



# Rural Energy Alternatives in India: Opportunities in Financing and Community Engagement for Renewable Energy Microgrid Projects

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*The villagers of Darewadi and their microgrid.*

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## List of Acronyms

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BMS	Battery Management System
BMT	Build, Manage, Transfer Model
BOD	Board of Directors
BOMT	Build, Operate, and Manage and Transfer Model
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CFL	Compact fluorescent light bulbs
CSR	Corporate Social Responsibility
DG	Distributed Generation
DDG	Decentralized Distributed Generation
DISCOM	Distribution Company
JNNSM	Jawaharlal Nehru National Solar Mission
MGP	Mera Gao Power
MOP	Ministry of Power
MNRE	Ministry of New and Renewable Energy
NGO	Non-governmental Organization
O&M	Operations and Maintenance
PDN	Power Distribution Network
REAP	Rural Energy Access Program
REC	Rural Electrification Corporation
RGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
RVE	Rural Village Electrification Program
RSO	Rural System Operator
SHS	Solar Home Systems
SEB	State Electricity Board
SERC	State Electricity Regulatory Commission
USAID	U.S. Agency for International Development
VEC	Village Electrification Committee
VESP	Village Energy Security Program

## Executive Summary

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Approximately one-third of the individuals living in India do not currently have access to electricity, and most of these individuals reside in rural areas. More specifically, an estimated 45% of rural households remain without electricity.<sup>1</sup> The Indian government has declared that one of their core priorities is to provide electricity to every household in India within the next five years.<sup>2</sup> While gradual progress has been made in extending the central electricity grid, reaching all rural households through such efforts is not a viable solution. Even for those villages for which grid extension is a possibility, the timing of when that might happen remains deeply uncertain.

A promising approach to the challenge of rural electrification is to increase the deployment of decentralized energy generation through the use of microgrids, which refers to a smaller-scale electric grid combined with a local generation source. The focus of this report is on how to scale up the deployment of microgrids. To date, microgrids have been successful at a project level. The challenge is to now replicate them on a broader scale, in all those villages where it is deemed the best option for rural electrification. In order to do so, it is essential to ensure that microgrids projects are both financially feasible and socially sustainable.

Our team has examined this challenge over the past few months by studying the theoretical literature and researching case studies. We also interviewed government officials, analysts, entrepreneurs, academics, activists, and consumers, in particular during a week-long trip to India where team members traveled to Delhi, Mumbai, Bangalore, Pune, Darewadi, and Jaipur. During our interviews, we repeatedly heard that financing and community engagement were two of the most important requirements to meet the challenges of feasibility and sustainability. The recommendations in this paper are therefore focused on effective financing strategies and community engagement.

To address financing challenges, we offer three major recommendations. First, we propose a hybrid subsidy model that would scale back existing upfront capital subsidies and complement them with performance-based subsidies. Second, we recommend increasing access to capital by streamlining the subsidy approval and payment process and drawing on other potential funding sources, including corporate social responsibility funds. Finally, we highlight how changes in rules to allow franchising and promoting expanded ownership opportunities can improve public-private partnerships and project quality. Ways to ameliorate the risks associated with the expansion of the grid and faced by project developers are also addressed in this section.

We also provide recommendations on how microgrid producers can better involve local communities in microgrid development and implementation. First, to ensure projects address community needs, microgrid producers should undertake feasibility and demand studies while working in partnership with community representatives and, if necessary, local NGOs. Second, microgrid developers should promote a “cooperative” model in communities with high levels of human capital and ownership over renewable resources. Additionally, private or non-profit enterprises should provide an overall facilitating service to rural microgrid cooperatives. Third, small frequent payments, employing community members for collections, and establishing retention mechanisms are crucial to addressing villagers’ ability to pay and gaining long-term buy-in for microgrid projects. Finally, producers should train local technicians to operate and maintain the microgrid.

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<sup>1</sup> Ministry of Home Affairs, Government of India, “Source of Lighting: 2001-2011,” *Census of India*, 2012, [http://www.censusindia.gov.in/2011census/hlo/Data\\_sheet/Source%20of%20Lighting.pdf](http://www.censusindia.gov.in/2011census/hlo/Data_sheet/Source%20of%20Lighting.pdf).

<sup>2</sup> Surya P. Sethi, “This Expensive Bulb Is Fused,” *The Hindu*, August 21, 2012.



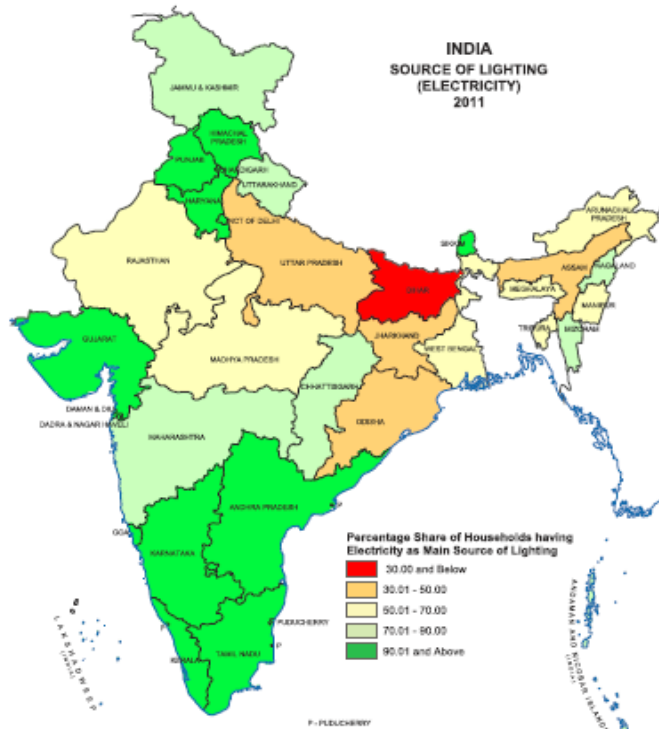
## Section I

### Current Status of Rural Electrification in India

This report is organized into six chapters. Chapter 1 provides an overview of the current state of electrification in India. Chapter 2 describes the major rural electrification policies that have been introduced by the Indian government. Chapter 3 compares the relative strengths and weaknesses of grid extension, microgrids, and solar home systems, and it provides guidance as to which might be most suitable under different circumstances. Chapter 4 and Chapter 5 discuss the main barriers to financing and community engagement and elaborate on the aforementioned recommendations to address those barriers. Finally, Chapter 6 concludes with a review of the major recommendations.

Despite the Indian government maintaining universal electrification as a policy goal for many years, approximately one-third of the Indian population of 1.2 billion individuals remains without access to electricity. According to the 2011 census, most of these individuals are concentrated in rural areas – 93% of urban households and a mere 55% of rural households currently receive electricity.<sup>3</sup> As shown in Figure 1, the states of the Northeast in particular suffer from low rates of household electrification.

**Figure 1.** Rates of Household Electrification per State



Source: Ministry of Home Affairs, "Source of Lighting: 2001–2011," Census of India.

<sup>3</sup> Ministry of Home Affairs, "Source of Lighting: 2001–2011."

Officially, 95% of villages in India are classified as electrified (see Figure 2).<sup>4</sup> The reason for this apparent disconnect is two-fold. First, villages are considered by the government to be electrified if at least 10% of their households are electrified and if their public structures such as schools and health centers are also electrified (see Box 1).<sup>5</sup> Second, hamlets – or settlements on the outskirts of a village – are often not included in the statistics on the percentage of villages currently receiving electricity. However, excluding hamlets skews those statistics because hamlets have a lower likelihood of being electrified. On this, Chaurey et al. make the point that electrification plans are made and implemented for census villages only and hamlets are neglected until recognized as a census village.<sup>6</sup>

**Figure 2.** Percentage of Villages Electrified per State as of October 2013

Andhra Pradesh	100.0%	Maharashtra	99.9%
Arunachal Pradesh	75.5%	Manipur	86.3%
Assam	96.1%	Meghalaya	86.3%
Bihar	96.7%	Mizoram	93.5%
Chattisgarh	97.1%	Nagaland	70.1%
Delhi	100.0%	Orissa	78.9%
Goa	100.0%	Punjab	100.0%
Gujarat	99.8%	Rajasthan	97.6%
Haryana	100.0%	Sikkim	100.0%
Himachal Pradesh	99.9%	Tamil Nadu	100.0%
Jammu & Kashmir	98.2%	Tripura	92.9%
Jharkhand	89.2%	Uttar Pradesh	88.9%
Karnataka	100.0%	Uttaranchal	98.9%
Kerala	100.0%	West Bengal	100.0%
Madhya Pradesh	97.7%	<b>Total</b>	<b>94.6%</b>

Source: Central Electricity Authority, “Progress Report of Village Electrification.”

This is not to say that progress on rural electrification is not happening. In the decade between the 2001 census and the 2011 census, the percentage of rural households with access to electricity jumped from 44% to 55%.<sup>7</sup> This was due in large part to grid extension efforts. However, reaching all rural households through such grid extension efforts will not be a viable solution. In 1999, about 18,000 villages were classified as “difficult to electrify,” suggesting that their remote location makes grid extension highly unlikely.<sup>8</sup> These have been the focus of the

<sup>4</sup> Central Electricity Authority, “Progress Report of Village Electrification,” 2013 October 31, [http://www.cea.nic.in/reports/monthly/dpd\\_div\\_rep/village\\_electrification.pdf](http://www.cea.nic.in/reports/monthly/dpd_div_rep/village_electrification.pdf).

<sup>5</sup> Ministry of Power, Government of India, “Rural Electrification Policy,” *The Gazette of India*, 2006, [http://powermin.nic.in/whats\\_new/pdf/RE%20Policy.pdf](http://powermin.nic.in/whats_new/pdf/RE%20Policy.pdf).

<sup>6</sup> Akanksha Chaurey, Malini Ranganathan and Parimita Mohanty, “Electricity Access for Geographically Disadvantaged Rural Communities—Technology and Policy Insights,” *Energy Policy* 32, no. 15 (October 2004): 1693–1705.

<sup>7</sup> Ministry of Home Affairs, “Source of Lighting: 2001-2011.”

<sup>8</sup> Debyani Ghosh, Ambuj D. Sagar and V.V.N. Kishore, “Scaling Up Biomass Gasifier Use: An Application-Specific Approach,” *Energy Policy* 34, no. 13 (September 2006): 1566–1582.

Remote Village Electrification program (described below) and, as of December 2012, about 9,500 villages and hamlets have been electrified under this program.<sup>9</sup> Even for those villages for which grid extension is a possibility, our interviews indicated that the timing of central grid arrival is often an area of uncertainty.

### **Box 1. Definition of “Electrified Village”**

The criteria that the Indian government uses to define an electrified village have been evolving. As of 2004–2005, the newest criteria consist of the following:

- Basic infrastructure, such as the distribution transformer and distribution lines, is provided in the inhabited locality as well as the Dalit Basti hamlet where it exists.
- Electricity is provided to public spaces like schools, panchayat offices, health centers, dispensaries, community centers, etc.
- The number of households electrified should be at least 10% of the total number of households in the village.

*Source: Ministry of Power, Rajiv Gandhi Grameen Vidyutikaran Yojana website.*

Another theme that came up in our interviews and in the literature was that although rural households want electricity, they have relatively low effective demand because of their income levels. Though that seems to contradict what is often heard about rural households demonstrating a willingness to pay for electricity, the two statements are not necessarily incompatible if there is indeed such willingness to pay but it only applies to a fairly small amount of electricity. Our interviews suggested that that is in fact the case. One microgrid provider found that the demand level that most villagers in the region they were serving could afford amounted only to enough electricity to power two light bulbs and a cell phone charger.<sup>10</sup> Even if their demand were to increase to a level that could power three light bulbs, a television, a fan, and a number of other appliances, the Rockefeller Foundation estimates that the average load for a rural household would amount to less than one-third of a kilowatt.<sup>11</sup> If a rural village consists of 45 to 60 households, peak load demand would thus only total approximately 15 to 20 kilowatts. This poses a challenge for rural electrification because low demand makes it harder to recover the upfront investment needed to extend the central grid or to install distributed generation (DG) technologies in remote areas.

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<sup>9</sup> Ministry of New and Renewable Energy, “Annual Report 2012-2013,” <http://mnre.gov.in/file-manager/annual-report/2012-2013/EN/chapter5.html>.

<sup>10</sup> Nikhil Jaisinghani, *Mera Gao Power*, interview by author (October 14, 2013).

<sup>11</sup> Rockefeller Foundation, “Smart Power for Environmentally-Sound Economic Development,” August 2011, <http://www.rockefellerfoundation.org/blog/speed-smart-power-environmentally-2>.



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## Section II

### Government Electrification Efforts To-Date

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The Indian government has been pursuing rural electrification efforts since the 1960s, but the issue has gained prominence in the past few years. Indeed, Prime Minister Manmohan Singh referenced it in his 2012 Independence Day speech: “Our next target is to provide electricity to each and every household in our country in the next five years and to also improve the supply of electricity.”<sup>12</sup> Similarly, the 2005 National Electricity Policy established the goal of providing universal access to electricity within five years. It also aimed to provide a minimum lifeline consumption of 1 kilowatt-hour (kWh) per household per day by 2012, although this target was not met.<sup>13,14</sup> In line with that goal, several major policies have been launched in the past few years.

#### A. Electricity Act of 2003

For the first five decades following independence in 1947, responsibility for the power supply lay in the hands of State Electricity Boards (SEBs). While the central government retained some overall coordination and planning functions, the vertically-integrated SEBs were largely responsible for power generation, transmission, and distribution.<sup>15</sup> However, the SEBs frequently operated at a loss. By the early 1990s, the Indian government had begun seeking alternative structures to promote more rapid expansion of the electricity sector. The culmination of this push to liberalize the power sector was the passage of the Electricity Act of 2003. The most salient features of the Act include:

- a) the unbundling of the SEBs into separate entities for generation, transmission, and distribution;
- b) the de-licensing of power generation so that it was open to investment and competition from the private sector;
- c) the granting of open access to transmission and distribution;
- d) efforts to improve the financial situation of distribution companies through an increased emphasis on metering and losses through theft; and
- e) the establishment of the Central Electricity Regulatory Commission (CERC) and the State Electricity Regulatory Commissions (SERCs).

The Act also allowed non-governmental entities to establish rural service agreements with remote communities that were not expected to gain grid access in the foreseeable future. However, businesses that undertook such projects did not always receive promised subsidies due to policy disparities and bureaucratic hurdles.

#### B. Remote Village Electrification Program

In 2003, the Ministry of Non-Conventional Energy Sources (now the Ministry of New and Renewable Energy) introduced the Remote Village Electrification (RVE) program with the objective of bringing basic lighting and electrification to un-electrified remote villages and also to un-

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<sup>12</sup> Surya P. Sethi, “This Expensive Bulb Is Fused,” *The Hindu*, August 21, 2012.

<sup>13</sup> Government of India, National Electricity Policy 2005, [http://www.powermin.nic.in/whats\\_new/national\\_electricity\\_policy.htm](http://www.powermin.nic.in/whats_new/national_electricity_policy.htm) (accessed November 28, 2013).

<sup>14</sup> India Development Gateway, *National Electricity Policy 2005*, <http://www.indg.in/rural-energy/policy-support/national-electricity-policy-2005> (accessed November 28, 2013).

<sup>15</sup> Sunila S. Kale, “Current Reforms: The Politics of Policy Change in India’s Electricity Sector,” *Pacific Affairs* 77, no. 3 (March 2004): 489-491.

electrified remote hamlets of electrified villages through renewable energy technologies. The goal of the program was to reach all remote villages by 2007 and all households by 2012. But following the launch in 2005 of Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), described in greater detail below, the RVE program was modified to focus only on those villages and hamlets where grid extension is uneconomical or infeasible and where RGGVY does not apply.<sup>16</sup> In particular, it focuses on villages of over 300 inhabitants that are more than 3 km from the nearest point of grid access. RVE provides subsidies for 90% of the installation costs of renewable energy projects, with the particular renewable energy technology chosen by the relevant state-level agency after an assessment of renewable resource availability. As of December 2010, the program had reached 7,408 villages and 2,145 hamlets.<sup>17</sup> Around 900 villages and hamlets were removed from the list because they were taken up for grid electrification.

### C. Village Energy Security Program

The Village Energy Security Program (VESP) was launched in 2004 by the Ministry of New and Renewable Energy (MNRE) with the aim of meeting the total energy needs of remote villages through locally-available renewable energy (e.g., biomass and biogas). MNRE provided a one-time grant to cover up to 90% of the capital costs of electricity generators using biomass gasifiers and/or vegetable oil in combination with the infrastructure necessary to distribute the electricity throughout the community. The program also promoted the use of clean cooking technologies through the distribution of improved cook stoves and biogas units. In all cases, community members were responsible for providing “at least 10% of an equity contribution with either cash or other contributions such as land and labor.”<sup>18</sup>

Community ownership was a central feature of VESP, and each community was responsible for the planning and the implementation of the program. This was accomplished through the formation of Village Electrification Committees (VECs) that brought together village representatives and local governance bodies (Gram Panchayats). In addition to the initial planning and implementation, the VECs were also responsible for the setting of tariffs, bill collection, and ongoing operations and maintenance, including the procurement of biomass fuel.

As of the end of 2011, 65 VESP projects had been commissioned in 9 states and 14 others were in the process of being implemented.<sup>19</sup> However, one study that looked into the progress of 50 of those projects found that less than half were operational and the remainder “were either non-functional... or had not been commissioned at the time of assessment.”<sup>20</sup> The same study found that VESP projects confronted challenges that included unorganized supply chains for biomass, insufficient technical knowledge about how to operate generators, inadequate maintenance networks, confusion about the division of responsibilities among stakeholders, and low demand for electricity.<sup>21</sup> As a result, VESP was discontinued in 2012.

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<sup>16</sup> Ministry of New and Renewable Energy, Government of India, *Remote Village Electrification*, <http://www.mnre.gov.in/schemes/offgrid/remote-village-electrification/> (accessed 2013 November 28).

<sup>17</sup> Ministry of New and Renewable Energy, “Annual Report 2012-2013,” <http://mnre.gov.in/file-manager/annual-report/2012-2013/EN/chapter5.html>.

<sup>18</sup> Debajit Palit, et al., “The trials and tribulations of the Village Energy Security Programme (VESP) in India,” *Energy Policy* 57 (June 2013): 412.

<sup>19</sup> *Ibid.*

<sup>20</sup> *Ibid.*

<sup>21</sup> *Ibid.*

## D. Rajiv Gandhi Grameen Vidyutikaran Yojana

In 2005, Prime Minister Manmohan Singh launched RGGVY as the government's overarching rural electrification program. The program was created by "essentially combining existing rural electrification programs under a new avatar and raising the outlay."<sup>22</sup> The scheme was implemented through the Rural Electrification Corporation (REC), which is a public enterprise that finances and promotes rural electrification projects throughout the country. RGGVY subsidizes 90% of the capital costs for grid extension to actors who are willing to undertake rural electrification projects. The remaining 10% is covered through loans from the REC. In addition, households below the poverty line are provided with free electricity connections.

In 2009, the Ministry of Power announced guidelines for the Decentralized Distributed Generation (DDG) program within RGGVY. Where grid extension is not feasible or foreseen in the next five to seven years, RGGVY recommends off-grid solutions and provides substantial capital and operating subsidies through DDG.<sup>23</sup>

As of the end of September 2013, the Ministry of Power reported that RGGVY had completed electrification efforts in 108,000 un-electrified villages and intensive electrification efforts in 302,000 partially electrified villages. In addition, it had provided free electricity connections to 2.1 million households below the poverty line.<sup>24</sup> However, there are some caveats to these successes. One important consideration is that their definition of "village electrification" does not mean that all, or even most, households within each village are electrified. Some states that claim to have 100% electrification still have up to 40% of their households without access to electricity.<sup>25</sup> As mentioned earlier [Box 1], a village is considered electrified if 10% of the households are electrified and if public structures such as schools and health centers are electrified.<sup>26</sup>

## E. Jawaharlal Nehru National Solar Mission

Inaugurated by Prime Minister Manmohan Singh in 2010 as part of the National Action Plan on Climate Change, the Jawaharlal Nehru National Solar Mission (JNNSM) aims to add 22,000 megawatts (MW) of on- and off-grid solar capacity by 2022 (20,000 MW from on-grid solar and 2,000 MW from off-grid solar).<sup>27</sup> This goal is to be achieved in large part through attractive feed-in tariffs. As of the end of 2012, the Ministry of New and Renewable Energy reported that 1.04 GW of grid-connected solar projects had been commissioned and that 161 MW of off-grid solar PV systems had been sanctioned in the first phase of the mission, which extended from January 2010 to March 2013.<sup>28</sup>

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<sup>22</sup> Sethi, "This Expensive Bulb Is Fused."

<sup>23</sup> World Bank, *Empowering Rural India: Expanding Electricity Access by Mobilizing Local Resources*, (Washington, DC, DC: World Bank, 2010).

<sup>24</sup> Ministry of Power, Government of India, "Rajiv Gandhi Grameen Vidyutikaran Yojana Progress Report," *Rajiv Gandhi Grameen Vidyutikaran Yojana*, 2013, [http://powermin.nic.in/bharatnirman/pdf/MIS\\_of\\_RGGVY.pdf](http://powermin.nic.in/bharatnirman/pdf/MIS_of_RGGVY.pdf).

<sup>25</sup> Sethi, "This Expensive Bulb Is Fused."

<sup>26</sup> Ministry of Power, Government of India, "Rural Electrification Policy," *The Gazette of India*, 2006, [http://powermin.nic.in/whats\\_new/pdf/RE%20Policy.pdf](http://powermin.nic.in/whats_new/pdf/RE%20Policy.pdf).

<sup>27</sup> E3, "Electricity Grid Evolution in India," (2011).

<sup>28</sup> Press Information Bureau, "Projects Under Phase 1 of JNNSM Completed," December 17, 2012, <http://pib.nic.in/newsite/erelease.aspx?relid=90842>.



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## Section III

### Technology Alternatives for Rural Electrification

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Rural electrification strategies have focused on three technologies: the central grid/grid extension, solar home systems (SHS), and microgrids. Selecting the most appropriate technology for a particular context depends on what characteristics are needed and best suited for that environment. The first subsection will highlight some of the key differences among these three types of technologies in the following areas: reliability, cost of generation for producers, price of electricity for consumers, load and capacity, losses, generation sources, and geographic- or location-based constraints, and operations and maintenance. The second subsection will compare microgrids, SHS, and grid extension to identify the advantages and disadvantages of each in choosing among the alternatives. The third subsection will classify villages into three categories and provide general guidelines on which technologies might be the most appropriate for each type of village. Finally, the last subsection will give examples of microgrids that have already been successfully implemented.

#### A. Three Technology Alternatives: Central Grid/Grid Extension, Solar Home Systems, and Microgrids

This section will look at each of these three major options that can increase rural electrification.

##### 1. Central Grid/Grid Extension

As explained in previous sections, a major focus of the Indian government's electrification strategy has been to extend the central grid to rural villages. However, this might be a suboptimal strategy if universal electrification is a priority for the government. More specifically, extending the grid to remote villages is not always the most cost-effective solution.

■ **Reliability:** The reliability of grid-based electricity supply has been a constant problem; in some states, even the limited goal of supplying at least 6 hours of electricity a day by the central grid has not been met.<sup>29</sup> In Bihar, villages surveyed in 2008–2009 receive anywhere from 1.3 hours to 6.3 hours, depending on the month.<sup>30</sup> Moreover, there was no correlation between the number of years a village had been electrified, the proportion of households electrified, and the hours of power available.<sup>31</sup> This shows that grid power reliability is not necessarily increasing with time.

■ **Price and Cost:** The price of power for grid electricity consumers pay commonly cited by experts to be Rs. 3/kWh, though the actual price varies from state to state and for each consumer category. Moreover, this does not reflect the actual cost of producing power, especially the cost of producing power and setting up transmission lines for areas that are very distant from the source of generation. Nouni et al. look at the actual cost of grid power in villages that are very distant from

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<sup>29</sup> Santosh M. Harish, Granger Morgan and Eswaran Subrahmanian, "When does unreliable grid supply become unacceptable policy? Costs of power supply and outages in rural India," Carnegie Mellon University (2013), 1-37. This paper uses data from the Central Electric Authority to estimate reliability.

<sup>30</sup> Hisaya Oda and Yuko Tsujita, "The determinants of rural electrification: The case of Bihar, India," *Energy Policy* 39, no. 2 (June 2011): 3086-3095.

<sup>31</sup> Ibid.

the central grid. They estimate the cost of generating, transmitting, and distributing electricity from a coal thermal power plant to remote areas of the country to range between Rs. 3.18/kWh to Rs. 231/kWh for villages that are between 5 and 25 km away from the central grid.<sup>32</sup> They find that for villages with about 20 households and a peak load of 5 kW that are 5 km from the grid, the cost of electricity is about Rs. 26/kWh. This cost of generation, transmission, and distribution increases to Rs. 95/kWh if the required grid extension is about 10 km.<sup>33</sup>

■ **Loads:** In general, the demand for electricity is surpassing the ability of the central grid to supply it, which has led to regular shortages during times of peak electricity demand. For all of India, there is a deficit of about 3261 MW of a total 144,225 MW required during peak demand.<sup>34</sup> However, for certain regions and states, the deficit is much higher. For example, the deficit for Uttar Pradesh is 2794 MW, which is 19.4% of the total electricity required during peak demand.

■ **Losses:** The central grid continues to experience widespread electricity theft and transmission losses. In 2010-2011, India's nationwide losses were 23.97%.<sup>35</sup> In comparison, according to the World Bank, China had transmission losses of just 6% from 2009 to 2013.<sup>36</sup> Most of the losses in India stem from three main causes: (a) theft and illegal use of electricity from the lines or tampering with the meters; (b) non-paying consumers; and (c) non/under-billing by the distribution companies.<sup>37</sup> The losses can be even higher in some states. Research from Greenpeace shows that the transmission and distribution losses in Bihar, the state with the lowest electrification rates, are as high as 46.4%.<sup>38</sup>

■ **Generation Sources:** The current electricity generation capacity mix in India is about 56% coal, 20% hydropower, with the remainder divided between other renewable sources and gas. Nuclear energy comprises about 2% of the total electricity generation capacity.<sup>39</sup>

■ **Geographic- or Location-based Constraints:** The results from Nouni et al. show that for hilly areas, decentralized options become increasingly more cost-effective as the distance to the grid increases.<sup>40</sup> This shows that for hilly areas, the central grid faces even more constraints and higher costs in extension due to logistical challenges and a higher cost of manual labor.<sup>41</sup>

■ **Operations & Maintenance:** Transmission and distribution losses from factors such as technical inefficiency and power theft can make maintenance of the grid supply difficult.<sup>42</sup> Moreover, the number of personnel responsible for maintenance is also lacking. For example, according to a survey of local households by Greenpeace in three states, the amount of time needed for

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<sup>32</sup> Nouni et al., "Providing electricity access to remote areas in India."

<sup>33</sup> Ibid.

<sup>34</sup> Central Electricity Authority, Government of India, "Load Generation Balance Report," 2013.

<sup>35</sup> Central Electricity Authority, Government of India, "Growth of Electricity Sector in India," 2012.

<sup>36</sup> World Bank, *Electric power transmission and distribution losses*, 2013, <http://data.worldbank.org/indicator/EG.ELC.LOSS.KH>.

<sup>37</sup> Deorah and Chandran-Wadia, "Solar Mini-Grids for Rural Electrification."

<sup>38</sup> Udupa et al., "Failed Aspirations: An Inside View of the RGGVY."

<sup>39</sup> Central Electricity Authority, Government of India, "Growth of Electricity Sector in India," 2012.

<sup>40</sup> Nouni et al., "Providing electricity access to remote areas in India."

<sup>41</sup> Ibid.

<sup>42</sup> Hisaya Oda and Yuko Tsujita, "The determinants of rural electrification: The case of Bihar, India," *Energy Policy* 39, no. 2 (June 2011): 3086-3095.

maintenance personnel to respond to an outage was usually four days or more in Bihar and Uttar Pradesh.<sup>43</sup>

## 2. Solar Home Systems

In the 1990s, the World Bank identified SHS as the least-cost solution to the problem of rural electrification and supported many SHS programs in developing countries. In India, by 2012, there were 500,000 SHS and 700,000 solar lanterns distributed across the country.<sup>44</sup> These SHS are standalone electricity systems that include a set of solar PV panels, a battery storage system, an optional battery charging controller, and various end-use equipment such as fluorescent lighting.<sup>45</sup> Because solar PV panels generate DC electricity, the end-use equipment is limited to DC appliances such as light bulbs, unless an inverter is included in the setup.<sup>46</sup>

■ **Reliability:** SHS are designed to provide reliable electricity for a set load, so there is a lower likelihood of a power shortage assuming that the amount of solar irradiation does not experience drastic variation.<sup>47</sup> However, to ensure that power demanded does not exceed the supply capacity, households must be familiar with the capacity of the system in order to not compromise its reliability.<sup>48</sup> The reliability and power quality of a SHS can be negatively affected by the low quality of its individual components as well as sub-optimal operations and maintenance. According to a survey of SHS set up in Zambia in the early 2000s, over the course of three years none of the households surveyed had experienced any problems with the solar PV panels. However, 25–30% of the batteries needed replacement within two years due to sub-optimal operations and maintenance.<sup>49</sup>

■ **Price and Cost:** The cost of installing a solar home system varies depending on the type and size of solar panel module and any storage units included. Small solar systems that are able to power a few light bulbs, fans, and a television set have an upfront cost of around Rs. 45,000, while larger systems like a 1-kW solar home system can cost between Rs. 120,000 to Rs. 180,000.<sup>50,51</sup> A typical unit cost of generation is Rs. 37/kWh.<sup>52</sup> With solar PV systems in general, the efficiency of

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<sup>43</sup> Udupa et al., "Failed Aspirations: An Inside View of the RGGVY."

<sup>44</sup> P. Raman, J Murali, D Sakthivadivel and V.S. Vigneswaran, "Opportunities and challenges in setting up solar photo voltaic based micro grids for electrification in rural areas of India," *Renewable and Sustainable Energy Reviews* 15, no. 5 (June 2012): 3320-3325.

<sup>45</sup> E. Martinot, A. Cabraal and S. Mathur, "World Bank/GEF solar home system projects: experiences and lessons learned 1993–2000," *Renewable and Sustainable Energy Reviews* 5, no. 1 (March 2001): 39-57.

<sup>46</sup> A. Chaurey and T.C. Kandpal, "A techno-economic comparison of rural electrification based on solar home systems and PV microgrids," *Energy Policy* 38, no. 6 (June 2010): 3118-3129.

<sup>47</sup> Chaurey and Kandpal, "A techno-economic comparison of rural electrification."

<sup>48</sup> Mathias Gustavsson and Anders Ellegård, "The impact of solar home systems on rural livelihoods: Experiences from the Nyimba Energy Service Company in Zambia," *Renewable Energy* 29, no. 7 (June 2004): 1059-1072.

<sup>49</sup> Mathias Gustavsson and Anders Ellegård, "The impact of solar home systems on rural livelihoods: Experiences from the Nyimba Energy Service Company in Zambia," *Renewable Energy* 29, no. 7 (June 2004): 1059-1072.

<sup>50</sup> G. Ananthakrishnan. "What It Costs to Go Solar Today." *The Hindu*. May 11, 2013. <http://www.thehindu.com/opinion/blogs/blog-urban-prospects/article4706014.ece>.

<sup>51</sup> There is also a government subsidy that can reduce the cost of SHS by about 40%, so the cost could decrease to between Rs. 72,000 and Rs. 108,000.

<sup>52</sup> Chaurey and Kandpal, "A techno-economic comparison of rural electrification."

the components of the system, such as the batteries and inverter, improves with the capacity of the system. Because efficiency is higher with larger capacity modules, larger modules will have a lower unit cost of generation and unit cost of storage.<sup>53</sup>

■ **Capacity:** The capacity of a solar home system is determined by both the size of the PV panel array as well as the battery storage unit.<sup>54</sup> SHS typically only support small loads such as a few household light bulbs, a fan, and an outlet for charging mobile phones. Adding PV panels or purchasing a battery with a larger storage capacity can increase the system's capacity. However, the capacity of a typical SHS is low, around 100 watts, so there is limited ability to add income-generating loads to the system or to handle varying connected loads.<sup>55</sup> In addition, SHS provide DC electricity, so typical systems will only be able to support DC-compatible appliances, which are less-widely available and more expensive.<sup>56</sup> Installing an inverter to the system can allow them to utilize conventional AC-compatible appliances; however, as inverters are quite expensive, this is likely to significantly drive up the costs of generation.

■ **Losses:** SHS provide DC electricity, so any losses come from any inherent inefficiencies or losses within each system component, such as that from charging and discharging a battery or converting DC to AC current through an inverter. As mentioned earlier, components with a larger capacity have greater efficiencies than those with a smaller capacity, so SHS in general exhibit lower efficiencies than a microgrid system with solar PV generation.<sup>57</sup>

■ **Generation Source:** SHS rely on individual household PV units and use solar irradiation to generate electricity.

■ **Geographic- or Location-based Constraints:** SHS can be considered the most versatile distributed generation. Because nearly all of India has a high degree of exposure to sunlight throughout the year, solar power as a source of fuel is widely available throughout India. In addition, SHS does not need to be connected to any existing infrastructure such as a grid distribution network, so it can be used in any place that can support the installation of a solar PV panel with the accompanying components.<sup>58</sup>

■ **Operations & Maintenance:** Although the setup of SHS is simple, the systems still require proper operations and maintenance to be cost-effective. While low-quality solar PV panels are damaged easily, industrial-grade solar PV panels are typically robust and do not require much maintenance. However, the battery tends to lose its storage capacity both due to environmental factors and operational factors and needs to be replaced every 3–5 years.<sup>59</sup> Most of the

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<sup>53</sup> Chaurey and Kandpal, "A techno-economic comparison of rural electrification."

<sup>54</sup> Gustavsson and Ellegård, "The impact of solar home systems on rural livelihoods."

<sup>55</sup> Srinivasamohan Narayanan, *Solar Rural Electrification*, 2011 September 20, <http://www.renewableenergyworld.com/rea/news/article/2011/09/solar-rural-electrification> (accessed 2013 December 16).

Chaurey and Kandpal, "A techno-economic comparison of rural electrification."

USAID and Alliance for Rural Electrification, *Hybrid Mini-Grid for Rural Electrification: Lessons Learned*, (Brussels: Alliance for Rural Electrification, 2011).

<sup>56</sup> Chaurey and Kandpal, "A techno-economic comparison of rural electrification."

<sup>57</sup> Chaurey and Kandpal, "A techno-economic comparison of rural electrification."

<sup>58</sup> Deorah and Chandran-Wadia, "Solar Mini-Grids for Rural Electrification."

<sup>59</sup> Raman et al., "Opportunities and challenges in setting up solar photo voltaic based micro grids."

environmental factors relate to the temperature, in that higher temperatures decrease the lifespan of a battery. With regard to the operational factors, low and variable charge currents with occasional deep-discharge cycles without proper recharging of the battery will decrease its lifespan.<sup>60</sup> To help address these operational factors, a battery management system (BMS) can help restrict the battery charge and discharge levels and prevent over-charging or discharging of the battery. A BMS can automatically disconnect the battery from the PV system when the current available is higher than the maximum allowable charging current.<sup>61</sup>

In many business models for SHS, the user of the SHS is the sole owner of the system for the duration of its operational lifetime and is thus responsible for the operations and maintenance of the whole unit. The location of the household using the solar home system can also be a factor in the ability to maintain such a system. The more remote a household is, the harder it will be to get access to technical support and supplies for maintenance.<sup>62</sup>

### 3. Microgrids

The term microgrid refers to a single electric power subsystem linked to a small number of distributed generators that can be powered by either renewable or conventional sources of energy, along with different load clusters.<sup>63</sup> The key feature of microgrids is that they are able to operate independently of the central grid. This can help improve the power quality and reliability, as well as allow the local community to have more control over their power network.<sup>64</sup> Even once the microgrid is connected to a central grid network, the community can still retain some level of control.

The basic microgrid architecture is comprised of the following components: DG resources, an energy storage system (optional), a distribution system, and a communication and control system.<sup>65</sup> The main criteria for distinguishing different kinds of microgrids are: (a) whether it is connected to a central grid; and (b) what kinds of generation sources are connected to the microgrid.<sup>66</sup>

■ **Reliability:** Microgrids can suffer from some power quality and reliability issues associated with renewable energy sources in general and electricity distribution. For example, some renewable energy sources may face limitations based on natural variations in the environment (e.g., exposure to solar radiation for solar PV). In addition, common problems affecting the distribution network include voltage-based sagging/swelling, voltage imbalance, and flicker.<sup>67</sup> However, compared to SHS, the power quality is better in large part because the components of a microgrid and appliances powered by a microgrid are generally of higher quality than those for a SHS.

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<sup>60</sup> Mathias Gustavsson, "With time comes increased loads—An analysis of solar home system use in Lundazi, Zambia," *Renewable Energy* 32, no. 5 (April 2007): 796-813.

<sup>61</sup> Gustavsson and Ellegård, "The impact of solar home systems on rural livelihoods."

<sup>62</sup> Chaurey and Kandpal, "A techno-economic comparison of rural electrification."

<sup>63</sup> Lubna Mariam, Malabika Basu and Michael F. Conlon, "A Review of Existing Microgrid Architectures," *Journal of Engineering* 2013 (April 2013).

<sup>64</sup> R. Lasseter, "Microgrids and Distributed Generation," *Journal of Energy Engineering* 133, no. 3 (2007): 144-149.

<sup>65</sup> Mariam et al., "A Review of Existing Microgrid Architectures."

<sup>66</sup> R. Lasseter, "Microgrids and Distributed Generation."

<sup>67</sup> R. Lasseter, "Microgrids and Distributed Generation."; Mariam et al., "A Review of Existing Microgrid Architectures."



While it is an optional part of a microgrid, incorporating an energy storage system into a microgrid can greatly improve the quality of power.<sup>68</sup> Energy storage systems can help balance short-term changes in energy supply and demand that are due either to system disruptions or to changes in the load. Some of the suggested storage devices are batteries, flywheels, and super-capacitors.<sup>69</sup> However, in the Indian context, given low capacities to pay, the only storage devices that might make economic sense are batteries. If including an energy storage unit is not feasible, alternative methods to provide flexibility to the microgrid include adding a controllable DG source (e.g., diesel generation) or connection to a larger grid network.<sup>70</sup>

■ **Price and Cost:** Typical costs of generation are around Rs. 23 to 33/kWh based on the type of generation used in the microgrid, with monthly payments of around Rs.100 to 200 per month.<sup>71</sup> As the cost of renewable energy generation falls due to technological improvements and more efficient manufacturing processes, microgrids are becoming more competitive as a cost-effective means of providing rural households with access to electricity.<sup>72</sup> For example, based on analysis conducted by Harish et al., including interruption costs, standalone microgrids are competitive with grid extension at distances more than 17 km. Harish et al. look at a case study that does not include the fuel subsidies that are provided for kerosene and diesel, but concludes that if these subsidies were included in the economic analysis, the social cost of unreliable grid supply would only increase and make standalone DG more attractive.<sup>73</sup> Overall, the literature reflects that DG becomes an increasingly more cost-effective option with larger distances.<sup>74</sup>

■ **Losses:** DG is able to address many of the barriers of conventional grid extension mainly by eliminating the need for long-distance transmission through localized generation. This minimizes the losses due to transmission and distribution and provides a feasible means of reaching remote or geographically hard-to-reach villages.<sup>75</sup> This also helps reduce the initial capital costs and time needed for setup because it requires less large infrastructure construction (e.g. setting up high-voltage wiring), which reduces the investment risk, although it may not similarly reduce the per unit generation cost.<sup>76</sup>

■ **Generation Sources:** In general, microgrids are able to accommodate a variety of DG sources. These include renewable sources (e.g., biomass, micro-hydro, solar, and wind), non-renewable sources (e.g., diesel), and hybrid sources (e.g., biomass-diesel and solar-diesel). However, the DG sources that are best suited to a microgrid largely depend on the climate and topography of the region.<sup>77</sup>

■ **Geographic- or Location-Based Constraints:** Microgrids that use generation sources such as hydropower are geographically constrained, but others such as solar power or biomass are very flexible in terms of where they can be used since solar irradiation and biomass resources are locally

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<sup>68</sup> Lubna et al., "A Review of Existing Microgrid Architectures."

<sup>69</sup> Ibid.

<sup>70</sup> Ibid.

<sup>71</sup> See Appendix 2.

<sup>72</sup> Hiremath et al., "Decentralised Renewable Energy."

<sup>73</sup> Harish et al., "When does unreliable grid supply become unacceptable policy?"

<sup>74</sup> Nouni et al., "Providing electricity access to remote areas in India."

<sup>75</sup> Chaurey et al., "Electricity Access for Geographically Disadvantaged Rural Communities."

<sup>76</sup> Hiremath et al., "Decentralised Renewable Energy."

<sup>77</sup> Mariam et al., "A Review of Existing Microgrid Architectures."

available across India.<sup>78</sup> Microgrids are also comparatively easier to install than extending the grid in areas that are especially hilly or forested.<sup>79</sup> In general, because microgrids can be used with a variety of generation sources, they can be suitable for many locations and geographic contexts.

■ **Operations and Maintenance:** The operations and maintenance requirements of microgrids vary greatly depending on the generation sources used. For solar PV generation, the solar PV panels are generally robust and only require basic surface cleaning to ensure optimum functionality, though battery maintenance will be required as mentioned in the above section on SHS. In micro-hydro generation, the technology is also very robust and can operate for 50 years with minimal maintenance.<sup>80</sup> Biomass gasification generation requires the highest level of maintenance; engine maintenance is the greatest concern as the process of gasification leaves residues in the engine that can reduce functionality.<sup>81</sup>

**Figure 3.** Technology Characteristics of Grid Extension, Solar Home Systems, and Microgrids for Remote Rural Villages

Characteristic	Grid Extension	Solar Home Systems	Microgrids
<b>Reliability/ Power Quality</b>	Low reliability, especially for rural areas that are not considered profitable because of low demand	Reliable power quality as long as the load is within the system’s initial capacity. Low-quality end-use appliances, replacement parts, and lack of standards may negatively affect reliability of system overall <sup>82</sup>	End-use appliances and replacement parts overall more reliable than those for SHS. Varies, though coupling generation sources and including energy storage device can improve power quality
<b>Cost of Generation for Producers</b>	For remote rural villages, can range from Rs. 3.18/kWh to Rs. 231/kWh, high range is mostly due to varying distances from central grid <sup>83</sup>	About Rs. 37/kWh <sup>84</sup>	Around Rs.23 to 33/kWh (varies by generation source, e.g., micro-hydro, biomass, solar PV, wind-solar) <sup>85</sup>

<sup>78</sup> World Bank, *India Biomass for sustainable development—Lessons for decentralized energy delivery in India*, (New Delhi: World Bank, 2011); Buljit Buragohain, Pinakeswar Mahanta and Vijayanand S. Moholkar, "Biomass gasification for decentralized power generation: The Indian perspective," *Renewable and Sustainable Energy Reviews* 14, no. 1 (January 2010): 73-92.

<sup>79</sup> Nouni et al., "Providing electricity access to remote areas in India."

<sup>80</sup> M.R. Nouni, S.C. Mullick and T.C. Kandpal, "Techno-economics of micro-hydro projects for decentralized power supply in India," *Energy Policy* 34, no. 10 (July 2006): 1161-1174.

<sup>81</sup> Buragohain et al., "Biomass gasification for decentralized power generation."

<sup>82</sup> Chaurey and Kandpal, "A techno-economic comparison of rural electrification."

<sup>83</sup> Nouni et al., "Providing electricity access to remote areas in India."

<sup>84</sup> Chaurey and Kandpal, "A techno-economic comparison of rural electrification."

<sup>85</sup> See Appendix 2.

Characteristic	Grid Extension	Solar Home Systems	Microgrids
<b>Price of Electricity for Consumers</b>	Usually estimated to be Rs. 3/kWh, though this varies greatly by customer category; monthly costs increase with extent of usage	High per kWh costs; total upfront cost about Rs. 45,000 for a small home system <sup>86</sup>	High per kWh cost, but typical weekly/monthly rates are of the order of Rs. 100 to 200/month
<b>Load/Capacity</b>	Unlimited capacity, although there is often load shedding during times of peak demand <sup>87</sup>	Limited capacity; small loads only (e.g., lighting, cell phone charging).	Limited capacity but greater than that of SHS; currently most microgrids are limited to small loads
<b>Losses</b>	About 23.97% in 2012 <sup>88</sup>	Losses exhibited are based on inefficiencies of the components within the SHS (e.g. battery and inverter)	Overall fewer losses than with SHS; losses exhibited are still based on inefficiencies of the components within the microgrid; losses can also take place in distribution infrastructure of electricity
<b>Generation Sources</b>	Varies, e.g. nuclear, renewable sources, coal, gas, oil, hydro, etc.	Solar	Determined by local DG resources (e.g. micro-hydro, biomass, solar, wind)
<b>Geographic- or Location-Based Constraints</b>	Cost for supplier increases for more remote villages, difficult to extend power lines across hilly or forested areas	Most appropriate in areas with high levels of solar irradiation	Generation sources may depend on location, but microgrid location itself is flexible
<b>O&amp;M</b>	Low O&M capacity, often takes days for the State distribution companies to fix a problem	Easy installation and relatively low amount of maintenance needed with proper battery use	Varies from low (solar PV) to high (biomass)

<sup>86</sup> "Solar on Rooftops – Cost of Solar Power in India – Over Rs 15 per kWh." *Energy Alternatives India*, July 12, 2009. <http://www.eai.in/blog/2009/07/cost-of-solar-power-in-india-over-rs-15.html>.

<sup>87</sup> Central Electricity Authority, Government of India, "Load Generation Balance Report," 2013.

<sup>88</sup> Central Electricity Authority, Government of India, "Growth of Electricity Sector in India," 2012.

## B. Selecting the Appropriate Rural Electrification Strategy<sup>89</sup>

In general, the appropriate rural electrification strategy will be largely based on whether or not the central grid is expected to reach a particular rural village. As the lifetime of most microgrids is about 15–25 years and the lifetime of SHS is about 20 years,<sup>90</sup> whether or not the capital cost investment for microgrids or SHS is financially worthwhile depends on when the grid will reach the village.<sup>91</sup> This is also assuming that there will be no concrete policy for the grid to purchase electricity generated by microgrids. In our conversations, industry experts estimated the amount of time needed to recover the capital costs of setting up a microgrid system to be anywhere from 15 to 25 years. Hence, while microgrids and SHS are the most optimal solution for villages where grid extension is unlikely for the foreseeable future, for villages where grid extension might arrive in less than 20 years (estimated average capital cost recovery time), those solutions may not be financially viable.

A number of other factors also complicate this decision. Given the diversity of rural villages and households in India, selecting the appropriate rural electrification technology depends on the specific characteristics of the village in consideration. The literature covers many factors that influence the choice of technology, such as the distance from existing grid, the village's capacity to pay, and the electricity needs of the village. Location is the most important factor in determining if a village is electrified by the grid or not, showing that distance is one of the major barriers.<sup>92</sup> Chapter 5 of this report will cover these factors in further detail, but here we note that it is important to conduct targeted village-level scoping before each project to determine which technology choice is most appropriate.

The decision tree below (Figure 5) describes three types of villages based on the estimated time of arrival of grid-based electricity and shows the types of technologies that might be suited for each type. Even if the arrival of grid-based electricity is expected, DG in the form of microgrids or SHS may be more attractive depending on the characteristics and needs of the village. Meanwhile, in villages where the arrival of grid-provided electricity is unlikely, microgrids and SHS are the only alternatives that should realistically be considered for electrification purposes. The two sub-sections that follow provide more detailed information to consider when deciding between waiting for grid-based electricity or opting for distributed generation, and within DG, whether microgrid or SHS would be best meet the needs of the village.

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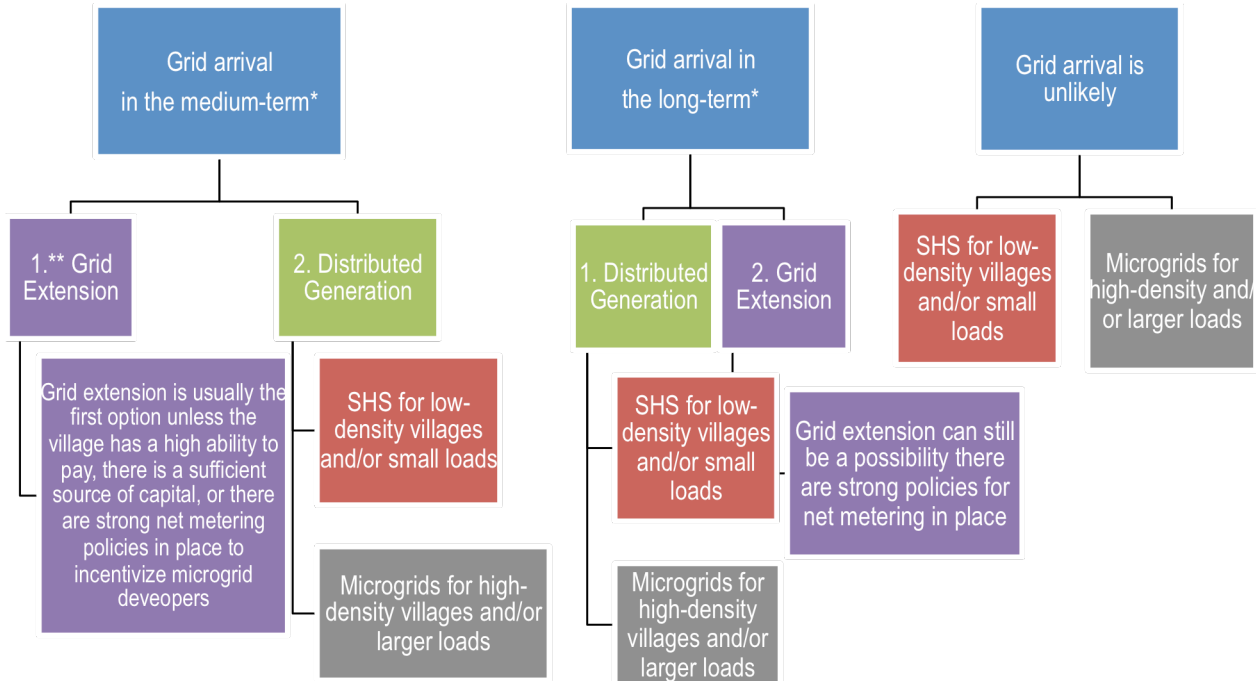
<sup>89</sup> World Bank, *India Biomass for sustainable development*.

<sup>90</sup> The effective lifetime of these systems might also be much lower due to the need to replace each component. For example, a LED bulb must be replaced every 2 years, a battery every 4-5 years, panels every 10-12 years. This means that systems tend to work for less than the perceived life.

<sup>91</sup> S.M. Najmul Hoque and Barun Kumar Das, "Analysis of Cost, Energy and Emission of Solar Home Systems in Bangladesh," *International Journal of Renewable Energy Research* 3, no. 2 (June 2013): 347-352.

<sup>92</sup> Oda and Tsujita, "The determinants of rural electrification."; Nouni et al., "Providing electricity access to remote areas in India."; Harish et al., "When does unreliable grid supply become unacceptable policy?"

**Figure 5. Technology Options by Village Type**



\* The use of medium-term and long-term in the decision tree is in order to illustrate whether or not the grid will arrive within the time needed for a DG developer to recover costs or not. If the grid is arriving in the medium term, this means that there probably is not enough time for the villagers to be using the DG electricity for the developer to recover costs. In contrast, the long-term refers to the villagers needing DG for sufficient time to cover the lifetime of the project. “Medium-term” and “long-term” are used in lieu of numbers because the lifetime of microgrid projects can vary based on capacity, generation source, etc.

\*\* The numbers in front of each technology option denote the likelihood in which this option is used. For example, if the grid will arrive in the medium-term, grid extension is usually the first option while distributed generation is the second option.

## 1. Comparing Microgrid with Grid Extension

Even for villages for which grid extension is a possibility, DG offers a number of advantages, both to the community as well as the government, as compared to the grid. If the government decides to implement policies enabling microgrids to sell electricity to the central grid, villagers could then use power from the central grid and a microgrid. In this case, this type of comparison would be irrelevant since the options would not be mutually exclusive. Currently, however, for villages that are considering microgrids even though grid extension is a possibility, two of the most important factors to consider when calculating the cost-effectiveness of microgrids are whether: (a) there are concrete grid integration plans from the government; (b) the capacity of the microgrid is sufficient so that grid integration would be cost-effective. The following can be important reasons for choosing the microgrid over grid extension:

- **Small loads means microgrids can be more economical:** Many remote villages have only around 50 households and their immediate need for electricity is very low, with demand often only for lighting, phone chargers, television, and sometimes transistors.<sup>93</sup> Through our on-site interviews in Darewadi, we found that the household demand for electricity was about 6-7 kWh a month,

<sup>93</sup> Nouni et al., “Providing electricity access to remote areas in India.”



which averages to about 0.2 – 0.25 kWh of electricity used per day. Most of the variation is due to whether or not the household uses a television. The cost of extending the grid for such a small load is often uneconomical as the capital cost that the government would have to pay for grid extension can be much higher than for microgrid development, especially for such low load levels.

■ **High cost of grid extension due to geographic distance:** As mentioned above, calculations from Nouni et al. show that the cost of grid extension to remote rural villages can be enormously high due to their distance from the grid, and this cost is often much higher than the cost of DG in these remote villages.<sup>94</sup> The cost of grid extension could potentially be lower if there were an anchor load such as a cell phone tower or an industrial plant, which would result in a cheaper per unit cost of electricity and provide the possibility of cross-subsidization. Unfortunately, due to the remote and inconvenient location of many of these villages, these load sources are difficult to find.

■ **Microgrid allows for local control over power generation:** At least in the case of microgrids, one advantage over grid extension is the ability for the village itself to control and take part in power management. More specifically, they can control the load in order to increase reliability and decide how to allocate load use.

■ **Microgrid power might be still be limited, though it may be more reliable:** Grid power is often not prioritized for rural areas. Load shedding often occurs for extensive time periods and at unplanned times. Research by Greenpeace in the state of Bihar shows that villagers often resort to alternative sources for lighting and often this is extremely expensive, with about 60% of their survey respondents spending between Rs. 50 to 100/month on kerosene to make up for the lack of reliable supply from the grid.<sup>95</sup> However, an important caveat is that many microgrids only allow limited electricity use due to limits on generation. For example, from field visits we learned that Gram Oorja's microgrid in Darewadi makes electricity available for 24 hours a day, but villagers have to be careful to limit electricity use. Mera Gao Power's (MGP) microgrids also provide very limited power for only two compact fluorescent light bulbs (CFL) and a charging source.<sup>96</sup>

## 2. Comparing Microgrids with Solar Home Systems

For villages that are primarily deciding between microgrids and SHS, the following factors should be taken into consideration:

■ **SHS is more cost-effective if microgrid distribution costs are high:** One main benefit of SHS is that the generation occurs very close to the load, which circumvents costs associated with transmission and distribution. The cost of the microgrid power distribution network (PDN) is a significant portion of the total cost of a microgrid project, and is affected by both the physical layout of the households and the load the wires need to carry. Longer distances between village households lead to higher costs of the PDN and can increase by 10–15% depending on the terrain of the village.<sup>97</sup> This means that the more scattered the households are in a village, the more expensive microgrids will be in comparison to SHS.<sup>98</sup> Furthermore, because the costs for

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<sup>94</sup> Ibid.

<sup>95</sup> Udupa et al. "Failed Aspirations: An Inside View of the RGGVY."

<sup>96</sup> Mera Gao Power, "What We Do," <http://meragaopower.com/whatwedo/>.

<sup>97</sup> Raman et al., "Opportunities and challenges in setting up solar photo voltaic based micro grids."

<sup>98</sup> USAID and Alliance for Rural Electrification, *Hybrid Mini-Grid for Rural Electrification*.

distribution infrastructure may increase if the terrain is hard to traverse, flatter and more even terrain is better suited for microgrids.<sup>99</sup>

■ **More expensive to add capacity in SHS:** Adding capacity with SHS can be expensive because of the previously mentioned lack of economies of scale, which makes the per-unit cost of additional capacity more expensive than that for microgrid or grid-based electricity. Also, each household is responsible for its individual unit, so expenses are borne at the household level and cannot be spread over the village.

■ **Limited capacity of SHS restricts income-generating potential:** SHS are only feasible and cost-effective for low loads, so it is unlikely that SHS will lead to income-generating opportunities or productive loads.

In summary, microgrids may be a better choice than SHS for villages that need higher capacities (either due to a greater number of households in the village or to support income-generating activities), are located on flat terrain, and in which households are not located too far apart from each other.

## C. Microgrids: Example Projects

As the central grid is still far from reaching all remote villages, a number of pilot projects have been successfully implemented using microgrids. This section will make the case that microgrids are not just a theoretical solution, but have actually translated to successful small-scale projects. This section will present three case studies of microgrids that have already been deployed. Through these case studies, this report hopes to illustrate the diversity of contexts in which microgrids can be used and the various implementation and deployment strategies that developers are using.

### 1. Gram Oorja

One example of electrification using microgrids is Gram Oorja's installation of a solar powered microgrid in Darewadi, which is north of Pune in Maharashtra. Despite being about 1 km from a nearby village that is connected to the grid, Darewadi has not been connected to the grid due to the hilly and uneven terrain separating it from the grid-connected village. Gram Oorja's project has installed solar capacity of about 10 kW for 40 households. The project was initially set up through a corporate social responsibility (CSR) partnership with Bosch Solar Energy. For this project, about 70% of the total energy has been earmarked for productive activities (i.e., a pump and a flour mill). This project has been implemented since October 2012 and is Gram Oorja's first remote electrification project. Bosch covered the upfront costs for the microgrid, but the villagers are charged a rate of about Rs. 20/kWh that ensures they can pay for their own battery replacement costs in 5 years. The villagers end up spending anywhere from Rs. 120 to Rs. 150 per month on electricity.<sup>100</sup> Though electricity is available for 24 hours a day, the villagers still have to manage their power use at night due to limitations on the battery storage. Gram Oorja helped the villagers set up a local committee, which is currently composed of three women and four men, and

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<sup>99</sup> Ibid.

<sup>100</sup> Anshuman Lath, interview by author, Pune (2013 November).

they are responsible for making any major decisions concerning the microgrid. Gram Oorja has also trained a local resident to clean the solar panels and performing basic maintenance work.<sup>101</sup>

## 2. Mera Gao Power

Another small enterprise that operates microgrids is Mera Gao Power. Currently, MGP serves a number of villages in the state of Uttar Pradesh. MGP provides DC electricity produced by solar photovoltaic panels.<sup>102</sup> The specifics of electricity provision, like timing and duration of daily provision, are decided primarily by MGP on the basis of a fairly standardized model with limited involvement of villagers. Electricity from their microgrids is available for seven hours in the evening, and the electricity provided is sufficient for two light bulbs and a cell phone charger.<sup>103</sup> This unit offering was fixed by MGP based on inputs gathered through community engagement during pilot projects. MGP provides LED light bulbs compatible with the DC connection<sup>104</sup> and cell phone chargers to their customers.<sup>105</sup> Installation of MGP's microgrid system is simple, and it takes three to four technicians only a day to complete the installation in a village or hamlet. The microgrid costs about \$900 per installation. MGP trains a local electrician who goes to the village once every two weeks to inspect the system. A local women's group is responsible for the collecting payments on a weekly basis in advance of the supply.<sup>106</sup> MGP estimates that it should be able to recover the capital cost of each project from villager payments in less than three years.<sup>107</sup> MGP does not rely on any government funding and has used private funding for all projects thus far.<sup>108</sup> It has received a \$300,000 grant from Development Innovation Ventures, U.S. Agency for International Development (USAID) and has raised \$1 million in equity to expand operations in the coming years.

## 3. Sagar Islands

The Sagar Islands in the Sundarbans region is an example of a collection of many hybrid DG microgrid projects, with the unique characteristic that the electricity provision is linked with water provision to the community. Until 1996, most of the island was powered for a few hours each evening using diesel generation with 300 kW of total capacity.<sup>109</sup> Because these diesel units both required high levels of maintenance and resulted in large amounts of pollution, MNRE in 1996 identified the area for new solar projects and set up a 26 kW solar PV microgrid. This project has now expanded to include 300 kW of generation capacity through solar PV, along with 400 kW from diesel generation, and 500 kW from wind-diesel hybrid power to meet expanded energy needs.<sup>110</sup> The system provides about six hours of electricity every evening for residential

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<sup>101</sup> Gram Oorja, *Remote Rural Electrification*, 2011, <http://gramoorja.in/our-projects/remote-rural-electrification> (accessed 2013 December 15).

<sup>102</sup> Smart Grid for India, "Mera Gao MicroGrid Power among the 10 emerging tech list of Technology Review," May 4, 2012, <http://smartgrid-for-india.blogspot.com/2012/05/mera-gao-microgrid-power-among-10.html>.

<sup>103</sup> WattNow, "Mera Gao Microgrid Power: Solar-powered network system for rural off-grid villages," July 6, 2012. <http://wattnow.org/2285/mera-gao-micro-grid-power-solar-powered-network-systems-for-rural-off-grid-villages>

<sup>104</sup> Ibid.

<sup>105</sup> Nikhil Jaisinghani, interview by author, Princeton, NJ (2013 October).

<sup>106</sup> Ministry of New and Renewable Energy, "Empowering Rural India the RE Way: Inspiring Success Stories."

<sup>107</sup> Ibid.

<sup>108</sup> Nikhil Jaisinghani, interview by author, Princeton, NJ (2013 October).

<sup>109</sup> Hiremath et al., "Decentralised Renewable Energy."

<sup>110</sup> V. S. K. Murthy Balijepalli, S.A. Khaparde and C.V. Dobariya, "Deployment of Microgrids in India," in *Power and Energy Society General Meeting* (Minneapolis, MN, USA: IEEE, 2010), 1-7.

consumers for a total of 30 kWh per month.<sup>111</sup> The community is involved primarily through the local cooperative members taking responsibility for the collection of electricity tariffs, the addressing of consumer grievances, and the basic operations and maintenance.<sup>112</sup>

**Figure 6. Case Studies Summary Table**

Characteristic	Gram Oorja	Mera Gao Power	Sagar Islands
<b>Size of Village</b>	About 40 households	About 35 households per village (many villages)	Population 160,000; 1500 to 2000 consumers
<b>Capacity</b>	10 kW	About 600 watts <sup>113</sup>	300 kW (PV), 500 kW (diesel), 500 kW (wind)
<b>Generation Source</b>	Solar PV	Solar PV	PV, Diesel, Wind
<b>Community Management</b>	Local village committee and local maintenance	Trains a local electrician to inspect village every two weeks, payment collections are done by a women's group in the village <sup>114</sup>	Local co-op collects tariffs, addresses consumer grievances and basic O&M of microgrid
<b>Price</b>	20 Rs./kWh with 90 Rs./month as a lower bound fixed cost	Flat connection fee per month of 25 Rs. and 25 Rs. per week for service <sup>115</sup>	5 Rs./KWh (residential); 5.5 Rs./kWh (commercial); 6 Rs./kWh (industrial)
<b>Capital Cost Recovery</b>	CSR donation from Bosch <sup>116</sup>	Capital cost can be recovered from village payments in 3 years <sup>117</sup>	Joint funding by MNRE, Indo-Canadian Environmental Facility (ICEF), and West Bengal Renewable Energy Development Agency (WBREDA)
<b>Electricity Availability</b>	24 hours a day availability with implicit limits on total use	7 hours of electricity availability a night <sup>118</sup>	Electricity available 5-6 hours a night for residential use; total of 30 kWh/month

As these case studies make clear, microgrids have been shown to be successful at the project level in different contexts. Although these are considered successes, even at the individual

<sup>111</sup> Hiremath et al., "Decentralised Renewable Energy."

<sup>112</sup> Kirsten Ulsrud, Tanja Winther, Debajit Palit, Harald Rohrer and Jonas Sandgren, "The Solar Transitions research on solar mini-grids in India: Learning from local cases of innovative socio-technical systems," *Energy for Sustainable Development* 15, no. 3 (September 2011): 293-303.

<sup>113</sup> Earth Techling, "GE Ecoimagination: Mera Gao Micro Grid Power," (February 21, 2011), <http://www.earthtechling.com/2011/02/ge-ecomagination-mera-gao-micro-grid-power/>.

<sup>114</sup> Ministry of New and Renewable Energy, "Empowering Rural India the RE Way: Inspiring Success Stories."

<sup>115</sup> Nikhil Jaisinghania, interview by author, Princeton, NJ (2013 October).

<sup>116</sup> Anshuman Lath, interview by author, Pune, India (2013 November).

<sup>117</sup> Ministry of New and Renewable Energy, "Empowering Rural India the RE Way: Inspiring Success Stories."

<sup>118</sup> WattNow, "Mera Gao Microgrid Power: Solar-powered network system for rural off-grid villages," July 6, 2012. [http://wattnow.org/2285/mera-gao-micro-grid-power-solar-powered-network-systems-for-rural-off-grid-villages\\_](http://wattnow.org/2285/mera-gao-micro-grid-power-solar-powered-network-systems-for-rural-off-grid-villages_)

project level, microgrid developers face the continuing challenges of obtaining the initial investment needed to get the project off the ground as well as figuring out how to create a system that can provide sufficient electricity to meet effective demand. However, in the context of meeting rural India's electricity needs, the challenge now is to replicate these individual project level successes at a wider scale (i.e., to scale up microgrids). In order to do so, it is essential to ensure that microgrid projects meet the criteria of feasibility so that developers are willing to undertake such projects in the first place, and also of sustainability so that such projects can be operational for many years. In our interviews, we heard overwhelmingly that financing and community engagement were two of the most important requirements for feasibility and sustainability. The recommendations in this paper are focused on addressing the challenges related to financing and community engagement. As mentioned earlier, these recommendations are most applicable to villages that are so remote that they are unlikely to ever be reached by the central grid, and villages that are unlikely to be reached by the central grid in the foreseeable future.



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## Section IV

### Enhancing Finance for Microgrid Projects

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Microgrid developers face two distinct but related financial challenges: (1) securing sufficient upfront capital to install microgrid systems; and (2) earning a sufficient rate of return on their investment in those systems over the medium- to long-term. Private capital markets are reluctant to invest in microgrids because of uncertainty over their long-run return. This limits the available sources of capital to government subsidy programs, corporate social responsibility arms, and donors that do not seek a significant rate of return on their investment. Even when developers can secure funding, they face an unclear future. As indicated by many notable failures, communities may be unable to consistently pay for the relatively high cost of microgrid power. Beyond the challenge of the ability of communities to pay, most developers believe they will lose their investment when the grid arrives because communities will purchase the cheaper grid power leaving them without demand for their microgrid electricity. When they can stay operational, unclear rules around ownership means the developer may not be able to capture the long-run microgrid profits. This uncertain financial climate is stifling the potential of microgrids to provide electricity access to rural India on a large scale.

During our fieldwork in India, interviewees repeatedly cited three weaknesses in the current policy framework around microgrid development that exacerbate these financial challenges. First, the upfront capital subsidies offered by the government provide an incentive for developers to build microgrids in the short-run without similar incentives to sustain operation in the long-run. Under this policy structure, government and NGO experts indicated that microgrids are set up, but not operated and maintained, as there is little incentive to invest past the initial construction of the microgrid. Second, while the current subsidy programs can conceivably tackle the upfront capital constraint, developers still face uncertainty about whether they will earn a return on their investment in the long run. Our interviews repeatedly cited their own experience with communities who stopped paying for microgrid power because the price of electricity was too expensive. Finally, our interviews referenced the lack of ownership opportunities for private companies as a limiting factor, as ownership of systems remains largely in the hands of the state and central government. Without more clarity over who will own the microgrid in the long-run, only a handful of social enterprises have entered the renewable microgrid space.

In light of these financial challenges, this section offers three recommendations on what relevant stakeholders can do to accelerate the deployment of microgrids across rural India. First, we propose a hybrid subsidy model, which would address the challenge of the long-term sustainability of microgrids by scaling back the current upfront capital subsidies and complementing them with performance-based subsidies. Second, we consider means through which project developers' access to additional sources of capital can be improved, including commercial bank loans and corporate social responsibility (CSR) funds. Finally, we discuss how franchising and other complementary ownership models can be used to improve public-private partnerships, including how the prospect of grid integration presents a set of challenges requiring further government action to reduce project risk.

## A. Existing Policy Framework and Barriers to Microgrid Financing

### 1. Current Regulatory Framework and Policy Responses

#### Subsidy Design

To date, the Indian government's primary policy response to the financing challenge facing developers has been to extend capital subsidies to those looking to build microgrid systems. These subsidies have been carried out under the auspices of two main government ministries, the Ministry of Power and the Ministry of New and Renewable Energy (MOP and MNRE), and offered through a wide array of government initiatives targeted at rural electrification. RGGVY, the flagship rural electrification program of the MOP, subsidizes 90% of the capital costs for decentralized and distributed generation in areas where grid extension is considered uneconomical or unfeasible.<sup>119</sup> The Rural Electrification Corporation covers the remaining 10% of the capital costs in the form of a "soft" loan at an interest rate of 5%.<sup>120</sup> Indian Minister Sushilkumar Shinde has requested an additional Rs. 50,000 crore for the program for the 12<sup>th</sup> Five-Year Plan (2012–2017),<sup>121</sup> a significant increase relative to previous budgets.<sup>122</sup> One MNRE official reported that incentive structure of RGGVY may be modified because the 90% subsidy level was proving financially unsustainable.<sup>123</sup>

Similarly to RGGVY, RVE offers a 90% capital subsidy for projects that provide basic lighting electrification services to villages of over 300 inhabitants not eligible for RGGVY.<sup>124</sup> It appears that MNRE is in the process of reconstituting a similar program under the name Rural Area Energy Access Program (REAP).<sup>125</sup> In conjunction with the JNNSM, the Indian government is currently sponsoring a program that is a combination of a 30% subsidy and a loan with an interest rate of 5% to off-grid solar projects.<sup>126</sup> Finally, MNRE offers financial incentives of varying degree for deployment of particular renewable technologies. Off-grid wind and wind-solar hybrid systems, for example, are eligible for a capital subsidy ranging from 50–90% of project costs.<sup>127</sup>

MNRE currently focuses its support on microgrid projects that fit a "Build, Operate, Manage and Transfer" (BOMT) model. BOMT and prevailing subsidies encourage private firms to enter the market as microgrid developers and managers for a short period of time, up to five years. After five years, or if the central grid reaches the microgrid during the interim, the project is transferred to the appropriate government agency.

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<sup>119</sup> Ministry of Power, Government of India, *Rajiv Gandhi Grameen Vidyutikaran Yojana at a Glance*, <http://rggvv.gov.in/rggvv/rggvvportal/index.html> (accessed December 8, 2013).

<sup>120</sup> Ibid.

<sup>121</sup> Press Trust of India, "Power Minister seeks Rs 50,000 cr for rural electrification," *Business Standard*, July 17, 2012.

<sup>122</sup> Greenpeace, *RGGVY – Progress Unlimited*, [http://www.greenpeace.org/india/Global/india/report/Final\\_RGGVY\\_Policy\\_Brief.pdf](http://www.greenpeace.org/india/Global/india/report/Final_RGGVY_Policy_Brief.pdf) (accessed January 14, 2014)

<sup>123</sup> MNRE official, interview by author, (October 30, 2013).

<sup>124</sup> Ministry of New and Renewable Energy, Government of India, *Remote Village Electrification Program for the Year 2011-2012*, <http://www.mnre.gov.in/file-manager/offgrid-remote-village-programme/rve-adm-2011-12.pdf> (accessed December 8, 2013).

<sup>125</sup> Ministry of New and Renewable Energy, Government of India, *Energy Access Programme*, [http://www.cseindia.org/userfiles/Veena%20Sinha\\_Energy%20Access%20Programme.pdf](http://www.cseindia.org/userfiles/Veena%20Sinha_Energy%20Access%20Programme.pdf) (accessed December 8, 2013).

<sup>126</sup> Shailesh Telang, *MNRE Capital Subsidy Scheme for off grid solar system*, July 17, 2013, <http://greencleanguide.com/2013/07/17/mnre-capital-subsidy-scheme-for-off-grid-solar-system/>.

<sup>127</sup> Ministry of New and Renewable Energy, Government of India, *Aerogenerators/wind hybrid*, <http://mnre.gov.in/schemes/offgrid/small-wind> (accessed December 8, 2013).

## Existing Franchise and Management Arrangements

The Indian government has experimented with a host of different ownership and management designs over the past few decades. This history of inconsistent support and limited private ownership opportunities has created uncertain market conditions, discouraging potential entrants. The current franchise and subsidy design has in recent years led some small entrepreneurs to forego government tariffs altogether. This decision to waive subsidy support is due in part to historic limitations on ownership rights and more recently the bureaucratic challenges of qualifying for and obtaining subsidy approval. A recent report by Dun and Bradstreet shows that India's electricity policy has led to the central or state governments owning over 80% of generation facilities.<sup>128</sup> Today, issues like becoming a "channel partner" can still present insurmountable obstacles for small startups. Eliminating bureaucratic hurdles to encourage greater private market interest, particularly from small entrepreneurs, is one of the primary recommendations of this report.

The reaction from the business community to forego subsidy support has not only increased rates for the rural poor; the government's policy structure has also created a niche industry that is at times at odds with MNRE and some future policy suggestions. For example, existing rural microgrid owners that waived subsidy support are currently uneasy about the idea of easing subsidy acquisition by new market entrants. Their fear is that if other companies can provide lower rates through subsidization then they will lose their existing market. This niche microgrid sector has also diverted philanthropic investments away from supporting government-financed projects. The Bosch-Gram Oorja project in Darewadi, cited earlier in this report, is an example of this phenomenon. Since the government, private companies, and donors have an interest in increasing market demand and electricity access, this lack of synergy is unfortunate.

Presently, the government authorizes franchises in the electricity market and gives third parties management rights for a specific component of the electricity system. For example, firms can currently secure franchise contracts from MOP to manage distribution, billing, collection, and metering. Renewable energy firms are given the option to build and manage generation systems for up to a limited period of time. MNRE suggests a limited period of 5 years, at which time the government has the right to acquire the system. In contrast to this management-based approach, many other countries have tended toward private ownership of distribution and generation facilities. The Electricity Act of 2003 allowed firms to set up microgrids without a license in rural areas.<sup>129</sup> However, these firms are not guaranteed tariffs.

MOP currently allows for six management and service-based franchise agreements. The following options were outlined in RGGVY.<sup>130</sup>

- **Revenue Collection Franchise:** Third parties receive rights to collect service fees on behalf of the government. Companies are given a share of the fees collected.
- **Revenue Collection Franchise, input-based:** This concept builds on the first franchise model by establishing benchmarks designed to encourage the third party to promote loss reduction.
- **Input-based Franchise:** This design allows for a third party to buy electricity from the utility at a set rate. The firm is then required to collect payment from the users.

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<sup>128</sup> Power Generation: India's Electricity Sector, Dun and Bradstreet.

[http://www.dnb.co.in/IndiasEnergySector/Power\\_Gen.asp](http://www.dnb.co.in/IndiasEnergySector/Power_Gen.asp) (accessed January 13, 2014).

<sup>129</sup> Ministry of Power, Government of India, "India Electricity Act 2003," 2003, [http://www.powermin.nic.in/acts\\_notification/electricity\\_act2003/pdf/The%2-Electricity%20Act\\_2003.pdf](http://www.powermin.nic.in/acts_notification/electricity_act2003/pdf/The%2-Electricity%20Act_2003.pdf) (accessed November 15, 2013). Parts III and IV.

<sup>130</sup> Ministry of Power, Government of India, *Franchisee Models*, [http://www.rggvy.gov.in/rggvy/rggvyportal/franchisee\\_model.htm](http://www.rggvy.gov.in/rggvy/rggvyportal/franchisee_model.htm).

- **Operation and Maintenance Franchise:** In addition to the characteristics of the above model, the firm is also given the responsibility of operating and maintaining the distribution system. The firm is compensated through a lower initial electricity purchase price.
- **Rural Electric Cooperative Societies:** RGGVY calls for the authorization of two ownership-based rural co-op models. The first is a traditional ownership model in which the community manages and operates the system; the second would allow a third party to run the operations of the co-op. It is unclear if these franchise concepts were ever enacted. It does not appear that any MOP supported ownership co-ops were initiated in recent years. MOP does list five active co-ops on its website; however, they appear to be Rural Electric Supply Cooperatives, which were started before 2003.<sup>131</sup> For its part, MNRE has promoted a BOMT model.

The main design parameters, according to a 2011 RVE implementation document, are the following:<sup>132</sup> (1) “Project Developers shall implement the project on BOMT basis for a period of 5 years. The assets will actually be owned by the State Government”; (2) “If the grid reaches the un-electrified village before 5 years then the State government will have the option to handover the project to the concerned Distribution Company (DISCOM)”; and (3) “Once integrated with the central grid, “the power from the Village Lighting project can be exported to the grid and imported from the grid, as and when required.”

The preceding comparison shows the wide variety of management opportunities that are offered by MOP and MNRE and illustrates that their different approaches create a disjointed and uncertain process for rural electrification. For example, MOP’s franchise offerings are more applicable for grid-based opportunities, whereas MNRE’s BOMT model is tailored for off-grid systems. MNRE’s model also leaves uncertainty for the developer, as it is unclear what will happen to the management of the system once the grid arrives, particularly if the DISCOM is privately owned and/or managed. Furthermore, neither text explicitly states what happens if the central grid reaches a microgrid system that was established without licensing, per the Electricity Act of 2003.

The data referenced throughout this report demonstrates that past and current initiatives offered by MOP and MNRE have not optimized rural electrification efforts and have not met goals outlined by federal policy initiatives, such as the RVE goals. As a result, the disparate management efforts may be difficult to align in the short-term.

Despite the myriad management opportunities and to the chagrin of many interviewees, neither agency provides an easily accessible, long-term ownership structure. Many of our interviews suggested that allowing privately owned generation and distribution systems to access the full range of subsidies is a simple solution to avoid future discontinuity. The benefits of extending ownership opportunities are considered below.

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<sup>131</sup> Ministry of Power, Government of India, *Address List of Rural Coops*, <http://rggvv.gov.in/rggvv/rggvvportal/AddeesList-COOPs.html>; Co-operation Department, Government of Andhra Pradesh, *Rural Electric Supply Cooperative Societies*, <http://www.cooperation.ap.gov.in/rescos.html>; Haribandhu, Panda, *Governance of Rural Electricity Systems in India* (New Delhi: Academic Foundation, 2007).

<sup>132</sup> Ministry of New and Renewable Energy, Government of India, *Remote Village Electrification*, <http://www.mnre.gov.in/schemes/offgrid/remote-village-electrification/> (accessed 2013 November 28).

## 2. Barriers to Microgrid Financing

### Lack of Upfront Capital

While the upfront capital requirements for microgrid systems are more modest than that of large-scale generation projects, these requirements are not insignificant. This is particularly true given that, in many cases, those looking to enter the market are small-scale social enterprises that cannot finance projects off their balance sheets. Moreover, successfully scaling up these enterprises and their systems will mean multiplying these unit costs hundreds or thousands of times over. Indeed, over the course of our interviews, multiple developers in India noted that the upfront capital requirements presented a barrier to market entry and/or scaling up their business.

In theory, financing for these system costs can come from a variety of sources, including the Indian government; commercial banks; private equity and venture capital firms; impact investors; mandatory corporate giving via the newly-created CSR law;<sup>133</sup> multilateral organizations; and donor agencies. Over the past two decades, the Indian government has offered numerous programs, such as RGGVY, that seek to extend upfront capital to microgrid developers. Due to a variety of administrative barriers, however, entrepreneurs have found it challenging to access these funds. In addition, commercial lenders (e.g., banks, private equity firms, venture capital firms) have shown limited interest in offering to finance microgrid projects. According to our interviews, this reluctance may be due to concerns such as: uncertain business models and/or revenue streams; lack of familiarity with energy projects; the inherent uncertainty of long payback periods; steep transaction costs; and a lack of clarity over the future policy direction of the Indian government.

Due to this hesitation on the part of traditional commercial lenders to enter the field of microgrid investment, the financing for enterprises operating in this space has tended to come from impact investment funds,<sup>134</sup> development agencies, foundations, and corporations. In our discussions, developers and policymakers highlighted that most financing comes from organizations that place relatively less emphasis on an investment-grade rate of return and have a greater appetite for risk. For instance, MGP was able to leverage USD 300,000 in grant support from USAID to secure financing from impact investment firm Insitor Management.<sup>135</sup> While their financial support has helped many projects get off the ground, a key question with respect to these sources of finance is one of magnitude. The current levels of funding have led to a relatively small number of pilot projects. Given the large number of villages lacking electricity, small-scale grants and investments are likely to be insufficient to scale up these projects and electrify rural India. To truly accelerate deployment of microgrids will require a fundamentally different type and magnitude of financial support.

### Revenue Generation

Microgrid developers struggle to consistently generate revenue from their customer base over the entire lifecycle of a microgrid project. To some degree, this is due to the fact that any the individuals and communities served by microgrids have a limited ability to pay. With microgrid power costing up to ten times the price of subsidized grid electricity, poor and rural customers are

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<sup>133</sup> Kordant Philanthropy Advisors, "The 2% CSR Clause: New Requirements for Companies in India," *Kordant Report Series*, February 2013, <http://www.kordant.com/assets/2-Percent-India-CSR-Report.pdf> (accessed December 8, 2013).

<sup>134</sup> We characterize impact investment firms to be institutions that invest capital in companies in the hopes of generating both a positive financial return and a positive "social" return

<sup>135</sup> "USAID press release regarding Gram Power funding," *Gram Power*, 2013 November, [http://grampower.com/PR\\_USAID.pdf](http://grampower.com/PR_USAID.pdf).



often unable to consistently pay the necessary amount for developers to make a consistent return on their investment and reliably cover their costs. Interviewees repeatedly cited doubts about whether developers would be able to collect enough revenue over the life of the project to cover operational and maintenance costs, while still generating medium- to long-term profits.

According to many interviews, the customers' continued ability to pay posed the primary challenge. Poor, rural communities struggle to earn a consistent income. Many rural customers are farmers who earn a seasonal income, meaning they may only be able to pay the high tariffs for some parts of the year. Others live on the edge of poverty where one disaster (e.g., a flood or a family medical emergency) can destroy a family's ability to pay for expensive power. Multiple failures where rural customers have stopped paying for expensive microgrid power reinforce this notion. Across our interviews, we heard examples of when villagers stopped paying due to a poor harvest or similar economic crisis. In particular, we learned about a company that stopped operating in India because they could not capture enough ongoing revenue to cover their costs.<sup>136</sup>

An additional challenge to revenue generation is that the arrival of grid-provided electricity will cause most—if not all—customers to opt for cheap, highly subsidized grid electricity over expensive microgrid power. For example, in the Darewadi village, microgrid customers pay a flat Rs. 90 per month plus an additional Rs. 20/kWh, while households in a neighboring village have access to power that costs a mere Rs. 3/kWh.<sup>137</sup> In light of this price differential, customers are liable to stop buying expensive microgrid electricity if and when they gain access to a cheaper power source. Numerous experts cited the likelihood that customers will not continue to buy microgrid power when the grid arrives as a reason that developers and financiers have stayed out of the market.

Finally, there is a strong case to be made that it is inequitable for some customers to pay low rates for electricity because it is subsidized, while rural, mostly poor, customers have to purchase power at high costs.

### Inadequate Franchise and Ownership Structures

Public financial incentives are most accessible to established, well-capitalized companies and those that provide management or services to government owned projects. The current offerings are disadvantageous to some smaller entrepreneurs, for example those not meeting the standards to qualify as a channel partner. Small, privately owned systems, like those developed by Husk Power, may therefore not receive federal tariff support because the barriers to obtaining subsidization are too great. In addition, management service agreements, like the MNRE's BOMT, are in competition with ownership opportunities. As discussed in the subsidy reform section, the current policy design does not create any incentives for long-term system sustainability and many firms do not benefit adequately from long-term ownership profits. The current approach incentivizes companies to maximize short-term profits through capital subsidies and 5-year payback rather than optimizing long-term system performance. For instance, standard PV systems, if properly maintained, can last for over 20 years.

Grid integration problems also arise as a result of the short-term focus of the current management framework. Substantial uncertainty exists in regard to when the central grid might reach the microgrid and what compensation the company will receive at that time. If the central grid reaches the microgrid ahead of schedule, the microgrid developer will lose profits for the remaining management period. Interviews suggested that, as a result, microgrid managers have lobbied for the central grid to avoid villages where they have installed systems until their

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<sup>136</sup> Natalie Pearson, Bloomberg, interview by author (November 2013).

<sup>137</sup> Darewadi household interviews, interview by author (October 31, 2013).

management period is complete. This lobbying may delay more robust electrification efforts from reaching rural areas.

Uncertainty regarding backend compensation is also problematic. Government documents refer to paying microgrid developers a fair market price when the central grid arrives to serve their customer base.<sup>138</sup> However, there are no details as to how this price will be determined. This vagueness regarding reimbursement adds to the financial uncertainty for microgrid developers.

## B. Recommendations for Improved Financing

### 1. Hybrid Subsidy Model

**RECOMMENDATION:** Reform the subsidy structure by scaling back upfront capital subsidies and complementing them with performance-based subsidies to incentivize long-term operation of microgrid systems.

In order to reduce uncertainty and create price parity between grid and microgrid power, we advocate a hybrid incentive model that provides limited upfront capital along with long-term operations and maintenance support. This approach builds on the recommendation by the World Bank that both upfront capital subsidies and performance tariffs are necessary to jump-start microgrid development and increase investor confidence.<sup>139</sup> The consulting company Idam Infrastructure Advisory also found that capital subsidies alone are insufficient to promote the sector because they fail to cover the viability gap between grid and microgrid power. They advocate a revenue subsidy of similar design to our performance subsidy.<sup>140</sup>

As it stands, one issue is that the upfront capital subsidy by itself does not address the medium- and long-run uncertainty around revenue generation, while simply moving to an ongoing operation and maintenance (O&M) subsidy structure would not resolve upfront capital constraints. As demonstrated by the ongoing reluctance for financiers to support microgrids, projects need to be financially viable for their entire lifecycle, not just the short-term, to incentivize widespread deployment of microgrids.

Under our model, the Indian government would provide a capital subsidy equivalent to the minimal initial investment necessary to get a microgrid project financed by a third party lender. The O&M subsidy will provide certainty of the long-term return on the investment by ensuring microgrid power is offered at the same low price as grid power. These two forms of incentives complement each other by reducing both sources of financial uncertainty plaguing producers—finding upfront capital and generating long-run revenue. The total net subsidy offered by the government will vary by project and technology type, but will always guarantee the same tariff to the end consumer. One possible way to ensure the total size of the subsidy remains reasonable would be for the government to cap subsidy levels by project characteristics, like technology, which could be negotiated with producers. The ultimate goal of these policies is to incentivize widespread microgrid development and create price parity between grid and microgrid electricity.

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<sup>138</sup> ABPS Infrastructure Advisory Pvt. Ltd., "Policy And Regulatory Interventions To Support Community Level Off-Grid Projects," 2011, [http://www.forumofregulators.gov.in/Data/Reports/CWF%20Off-grid%20final%20report%20nov%202011\\_Latest\\_feb2012.pdf](http://www.forumofregulators.gov.in/Data/Reports/CWF%20Off-grid%20final%20report%20nov%202011_Latest_feb2012.pdf).

<sup>139</sup> World Bank, *Empowering Rural India*.

<sup>140</sup> Balawant Joshi, Sanjay Mande, Gagan Srivastava and Shagun Maheshwari, *Re-visiting the Decentralized Distributed Generation Guidelines Under the Rajiv Gandhi Grameen Vidyutikaran Yojana*, (Mumbai: Idam Infrastructure Advisory Private Limited, 2013), 18.

## Design of Capital Subsidies

Efforts to support rural electrification in other countries suggest that upfront capital subsidies, structured properly, can be a useful financial incentive to offer prospective project developers.<sup>141</sup> Such subsidies can substantially reduce the perceived risk that developers face when investing in a capital-intensive project by guaranteeing their short run capital costs.<sup>142</sup>

Even so, while there may be an economic rationale for an upfront capital subsidy, the Indian government should reevaluate what the appropriate level of subsidy should be. Of particular concern is whether generous subsidies under programs such as RGGVY—under which all of a developer's capital expenditures are covered by government—may have distorting effects. To the extent project developers do not need to generate ongoing revenue to cover an initial capital outlay for a project, they may show a lack of interest in the long-term sustainability of that project. In this way, such subsidies could lead to the construction of microgrid systems without providing incentives for any ongoing maintenance or operational management.

Beyond the lack of incentive to maintain microgrids, the current subsidy structure has limited the role of private sector investors in microgrid projects. Due to the current 90% capital subsidy structure, the private sector has little incentive to ensure in the success of microgrid projects and little opportunity to earn a return on their equity investment. The role of the private sector has essentially been relegated to that of a technology supplier, rather than investors seeking a strong return on their investment.<sup>143</sup> Lowering the upfront capital subsidy will provide room for private capital to invest and earn a return, incentivizing additional private liquidity to finance microgrid projects. With a guaranteed low rate, developers can now be more certain that consumers can pay and that a sizeable portion of their costs will be covered through the subsidy over the life of the project.<sup>144</sup>

In recognition of the drawbacks of the structure of the current capital subsidy, we advocate a level of capital subsidy that covers the collateral or down payment required by a private lender to secure a loan. This structure has two distinct benefits. First, this approach limits the upfront expenditure needed by the government, while inducing private sector participation by providing them with additional sources of collateral.<sup>145</sup> Second, with a guaranteed source of collateral subsidy, this should reduce the uncertainty for the lender and reduce long-term interests on the loan. Developers now have a long-term incentive to manage the project well and maximize their profits. Coupled with the ongoing performance subsidy discussed below, this level of capital investives should assuage some lender concerns and encourage ongoing maintenance by the firm.

## Design of Performance Subsidy

The performance subsidy should be designed to cover the difference between the end user price and the cost of microgrid power. For equity reasons, we propose the end-user price be the same as that charged for grid power, thus covering the viability gap between grid and microgrid

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<sup>141</sup> World Bank, *Analysis of Models for Improving Rural Electricity Services in India through Distributed Generation and Supply of Renewable Energy*, (New Delhi: World Bank, 2010).

<sup>142</sup> Ramit Malhotraa, and Atul Kumar Debajit Palit, "Sustainable model for financial viability of decentralized biomass gasifier based power projects," *Energy Policy* 39, no. 9 (September 2011): 4893–4901.

<sup>143</sup> Balawant Joshi, Sanjay Mande, Gagan Srivastava and Shagun Maheshwari, *Re-visiting the Decentralized Distributed Generation Guidelines Under the Rajiv Gandhi Grameen Vidyutikaran Yojana*, (Mumbai: Idam Infrastructure Advisory Private Limited, 2013), 18.

<sup>144</sup> World Bank, *Empowering Rural India*, 41.

<sup>145</sup> Ricardo Caballero and Arvind Krishnamurthy, "International and domestic collateral constraints in a model of emerging market crises," *Journal of Monetary Economics* 48, no. 3 (December 2001): 513-548.

power.<sup>146</sup> Providing this viability gap subsidy encourages long-term sustainability and upkeep by the owner in order to continue collecting the subsidy and making a profit. The subsidy would be allocated as follows:

1. The total subsidy would be calculated based on the value of the operating profits guaranteed to power generators, the annual average levelized cost of electricity, and consumer tariffs over the life of the project.<sup>147</sup> Producers would earn enough to cover cost of operation and maintenance, future capital investments, and the operational cost of capital (i.e., interest payments), while making the level of profits expected across the industry. The subsidy and contract would cover the roughly 15 years necessary for a standard distributed generation company to make a return on their investment.<sup>148</sup>
2. Over the life of the contract, the company would collect the tariff from the consumer, while a third party, either a distribution company or a neutral financial entity, would pay the subsidy to the producer.<sup>149</sup> The company would have to charge customers based on their use through individual- or community-level metering for the subsidy to provide the right level of incentive to the producer.<sup>150</sup> Metering and the need for accurate bill collection would also promote grid maintenance and theft reduction.

### Benefits of Hybrid Approach

This structure promotes equity for consumers, lowers initial costs to the government, and creates a more certain return for investors. Under this tariff structure, urban and rural consumers come closer to an equal affordable rate regardless of their power source or geography. With a guaranteed low rate, developers can now be more certain that payments by consumers will cover their costs over the life of the project.<sup>151</sup> Moreover, developers have an incentive to reduce costs over the life of their project to increase the revenue they earn from the subsidy. The government is now also able to spread their subsidy expenditures out over time, rather than giving out all the funds at once in a lump sum upfront capital subsidy.

A possible constraint to state-level subsidy reform is the potential that voters view grid power as a sign of development, while perceiving microgrid power as an inferior, more expensive option. Many of our interviews cited this political challenge as the reason that microgrids will never receive the same financial support as grid power, given that Indian state-level politicians who gained office by promising grid power to their voters. The price parity between the two options created by national level reform would place grid and microgrid power on a more equal economic footing to rural consumers. The choice then would be between the greater reliability of microgrid power and the potential for higher levels of electricity consumption offered by the grid. Reliability is indeed a key consideration for rural households and was the main reason that consumers in Darewadi offered for preferring microgrid to grid power. With a national subsidy policy making the

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<sup>146</sup> Ernst & Young, *Models of Rural Electrification: Report to Forum of Indian Regulators*, (Ernst & Young, 2007).

<sup>147</sup> In Indian regulation, operating profits are guaranteed to power providers under the tariff and subsidy structure. This is necessary here to incentivize investment. In addition, the average levelized cost of electricity is a standard formula used across the industry.

World Bank, *Empowering Rural India*, 6.

<sup>148</sup> *Ibid*, 41.

<sup>149</sup> Third-party subsidy management is discussed in a following section.

<sup>150</sup> Jonathan A. Lesser and Suejuan Su, "Design of an economically efficient feed-in tariff structure for renewable energy development," *Energy Policy* 36, no. 3 (March 2008): 981-990.

<sup>151</sup> World Bank, *Empowering Rural India*, 41.

two options politically comparable, policymakers may be more able to choose the most socially optimal electrification policy, rather than extending the grid for political motivations.

### Drawbacks of Hybrid Approach

The drawback of this approach is that it may incentivize higher-cost generation than the market would otherwise bear. Producers have an incentive to exaggerate their costs to ensure a larger subsidy. Due to the small number of firms building microgrids, producers could coordinate to present equally high costs to the government, making it hard for regulators to use the market to discover the true costs of microgrid power. The government could then be locked into subsidizing costly generation when there are lower cost alternatives.

The government could avoid this problem by undertaking a reverse auction with respect to electricity generation for a defined geographic area, as is being pursued in other contexts.<sup>152</sup> In addition, anti-collusion policies could prevent companies from skewing the government's perception of their costs. This risk will also be reduced as more information is gathered, thereby allowing for capital costs verification, and as more competitors enter the market.

Another drawback is that the overhead and administrative costs of the hybrid model may be higher than the costs of the current capital subsidy system. Additional government resources will be necessary to monitor the ongoing performance of companies and calculate the level of subsidy when firms incur future costs. While this is of concern, we believe that these costs will not be prohibitive, as this subsidy model is similar to the current subsidies provided to grid power. The government can leverage their current level of expertise in grid power to administer this subsidy regime to microgrid providers.

## 2. Unlocking Additional Capital

In addition to reforming existing financial incentives for project developers and clarifying ownership of microgrid projects, the Indian government could take a series of measures to facilitate the access of microgrid developers to additional sources of capital. The goal of these recommendations is to complement government funds with greater access to private capital in order to transform the microgrid sector from a few successful pilots to a viable option for widespread electrification in rural India.

### Streamlining Subsidy Approval

**RECOMMENDATION:** Streamline approval process for subsidies.

Many of the companies we visited indicated that they were not seeking upfront capital subsidies from the government. When asked why, entrepreneurs suggested that the processes by which subsidies are dispersed tended to be unwieldy, opaque, and time- and labor-intensive. In recognition of this, MNRE has sought to expedite the subsidy distribution process that falls under the auspices of the JNNSM by designating certain actors as “channel partners.” Of note, however, designation as a channel partner is contingent on an actor's “financial strength”.<sup>153</sup> Especially for

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<sup>152</sup> Natalie Obiko Pearson, *India's 'Astonishing Auction' Pushes Down Global Solar Price*, December 5, 2011, <http://www.bloomberg.com/news/2011-12-02/india-s-solar-power-bid-prices-sink-to-record-consultant-says.html>.

<sup>153</sup> Ministry of New and Renewable Energy, Government of India, "Accreditation of Channel Partners under Off Grid and Decentralized Solar Applications," January 18, 2011, <http://mnre.gov.in/file->

nascent social enterprises, this financial strength criterion may be a limiting factor. In any case, in July of this year, MNRE issued a notice stating that it would no longer be accepting applications for new channel partners under the NSM program.<sup>154</sup>

Given the central role social enterprises are likely to play with respect to microgrid deployment, the Indian government could modify the bureaucratic design of the subsidies process with an eye toward their relative strengths and weaknesses. Based on our conversations, process improvements could include reducing the administrative burden with respect to subsidy applications; identifying a single governmental focal point with which a social enterprise could interact throughout the application process; and delineating roles and responsibilities of government ministry with equities in the application process. The approach the Indian government has taken with respect to the channel partners program suggests it is concerned about the financial risk associated with expediting subsidy dispersal to social entrepreneurs. To the extent this is the case, the government could set aside some portion of the capital subsidies funding to support pilot testing of innovative rural electrification business models that may present higher levels of financial risk but which also hold great promise for meeting the challenge of rural electrification.

### Establish Escrow Account for Subsidies

**RECOMMENDATION:** To expedite subsidy payment and further reduce financial uncertainty, committed subsidies could be placed in an escrow account at the time a contract is finalized.

In order to create regularity with respect to the dispersal of subsidy payments, subsidy funds should be held by a third-party financier. This approach will provide assurance to lenders that the full subsidy amount can and will be paid. Furthermore, private financing organizations will likely be more efficient at distributing funds than the central government. Well-defined benchmarks for releasing funds will optimize subsidy payments. While using a third party would be associated with a higher administrative cost, this may be necessary given the poor financial status of DISCOMs.

### Encourage Direction of CSR Funds to Microgrid/DG Projects

**RECOMMENDATION:** Play a convening role in light of new Corporate Social Responsibility law.

In August 2013, the Indian central government passed an unprecedented CSR law.<sup>155</sup> The new legislation stipulates that large companies—defined as those with a valuation of more than Rs. 500 crore or net profit of more than Rs. 5 crore—spend at least two percent of the profit they earned over the preceding three years on approved projects with a social impact. The Indian government has opted not to specify what precisely constitutes an “appropriate” project, but

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manager/UserFiles/channel\_partners\_offgrid\_decentralised\_solar\_application.pdf (accessed December 8, 2013).

<sup>154</sup> Ministry of New and Renewable Energy, Government of India, "Notice to Channel Partners," July 11, 2013, <http://mnre.gov.in/file-manager/UserFiles/notice-to-channel-partners-10072013.pdf> (accessed December 8, 2013).

<sup>155</sup> Kordant Philanthropy Advisors, "The 2% CSR Clause".



“ensuring environmental sustainability” is one of the “focus areas” of the new law. According to one estimate, the law will apply to approximately 2,500 firms and raise Rs. 122 billion in revenue.<sup>156</sup>

This new stream of financing represents an enormous opportunity to direct funding toward rural electrification using renewable powered microgrids. Given the challenges associated with the capital subsidies program, it may be beneficial for the Indian government to take a relatively hands-off approach to administration of this funding. With that said, multiple social and development programs will likely compete for this funding stream. To promote microgrid developers access to these funds, the government could play a useful role as a convener with respect to CSR. For example, MNRE and MOP officials could seek to bring together, in a workshop-style setting, all the actors who would potentially be involved in a microgrid project, including interested corporate entities, social entrepreneurs, regulators, and other similar organizations. It may be useful to conduct such an event in the near-term, as the CSR law gets off the ground. To the extent it would be useful to do so, this workshop could then be repeated on a periodic basis, perhaps annually. The goal of such a workshop would be to allow social entrepreneurs in need of project finance with large companies looking to comply with the CSR law through spending on rural electrification projects. An early precedent for such an approach, though done without a government mandate, is the partnership between Bosch and Gram Oorja in the village of Darewadi.<sup>157</sup>

### Benefits and Drawbacks of Unlocking Additional Capital

The benefits of the above approaches are clear enough: by reducing the administrative complexity associated with the subsidies program, uptake of capital subsidies among project developers is likely to increase. Furthermore, taking advantage of the new CSR law provides project developers a new and potentially large source of upfront finance for microgrid projects.

At the same time, we recognize that the funds made available through the CSR law are, to some extent, zero-sum in that corporations are allocating their CSR across a wide variety of worthy causes such as education and health, not just energy. Thus, if the Indian government chooses to promote the investment of CSR funds into microgrid projects, it should be thoughtful about how best to prioritize the use of these limited funds. In addition, it is clear that a few administrative changes to subsidy programs alone may not be sufficient to bring project developers to the table. Accordingly, while the recommendations noted in this section may be a useful complement to the other recommendations we have provided earlier on subsidy reform, they are likely insufficient on their own.

## 3. Reforms to Franchising Agreements

### Recommendations for Franchising Agreements

A 2012 report by ABPS Infrastructure completed for the Forum of Regulators advocated for a Rural System Operator (RSO) model.<sup>158</sup> Many of ABPS’s suggestions are similar to recommendations expressed in this report. The RSO approach essentially allows private companies to become generators and distributors. Our recommendations provide further support for extending well-defined ownership rights.

However, much like the existing BOMT and franchise models, ABPS’s recommendations maintain the government distribution company’s right to terminate franchise contracts once the central grid meets the microgrid. At that time, the RSO will be compensated the “prevalent book

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<sup>156</sup> Ibid.

<sup>157</sup> Gram Oorja, interview by author (2013 November 1).

<sup>158</sup> ABPS, "Policy And Regulatory Interventions To Support Community Level Off-Grid Projects."



value of the asset.”<sup>159</sup> As discussed above, more precise language is necessary to appease investor uncertainty. Grid integration issues are discussed in greater detail in the following section.

We recommend that the government should adopt the following provisions in order to create sustainable, capital ownership models and accelerate rural electrification. In implementing such models, both MOP and MNRE, should follow the following recommendations:

**RECOMMENDATION:** Provide defined ownership opportunities to private, non-profit and community corporations. Contracts should clearly define geographic service boundaries, the company’s deliverables, and benchmarks for subsidy distribution.

A number of interviewees emphasized the importance of allowing ownership opportunities to promote long-term sustainability and system performance. Two primary reasons cited during interviews are that private companies will operate more efficiently than the central and state governments and that financial losses will be reduced as they will no longer be able to be socialized. It is imperative that the program’s structure is very clearly defined to avoid investment uncertainty from the firm and lender.

**RECOMMENDATION:** Provide the same allowance of capital and operational subsidies to all owners and operators.

Creating an equal playing field for all potential owners (i.e., private companies, non-profits, or communities) will increase competition and thus encourage innovation and lower retail rates. Standardized support will also alleviate the existing discontent between those that receive subsidies and those that do not. Finally, consistent subsidization will further reduce investor insecurity.

**RECOMMENDATION:** Auction predefined franchise regions. As a longer-term goal, the federal and state governments should define and auction predetermined franchise opportunities by geographic scope.

Auctioning franchises has a number of benefits including: allowing for parcels to be designed to include mixed loads and ample demand; promoting cost-minimizing system installation; and reducing approval time for interested firms.

**RECOMMENDATION:** Provide a transparent operating protocol to encourage CSR and non-profit partnership. Presently, CSR and non-profit support for microgrids is disjointed from federally designed programs.

A defined and transparent ownership model can encourage outside funding partners to work in greater concert with federally funded projects. For example, philanthropic organizations or CSR support could buy down interest rates, provide financial support for system upsizing and resiliency, or fund complimentary high-efficiency products.

### Benefits of Reforms to Franchising Agreements

Improving existing franchise models, specifically allowing for capital ownership, coupled with subsidy reform, provides an opportunity for the Indian government to accelerate rural

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<sup>159</sup> Ibid.

electrification efforts by reducing owner and investor uncertainty and promoting greater competition within the marketplace. Electricity system ownership is an improvement to the current scheme as it encourages third parties to install high-quality, sustainable systems and maintain system performance in order to capture income and maximize profits in future years. Private ownership, which directly incentivizes financial performance to avoid bankruptcy, will theoretically produce more efficient results than government ownership, which can lead to socialized losses. As an example, private systems will likely maintain meters and monitor theft more closely in order to secure accurate bill payments. Many current systems in India that are owned and operated by the government do not meet this performance metric. A 2012 report from IRADe finds that roughly 30% of meters in Rajasthan are defective and that a small percentage of those are actually fixed or replaced.<sup>160</sup>

The opportunity for capital ownership also opens the door for a diverse set of potential developers, from small entrepreneurs and international corporations to non-profit organizations and motivated communities. Beyond the general ownership benefits listed above, community owned systems have the additional upside of potentially reducing retail rates, reinvesting profits in the community, and building local capacity.

Synchronizing a new ownership structure with government financial support can provide more efficient distribution of subsidies as well. As discussed in the subsidy section of this chapter, there has been considerable frustration regarding the length of time it takes to receive subsidy payments in many cases. Placing all the subsidies from a specific franchise agreement in an escrow account will provide more timely payment, more security to the company, and more certainty to the lender. System owners will need a more efficient and transparent subsidy and repayment structure to lower their interest rates and alleviate potential cash flow concerns.

Ultimately, in making new policy, MOP and MNRE must be cognizant of their past shortcomings, acknowledge existing companies that have succeeded in providing energy to remote regions with and without federal support, and commit to a long-term structure that adequately compensates businesses for their investments and services. Opening the market and extending subsidy support to a private ownership model are direct means to accomplish these goals and promote the development of high quality rural electrification.

#### 4. Grid Integration

Uncertainty surrounding the timing of the grid's arrival renders microgrid projects risky and thus unattractive to potential developers, with the exception of projects financed by risk-free capital (e.g. CSR funds). This is especially the case for villages where the central grid is not expected to arrive in the immediate future. DG is currently unregulated, and, by extension, no uniform rules exist for microgrid and other DG systems that feed back to the grid. While the government of India could publish a list of villages that the grid will not reach within the typical project timeframe of ten or so years, many of our interviewees pointed to the political infeasibility of such an approach.

Hence, we provide a number of recommendations for the government of India to reduce the risk associated with microgrid projects in villages where grid integration is a possibility within the lifetime of a project.

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<sup>160</sup> IRADe, *Final Report on Evaluation of Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) in Rajasthan, Assam, Gujarat, Himachal Pradesh and Uttar Pradesh* (Rural Electrification Corporation Ltd., 2013).

## Recommendations for Grid Integration Policy

As mentioned above, a large source of uncertainty for project developers considering establishing a microgrid system is the timing of the central grid's arrival. This is especially true given the risk of the microgrid system being ordered to shut down. One simple way that to reduce the risk associated with grid arrival, and encourage microgrid developers to enter the rural electrification space, is for the government to explicitly signal to developers that microgrids will be allowed to continue operations upon grid arrival.

**RECOMMENDATION:** The Central Electricity Authority and State Electricity Regulatory Commissions should introduce clear rules and tariff structures for feeding electricity back into the grid.

In order to ensure the security and reliability of the central grid, microgrids feeding electricity into the grid must meet certain technical standards. Currently, the Central Electricity Authority (CEA) has standards for connecting to the grid, but these have been developed for large generating units rather than for microgrids. In a few cases, state agencies have developed technical standards for microgrids (e.g. Chhattisgarh Renewable Development Agency).<sup>161</sup>

Given the different technologies associated with DG systems, the CEA should therefore create another set of technical standards for DG systems considering connecting to the grid, and SERCs should also update their standards accordingly. Interconnection standards for different technologies and voltage levels will ensure the security and power quality of the grid as the grid expands into areas electrified with microgrids.<sup>162</sup>

In addition to the introduction of standards, clearly articulated tariff structures for when the grid arrives are also essential to minimize the revenue risk associated with grid integration. The above proposal for a tariff structure, including the viability gap subsidy whereby consumers pay the grid rate and the project developer is subsidized up to its generation costs, is a promising option for when the grid arrives.

**RECOMMENDATION:** The Ministry of Power should agree to purchase electricity from all microgrids upon grid arrival, provided that projects meet the necessary technical standards.

The India Smart Grid Forum has been tasked by the MOP to develop some interconnection standards for microgrids. Working Group #9 has objectives that are related to “developing standards, guidelines, and technology recommendations for integration of renewable-based microgrids with the main grid; developing a methodology for cost-benefit analysis of microgrid projects specifically in the Indian context; and developing tariff policy recommendations for grid-connected renewable energy microgrids.”<sup>163</sup> This is a channel with potential to develop new and innovative policies that can help ease grid interconnection.

**RECOMMENDATION:** The MOP and MNRE should extend their capital subsidies to include interconnection equipment.

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<sup>161</sup> Chris Greacen, Richard Engel and Thomas Quetchenbach, *A Guidebook on Grid Interconnection and Islanded Operation of Mini-Grid Power Systems Up to 200 kW*, (Berkeley, CA: Lawrence Berkeley National Laboratory, 2013), 62.

<sup>162</sup> World Bank, *Empowering Rural India*, 47.

<sup>163</sup> Greacen et al., *A Guidebook on Grid Interconnection and Islanded Operation*, 62.

There is currently debate at the state level as to whether DG project developers should bear the full cost of interconnection equipment when the grid arrives.<sup>164</sup> Whether the state in question stipulates that the developer bears the full cost or whether the developer and the utility share the costs, the possibility of grid integration creates some project financing risk.

As such, extending capital subsidies to include interconnection equipment may make DG projects more attractive to project developers, especially in states where the project developer bears the full cost. As this would increase electrification in rural households, this is consistent with the program's objectives. However, our expert elicitations have suggested that, as interconnection equipment is a small portion of the total project cost, this may be of secondary concern relative to the aforementioned need for clear rules and tariff structures.

### Benefits and Drawbacks of Grid Integration Policy

Uncertainty surrounding project risks creates a unique set of challenges that necessitate government action, and the above recommendations with respect to clarity in rules, tariff structures, and interconnection equipment aim to reduce project risk. In addition to stimulating private investment in microgrid projects on the short term, well-defined grid integration policy has the benefit of setting the foundation for further addition of renewable energy sources to the grid.

With that said, a number of challenges exist with implementing such recommendations in practice. One such drawback is that the need for projects to fulfill such technical standards increases the costs associated with microgrid projects, especially for smaller-scale projects, and the need for compliance verification may increase the administrative cost. In addition to these increased costs, incentive measures such as capital subsidies for interconnection equipment may divert investment from other equipment upgrades such as battery storage capabilities that would potentially increase the viability of standalone microgrid projects.

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<sup>164</sup> World Bank, *Empowering Rural India*, 46.

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## Section V

### Community Engagement and Implementation for Microgrid Projects

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The previous chapter outlined policy recommendations to improve the financial feasibility of microgrids. In this chapter, we address community engagement, which is a significant driver of the long-term sustainability of microgrids.

Microgrid implementation often lacks inclusion of an important system stakeholder: the community it serves.<sup>165</sup> However, throughout our review of the literature and interviews with stakeholders in India, community engagement in the planning and implementation of microgrids was often cited as integral to project success and sustainability.<sup>166</sup> Community participation has been found to instill a sense of community ownership in infrastructure projects in other sectors. In particular, experience from the water sector demonstrates that community engagement can be a driver of sustainability for projects that require continued operations and maintenance.<sup>167</sup> Yet, most stakeholders also agreed that genuine engagement with the community is difficult and costly to achieve.<sup>168</sup>

In this chapter we will discuss the social and economic rationale for community engagement. We will then outline the significant barriers that make it difficult for an energy service organization to engage with a community in a fair, transparent, and consistent way. Lastly, we will present specific recommendations to achieve meaningful engagement throughout the microgrid implementation process, including planning, ownership, and operations.

#### A. The Social and Economic Case for Community Management

Community engagement in microgrid projects can be justified on both social and economic grounds, but the economic justification is highly case-specific. The existing microgrid literature focuses on the social rationale and provides fewer details on the economic case. The following summary offers an integrated view of both the social and economic factors that affect community engagement in microgrids. This chapter also discusses a possible scenario where the most profit-driven enterprises overemphasize the short-term costs of engaging the community and underestimate the long-term costs of neglecting to engage the community. In these situations, an

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<sup>165</sup> Victoria Gómez García and Mercedes Montero Bartolome, "Rural electrification systems based on renewable energy: the social dimensions of an innovative technology," *Technology in Society* 32, no. 4 (November 2010): 303-311.

Ray Holland, Lahiru Perera, Teodoro Sanchez and Rona Wilkinson, *Decentralised Rural Electrification: The Critical Success Factors (Experience of ITDG)*, Community electricity for sustainable livelihoods through public-private partnerships (R8148) (UK Department for International Development, 2002), 1-5.

<sup>166</sup> Benjamin K. Sovacool, "Design principles for renewable energy programs in developing countries," *Energy & Environmental Science* 5 (2012): 9157-9162.

Parimita Mohanty, The Energy and Resources Institute (TERI), interview by author (October 28, 2013).

Douglas F. Barnes, *Meeting the Challenge of Rural Electrification in Developing Nations: The Experience of Successful Programs (Draft)*, (Washington, DC: World Bank, 2005), 40-42.

<sup>167</sup> Sara J. Marks and Jennifer Davis, "Does User Participation Lead to Sense of Ownership for Rural Water Systems? Evidence from Kenya," *World Development* 40, no. 8 (August 2012): 1569-1576.

<sup>168</sup> Arabinda Mishra and Gopal Krishna Sarangi, "Off-grid Energy Development in India: An Approach Towards Sustainability," 2011 December, <http://oasyssouthasia.dmu.ac.uk/docs/oasyssouthasia-wp12-dec2011.pdf>.

enterprise could be better served by taking into account the long-term costs before determining its engagement strategy.

## 1. The Social Case

Four social factors justify community engagement in microgrid projects, and the literature suggests that this is true whether or not it is a public or a private microgrid system.<sup>169</sup>

First, microgrids are strongly recommended for electricity access in areas where there is no conventional grid.<sup>170</sup> These areas are typically remote, consist of only a small number of households, and lack access to external resources such as outside labor. Assuming a community has awareness and capacity, its participation in a microgrid system will increase its self-reliance.

Second, the community possesses the best knowledge of local conditions and resources.<sup>171</sup> These can aid in the selection of the type of technology and operating model.<sup>172</sup> For instance, if a village does not get enough sun but engages regularly in agriculture and animal husbandry, then biomass would be a more feasible option to them than a solar microgrid. In this case, locals would be critical to establishing a consistent biomass supply for the plant. Alternatively, a hydro plant would require a good understanding of the different uses to which the water from the stream is put, and the seasonal variations in the demand for this water. The community can also best assess its electricity needs, which will inform the capacity design of the generation facility. Furthermore, payment models should correspond to the types of livelihoods and income structures in the community.

Third, the community is the primary beneficiary of the microgrid, and involving them from the beginning will help the provider understand community needs and preferences, raise awareness about the microgrid and its benefits, and can even increase demand for electricity.<sup>173</sup> In some cases, the community will also provide labor to setup and maintain the microgrid. Experience from microgrid developers indicates that having an active stake in the microgrid could make community members more accountable to the service and more likely to use it judiciously. For example, during monsoon season when there is less sun, Gram Oorja's consumers in Darewadi self-moderated their electricity usage so that the microgrid could keep functioning.<sup>174</sup>

Lastly, the community's investment in a microgrid enhances the probability that the system will be successful.<sup>175</sup> Communities that have the ability and knowledge to fix the system can provide more timely services and can actively maintain the system for enhanced longevity.

## 2. The Economic Case

Interviewed sources suggested that the main reason producers neglect community engagement today is the common perception of high upfront costs of time and money associated with the practice.<sup>176</sup> Community engagement is often not the most expedient planning or

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<sup>169</sup> R. Cynthia Neudoerffer, Preeti Malhotra and P. Venkata Ramana, "Participatory rural energy planning in India: a policy context," *Energy Policy* 29, no. 5 (April 2001): 371-381.

<sup>170</sup> Mishra and Sarangi, "Off-grid Energy Development in India."

<sup>171</sup> Ibid.

<sup>172</sup> World Bank, *Biomass for Sustainable Development*, 100.

<sup>173</sup> Parimita Mohanty, The Energy and Resources Institute (TERI), interview by author (October 28, 2013).

<sup>174</sup> Darewadi Community Women, Gram Oorja, interview by author (October 31, 2013).

<sup>175</sup> Bunker Roy, Barefoot College, interview by author (November 1, 2013).

Srinivas Krishnaswamy, *Shifting of Goal Posts: Rural Electrification in India: A Progress Report*, (Bangalore: Vasudha Foundation, 2010), 97.

<sup>176</sup> Bunker Roy, interview by author, , *Barefoot College*, (November 1, 2013). Sameer Nair, interview by author, , *Gram Oorja*, Princeton, NJ (November 14, 2013).

operational option, and some producers appear to view it as time consuming.<sup>177</sup> However, neglecting local engagement could yield increased long-term costs.

Using training at Gram Oorja as a case study, we demonstrate in Figure 7 that the short-term costs of training locals can be less than the long-term costs of hiring repair people from outside the village.<sup>178</sup> Although outside repair people will be cheaper initially to train, they will require a higher salary over time than the local village technician; incur transportation costs in getting to the repair site; and take longer to repair outages due to transportation time. The aforementioned case study is not a universally applicable cost estimate for microgrid training. Training and repair costs will hinge on a wide variety of factors including the profile and distance of the outside repairperson, the variable depth of initial training, and the severity of the repair. Indeed, the range of potential repairs is broad. We acknowledge the possibility that local technicians may still be unsuited to repair the most severe of breakdowns in spite of the highest level of training. Nevertheless, the example illustrates that focusing only on the high initial costs of community engagement is myopic and ignores the long-term benefits of community involvement.

**Figure 7. Gram Oorja Training and Repair Cost Comparison**

Cost Category	Locally Trained Technician	Outside Repair Person
Cost of Training Repair Person	50,000	0
Time to Train Repair Person	1 month	0
Total Short-Term Costs	50,000	0
Salary of Repair Person (Rs/pm) <sup>a</sup>	2,000	8,000
Repair Person Transportation Costs <sup>b</sup>	0	3,500
Waiting Time Before Repair <sup>c</sup>	1	5
Revenue Lost / day	300	300
No. Of Incidents per annum	3	3
Direct Repair Cost	Identical	Identical
Total Long-Term Costs <sup>d</sup>	-149,600	-156,000

a. For outside person its cost per visit, each visit could actually mean 2 days including travel  
b. Round-trip cost  
c. This can be highly variable, depending on availability  
d. Please see Appendix 1 for detailed calculations of and assumptions behind these costs.

## B. Barriers to Community Participation

While community involvement is important, three factors limit the community's incorporation in the installation and operation of microgrids.

■ **Top-down models:**<sup>179</sup> Today, private enterprises run a large proportion of microgrids. Entrepreneurs select a technology and business model based on their own feasibility assessment and with limited active contributions from the community. For instance, an analysis of 74 off-grid

<sup>177</sup> Nikhil Jaisinghani, *Mera Gao Power*, interview by author (October 14, 2013).

<sup>178</sup> Ibid.

<sup>179</sup> Neudoerffer et al., "Participatory rural energy planning in India."



project interventions found that only a fourth of the operational projects are characterized by serious community participation and the remaining projects are largely led by private enterprises.<sup>180</sup>

■ **Limited awareness and capacity in the community:**<sup>181</sup> This is a significant factor since the un-electrified communities that this paper focuses on tend not to have the necessary skills and networks needed to set up a microgrid and pursue electrification. In some cases, entrepreneurial community members from villages that are closer to electrified towns can potentially observe and replicate innovative electrification models—yet these are also the villages where the grid is more likely to reach given its proximity to the grid-connected areas.<sup>182</sup>

■ **Tradeoffs between sustainability and scalability:**<sup>183</sup> While community engagement is an important driver of microgrid sustainability, some for-profit energy service companies perceive a tension between the high upfront costs of engaging the community and scaling up microgrid deployment.<sup>184</sup> Meaningful engagement in each village is time- and resource-intensive. Profit-oriented enterprises often prefer achieving scale at minimal cost, which may mean foregoing community engagement.<sup>185</sup> On the other hand, NGOs may have a greater propensity to accept higher upfront costs of time and resources to engage the community and engender sustainable community ownership, but they may not have the resources to bring microgrids to scale across the country.

Two other factors could come in the way of meaningful community participation, even in those cases when project developers are keen on such involvement. These are:

■ **"Elite capture":**<sup>186</sup> Local governance structures like Gram Panchayats, or local village advisory councils such as Rural Electrification Committees, are likely actors who could facilitate community participation. But the reality is that even if community participation mechanisms are put in place, it is often the village 'elite' who dominate community opinion.<sup>187</sup> Often the lower caste members and women do not get a say in decision-making.

■ **Local conflicts in the community:** Religion and caste identities are deeply embedded in the fabric of Indian society, and many communities are divided along these lines. Key actors in rural electrification in India have noted how conflict among communities can make collaboration on projects difficult.<sup>188</sup>

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<sup>180</sup> Mishra and Sarangi, "Off-grid Energy Development in India."

<sup>181</sup> As mentioned in reference to remote villages where VESP was tested by the Indian government in the following paper: Debajit Palit, et al., "The trials and tribulations of the Village Energy Security Programme (VESP) in India," *Energy Policy* 57 (June 2013): 412.

<sup>182</sup> Dipti Vaghela, Gram Vikas, interview by author (December 14, 2013).

<sup>183</sup> Interviews with multiple social enterprises and non-profits, including Gram Vikas, Gram Oorja, MeraGao Power, Barefoot College

<sup>184</sup> Ibid.

<sup>185</sup> Mishra and Sarangi, "Off-grid Energy Development in India."

<sup>186</sup> Ibid.

<sup>187</sup> Similar reference by Deep Joshi about villagers not wanting to "antagonize the 'sarpanch'", village headman, even if they want something done. See Deep Joshi, *Wall Street Journal*, August 10, 2009 .

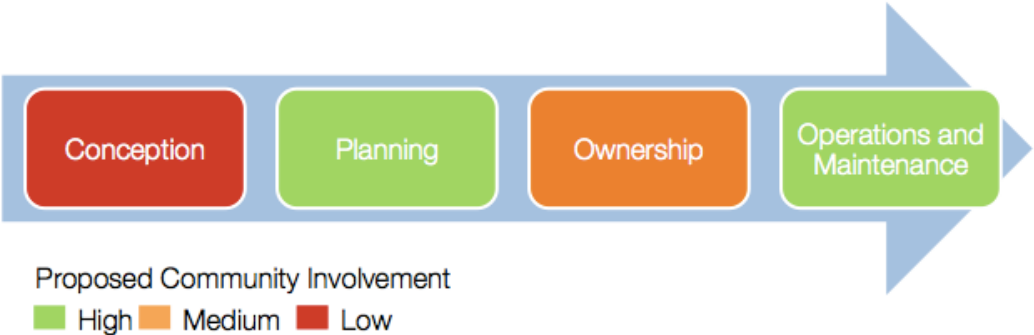
<sup>188</sup> USAID and Alliance for Rural Electrification, *Hybrid Mini-Grids for Rural Electrification*, 21.

- **Community lack of interest or time:** Organizations working at the grassroots level have sometimes experienced hesitance and even reluctance from the community about being actively involved in service provision.<sup>189</sup> Just like urban consumers, rural consumers expect electricity service to be provided without requiring extensive participation. In addition, there may be multiple development projects being executed in villages, each with their own community councils. Introducing a new committee could further tax the community's limited time.

### C. Policy Recommendations for Community Engagement

The remainder of this report provides recommendations on ways the community can be involved at each stage of a microgrid project. Although ideal community engagement would occur at all stages of the project,<sup>190</sup> our key recommendations focus on ways to involve the community through planning and operations and through community ownership.

**Figure 8. Stages of a Microgrid Project**



The following recommendations apply to all microgrid developers including governments, NGOs, private companies, or social enterprises. We direct these recommendations at microgrid producers because most producers can choose the extent to which they will engage the community when implementing a microgrid project.

These recommendations directly address the barriers to community engagement we identified above. All recommendations address the barriers pertaining to top-down implementation models and limited awareness and capacity. Further, recommendations at the Planning stage also address barriers arising from elite capture and local conflicts. Recommendations related to both Ownership and Operations and Maintenance address the barrier related to the tradeoffs between sustainability and scalability, in addition to top-down implementation models and limited awareness and capacity. Finally, community ownership requires relatively more community participation than planning or operations and maintenance stages. Our emphasis on community involvement at the planning and operations and maintenance stages of implementation therefore mitigates the barrier related to community time constraints. A summary of these recommendations, and the specific barriers they address, is presented in Figure 9:

<sup>189</sup> Prayas, interview by author, February 21, 2014.

<sup>190</sup> Prayas, *Decentralised Renewable Energy (DRE) Micro-grids in India: A Review of Recent Literature*, (Prayas Energy Group, 2012), 14.

Figure 9. Recommendations for Community Engagement

Implementation stage	Recommendation	Barriers addressed by this recommendation
Planning	Producers should undertake feasibility and demand studies. Energy service providers should partner with local NGOs to conduct these studies, and they should identify a local council of villagers to co-lead the planning and implementation.	Limited awareness and capacity in the community; elite capture; local conflicts; top-down models
Ownership	1. The cooperative model is most appropriate in communities with high levels of human capital, and renewable resources over which the community feels a strong sense of ownership.	Top-down models; tradeoffs between sustainability and scalability
	2. Private enterprises can earn profits or non-profits can add value by providing a crucial overall facilitating service to rural microgrid cooperatives: identify prospective villages for cooperatives, secure financing, set up and train managers and technicians, and provide ongoing support.	Limited awareness and capacity in the community; tradeoffs between sustainability and scalability
Operations & Maintenance	1. Frequent and small collections, employing community members for collections, and establishing retention mechanisms are important. <ul style="list-style-type: none"> <li>• <i>Short-term, or in cases where household electricity consumption is relatively uniform:</i> Fixed regular payments are better suited to collect payments.</li> <li>• <i>Long-term, or in cases of disparate household consumption patterns:</i> Metering can be used to collect payments.</li> </ul>	Limited awareness and capacity in the community; top-down models; tradeoffs between sustainability and scalability
	2. Producers should train a local technician to operate and maintain the microgrid.	Top-down models; limited awareness and capacity in the community; tradeoffs between sustainability and scalability

1. Planning

**RECOMMENDATION:** During the planning stage, we recommend that producers undertake studies with the community that analyze demand, assess feasibility, and identify income generation opportunities.<sup>191</sup> Furthermore, we recommend that energy service providers partner with local NGOs to conduct these interactions.<sup>192</sup> At the outset of the planning process, the NGO should identify and recruit a local council of village entrepreneurs to co-lead the planning and implementation with them.

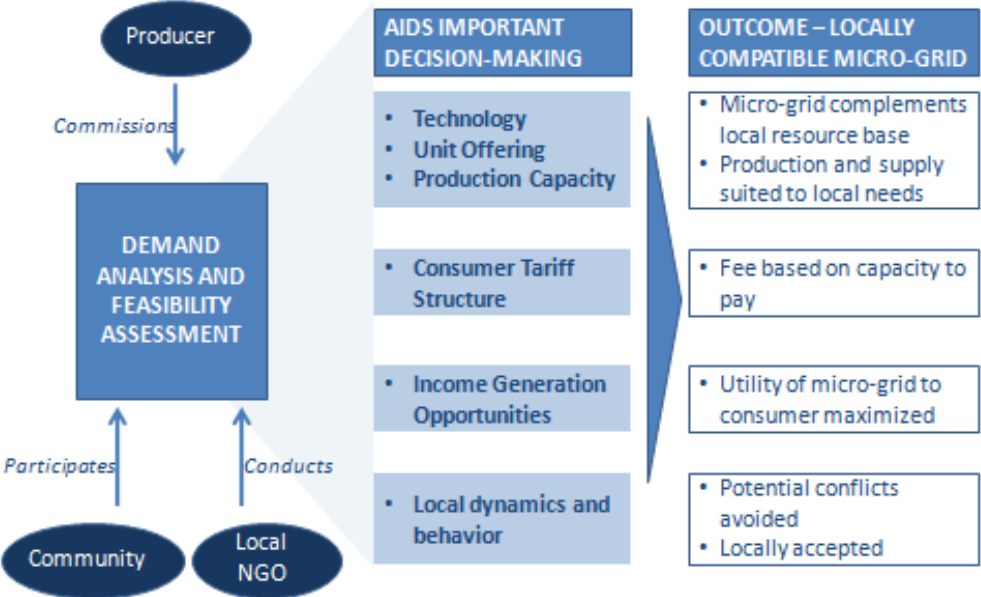
<sup>191</sup> Sovacool, "Design principles for renewable energy programs in developing countries."

<sup>192</sup> Importance of working with local non-profits that understand the community and have built credibility was a common theme that come up during our interviews with multiple grassroots actors, including TERI, Gram Vikas, Selco, FluxGen Engineering Technologies Private Limited, and Gram Oorja.

### Demand Analysis and Feasibility Assessment

The producer should survey individual households or a representative village body to determine microgrid feasibility. A robust analysis should span issues such as the local socio-economic situation, energy needs, level of basic service provision in the area, existing renewable and nonrenewable energy sources, supply priorities, and household capacity to pay.<sup>193</sup> Working with local NGO partners who have already mobilized and built credibility with the community may be the easiest and most cost-effective way to conduct these interactions, particularly in cases where the producer lacks bandwidth for deep local engagement.<sup>194</sup> In addition, working alongside a local council recruited with the help of the NGO partner is an effective way to overcome the elite capture barrier. Alternatively, if the private producer or social enterprise possesses the capacity to lead community engagement independently, it can play the role on its own, without assistance from a local NGO. The “Community Ownership Models” section below discusses in further detail how an NGO or a private enterprise may play a comprehensive facilitating role for appropriate rural microgrid cooperatives.

Figure 10. Microgrid Planning



All feasibility and demand assessments should cover the following areas:

- **Choice of technology, unit offering, and production capacity:** These studies test the feasibility of a technology against the available local resources and household needs. Villagers should be urged to accurately report their predicted electricity usage, as mistakes could directly affect production capacity and have grave consequences for the reliability and quality of the electricity they receive. For instance, MGP conducted a demand and feasibility study with the

<sup>193</sup> Intelligent Energy Europe, European Commission, *Microgrids: Promotion of microgrids and renewable energy sources for electrification in developing countries*, 2008, [www.microgrids-eie.com](http://www.microgrids-eie.com).

<sup>194</sup> Prayas, *Decentralised Renewable Energy (DRE) Micro-grids in India*, 6, 12, 14.

villagers. Given their limited financial resources, many residents only demanded one plug-point for charging cell phones and two bulbs. As a result, MGP chose a system that would not be able to support household appliances like televisions.<sup>195</sup>

■ **Consumer tariff plan:** The tariff needs to be based on consumers' ability to pay. To arrive at the best-suited model, certain critical questions about income and expenditure patterns need to be answered at this stage.<sup>196</sup> For instance, how big a payment is feasible as a down payment, and at what level does it deter participation? Or, how frequently can people pay?

■ **Income generation opportunities:** Income and employment generation opportunities that utilize energy from the microgrid should be incorporated during the planning stage.<sup>197</sup> Local NGO partners are often well suited to integrate the development priorities for a village with benefits from the microgrid. There are two main ways of incorporating income generation into the plan.

- 1) First, productive load generation is frequently described as a way to make decentralized electricity projects viable.<sup>198</sup> It complements the low electricity levels demanded by a typical rural household and provides microgrid producers economies of scale to reduce cost and augment production capacity associated with the plant. Examples of carefully chosen productive load projects abound and include, agro-processors like rice mills, wheat grinders, turmeric grinders, and tire repair shops. However, The Energy and Resources Institute's (TERI) experience of working with NGO partners to install and use these machines for income generation shows that creating commercially-viable products is a complex process. Despite careful selection of an income-generating machine based on local resources and skill sets, a reasonable investment in marketing and packaging is required to sell the resulting product, especially in the cities.<sup>199</sup> If such challenges can be overcome, perhaps through working closely with a local NGO, the possibility of employment and additional income through the microgrid could significantly increase community buy-in and the likelihood of financial sustainability for the project. With the subsidy model outlined in Chapter 4, low demand need not be a barrier to developer entry. Under the proposed structure, developers have an incentive to build a productive load into their microgrids to capture additional subsidy revenue.
- 2) Second, local involvement in maintenance and operation is an effective mode of engagement that generates income and is discussed in greater detail in the section on Training under Operations and Maintenance.<sup>200</sup> Recruiting and training an enterprising group of villagers is likely to create a natural group of leaders who could take over the operation and maintenance of the grid. For example, Gram Oorja has employed a local community member in Darewadi for upkeep of the solar panels.<sup>201</sup> Another example is that

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<sup>195</sup> Nikhil Jaisinghani, *Mera Gao Power*, interview by author (October 14, 2013).

Note: It is important to note here that this point pertains to units and type of consumption at the household level. It is different from assessing and incorporating the possibility of a productive load associated with the microgrid as a whole, which is detailed later in this section

<sup>196</sup> Dipti Vaghela, interview by author, Gram Vikas (December 14, 2013).

<sup>197</sup> Parimita Mohanty, *The Energy and Resources Institute (TERI)*, interview by author (October 28, 2013). Mishra and Sarangi, "Off-grid Energy Development in India."

<sup>198</sup> Prayas, *Decentralised Renewable Energy (DRE) Micro-grids in India*, 6, 12, 14.

<sup>199</sup> Parimita Mohanty, The Energy and Resources Institute (TERI), interview by author (October 28, 2013).

<sup>200</sup> Interviews with multiple grassroots actors in the rural energy space, including TERI, Gram Vikas, Gram Oorja, MeraGao Power, Barefoot College.

<sup>201</sup> Darewadi Community Women, Gram Oorja, interview by author (October 31, 2013).

of MNRE's Village Energy Security Program, which was driven by the locally constituted VECs. The committee was tasked with creating the Village Electrification Plan, and operating and maintaining electrification under the program. The VESP experience demonstrated that training these VECs was crucial to them fulfilling their responsibilities.<sup>202</sup> Working with a local NGO that understands and has a relationship with the community to identify and engage the village council is considered an effective method by most grassroots actors.

■ **Understanding local behavior and dynamics:** Cultural sensitivities can affect the implementation and long-term of a microgrid project substantially. Designing and implementing the microgrid based on this understanding can attempt to reduce the adverse effects that the local conflict barrier can have on the process.

## 2. Cooperative Ownership Models

Direct community ownership through cooperatives is another effective option for deploying microgrids. The ownership model described in Chapter 4 includes community-owned systems. Cooperative models for rural electrification have been used around the world, most notably in the United States beginning in the 1930s.<sup>203</sup> In India, there is a robust history of producers' cooperatives, and some history with cooperatives focusing on electricity.<sup>204</sup> This section will identify which communities are most conducive to cooperative ownership; describe characteristics of cooperatives; discuss the importance of an external facilitator that can setup and support cooperatives; and describe current efforts to create renewable energy cooperative microgrids in India today.

**RECOMMENDATION:** The cooperative model is most appropriate in communities with the following characteristics: 1) Higher levels of human capital, technical, and managerial capacity to run the cooperative; and 2) Physical renewable energy resources over which communities have a strong sense of ownership, such as hydro or biomass.<sup>205</sup>

### Characteristics of Cooperative Ownership

Cooperative ownership is characterized by the re-investment of profits into the community through dividends paid to cooperative members, or re-investment in the microgrid system. In this way, the cooperative model is a social business that makes electricity cheaper for its members. Rural microgrid co-ops are typically formed by the consumers who will use the energy. As a result, this structure may increase end users' incentives to make the microgrid project work.<sup>206</sup>

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<sup>202</sup> Debajit Palit, et al., "The trials and tribulations of the Village Energy Security Programme (VESP) in India," *Energy Policy* 57 (June 2013): 412.

<sup>203</sup> National Rural Electric Cooperative Association, "Co-op Facts & Figures," <http://www.nreca.coop/about-electric-cooperatives/co-op-facts-figures/> (accessed 2013 йил 15-November).

<sup>204</sup> Donald W. Attwood and Baburao Shravan Baviskar, *Finding the Middle Path: The Political Economy of Cooperation in Rural India* (Boulder, Colorado: Westview Press, 1995), and Ministry of Power, Government of India, *RGGVY Cooperatives in operation*, <http://rggvv.gov.in/rggvv/rggvvportal/AddressList-COOPs.html> (accessed November 13, 2013).

<sup>205</sup> Purnamita Dasgupta and Kanchan Chopra, *Policy Implications of Common Pool Resource Knowledge in India, Tanzania and Zimbabwe*, National Resources Systems Programme Semi-Arid Production System, Project R7973 (UK Department for International Development, 2001).

<sup>206</sup> Annabell Yadoo and Heather Cruickshank, "The value of cooperatives in rural electrification," *Energy Policy* 38, no. 6 (June 2010): 2941-2947.

**Figure 11. Characteristics of a Cooperative**

<b>Membership</b>	All households in the pre-defined community are members; participation can yield important dividends in terms of empowerment for men and women in rural areas by providing an opportunity to be actively involved in local development and energy access <sup>207</sup>
<b>Governance: Board of Directors</b>	Board of Directors (BOD) members are elected from among all members in a one-member, one-vote democratic system <sup>208</sup>
<b>Management and staffing</b>	Co-op management is appointed by the BOD from within the community, thus generating local employment; or the BOD can contract an outside firm for management <sup>209</sup>
<b>Cooperative staff responsibilities</b>	Management, maintenance, and operation of system assets, as well as tariff collection <sup>210</sup>
<b>Accountability mechanism</b>	Co-ops create direct accountability, as service providers are the users themselves; for instance, community-level monitoring can mitigate usage at times of peak load more immediately and effectively than State Electricity Boards (SEBs) can <sup>211</sup>

### Importance of an External Facilitating Organization and Potential for Local Leadership

**RECOMMENDATION:** Private enterprises can earn profits or non-profits can add value by providing a crucial overall facilitating service to rural microgrid cooperatives: identify prospective villages for cooperatives, secure financing, setup and train managers and technicians, and provide ongoing support.

<sup>207</sup> UNDP, *Energy in National Decentralization Policies: A Review Focusing on Least Developed Countries and Sub-Saharan Africa*, (New York: United Nations Development Programme, 2009), iii, 25.

<sup>208</sup> Yadoo and Cruickshank, “The value of cooperatives in rural electrification.”

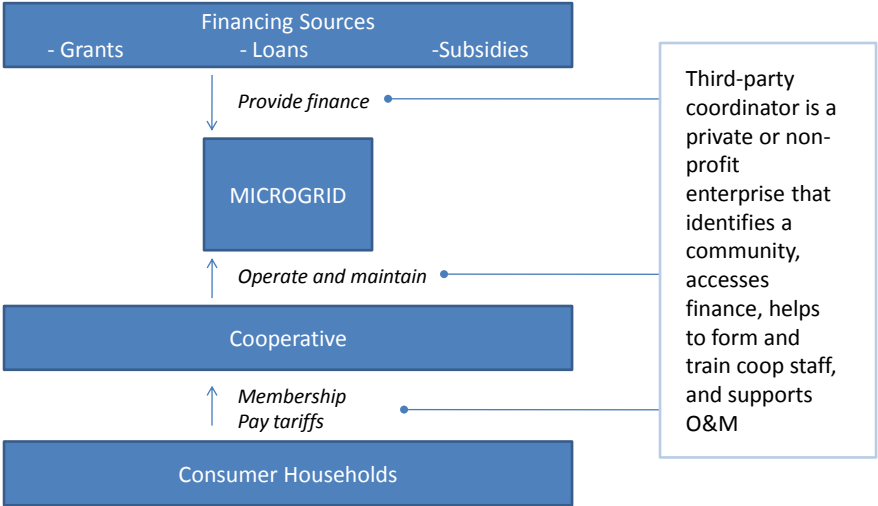
<sup>209</sup> Douglas F. Barnes, *Meeting the Challenge of Rural Electrification in Developing Nations: The Experience of Successful Programs (Draft)*, (Washington, DC: World Bank, 2005), 40-42.

<sup>210</sup> Ministry of Power, Government of India, *Gokak Committee Report on Distributed Generation*, 2002, [http://powermin.nic.in/reports/pdf/gokak\\_report.pdf](http://powermin.nic.in/reports/pdf/gokak_report.pdf) (accessed 2013 йил 14-November), and Sameer Nair, Gram Oorja, interview by author, Princeton, NJ (14 November 2013).

<sup>211</sup> Sameer Nair, Gram Oorja, interview by author, Princeton, NJ (2013 November 14).



**Figure 12. Role of the Third-Party Microgrid Coordinator**



Due to limited capacity within many rural communities, external technical and managerial support will be required to initiate cooperatives.<sup>212</sup> Particularly in the setup and early operation stages in rural India, a third-party facilitator (private or non-profit) will need to provide support to cooperative managers and operators.<sup>213</sup> Non-profit organizations could play this role as facilitator without a profit motive. For-profit social entrepreneurs can also enter the rural cooperative space as facilitators that guide and support cooperative operations in a build-manage-transfer (BMT) model, retaining a portion of tariff collections as a fee and earning profit on capital subsidy reimbursements. As cooperatives mature, the facilitating organization can gradually turn over all responsibility and go on to set up cooperatives in other villages.

When selecting villages for microgrid deployment, facilitators should understand that empirical reviews of cooperative experiences in India and internationally find that strong and capable local leadership is key to cooperative success, particularly given cooperative managers’ extensive set of responsibilities (as detailed in box 2, above).<sup>214</sup> Though a facilitator will still be needed to get a cooperative off the ground, cooperatives may be most appropriate in villages that have greater human capital, or more robust civic and associational life.<sup>215</sup>

**Cooperative financing: Start-up capital, franchising, and tariff collection**

Rural cooperatives may vary in their ability to contribute to the initial capital cost. However, as suggested in the previous section, they can seek financing from a variety of sources, including subsidies, loans, and grants provided by the central government, international donors, CSR funds, private lenders, or private philanthropy.<sup>216</sup> The ability or otherwise of the rural cooperative to put in their own investment is not necessary for the success of the project. Cooperative members have a financial stake in the microgrid investment because they assume responsibility for repaying initial capital loans and covering O&M costs. Given communities’ limited ability to generate significant

<sup>212</sup> USAID and Alliance for Rural Electrification, *Hybrid Mini-Grids for Rural Electrification*, 21.  
<sup>213</sup> USAID and SARI Energy, *Rural Energy Services Best Practices*, (White Plains: Nexant, 2002), 7-4.  
<sup>214</sup> Ernst & Young, *Models of Rural Electrification*, 38-39.  
<sup>215</sup> Ibid.  
<sup>216</sup> Sreevas Sahasranamam, Soumyarup Dasgupta, Abhinav Asati, Reetika Singh and Arkaprabha Debnath, “Powering villages with renewable energy co-ops,” *The Hindu*, November 25, 2013.

profits, loans must carry low interest rates and long repayment periods.<sup>217</sup> After repayment of the initial loans, the community assumes full ownership of microgrid infrastructure and distribution assets.<sup>218</sup>

Community-owned cooperatives should be eligible franchisees if one of the franchising models discussed in Chapter 4 is accepted as policy. In rural areas not connected to the grid, the Electricity Act of 2003 allows setting tariffs based on agreements between the distributor/generator and consumers.<sup>219</sup> This regulation applies to rural cooperatives managing microgrids; like private energy service firms, cooperatives have latitude to set tariffs. (See subsection iii below for more on tariff-setting).

### Renewable energy microgrid cooperatives in India

India has a history of electric and other rural cooperatives. Since the 1960s, RECs, grid-connected cooperatives, have purchased electricity in bulk from the State Electricity Boards, received funding from the Rural Electrification Corporation, and operated with some degree of autonomy—though SEBs set tariffs for grid-connected cooperatives. In Andhra Pradesh and West Bengal, RECs have been particularly successful, while in other parts of India, they have struggled to remain economically viable.<sup>220</sup> More broadly, agricultural and producer cooperatives are a common business model in India.<sup>221</sup> Thus, there is untapped potential for microgrid cooperatives in India.

In the microgrid space in India today, a number of energy service firms implement microgrids through quasi-cooperative models (see Box 3).<sup>222</sup> In these models, the energy service firm acts as a value-adding facilitator and helps the village to set up a cooperative, provides training and support, and over time may transfer greater management responsibility to the community. In this way, companies can reap the subsidy benefits allotted by MNRE via their BOMT approach; however, they are not necessarily incentivized to stay involved once the capital subsidy support disappears. These enterprises, unlike the ideal facilitator described in the recommendation above, either plan to continue operating as the facilitator in the longer term or are still identifying their exit strategy that will render the cooperative independent.

### Risks and Constraints

Certain risks and constraints apply to all local development initiatives, as we discussed in the “Barriers” section. Limited local capacity to manage a cooperative can hinder success. Local conflict dynamics can undermine community accountability. Tariff-setting or distribution decisions can be politicized, and cooperatives run the risk of elite capture, despite democratic elections for Board of Directors.<sup>223</sup>

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<sup>217</sup> Barnes, *Meeting the Challenge of Rural Electrification in Developing Nations*, 40-42.

<sup>218</sup> Yadoo and Cruickshank, “The value of cooperatives in rural electrification.”, and in Bangladesh for instance, the transfer of assets has yielded largely positive results and has demonstrated the importance of local ownership.

<sup>219</sup> Ministry of Power, “India Electricity Act 2003.”

<sup>220</sup> USAID and SARI Energy, *Rural Energy Services Best Practices*.

<sup>221</sup> National Dairy Development Board, *New Generation Cooperatives Leading Producer Companies*, <http://www.nddb.coop/English/Services/CS/Pages/New-Generation-Cooperatives-Leading-Producer-Companies.aspx> (accessed 24 November 2013).

<sup>222</sup> To varying degrees, these quasi-cooperatives can include Gram Power and Desi Power.

<sup>223</sup> Ernst & Young, *Models of Rural Electrification*, 38-39.

## Box 2. Quasi-Cooperative Models in Energy Service Firms

### Gram Power

Gram Power is an energy service company that establishes renewable energy microgrids in India. They build standalone and grid-connected microgrid systems. Their revenue model revolves around formation of a village cooperative with all connected households as members.

Gram Power arranges access to government subsidies and bank loans for the cooperative to fund the microgrid and provides a guarantee to the financier. Gram Power then sets up the microgrid, including local generation on a complete turnkey basis. Power from captive generation is sold to community members on a prepaid basis through the local cooperative. Revenue from selling power to local consumers will pay back the initial loan over time, after which the community will own the microgrid and effectively become the distribution franchisee.<sup>224</sup>

None of Gram Power's 21 microgrids has yet reached this milestone and become an independent cooperative, though Gram Power aspires to enable this over the next few years. It has also secured donor funding to build 40 new microgrids.<sup>225</sup>

### Desi Power

Desi Power is an independent rural renewable power producer that builds and operates decentralized microgrids. It focuses on the rural infrastructure required for supplying electricity and generating economic development through access to energy. Key to Desi Power's model is the mobilization and formation of village cooperatives, which ultimately take on management of the microgrid.<sup>226</sup> This cooperative society is also a venue to promote and develop microenterprise ideas for the community that utilizes electricity.

Cooperatives in India traditionally revolve around a shared livelihood or production and sale of a specific commodity. However, electricity is understood differently than other commodities, and the notion that they need to generate their own electricity might not be prevalent; instead, the government is perceived as a provider of electricity.<sup>227</sup> Micro-hydro or biomass may be an exception—there may be more of a notion of community ownership over local water or agricultural waste resources, thus making these renewable energy sources more viable for cooperative ownership.<sup>228</sup> With examples of successful microgrid pilot projects, these notions could begin to shift. For instance, inhabitants of Darewadi's neighboring village were reportedly interested in the Gram Oorja microgrid model.

## 3. Community Operation and Maintenance

The final stage of microgrid implementation is operation and maintenance. We categorize it into two sub-phases: (a) payment and collection; and (b) training and maintenance.

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<sup>224</sup> Yashraj Khaitan, "Gram Power" (Powerpoint presentation, 2012).

<sup>225</sup> "USAID press release regarding Gram Power funding," *Gram Power*, 2013 November, [http://grampower.com/PR\\_USAID.pdf](http://grampower.com/PR_USAID.pdf).

<sup>226</sup> Desi Power, "Desi Power Company Profile," 2013, [www.desipower.com/downloads/DESI-Power-Company-Profile.pdf](http://www.desipower.com/downloads/DESI-Power-Company-Profile.pdf) (accessed 2013 November 20).

<sup>227</sup> Sunila S. Kale, "Current Reforms: The Politics of Policy Change in India's Electricity Sector," *Pacific Affairs* 77, no. 3 (March 2004): 489-491.

<sup>228</sup> USAID and SARI Energy, *Rural Energy Services Best Practices*, and Dasgupta and Chopra, *Policy Implications of Common Pool Resource Knowledge*.

## Payment and Collection

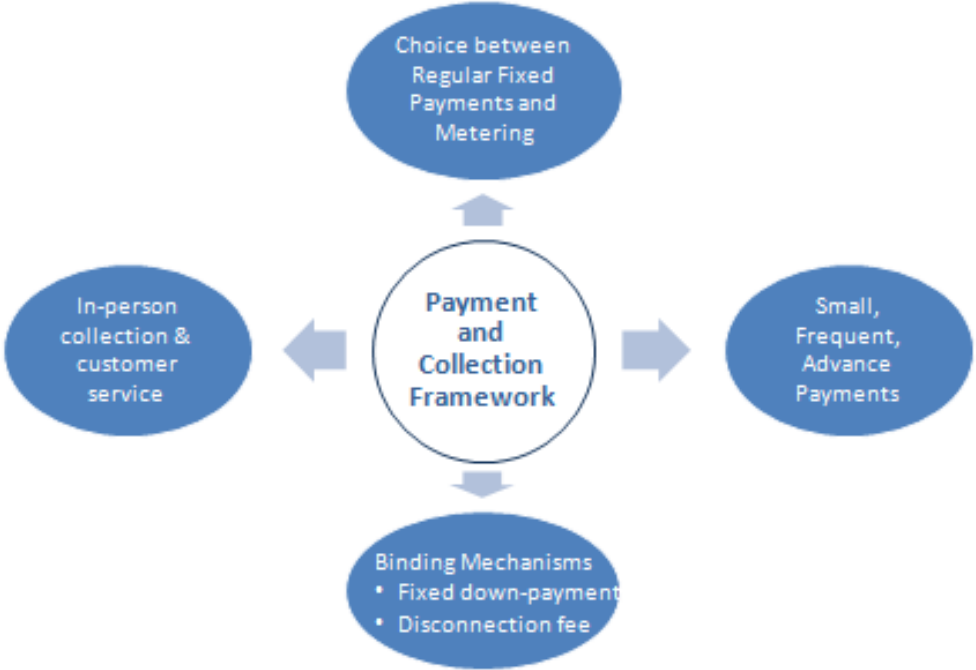
Monetary involvement of the community in lieu of a strictly donor-based model is an important component of some microgrid successes.<sup>229</sup> Putting in place an appropriate payment mechanism and collection plan will facilitate this monetary involvement.

**RECOMMENDATION:** Payments should be collected frequently to keep the payment amounts small; community members be employed for collection; and appropriate binding mechanisms to retain customers be established. In the short-term and in cases where household electricity consumption is relatively uniform throughout the village, we recommend fixed regular payments without meters. In the long-term or in cases of disparate household consumption patterns across the village, metering can be used to collect payments.

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<sup>229</sup> Interviews with multiple grassroots actors in the rural energy space, including TERI, Gram Vikas, Gram Oorja, MeraGao Power, Barefoot College, 2013. Sovacool, "Design principles for renewable energy programs in developing countries."

Figure 13. Payment and Collection Framework



The four key characteristics of the payment and collection framework as outlined in Figure 12 are described in the following paragraphs.

First, *small, frequent, advance payments* are particularly suited to a consumer base that has limited capacity to pay large upfront sums of money. After experimenting with varying amounts of post-use payments collected monthly, MGP decided to collect weekly payments in advance. In-person collection is an effective way of payment collection, which also generates local employment.

Second, *door-to-door visits*—either to read the meter or to collect payment in cash—provide a unique opportunity to interact with customers and provide customer service for maintenance and repair complaints.<sup>230</sup> Most social enterprises recruit and train local youth to take up this task, reinforcing the income generation motive highlighted in the planning section. Additionally, with in-person collection, consumers are less able to avoid paying.

Third, *regular fixed payment models* generally have a fixed flat fee for installation and fixed advance payments collected at regular intervals. These payments are decided based on an estimate of household consumption. In contrast, metering gives providers the ability to charge for only the amount of electricity consumed. However, purchasing and installing meters is generally quite expensive.<sup>231</sup> A regular fixed payment is likely to be best suited to a situation where a microgrid is first set up and the producer is generating demand and getting community buy-in. If all households in a village have more or less the same electricity consumption, installing a meter represents an added cost for little incremental benefit. As the microgrid evolves, generation stabilizes, and demand grows, meters can be installed and used for payments.

<sup>230</sup> Nikhil Jaisinghani, Mera Gao Power, interview by author (October 14, 2013).

<sup>231</sup> USAID and Alliance for Rural Electrification, *Hybrid Mini-Grids for Rural Electrification*, 21.

Both models function well for different types of enterprises. For example, Gram Power installs prepaid meters to ensure payment and prevent the free-rider problem. They charge Rs. 3,500 upfront for the connection, which includes a smart meter and two 8-watt CFL's. However, the meter is not the consumer's property.<sup>232</sup> On the other hand, MGP's collection mechanism consists of a small fixed cost of Rs. 25 to install the panel at consumers' homes and then regular weekly payments of Rs. 25 collected in advance.<sup>233</sup> The biggest disadvantage of this model is that preventing overloading is difficult. Consequently, MGP has installed circuit breakers to prevent this from happening, which incurs an additional cost.

Fourth, *binding mechanisms* to retain customers and ensure regular flow of revenue are important from the producers' perspective. While there are multiple ways to do this, most entrepreneurs agree that a down payment before the system is set up helps ensure that the community continues to purchase from the microgrid. A down payment serves the dual purpose of assessing the ability and willingness of community members to pay, and securing them as customers for the grid by compelling them to make an investment in the system.<sup>234</sup> Opinion among enterprises varies about the ideal payment amount and depends on the socioeconomic condition of the community being serviced. MGP charges Rs. 25 since that is what they believe people can reasonably afford, while Gram Oorja charges Rs. 1000-1500 since they believe a large upfront payment gets people involved in the a deeper way.

Another popular binding mechanism in literature is a disconnection policy. While this does incentivize customers to continue purchasing power, it is more punitive in nature. Disconnection policies are observed globally by producers to penalize theft or repeated non-payment. Although the severity of electricity theft in India offers a case for producers to use disconnection policies, this may be too harsh a step for the target population of microgrids: poor rural households. Modified mechanisms could be considered in this context, such as, disconnection for a specific period of time after a certain number of warnings given by the producer.

## Training and Maintenance

**RECOMMENDATION:** We recommend that producers always train a local technician to operate and maintain the microgrid.

Training builds the capacity of the local village to sustain the microgrid, thereby increasing village buy-in and ownership.<sup>235</sup> We previously reviewed one way in which the short-term costs of training locals were outweighed by the long-term costs of bringing in outside engineers and repair people. Gram Vikas is an Indian non-governmental organization based in Orissa that implements water, sanitation, and biogas energy projects in rural communities. Gram Vikas initially hired outside technicians to conduct their system repairs, but they stopped at later stages because they determined that external actors were more expensive and failed to serve a capacity-building role in the community, and thus Gram Vikas decided they were not worthwhile.<sup>236</sup> Whether a producer

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<sup>232</sup> Ankur Paliwal, "Budgeting Power," *Down to Earth*, 2013 July 31, <http://www.downtoearth.org.in/content/budgeting-power>.

<sup>233</sup> Nikhil Jaisinghani, *Mera Gao Power*, interview by author (October 14, 2013).

<sup>234</sup> USAID and Alliance for Rural Electrification, *Hybrid Mini-Grids for Rural Electrification*, 21.

Interviews with entrepreneurs in the rural energy space, including Gram Oorja, MeraGao Power and TERI; TERI's binding mechanism is to encourage the community to partly cover the cost of the microgrid to complement subsidy and other sources of supporting capital costs

<sup>235</sup> Mwangi Chege, SAIS, interview by author (October 28, 2013).

<sup>236</sup> Dipti Vaghela, Gram Vikas, interview by author (December 14, 2013).

utilizes local training and maintenance will depend on its business model; can they accept the short-term cost in exchange for the long-term gain? For example, MGP seeks to keep its short-term costs as low as possible, but Gram Oorja has expressed interest in paying more today in pursuit of long-term savings.<sup>237</sup> One alternative that falls between local and outside technicians is to have cluster-level technicians. MGP installs microgrids in clusters of villages, thus making one repair person for the entire cluster more affordable than hiring local repair people in each village.<sup>238</sup>

Even in cases when the costs are more variable, we believe the numerous but unquantifiable benefits of local training and maintenance justify its use. Local training enables the community to become involved in the decisions that affect their livelihoods. Training also has the potential to generate small-scale employment for the community, which can spur a virtuous cycle of income generation and higher quality of life for those few employed locals.<sup>239</sup> Even though only a few villagers earn additional income from local employment in operations and maintenance, this form of community engagement is valuable in building local skills that ensure the long-term viability of microgrids.

The relationship between local capacity building and longer-term microgrid sustainability is demonstrated by Gram Vikas' experience with system breakdown frequency.<sup>240</sup> For their first two biogas projects, they employed outside designers and installers. For their next three projects, they switched to local fabricators. They found that the repair frequency of the first projects (externally installed and maintained) were ten times the repair frequency of the later projects (locally installed and maintained). In fact, the early projects required attention every 1–2 weeks, and the later projects worked smoothly for two years straight. Even when one of the later projects eventually suffered a major breakdown, Gram Vikas found that the community did not wait for the NGO to fix it; instead, they raised the repair costs themselves (Rs. 8,000) and traveled to the fabricator on their own and learned how to fix the problem. Gram Vikas believes local capacity building and training enhances the chances of microgrid success.

Microgrid capacity building within communities can describe a number of activities, which are detailed in the table below. Training can be directed at a variety of stakeholders, from newly hired local technicians to end-user consumers. Recognizing that resource constraints may limit a producer's ability to partake in all activities below, we recommend focusing training on local operation and maintenance of the microgrid.

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<sup>237</sup> Nikhil Jaisinghani, Mera Gao Power, interview by author (October 14, 2013); Sameer Nair, Gram Oorja, interview by author, Princeton, NJ (November 14, 2013).

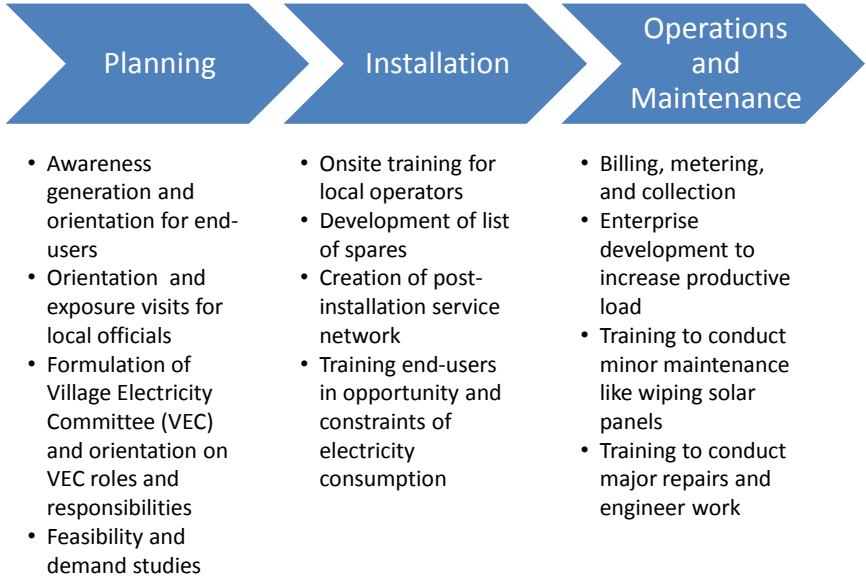
<sup>238</sup> Nikhil Jaisinghani, Mera Gao Power, interview by author (October 14, 2013).

<sup>239</sup> Gómez García and Montero Bartolome, "Rural electrification systems based on renewable energy."

<sup>240</sup> Dipti Vaghela, interview by author, Gram Vikas (December 14, 2013).



Figure 14. Building Capacity for Microgrids with Training



241

A common misconception about community training is that microgrid technology is too complicated to be taught to uneducated villagers. This is belied by Barefoot College—an NGO in a village in the state of Rajasthan that has trained 700 illiterate women from poor communities all around the world. At Barefoot College, it costs approximately Rs. 300,000 to train one solar engineer full-time over the course of 6 months, but the figure is high because it includes the cost of round-trip airfare and a Rs. 60,000 retainer awarded to the villager when they graduate from the program.<sup>242</sup> The course time is also high because illiterate women teach the villagers, who are illiterate themselves. In addition, the burgeoning solar engineers often do not even speak the same verbal language as their teachers. Nevertheless, Barefoot College demonstrates that illiterate villagers can learn the technical skills normally reserved for college graduates, and they can in turn contribute to the sustainability of their community’s microgrid.

<sup>241</sup> Generated with input from: Atul Kumar, Parimita Mohanty, Debajit Palit and Akanksha Chaurey, “Approach for standardization of off-grid electrification projects,” *Renewable and Sustainable Energy Reviews* 13, no. 8 (October 2009): 1946-1956.

<sup>242</sup> Bunker Roy, Barefoot College, interview by author (November 1, 2013).

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## Section VI

### Conclusion

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The goal of the recommendations in this paper is to suggest how both market and policy conditions and practices can be improved to advance microgrids in rural India in order to significantly increase the number of households with access to electricity. More specifically, the recommendations focus on how to address challenges to project financing and engaging the target community. While microgrid projects also face other challenges (e.g., bureaucratic hurdles and limited demand), we focused our recommendations on financing and community engagement since our interviews suggested that they were the two most critical elements to ensuring that microgrids projects achieve both feasibility and sustainability.

**To improve *financing* for microgrid projects, we recommend that:**

- The subsidy structure should be reformed by scaling back upfront capital subsidies, and complemented them with performance-based subsidies. Only this way can long-term operation of microgrid systems be incentivized.
- Access to additional sources of capital by project developers should be improved by streamlining approval process for subsidies, placing committed subsidies in an escrow account, and convening together corporations and project developers to facilitate access to money funds generated by the new Corporate Social Responsibility law.
- Franchising agreements should be revised to provide defined ownership opportunities to private, non-profit, and community corporations; the same design of capital and operational subsidies to all owners and operators; auctions of predefined franchise regions; and transparent operating protocols to encourage CSR and non-profit partnership.
- Grid integration should be facilitated through purchase agreements for electricity from all microgrids upon grid arrival; clear rules and tariff structures for feeding electricity back into the grid; and extending capital subsidies to include interconnection equipment.

**To improve *community engagement*, we recommend that:**

- Microgrid producers should undertake feasibility and demand studies by partnering with NGOs and a local council of villagers.
- Microgrid developers should promote the cooperative model in those communities with high levels of human capital, and renewable resources over which the community feels a strong sense of ownership.
- Private or non-profit enterprises should provide an overall facilitating service to rural microgrid cooperatives by identifying prospective villages for cooperatives, securing financing, setting up and training managers and technicians, and providing ongoing support.
- Microgrid operators should collect small payments frequently, employ community members for collections, and establish retention mechanisms to address villagers ability to pay and to gain their long-term buy-in.
- Producers should train a local technician to operate and maintain the microgrid.

## Appendices

### Appendix 1. Gram Oorja's Calculations of Long-term Training Costs<sup>243</sup>

#### Locally Trained Long-Term Costs (Rs.)

	Year 1	Year 2	Year 3	Year 4
Training cost	50,000	0	0	0
Manpower Cost	24,000	24,000	24,000	24,000
Revenue Lost	900	900	900	900
<b>Total</b>	<b>74,900</b>	<b>24,900</b>	<b>24,900</b>	<b>24,900</b>
			<b>Overall Total</b>	<b>149,600</b>

#### Externally Serviced Long-Term Costs (Rs.)

	Year 1	Year 2	Year 3	Year 4
Training cost	0	0	0	0
Manpower Cost	24,000	24,000	24,000	24,000
Transport Cost	10,500	10,500	10,500	10,500
Revenue Lost	4,500	4,500	4,500	4,500
<b>Total</b>	<b>39,000</b>	<b>39,000</b>	<b>39,000</b>	<b>39,000</b>
			<b>Overall Total</b>	<b>156,000</b>

#### Assumptions of Calculations:

- The outside repair person is assumed to be a fully trained person, and hence there is no cost of training. (The person is assumed to be on the rolls of the inverter or battery manufacturer.)
- The cost to train a locally trained person includes transportation cost of Gram Oorja (GO) trainer, man day costs of GO, plus other incidentals.
- The local repair person is paid a fixed retainer fee and will perform some preventive maintenance (PM) activity. The economic benefit of the PM is not explicitly captured.
- The local repair person is also not usually fulltime dedicated only to this activity. He/she will usually be doing other productive activity, hence his/her low cost.
- Revenues lost is a measure of the cost of not having energy. For the sake of simplicity, this has been taken as the billing of 15 kWh per day @ Rs 20 per unit, which is the marginal cost of power.
- Since the direct repair cost is usually in the form of parts replaced and are likely to be identical, we have not added it in the comparative analysis.
- Average number of incidents are set as 3 per year. This in GO's opinion is at the lower end of the spectrum. As the number of incidents increase, they believe "local" repairs yield increasing utility when compared to "outside" repairs. GO observes that in later years, the number of incidents is expected to increase.
- Calculations are not adjusted for time value (training cost is upfront whereas long term costs are staggered, and at the same time we are not considering the impact of inflation on long term costs)
- Calculations considered over 4 years as the breakeven is achieved in the 4th year, i.e. in between the 3rd and 4th year "training the local person" strategy gets cheaper. Since the typical projects last 25 years, the strength of this argument grows over time.

<sup>243</sup> Sameer Nair, Gram Oorja, interview by author, Princeton, NJ (November 14, 2013).

## Appendix 2. Microgrid Cost Calculations

### Solar Microgrid<sup>244</sup>

	Expenses	Quantity /Units	Cost Per Unit (Rs.)	Life (Years)	Total (Rs.)	Monthly Capex Recovery (Rs.)
<b>Capital Expenses</b>	PV module including inverter	7.6 kWp	100,000	25	760,000	7,974
	Construction costs			25	450,000	4,740
	Battery	19.2 kWh	10,000	5	170,000	3,844
	Distribution	30 poles	20,000	25	600,000	6,319
<b>Maintenance Costs</b>	Labor (cleaning panels, simple maintenance)	Cost of labor per month	2,000			2,000
	Periodic visit from project developer	Once a month	500			500
				<b>Total Monthly Expenses</b>		<b>25,377</b>

\*Assumed 12% rate of interest for calculations

### Other Assumptions

Total losses related to battery storage & photovoltaic panel performance	30%
Capacity Factor	0.2

<b>Unit Cost of Power (Rs./kWh)</b>	<b>33</b>
<b>Cost per household (Rs./month)</b>	<b>159</b>

<sup>244</sup> Our calculations based on some input figures provided by Gram Oorja and our assumptions. The authors would like to express deep appreciation to Gram Oorja for sharing these figures.

## Biomass Microgrid<sup>245</sup>

Capital Expenses	Power Rating (kW)	Cost Per Unit (Rs./kW)	Total Cost (Rs)	Life (Years)	Monthly Capex Recovery (Rs.)
Gasifier	3.5 kW	25,000	87,500	20	4,901
Engine	3.5 kW	30,000	105,000	20	5,881
Civil Works (Fixed)			72,000	20	3,990
Civil Works (by kW)	3.5 kW	9,000	31,500	20	1,764
<b>Total</b>					<b>16,537</b>

\*Assumed 12% rate of interest for calculations

### Usage Calculations

Number of households	160
Average per household capacity (including community uses) (W)	20
Average number of hours of use (h)	8
Combined losses	10 %

### Biomass Calculations

Price of Biomass (Rs./kg)	1.5
Biomass Consumption (kg/kWh)	1.1
Total Cost of Biomass (Rs./Month)	1,261

<b>Unit Cost of Power (Rs./kWh)</b>	<b>23</b>
<b>Cost per Household (Rs./month)</b>	<b>111</b>

<sup>245</sup> Our calculations, based on figures from: Nouni, M.R., S.C. Mullick, and T.C. Kandpal. 2007. "Biomass Gasifier Projects for Decentralized Power Supply in India: A Financial Evaluation." *Energy Policy* 35: 1373–1385; and Harish, Santosh M.; Granger Morgan and Eswaran Subrahmanian, "When does unreliable grid supply become unacceptable policy? Costs of power supply and outages in rural India," Carnegie Mellon University (2013), 1-37.