Policy and Financial Barriers to Micro-Grid Development in India

Roberts Environmental Center

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INTRODUCTION

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In the spring of 2019, the Sustainable Development Policy and Finance team of the Roberts Environmental Center began compiling this report to assist the social enterprise Grassroots and Rural Innovative Development (G.R.I.D) in improving their business operations. This report details a comprehensive analysis of existing micro-grid policies in India, comparison of different business models, and research on the renewable energy financing gap.

Goals of Research

This report has two overarching goals: 1) to advise G.R.I.D. and other rural micro-grid companies on how to best expand and improve their existing operations, and 2) to assist G.R.I.D in obtaining funding for their projects. To accomplish these goals, this report will analyze and explain financing obstacles for renewable energy investment, analyze Indian energy policy, and evaluate existing micro-grid business models. These tasks are ultimately designed to help G.R.I.D and other companies navigate the complicated and challenging arena of renewable energy development in India.

Methodology

Each analyst in the Sustainable Development team conducted an extensive literature review of renewable energy financing (including grants, debt, and equity investment), existing micro-grid business models, and renewable energy policy in India. These three topics were divided into specific areas of interest: Indian federal government policies, Indian state policies, financing policies, and business models. These areas of interest were selected after an exhaustive literature review process, after which the team deemed these areas to be the most crucial for micro-grid development.

BACKGROUND

Katie O'Neill (CMC '21), Sami Murphy (CMC '21)

1. Energy Poverty in India

Although global electrification has risen drastically in the past few decades, over 13% of the total world population, roughly one billion people, still lacks access to electricity. India remains the country with the largest unelectrified population in the world, with roughly 300 million people without access to electricity.[1] In addition, there is a striking gap in electrification between urban and rural areas: in India, although 97% of urban areas are electrified, but only 77% of households have access to electricity.[2] Discrepancies of energy accessibility stem from issues connecting remote areas to centralized electrical grids. Although the Indian Government announced the country achieved 100% village electrification in 2018, the definition of "electrified" used by the government allows a village to be "electrified" when only 10% of households in a village have access to electricity.[3] This means that villages considered fully electrified may have up to 90% of its residents still relying on kerosene, coal, or no form of electricity at all.[4]

2. Sustainable Development Goals

The United Nations announced the Sustainable Development Goals in 2015 to encourage countries to implement policies towards economic development while ensuring natural resources for future generations. United Nations Sustainable Development Goal (SDG) 7 is **Affordable and Clean Energy for All**.

Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all

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[1] World Bank. (2014). Switching on Power Sector Reform in India. Retrieved from http://www.worldbank.org/en/news/feature/2014/06/24/switching-on-power-sector-reform-in-india

[2] World Bank Group. (n.d) SE4ALL Global Tracking Framework. Access to electricity (% of population) Retrieved from https://data.worldbank.org/indicator/eg.elc.accs.zs.

[3] Dutt D'cunha S.(2018). Modi Announces '100% Village Electrification', But 31 Million Indian Homes Are Still In The Dark. Retrieved from https://www.forbes.com/sites/suparnadutt/2018/05/07/modi-announces-100-village-electrification-but-31-million-homes-are-still-in-the-dark/#36ba5ccb63ba

[4] Bhushan, C. B., & Kumarankandath, A. (2016). Mini-grids Electricity for All. Retrieved from https://www.cseindia.org/mini-grids-electricity-for-all--6864

Under the umbrella of SDG 7 are five smaller targets:

1) Universal access to modern energy services,
2) Increase renewable energy,
3) Double the global rate of energy efficiency improvement,
4) Enhance international cooperation, and
5) Upgrade renewable energy technology and infrastructure.[5]

However, while there has been major headway in increasing affordable access to energy throughout India, this has come at the cost of increased environmental detriments. In India, most electricity is produced via coal-powered plants, which emit greenhouse gases in significant quantities. Despite this, the federal government of India has recently increased its role in incentivizing renewable electrification throughout the country to accomplish SDG 7. Investing in clean and renewable energies, particularly in areas with limited access to electricity, is key to fulfilling SDG 7 and to slowing climate change.[6]

3. Vision for Achieving Universal Electrification in India

India's existing efforts to supply clean, affordable, and reliable energy to its population would greatly benefit from an increased emphasis on last-mile electrification projects. The current approach by the Indian government in decarbonizing its energy supply is characterized by centralized mega-grids and large-scale solar and wind projects. However, this approach does not create a solution for achieving universal electrification. Even though the government has recently achieved grid connection to every village in India, over 200 million people still lack access to electricity.[7] For this reason, the use of off-grid systems is crucial to closing the urban-rural electricity gap and eventually electrifying the entire population. India's electricity needs are decentralized, so they need decentralized energy solutions. An alternative approach to achieve both universal electrification and decarbonization would include thousands of self-sustaining electricity projects connected to the larger central grid, which can be used if there are ever power shortages. Such an approach would improve reliability and accessibility to all in India, especially the country's rural poor.[8]

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[5] United Nations. #Envision2030 Goal 7: Aforable and Clean Energy. Retrived from https://www.un.org/development/desa/disabilities/envision2030-goal7.html.
[6] United Nations. Sustainable Development Goals. (2016). Retrieved from https://www.undp.org/content/undp/en/home/sustainable-development-goals.html.
[7] BBC News. (2018) India says all villages have electricity. Retrieved from https://www.bbc.com/news/world-asia-india-43946049
[8] Bhushan, C. B., & Kumarankandath, A. (2016). Mini-grids Electricity for All. Retrieved from https://www.cseindia.org/mini-grids-electricity-for-all--6864

4. Challenges to Micro-Grid Investment

Despite this, many barriers to electrification still remain. Only 9 out of 28 states have reached more than 90% electrification, meaning India is still very far away from meeting its goal of "Power for All" by 2012 as established in its 2001 REST (Rural Electricity Supply Technology) mission.[9] While the cost of implementing renewable energy technology has fallen dramatically in recent years-- enough to make it competitive with the fossil fuel industry-- the renewable energy sector is emerging, relatively unexplored, and generally perceived as highly risky. Further complicating the issue is the plethora of different business models employed by different renewable companies. To navigate diverse energy needs, these companies have become highly tailored and location specific to better serve their own, niche clienteles. Consequently, this makes it difficult to compare impact and success across micro-grid companies, which can discourage investors who are unable to adequately project future cash flows and the true potential behind each individual opportunity. Coupling this, many electricity companies face high Aggregate Technical and Commercial (AT&C) losses and uncertain returns on investment in rural areas. Often, this is because of poor management practices, off-grid ineligibility to cross-subsidy benefits, and flawed economic models that have difficulty matching energy supply to demand. As for policy-specific limitations, many argue that the government's enthusiasm to electrify India has been counterproductive in some regards. Because they have created many programs oriented around increasing electricity, less funding has been allocated to each one and there is a need for quality over quantity in their efforts.

[9] Palit, D., Bhattacharyya, S. C., & Chaurey, A. (2014). Indian Approaches to Energy Access. *Energy Poverty,*237-256. doi:10.1093/acprof:oso/9780199682362.003.0012

1. Federal Government Policies

Sami Murphy (CMC '21)

Table 1.1. Indian Federal Energy Policy Timeline

Year Enacted	Policy Introduced	Key Points
2001	Rural Electricity Supply Technology (REST) Mission	• Power for all by 2012
2003	Pradhan Mantri Gramodaya Yojana	• Electrify villages by 2012 through decentralized renewable sources • Introduction of multiyear tariffs + open access
2003	Electricity Act of 2003[10]	• Eliminated licensing requirement for ESCOs to encourage private micro grid projects in rural areas • Exempts privately owned micro-grid companies from tariffs[11] • Focus on improvement of distribution
	2018 Amendments to Electricity Act of 2003[12]	• 24-7 supply of energy • Initial reduction of cross subsidies by 20% • Eventual elimination of cross subsidies within 3 years • Increased State Commission oversight • Penalties or removal of license if failure to supply quality power
2003	Accelerated Rural Electrification Programme (AREP)	• Government provides interest subsidy of 4% on loans to extend rural electrification
2005	National Electrification Policy: RGGVY (Rajiv Gandhi Grameen Vidyutikaran Yojana)	• Provide small distribution networks to low income and low consumption rural communities where grid extension is cost inefficient • REC provides 90% subsidies for capital costs of grid extension[13] • Provide free connections to households under the poverty line • Consolidated existing electrification programs[14]
2006	Rural Electrification Policy	• Created detailed framework of RGGVY (guidelines, definitions, institutional structures) • Mandated the provision of 1 unit of electricity per day all

[10] http://www.cercind.gov.in/Act-with-amendment.pdf

[11] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Oct/IRENA_mini-grid_policies_2018.pdf

[12] Tongia R., Gupta G. (2018). Amendments to the Electricity Act 2003: A summary, analysis, and public comments Discussion note. Retrieved from https://www.brookings.edu/research/amendments-to-the-electricity-act-2003-a-summary-analysis-and-public-comments-discussion-note/

[13] http://documents.worldbank.org/curated/en/815021468042283537/pdf/889060PUB0978100Box385252B00PUBLIC0.pdf

[14] ibid

		households by 2012[15]

1. India's Central Government's Policy Goals

In 2001, India's Central Government declared a Rural Electricity Supply Technology (REST) mission to electrify all of India by 2012, and has since significantly increased its engagement within the energy sector. The main objectives of this initiative were aimed at increasing energy access and affordability, shifting away from fossil fuels, and mitigating climate change. Because electrification and development are inextricably linked, India's rural development goals also drive this effort. With 45 million households lacking electricity, this is undoubtedly a difficult task. To accomplish this scale of electrification, the Ministry of Power has assumed a larger role in supporting renewable energy projects while minimizing barriers to entry for businesses through deregulation. Although the Ministry continues to enforce safety and technology standards, it has reduced regulations for private Energy Service Companies (ESCOs). To economically incentivize private investment, the Ministry recognizes the need for policy reform as well as sustainable partnerships to meet its larger goal of national electrification.

2. Multilateral Partnerships

The Central Government facilitates public-private partnerships with a range of stakeholders to enlarge the micro-grid sector. Collaboratively, they design energy projects that are sustainable in the long run. The ministry works closely with Public Sector Institutions like the Solar Energy Corporation of India (SECI), financial institutions like the National Bank for Agriculture and Rural Development (NABARD) and the Indian Renewable Energy Development Agency (IREDA), government agencies (SNA), and local governance (Panchayats) to achieve this.

New tariffs put into effect in 2016 have facilitated federal-ESCO partnerships, incorporating mini-grids under federal oversight as Rural Energy Service Providers (RESPs)[16]. This partnership increases private sector investment in micro-grid projects by offering financial incentives and benefits. While the Ministry of Power prioritizes empanelling ESCOs in underserved communities (i.e. North East states, Jammu, Kashmir, Himachal Pradesh, Uttarakhand, Andaman, Nicobar, and Lakshadweep), ESCOs operating in all rural regions are eligible to apply for these benefits.

[15] http___cdn.cseindia.org_attachments_0.56987100_1505302211_mini-grids.pdf
[16] ibid

3. Electricity Act of 2003

Aimed at electrifying rural regions, the Electricity Act of 2003 liberalized the electricity sector in India. A primary focus of this act is to fortify distribution networks because of poor quality and performance at the distribution level ultimately hurt the entire entire supply chain.[17] Therefore, the act outlines the importance of decentralizing the energy sector and promoting generation from privately run off-grid systems.[18] To ensure these off-grid systems are economically sustainable, the Electricity Act of 2003 also provides quality, management, and transparency measures. Additionally, is has eliminated licensing requirements for ESCOs (private providers), encouraging market investment and competition as a result.[19]

4. RGGVY

India's Ministry of Power also famously implemented the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) program in 2005, which aimed to reform electricity infrastructure, synthesize existing finance models, and make electricity accessible in even the most impoverished of villages. It is a loan based system in which the government provides 90% of electricity financing in the form of a grant and the other 10% as a loan, funded by the Rural Electrification Corporation. RGGVY also includes metering, billing, and revenue collection (MBC) systems and the implementation of input based franchises (IBF) to improve management efficiency, financing of projects, and sustainability of these electrification efforts overall.

[17] Palit, D., & Bandyopadhyay, K. R. (2017). Rural electricity access in India in retrospect: A critical rumination. *Energy Policy,109*, 109-120. doi:10.1016/j.enpol.2017.06.025
[18]Tangia R. (2018). micro-grid in India: Myths, Misunderstandings and the Need for Proper Accounting. Retrieved from
https://www.brookings.edu/wp-content/uploads/2018/02/impact_series_micro-grid-folder_feb10-2.pdf
[19] Palit, D., & Bandyopadhyay, K. R. (2017). Rural electricity access in India in retrospect: A critical rumination. *Energy Policy,109*, 109-120. doi:10.1016/j.enpol.2017.06.025

2. State & Local Level Policy

Sami Murphy (CMC '21)

Table 2.1. Key Stakeholders of State & Local Policy

<table>
<tr><th>Organization</th><th>Classification</th><th>Key Roles</th></tr>
<tr><td>State Nodal Agencies (SNAs)</td><td>State-Level Agency</td><td>Build, operate, manage, monitor micro-grid facilities
Identify areas in need of energy projects
Generate and distribute electricity
Collaborate with ESCO supervisors
Replace ESCO management in scenario of non-operational, abandoned, or poorly functioning ESCO
Mostly for non-subsidy electricity projects, though applicable to private ESCOs as well
Contribute technical and operational support to SERCs settling ESCO disputes
Ease exit procedures by providing support throughout process
Provide advice and guidelines on procedures
Assists with closures
Helps prepare and finalize contracts
Collaborate with Ministry of Power to generate data for PIA (Federal Database)</td></tr>
<tr><td>State Electricity Regulatory Commission (SERC)</td><td>State-Level Agency</td><td>Create secure payment methods for exit options and oversees exit procedure
Set energy tariffs in accordance with National Tariff Policy
Help settle ESCO disputes
Develop clear and measurable metrics of performance
Encourage domestic electricity consumption
Promote hybrid solutions to increase reliability of electricity supply
Ensure minimum hours of domestic electricity supply</td></tr>
<tr><td>DISCOMs</td><td>Energy Provider</td><td>Buy excess micro-grid energy from ESCOs
Careful to avoid over-competition and interference with micro-grid market
Not economically viable in rural or low-income areas</td></tr>
<tr><td>ESCOs</td><td>Energy Provider</td><td>Abide by state-specific policy and tariffs
Can charge tariff to local community with their consent (if operating in an open market)
Typically operate in rural areas that cannot access main grid systems (DISCOMs)
Often eligible for state subsidies</td></tr>
<tr><td>Project Implementation System (PIA)</td><td>State-Level System</td><td>Developed by state's Investment Promotion Board
Database registered ESCOs must regularly upload data and metrics of performance to
Location of grids
ESCO details
Quantity of households connected</td></tr>
</table>

		● Data is publically available ● Categorizes micro-grids based on kW size[20] ○ Less than 10kW—Category A ○ 10 kW to 100 kW—Category B ○ 100 kW to 250 kW—Category C ○ 250 kW and above—Category D
Panchayat (village council)	**Village-Level Agency**	● Organize Village Energy Committee (VEC) to address community disputes regarding companies ● Collaborate with energy providers to set tariffs ● Certify No Objection Certificate mandating the community's permission to legally implement new projects ● Promote community participation of projects
Village Energy Committees (VECs)	**Village-level Agency**	● Determine energy tariffs ● Recalculate tariffs if surplus energy is sold to DISCOMs

Table adopted from Bhushan, C.B., and Kumarankandath, A. (2016).

1. Overview

Although federal policy initiatives since the early 2000s have drastically improved energy access within India, states play and equally important, if not larger regulatory role. State governments are responsible for setting offical tariffs and creating state-specific energy regulations. State nodal agencies (SNAs) often bridge the gap between private energy providers and the communities in which they operate. Tasked with developing state-level policy, SNAs are responsible for targeting high priority areas for electrification and innovating ways of attracting financial investment. SNAs function as mediators between ESCOs, DISCOMs, and the local villages they service regarding the implementation of new electricity projects, energy generation and distribution, and resolving local disputes. SNAs are vital to ensuring the larger national interest of universal electrification is positively embraced by villagers, ensuring communities respond consensually to the implementation of electrification projects. SNAs collaborate with ESCOs and the SERC to create fair tariffs that are agreed upon by energy providers as well as their consumers, reducing vulnerability to energy monopolization in rural communities. Additionally, they oversee and track the success of ESCOs by creating audit procedures and report outlines that ESCOs must regularly submit. Perhaps their most unique function is to assist failing ESCOs throughout shut-down scenarios or managerial transfer. To aid in this process, they have a contingency fund in place that allows them to maintain and continue operating stranded or failing micro-grids.[21]

[20] Bhushan, C. B., & Kumarankandath, A. (2016).
[21] Ibid.

States clearly retain large sums of power that allow them to regulate and intervene in micro-grid projects. While their political presence within private operations is meant to strengthen the viability of energy projects, they can also act as a barrier to production. Arguments against the heavy role of state regulation contend that micro-grid companies are often pressured to offer energy at minimal and cost-ineffective rates in order to service larger proportions of the population. Because these companies are compelled to sacrifice potential revenues in order to provide low income customers, an estimated one-fifth of power supplied is never paid for.[22]

2. Case Study: Uttar Pradesh

Although the Central Government has failed to provide policy certainty for micro-grid companies, several states have taken the lead introducing policies to ensure a welcoming investing environment for micro-grid operators. In particular, Uttar Pradesh (UP) was the first state in India to introduce a mini-grid policy in February 2016.[23] The Uttar Pradesh Mini-Grid Policy embraces the installation of solar plants by private players to power rural households under 500 kilowatts (kW) in size. The policy allows developers to apply for a subsidy offered by the UP government in addition to the existing 30% capital subsidy offered by the Federal Government's Ministry of New and Renewable Energy (MNRE). As part of this policy, energy providers (ESCOs) set tariffs their customers mutually agree to and are expected to comply with guidelines set by the Uttar Pradesh Power Corporation Limited.[24] Providers operating at the 50 kW level and higher are bound to more stringent regulations while smaller mini-grids have modified regulations.

Uttar Pradesh has been careful to frame its energy policy in a way that preempts micro-grid failure through two main avenues. First, much of its policy is tailored to promote the long-term sustainability of energy projects. For example, a mandatory 10 year period of operation and maintenance is required in order for ESCOs to be eligible for their government subsidy.[25] Second, it offers detailed exit plans for private micro-grid companies. If grid extension becomes introduced to a micro-grid's area of operation or if micro-grids are built in areas with preexisting DISCOMs, ESCOs may consider a variety of exit paths: continuing to

[22] http://www.worldbank.org/en/news/feature/2014/06/24/switching-on-power-sector-reform-in-india
[23] https://www.cseindia.org/content/downloadreports/6864
[24] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Oct/IRENA_mini-grid_policies_2018.pdf
[25] Ibid.

operate alongside the DISCOM, selling surplus energy to the DISCOM, or selling all energy exclusively to the DISCOM.[26] Most importantly, the UP policy addresses one of the most frequent concerns of mini-grid developers, which is uncertainty about the future of a project once the conventional grid arrives in the village. Because of its substantial micro-grid policy measures, Uttar Pradesh has become a magnet for micro-grid investment, now containing upwards of 1.850 operating micro-grids.

Room for Improvement

Although great improvements have been made nationally with 82% of India's population now electrified, Uttar Pradesh is still considered one of the least electrified states within India, with only 68% of households able to access electricity. Inequity of access is a prevailing problem for rural areas specifically within Uttar Pradesh, wherein only 57% of rural Uttar Pradesh households benefit from electrification. While Uttar Pradesh's policy mandates a minimum supply of 3 hours in the morning and 5 hours in the evening-- a total of at least 8 hours of electricity-- unmet energy demands at peak productivity hours of the day prevail, limiting development and economic growth.[27] Despite these pitfalls, the burgeoning renewable energy sector is promising for reaching higher levels of electrification and creating rural employment opportunities. Overall, Uttar Pradesh's state government illustrates the powerful role state-level governments play in electrification across India.

[26] Bhushan C., Kumarakandath A. (2016).
[27] Ibid.

3. Financing Barriers

Sam Willett (CMC '20) and Cade Moffatt (CMC '21)

Micro-grid enterprises in India must overcome several financing barriers in order to gain funding. Perceived risks and uncertainty ingrained in the market have caused capital providers to avoid investing in these projects. Companies are met with volatile payback periods and high barriers to enter, making it very hard to obtain the necessary funding without the involvement of the government or foreign impact investors.

From an investor's perspective, micro-grid firms are shrouded in uncertainty and Indian institutions have not yet been convinced on their practicality or feasibility. High upfront capital expenditures for resources such as solar panels coupled with the inherent risk of targeting a rural consumer base, has contributed to an unwillingness to fund projects in the greatest impoverished areas of India. Instead of providing services to rural consumers, projects have been moved to wealthier areas where the marginal benefit is much lower. Rural villagers have the highest willingness to pay for electrification and micro-grid companies should be incentivized to focus their efforts on this segment of the market, however, there is a clear shortage within the market for electricity.

These business models are new to the world of energy in India with initial case studies of effectiveness dating back only roughly a decade.[28] Additionally, the micro-grids that have been commissioned are incredibly location specific and tailor closely to the needs of their clients, leading to high variance across business models. Without a standard model for new projects to follow, success and investor returns has fluctuated. Until there is an easy way to proactively predict the return on investment of a micro-grid project, varying returns will continue to drive off potential investors. Because of these factors, investors are hesitant to provide financing at reasonable rates and the typical micro-grid financing rate hovers between 13% and 18%. This astronomically high rate has disincentivized the use of traditional investment institutions and has caused the search for funding to shift toward governments and foreign impact investors.

While searching for investors abroad or through alternative channels, micro-grids encounter a new set of barriers. Typically foreign impact investors and government alternatives do not have as many issues with such volatile potential returns. While these are

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[28] Gambhir A., Torro V., Ganapathy M. *(2012). Decentralised Renewable Energy (DRE) micro-grids in India: A review of recent literature* Retrieved from http://www.prayaspune.org/peg/publications/item/187.html

possibilities they do not come without restrictions. Government subsidies are very difficult to apply for and often, if awarded do not cover the entire demonstrated need of projects. Current companies operating in India have relied heavily on these government subsidies and grants, but the lack of adequate funds leads to insufficient levels of working capital to support operations. These companies are the few that deemed that the associated payment for navigation of many bureaucratic layers is worth it. If a micro-grid looks to finance through debt instead of equity, the infrastructure they create is often not accepted as collateral. In other words, solar panels and batteries or windmills cannot be considered as assets by banks though they retain efficiency and value.[29] For foreign impact investors, the Reserve Bank of India (RBI) implements many barriers. All foreign impact investments must be approved by the RBI and these investments are not allowed to be used for working capital in these projects. Because of these restrictions, investors are encouraged to finance quick projects that immediately sell infrastructure as a way to recoup the investment with little risk. With respect to collection methods that are important to ensuring payback, the RBI requires payments come from official bank accounts which is not readily accessible to most rural communities, and organizing payments in an either fixed, or pay as you go methodology can be inconsistent.

These barriers, however, have not kept companies from successfully implementing micro-grids. While micro-grid financing in India does not look to become streamlined any time soon, there are things that companies have had success with in terms of ensuring payments and appealing to investors. The overall cost of payment collection for some Indian micro-grid companies has fallen by 60% due to new methods such as cell phone collection strategies.[30] Companies have used varying methods of repayment and financing to lure investors as well. These include vendor financing, direct ownership, energy service contracts, power purchase agreements, debt financing, Green Banks, and other alternative energy financiers that have become more prevalent in the past 2 decades. As more micro-grid enterprises continue to deliver strong returns, more pathways to attain funding will open to the industry.[31]

[29] Energy Information (2014). The Real Lifespan of Solar Panels. Retrieved from https://energyinformative.org/lifespan-solar-panels/
[30] See OMC power and Naturetech
[31] Sources for further reading: Tangia R. (2018); International Finance Corporation. (2012).

4. Comparing Strategies for Electrification

Katie O'Neill (CMC '21)

There are three main strategies for rural electrification in India: the Central Grid, Micro-grids, and Solar Home Systems (SHS's). Each system has its unique benefits and limitations and often work best in different environments and contexts. For this reason, it is important for any organization or company involved in rural electrification to fully understand each strategy so that they can target their project to the areas where they will be most effective.

1. Central Grid

The Indian National Electricity Grid, or Central Grid currently powers most households with electricity in India. For villages that are located in close proximity to electricity distribution centers, the service is reliable and cheap, typically costing about 3 rupees per kilowatt. This makes the National Grid highly appealing for large cities, and other areas near distribution centers. However, for many rural villages that are distant from distribution centers, National Grid electricity is expensive and highly unreliable. Villages located furthest from the National Grid are often charged up to 98 rupees per kilowatt, but are only able to use the electricity for up to 6 hours a day. For example, in rural areas of Uttar Pradesh, the electricity deficit during peak hours is 19.4%. Further, there are widespread instances of electricity theft and system failure that prevent reliable access to electricity. Maintenance of the National Grid connections is mismanaged and there are not nearly enough maintenance personnel to adequately respond to outages, meaning villages are often left without electricity for days. On an environmental note, 56% of the electricity produced by the National Grid is made using coal-fired plants.

A key difference between on-grid and off-grid systems is subsidy eligibility. Specifically, off-grid systems do not qualify for federal cross-subsidy benefits while on-grid systems may. Cross-subsidies are subsidies that raise the price of energy higher than market value for urban and affluent consumers in order to keep prices low for rural and impoverished consumers who could not otherwise afford it. Because the former have higher purchasing power, they can absorb the higher cost and a balance is struck that allows rural populations to gain access to energy affordably. As per 2018 amendments to the Electricity Act of 2003 however, India's government plans to reduce cross subsidies by 20%.[32]

[32] Tongia R., Gupta G. (2018). Amendments to the Electricity Act 2003: A summary, analysis, and public comments Discussion note. Retrieved from

In addition, on-grid energy providers are connected to DISCOM networks, meaning they have direct access to sell surplus energy back to regional DISCOMs, while off-grid micro-grids have difficulty meeting interconnection standards to feed energy back to conventional grids. Despite this, India's Ministry of Power promotes the extension of energy into rural areas through a variety of policy avenues.

In 2010, India created the National Solar Mission (JNNSM) to increase use and production of solar power, both on and off grid. The off-grid portion of the project aimed to create 200 MW of energy for rural areas by the end of 2013. Using 30% capital subsidies and a 50% interest subsidy to build micro-grids in rural villages, JNNSM was able to produce over 252 MW of off-grid energy. India has attempted a great number of energy solutions in the past several decades, but the ones that have been the most successful have involved off-grid systems and renewable energy.[33] In addition, India's Ministry of Power specifically pushes to empanel Energy Service Companies (ESCOs) as certified Rural Energy Service Providers (RESPs), availing them benefits in the form of financial and managerial assistance. Because of efforts like this, almost 100% of those who have gained electrification since 2001 can thank federal grid extension.

2. Solar Home Systems

During the 1990's, Solar Home Systems (SHS's) were the World Bank's primary method for rural electrification. In fact, by 2012, the World Bank had distributed over 500,000 SHS's in India. These systems are solar powered and usually include a set of solar panels, a small battery storage system, and equipment such as solar lanterns and phone chargers. SHS's are inexpensive and easy to install; however, they offer a relatively high price of operation for the user at 37 rupees per kilowatt. As long as the capacity of the systems is not exceeded they are highly reliable, but the typical capacity is low at 100 kilowatts. Additionally, the systems require significant maintenance as the batteries must be replaced every 3-5 years and this must be performed by a trained professional. Given the location of the village, this type of maintenance can be very difficult to obtain.

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https://www.brookings.edu/research/amendments-to-the-electricity-act-2003-a-summary-analysis-and-public-comments-discussion-note/

[33] Bhushan, C. B., & Kumarankandath, A. (2016). Mini-grids Electricity for All. Retrieved from https://www.cseindia.org/mini-grids-electricity-for-all--6864

3. Micro-Grid

Though micro-grid systems do have some issues with reliability and power quality, they are considered better in these aspects than both the Central Grid and SHS's. They are slightly less expensive for the user at 23 to 33 rupees per kilowatt. Their main benefit is their ability to be customized to the needs of the village. Unlike SHS's and the Central Grid, micro-grids can tailor their energy source to the climate and location. This creates both environmentally friendly and more reliable electricity. Some common energy sources for micro-grids are solar, wind, hydro, and biomass. With the exception of biomass systems, micro-grids require considerably less maintenance than the other two electrification strategies. Micro-grids can also be scaled up or down to meet the capacity needs of the village. However, micro-grids work best with energy storage systems, which can be expensive and difficult to install.

Table 4.1: Different Means to Extend Electricity Access to Rural Areas

The following table is taken from a Princeton University report titled "Rural Energy Alternatives in India: Opportunities in Financing and Community Engagement for Renewable Energy Micro-grid Projects." It summarizes the benefits and limitations explained above.

Characteristic	**Grid Extension**	**Solar Home System**	**Micro-grids**
Reliability/Power Quality Cost of Generation for Producers	Low reliability, especially for rural areas that are not considered profitable because of low demand 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	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 About Rs. 37/kWh	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 Around Rs.23 to 33/kWh (varies by generation source, e.g., micro-hydro, biomass, solar PV, wind-solar)
Price of Electricity for Consumers	Usually estimated to be Rs. 3/kWh, though this varies greatly by	High per kWh costs; total upfront cost about Rs. 45,000 for a small	High per kWh cost, but typical weekly/monthly rates are of the order

	customer category; monthly costs increase with extent of usage	home system	of Rs. 100 to 200/month
Load/Capacity	Unlimited capacity, although there is often load shedding during times of peak demand	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
Losses	About 23.97% in 2012	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
Generation Sources	Varies, e.g. nuclear, renewable sources, coal, gas, oil, hydro, etc.	Solar	Determined by local DG resources (e.g. micro-hydro, biomass, solar, wind)
Geographic- or Location-Based Constraints	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
O&M	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)

The following questions should help rural electrification organizations determine villages that will be best suited to their electrification strategy:

1. **How far is the village from the nearest Central Grid distribution center?**
   - ➔ Micro-grids and SHS's are better for villages in rural areas, far from distribution centers.

2. **How likely is the village to be connected to the Central Grid in the near future?**
    - ➔ Micro-grids and SHS's typically require 10 to 25 years to recoup their value, so if there is a strong possibility that this village will be connected to the Central Grid within this period, it is not an ideal location for an off-grid system.

3. **What is the village's capacity to pay?**
    - ➔ If the village has a low capacity to pay and is not located near a Central Grid distribution center, then an off-grid solution is preferable. In this case, it should also be considered that SHS's are slightly more expensive than Micro-grids.

4. **What are the electricity needs of the village and are these needs likely to change drastically in the next 10 to 25 years?**
    - ➔ Micro-grids are better for villages with medium electrical loads, while SHS's are best for villages with small electrical loads. If electricity is going to be used for income-generating activities, Micro-grids are ideal for their increased reliability. If increased electricity capacity is expected to be needed in the near future, then SHS's should not be used as they operate at a fixed capacity.[34]

[34] Source for further reading: Ramana, M. V. (2014). Rural Energy Alternatives in India: Opportunities in Financing and Community Engagement for Renewable Energy micro-grid Projects. Retrieved from https://cleanenergysolutions.org/resources/rural-energy-alternatives-india-opportunities-financing-community-engagement-renewable

5. Current Companies Operating

Matt (CMC '19)

Introduction

As a relatively new technology, new players are entering the micro-grid market constantly. As such, it is important to understand the competition's business models and histories of expansion. Through an extensive research phase, the REC team found approximately 24 micro-grid firms. While this research was focused toward a presence in India, some firms on the final list also operate in certain Sub-Saharan African countries. Additionally, despite operating mainly in the two previously mentioned geographies, these firms are headquartered in many different cities and countries around the world.

We identified a key distinction between some of the firms operating in the micro-grid space, denoting them as either "Micro-Grid Firms" or "Micro-Grid Support Firms." Micro-Grid Firms construct solar powered grids while Support Firms generally do not operate a grid system, but may assist Micro-Grid Firms through the construction or installation of a grid system, provision of solar panels and other, complementary technology that benefit from newly installed electricity (e.g., televisions, refrigerators, etc.), or deployment of apps that assist the Micro-Grid Firm monitor, operate, and optimize their business at micro-grid locations. We only included the "Micro-Grid Firms" below for brevity's sake.

For Micro-Grid Firms, where possible, we identify the total number of solar sites a firm operates, along with the annual electric output of all of these sites combined. The complete list of research on micro-grid firms is included below:

Table 6.1. Micro-Grid Firms (Note: Missing Data Denoted by Empty Cell).

	Name of Company	Website	Year Founded	Location	Number of Sites (Solar)	Scale of Micro-Grid Systems (MW)
1.	**OMC Power**	http://www.omcpower.com/	2011	Mumbai, Maharashtra	70	3
2.	**Husk Power Systems**	http://www.huskpowersystems.com/	2008	Patna, Bihar	75	1.75
3.	**Mlinda**	https://www.mlinda.org/	2005	Kolkata, West Bengal	50	1.12
4.	**Mera Gao**	http://www.meragaopower.com/	2010	New Delhi, Delhi		
5.	**Boond**	http://www.boond.net/	2010	New Delhi, Delhi		4.5
6.	**NatureTech Infrastructure**	http://www.naturetechinfra.com/	2011	Lucknow, Uttar Pradesh		
7.	**Renew Power**	https://www.renewpower.in/	2011	Gurugram, Haryana	200	5800
8.	**Saran Renewable**	http://www.saranrenew.in/	2008	Saran, Bihar	105	3
9.	**Onergy**	http://www.onergy.in/	2009	Kolkata, West Bengal	20	10
10.	**ReNew Power Ventures**	https://www.renewpower.in/	2011	Gurugram, Haryana	200	
11.	**Azure Power**	https://www.azurepower.com/	2008	New Delhi, Delhi	24	3000
12.	**Smart Power**	http://www.smartp	2017	Gurugram,	160	5

	India	owerindia.org/		Haryana		
13.	**Central Electronics Ltd**	http://www.celindia.co.in/	1974	Ghaziabad, Uttar Pradesh	1	1
14.	**Asea Brown Boveri**	https://new.abb.com/	1990	Zurich, Switzerland		
15.	**Raychem RPG**	https://www.raychemrpg.com/	1988	Mumbai, Maharashtra		1
16.	**Schneider Electric**	https://www.schneider-electric.com/	1989	Rueil-Malmaison, France		
17.	**Welspun Energy**	http://www.welspun.com/	1925	New Delhi, Delhi	9	600
18.	**Simpa Networks**	http://www.simpanetworks.com/	2002	Bangalore, Karnataka		
19.	**Adani Power**	http://www.adanipower.com/	1996	Ahmedabad, Gujarat	1	688
20.	**KSK Energy Ventures**	http://www.ksk.co.in/	1962	Hyderabad, Andhra Pradesh	1	10
21.	**Aggreko**	https://www.aggreko.com/	1962	Santa Fe Springs, California	50	220
22.	**PowerCorner**	http://www.powercorner.com/	2016	Paris, France	2	140
23.	**Zola Electric**	http://www.zolaelectric.com/	2012	Amsterdam, North Holland		
24.	**Odyssey Energy Solutions**	https://www.odysseyenergysolutions.com/	2018	Boulder, Colorado	550	150

6. Case Studies: Micro-grid Companies

Sami Murphy (CMC '21), Cade Moffatt (CMC '21), Ally So (CMC '21)

As stated in the financing barriers section, there is a clear lack of standardized business models for micro-grid companies to follow. However, we have identified five firms that have been able to navigate the numerous obstacles within the industry and find success. We expect this list to continue to grow and suggest using these case studies as examples going forward.

1. Gram Oorja

Like many other micro-grid companies, Gram Oorja has set out to provide electricity to the millions forced to use kerosene lanterns in rural India. Gram Oorja created a model based upon "corporate-social partnership" and gain funding from corporate charity funds. Their first project was in Darewadi, a rural village with 39 households. They received funding from Bosch Solar Energy and consultation and guidance from the Shakti Foundation. Gram Oorja created a solar power plant capable of producing 9.4 kilowatts of energy and a backup biogas unit to be utilized when sunlight was not available. Utilizing local people for operations is a key element of Gram Oorja's business model, which encourages participation in the set up and management of projects. A village trust collects bills every month and deposits the revenue into a corpus fund which covers the expenditures and administration of the project. This hybrid model proved to be successful and has been implemented in over 10 villages. Gram Oorja currently has an installed capacity of 45.7 kW and serves 230 households. They have also partnered with Bank of America to continue to implement similar projects across India.

2. Zola Electric

ZOLA Electric is a successful micro-grid enterprise that can be used as an example for business models. Since their founding in January 2012, ZOLA has worked to implement renewable off-grid energy solutions in rural Africa where a large percentage of the population lacks electricity. They have been incredibly successful in scaling their operations and gaining financing, currently powering over 180,000 homes and businesses across Tanzania, Rwanda, Ghana, Nigeria, and the Ivory Coast. ZOLA has been able to deftly navigate the barriers to financing most firms meet, and has raised capital from massive firms such as Tesla, GE, and DBL Partners. They provide their consumers electricity at affordable prices, utilizing PAYGo micro-finance leasing and mobile money payments. The company differentiates itself based upon its implementation of emerging technology in business operations.

3. OMC Power

OMC Power advertises itself as a Renewable Energy Services Company (RESCO). The firm builds, owns, and operates both power plants and "smart mini-grids" that are used to serve telecom companies, businesses, and communities in rural off-grid places. The firm's headquarters are in Gurugram, India. They produce clean energy from solar, wind, and biofuel sources. In terms of serving rural communities, they mostly operate in Africa and India. They heavily emphasize their "ABC model": Anchor Loads, Businesses Via Smart Grids, and Community Households via Smart Grids. The company uses anchor loads to provide electricity in off-grid areas. The next category focuses on providing power to businesses and other buildings by using smart grids. The last category uses smart grids to supply electricity directly from power plants to homes. For this, OMC Power charges less than kerosene. Due to the presence of anchor loads, schools, health clinics, enterprises and homes throughout the surrounding village benefit from the availability of reliable and clean energy.

OMC Power also offers technology products to villages. Among its offerings are solar lanterns with a maximum of 10 watts to power a single room, a solar home system to power a household at up to 100 watts, a micro-grid (several rooftop solar panels connected together) to generate up to 1000 watts of energy, and a solar power mini-grid to electrify an entire village (this energy is stored at a micropower plant) at 10,000-1,000,000 watts of power. Mini-grids represent the traditional way of powering an area, but on a much smaller scale, making it more financially and practically efficient. Unlike traditional electricity grids, which use coal, nuclear, and oil fuels, a minigrid uses mostly renewable sources of power. By utilizing multiple technology options, OMC Power makes their products affordable to poor rural communities.

In 2016, OMC Power made a $4.5 million deal with the Rockefeller Foundation to finance 100 mini-grids. This financial arrangement was part of the Smart Power for Rural Development initiative.

4. SELCO Foundation

As a branch of SELCO India, a for-profit social enterprise, SELCO Foundation, founded in 2010, is a prime example of a successful non-profit public charitable trust used for a company's Corporate Social Responsibility (CSR). Based in Bangalore, Karnataka, the SELCO Foundation's overarching vision is to improve access to sustainable energy by incorporating wellbeing, health, education, and livelihood solutions. Their mission is to identify the needs of underserved communities while focusing on sustainability, create and support solutions to fulfill those needs, and to advance development in the social sector through technology, finance, entrepreneurship, and policy. Their work ranges from education projects, to creating efficient everyday technologies, to solar powered initiatives. SELCO Foundation has also created a standardized process of each project: identify the issue, research and understand the need for a solution, test the potential of building a solution, build the solution, pilot the solution, and finally replicate the solution. The company claims that this standardized process ensures that each initiative will be successful in the field.

SELCO Foundation's project on integrating mini-grids seeks to to couple existing infrastructure with decentralized renewable energy generation and storage technology to provide power to rural villages across India. In addition, their work pushes current policy framework and promotes community engagement. For this initiative, the Foundation works with partners on different technical, financial, and ownership models for mini-grids. Each model is specific to the particular requirements of a community and the geographical constraints. The purpose of this project is to determine when and where mini-grids are a better option than individual solar systems.

SELCO gets much of their funding from impact investors, such as The Lemelson Foundation, Good Energies Foundation, and S3IDF. In the past year, SELCO Foundation has partnered with DOEN Participaties, a Dutch impact investor, and has pledged to use the funds to expand its social interventions.

5. Mera Gao[35]

Mera Gao Power operates mainly in the state of Uttar Pradesh. Their projects are concentrated in one district of the state, allowing Mera Goa deeper market penetration in that area. Further, they have a number of smaller, branch offices scattered throughout the district to provide efficient service and maintenance for their existing projects. Like many other Indian micro-grid companies, Mera Gao uses solar photovoltaic (PV) panels to provide electricity to poor and underserved communities. The villages in which they operate are either not connected to the national grid or their connection to the national grid is largely unreliable.

Mera Gao Power uses a standardized model to determine timing and allotment of electricity. Although villagers do not provide input on this system, as it is standardized to provide the same service everywhere it is installed, Mera Gao did conduct an extensive

[35] Aggarwal, V. (2014). *Rural energy alternatives in India: Opportunities in financing and community engagement for renewable energy micro-grid projects*. Princeton, NJ: Woodrow Wilson School of Public & International Affairs, Princeton University.

consultative process to determine their standardized model. The process incorporated the participatory development model used by the World Bank through pilot projects that sought out community engagement and feedback. Though each Mera Gao installation is not tailored to the specific needs of each village, a number of villagers were consulted in order to preliminarily determine general electricity needs. Through their micro-grids, Mera Gao provides each home in a village with enough electricity to power two light bulbs and a cell phone charger. However, electricity is only available for about seven hours each evening, usually after sunset.

Mera Gao's differentiating characteristic is the simplicity and efficiency of their systems. With just one day, three technicians, and $900, Mera Gao can install a micro-grid system which will provide their standardized electricity service to an entire village. After installation, Mera Gao trains a local technician to maintain and inspect the micro-grid. This provides valuable jobs to local villagers and generates community investment in the systems. Women's groups are also trained in each village to collect and manage payment, helping decrease the gender gap in these rural villages.

Notably, Mera Gao uses only private funding through investment and grants. They do not receive Indian government funding. Two of their most important investors and donors are Development Innovation Ventures and the U.S. Agency for International Development (USAID). Mera Gao's co-founder and longtime CEO, Nikhil Jaisinghani, recently stepped down from his position as CEO and is no in charge of procuring investments. The new CEO is another co-founder, Sandeep Pandey.

7. Case Studies: Funding Organizations

Cade Moffatt (CMC '21), Ally So (CMC '21)

While there has been an unwillingness to fund micro-grid projects, the three organizations listed below have shown a willingness to invest in this industry. We suggest looking into these agencies and others like them to find funding opportunities. As micro-grid enterprises continue to demonstrate financial success, we expect funding for micro-grids to increase.

1. Rockefeller Foundation

The Rockefeller Foundation has the mission to "promote the well-being of humanity throughout the world." Today, they strive to solve global challenges related to health, food, power, economic mobility, advancing science, data, policy, and innovation. The Foundation follows a science-driven philanthropic philosophy, having given over $17 billion since their founding in 1913. They have offices in Italy, Kenya, Thailand, and the United States.

Regarding micro-grid and solar funding and projects, the Rockefeller Foundation has had a "Smart Power for Rural Development" program in place since 2015. This is a $75 million initiative, bringing together energy service companies, technology experts, local businesses, national and local governments, and the private sector to build partnerships around decentralized renewable energy (DRE) solutions. Smart Power India, a micro-grid company that focuses on rural electricity access in India, was established through the Rockefeller Foundation's program to implement their program in India, focusing on Jharkhand, Bihar, and Uttar Pradesh. In 2016, Smart Power India also received an almost $8 million grant from the Foundation to support the initiation of three hundred new decentralized renewable energy power plants. The Rockefeller Foundation is also partnering with the Virgin Unite Foundation and Rocky Mountain Institute to further Sustainable Energy for Economic Development (SEED) in sub-Saharan Africa.

2. DBL Partners

Since opening their doors in 2003, the San Francisco and Palo Alto based DBL partners has sought to provide venture capital and impact investment to companies that deliver top-tier returns while simultaneously providing social, environmental, and economic benefits. Their double bottom line investment philosophy is based primarily on the idea that financial performance and positive social change are inherently connected and thus have two strong bottom lines. They focus heavily on clean technology, health care, information technology, and sustainable products and services. DBL Partners provides capital to accelerate an organization's financial success and social impact while also assisting portfolio companies in developing “double bottom line practices.” For example, the implementation of local hiring, employee development and education, pollution reduction, and resource efficiency are a few of the many practices DBL partners hope to implement. The adoption of these practices can be incredibly beneficial to a firm’s fiscal bottom line “both via direct benefits of cost savings and value creation, and via indirect benefits of creating goodwill with their market, customers and community, and enhancing employee morale and retention.”

Within clean technology, DBL Partners has primarily invested in the production manufacturing side, however, they have recently added ZOLA Electric to their portfolio. ZOLA implements renewable off-grid energy solutions in rural Arica. They provide their consumers electricity for affordable prices, utilizing PAYGo micro-finance leasing and mobile money payments. They currently power over 180,000 homes and businesses in Tanzania, Rwanda, Ghana, Nigeria, and the Ivory Coast.

3. USAID’s PACE-D Program

In 2012, the United States Agency for International Development (USAID) launched the Partnership to Advance clean Energy– Deployment (PACE-D). In this program, USAID has supported the Ministries of Power and New and Renewable Energy to encourage the growth of clean energy in India. The PACE-D program is currently successfully assisting the Government of India in the deployment of energy efficient technologies and decentralized renewable energy systems by strengthening policy and regulatory institutions, increasing access to finance, and enhancing institutional capacity. Their efforts are focused on renewable energy, “greening the grid”, energy efficiency, and clean energy finance.

Partnering with policymakers, energy utilities, customers, the public and private sector, civil society organizations, and financial institutions, USAID helps to deploy fast and cost-effective renewable energy systems in India. They accomplish this by designing, developing, and implementing programs, policies, and regulations for renewable energy. In Karnataka and Madhya Pradesh, the PACE-D program helped culminate the solar rooftop policy, and is assisting BESCOM, one of Karnataka’s largest electricity utilities, in installation of rooftop solar systems. Additionally, USAID supports the GOI’s National Institute of Solar Energy to establish a “Solar Energy Training Network” to build the workforce of skilled solar energy professionals.

"Greening the Grid" is USAID and India's Ministry of Power's major new initiative, under the PACE-D program, to manage the large-scale implementation of renewable energy into its power grid at a realistic cost. The "Greening the Grid" program focuses on: "(1) rigorous analytical modeling of reforms to integrate 175 gigawatts of renewable energy by 2022; (2) supporting six grid-integration pilots to test the building blocks for improved integration of renewable energy in India's power grid; and (3) facilitating exchanges between U.S. and Indian regulators, grid operators, and utilities to strengthen the enabling environment."[36]

To promote energy efficiency, USAID supports India's Ministry of Power and the Bureau of Energy Efficiency (BEE) on many initiatives, such as helping the National Smart Grid Mission monitor the GOI's smart grid pilots. The PACE-D program has assisted in creating a successful knowledge portal to promote net-zero energy buildings in India.

USAID is also developing market-based mechanisms to help India overcome barriers to rural energy access and decentralized renewable energy generation through microfinance. In 2015, the PACE-D program established partnerships with Tata Cleantech Capital Limited to start the Corporate Energy Audit Program, the Indian Infrastructure Finance Company to establish an Infrastructure Fund, and the Chhattisgarh State Renewable Energy Development Agency in order to build an off-grid Corporate Social Responsibility Fund. The program also helped begin loan programs and develop a Solar Rooftop Project Evaluation Tool for financial institutions.

[36] US Department of Energy. (2012).

8. Additional Sources of Financing

Lude Rong (CMC ‘20)

There are several alternative mechanisms that micro-grids may utilize for financing their operations. We detail several options below.

1. Carbon Offsets

A micro-grid project may realize an additional source of revenue by selling its carbon offsets at an applicable offset market. A carbon offset is a scientifically quantified reduction in greenhouse gas emissions created when one metric ton of greenhouse gas is captured, avoided, or destroyed, as a result of a specific project, in order to compensate for an equivalent emission made elsewhere. The offset market is designed to collect capital to sponsor sustainability efforts that would not have happened. The Kyoto Protocol provides three mechanisms for countries or operators in developed countries to acquire greenhouse gas reduction credits: 1) the Joint Implementation (JI) allows a developed country with relatively high costs of domestic greenhouse reduction to set up a project in another developed country; 2) under the Clean Development Mechanism (CDM), a developed country can 'sponsor' a GHG reduction project in a developing country where the cost is usually much lower, but the atmospheric effect is globally equivalent; 3) the International Emissions Trading (IET) countries can cover their shortfall in Assigned amount units by directly purchasing surplus credits from other countries. As a result, Kyoto signatories can meet their carbon reduction requirements either through reducing domestic carbon or by pursuing offsetting emission reduction units. Because India allows unilateral development of CDM projects, project owners have flexibility in choosing when and at what price to sell their CERs.

Although carbon offset projects can vary greatly in type (e.g. sustainable forestry, landfill gas, livestock methane, industrial processes) and geographical location, they all must meet certain minimum criteria, including evidence of additionality (emission reductions contingent on carbon offset sales), quantification through an approved methodology, verification by an accredited third-party verifier, and registration on a third-party public registry. Beyond these minimum standards, additional criteria include co-benefits to the environment or society, project participants who benefit from the sale of the offsets, as well as industry connections with respect to credit purchasers.

2. Carbon Offset Markets

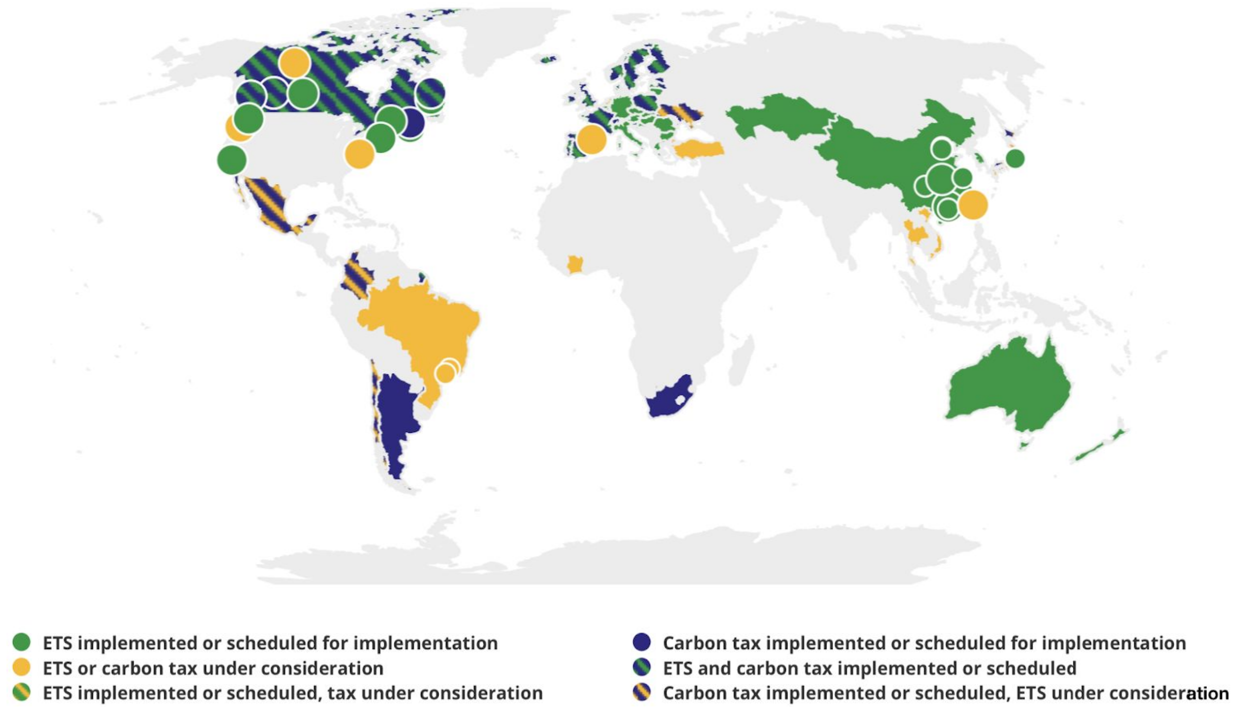

Figure copied from World Bank (2019).[37]

Above is a summary map of regional, national, and sub-national carbon pricing initiatives, as of February 2019. As of May 2, 2019, the closing carbon price was €25.02 (~$28) in the European carbon emission allowance market.[38] Despite the official formalization efforts in the Kyoto Protocol, global concerns for international offsets stemmed when participants observed that some entities generated excessive greenhouse gases so they could get paid to destroy them, as well as outright falsification of documents. There have also been regional efforts to set up more enclosed carbon markets. For example, although Kyoto Protocol is not binding in the United States, California developed its own emissions protocols for different types of activities through the California Cap and Trade program, which took effect in early 2012. Because the program is restricted to California, Québec, and Ontario,[39] however, it is not very relevant to micro-grid projects in India.

[37] The World Bank (2019). Carbon Pricing Dashboard. Retireved from https://carbonpricingdashboard.worldbank.org/map_data
[38] Business Insider (2019). CO2 European Emission Allowances. Retrieved from https://markets.businessinsider.com/commodities/co2-emissionsrechte
[39] Ontario left the program in February, 2018.

3. Renewable Energy Certificates (RECs) and Guarantees of Origin (GOs)

An alternative source of financing comes from selling renewable energy certificates (RECs) instead of carbon offsets. A single MWh can either be claimed as a REC or the reductions associated with it can be claimed as an offset, provided the project meets criteria for both commodities. The main difference between renewable energy certificates versus carbon credits is what they offset. While carbon credits help reduce greenhouse gas emissions, renewable energy certificates offset electricity use from non-renewable sources. Instead of offsetting carbon, RECs offset kilowatt hours. According to the Center for Resource Solutions (CRS), one REC embodies the full suite of renewable attributes of one megawatt-hour (MWh) of renewable electricity generation, including the zero-carbon emissions attribute.[40] RECs serve as the currency for renewable energy claims in both compliance and voluntary markets in the U.S., and the prices vary greatly depending on regional regulations and demands, as well as project-specific attributes of the RECs. Due to variations in mechanism standards and market prices, it is important for a micro-grid project to decide which market it wants to sell to. For example, the market equivalent to a REC in the EU market is a Guarantee of Origin (GO), which is regulated by the European Energy Certification System (EECS). Moreover, because India has state-level Renewable Purchase Obligations (RPO) targets for the most populated Indian States such as Uttar Pradesh, Maharastra, Bihar, West Bengal, and Andhra Pradesh, there is always the option to sell RECs to the domestic market.[41]

4. Clean Development Mechanism[42]

The Clean Development Mechanism (CDM) is organized under the United Nations Framework Convention on Climate Change (UNFCCC). Through the CDM, developed countries can receive Renewable Energy Certificates (RECs) for emission-reduction projects they finance in developing countries. RECs are then subtracted from the developed countries' overall emissions, allowing them to meet their Kyoto Protocol emission targets.

The CDM does not fund projects, instead it serves primarily as an oversight mechanism. The CDM tracks projects, assesses their viability, measures emission reduction, and distributes RECs. Some examples of projects in India include:

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[40] Center for Resource Solutions (2012). Renewable Energy Certificates, Carbon Offsets, and Carbon Claims. Retrieved from https://resource-solutions.org/wp-content/uploads/2015/08/RECsOffsetsQA.pdf
[41] Sustainability Round Table (2012). International Markets for Renewable Energy Certificates (RECs). Retrieved from http://sustainround.com/library/sites/default/files/SRER_Member%20Briefing_International%20Markets%20for%20Renewable%20Energy%20Certificates_2012-07-16.pdf
[42] UNFCCC. (2019). Clean Development Mechanism. Retrieved from https://cdm.unfccc.int.

1. Project for GHG emission reduction by thermal oxidation of HFC 23 in Gujarat, India. This project was funded jointly by the UK, Switzerland, the Netherlands, Italy, and Japan. It took place from 2006 to 2015, and the RECs garnered from the project were distributed among the supporting countries according to their level of investment in the project. The project took place in the state of Gujarat, using advanced technologies to reduce CO_2 emission by incinerating HFC 23 waste from industrial activities. The project reduced CO_2 emissions by 3,000,000 metric tons per year.

2. 5 MW Dehar Grid-connected SHP in Himachal Pradesh, India. This project was significantly smaller than the first project. It was funded by Germany and administered through an Indian company called Asthra Projects. The project built a 5 MW hydro-powered micro-grid in a rural village that lacked stable access to electricity. The micro-grid was built in 2004 and is still generating RECs for Germany. The project reduces CO_2 emissions by 16,243 metric tons per year.

Indian micro-grids are valuable and desired CDM projects. Micro-grid organizations in India should consider reaching out to industries in developed countries, especially in Europe, for funding through the CDM. To determine the value of micro-grid projects through the CDM, organizations should measure emissions reduced. This can be calculated by measuring the net electricity produced by the project, subtracting the emissions produced by the project and the electricity leakage of the project. The emissions reduced information can help organizations estimate how much investment their projects could garner through the CDM by comparing the investments received by projects with similar emissions reductions.

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Appendix:

Definitions of Important Financial Terms for Micro-Grid Companies

80% Accelerated Depreciation Tax Benefit - Introduced by the Government of India Ministry on New and Renewable Energy (MNRE) in the 1990s, accelerated depreciation is a method used by renewable energy companies to avoid high taxes at the initiation of new projects. This method allows projects to deduct a larger portion of depreciation then actually incurred in order to pay a smaller amount in taxes in the first year or two of a project. This method does not fully avoid the tax payment but rather is taken into consideration as a deferred tax credit. Essentially the company is saying that the value of their “machine” or other good such as solar panel is “used up” at a greater rate than in actuality.

Discounted Payments - Payments that occur at a point in time that is not the present and then adjusted for both inflation factors and interested parties desired rate of return on an investment to give you value of that payment in present terms. For instance if a payment of $100,000 is expected to come from an investment in a year, and required rate of return from an investor is 8% a year--including an adjustment for inflation--then the discounted payment would tell you how much that expected payment in the future is worth today and can help you make a decision on whether it is a worthwhile investment.

Net Present Value (NPV) - The net present value of a project is the value of projected future payments discounted at a certain rate that then give you the value of the project in terms of today's money. The discount rate is determined by many factors but is largely a measure of willingness to assume risk by an investor. The Net Present Value of a project is a major factor in determining whether to invest in a project or company. If a NPV is positive a project will return cash in the years to come that will outweigh the initial investment that must be made considering the time value of money, if the NPV is negative the project future payout are not worth the initial investment.

Internal Rate of Return (IRR) - The internal rate of return is a single percentage value that, if used to discount projected cash flows, will result in a Net Present Value of 0. This means that if the discount rate or the required rate of return is equal to this number for an investor, they will be exactly indifferent as to whether to invest. If the actual discount rate is lower then the project will have a positive net present value and vice versa. A calculated IRR is used by investors to compare to their required return on an investment to determine feasibility.

Free Cash Flows (FCFF) - Free cash flows are determined by taking a company's after tax income then adding back any depreciation or amortization of assets, and subtracting capital expenditures and changes in net working capital. This value is used for determine net present value and IRR values.

Depreciation and Amortization - Depreciation and amortization can be applied to assets or patents that have a limited lifespan. When computing yearly profits for a firm you only take a portion of the total cost of an asset that should closely reflect the value of that asset that has been "used up" during that year. This is used by investors to spread the cost of new equipment, plants, patents, etc over a longer time period to maintain relatively constant profit lines. For example if a new machine costs $5000 and is expected to last 5 years, under one of many methods, you would count $1000 as your depreciation expense for each year.

Capital Expenditures - Capital expenditures are investment in assets such as land, equipment, or anything that increases the value of the company that is not labor.

Net Working Capital - Net working capital is the difference in current assets and current liabilities of a company and reflects the company's liquidity. Companies with high net working capital are able to meet immediate monetary obligations. Simply put the levels of net working capital reflect the money a company has that has not been designated for an intended purpose and can be used to pay for unforseen or unsure needs of the company.

Debt - Debt is financing received in the form on a loan, typically from a bank or other financial institution. Debt financing is lower risk than equity financing for investors because payment is not based on company performance, and in the event on bankruptcy, debt is paid before investors.

Equity - Equity financing is the exchange of money in exchange for a certain amount of the company, or stock. Exchange of stock for money is associated with higher risk but, in efficient markets, higher returns as there is limit to the value that the company to grow to. Buying stock in a company allows you to benefit from the success of the company but also puts you at risk in the event of failure.

Capital Structure - The capital structure of a company affects the rate at which the company's future cash flows are discounted to arrive at the current value of the company. As the level of debt and equity correspond to the required return of a company to meet investor expectations. A capital structure that contains more debt will be under less obligation to provide higher returns because its investors are only expecting a fixed, relatively low amount of return on their investment.

Discount Rate/Required Rate of Return/Weighted Average Cost of Capital (WACC)- The weighted average cost of capital is determined by the capital structure of a company and the corresponding return for both debt and equity. It basically weights the rate of return for a bond, which might be around 4%, and the rate of return for equity, which might be around 10% based on the financing/capital structure. This allows a company to determine whether their rate of growth meets investor expectations.

Build Only - Build only microgrid companies simply build and install a microgrid in a community and then transfer to a local community or government. These models are the most appealing to short term investors as CAPEX costs are recovered immediately.

Build-Operate-Transfer - This microgrid business model still includes development and installation of a micro-grid project but then the developer operates the project for a set amount of time to accumulate additional revenues before transferring to a local entity.

Build-Own-Operate-Maintain - The BOOM method is often to most appealing for impact investors as the company who installs the project continually maintains the project rather than immediately selling for profit. This method is particularly common in Uttar Pradesh as policy dictates that companies may not transfer their grids. Additionally, the company supplies its own collectors and staff for payments and maintenance.