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Human, Social, And Cultural Practices For Rural Electrification Using Microgrids

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Contents

1 Introduction

The process of providing electricity to rural communities has been occurring for over a century. Yet, there are still large populations without electricity access, and others that remain in the dark, surrounded by electrification infrastructure that no longer functions. The following document focuses on the importance of community-centered practices in the design, implementation, and maintenance of electricity systems in rural and developing communities, so as to incorporate essential human, social, and cultural factors. A generic implementation process is presented, focusing on community engagement, system design, deployment, and utilization. A brief analysis of various techniques and practices are suggested, that help to create information flow between communities and developers, opening the potential for development of systems tailored to the needs, capacities, and goals of the widely variant communities that remain without electricity access, thereby ensuring the systems' ultimate success.

This document begins with a basic overview of the role that electrification can provide in the socio-economic development process, the importance of micro-grid implementation for remote communities, and a summary of some rural electrification best practices.

2 The promise of electrification

Electricity access has come to be seen as a human right, critical in the development of livelihood choices related to education, income development, gender issues, and health care. The International Energy Commission estimated that 18% of the world population (1.3 billion people) didn't have access to electricity in 2011, while another 1 billion only had access to limited or unreliable electricity networks (IEA, 2013; UNDP, 2010). In India, 25% of the population (300 million) didn't have access to reliable electricity, making it the country with the world's largest population without electricity access (IEA, 2013). While the global share of un-electrified populations have decreased slightly in the past few years due to electrification initiatives, the proportion of un-electrified people in India has increased, as electrification efforts have not matched rates of population growth.

Universal access to electricity is largely a rural challenge[1], with 31% of the global rural population without electricity, but only 6% of the urban population without access (IEA, 2013). Rural electrification is a key component in the reduction of rural poverty, given its correlation to improvements in health, education, and income generation (Cabraal, Barnes, & Agarwal, 2005; Flavin & Aeck, 2005; Kirubi, Jacobson, Kammen, & Mills, 2009; UNDP, 2010). The potential benefits of electricity are highly dependent upon local conditions. However, there is sufficient evidence demonstrating how electricity access can lead to positive gains in a number of development areas. While access to minimum electricity services may not necessarily provide access to labor saving devices (over 80% of consumption of electricity in rural areas is typically used for lighting and television (IEG, 2008)), better lighting can improve household labor conditions, which primarily benefit women and children (Bose, 1993; Cecelski, 2000). Improved lighting provides better conditions for school goers to read and do homework at night. Street lighting has been shown to improve sense of security among women (Cecelski, 2000). In terms of

[1] The world is now almost equally divided, with 3.3 billion people living rurally and 3.6 billion in urban areas.

health care, improved lighting in both hospitals and clinics make working conditions safer, and minimal electricity can provide access to a swath of life-saving electrical devices and access to refrigeration needed to store vaccines and heat-sensitive medicines (Adair-Rohani et al., 2013). Doctors, nurses, and teachers are more willing to reside in rural settings when they have access to lighting, TV, and radio (Modi, McDade, Lallement, & Saghir, 2005).

Even low levels of electricity access have been shown to improve economic opportunities for rural communities, providing opportunities for selling chilled drinks and foods, opening electronic repair shops, or performing basic services such as tailoring or barbering (Kirubi et al., 2009). With greater levels of electricity access, farmers are able to use pump irrigation, and entrepreneurs and technicians can open mills, carpentry shops, and welding shops (Practical Action, 2012). The figure below shows how electricity can provide access to services that may impact welfare of education, income, and health.

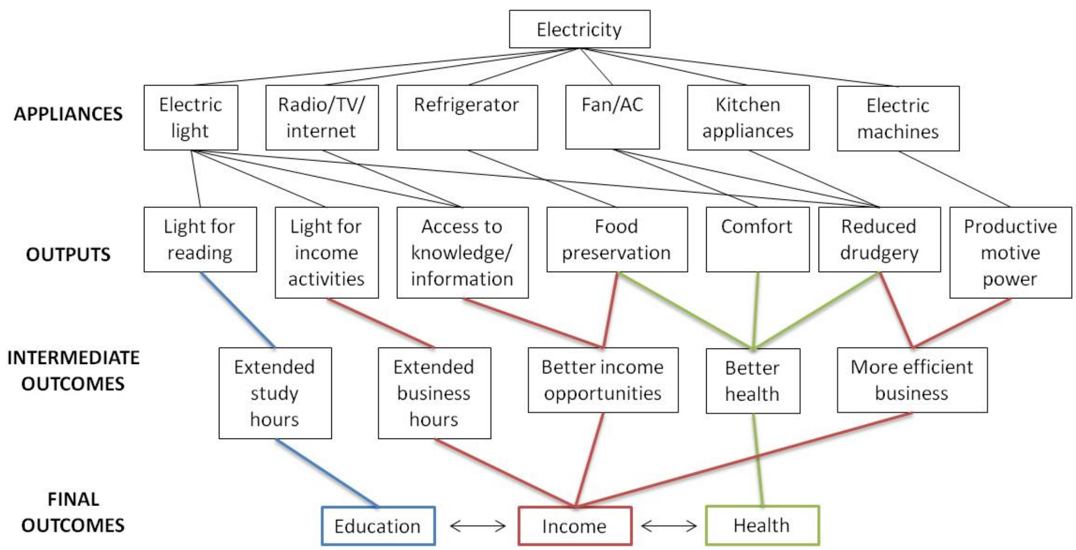

Figure 1: Causal pathways that electricity can lead to positive welfare changes in education, income, and health (Khandker, Barnes, & Samad, 2013)

Discussions of electricity as a driver of economic growth are often limited to thinking about welfare benefits derived from the utilization of electricity. However, there is also potential for rural livelihoods to benefit from employment related to electricity generation and management. Some systems, such as micro-hydro, require significant labor during construction, and biomass generation systems using gasification or biogas require ongoing labor to secure biomass resources that are transformed into heat and electricity, while also recycling nutrients for agriculture (Gowda, Raghavan, Ranganna, & Barrington, 1995; Kammen, Bailis, & Herzog, 2001a).

It is important to note while electricity is often strongly correlated to welfare improvements, this does not mean that it is should necessarily be the first priority for a rural community, especially when financial resources for development are limited. An integrated, cross-sectoral approach is needed to address locally specific challenges of education, health, gender issues, and economic growth. For example, while improved lighting may reduce the drudgery of cooking, stoves with improved combustion or chimneys will have a much greater impact on women's and children's health. A bright light in a rural health clinic will not have the same impact as adequately trained health care practitioners or appropriate medicines. Cross-sectoral approaches involve collaborative, long-term planning, an in-depth understanding of local priorities and culture, and project implementation that includes working with all development partners (local and regional governments, community organizations, non-profits, and private partners).

3 Alternatives for the delivery of rural energy services

One of the primary challenges to wide-spread, rapid increase of electricity access is cost. It has been estimated that in order to achieve universal levels of electricity access by 2030, 30-40 billion dollars in annual investment will be needed (Bazilian et al., 2011; UNDP, 2010). As mentioned, the majority of the poorest users live in rural areas, far from the central grid, with limited infrastructure and low population density. These variables mean that the marginal cost per household connection to the central grid becomes quite high, when compared to electricity access for urban populations. There are a number of alternatives to grid extension for the most isolated populations. For households that are widely distributed in the rural countryside, using individual solar home systems (SHS) is a common approach. Each SHS typically has a small solar photovoltaic (PV) panel for generation and a battery to store energy. Stand-alone electric lanterns with internal batteries that can be recharged with tiny solar panels (solar lanterns) are seen as an interim solution for increasing lighting quality for the poorest users. For communities with populations clustered in villages, an isolated micro-grid, powered by diesel generators, or renewable energy such as hydro or solar, has become common.

A micro-grid is usually characterized as a stand-alone electricity grid with its own generation source that may have the potential to connect to the main electricity grid. There is not a universally agreed upon definition of a micro-grid, which might be smaller than a mini-grid, although the terms are often used interchangeably. Micro-grids typically have a generating capacity of less than 10 MW, and often less than 1 MW. In the context of rural electrification, isolated grids with capacities of less than 100 kW are common.

In comparison to extending the centralized grid to remote communities, micro-grids are attractive alternatives, offering the potential for greater electricity access than SHS or solar lanterns. The table below shows some of the pros and cons of electrification using micro-grids (Deshmukh, Carvallo, & Gambhir, 2013).

Advantages of micro-grids	Disadvantages of micro-grids
• Can have lower costs per unit of electricity than extending the central grid • Have smaller wire losses since there is are no transmission lines due to local generation • Can have greater reliability than extension of the central grid, in countries where the main grid has insufficient capacity and there are frequent black-outs. • Can provide electricity for both households and businesses (irrigation, mills, shops), supporting economic development, in	• Often have higher tariffs than the central grid • Have higher generation costs than centralized grid • Often cannot meet demand of future load growth • High up-front costs, for micro-grids using renewable energy, such as solar or hydro • Can suffer from prolonged periods of technology failure when there is not local capacity to maintain the systems. • Poor policies for grid inter-connection, for

comparison to SHS and solar lanterns • Low operating costs, for micro-grids using renewable energy, such as solar or hydro • Can provide local jobs for construction, operation and maintenance of the micro-grid	communities where electricity grid will reach in the future

Table 1: Pros and cons of micro-grids for rural electrification

Micro-grids can have a number of different ownership and management structures. Many existing models can be grouped as owned and operated by cooperatives, communities, the private sector, and private/government utilities. The table below, adapted from Bhattacharaya (Bhattacharya, 2013), generalizes a number of traits typical for micro-grids owned and operated by different entities. Micro-grids operated by utilities do not appear in the table, but would have similar characteristics to ones operated by the private sector, with the notable exception that tariffs are generally low and community members tend to be employed in the operation and maintenance of the system.

Characteristics	Cooperative	Community managed	Private sector
Ownership	Members of the cooperative own and operate the model	Can be of two types: • Owned by private/public entity and managed by communities • Owned and managed by communities	Owned and operated by the private sector except in public/private partnerships where the ownership of assets may remain with public entity
Management	Managed by a board of directors or a governing body elected by the consumers	Managed either by an NGO or local self-governing institutions such as village electricity committees (VECs) or village councils	Managed by private sector
Maintenance	Cooperative is responsible for O&M	Maintenance is undertaken by the village electricity committee, village council	O&M undertaken by the private sector
Pricing	Low upfront cost and monthly tariffs; usually regulated	Low to moderate tariffs (mutually decided by the community and)	Moderate to high tariffs (set up by service provider)
Community participation	Moderate to high participation. Communities are members of cooperatives. Local youths may also be involved for bill collection, undertaking minor repairs etc.	High participation. Communities are involved right from the planning stage till the end implementation stage. Labor contribution for construction, management, maintenance, and grievances are performed by communities.	Consumers are generally not involved in the planning or management of the business.
Risks	Susceptible to political interference.	Communities may lack technical and managerial skills, and management susceptible to political interference	Private operator can discriminate by charging high tariffs

Table 2: Typical characteristics of different ownership and management models of rural micro-grids. Adapted from Bhattacharaya (Bhattacharya, 2013).

4 Review of best practices

There are decades of experience, analysis, and reflection on the successes and failures in increasing electricity access to rural communities. These range from high capital cost, top-down practices, such as the capital intensive rapid electrification of rural America in the 1930's through extension of the centralized grid, and China's rural electrification scale-up using hydro, coal, and diesel mini-grids, to the increasing experiments with private entrepreneurs using government subsidies to set up rural micro-grids in India (Liming, 2009; Pachauri & Jiang, 2008; Yang, 2003).

One of the primary challenges of rural electrification is overcoming capital cost challenges, as well as variable costs needed for ongoing operation and maintenance. There is almost universal agreement that rural electrification is not possible without the electrifying entities receiving subsidies from public or private sources (Bazilian et al., 2011; IEG, 2008). This being the case, there is still room for private entrepreneurs with a for-profit business model, versus government entities whose primary role is to broaden electricity access (which is often correlated to political motivations). This brief summary of best practices is divided into practices used to primarily broaden electricity access, as well as practices focused to increase cost recovery. It is important to keep in mind that these practices are not mutually exclusive. Even in cases where social outcomes are the primary focus, without a revenue stream that will cover ongoing costs, the system is bound for failure.

4.1 Broadening electricity access

There is substantial evidence that the poorest users are not the primary beneficiaries from most rural electrification projects, as most electrification entities look for connection cost and operation based on a least-cost basis (Barnes & Floor, 1996; IEG, 2008). Often the least-cost increase in electrification access can be attained by increasing connections where a grid already exists, rather than creating new connections where generation and grid infrastructure need to be built. However, World Bank studies have found that some villages with electricity access for over 15 years still have populations of non-connected users in the 20-25% range (IEG, 2008). Government should provide subsidies that incentivize 100% connection rates where grids or micro-grids exist (or will be built).

When subsidies are primarily used for capital costs, such as infrastructure needed for grid-extension or generation and distribution, the beneficiaries of these subsidies will be the primary consumers of electricity, which tend to be business owners and the wealthier clients with the most appliances and income to pay ongoing electricity bills (Barnes & Floor, 1996). The upfront cost for connecting individual households to the distribution grid, in either micro-grids or central grid extensions, is often prohibitive for the poorest households. Therefore, it is important for grid developers (private, public, or NGO) to offer subsidies, or financing for household connections and meters, capable of reducing this initial barrier. Though this may seem obvious, it has not been an integral part of most electricity programs, leaving the poorest households without access (IEG, 2008). Straightforward financing solutions include upfront subsidies dependent on household income, or spreading the connection and meter costs into monthly bills.

Misunderstanding tariffs also hinders the poorest users from consuming adequate electricity for basic lighting. Many tariff systems offer a "lifeline rate" for the poorest users, which is a fixed monthly charge that allows users to consume up to a fixed amount. However, users often have no intuition or information allowing them to consume up to the fixed amount, and often think they are being billed per unit of energy consumed. Also, their access to sufficient amounts of high quality light vastly increases when they have access to efficient light bulbs such as compact fluorescent lights (CFLs) or light emitting diodes (LEDs), as well as an understanding of the potential long term financial savings of efficient appliances. Public education, as well as access to high quality efficient appliances with subsidies and options for installment payments is important (C. E Casillas & Kammen, 2011).

There are often government policies that have adverse impacts on electricity access for the poorest users, or the sustainability of the system. Utilities may be mandated to extend connection to new communities or villages, but there may low requirements for internal village connection. Electrification schemes are powerful political tools, often used by political leaders to attract votes. The RGGVY[2] rural electrification scheme in India is a project with the goal of rapidly electrifying communities using renewable energies, providing up to 90% subsidies for the start-up costs and capital for projects. However, the government considers a community electrified if only 10% of its households have electricity access, and there have been high rates of failure and project abandonment.

Experience from numerous electrification projects have found that collaboration with communities plays an important role in developing appropriate ownership and management models (Bhattacharya, 2013), and ensuring project success over the long term.

4.2 Electrification for cost recovery

Rural electrification can have reasonable rates of return on investment if least cost supply is utilized and a balance is made between reaching the poor, enabled through subsidies, and addressing financial sustainability (IEG, 2008). Studies have found that rural households tend to have a willingness to pay (WTP) in the range of 0.10 – 0.40 $/kWh, which can exceed typical long run marginal supply costs (0.05-0.20 $/kWh) (IEG, 2008). Recent solar micro-grid experiments using smart grid technology, in which households use pay-as-you-go metering systems and high efficiency LED lights, have found WTP between 1.00-5.00 $/kWh for lighting, resulting in cheaper monthly expenditures in comparison to kerosene lamps (Soto et al., 2012). There is now substantial experience using various pay-as-you-go metering schemes (Tewari & Shah, 2003). These systems allow more intuitive payment schemes, similar to mobile phone plans, as well as typical consumption patterns of other energy services such as kerosene, where users purchase as much as they can afford. Conventional metering often utilizes tariffs that are not well understood by users, and do not give real-time feedback on their usage, often resulting in accumulating bills that can't be paid, and disconnection. While pay-as-you-go meters cost more than conventional meters, costs are continuing to decrease, and long term savings from reduced transaction costs, including mobile payment schemes, and user satisfaction may be worth the initial investment.

There are often generous government and donor subsidies for rural electrification schemes, especially when they use renewable energy technologies. However, it is essential to have government policies and subsidies that are transparent to entrepreneurs and have long timelines. This includes plans for grid-extension, that also include policies allowing grid interconnection with favorable feed-in tariffs. Research has shown that rural electrification projects are more likely to maintain financial solvency when they are coupled with projects that lead to economic growth (Barnes & Floor, 1996; Rolland &

[2] Rajiv Gandhi Gramin Vidyutikaran Yojana

Glania, 2011). Micro-grid revenue can be substantially increased when it supports a particular industry that would serve as a revenue base, as well as being coupled to the growth of carpentry, agriculture, telecom, or other businesses that can also increase household income (Rolland & Glania, 2011). This requires project developers to work closely with other organizations that will provide market analysis, training, and financing for entrepreneurs.

5 Human, social, and cultural factors toolkit

Only those institutions which can successfully mobilize the communities by engaging with them can be sustainable in the long run. (Bhattacharya, 2013)

Community engagement is the critical starting point for rural micro-grid developers to assess whether or not the community's development vision, capacities, and motivations are compatible with the developer's own business model and capabilities. Over the course of the past 70 years, western industrialized nations have created an industry of International Development, often with an underlying assumption that materially developed societies and their associated social and cultural values are superior to less materially endowed communities (Hart, 2004). One of the fundamental suppositions held by most governments and institutions involved in international development is that economic growth is fundamental. Having this perception led to the role-out of decades of top-down development projects, often characterized by plans, processes, and technology being defined and driven by engineers, managers, government officials, development consultants, and financiers, who reside outside of the target communities. Top-down development processes have the attractive aspect that, since they are designed by outside institutions, they can create their own time-lines and be easily scaled and replicated because they are not closely tied to the idiosyncratic characteristics that inherently define any community, such as their unique beliefs, geography, climate, capacity, history, conflict, arbitration, governance, economy, and aspirations.

Consistent project failures and community feedback has led to the widespread adoption of an array of various participatory practices, in which governments, NGOs, or private developers seek to incorporate a more authentic form of community engagement. However, mainstream participatory practices within development institutions have been heavily critiqued (Cooke & Kothari, 2001; Cornwall, 2006; Hickey & Mohan, 2004; White, 1996). Some argue that large development institutions create blueprints that serve primarily to legitimize external development agendas, leaving a narrow space for contributions from community members (Cornwall, 2006, p. 75). The unequal power relations created by the facilitators from these institutions impact participatory decisions, and their pre-formulated agendas can co-opt local development processes (Singh, 2009). Communities are composed of a complex web of relations, founded on differences of race, ethnicity, gender, or economic class. Participatory methods that do not account for the heterogeneity within communities will likely be dominated by local elites (Cornwall & Jewkes, 1995, p. 1673; Platteau, 2004), and so may not reflect the range of local viewpoints. There are corrective mechanisms to ensure that the marginalized have influence in decisions (Cooke & Kothari, 2001, p. 69), but many community-based methods refrain from challenging local structures of power (Hickey & Mohan, 2005), which can originate at the highest levels of social and political structure, and which often leads to sub-optimal outcomes.

Typical electrification projects are greatly influenced by top-down processes. They often involve technology components that are engineered and manufactured externally and projects have timelines and deliverables that are narrowly constrained by donors. However, no matter what the business implementation model for micro-grid electrification, if one is concerned about the long-term sustainability of the system, some (and in the case of very poor populations, early and thorough) engagement with the community is essential for developing an electricity system that has the potential to meet the needs, finances, and economic and social values of the users.

In this section we present a general, iterative framework for designing a micro-grid that is reflective of the needs, capacities, and priorities for a rural community. The process begins with identifying and engaging with a community in a target region, collaborating with the community on the design and deployment of the system, followed by actual use and feedback, which will again lead to re-engagement with the community, and a subsequent iteration of this design process. A depiction of the process is shown in the figure below.

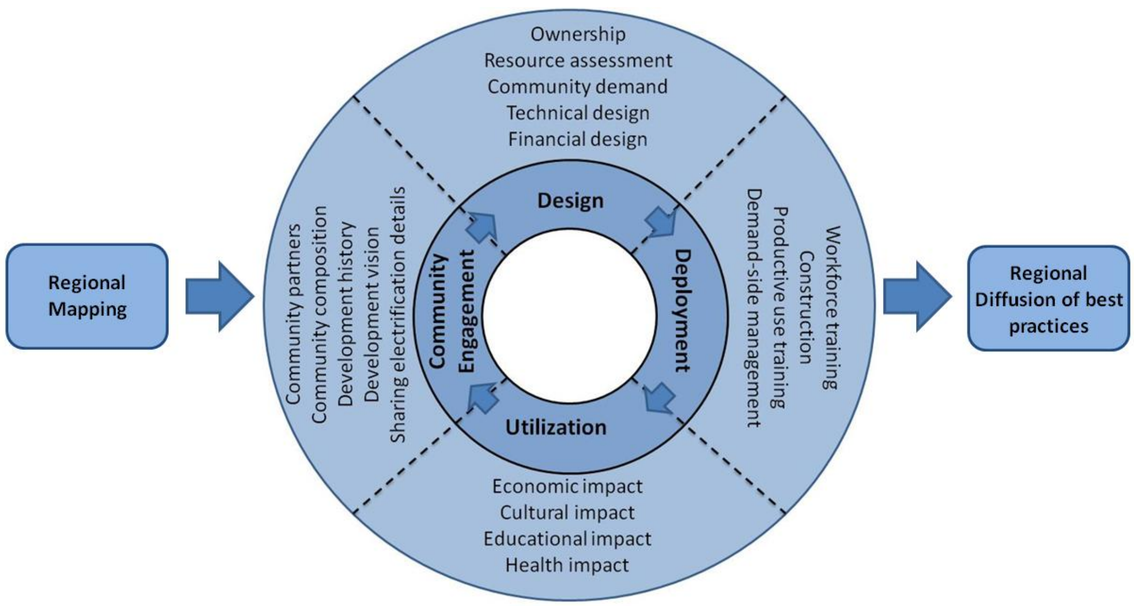

Figure 2: Outline of an iterative HSC design process for creating, implementing, and maintaining appropriate micro-grids in rural communities.

The boundaries between the "stages" are shown with a dashed line, to denote the fluidity of the process. At each stage, there may be a need to revisit processes from the prior stage. During the evolution of the process, there should also be mechanisms for the diffusion of best practices to other communities within the region.

The following sections will describe each of the four design phases, the goals, and various techniques or processes that will help to ensure that there are appropriate levels of community participation in the project, and developers are able to adequately communicate their plans and capabilities.

5.1 Regional mapping

In many countries, such as India, there are large regions that contain numerous villages that don't have access to electricity. Among these villages, there may be a wide range of community characteristics that might be more or less supportive of the successful installation and operation of a micro-grid. It is important to conduct rapid assessments of some of the key characteristics within the region's villages, to determine which ones might increase the probability of long-term success of a micro-grid. From the ongoing experience and lessons-learned in the easiest communities, subsequent projects can branch out to communities where installation and operation may require overcoming greater challenges. For example, DESI Power, a private micro-grid developer in India, conducted a market survey in 100 villages before determining the location for their second micro-grid installation (Schnitzer et al., 2014, p. 36). Important characteristics might include things such as road access, community leadership and cohesiveness, capacities within the community (e.g., masons, blacksmiths, carpenters, literacy rates, incomes), and potential industry development. Critical metrics that may increase the probability of success will also depend upon the capabilities, technology, and management model of the developers.

5.2 Community engagement

There are a number of organizational models for the implementation of micro-grids in rural communities. Ownership, operation, and management can fall in the hands of the government, community, NGOs, or private companies (Bhattacharya, 2013; Deshmukh et al., 2013; Rolland & Glania, 2011). Regardless, the first step for development of the project will be community engagement. The primary objective is for the developer to better understand the community's resources, capacities, and aspirations, as well as for the community to have a detailed understanding of the goals and potential services that the developer has the capability to offer.

5.2.1 Developing community partners

The first step for community engagement is connecting to a partner that can facilitate the formation of relationships within the community. The partner should be someone who has strong ties within the community, and a substantial history working or living in the community. He or she should also be someone who can provide background information on the community, and make introductions to various community stakeholders. The partners may be community leaders living in the community, or employees of the government, NGOs, or businesses, who have an established history working and interacting within the community (see, for example, the work of Mlinda in the Sundarbans region). Every individual or organization will have their own particular perceptions and biases. Affiliating closely and immediately with a particular person or group may alienate some sectors within the community. Ideally, the micro-grid developer will have the opportunity and ability to make multiple connections with different groups within the community, allowing him or her to understand the needs and interests of various internal groups. Connection to good community partners can greatly facilitate information transfer for the developer.

5.2.2 Understanding community composition and key characteristics

One of the first steps for a micro-grid developer is to understand the heterogeneity that defines a particular geographic community. Some common characteristics that may define community sub-groups are shown in the table below:

Characteristic defining a community group	How this characteristic may impact their interest, decision-making participation, or electricity access
Income	What is their ability to pay for electricity, and capacity to consume?
Land holding	Do they control right-of-way for distribution grids or generating stations?
Business activities	Will electricity benefit their businesses? What will be their electricity demand?
Religious affiliation	How are religious affiliations connected to the dominant power structures in the community?
Political affiliation	How much control do they have in the community?
Ethnic or racial differences	Do they have political power, community voice, or are they marginalized by economics or caste?
Linguistic differences	Is there a common language? Who is excluded when meetings/documentation is in a particular language?
Age	Do the youth or elderly have unique electricity needs? Are they excluded from public discussion?
Gender	Who benefits most from electricity services in a household? Who are the decision makers in the household (e.g., matriarchal vs. patriarchal structures)?
Educational background	Does everyone understand the finances, management, and impacts of electrification?

Table 3: Various characteristics defining community subgroups, and how these might influence motivations for electrification, or access.

There are many participatory practices that continue to be widely used and developed by organizations and individuals working within communities. Many of them are extractive in nature, and focus on information collection by outsiders. Processes such as Rural Rapid Appraisal (RRA) emerged in the late 70's as a cheaper and more effective alternative to household surveys for development actors and researchers to collect information on rural communities. There was sufficient disillusionment regarding the costs and effectiveness of traditional survey work, and a number of researchers became convinced that RRA, consisting of a suite of tools that included informal interviews, meetings, and group activities, was more cost effective and accurate than traditional survey work (Chambers, 1994). While RRA was primarily extractive and used by universities and development organizations, it has since evolved into more participatory methods (e.g., participatory rural appraisal (PRA)), in which community members are involved in not just the collection of information, but also its presentation and use. There are a wide array of handbooks that describe various participatory methods. PRAs are often conducted by a team of facilitators who may spend several days to weeks within a community, working with various focus-groups that are representative of different sectors of the community, or with an inter-mixed group. Activities often involve the workshop participants breaking into groups and reviewing their shared knowledge about a particular topic, compiling the information in a picture or chart, and then presenting the information back to the group for discussion. The table below lists a number of common PRA practices that can be useful in assessing community capabilities relevant to the design of an electricity system.

Community group activities	Importance
Community map of town	Geographic composition of community, historic and contemporary significance of land and resources, emphasizing cultural/religious significance.
Cultural/religious calendar and map	Understand the different religious beliefs and practices. How do these impact activities and practices, and how they impact views of technology, natural resource use, gender/ethnic/racial roles.
Community resource assessment	What locally available materials within the community are seen as resources and what is seen as waste? Especially important when assessing generation using biomass, as well as potential for value-added processing.
Diagram of resource flows into/out of the community	Creates a picture of the local economy: consumption and production patterns and supply chains. Important for assessing how electricity may support different productive uses.
Calendar of economic activities	Especially important for agronomy-based communities. Labor supply and income may be lumped in certain seasons , important for assessing billing cycles for electricity
Gender roles	What gender roles do women/men hold within the community and family? May be important in understanding decisions, limits in participation, and choices for system management.
Household budgets	Must cut across income levels. Important for assessing ability to pay for electricity services
Household composition	What is typical family size, and jobs/roles. Understanding what a typical day for a man, woman, or children looks like will be important in understanding the potential for labor contributions in system development.
History of development projects	Helpful for understanding what development projects have been seen as success and failures, and what dynamics were important
Ranking of community development challenges	This will range by community sub-group. Can provide insight into how electrification can support community development priorities, such as improved healthcare, education, or employment opportunities.
Picture of community in the future	Reveals community group aspirations, allowing developers to understand how electrification can complement/support development
Matrix of community institutions/organizations	Shows what organizations and groups are doing work within the community, and how they are viewed. Helpful in determining collaborative partnerships.

Table 4: Participatory Rural Appraisal (PRA) activities conducted by community groups, and their relevance for electrification

5.2.3 Understanding development history and vision

Understanding development history is a critical aspect that has the potential to greatly inform whether or not a developer's capacity, constraints, and motivations are compatible with the community. An important challenge will be to utilize a process that will allow various subgroups to share their own visions of the town's or village's history, as well their own goals and aspirations for the future. The process may involve individual interviews, workshops with various groups, or inter-mixed workshops. Community members should be able to create a simplified history of development projects within their community over the last several decades. This history will provide insights into how projects have been implemented, who has been involved, and what have been the outcomes, from the perspectives of various community groups. Understanding community visions of the future, as well as current challenges facing sectors of the community, developers can work with community members to better understand if or how electrification can support varied development aspirations.

5.2.4 Developing community baseline data

During the participatory workshops, facilitators should work with community members to discuss the importance of defining baseline metrics. This will be an ongoing process that will be started during the stages of community engagement, but revisited during later phases, especially the utilization phase. In order to evaluate the impact and effectiveness of any proposed electrification scheme, it will be helpful for the community to evaluate how their lives have changed, once the electrification project is functioning. The metrics will allow them to take a more quantitative look at impacts and provide a feedback mechanism for evaluating changes to the operation and management of the electrification system. Possible metrics that can be compiled based upon outcomes from the PRA exercises and any surveys could include: average household income, household expenditure on energy, accessibility of health services, diversity of economic activities, learning opportunities, and nighttime activities. Evaluation metrics are discussed in more detail in the later section on utilization.

5.2.5 Divulging costs and benefits of electrification

A common shortcoming during the initial stages of community engagement by project developers is to focus on information collection, without appropriate emphasis on accurately sharing information about the prospects of the electrification project. This can lead to unreal expectations from community members regarding what will be the actual costs and benefits of electrification, timeline, and sustainability of the project. Unfulfilled expectations may be one of the primary aspects that lead to eventual project failure. For example, a government agency in Chhattisgarh, India, has contracted the development of numerous solar micro-grids, designed specifically for lighting. It has witnessed ongoing power shortages and demands from clients that want access to other electricity services (Schnitzer et al., 2014, p. 35). Widespread and sustained community buy-in will require honest and accurate communication with the diverse stakeholder groups. This requires using various techniques that will allow groups to gain some form of experiential understanding of the process and prospects of a potential micro-grid. An unfortunate tendency is for a developer to play the role of a salesperson or politician, telling constituents what they want to hear. While this may be useful for gaining initial support, when the true costs and benefits of the project reveal themselves, over-sold expectations will lead to disillusionment, resentment, and possibly even opposition, hindering or destroying the long-term operation of the project.

Developers can share information through presentations and community meetings, but these are often high-level, and do not facilitate an understanding of the details, in ways that may relate to individual experiences. If there are similar projects in nearby communities, developers can arrange field trips, in which community members can visit the systems and talk with consumers and operators.

Participatory modeling is another promising technique in which community members work with a facilitator to develop a model of some aspect of their community (such as their economy; see, for example, the work of the Indian NGO SAMBANDH) or a particular development project (such as a micro-grid). This process can be further enhanced by incorporating the model information into a board game (Bousquet, Trébuil, & Hardy, 2005). Another approach involves the facilitator bringing in a board game or computer simulation that allows the users to gain intuition about what appliances they may be able to use, their associated costs, generation capacity limits, and challenges of management. One group has developed a computer simulation tool that can be done on computer tablets, in which participants choose appliances and consumption patterns, and then can see associated monthly bills and impacts on overall generation load requirements[3].

5.2.5.1 Tools for community engagement

Task	Tools
Understanding community composition, development history and visions, culture, and local economies	Community meetings Socio-economic surveys Community observation Structured/unstructured interviews PRA techniques
Baseline metrics	PRA, community discussions
Sharing details of potential electrification projects	Presentations Meetings Modeling and simulation games

5.3 Design

Once a community has been identified as a viable prospect for community electrification using a micro-grid, the developer will need to work closely with the various community segments to design a socially, culturally, politically, economically, and technically appropriate micro-grid. Depending upon the community context specifics, it may be critical for the community to be engaged in the process and have a detailed understanding of the design plan. The figure below depicts some of the critical components that are part of the micro-grid design.

[3] See the load simulation game developed by http://www.arc-initiative.org/#&projects

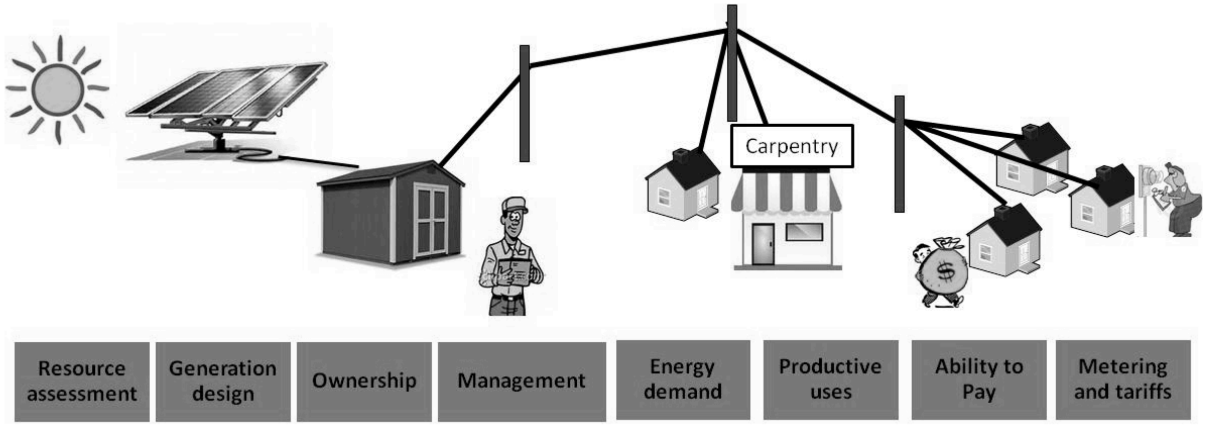

Figure 3: Various design components for a rural micro-grid

5.3.1 Ownership structure

Whether the micro-grid is built, owned, and operated by a private company, the community, or a public utility, there are aspects of the management structure that must be compatible with the community context. In communities that are highly cohesive with strong leadership, having greater community involvement within the ownership or management structure may make sense. In 2000, the Nicaraguan community of La Pita banded together to ask a local NGO to support training for the fabrication, installation, and operation of a community micro-grid. Interviews in 2008 revealed that the community was effectively managing the system, and didn't want to give up ownership. In contrast, a community-run diesel micro-grid in the Nicaraguan community of Orinoco was having difficulty collecting tariffs and managing the grid, and requested the national utility to take over ownership. The improved training and official uniforms played important roles in improved operation and tariff collection, and protects against the risk of theft and sale of equipment.

Community members may be employed to work on construction, operation, and maintenance of the micro-grid. This will require understanding what sort of local capacity and interest exists within the community, and what sort of workforce development will be needed. Employing community members in plant operations and tariff collection will require community dialogue to address potential tensions that might arise within during hiring and carrying out their jobs. For example, community employees may be unwilling to refrain from enforcing payment or disconnection rules with friends or relatives. In several community-based micro-hydro projects in Orissa, India, leadership qualities emerged among youth during initial installation work, leading to capacity development and incorporation of system operation and management (Vaghela, 2010).

5.3.2 Local resource assessment

Depending upon the capacity and financial model of the developer, local resource assessment is an essential component for the design of an environmentally and economically sustainable electricity system. Small scale generation systems utilizing locally derived fuels can provide greater socio-economic benefits than systems that simply produce the least-cost unit of electricity, such as diesel generators, which have the bulk of their lifetime costs tied up in imported fuel (Kammen, Bailis, & Herzog, 2001b; United Nations Department of Economic and Social Affairs, 2007). It will be critical to involve community groups in the evaluation of local resources that could be used for power generation. There may be very strong economic or cultural reasons why biomass resources or river diversion may not be appropriate for use in an energy system. Depending upon the scale and model of the electrification system, resource assessment is something that can be done in a participatory manner that can support local capacity development of assessment skills and techniques for evaluating the energy potential of local resources.

Resource	Rivers	Wind	Solar	Biomass
Generation	Micro-hydro	Wind turbines	Solar PV	Biogas or gasification
Assessment	river flow, seasonality, head, site for civil construction, , environmental laws	Appropriate site, wind speed, seasonality	Solar radiation, site for power house and panels, seasonality	Type of biomass availability, site for powerhouse, local uses, seasonality
Community participation	Yes	Marginal	Marginal	Yes
Technical capacity	Moderate	Moderate/High	High	Moderate/High

Figure 4: Resource assessment and potential community involvement for various renewable energy sources

5.3.3 Community demand and productive use

Assessment of community demand will require active community participation, and is closely linked to the existing businesses, local skills, household incomes, and development visions of the community. Household energy use surveys as well as PRA techniques are valuable for assessing potential electricity demand. Critical factors in a demand assessment are described in the table below:

Metric	Definition	Tools
Ability to pay	How much are households currently spending on energy services, such as lighting and batteries?	Participatory budget mapping Household surveys
Willingness to pay	How much will households be willing to pay for more modern energy services, such as improved lighting, television, fans, etc.	Focus group discussions Simulation game playing Household surveys
Household electricity demand	What types of electricity services are people interested in and able to acquire? What are the availability and finance options for efficient appliances?	Focus group discussions Simulation game playing Supply chain analysis Meetings with finance institutions
Business demand	What types of businesses could benefit from electricity? How can electricity support local incomes in agriculture, carpentry, small stores, etc.	Focus group discussions Productive use surveys
Demand by public institutions	What types of social services can benefit from electricity, such as health clinics, street lighting, schools, and community buildings?	Community meetings Government/institution meetings
Demand growth	How fast the population is growing. Are there other development projects pending that	Population census Mapping of development institutions

projections	may impact incomes and business opportunities, such as road construction, industry, or agricultural extension projects.	Government/institution meetings Focus group on community development visions

Table 5: Important metrics for evaluating potential electricity demand and assessment tools

An important aspect of demand assessment involves an investigation into how electricity can facilitate the expansion or creation of new economically productive activities that support local livelihoods. Many activities may have high power and energy requirements, such as carpentry, mills, irrigation, and refrigeration or ice-making. Past experience has shown that connecting a micro-grid to an anchor tenant who has both high demand, and ability to pay, can be a critical component for the financial solvency of the micro-grid. In some cases, there may be entrepreneurs who already have a profitable business supported by their own diesel generators, so connecting to a micro-grid will likely reduce their costs. In other cases, entrepreneurs or farmers may need additional training in both business planning and skills needed to operate and maintain new machinery. Experience in rural fishing villages in Nicaragua has found that there is high demand for local ice generation, but insufficient skills managing and maintaining the machines has led to frequent failures (Christian E. Casillas, 2012). Small business development, such as household shops that use refrigeration, tailoring, or hair salons have been shown to increase local incomes (Kirubi et al., 2009). This may translate into increased ability to pay for electricity, as well as overcome capital costs for more efficient appliances.

Human capacity development takes time and resources. In order to do this well, it will likely require partnering with organizations that have strong histories of implementing successful training for entrepreneurs and technical skills. This may involve sending community members to training courses at universities or technical schools, or apprenticing with experts in nearby communities.

5.3.4 Technical design

Technical design includes the mechanical and electrical design of the generator, construction of power houses, roads, and resource intakes, distribution lines, demand-side regulation such as load limiters or meters, availability of efficient appliances, and tariff design and payment methods. The technical design will depend on the ownership, management, and financial model of the micro-grid, as well as the local capacities of the community. For community owned systems, it is essential that local capacity and supply chains can support the operation, maintenance, and repair of the generation, distribution, and metering systems. For micro-grids that will be owned, operated, and maintained by a private entity, the technical sophistication of the micro-grid will be limited by the financial model of the owners.

While the technical design of micro-grids is typically done by engineers and technicians, it is essential to have ongoing community dialogue during the design process. This is a critical step where communication between the developers and the users often breaks down. The engineers will base their design upon analysis of community capacity, resource availability, and community demand. However, there is often hidden or misinterpreted information, or the designers' own limited experiences and biases may lead them to come up with a solution that has problems obvious to community members. Lean start-ups in the U.S. often ensure that engineers and designers are in close communication and there are pathways for direct feedback. This best-practice is often non-existent when products are off-the-shelf components from foreign countries. Work on community micro-hydro systems has shown reduced failure rates when time is taken to train electricians and metal fabricators to make components regionally (Vaghela, 2010). Installing regionally fabricated wind turbines in rural communities in Nicaragua has shown that service contracts with skilled professionals was more cost effective and viable than trying to develop all maintenance capacity within the isolated communities themselves (Marandin, Craig, Casillas, & Sumanik-Leary, 2013).

Developing an appropriate technical design will necessitate pathways of communication between the engineers and designers and the community throughout all stages of the micro-grid implementation process. The technical team should be involved in various aspects of the community-engagement process, so they are not just learning about the community through reports or anecdotes. During the design process, the pathways of communication should involve conversations and visits with community members, getting their direct input during the design process.

In addition, it is important that the technical design team is aware of other development projects that might be unfolding within the community. There may be plans for new public structures, or renovations, such as schools and health clinics, or organizations that are supporting economic development projects within the community. Effective design will involve communicating with other actors, and understanding how electricity design and construction can complement other projects.

5.3.5 Financial design

In order to create a sustainable financial model that will allow the construction, operation and long term maintenance of the system, understanding of government policies and local and non-local funding sources will be necessary. As mentioned earlier, a sustainable rural electrification scheme is not viable without subsidies. Thus, the question becomes how to best apply the subsidies. Many countries have national and local level policies that offer substantial subsidies to reduce the capital costs of electrification projects. For example, the RGGVY rural electrification policy in India will provide up to 90% of the capital costs and some soft costs (such as feasibility studies) for micro-grid implementation using renewable energies in target communities. The longevity of the micro-grid may be impacted if there are future plans for inter-connection to the main grid, but there are no grid inter-connection and feed-in tariff policies. The table below lists a number of government policies that are important for the longevity of the micro-grid.

Government policies that impact the financial design for micro-grids
Capital subsidies
Mandatory tariff rates or structures for micro-grids
Legal/technical laws for grid inter-connection
Feed-in tariffs for grid inter-connection
Local, regional, and national taxes
Tax breaks on renewable energy technology imports
Banks and government institutions that give loans at preferential rates for electrification projects

Table 6: Financial policies that may impact micro-grid development

Often tariffs systems are implemented as afterthoughts to the design process, even though a well designed tariff system may determine whether a micro-grid fails or persists. It is also important to understand national tariff policies that may constrain the forms the tariffs can take. In India, tariffs may be defined by individual states, with variation within the municipality or district level. Subsidized tariff structure can even be used as a political tool to gain support or re-election. A number of authors have argued that tariff design should be measured by metrics of cost recovery, economic efficiency, and equity, while striving to have them transparent and understandable to consumers (Boland & Whittington, 1998). There are a number of electricity tariff systems in affect throughout the world, the most common being two-part tariffs and inclining block rate tariffs (IBTs), the latter of which is prevalent throughout Latin America (Foster & Yepes, 2006). A two-part tariff is one that has a fixed monthly cost, regardless of consumption, and then a per-unit cost for consumed electricity. IBTs have a per-unit cost for electricity consumption, that increases as consumers pass fixed consumption amounts. With IBTs, the largest residential consumers pay higher rates than lower consumers, cross-subsidizing the poorest households and are incentivized to invest in more energy efficient technology (such as new refrigerators), as well as reduce consumption for all but the most valued use.

Within the developing world, IBTs have gained popularity in both the water and electricity sector, primarily due to their purported ability to provide more equitable access than the two-part tariffs. While there have been a number of critiques of the shortcomings of IBTs (Boland & Whittington, 1998; Crase, O'Keefe, & Burston, 2007), due to their familiarity and ease of implementation, they are suitable in many contexts. Several aspects of regressive tariff systems can be improved by utilizing an IBT in which the lowest consumers can be given 'life-line' rates that are cross-subsidized by higher consumers (Barnes & Floor, 1996).

5.3.5.1 Appropriate tariff design will need to involve community discussions and educational workshops where tariff structure is explained. Families on a privately operated micro-grid will likely need to pay higher tariffs than friends or relatives on the centralized grid, which will have lower generation costs and more subsidies and is subject to political manipulation. In communities where families don't understand the tariff system, and/or feel that it is unjust, there will be greater incentives for bypassing meters or load limiters, or not paying bills. Even with increasing excitement about smart-metering with options for pay-as-you-go services, mobile payments, and remote disconnections, human interface is still critical. An employee at Husk Power Systems, a micro-grid developer in India, has stated that he doesn't believe that any technological solution will obviate the need for trust-worthy employees (Schnitzer et al., 2014). Tools for design

The table below summarizes some participatory practices relevant to the technical design phase of micro-grids.

Design component	Tools
Ownership	Community meetings to discuss potential ownership models Management models, in the form of computer or board games, in which participants can gain insight into the details of various structures Community visits to nearby micro-grids with various management structures.
Resource assessment	Workshops, community training (solar eval, hydro eval)

	Focus group (biomass evaluation) Instrument installation (wind)
Community demand	Community meetings to discuss potential ownership models Household and business surveys Participatory workshops – household focus groups assessing household demand, businesses growth, public institutions like schools, clinics, and proactive uses like mills, irrigation, carpentry, stores Community census tallies and projections Government and NGO development plans and prospects Electricity load simulation games (board games and computers)
Financial design	Mapping relations of financial actors, and impacts of policies Setting up community savings accounts, links to micro-lenders/banks Community census tallies and projections Government and NGO development plans and prospects Electricity load simulation games for assessing tariff viability

5.4 Deployment

Deployment of the micro-grid provides the opportunity for short-term and long-term job creation, bringing economic opportunity to the community, in addition to the provision of electricity. This will require the micro-grid developer to have internal capacity, or appropriate partners, who can provide workforce training within the community. For example, the construction of the powerhouse for generation and storage will require masons, carpenters, and unskilled laborers, as will the more extensive civil construction needed for a micro-hydro system. System construction could takes weeks or months, depending upon the generation type, size of the community, and availability of labor.

Short term employment opportunities	Ongoing employment opportunities
Civil construction (hydro) Powerhouse construction Distribution grid construction	Linesman Bill collector Administrator Plant operator Fuel stream providers

Table 7: Short term and long term job opportunities, depending upon the generation technology

During the deployment process, new information will be revealed regarding the capacities, motivations, and leadership among community members (Vaghela, 2010). While some people may be silent, or shy, during community meetings or workshops, they may be very active when it comes to participating in hands-on work. The more closely community members are able to participate in system construction, the more likely it will be that they can repair it when problems arise. This will involve not just carrying out construction tasks, but understanding the function and rationale for particular aspects of the design.

It is important to make sure that there are ongoing community meetings during the construction phases to make sure that voices are heard, and participation is equitably distributed. There will always be more active participants, as well as free-riders. Public meetings and good facilitators may be necessary to make sure that the deployment phase doesn't become divisive, especially when the project is dependent upon community labor.

Deployment may also entail closely partnering with micro-finance groups or businesses, in order to make sure that all users have connections and access to minimally efficient appliances, such as compact fluorescent light bulbs or LED lights, as well as equipment needed to support economic, civic, and socially beneficial activities.

In the case where there are entrepreneurs or business owners who may be able to start new businesses, or increase productivity in current ones, it will be necessary to provide access to both skills training and micro-finance institutions. It is common for households to set up small businesses selling chilled drinks, small stores and bars to acquire stereos and refrigerators, or farmers to acquire pumps for irrigation. In Nicaragua, appliance franchises offered microcredit directly to remote villages, allowing them to purchase TVs, refrigerators, and stereos on credit (at annual interest rates above 30%), while micro-lenders provided loans in other communities. However, opportunity can quickly turn to tragedy, as small entrepreneurs get caught in endless debt-cycles, unable to pay back loans taken at high interest rates, especially in the agricultural industry where business is tied to the vagaries of weather.

Community members will greatly benefit from workshops that will help them to develop business plans and assess the risk of loans. In addition, skill workshops may be necessary when electricity can provide the opportunity for the use of new equipment, such as carpentry machines or mills, or new job opportunities, such as barbers or electronic repair shops. Electricity access can provide new economic opportunities, but these are often dependent upon human capacity development, requiring integration and collaboration with other development organizations.

5.4.1.1 Tools for deployment

- Partnering with institutions for skills training workshops
- Short workshops reviewing rationale and function of system design
- Ongoing community meetings
- Business planning workshops
- Workshops on tariff design and loan risks
- Educational workshops on efficient appliances and productive use equipment

5.5 Utilization

Post deployment is typically where most development planners think that their work has ended. Project budgets often do not include support for the problem-solving needed to address the many unforeseen problems that arise once the system has begun operating. Post-deployment, if planned carefully with partners and resources, is the opportunity for electricity access to truly support the development visions of local community groups. The table below shows a number of potential outcomes that may result from a rural electrification scheme:

Rural development challenge	**Potential welfare improvement through electrification**
Poverty and Hunger	• Reducing share of household income spent on lighting • Reducing post-harvest losses through better preservation.

	• Enabling irrigation to increase food production and access to nutrition. • Enabling enterprise development, utilizing locally available resources, and creating jobs. • Generating light to permit income generation beyond daylight. • Powering machinery to increase productivity.
Primary Education	• Providing light for reading or studying beyond daylight. • Improving access to clean water, lighting, and space cooling • Providing lighting in schools, helping retain teachers. • Enabling access to media and communications that increase educational opportunities.
Gender Equality and Women's Empowerment	• Improvement of domestic working conditions • Increased opportunities for income generation. • Lighting streets to improve women's safety. • Providing lighting for home study and the possibility of holding evening classes.
Health	• Improved lighting in health clinics and hospitals • Access to lifesaving electrical devices • Allowing for medicine refrigeration and equipment sterilization • Providing access to health education media. • Improve willingness of doctors and nurses to reside in rural areas • Tele-health services
Environmental Sustainability	• Boosting agricultural productivity through irrigation, increasing quality instead of quantity of cultivated land. • Reducing greenhouse gas emissions from lighting

Table 8: Summary of potential welfare impacts from rural electrification. Adapted from (Flavin & Aeck, 2005)

Such outcomes are hardly inevitable, and many will depend upon the thoughtfulness of the implementation, and require feedback and restructuring in order to achieve desired impacts. While the owners of the micro-grid will have their own form of monitoring and evaluation, it will be beneficial for developers to collaborate with community sub-groups to determine what impacts are most important, and what type of monitoring and evaluation system would be sustainably managed by the community. These discussions will build off of any work that was carried out during the initial stages of community engagement (see above), when workshops and surveys produced baseline data than can be measured again, after the micro-grid has been in operation for some time.

The table below gives some examples of metrics that a community might choose to measure, as well as aspects of the micro-grid that may require revision and alteration.

Issue	Metric	Potential intervention
Household access	Minimum hours of lighting per night	Tariff reduction, life-line rates
Revenue collection	100% collection Revenue exceeding costs	Tariff re-evaluation, employee training, town meeting Tariff evaluation
Brown-outs/Black-outs	Load factor (peak load/ave load)	Assess community access to efficient appliances

		Assess the technical capacity of the operators, fuel chain, equipment supply chain
Business impact	Net annual revenue	Evaluate tariffs and generator capacity and maintenance Human capacity of workforce and the potential for ongoing skills training
Cultural impact	Change in intra-household socializing	Provide increase lighting in outdoor spaces, additional community spaces
Educational impact	Hours of TV/household Type of TV being watched	Increase access to educational movies Training to develop a local, youth-run TV program

Table 9: Possible metrics and levers that may be adjusted to impact them

In order for observations and challenges to lead to locally appropriate changes in the micro-grid system, there needs to be some form of institutional structure that creates a feedback loop between the community and the ownership and management structure of the micro-grid. This may be one of the most challenging aspects of micro-grid management. The structure must have hierarchies of management and feedback that will allow versatility.

In the Indian state of Chhattisgarh, the government has contracted private companies for the installation and operation and maintenance of the micro-grids. The government has a well developed system of monitoring the functioning of the micro-grids, with a well defined structure for community members to communicate issues, first to the contractors, and then directly to the government (Schnitzer et al., 2014). In contrast, solar micro-grids in the neighboring state of Orissa were found to have a low rate of operation, with poor maintenance records from the contractors, and confusion within the communities about who to contact for system repairs.

5.5.1.1 Tools during utilization

- Surveys
- Participatory workshops
- Community organizing
- Ongoing meetings between funders, contractors, NGOs to make sure that established systems of monitoring, auditing, and penalization are functioning
- Training workshops for the collection and analysis of metrics
- Ongoing workforce training workshops
- Skills training in use of computers, video, photography, editing

5.6 Developing and implementing an HSC toolkit

While there is sufficient evidence that integrating human, social, and cultural factors into the process of rural electrification will likely improve the development outcomes, it is difficult to place a monetary value on that outcome. Therefore, it is challenging to ensure that rural electrification, when carried out by actors in the private sector, or donors operating on short-term metrics relating to project costs, will make the investment of time and money needed to create and utilize a community engagement process. A developer may not have the capabilities within their organization, such as adequate knowledge of local language or culture, to develop and implement appropriate community activities.

In the case of a large rural electrification effort carried out in a particular region, it may be appropriate for donor agencies or governments to support the capacity development of an HSC team residing within, or intimately familiar with, the region. The effectiveness of HSC practices will be highly dependent upon skill, effort, and ethics of the facilitators. However, good HSC facilitators will not necessarily need a high level of technical skills, but rather good communication and organizational skills, which may be found or cultivated within rural communities.

Determining the best method for the development and implementation of effective HSC practices for rural electrification practitioners will require varied experiments, appropriate to the context in which the electrification programs are occurring. These might include having manuals and training videos for developers, internal HSC process experts within the development organization, local NGOs that have the mandate and capabilities for carrying out HSC processes for developers, dedicated teams of HSC practitioners that are contracted from regional universities, or programs carried out by universities to train local teams in appropriate HSC processes.

HSC processes will likely be more important for smaller communities where community members play an active role in the community, and will be involved in the operation and maintenance of the micro-grid. The figure below shows what would likely be the decreasing importance of HSC processes for micro-grid development under different contexts.

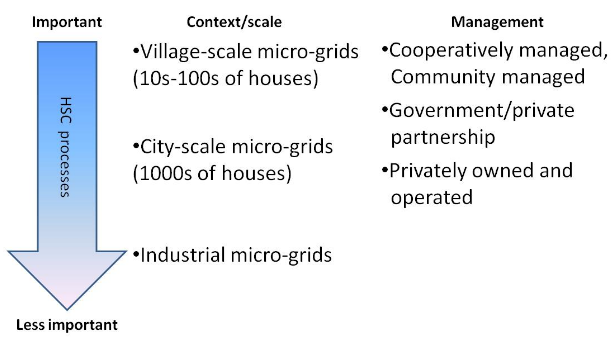

Figure 5: The importance of having HSC processes integrated into the development of a micro-grid

5.6.1 Development code of ethics

Bringing electricity to rural communities will, without fail, have profound transformation on the daily lives and livelihoods of community members. Hopefully, most of these transformations will be viewed positively by the community members themselves, increasing access to a variety of livelihood choices that were previously absent. As discussed earlier, electrification holds the potential to support greater opportunity and improved working conditions in the home, schools, workplaces, and health clinics. However, with the introduction of new technologies, there can also be challenges and pitfalls, such as the erosion of local traditions with an influx of foreign TV and movies, an increased emphasis on material consumption, and financial trouble through equipment loans and electricity bills.

There will certainly be tensions between the local culture and the modernizing influences of technology. There will also be tensions between governments, eager to rapidly increase electricity access without sufficient regulation or oversight, donors and developers without sufficient understanding of local culture and context, and private contractors desiring to make sufficient profits.

It would therefore be helpful, and not unprecedented, for an HSC team to help local and regional government and community groups to draft and adopt a code of ethics that provides explicit expectations for developers. The table below provides an example of some topics that might appear within a code of ethics for rural electrification. A code of ethics will only have meaning when developed with community members, and introduced within the framework of a dialogue between beneficiaries and developers, making sure that the developers understand the meaning and context behind the words.

Example of a development code of ethics for rural electrification
• The electrification system should be accessible to all community members, regardless of religion, age, gender, race, or ethnicity • Provisions will be made so that the poorest households will have access to a minimum standard of energy services • Developers will not work within communities where the electricity system will be dominantly utilized by a minority group in processes that support marginalization of the majority or environmental degradation. • The developers recognize the knowledge and culture of the rural community • The technical team of the development organization will spend time within the community, with the HSC team, before the design phase. • The developers will provide honest and accurate information regarding their capabilities, potential project costs, timelines, and system output and lifetimes. • Developers and community members will work together to develop a set of social, economic, cultural, and environmental metrics that will be used to evaluate the impact of electrification, and used to modify the system and implementation, as needed. • The regional government will commit to supporting the monitoring of the design, implementation, and utilization of the electricity system, holding developers accountable to social and environmental standards. • The developers will commit to providing a service contract to the community, explained through a community meeting, with clear and accessible manners for contacting them.

Table 10: Example of aspects that might be addressed within a code of ethics for rural electrification within a particular community

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7 References

Adair-Rohani, H., Zukor, K., Bonjour, S., Wilburn, S., Kuesel, A. C., Hebert, R., & Fletcher, E. R. (2013). Limited electricity access in health facilities of sub-Saharan Africa: a systematic review of data on electricity access, sources, and reliability. *Global Health: Science and Practice*, *1*(2), 249–261.

Barnes, D. F., & Floor, W. M. (1996). Rural energy in developing countries: A challenge for economic development. *Annual Review of Energy and the Environment*, *21*.

Bazilian, M., Nussbaumer, P., Gualberti, G., Haites, E., Levi, M., Siegel, J., … Fenhann, J. (2011). Informing the Financing of Universal Energy Access: An Assessment of Current Financial Flows. *The Electricity Journal*.

Bhattacharya, S. (Ed.). (2013). *Rural electrification through decentralized off-grid systems in developing countries*. London: Springer.

Boland, J. J., & Whittington, D. (1998). The political economy of increasing block tariffs in developing countries. In *World Bank Sponsored Workshop on Political Economy of Water Pricing Implementation, Washington, DC*.

Bose, S. (1993). *Money, energy and welfare: the state and the household in India's rural electrification policy*. Oxford University Press, USA.

Bousquet, F., Trébuil, G., & Hardy, B. (2005). *Companion modeling and multi-agent systems for integrated natural resource management in Asia*. Philippines: International Rice Research Institute.

Cabraal, R. A., Barnes, D. F., & Agarwal, S. G. (2005). Productive uses of energy for rural development. *Annual Review of Environment and Resources*, *30*, 117–144.

Casillas, C. E. (2012). *Rural electrification, climate change, and local economies: Facilitating communication in development policy and practice on Nicaragua's Atlantic Coast* (PhD Dissertation). University of California, Berkeley, Berkeley, CA.

Casillas, C. E., & Kammen, D. M. (2011). The delivery of low-cost, low-carbon rural energy services. *Energy Policy*, *39*(8), 4520–4528.

Cecelski, E. (2000). *Enabling equitable access to rural electrification: current thinking and major activities in energy, poverty and gender* (Briefing Paper) (pp. 2–3). Washington DC: The World Bank.

Chambers, R. (1994). The origins and practice of participatory rural appraisal. *World Development*, *22*(7), 953–969.

Cooke, B., & Kothari, U. (2001). *Participation: the new tyranny?* Zed Books.

Cornwall, A. (2006). Historical perspectives on participation in development. *Commonwealth & Comparative Politics*, *44*(1), 62–83.

Cornwall, A., & Jewkes, R. (1995). What is participatory research? *Social Science & Medicine*, *41*(12), 1667–1676.

Crase, L., O'Keefe, S., & Burston, J. (2007). Inclining block tariffs for urban water. *Agenda*, *14*(1), 69–80.

Deshmukh, R., Carvallo, J. P., & Gambhir, A. (2013). Sustainable Development of Renewable Energy Mini-grids for Energy Access: A Framework for Policy Design. *LBNL Report Number (LBNL-6222E)*.

Flavin, C., & Aeck, M. H. (2005). *Energy for Development: The Potential Role of Renewable Energy in Meeting the Millennium Development Goals*. Worldwatch Institute.

Foster, V., & Yepes, T. (2006). *Is cost recovery a feasible objective for water and electricity? The Latin American experience* (No. WPS3943). The World Bank.

Gowda, M. C., Raghavan, G. S. V., Ranganna, B., & Barrington, S. (1995). Rural waste management in a south Indian village–A case study. *Bioresource Technology*, *53*(2), 157–164.

Hart, G. (2004). Geography and development: critical ethnographies. *Progress in Human Geography*, *28*(1), 91–100.

Hickey, S., & Mohan, G. (2004). *Participation: from tyranny to transformation?: exploring new approaches to participation in development*. Zed books.

Hickey, S., & Mohan, G. (2005). Relocating participation within a radical politics of development. *Development and Change*, *36*(2), 237–262.

IEA. (2013). *World Energy Outlook*. Paris, France: International Energy Agency.

IEG. (2008). *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits*. Washington DC: The World Bank.

Kammen, D. M., Bailis, R., & Herzog, A. V. (2001a). Clean energy for development and economic growth: Biomass and other renewable energy options to meet energy and development needs in poor nations. In *UNDP report for the 7th Conference of the Parties to the UN Framework Convention on Climate Change (COP7-UNFCCC): Marakech, Morocco (October 29-November 9)* (Vol. 111).

Kammen, D. M., Bailis, R., & Herzog, A. V. (2001b). Clean energy for development and economic growth: Biomass and other renewable energy options to meet energy and development needs in poor nations. In *UNDP report for the 7th Conference of the Parties to the UN Framework Convention on Climate Change (COP7-UNFCCC): Marakech, Morocco (October 29-November 9)* (Vol. 111).

Khandker, S. R., Barnes, D. F., & Samad, H. A. (2013). Welfare Impacts of Rural Electrification: A Panel Data Analysis from Vietnam. *Economic Development and Cultural Change*, *61*(3), 659–692.

Kirubi, C., Jacobson, A., Kammen, D. M., & Mills, A. (2009). Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya. *World Development*, *37*(7), 1208–1221.

Liming, H. (2009). Financing rural renewable energy: A comparison between China and India. *Renewable and Sustainable Energy Reviews*, *13*(5), 1096–1103.

Marandin, L., Craig, M., Casillas, C. E., & Sumanik-Leary, J. (2013). *Market analysis of small-scale wind power in Nicaragua 2012-2013*. Managua: Green Empowerment.

Modi, V., McDade, S., Lallement, D., & Saghir, J. (2005). *Energy services for the Millennium Development goals*. New York, NY (EUA).

Pachauri, S., & Jiang, L. (2008). The household energy transition in India and China. *Energy Policy*, *36*(11), 4022–4035.

Platteau, J. P. (2004). Monitoring Elite Capture in Community-Driven Development. *Development and Change*, *35*(2), 223–246.

Practical Action. (2012). *Poor people's energy outlook 2012: Energy for earning a living*. Rugby, UK: Practical Action Publishing.

Rolland, S., & Glania, G. (2011). Hybrid mini-grids for rural electrification: Lessons learned. *Alliance for Rural Electrification (ARE), Brussels, Belgium, Mar*.

Schnitzer, D., Lounsbury, D., Carvallo, J. P., Deshmukh, R., Apt, J., & Kammen, D. M. (2014). *Microgrids for rural electrification: a critical review of best practices based on seven case studies*. United Nations.

Singh, S. (2009). World Bank-directed Development? Negotiating Participation in the Nam Theun 2 Hydropower Project in Laos. *Development and Change*, *40*(3), 487–507.

Soto, D., Adkins, E., Basinger, M., Menon, R., Rodriguez-Sanchez, S., Owczarek, N., … Modi, V. (2012). A prepaid architecture for solar electricity delivery in rural areas. In *Proceedings of the Fifth International Conference on Information and Communication Technologies and Development* (pp. 130–138). ACM.

Tewari, D. D., & Shah, T. (2003). An assessment of south african prepaid electricity experiment, lessons learned, and their policy implications for developing countries. *Energy Policy*, *31*(9), 911–927.

UNDP. (2010). *Energy for a Sustainable Future: The Secretary-General's Advisory Group on Energy and Climate Change Summary Report and Recommendations*. New York: UNDP.

United Nations Department of Economic and Social Affairs. (2007). *Small-Scale Production and Use of Liquid Biofuels in Sub-Saharan Africa: Perspectives for Sustainable Development* (Background Paper). New York.

Vaghela, D. (2010). Transformative participation in community micro hydro: Gram Vikas micro hydro projects. *E-Net*, *1*.

White, S. C. (1996). Depoliticising Development: The Uses and Abuses of Participation. *Development in Practice*, *6*(1), 6–15.

Yang, M. (2003). China's rural electrification and poverty reduction. *Energy Policy*, *31*(3), 283–295.