capacity of 429 kWp was serving about 10,170 home light connections and around 1120 street light connections. While in Korba, a similar cumulative capacity (426 kWp) was serving around 5350 home light connections and 874 street lights.



*June 2011 data was not available

Figure 9: Monthly energy consumption in Korba in 2011-12 (Source: CREDA, 2012)

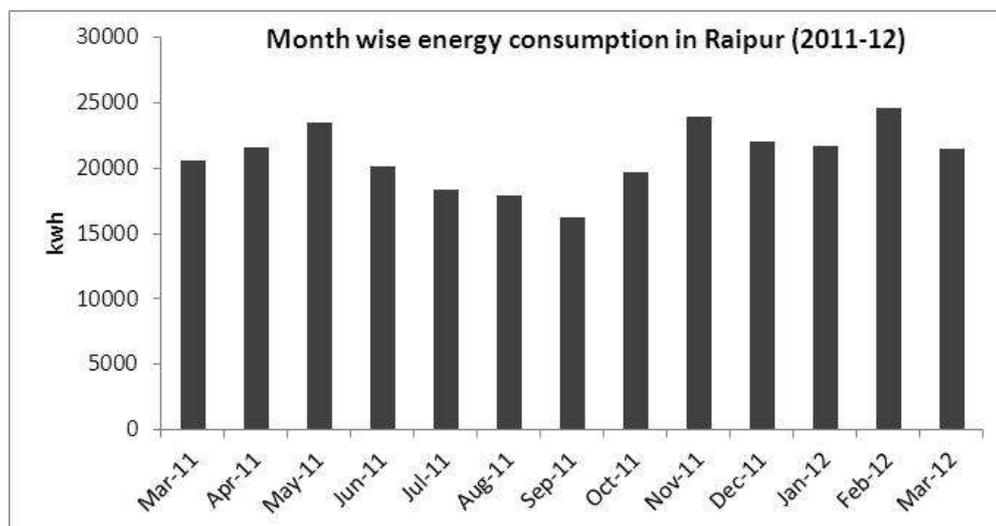


Figure 10: Monthly energy consumption in Raipur in 2011-12 (Source: CREDA, 2012)

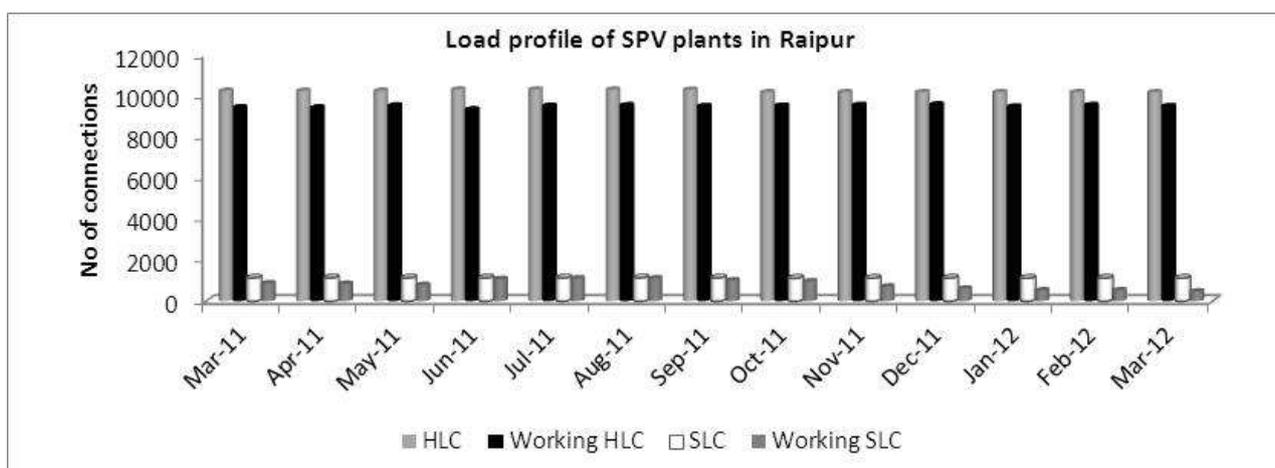


Figure 11: Month wise no. of connections served by SPV plants in Raipur (Source: CREDA, 2012)

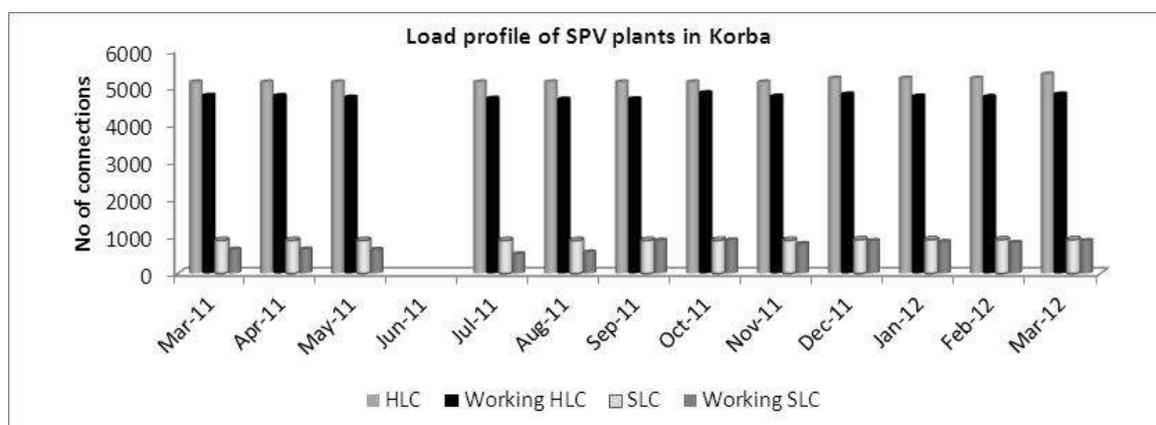


Figure 12: Month wise no. of connections served by SPV plants in Korba (Source: CREDA, 2012)

3.8 Operation and maintenance aspects

In most of the states in India, where mini-grids have been implemented either by state renewable energy development agencies or NGOs, the system operator under the supervision of the VEC is always made responsible for O&M of the mini-grids. However, in Chhattisgarh, CREDA has developed its own innovative model by standardizing all aspects of O&M. The model is called “*Cluster based service delivery model*” or as “*GOLD*” (Group the partners, Organize their skills, Allocate load in villages, Deliver service), where the installation is steered by CREDA and operation and maintenance of the plants is undertaken through a three tier set-up. CREDA signs an annual maintenance contract with the system integrators/AMC contractors for operation and maintenance of the solar power plant. O&M at the village/individual plant level is carried out by the operator, selected from the village and paid by the system integrators. The operator is responsible for cleaning the solar panels, switching the plant on-off, daily reading of the energy meter and recording and checking the battery- top up. At the next level, a cluster of villages is handled by a cluster technician who performs more advanced maintenance. The cluster technician, engaged by the system integrator, is assigned the responsibility to supervise the operator, make weekly visits to the village for preventive maintenance, check wiring and power distribution network, attend to any break down calls/repairs, and duly fill up and send the monthly monitoring report as per the format provided by CREDA. Every technician is provided with a motorbike by the service provider to facilitate his weekly visits to villages. The supervision of the activities at multiple clusters or a block level is done by the supervisor who monitors the activities of technicians, makes monthly visits to villages and collect reports for submission to CREDA. The appointment of the operator, technicians and supervisors is the responsibility of outsourced companies and salaries and incentives of these staffs are paid by the AMC contractor/outsourced company. However, regular CREDA staffs are engaged in parallel with AMC staffs to ensure that assigned tasks like routine maintenance are being properly carried out.

A third tier is managed by CREDA, which monitors all of its installations through monthly reports and replaces damaged equipment. This record based on continuous power output, has not only minimized cases of stealing and selling solar modules, it has rather also fuelled commercial demand for solar systems in the region. CREDA’s maintenance framework also ensures that the mini-grids provide an uninterrupted power supply as adequate supply of replacement lamps is kept in stock with each technician in case a light burns out.

Continuing with the innovative mechanism, CREDA has a structured mechanism in place to address the fault management. Especially for the monsoon season, when heavy rains can make roads inaccessible, spare inverter(s) for each cluster is supplied by the authorities. Thus, if failures occur, inverters can easily be replaced thus reducing the external dependency on the manufacturer's technician to come and repair it. Since only two rating of inverters are used with the power plant in the state, the replacement is easily done as spare inverters of such rating only need to be kept at the regional office of CREDA. In addition, CREDA have also ensured that extra inverter circuit boards of the two selected ratings are also provided by system integrators during the setting up of any power plant, so that faulty circuit boards can easily be replaced, from the spares supplied, by the cluster technicians. Furthermore, the drivers of the vehicles, that transport technicians and supplies, are also provided basic training on replacement of lamps and topping up of batteries in cases of emergency.

Technicians and operators are trained by CREDA and are also provided periodic refresher training courses in every six months. All the expenses for the trainings are borne by CREDA. CREDA has provided training to more than 1400 operators for carrying out responsive maintenance of the mini-grid systems [21]. A further 75 technicians and some 60 supervisors repair inverters and other electronics. CREDA has also trained more than 500 people to install and maintain various solar power systems that have been implemented in the state. The training session for the technicians is in general around one week with six hours training per day teaching them about electricity, electronic components, batteries and solar power and maintenance [20].

Every cluster has around 15-25 villages with around 50-75 households in each village. Given the operational subsidy provided by the state Government, the revenue from each cluster is to the tune of Rs 22, 500 per month, while the expenses inclusive of operator, technician and other staff salaries is around Rs 16, 500 per month ensuring the operational sustainability of the model (Table 4). During the field visits the model was found to be effectively working with regular payments ensured to the staff. In addition, some additional fund is also provided by the state government to meet the expenses like replacement of battery and inverter and for conducting the trainings. This fund is generated by keeping 10% of the project cost at the beginning in bank fixed deposits.

Table 4: Income and expenses for cluster based service delivery of solar mini-grids (in INR)

Revenue/ Month/cluster			
No. of villages/ cluster	15		
No. of customers/ village	50		
Total no. of customers/ cluster	750		
Collection per customer	30		
Through CREDA from Government	25		
Direct from beneficiary	5		
Total collection/cluster/month	22500		
Expenses/ Month/ Cluster	No	Rate	Total
Technician	1	4000	4000
Helper	1	2000	2000
Conveyance	1	2000	2000
Others	1	1000	1000
Operators	15	500	7500
Expenses/ Month/cluster	16500		

Source: CREDA, 2012

3.9 System of monitoring and oversight

Strong monitoring is ensured through the presence of well structured hierarchical monitoring system developed by CREDA, depending on the strength of each stakeholder. Starting from the village level up to the top of the hierarchy of monitoring at CREDA head quarter, presence of a strong and routine monitoring system is playing a key role in the better functionality of the plants. Importantly, since operation and maintenance activity are outsourced to private companies, CREDA officials are employed at each level of hierarchy for oversight on the activities of the private companies.

The overall monitoring and oversight is the responsibility of CREDA, however, at the village level VEC is also involved for local monitoring of systems. The VEC keeps an eye on the performance of the operator and receives first level of complaint from users. Unlike in mini-grid projects implemented under VESP or RVEP in other states, here the VEC is not involved in technical operation of the power plant act. Instead, they act as a lubricant for the social engineering required for smooth operation and management of the plant. VECs are also entrusted to resolve social conflicts and control on theft and other mismanagement of plants. Though their role has been kept limited, their importance in the whole institutional hierarchy cannot be negated.

3.10 Project impacts

While the focus of the study was more to understand the institutional and financial aspects and nuts and bolts of operation and maintenance, the study also attempted to qualitatively assess some of the direct impacts of the mini-grids. Based on the results from the focus group discussion, it can be said that the solar mini-grid systems in the state have been able to contribute to the socio-economic development of the community in many ways. During the visit it was observed that some households in the villages were also using mobile phones, fans, and entertainment facilities such as TVs and radios (Figure 12). This has led to increase in flow of information resulting in higher level awareness among beneficiaries. In specific terms, it was found that educational benefits are accrued through provision of lighting during the evening hours. Environmental benefits are being accrued through reduction in use of kerosene use. Information obtained through focus group discussion with community reveals that before these interventions were made, a household on an average used to spend about INR 100 per month on kerosene. However, with the provision of solar lighting systems, kerosene use has been drastically reduced and average monthly expenditure on kerosene has come down to less than INR 50. The study by Millinger et al. [20] also observes that the average saving on kerosene for households with mini-grid connection in Chhattisgarh is INR 30 per month. It should be mentioned here that since the lighting facility is for limited hours in the evening, some households still rely on kerosene, to some extent. In addition, electrification process has also led to income generation and employment creation. For instance, in the surveyed villages of Surkha, Saplowa and Raha, villagers reported working till late in the night for dana pata making (sal leaf cup-plate), thereby able to generate some incremental income for their families. In addition, at the system level, installation of mini-grids and other solar devices has been able to create a vast pool of skilled, semi-skilled human resources in the state, thereby meeting the employment needs and contributing to the socio-economic development of the state. CREDA also organised regular training course for developing solar technicians in the state and such trained technicians get engaged by the service providers maintaining the solar mini-grids and other solar devices in the state.



Figure 12: A solar mini-grid beneficiary household in village Latadadar, Raipur district

4. Discussion

While CREDA solar mini-grid model has been comprehensively discussed in the above sections, this section highlights the key aspects contributing to the success of the solar mini-grids in the state.

4.1 Robust institutional framework

One of the key ingredients of mini-grid's success could be linked to the strong and robust institutional structure created, nurtured and enlivened by CREDA (Figure 13). This is evident in multiple dimensions of the operational and management of mini-grids starting from the policy makers and planners in the state down to the very level in the hierarchy like operator of a single plant. Policy level support has been an important part of this institutional structure, which has been acting as a major impetus for the success of the model. In addition, it is also noteworthy to mention the public-private partnership structure engaged in the management and operation of the plant. The CREDA model also contradicts the notion that bottom-up approach with community involvement is the key to success of any decentralised project. While many researchers and practitioners have argued that decentralised energy systems should be implemented with a decentralised approach, with full planning and implementation by the community, the CREDA model clearly indicates that top-down approach of using standard designs, implementation and maintenance model, with community's involvement

for only local social engineering work, which they can do best, is a better (if not best) model to implement and operate the decentralised electricity infrastructure projects in remote communities. The outsourcing of maintenance to private management also brought in better efficiency of service into the project operation and management, which is difficult to ensure in a publicly devised and operated model.

Further, tariff collection is done by the AMC technician and supported by the operators in his effort. It is important to mention that there has been a clear cut fragmentation of the amount collected from tariffs and salary of operators. Irrespective of the tariffs collected in a village, operator gets a fixed monthly remuneration from the AMC contractor. Designing of this leads to successful operation of the plant as operator is assured to get their monthly payment. This is also corroborated from the study by Palit et al.[10] on Village Energy Security Programme where one of the key reasons for failure was that the project management was completely entrusted with the VEC without ascertaining whether they are adept at managing the project or not. Further, the same operator was made responsible for system operation and tariff collection and in case of non-payment by consumers, the operators' salary was delayed by the VEC which acted as a disincentive for the operator. The solar mini-grid experience from Sunderbans region also shows that decentralised projects are more successful when implemented and managed in an organised way with clear cut roles and responsibilities of different stakeholders [8]. Shrank [33] also observes, that the community management system do not always create incentives for maximizing profit at each power plant, thus creating problems for the coverage of costs of the power supply.

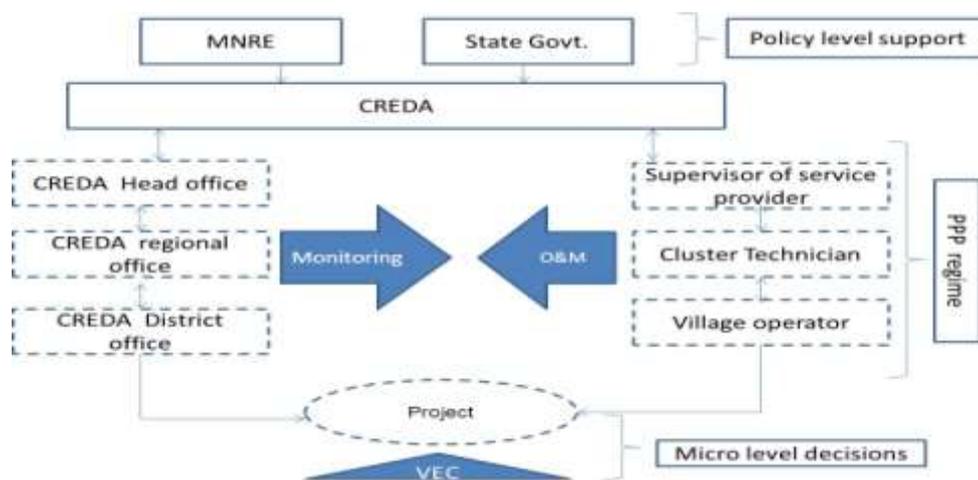


Figure 13: Institutional framework of solar mini-grid model

4.2 Social engineering is pivotal

The study also indicates that one of the key reasons to the success of solar mini-grids in Chhattisgarh is continuous and regular social engineering through continuous engagement and making the community adapt the system. While, there have been places where social conflicts have led to dismantling of the installed system, overall the VEC has played their role in shaping the social engineering. This was also made possible as the VEC could focus on this aspect only, as the technical operation and maintenance was outside their purview. Extensive capacity building and awareness generation of local stakeholders also helped as the social engineering is executed through regular training programmes, both formal and informal etc to different stakeholders.

4.3 Thin link between electricity supply and creation of productive activities

While provision of electricity has been primarily for lighting and no productive loads have been targeted as part of the initiative, there have been positive impacts on the local livelihood. Direct impacts are in terms of doing additional hours of work in the evening. For instance, during the *tendu* leaves collection season, extended hours of work could be possible as lighting is available during the evening. Further, in some cases, appliance uses such as use of radios, televisions etc. was also found in some of the households in the villages visited. Indirect impacts are in the form of growing awareness by use of mobiles, radios, televisions etc. Further research on this subject may be required for Chhattisgarh to quantitatively and qualitatively investigate the impacts of solar electrification on local economies in the state. It may also be relevant to do a social cost benefit analysis of installing smaller capacity systems, as have been done in the state, to see if benefit outweighs costs. Though productive applications has its own importance in increasing local income, it was also important for the Chhattisgarh government to facilitate electricity access for lighting for such remote population and provide necessary exposure, where they can initiate or get involved in some income generation activities to have enhanced income to pay for the services availed. The critical aspect here is that since mini-grids have been primarily used to provide electricity services, any new demand for load enhancement can now be met using the existing grid infrastructure by increasing the solar panel and using additional inverter (as productive demand may be during daytime, additional storage will not be required) at an marginal incremental cost which otherwise may not be possible with individual solar home systems.

4.4 Enabling policy environment

Enabling policy regime for promotion of solar mini-grids has been instrumental in accelerating the growth of off-grid electrification in the state. Realizing the importance of off-grid electrification for the state, the government of Chhattisgarh has been very proactive in providing supports to mainstream off-grid electrification options for geographically difficult locations of the state. While the solar mini-grids have been implemented under the REVP, the state government has also equally been generous of sanctioning fund to as high as 55% of the project cost to install mini-grids at the remote locations. Further, the tariff subsidy mechanism provided to grid electricity consumers was also extended to subsidize households getting electricity through off-grid generation. While it can be debated whether we can call the CREDA model a success or not, as operational subsidy is also provided by the government in addition to capital subsidy, it is to be kept in mind that the provision of electricity is for villages with extremely poor economic conditions. Thus, envisaging a business sense through energy intervention becomes difficult. Moreover, the state is following an equitable approach whereby the off-grid areas are also getting similar support provided in the grid connected areas, which otherwise is absent in most of the other states (where only grid connected consumers are provided tariff subsidy or cross-subsidy). Provision of electricity in these remote and far off localities could at best be considered as merit goods as also envisaged in Integrated Energy Policy of the Government of India. Lately, however, there is an on-going thinking within CREDA that now the time has come for a strategic shift in the provision of electricity from subsidized service to a paid one in at least few select sites. The idea is to spilt up the entire beneficiaries into two different groups. Households will be provided at a marginal fee whereas business units such as rural banks, tailoring shops, grocery shops etc. will be provided on the basis of full recovery of operation and maintenance cost.

5. Concluding remarks

This paper attempted to present an analysis of the development and operation of the solar mini-grid model for enhancing electricity access in India, with special focus on the state of Chhattisgarh. It is observed from the study that the rate of success of mini-grids is directly dependent on the government's commitment to create an enabling environment, which includes having a clear cut policy framework and milestones, systems for defining and enforcing appropriate technical standards, financial support mechanisms both towards installation and operation, and support for capacity building. The Chhattisgarh state has

developed a robust institutional framework not only for implementation, but also for ensuring responsive after-sales service and maintenance of the solar mini-grids in the state paving the way for success of the programme.

While there may be debate on what constitute a success as the model followed in Chhattisgarh is highly subsidized and the capacity of the power plants are designed to take care of only lighting load, there is no denying the fact the provisioning basic minimum electricity access to population who are at the extreme base of the pyramid is also important and requires innovative approach for success. While, many mini-grid projects fail in such remote areas because of lack of strong institutional framework and maintenance services, the implementing agency here have been successfully operating and maintaining the power plants by utilizing the fund made available by the state government towards the operational subsidy.

The mini-grids have also proved to be a reliable solution for such remote areas in comparison to solar home systems. Technically also, mini-grids are preferred over other modes like solar home-lighting systems and solar lamps, as mini-grids can provide electricity services for lighting as well as to run various appliances, whereas solar home-lighting systems and solar lamps typically provide only lighting services. Organizationally, Chhattisgarh experience shows that managing mini-grids may be easier compared to individual systems due to their centralised operation in a village through a proper institutional structure. Further, the design also ensured that any future demand, in the form of new household connection or power for community load, can be catered. The standardization of design and operation and maintenance model by local level service providers also ensured that the solution is cost-effective at the local scale. The system also do not lock-in the community to a particular development path as the mini-grid capacity can easily be enhanced by addition of modular capacity in case of enhanced demand for any productive loads in future, which otherwise is a constraint in case of individual solar home systems. Infact, the study clearly brings out this fact of capacity enhancement iwhich have been carried out in case of some villages using dismantled systems from other project villages where grid has reached over time.

Another key lesson from the mini-grid experience reveals that appropriate support systems should be a mixture of both “participatory approach” and “top-down approach”. While issues of a local nature could be better addressed through a participatory governance structure, technical, policy and financing matters can be dealt with at the appropriate intermediary

and/or higher level. It is important to design support systems so as to ensure that plans and policies match the needs of all stakeholders – consumers, owners and technology suppliers. Also, a divided ownership model, where operation and revenue collection have been kept independent of each other, is seen to bring better focus on generation and distribution. Lastly, for the renewable energy-based, rural electrification sector to reach significant scale, implementation agencies need to work on overcoming the challenges of supply, demand and scalability and at the same time adopt standard processes and metrics, which will also help them to attract the necessary level of investment from financial institutions in support of “energy access” programmes.

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Disclaimer

The views expressed in this report are those of the authors and do not necessarily represent the views of the institutions they are affiliated to or that of the funding agencies.



OASYS South Asia project

The Off-grid Access Systems for South Asia (or OASYS South Asia) is a research project funded by the Engineering and Physical Sciences Research Council of UK and the Department for International Development, UK. This research is investigating off-grid electrification in South Asia from a multi-dimensional perspective, considering techno-economic, governance, socio-political and environmental dimensions. A consortium of universities and research institutes led by De Montfort University (originally by University of Dundee until end of August 2012) is carrying out this research. The partner teams include Edinburgh Napier University, University of Manchester, the Energy and Resources Institute (TERI) and TERI University (India).

The project has carried out a detailed review of status of off-grid electrification in the region and around the world. It has also considered the financial challenges, participatory models and governance issues. Based on these, an edited book titled “Rural Electrification through Decentralised Off-grid Systems in Developing Countries” was published in 2013 (Springer-Verlag, UK). As opposed to individual systems for off-grid electrification, such as solar home systems, the research under this project is focusing on enabling income generating activities through electrification and accordingly, investing decentralised mini-grids as a solution. Various local level solutions for the region have been looked into, including husk-based power, micro-hydro, solar PV-based mini-grids and hybrid systems. The project is also carrying out demonstration projects using alternative business models (community-based, private led and local government led) and technologies to develop a better understanding of the challenges. It is also looking at replication and scale-up challenges and options and will provide policy recommendations based on the research.

More details about the project and its outputs can be obtained from www.oasyssouthasia.dmu.ac.uk or by contacting the principal investigator Prof. Subhes Bhattacharyya (subhesb@dmu.ac.uk).

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