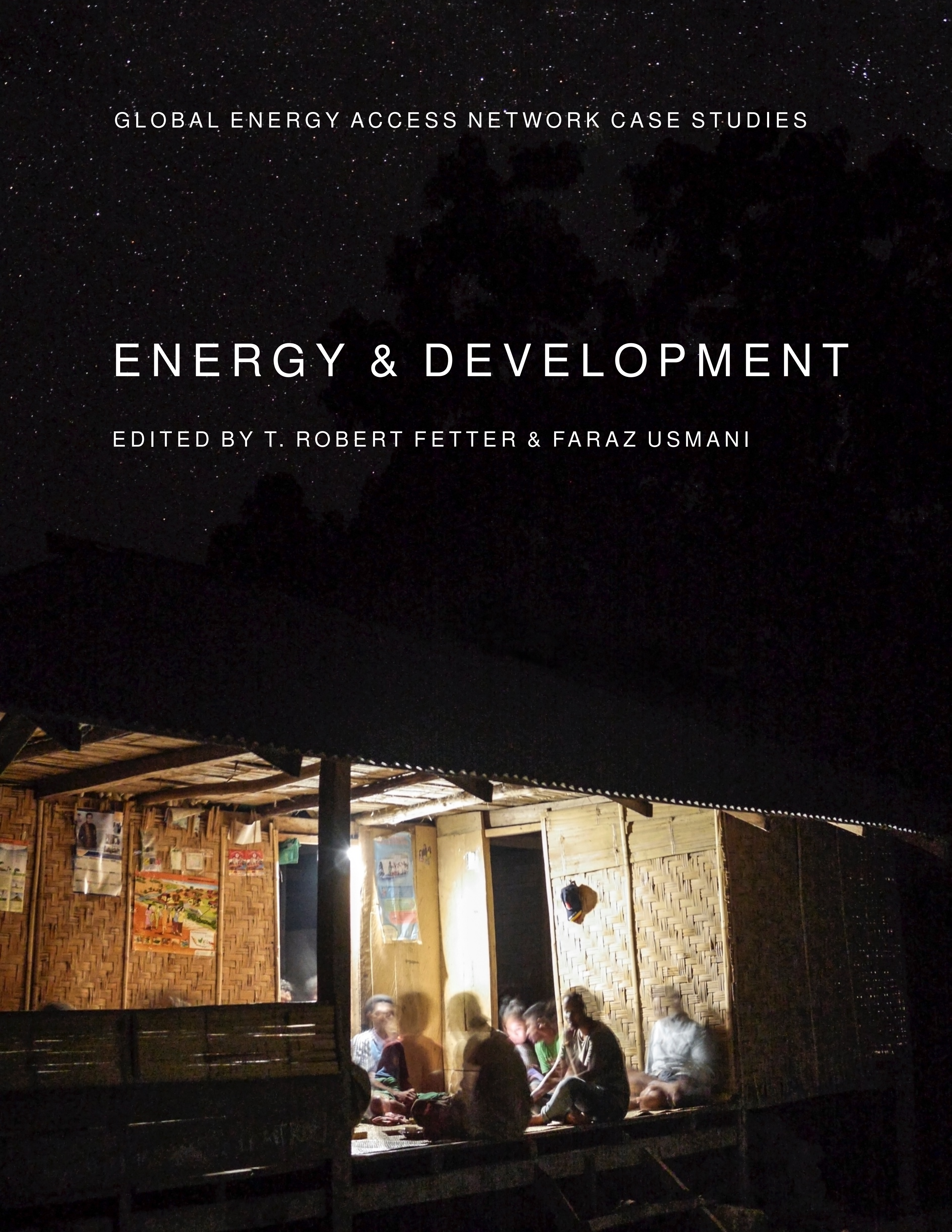
GLOBAL ENERGY ACCESS NETWORK CASE STUDIES

ENERGY & DEVELOPMENT

EDITED BY T. ROBERT FETTER & FARAZ USMANI



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Contents

Introduction

T. Robert Fetter & Faraz Usmani

T. Robert Fetter (rob.fetter@duke.edu) is a Senior Policy Associate at the Nicholas Institute for Environmental Policy Solutions at Duke University. Faraz Usmani (faraz.usmani@duke.edu) is a doctoral candidate at Duke University's Nicholas School of the Environment, and a Doctoral Student Fellow at the Duke University Energy Initiative.

Access to reliable, safe, affordable, and sustainable energy is fundamental to achieving economic growth, social equity, political stability, and environmental sustainability. Yet billions of people live in energy poverty: forty percent of the world's population depend on solid fuels and dirty technologies for lighting, cooking and heating (WHO, 2016c), fifteen percent of the globe lives without any electricity, and many more have only intermittent electricity supply and consume energy at very low levels (IEA and World Bank, 2015).

This lack of energy access has profound implications for economic growth and equity. Electricity is indispensable for household activities, health clinics, schools, and successful enterprises; it is foundational in promoting health, education, and livelihoods. Even in locations with some access to electricity, frequent service disruptions constrict activities that enhance productivity and generate income. In addition to economic effects, lack of energy access has adverse effects on human health and the environment. Household air pollution caused by the use of dirty fuels for cooking, heating, and lighting causes over four million premature deaths annually, a health burden borne largely by the poor in low-income countries (Mills, 2012; WHO, 2016c). The use of dirty fuels also causes environmental degradation; for instance, burning solid fuels results in higher emissions of "black carbon," an exceptionally potent contributor to climate change that is already impacting millions by disrupting weather patterns and accelerating glacial melt in vulnerable regions.

The Duke University Global Energy Access Network (GLEAN) was formed in May 2016 to bring together graduate and undergraduate students working on global energy transitions, energy access, and energy poverty. GLEAN provides a forum for students to explore shared interests, learn from experienced researchers and practitioners, and build a platform of data and information as a hub for ongoing energy access research and engagement activities at Duke and beyond. Ultimately, we aim to ignite a research and policy dialogue around an unfortunately understudied global issue, and to help position Duke as a central contributor to that dialogue within a global network.

GLEAN is housed at the Duke University Energy Initiative,[1] Duke's interdisciplinary hub for energy research, education, and engagement. The Energy Initiative nominated GLEAN to receive a generous Duke Support for Interdisciplinary Graduate Networks (D-SIGN) grant from the Office of the Vice Provost for Interdisciplinary Studies in 2016-17.

[1] http://energy.duke.edu/

The present volume represents the culmination of one of GLEAN's central initiatives in our inaugural year. We observed that many of our student members had previously worked in areas of poor or missing energy access, even if the projects that brought them to those communities were not directly related to energy access. We sought to take advantage of students' contextual knowledge from these experiences, and provide a forum for them to share their latent experiences widely with others.

We also sought to offer qualitative perspectives on different aspects of the energy access puzzle. Much of the existing research on energy access is quantitative in nature: measurement of rural householders' willingness-to-pay for grid connections, baseline and post-intervention health measures before and after a cookstove dissemination program, or assessments of earnings and education before and after a policy change. These quantitative assessments are undeniably useful—indeed, many of the studies in this volume rely on quantitative measures—but may also mask critical insights that can be gleaned from descriptive stories of community conditions, or reflections on implementation dynamics within and among the organizations that craft and implement interventions on the ground. In addition, reflecting on these narrative stories can assist readers to cultivate innovative ideas—including solutions to address the needs of organizations or affected communities, or interesting new questions to pursue in future research—in ways that may not come about by reviewing research reports that focus on narrower, more specific questions.

The six vignettes in this volume address a diverse set of topics related to energy access. They span five countries (India, Indonesia, Madagascar, Nicaragua, and Peru), primarily in rural areas, but sometimes address issues in urban areas as well. The entities featured in these stories include local and state governments, community-based organizations, and non-governmental organizations (NGOs). Topically, they address a variety of technologies, including solar, wind, and hydroelectric power, as well as improved cookstoves. The issues discussed range from financial viability of utility providers, to relationships between local community members and distant institutions, to the gap that sometimes persists between householders' beliefs and "expert knowledge." Throughout, the authors highlight the richness of the setting and context even as they focus in on issues specific to energy access.

Though the chapters address a diverse array of geographic and thematic contexts, they have some common themes. Four themes seem particularly prominent across most or all of the case studies, namely:

1. Where formal governmental entities have struggled to provide adequate services, local organizations can play a substantial role in meeting communities' needs in ways that may yield unanticipated positive consequences. (This seems particularly evident in the chapters by Tyler Wakefield, Sushmita Samaddar, and Aashna Aggarwal and co-authors.)

2. Involving local community members is often critical for long-term project viability. This includes local involvement in developing the overall strategy (Tyler Wakefield) and adaptive iterations of the strategy (Aashna Aggarwal and co-authors); providing mechanisms to ensure local accountability (Samantha Childress); and working with local leaders (Emily Rains; Sushmita Samaddar).

3. The tactics used to persuade local community members to take up new technologies should correspond to local needs, understandings, and beliefs. For instance, both Erin Litzow and co-authors, and Sushmita Samaddar find that households seem more likely to take up improved cookstoves when the marketing tactics focus on time savings, rather than household air quality benefits.

4. Although providing energy access offers useful community benefits, in some ways the act of any form of community gathering that results in the execution of a community project generates a "coming together" effect that, in itself, offers community benefits. (This seems particularly prominent in the studies by Tyler Wakefield, Aashna Aggarwal and co-authors, and Samantha Childress.)

During the iterative process of compiling and editing the studies in this volume, several authors noted that the process of developing their case studies helped them reflect on topics that could be usefully addressed in follow on work. Indeed, every one of our authors is currently pursuing follow-up research in the communities they describe here, or similar themes in closely related communities; in several cases the authors' follow-on inquiry is directly inspired by reflections that occurred to them in the process of writing these chapters in this volume. As editors we, too, have been inspired in new directions as we reflect on the stories contained here. We hope the same will be true for you.

Paying for Power: The Political Economy of Energy Insolvency in Bihar, India

Emily Rains

Emily Rains (emily.rains@duke.edu) is a doctoral student at Duke University's Sanford School of Public Policy.

A GROWING BODY of evidence demonstrates the importance of energy access for human development.[2] The vast majority of growth in energy demand in the coming decades will occur in low-income countries, where over a billion people require connections and energy demand is expected to increase exponentially (Wolfram et al., 2012). These demand projections have led policymakers to view energy poverty with an "increasing sense of urgency" (Lee et al., 2016b).

Financing public utilities remains a formidable challenge in the developing world.[3] Energy utilities have accrued substantial debts in resource-poor contexts at the expense of investment in other public goods that are necessary for human development. Consequently, a growing body of work has focused on measuring and increasing consumer willingness to pay for power as well as reducing government costs to supplying power (Abdullah and Jeanty, 2011; Barron and Torero, 2015; Bernard and Torero, 2013; Bose and Shukla, 2001; Dossani and Ranganathan, 2004; Lee et al., 2016a,b).

Yet these studies largely take government capacity or willingness to collect revenues from consumers for granted. This case study discusses an intervention introduced by the public energy utility in Bihar, India, in an effort to increase revenue collection. Considering government capacity to collect revenues is a crucial—and oft-overlooked—policy issue that could pose substantial barriers to sustainable electrification.

[2] For example, analysis in South Africa revealed electrification significantly raised female employment outcomes in the short and medium term (Dinkelman, 2011). Recent studies of the effects of electrification in rural Vietnam and Bangladesh found positive impacts on education levels and income (Khandker, 2012; Khandker et al., 2013). Energy access also affects health outcomes through several channels, including improved air quality, improvements of health facilities, and better nutrition through food storage options (Ezzati and Baumgartner, 2017; IEG, 2008).

[3] Reports estimate that debts from India's publicly run energy utilities cost the country three percent of GDP. See, for example: http://wapo.st/1PfEz9L

Energy Poverty in Bihar, India

Bihar, displayed in Figure 1, is one of India's poorest states. The majority of its approximately 100 million people live on less than $1.25 per day (World Bank, 2014). Furthermore, Bihar's government institutions are among the weakest of all Indian states (Asadullah and Yalonetzky, 2012). Improved governance and inclusive growth policies have led to rapid development over the last ten years, but the government continues to face arduous tasks in combating poverty and strengthening service delivery (Singh and Stern, 2015; Witsoe, 2013). Bihar therefore provides a compelling case to examine the role of government capacity in barriers to sustainable electrification.

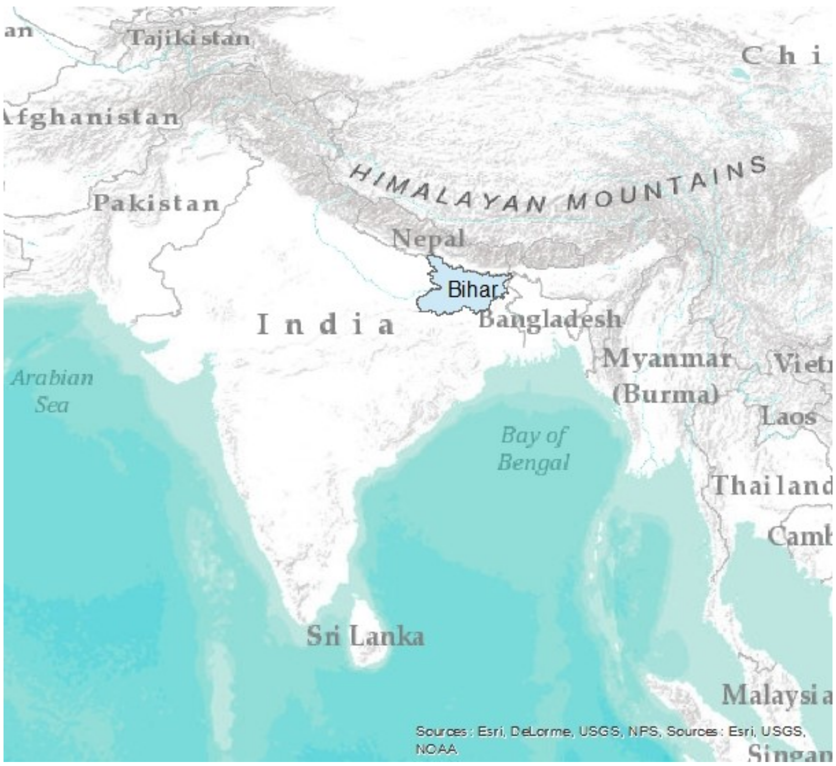

Figure 1: Map of Bihar

Bihar is ninety percent rural, and much of the development focus of the past ten years has been on rural areas (Census of India, 2011; DFID, 2011). However, energy poverty, especially in rural areas, remains a pressing problem. Recent estimates conclude that 64 million people in the state live without access to energy (IEA, 2015). For the minority with formal electricity connections, supply is erratic. A study from 2015 estimates that nearly 80 percent of rural consumers with connections have under 4 hours of access per day (Jain et al., 2015). It follows that per capita consumption is lower than in any other Indian state; average residential consumption is estimated to be "consistent with an average household use of a fan, a mobile telephone and two compact fluorescent light bulbs for less than five hours per day" (IEA, 2015, p. 21). Not only does deficient energy supply pose obstacles to human development, but the neglect of dilapidated infrastructure poses a serious public health risk, causing avoidable injuries and deaths from exposure to live wires.[4]

[4] Selected (and not exhaustive) examples of headlines from Hindustan Times Patna during 2014 include the following: "Power firm pays compensation to electric shock victims," "Livewire snaps in Jamui, 6 kids dead," "3 electrocuted in Samastipur village," "Electric shock claims three lives in Siwan," "Irate mob torches train after student's death in Saharsa," and "Live wire ends schoolgirl's life, 3 others injured."

Sustainability, Equity, and Efficiency

Financing public utilities remains an imposing challenge in Bihar, as well as elsewhere in the developing world. Public economics literature theorizes that financial insolvency can lead to a low-level equilibrium of utility provision (Savedoff and Spiller, 1999; Singh et al., 1993; Strand, 2012). The low-level equilibrium is characterized by low prices for consumers, limited provision, and low quality services. While low consumer prices may seem equitable for low-income consumers, limited revenue collection can undermine government ability and willingness to improve infrastructure quality and reach (McRae, 2015; Tiger et al., 2014). As summarized by Whittington (2003):

> "At first glance [low pricing] appears to be good for households and bad for the utility, but low revenues for the utility rebound to adversely affect households. Low revenues mean that utilities lack (1) the resources to provide high quality, reliable [public] services and (2) the financial incentives to extend service to unconnected households."

The data suggest Bihar may be stuck in a low-level equilibrium, with financial insolvency inhibiting the government's ability to invest in improvements. Millions of citizens are disconnected from the grid, quality is lacking, and the publicly run energy company owes as much as $66 billion in debt to the central government.[5]

[5] http://wapo.st/1PfEz9L

The Energy Secretary estimates the public utility loses thirty percent of the amount it expects to collect due to distribution losses, but independent analysts suggest this amount may be considerably higher.[6] In qualitative interviews in rural districts, state company engineers cited even more troubling figures of estimated losses up to 77 and even 91 percent.[7]

[6] Ibid.

[7] Engineers estimated up to 77 and 91 percent losses in parts of Muzaffarpur and Saharsa districts. Interviews were conducted on February 12, 2014 and between February 25-27, 2014.

Financial losses can occur due to breakdowns at any step of the electricity distribution chain (examples are illustrated in Figure 2). For every dollar that the utility expects to recover, if—for instance—ten cents worth of energy is lost to burnt transformers, ten cents is lost to illegal connections, and ten cents is not collected, then the utility fails to recover thirty percent of expected revenue. Breakdowns at all steps of the distribution chain can contribute to insolvency in this way, adding to the erratic supply and dangerous infrastructure conditions. While it is clear that the magnitude of losses is substantial, neither the exact statewide amount nor the exact causes of losses are known.

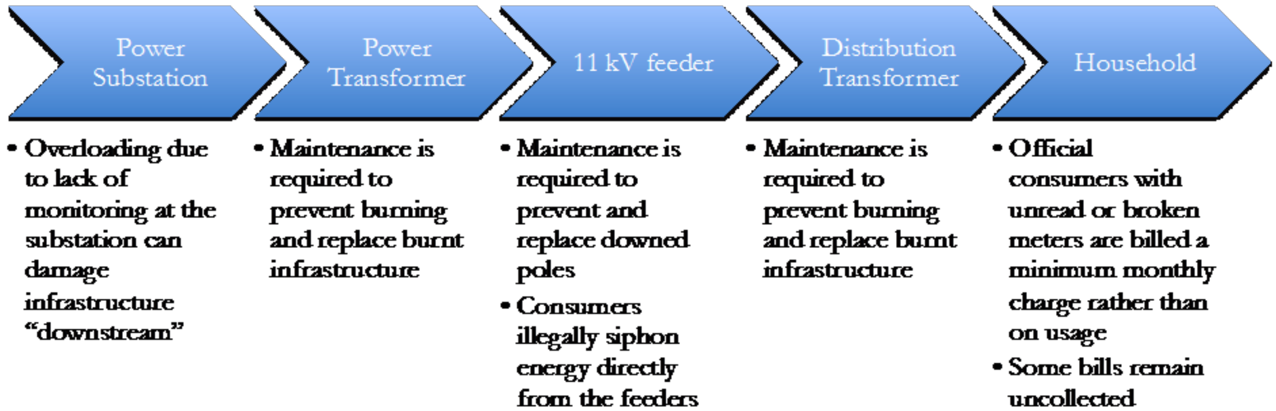

Figure 2: Distribution and cost recovery chain

Policy Interventions to Improve Revenue Collection

In 2013, Bihar's public utility implemented a policy in an attempt to improve revenue collection. The policy, called the rural revenue franchisee (RRF) program, authorized the utility to hire local contractors to perform meter reading, bill distribution, and collect bills from consumers in rural areas. The local contractors were offered an incentive of six percent of all revenue collected. This program differed from the status quo in several ways, as summarized in Table 1. Before the RRF program was introduced, local state-utility engineers were expected to read meters and distribute bills as one of their many responsibilities, with no direct financial incentive for better performance. Engineers were not required to collect bills directly from households and the onus of bill payment was on the consumer, who was supposed to either pay in person, over the phone, or online. Hypothetically, consumers should be incentivized to pay their bills in order to avoid disconnection by the power company. However, field interviews with engineers revealed that disconnection is exceedingly rare for small domestic consumers in Bihar.[8]

In order to evaluate the impact of the RRF program on meter reading and revenue collection, administrative units were randomly assigned to a treatment or control group. The treatment group was instructed to outsource billing responsibilities to local contractors ("revenue franchisees"). The control group maintained the status quo. The study was administered in 62 rural sections in ten of Bihar's 38 districts.[9] The ten districts were selected to represent central and remote districts, varying linguistic traditions, literacy rates, and population sizes.[10]

Administrative data from the private agencies that maintain billing data for all of Bihar were collected and aggregated for the period August 2013 to July 2014. These data are electronic and are financially audited by the government, making them a reliable record of household-level consumption, billing, and payment. For the 62 study sections, the data

[8] For example, engineers explain in interviews in Fatuha district (February 5, 2014) that there are too many nonpayers to disconnect each month, so they focus on disconnecting the largest consumers.

[9] Sections are the energy utility's smallest administrative unit. A section covers multiple rural villages. The number of villages ranges by section. The average number of official energy consumers in the study sections is approximately 11,000.

[10] Details of the study are provided in a working paper (Rains et al., 2017).

	Status quo	Rural revenue franchisee
Meter reading	Local energy company employee	Revenue franchisee
Bill distribution	Local energy company employee	Revenue franchisee
Standard revenue collection mechanisms	Collection counters, rural banks, online, over the phone, etc.	
Additional revenue collection mechanisms		Revenue franchisee household visits

Table 1: Comparison of revenue collection process under status quo and RRF program

contain information for over 700,000 rural domestic consumers with formal electricity connections. Before roll-out of the policy in these study areas (in March 2014), the treatment and control sections were balanced on important observable characteristics—thus ensuring that the only important difference was the RRF program itself. Average characteristics across all sections are displayed in Table 2.

Before implementing the policy, the government collected only 39 percent of the amount billed on average in these areas. This is a daunting figure. Bill collection is the last link in the distribution and cost recovery chain. Thus, losses due to technical issues, informal connections, billing on minimum charges rather than according to metered use, and other issues would lead the actual amount recovered to be substantially lower. This implies a formidable consequence for equilibrium payments to the utility and, thus, its long-term fiscal sustainability.

Did the RRF program reduce these losses in the sample areas? The evidence suggests that within the first four months, revenue franchisees were significantly more likely to collect bills from small, hard to reach rural consumers than the energy engineers were. Examining impacts by quartile of baseline bill size reveals that the most significant gain in payment under the RRF program was from consumers in the second quartile (i.e., those who were billed less than the median consumer, but not the lowest amount).[11] For these groups, each additional franchisee increased revenue collection by seven percentage points and expanded the base of paying consumers by one percentage point on average. For instance, if a section hires one revenue franchisee per 1,000 consumers, the program is expected to expand the proportion of paying consumers for this subgroup from 15 to 30 percent.

[11] Consumers are assigned to quartiles based on bill size before the RRF program was implemented. Unmetered consumers and metered consumers whose bills were not read are billed a minimum monthly charge, rather than on actual energy consumption.

Notably, in sections affected by the RRF treatment, the number of

Characteristic	Average
Proportion of population below poverty line	44 percent
Bi-monthly bill amount	376 rupees (~ $6)
Bi-monthly bill collection	148 rupees (~ $2)

Table 2: Baseline consumer characteristics

meters read decreased significantly. This impact was largest for second and third-quartile consumers (i.e., those who were billed somewhat less than, somewhat more than or at the median bill level). The proportion of paying consumers significantly increased for those whose meters went unread. Taken together, the evidence suggests that relative to the status quo, the revenue franchisees diverted attention away from slightly larger, metered consumers to smaller consumers billed on minimum amounts.

Overall, however, the increase in collection was minimal—even among the second quartile, who showed the most responsiveness to the RRF policy—compared with the amount that would be recovered if all consumers paid their bills. Four months after implementation, just 32 percent of formally connected consumers in these rural districts paid a bill. This suggests that expanding the base of official consumers who are paying for power, even in the absence of other changes, may considerably improve financial sustainability. The deficiency in bills collected in this context has important implications for scholars and practitioners studying barriers to sustainable electrification in Bihar, and perhaps in other contexts as well.

Discussion

What are the important lessons that emerge from this policy and this context? A key insight is that institutional failures—both among those who set policy, and those who implement it—must be incorporated into plans for and analyses of efforts promoting sustainable electrification. Three specific lessons seem most relevant. First, the ability and willingness of government agencies to collect revenues should not be taken for granted. Second, consumers' ability to pay their bills should not be conflated with the incentive or inclination to pay. Finally, decision makers at all levels should consider both political and social feasibility (and resistance) when crafting plans for service provision. The following sections offer more discussion of each of these ideas in turn.

Government ability and willingness to collect revenues

The Bihar RRF program aimed to improve bill collection for small rural consumers with formal grid connections. For the sample studied, revenue collection is unsustainably low—both before and after the program, although higher with the program. On average only about one-third of the households sampled paid any bill amount during the 12-month study period. How can collection be so low? Evidence and theory suggest that both limited capacity and limited political will can thwart implementation efforts.

Scholars attribute failures of public service delivery in India to absenteeism, inertia, and corruption among the field officers responsible for implementation (e.g., Pritchett, 2009). The World Bank cites chronic absenteeism among public sector employees and lack of monitoring as challenges to development in Bihar in particular, and asserts that Bihar's absenteeism rates among public sector employees are among the highest in India (World Bank, 2005). Scholars have also noted that implementation of public service delivery in Bihar has been particularly ineffective in the past, arguing that in previous political administrations, elected politicians intentionally undermined the effectiveness of bureaucratic institutions (Witsoe, 2013). Institutions have become stronger under the current political regime, but low levels of revenue collection and infrastructure maintenance reflect enduring institutional inertia.

In addition to issues of institutional capacity, some studies suggest that elected government leaders may lack the political will to enforce contracts with voters, especially (though not exclusively) close to election dates. In a different setting (Latin America), Holland (2016) argues that politicians intentionally allow illegal encroachment in order to garner political support from informal workers. Min and Golden (2014) find that losses from electricity theft in Uttar Pradesh follow an electoral cycle, suggesting politicians pardon energy theft as a campaign strategy. These studies provide cautionary evidence that one should also not take political willingness to collect as given.

In the Bihar RRF context, offering a simple incentive to local contractors to collect bills from consumers had a measurable impact on collection from small consumers, who previously were not incentivized to pay. Given the effects of this simple incentive, it is clear that the decidedly low levels of collection before were likely a product of limited government capacity or will to collect. At the same time, the gains from the RRF incentive program were modest, suggesting additional or modified incentives may be necessary to further increase revenues.

Ability to pay and willingness to pay

The results of analyzing Bihar's RRF policy suggest that the consumers who began paying their bills under the new policy, while not incentivized to pay for electricity under the status quo, were willing to pay when requested by the franchisees. The results of this analysis suggest that some consumers had the ability to pay before the policy, but not the willingness to do so—since they did not pay under the old policy, but did pay under the RRF policy (i.e., when requested by the franchisees). Yet, policymakers and researchers have expressed concerns with demand in developing countries. Consumer willingness to pay for power is an active area of research (Abdullah and Jeanty, 2011; Barron and Torero, 2015; Bernard and Torero, 2013; Bose and Shukla, 2001; Dossani and

Ranganathan, 2004; Lee et al., 2016a,b).

At least for some consumers, such as those who began paying for electricity under the RRF program, not being willing to pay may pose less of a problem to solvency than not having motivation to pay. Other sources suggest that at least some consumers are willing to pay for power in Bihar. Studies show that the rural poor in Bihar are willing to pay for energy, especially for reliable energy (Boyle, 2010; IEG, 2008). In field interviews with energy company engineers as well as with consumers, respondents note that more people want to be connected to the grid in Bihar than the government has the capacity to accommodate at any given time.[12] Wealthier residents of nonelectrified villages reveal willingness to pay for power by investing their own money in solar panels.[13] In one field visit to the district of Saharsa, villagers recounted their collective action story: their village was electrified but their houses were not, and when they lost patience with the government, they came together to finance a private contractor to build poles and connect them to the grid.[14] Needless to say, willingness to pay for power may not be the most pressing challenge to revenue collection in this context.

[12] As discussed in interviews with revenue franchisees, engineers and consumers in field interviews in Fatuha, Muzzafarpur, and Saharsa.

[13] See https://www.scientificamerican.com/article/coal-trumps-solar-in-india/ and http://wapo.st/1PfEz9L.

[14] As discussed in interviews in Saharsa (February 25, 2012–February 27, 2014).

Studies of willingness to pay not only assess whether nonpayers will be willing to pay for connections, but also whether consumers are willing to pay for tariff increases. Some policymakers and scholars assert that tariff hikes may be key to reducing deficits and promoting long term fiscal health (e.g., Dossani and Ranganathan, 2004). While this may be necessary in the long run, tariff hikes in a context of scarce repayment may not be the optimal first policy step. In the area of this study, one can infer that increasing tariffs without expanding the payment base would likely impose an even higher burden on the minority of households who regularly pay without increasing collection from the majority who are nonpayers.

Political feasibility and fiscal sustainability

Furthermore, while technocrats and scholars often propose price increases, tariff increases are extremely unpopular and may be politically infeasible. Tariff increases proposed by bureaucrats in Bihar in the months prior to implementation of the RRF program were met with resistance. Political parties led protests against the proposed hikes, and the plans ultimately fell through.[15]

[15] Selected (and not exhaustive) examples of headlines from Hindustan Times Patna during January and February 2014 include the following: "CPI's Bihar bandh today to protest power tarif," "Left parties protest power woes during bandh," "ML's Bihar Bandh on Feb 23 Over Power Tariff" and "Politics over power gains momentum in Vaishali." These were followed by the announcement on March 1, 2014 that there would be no tariff increase: "Relief for consumers as no hike in power tariff."

Another potentially challenging approach to reducing deficits is to adopt cheaper technologies. Scholars, and some NGOs, emphasize non-grid alternatives as a more economically viable option for rural electrification than grid expansion (Boyle, 2010; Oda and Tsujita, 2011). In fact, ongoing research in Bihar focuses on measuring the demand for and benefits of solar microgrids (Ryan et al., 2014).[16] However, it is

[16] Nevertheless, as the WindAid case study in this volume notes, even in a small and tightly knit community, microgrids can still suffer from free-rider problems.

important to predict the community political response when considering whether consumers will be interested in or satisfied with these more cost-effective alternatives.

The Chief Minister of Bihar from 2005-2014, and again from 2015, has made grid electrification a pillar of his platform. For instance, he promised he would not seek reelection in 2015 if Bihar were not fully electrified—a broken promise that has elicited censure from opposing politicians and intensified commitments from the current administration.[17] Given the political sensitivity around grid expansion, it should not be assumed that these alternatives would be politically viable. An illustrative example is the case of Greenpeace's solar experiment in Bihar's Dharnai village. In 2014, Greenpeace installed a solar micro grid in Dharnai. Residents were unsatisfied with the amount of power supplied for the cost. When the Chief Minister came to inaugurate the solar village, residents protested, "We want real electricity, not fake electricity!"[18] A week later, the village was connected to the grid.

[17] For example, in Hindustan Times Patna's January 18, 2014 article, "CPI's Bihar bandh today to protest power tariff," the paper reports the CPI state secretary publicly reminded Nitish Kumar of his promise not to run for reelection if he did not electrify every village—also see http://bit.ly/2pDmo4M; http://bit.ly/2pFWZcQ; and http://bit.ly/1nPUFf6.

[18] https://www.scientificamerican.com/article/coal-trumps-solar-in-india/

Political feasibility and citizen expectations condition the options available to policymakers and should be carefully considered when developing policy solutions. In this context, electrification is a salient political issue, and collective resistance to increasing prices and cheaper technologies may influence political decisions. The evidence that revenue collection is scant but consumers appear willing to pay suggests increasing collection efficiency may be more politically viable than raising tariffs or adopting off grid technology.

Augmenting incentives like the RRF program to include motivations for meter reading and reaching remote consumers may optimally increase revenues while maintaining political capital. To the extent that politically attractive solutions are not sufficient for creating sustainable systems, unpopular solutions should either be reframed or compromises must be made. Ignoring politics in the policy design calculus will likely lead to continued policy failures.

Implications for Future Enquiry

Financial sustainability is crucial for expanding and maintaining electricity access in the Global South. Policymakers and analysts have studied and proposed solutions around assessing willingness to pay, increasing tariffs, and reducing costs with less expensive, non-grid alternatives. However, these studies largely take for granted government capacity and willingness to collect energy bills from consumers.

Future work on electrification in Bihar and similar contexts should evaluate ways to improve accountability of the government employees in charge of distribution. This case study highlights several issues relevant to assessing the challenges of bill collection and fiscal sustainability, and also identifies one possible—but ultimately partial—solution. Direct incentives for bill collectors work to encourage state engineers to follow through on revenue collection and thus provide funds required for infrastructure maintenance, but they may not be able to solve the whole problem.

More generally, this case study suggests that the political economy of service provision should be incorporated into designing electrification interventions and analyzing program effectiveness. Discussions of low-level equilibria in the context of the infrastructure quality trap should consider not only low rates, but also agencies' limited capacity or will to collect revenues. Similarly, discussions of non-grid alternatives should consider not only consumer willingness to pay for alternatives, but also consumer willingness to accept a non-grid solution—especially one led by a central government. The case of Bihar illustrates that paying for power poses a formidable and complex impediment to universal energy access.

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Challenges in the Implementation of an Improved Cookstove Program in Rural India

Sushmita Samaddar

Sushmita Samaddar (sushmita.samaddar@duke.edu) is a Master of Public Policy candidate at Duke University's Sanford School of Public Policy.

Nearly three billion people—primarily in developing countries—rely on solid fuels such as fuelwood, dung, agricultural residue, and coal to meet their primary energy needs (Duflo et al., 2008; Lewis and Pattanayak, 2012). Cooking and heating with dirty fuels leads to 4.3 million premature deaths annually—more than HIV/AIDS, tuberculosis, and malaria combined; women and children are disproportionately affected (Lim et al., 2013; WHO, 2016c).

Adoption of improved cookstoves (ICS) and fuels may help reduce deaths from smoke-related illnesses by improving household air quality and mitigate climate change by lowering greenhouse gas emissions. The use of ICS can also deliver additional welfare benefits: reduction in time spent cooking, or time spent collecting and preparing fuel for combustion. These time savings can be allocated to productive, income-generating activities by women thus improving household welfare (GACC, 2011).[19]

[19] For instance, in a recent study, Brooks et al. (2016) find that the use of a cleaner stove is associated with daily reductions of 4.5 kg of biomass fuel, as well as 161 fewer minutes spent cooking and 106 fewer minutes spent collecting fuels.

Nonetheless, interventions to encourage adoption of ICS frequently yield relatively low take-up rates. As a result, recent years have seen many new initiatives and developments regarding the promotion of adoption of improved cook-stove technologies. These include increased funding to reduce costs for adopters, small-scale credit operations to ease credit constraints, and the coordination of various activities (including integration of research and practice) through the formation of the Global Alliance for Clean Cookstoves (GACC) (GACC, 2011). The GACC aims to increase ICS adoption by 100 million homes. In addition to these developments, many national governments have started showing more political will to address the issue (MNRE, 2009) and there have been more programs dedicated to the promotion and adoption of clean cookstoves.

While much of the literature has looked at adoption and impacts of ICS, the effectiveness of promotional strategies employed by suppliers of these technologies has received little attention. Implementers of these programs often have to adapt to the field and the context within which they work. This represents a critical knowledge gap regarding the challenges faced by implementers working to introduce new technologies in remote, rural settings. At a minimum, for instance, knowledge sharing among suppliers working in diverse and complex contexts can help identify best practices related to the implementation process. To this end, this case study qualitatively maps out the rural marketing and promotion strategies adopted by a supplier of ICS technologies in rural Rajasthan, India. In so doing, it complements the relatively larger body of knowledge on demand for—and impacts of—these devices by highlighting the experiences on the supply side of the equation.

Project Design

Udaipur Urja Initiatives c/o Seva Mandir, an NGO based in Rajasthan, India started its ICS promotion program in 2013 as a part of the Gold Standard for CDM (GS VER) methodology for carbon offsets.[20] The Voluntary Gold Standard measures high-quality emissions reduction projects in the carbon market, enabling corporations to voluntarily fund the projects that promote sustainable development of local communities. Seva Mandir is a rural development organization based in the Udaipur district of Rajasthan and working with rural communities on education, health, sustainable use of natural resources, women empowerment, youth development and child care for 45 years. The NGO has a strong relationship with the rural communities in Udaipur based on its history of development interventions in these villages.

[20] Carbon offsets allow for reductions in carbon emissions in one setting to compensate for emissions made elsewhere.

Udaipur Urja Initiatives is a for-profit organization c/o Seva Mandir focused exclusively on the sale of improved cookstoves in rural communities as a retailer under the GS VER methodology. As the sole retailer of these cookstoves in Udaipur, the program is focused on the promotion and distribution of these ICS in Udaipur district. In particular, buyers of ICS enter into a contractual agreement with Udaipur Urja, agreeing to a full transition to ICS and going so far as to dismantle their traditional cookstoves. In exchange, Udaipur Urja provides payments for the carbon credits generated by these adjusted energy-use patterns.

Stove Selection

Recognizing that any ICS must cater to beneficiaries' needs, Udaipur Urja chose the ICS technology for its promotion program after a period of extensive pre-testing, where households provided feedback after receiving different types of ICS on a trial and rotational basis. As focus-group discussions conducted prior to the intervention revealed that most households used multiple devices for cooking, Udaipur Urja decided to design its program in line with these energy-use patterns and offer a package of devices. Ultimately, the organization settled on the Greenway Smart Stove and the Greenway Jumbo Stove.

Both devices are single-burner high-efficiency ICS that deliver fuel savings of up to 65 percent in lab settings, minimize harmful emissions of CO, CO_2 and particulate atter ($PM_{2.5}$), and deliver convenient cooking conditions that do not require fuel processing or large changes in cooking habits. In addition, no change in fuel is required—in particular, solid fuels already in use in the communities (such as fuelwood or agricultural waste) can continue to be used. Finally, the combustion mechanisms allow for flexible adjustments in line with the user's needs, further lowering costs of adoption. As the stoves have an expected useful life of up to five years, they have the potential to deliver significant benefits related to health, environment and household time allocation.

Intervention: Promotion and Distribution

In promoting and distributing Greenway stoves among rural households, Udaipur Urja built on its target communities' existing relationships with Seva Mandir (its parent NGO). In particular, staff members—who were previously known to the village through their work with Seva Mandir—centrally coordinated key elements of the campaign. This involved, for instance, village-level meetings to provide information about the new stoves, and signing agreements with households who voluntarily purchased devices at this early stage. This initial promotion strategy was mostly dependent on the pre-existing relationship that practitioners from Seva Mandir had with the village members.

This centralized, village-level approach ultimately gave way to a more decentralized strategy that involved members of the communities themselves. This was partly necessitated by initial adoption rates, which were lower than anticipated. Thus, Udaipur Urja worked to identify local women to serve as leaders and influencers in their respective communities. They were employed and trained by Udaipur Urja as a part of the program to promote and distribute cookstoves in the village. These local influencers (referred to as "monitors") reached out to their peers and other women in the village—a key demographic, as cooking responsibilities largely fall on female members of the household. This person-to-person approach led to a marked rise in membership to the program. Monitors also became responsible for stove distribution, ultimately becoming the face of the product within their communities. Through reliance on key community members, Udaipur Urja fostered a product image that the beneficiaries could relate to, identify with, and invest in.

Monitors also successfully enhanced targeting of the promotion in the villages. Since each village had at least one monitor, program implementation was extremely decentralized in nature. Door-to-door marketing by monitors, for instance, was the primary mode of information dissemination to families who had not attended the village-level meetings or needed reinforced promotion about the devices. Monitors also specifically targeted village leaders who had worked with Seva Mandir in the past fold so as to leverage their influence in the village to build trust in the new products. Whenever possible, monitors relied on in-person demonstrations, including in front of relatively large audiences, such as at schools set up by Seva Mandir. These approaches led to sustained expansions in program membership.

Challenges in Implementation

Somewhat unexpectedly, two national government policies significantly impacted the dynamics of program implementation, and resulted in key challenges for effective program implementation. First, the Government of India launched the Pradhan Mantri Ujjwala Yojana (PMUY), an initiative that provides rural households under the poverty line with a liquefied petroleum gas (LPG) connection free of cost, at approximately the same time as the roll-out of Udaipur Urja's stove promotion programs. Households opting into PMUY were ineligible for the carbon-credits funded Udaipur Urja cookstove program, as these households were technically adopting a cleaner technology with a greater carbon mitigation potential. In addition, the households most likely to adopt the Greenway stove were similar to the households likely to opt for the LPG connections.

Second, the other external challenge to the program was a currency change at the national level in 2016 which demonetized some currency notes. This came as a financial shock to rural households and served to significantly constrain budgets. Accordingly, the price of the cookstove suddenly became a more significant barrier for household adoption—in particular for relatively poorer households, as evidenced by focus group discussions and insights from implementers at Udaipur Urja. Relatively wealthier households appeared to have weathered the monetary constriction better.

Navigating the difficult local terrain to reach households that lived in remote areas provided additional barriers to implementation. Although training monitors within villages decentralized household targeting, monitors themselves were less likely to visit households located on the outskirts of geographically dispersed villages. Thus, a key component of the promotion strategy appears to have been diluted somewhat in relatively less dense communities.

In addition, despite extensive pre-testing, the characteristics of the stove itself served as a barrier to adoption for some households. For example, larger households found the size of the cookstoves insufficient for their needs. Traditional mud or three-stone cookstoves can be modified and customized easily if needed. The Greenway cookstove was not seen as a product that could be customized similarly to cater to the diverse needs of the household.

Finally, dynamics related to intra-household decision-making served as another limitation to the adoption of the cookstove. While women are almost always the primary cooks in the household, the head of the household is usually male. This leads to an imbalance of interests within the household. Male members tended to be less receptive to both the devices themselves—as well as to female monitors' promotion efforts—than primary cooks, limiting overall adoption rates.

Key Guiding Principles for Promotion of ICS in Rural India

Udaipur Urja's experience of in this context illustrates several principles that should guide ICS promotion efforts in rural India: a decentralized system of promotion and distribution that leverages local institutions and existing trust relationships; a strategy that prioritizes customer feedback and organizational accountability; a remuneration system that aligns the incentives of local contractors or employees with the program or organization as a whole; and continual monitoring to verify that households are actually using as intended the products that are distributed at low or no cost. These principles likely have broader application for other settings and other types of improved technologies intended for household adoption.

Decentralized promotion

The decentralized system of promotion and distribution is a key component of program implementation and effectiveness. It generated and sustained interest in the program through the information-sharing efforts of key community members themselves. Delegating the responsibility of promotion and distribution of the cookstoves to local women served as a key factor for the increase in adoption rates.

Leveraging local institutions (such as the childcare centers, schools and self-help groups coordinated by Seva Mandir) was instrumental in enhancing the reach of these decentralized promotion efforts. Stove demonstrations were often held using these institutions to familiarize beneficiaries with the devices. Door-to-door marketing built on these efforts to further increase membership, leading to increased visibility of the product and "snowball" adoption rates as trust in the devices grew.

Accountability and service oriented intervention strategy

The relationship between the community members and Udaipur Urja practitioners was somewhat different from a relationship between an NGO and its beneficiary. As a retailer of the technology, Udaipur Urja had a contractual agreement with the village members who adopted the improved cookstove. While Seva Mandir, the parent organization, is very accountable and service-oriented towards the community, Udaipur Urja's contractual agreement necessitates a client-oriented service strategy making it even more accountable to the adopters of the technology directly. In turn, given the nature of the ICS agreement, the buyers of the devices were also accountable to Udaipur Urja to ensure sustained use of the improved cookstove. This "symbiotic" relationship (characterized by mutual benefit and accountability) created a system of checks and balances, and increased the agency of the village members participating in the program.

That Udaipur Urja was responsive to the needs of the households and modified their promotional strategies accordingly. For instance, although Udaipur Urja started its promotion efforts with a heavy focus on improvements in household air quality, this promotional messaging was adjusted when they found that households initially valued other benefits more, such as time savings in cooking and fuel collection. Households responded more strongly to benefits that they believed related to them personally than either the benefit of improved indoor air quality or the broader societal and environmental benefits of the cookstove.

Variable remuneration systems to align incentives

Another important, successful program feature was the remuneration system used to pay local monitors. Initially, Udaipur Urja had a fixed payment system wherein the local monitors in the village were paid a fixed amount for the promotion and distribution of the cookstoves. This was modified to an incentivized variable payment wherein monitors were paid according to the number of cookstoves sold in the village. Combined with their extensive training, this adjustment enabled a deeper engagement with the community, as it aligned Udaipur Urja's incentives with those of its monitors.

Monitoring household adoption and use

The monitoring system in place was crucial in ensuring compliance in the program once the households had adopted the new cookstove. Monitors were responsible for visiting each household that bought the ICS technology in order to ensure that the household had not switched back to using their traditional cookstoves and collect any complaints the households had about the stove for the Udaipur Urja practitioners. This increased the accountability on both sides and created mutual trust and responsibility toward the program. In the future, it may also create opportunities for continued feedback that lead to further adoption of ICS, which would benefit local households and also serve the mission of Udaipur Urja.

Conclusion

ICS dissemination programs have been evolving across the country as a means of enabling clean energy transitions away from traditional biomass cookstoves. In order to ensure the success of the program it is important to evaluate programs holistically. The lessons that emerge from such an exercise highlight the importance of customizing the technology, adopting innovative promotion strategies, fostering relationships, building trust among communities, and market development. In the absence of such a contextual understanding, the conditions of the place, the people and product are unlikely to align in ways that ensure program effectiveness.

WindAid in Playa Blanca, Peru

Aashna Aggarwal, Katherine Guo, & Danielle Holt

Aashna Aggarwal (aashna.aggarwal@duke.edu), Katherine Guo (katherine.guo@duke.edu), and Danielle Holt (danielle.holt@duke.edu) are undergraduate students at Duke University.

Although Peru has a high national electrification rate of about 84 percent, many Peruvians still live without electricity. Multiple organizations have launched projects to bring electricity to these rural communities, including the national government. For instance, in conjunction with the World Bank, the Peruvian government launched the Peru Rural Electrification project to provide electricity to about 450,000 citizens. However, the national government defines a community as electrified when it has access to a distribution line. Since the burden of connecting the distribution lines to the community falls on the people and the process of connecting the power lines is difficult, many individuals do not connect and are still unelectrified, even though the government classifies the whole community as electrified. Thus despite prior efforts, the actual rural electrification rate in Peru is still about 38 percent, which is one of the lowest in South America.

The WindAid Institute, established in 2014, works toward community empowerment through access to electricity by bringing together volunteers from around the world who are interested in energy access or clean energy technologies. These volunteers are taught how to construct wind turbines, which are then installed in rural communities lacking access to grid electricity. Though a young organization, the structure and operation of this NGO foreshadows its continuing upward trajectory in increasing energy access in the country.

The authors of this case study spent ten weeks with WindAid, where they contributed to the Playa Blanca project by installing turbines and conducting an impact analysis survey of turbine users within the community. Playa Blanca is a fast-growing community on Peru's coast just south of Ecuador (Figure 3). Most families started moving to Playa Blanca twenty years ago, and currently, there are around sixty families and two schools in Playa Blanca. Community members fish for a living, and some earn money by working at the nearby scallop farm. This community values nature and sustainability, lending to their excitement for clean energy solutions.

Figure 3: Location of Playa Blanca in Peru

Prior to electrification, community members in Playa Blanca relied on kerosene lamps, candles, and gas or diesel generators for energy (Figure 4).

In addition to being harmful for human health and expensive to obtain, these energy sources are unsustainable, in that they deplete natural resources in addition to causing pollution. When WindAid staff first approached the community in 2012, community members expressed high interest in wind turbines and welcomed WindAid's involvement.

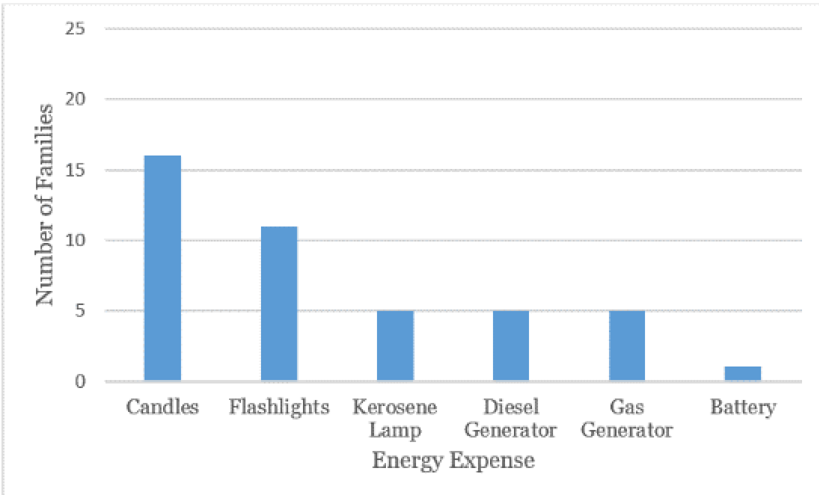


Figure 4: Previous energy sources of community members

WindAid's Strategy

The WindAid Institute uses three primary strategies, which the authors of this case study helped improve and implement during their volunteer experience. The first of these is the "feedback loop," through which WindAid continuously evaluates the relation between community desires and project activities. The second is adaptive sustainable management, including educational workshops and agreements about maintenance schedules. The third strategy is community empowerment: rather than focusing exclusively on providing wind turbines, WindAid adopts a holistic approach to economic and social development in the community.

Feedback loop

WindAid constantly evaluates their projects to ensure that they are meeting the wants and needs of the community to the best of their ability, while not compromising their mission of community empowerment. This is achieved through their use of a continuous feedback loop. WindAid leaders maintain contact with the elected community leaders and the community members, evaluating what is working with a project, what is not working, and how the project could be improved. One way to better characterize this feedback loop is to consider how it has operated in Playa Blanca.

About four months after installing the first turbine, a 2.5 kW turbine in the community school in Playa Blanca, WindAid returned to find that community members had disconnected the turbine electricity from the school and wired it to the community church (see Figure 5 for a timeline). Unsure about where

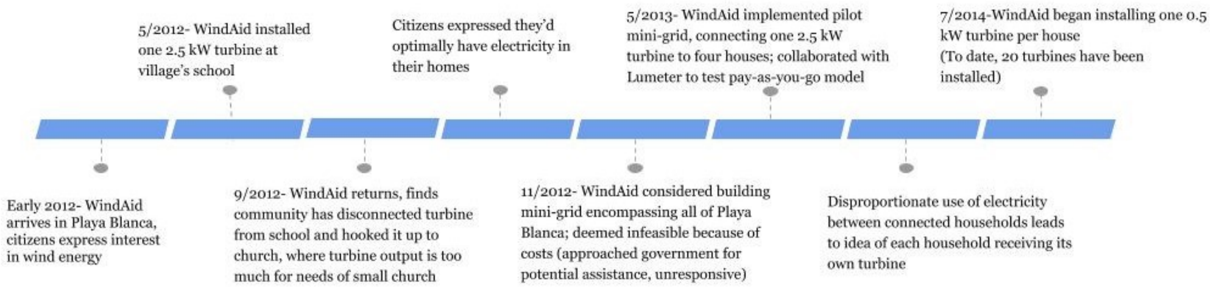


Figure 5: Key events in WindAid Institute's involvement in Playa Blanca

the community stood in terms of electricity needs, WindAid then sat down with the community. The meeting prompted citizens to communicate their chief desire for electrification of their individual homes, in place of electrification of the church or school. In response, WindAid suggested and implemented a pilot project in which a 2.5 kW turbine was installed on a mini-grid that connected four houses. This was achieved through a partnership with Lumeter, a San Francisco-based company offering pay-as-you-go solutions for metering and payment platforms for energy.

Lumeter helps energy consumers to finance electricity by allowing them to make payments in the most practical manner possible. Under Lumeter's model, a small meter is hooked up between the wind turbine and the user's home. This way, the meter can shut off electricity flow to the house should the consumer use all the electricity that they have paid for. Once this happens, the consumer simply needs to add credit to the account by buying tokens at a local shop. The money accumulates every time a user adds a credit, and this money is put into a fund dedicated to the turbines and managed by citizens (e.g., for maintenance and building more turbines).

Nonetheless, the four households in the pilot mini-grid project found that if one family were to disproportionately use energy, all four families could run out of electricity. In addition to the inconvenience of running out of electricity, some families may have paid for electricity that they did not end up using because it would get used up by a different family. Based on this finding in the pilot project, WindAid returned to discussions with leaders and community members of Playa Blanca to determine alternative solutions.

To avoid turbine disputes between households, WindAid and the community decided the best solution would be to build one turbine per house. Since having one 2.5 kW per house would be too much energy for one household, WindAid developed a smaller 0.5 kW turbine based on Hugh Piggott's turbine designs. They began installing these smaller turbines in July 2014; as of April 2017, they have installed 24 turbines in Playa Blanca, two of which have been decommissioned and another two of which are not functioning and require maintenance. The 24 turbine-owning families represent about one-third of the families in the village. Under the agreement with WindAid, each household is required to pay a monthly fee of 30 soles (about $10), which was determined by estimating that every family was spending about one sole per day on candles before having their turbine. From our survey, we gathered that households used to spend on average 128 soles per month on energy such as generators and candles, whereas now they spend only the 30 soles per month. Decommissioning of a turbine may be caused by frequent lack of payments or a family no longer desiring the turbine. After decommissioning, turbines undergo maintenance and are reassigned if possible. If not, salvageable parts are used for future turbines.

In addition, WindAid and the community agreed to create a group of volunteers (designated the "Directiva") from the local community to handle all matters related to the turbine. This includes keeping track of payments, determining the order in which households receive turbines, arranging maintenance schedules, ordering parts, and handling turbine-related disputes among community members. WindAid now maintains constant communication with the community through the Directiva, including monthly in-person meetings.

One recent challenge that WindAid faced in Playa Blanca was when the provincial government installed solar panels on every house of Playa Blanca. WindAid was initially concerned this would diminish interest in wind turbines, but they found community members were still very interested in having wind turbines installed in their homes, partly because of the strong bond of trust that WindAid had built in the past. In addition, community members voiced the benefit that wind turbines could generate electricity both night and day, whereas the solar panels could only generate electricity during the day and only had a small battery to store the power. Hence, with the solar panel, if the power were to run out at night, no more electricity could be produced until sunrise. Because community members strongly desired energy to expand productive hours after sunset, the ability to produce energy at night was a strong advantage of turbines. In addition, the community members also learned that if the solar panels broke or developed faults, there was no maintenance plan from the government project, meaning they would no longer be functional. WindAid, on the contrary, had a well-developed commitment to both community feedback and ongoing maintenance, which helped them solve these types of issues.

WindAid continues to evolve their business model to better fit the needs of the communities in which they work. In 2016, WindAid conducted an impact analysis survey of Playa Blanca to determine their impact and potential areas for improvement. In a related development, the Directiva voiced an issue that some community members were not paying their monthly maintenance fee. They could not figure out how to incentivize community members to pay since some community members did not realize the importance of collecting money now as insurance for future turbine failures. WindAid suggested that performing some relatively simple financial calculations could convince the community they were saving money by making use of the turbines. Thus, as a part of the "Energy Usage" section of its assessment interviews, WindAid calculated the amount of money each household would spend on diesel generators and lighting supplies in a month pre-turbine, and compared it to the 30 soles they now had to pay for security of their own turbines. Each family was then given a one page report demonstrating their individual savings from using the turbines. This information came as a surprise to many households, and led to a rise in payment of the dues—which had been below 50 percent prior to the initiative, and rose to 100 percent after.

WindAid's use of continual feedback cycles ensures that community members have a voice in the project, and ensures that the organization is actively listening to and collaborating with the community to meet their energy needs.

Sustainable management

For a project to have lasting impacts, provisions for sustainability are crucial. Otherwise, as the example of the government-granted solar panels shows, interventions may become useless if routine maintenance is not performed. WindAid believes deeply in ensuring the sustainability of their wind turbines within communities. Rather than solely installing the turbines, WindAid works with leaders of the community to draft out how turbines will be maintained. They also provide educational workshops about turbine maintenance and usage, and follow up with communities to improve the design of both turbine infrastructure and institutional infrastructure (roles for community members, and the overall business model).

In the specific case of Playa Blanca, WindAid set up multiple programs to ensure institutional sustainability and proper maintenance. WindAid worked with community leaders to create the Directiva that would handle matters relating to the turbine. Allowing members of the community to play a large role in the logistics of having wind turbines, instead of having WindAid control this process, was important for sustainability for several reasons. One of these reasons is practical: WindAid's central office is distant from the community, so even when WindAid staff are not present in the community, the local Directiva can deal with turbine related matters. Second, the Directiva serves as a bridge between the community at large and WindAid, creating a deeper sense of community ownership. In this way, the Directiva allows WindAid to partition the responsibility of the turbines to the community in hopes that turbines can remain functioning without WindAid personnel.

In addition to building administrative support through the Directiva, WindAid is also building a workshop facility in the center of Playa Blanca. They intend this workshop to be a place where turbines can be maintained in the community, improving the current situation in which turbine maintenance requires travel for over six hours from Playa Blanca to WindAid's main workshop in Trujillo. The space would also be used as a classroom to train community members to be able to provide maintenance on their own turbines. Education of these community members on turbine maintenance would decrease their dependence on WindAid personnel and greatly reduce the time it takes for a turbine to be fixed, and consequently the time a family is without electricity. As a long-term goal, WindAid also hopes for community members to fabricate turbines in Playa Blanca. This would reduce costs for the community members, offer a source of employment and income from outside the community, and would increase the overall economic sustainability of wind power in Playa Blanca by reducing their dependence on WindAid personnel to offer oversight or training.

Community empowerment

The Playa Blanca community offers a striking example of how small-scale wind turbines could have an enormous impact in rural electrification, reducing carbon footprint as well as increasing community empowerment. Community engagement impacts several factors of a rural energy projects including service quality, installation, maintenance and performance.

In this case, WindAid has developed a sustainable business model that, at its core, is consumer-centric. As previously discussed, WindAid has devoted substantial effort to understand what would be the ideal value proposition for the households served by its turbines. As part of this, WindAid approaches its projects holistically and does not restrict their service to the community to only energy access. Education and access to information about the benefits of electricity are the pillars that contribute to economic development. While most of the men are out fishing, some of the women run small scale businesses, such as small shops (bodegas) or restaurants which can stay open later because of being electrified (Figure 6). Increase in access to energy helps them grow economically.

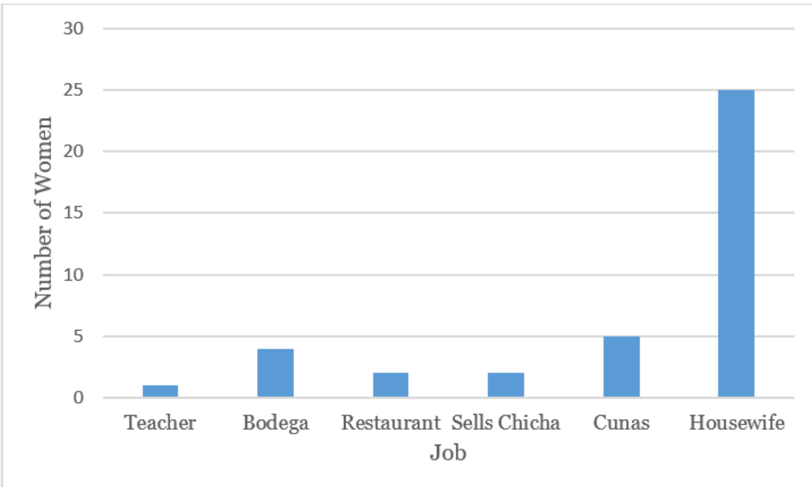


Figure 6: Current employment of women

The relationship that WindAid has developed with its community members has had positive effects on the usage of time, creating new opportunities for economic growth. The capacity to generate electricity after sunset has opened late hours of the night for family members to do their respective tasks. A child recalled how he would never get his homework done because he had to help his mother at her restaurant during the evening. Now he has access to lighting after sunset to finish his homework. A member of the community also started a business to sell cold beer and soda by using their refrigerator that is powered by the wind turbine. Long-term impacts of the wind turbines have yet to be determined due to the recentness of their installation. The other positive impact on school-age children is that they have an avenue for hands-on learning about the relationship between environmental degradation and energy. The community members can now use various appliances (Figure 7) to ameliorate their quality of life.

As mentioned earlier, WindAid is also building a regional test center in Playa Blanca. Creating this hub, close to the site of installations, would facilitate building of new turbines and maintenance of existing ones. Based on current design plans, the test center would have a low-impact and sustainable design, featuring mainly bamboo construction, a rooftop garden, and a composting sewage system. The uses of the test center include:

1. providing adequate accommodation for volunteers on site to allow for longer stays;
2. having a training center for local technicians, who can diagnose and fix minor problems;

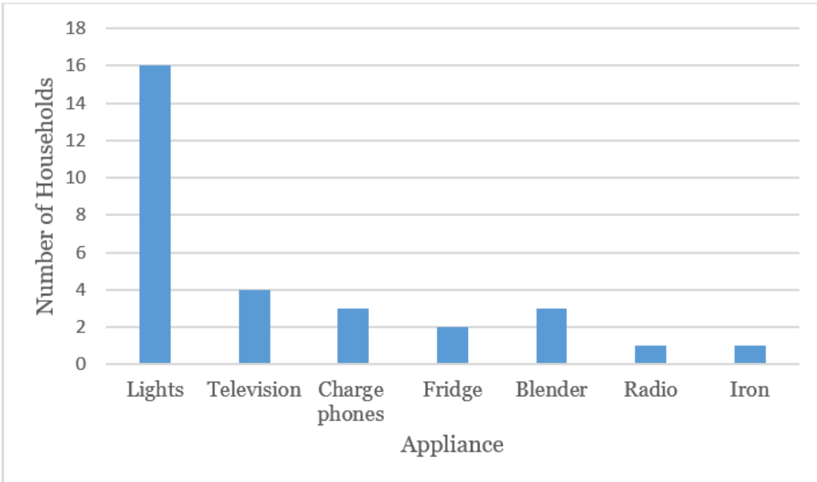


Figure 7: Use of wind turbine energy

3. fabricating and designing new turbine systems; and
4. involving the community in activities discussing optimal uses of the turbine in the context of education, health, economics, and the environment.

The workshop contributes to the idea of community empowerment because the goal is to empower the members so that they can generate their own energy, maintain their own turbines, and create jobs and make income through this means.

Conclusion

WindAid's implementation and experimentation of different practices in Playa Blanca has highlighted the importance of developing a program with and for the community of service, by responding to their concerns and ensuring sustainability of the project. The three pillars of WindAid's strategies start with the continuous feedback loop. In order to create a meaningful project, WindAid works with the community to develop a plan and constantly alters their goals and projects based on the voices of the community members. The second pillar, sustainable management, is best illustrated through the Directiva, which serves as a bridge between WindAid and the community. By having a group of leaders in the community on the Directiva, turbine matters could be handled even when WindAid personnel were not physically present in the community. The final pillar is community empowerment. As a result of providing the community with electricity, WindAid empowers them by giving them the resources necessary to develop.

Electricity is crucial for economic development, and citizens of Playa Blanca hope to expand their uses of electricity to develop their community. The future vision of Playa Blanca is for the town to become a tourist destination, where businesses could be sprouted from restaurants, juice bars, and activities, all made possible by having electricity. Additionally, with the energy, the hope is that children will be able to use the electricity to study more, leading them to higher education and higher-paying jobs. Since the project began only three years ago, this current case study is limited in that the authors could not explore the lasting results of the turbine. Future examinations of the economic impacts of the wind turbine are necessary in Playa Blanca to determine the long-term uses and benefits of the turbine.

Organizations can learn from WindAid's failures and successes in developing rural electricity access projects. We hope that WindAid's experiences can serve as guiding examples for other organizations and initiatives in the energy access space.

Acknowledgements This case study would have been impossible without the assistance of the WindAid team, specifically Jessica Rivas, Nicholas James, and Ross Picken. Special thanks is also extended to Leighanne Oh.

Solar Development and Community Engagement in Rural Nicaragua

Samantha Childress

Samantha Childress (samantha.childress@duke.edu) is a Master of Environmental Management candidate at Duke University's Nicholas School of the Environment. She also serves on the Board of Directors of United Solar Initiative, Inc.

United Solar Initiative (USI) is a North-Carolina-based 501(c)(3) non-governmental organization (NGO) focused on facilitating solar energy solutions to address energy and water poverty in underdeveloped communities. The organization has installed eight solar photovoltaic (PV) systems to date on community centers and schools in the rural outskirts of San Ramon, Nicaragua, a municipality of about 30,000 people. USI partners with a Nicaraguan based NGO—Sister Communities of San Ramon, Nicaragua (SCSRN)—to identify potential system locations based on energy needs and the engagement level of community leaders.

This case study offers insights into how organizations like USI can effectively foster relationships with communities in energy-poor settings so as to ensure effective implementation. In addition, the case study also describes evaluation methods for understanding the impacts that energy access brings to communities. The final portion of this study will describe the challenges of renewable energy access projects and strategies and tactics for overcoming those barriers. On the whole, I hope readers will find useful insight in learning about the methods that USI has found appropriate for implementing beneficial renewable energy projects in developing community settings, and the ways we have addressed key challenges.

As a member of USI's Board of Directors, I have participated in installing three of the eight PV systems on the ground in Nicaragua, and have organized logistics for five installations in the previous three years. I also hold the role of Operations Director for Nicaragua projects. In that role, I am responsible for coordinating a reporting structure to ensure that the solar PV technology meets both the specific needs of the community (i.e., lighting, health equipment, and cell phone charging) and the goals of USI whose primary focus is on improved education.

The energy users in this study include primary school students, adults enrolled in night classes, teachers, parent association members, and the attendees of community meetings and gatherings. The energy generated by the PV systems primarily goes to lighting classrooms on cloudy days and during night classes, but is also used for cell phone charging and powering music playing devices that are used in classroom learning and community celebrations.

Pillars of Effective Implementation

USI has identified three pillars that are critical to effective implementation of a renewable energy project. The first is the use of a formal due diligence procedure for project selection, based on a set of clear (but adaptable) criteria and a direct recommendation from our Nicaragua-based sister organization. The second is to design the system with the end users in mind. The third pillar is to employ regular follow-up evaluations to promote community participation and maintenance of the technology. The following sections describe each of these principles in turn.

Due diligence in project selection

USI's approval for system procurement occurs only after a direct recommendation from SCSRN. The recommendation from SCSRN, in turn, is based on the quality of community leadership, the involvement of parents and teachers, the community's desire for night classes, and the community's need—that is, the degree to which the community has or lacks access to reliable electricity. When SCSRN representatives believe these criteria are met, based on interactions through various community outreach efforts, the SCSRN's director invites the community to request a system from USI through a formal application process. The application is intended to act in part as a self-vetting process, as it allows the community and USI to further evaluate the degree to which community leaders are committed to renewable electricity implementation and maintenance.

The application process is vital to gauging the involvement of the community after the installation. In requesting consideration for a PV system, the community leaders must share the importance of cultural gathering activities, the commitment to education for children and adults, and the energy needs or desires of the residents. While it has proven invaluable to establish an application process, USI has also found that certain additional items should also be considered in this initial phase of project development.[21]

[21] See section on "Challenges of Implementation" below.

Even with the accountability provided by a formal application process, it is sometimes difficult to ensure that the system USI is installing will indeed fulfill the needs that the community seeks to address. A number of external factors such as local politics, theft, reliability of teachers, and changes in leadership—some of which may change after a PV system has been installed in a given community—are challenging to predict. However, these challenges are more or less universal for all types of rural community development. USI has found that the due diligence process and the formal application do provide some confidence that the technology can provide the intended benefits for the community.

Designing for the end users

Once the application is reviewed and approved by USI's board of directors, the planning and design begins. System design is the most crucial element of project implementation. Undersized systems leave the community limited in the services and benefits that electricity can provide, while oversized systems waste the resources that could otherwise benefit an additional system for a different community.

USI develops the system size based on community-led considerations, including the information provided by community leaders about what appliances and features would benefit the community during school hours, social gatherings, meetings, and night classes. Systems are always designed with more capacity than initially listed in the community's application, in order to prepare for a growing demand for energy and for greater flexibility of the building space. In addition, USI has adopted a "forward-looking" mindset. This leads us, for instance, to anticipate future rural electrification efforts by the Nicaraguan government and therefore use inverters to transform direct current to alternating current, which allows end users to make use of standard outlets for appliances. This promotes integration with a future (perhaps non-solar-based) electric grid.

Furthermore, USI constantly considers and evaluates new, emerging technologies for future installations. For instance, at the moment we expect our next wave of projects to include the installation of monitoring equipment that can be easily understood and managed on a mobile phone platform. As new monitoring technologies become cost competitive, USI is committed to providing the best interface for the community to interact with the system directly. This will strengthen the community's connection to the system while also improving performance and power output over its lifetime.

Other design decisions, such as component selection, are made based on the anticipated maintenance needs over the life of the system. For example, different battery options are provided by the solar company in the proposed budget based on the varying costs, quality, and capabilities of battery chemistries; however, USI has made the decision to use only sealed batteries. Though more expensive than the flooded alternative, sealed batteries require no bi-monthly maintenance or careful refills that require the use of (difficult-to-obtain) purified water.

Other individual component decisions affect the output and ease of use of the entire system, such as modules, inverters, and charge controllers. Solar companies in this sort of niche market likely have brands that they are familiar with; therefore, we respect the decisions of the installer in a niche market to source the pieces and brands of equipment that they are familiar with to ensure a high quality product (see Figure 8).

Overall, we have found it is essential to use the design phase to weigh the costs and benefits of each component, but also to consider the system as a whole and the role it plays in addressing the needs of the communities. Projects are too often planned with limited thought into what services and opportunities a technology can provide. Though our detailed attention to design extends the length of the initial design process, the usefulness of the system and the duration of its useful life are certainly enhanced by focusing on the end user instead of dropping identical systems in different communities, each of which have different needs.

Developing post-installation accountability through routine evaluations

On the afternoon of the final installation day, community members are invited to attend a gathering where USI ceremoniously transfers ownership to the citizens and hosts a workshop, led by the local solar provider, on PV technology to explain how the system works, basic maintenance requirements, and best practices for ensuring the system remains in top shape. At this event, teachers, leaders,

Figure 8: USI partners with local solar company for design and installation at the remote San Jose School location

and parents are invited to ask questions, test out the system's capabilities, and speak about the importance of reliable electricity in their community (see Figure 9).

For the first two years following an installation, USI has adopted a standard practice for coordinating quarterly evaluations of the system to ensure proper function and use. A SCSRN representative travels to the community centers and schools to test basic system functions and interview the community members about how well the system is operating, the main uses, and concerns or recommendations for improvement. The qualitative responses we gather from the community are our best method for understanding the impact of the technology and evaluating improvements in our own project development process.

We have recently incorporated a quantitative element into the survey to compare power output of the panels and battery health to previous months and other locations with similar systems, so that we can verify that best practices are being used in recharging and discharging. These technical battery tests have shown a decline in battery health, which is a direct result of poor battery bank management due to regular depletion of battery bank capacity, a lack of fully charging the batteries, or a faulty piece of equipment that may still be under warranty. These issues are difficult to explain in a single afternoon workshop, and often malfunctions can only be determined through monitoring devices like the ones we have provided to SCSRN for these evaluations. Past experiences with premature battery failure have driven USI to implement quarterly check-ins, and we expect and hope that these regular check-ins will extend the useful life of batteries and maintain the resting battery voltage.

The adaptations of standard practice to address the challenges that develop in the implementation phase have allowed USI to limit future system failures and therefore improve overall efficiency for the organization through better use of time and efforts. By comparing the data from previous visits, we have a better understanding of how the system is being used even though USI volunteers reside thousands of miles away. Discovering the lack of attention from the community in maintaining battery capacity early on allows the community to make adjustments in system use to extend the life of the batteries and other system components for the future.

Figure 9: Post-installation ceremony and community workshop at Santa Ana School

Challenges of Implementation

In USI's infancy, we implemented our mission to provide solutions for energy poverty purely through a trial-and-error process, which left room for significant improvement between the first installation and the three that followed a year later. Some of those mistakes, resulting primarily from a lack of experience in the field, are now leading to a misalignment in the roles and responsibilities for system upkeep three to four years after the installations. The distinction and agreement upon the financial responsibilities of USI, SCSRN, and the communities is an essential piece of these partnerships that was not clearly defined at the time of installation. In the initial years after installation, there were few discrepancies as the panels were producing electricity properly. Only recently have we found costs to be a concern as normal maintenance needs are beginning to lower the energy output. In trying to resolve these disputes, USI has adjusted our project standards for future projects, but we still find it important to retroactively attempt to address this issue by devising an agreement for the systems that are already in place. We have identified three elements that promote successful agreements: well-defined ownership, agreement on maintenance responsibilities, and an emphasis on communication between USI, SCSRN, and the community.

Defining ownership

USI organizes the installation of the PV system and is financially responsible for 75 percent of installation costs. SCSRN covers the remaining 25 percent of installation and oversees the community's responsibility in keeping a functioning system. There is no legal or contractual transfer of ownership; however, since

USI's inception, the intent has been for the individual communities to consider themselves the owners, with the assumption that the community members would be responsible for organizing expenses as needed throughout the lifetime (except for parts under manufacturer warranty, which USI would replace and then claim reimbursement directly from the manufacturer).

Overcoming the challenge of clearly defining ownership of the system is compounded by our geographic distance from the communities and lack of direct interaction with its leaders. This has become quite salient recently, in view of a recent election that caused a great divide in the community. A political vote led to disputes among teachers and parents, ultimately leading to lower use of the shared community space and the attached solar PV system. During this time, it was challenging for SCSRN to moderate these disputes in an appropriate manner and also made evaluations of the system difficult because no one claimed responsibility for the community center. With division among community members, leaders often must pick sides to stand with as well, furthering the gaps in a once cohesive unit. As this is a new issue brought about by a specific community's political environment, we aim to find resolutions that solidify ownership responsibilities but are mindful not to step in the way of community matters. After the reconciliation amongst the community, which included a new teacher and reinstallation of night classes, we relied on SCSRN to open the topic for discussion with the community about their understanding of ownership and the degree to which they feel responsible for handling the upkeep of system components. While USI and SCSRN are on the same page about ownership belonging to the community, this situation has presented a challenge, since at the same time that some components (batteries and light-bulbs) were deteriorating after a few years of service, the community encountered additional internal stressors that limited the interaction between leaders and USI's on the ground partner. Going forward, we believe that the community should have an opportunity to express the impression they have been under about their role in keeping the systems functioning and discuss how we (USI and SCSRN) can help to prepare for future expenses that will arise.

For future projects, we have devised a contract that USI, SCSRN, and a community leader will sign that will legally transfer ownership from the granters to the community, and will also outline an expected timeline for part replacement and a savings plan so the community will set aside funds for ongoing maintenance. This information will serve as a tool to ensure the community understands their responsibility as owners and can cover these expenses with a plan for soliciting donations or generating funds through other means. USI adopts the position that it is our responsibility as providers of the system to help the community prepare for the inevitable maintenance costs, but it is not our responsibility to directly pay those costs.

Maintenance expenses

An agreement upon ownership is the first step in preventing long periods of system downtime; however, USI has determined, since we are responsible for the lack of clarity in all of our initial system installations, that we will pay half of all maintenance costs for the first five years following the installation on both installed and future systems. This leaves SCSRN to split the remaining costs equally with the community. The intention of this backdated policy is to initially subsidize expenses that come with technological components, while also preparing the community for future expenses by encouraging them to adopt a regular savings plan. We are hopeful that this agreement will clarify that the community is the long-term exclusive stakeholder of the system.

In a recent evaluation for the San Ramon Art School, we received a note that the system was not lasting the duration of night classes. This cause for concern led us to dispatch our local solar provider where his team examined the system and determined that the battery bank would not reach full charge, even under full sun conditions. His team made recommendations for new batteries, which SCSRN purchased soon after and USI has since reimbursed the 50 percent share of the expense. Along with the evaluation of the problem, we asked the solar professionals to make recommendations for future charging and discharging practices based on the size of the system and its regular load. This information has been shared with the community; however, the batteries have yet to be replaced. SCSRN is holding the batteries at its office until the community and building's users raise the portion that we have all agreed upon. The length of time it is taking for the community to come up with the funds is disconcerting, but hopefully its users will be motivated by the firm response from both USI and SCSRN.

This event symbolizes one of the inevitable challenges of community development. There can be a number of reasons why the community has yet to raise the funds required to fix this once beneficial system. Political disagreements can cause a divide among users. Also, the required expenses for parts, a lack of agreement upon ownership among members, or simply apathy, are all viable and realistic excuses. We have concluded it is not possible to fully understand the reasons a community—even one that has offered detailed and positive feedback about the usefulness of the system—cannot or will not prioritize its repair. In this case, it is fortunate that we have a partner who has actively pursued the engagement of leaders to begin asking the users for donations. Through this situation we have seen the importance for a community to understand their responsibility to maintain the system and the imperative collection of funds beginning at the time of installation to prepare them for the expenses as well as the proper use of the equipment.

Emphasis on communication

Both project development and the supervision of installed systems are particularly challenging for USI due to the geographic dispersal of all parties involved. USI staff are only able to make short and inconsistent trips to Nicaragua, since all USI staff are volunteers with full-time careers in the US. This makes the partnership with the "on the ground" partner SCSRN vital to the impact of past projects and the potential for future projects. However, SCSRN also has a number of responsibilities within their organization that are not solely related to the communities where PV systems are located, which limits the regularity of their own trips to these remote locations, further inhibiting communication between USI volunteers and SCSRN personnel.

Oftentimes, USI, SCSRN, and community members communicate only when there is an event that adversely affects system performance, or a rift in a community (as in the example above). Recognizing that more frequent communication might forestall problems and improve feedback processes, USI and SCSRN have committed to arranging quarterly visits to each community that has received a system in the prior two years at which time SCSRN will perform an evaluation of system performance and community expectations. Systems previously installed three years and beyond are on a bi-yearly evaluation schedule with the mindset that, at this point in the community's ownership, the system should be understood and used according to the best practice guidelines and visits twice a year should suffice for equipment checks.

The other important aspect of communication comes in addressing the discrepancies of design between USI's Board of Directors and the local solar installer. The communication and cultural barrier is often most apparent in the installation process. While the language barrier is not much of a concern on the ground—since both installers we have worked with spoke fluent English—the Bill of Material for component orders are in Spanish and must be translated for the Board of Directors. In addition, the promptness of one of the companies we have worked with was a serious concern. The US-based cultural norm for tight schedules and efficiency is not a priority that has been shared by all of our counterparts in Nicaragua. In our early projects, we failed to anticipate the lack of preparation and effective use of time by our installation team. While we adjusted for subsequent projects to incorporate slack time for forgotten materials and late arrival by the team of installers, we also had to communicate the importance of preparedness and efficient installation because volunteers' flights and travel plans were dependent on deadlines. These challenges span beyond interpersonal communication and directly relate to our differences in cultures. The adjustment for cultural differences was not originally perceived as an inhibiting factor in the relationship between USI and our installation partners, but it proved to be an important area for compromise once we had experienced it firsthand.

As USI evaluates our internal operations for engaging with the communities and owners of the systems after installation, we aim to incorporate monthly communication and updates regarding the ongoing projects (either related to the Nicaraguan systems or not) between USI and SCSRN in order to keep a regular dialogue open between the two organizations. While the content of these conversations may not be directly pertinent to any individual system, the regular communication will allow ideas for improvement or overall concerns to easily flow back and forth. It also will inform USI of the different aspects of community development that may be implemented for future projects alongside PV installation. Keeping the door open between partners can only benefit the future relationships with the communities that USI aims to reach.

Conclusion

Combating energy poverty at the community scale has proven to be no light task; however the lessons that USI has learned as an organization can hopefully be translated to other projects in various locations that are addressing this issue. Every project is a learning opportunity, and as we have recently found, some issues may not be visible until years later.

USI's aim is to adapt in the ever-changing political and social climates that are specific to each of the communities that our projects serve, while also promoting business ventures to grow the solar industry in Nicaragua. In an effort to ensure the sustainability of the solar industry in new marketplaces like Nicaragua, it is important to commit to hiring local solar professionals to increase their business opportunities and promote renewable technology as a reliable participant in the expanding energy industry. We are continuing to learn the best ways to partner with new energy users and NGOs on the ground. It is essential to incorporate advice from other industry members' successes and failures, while also sharing our own shortcomings to improve methods for addressing the worldwide energy poverty crisis.

Additional research into the practical implementation of sustainable energy access projects would help USI as an organization as well as other practitioners and NGOs develop ways to further boost the local economy through PV development. NGOs donating free energy is not a scalable solution for all energy access issues; therefore, it would be helpful to understand an individual or family's willingness to pay for access to phone charging, medical equipment, and other energy services in a community-owned setting. This research and further understanding of energy usage would elevate the community to a more sustainable path for lasting technology adoption.

Cooking Practices, Human Health, and the Environment: The Case of Mandena, Madagascar

Erin Litzow, Lydia K. Greene, Laura Guidera, & Thomas Klug

Erin Litzow (erin.litzow@duke.edu) is a Master of Environmental Management candidate at Duke University's Nicholas School of the Environment; Lydia K. Greene (lydia.greene@duke.edu) is a PhD candidate in the Duke University Program in Ecology; Laura Guidera (laura.guidera@duke.edu) and Thomas Klug (thomas.klug@duke.edu) are undergraduate students at Duke University.

The island nation of Madagascar has some of the richest biodiversity of all countries on the planet (Myers et al., 2000). Forests are one of Madagascar's greatest assets, providing critical habitat for wildlife and combating climate change by removing carbon dioxide from the air. Despite its biological wealth, Madagascar ranks among the poorest nations on earth, with more than sixty percent of the population living below the international poverty line of $1.25 per day (on a purchasing power parity basis) (UNDP, 2011). Many of the country's 24 million citizens reside in rural agricultural communities with limited access to electricity and other modern energy sources. In these communities, households rely on biomass fuels (such as locally collected fuelwood and agricultural residue) to meet many of their energy needs. These energy use patterns exact a heavy toll on Madagascar's forest resources, contributing to the deforestation that has reduced remaining forest cover to a fraction of what it once was (WRI, 2007). Additionally, inhalation of smoke and particulate matter (produced from open fires and other traditional stoves used for cooking) is a contributing factor to many respiratory and cardiovascular diseases (WHO, 2016b). The health burden falls most heavily on women, who are often the primary cooks in rural Malagasy households.

These realities motivated a group of researchers from Duke University and around the globe to investigate the links among household energy use patterns, human health, and fuelwood consumption in rural Madagascar. The objectives of the project were to:

1. document household energy use patterns;
2. quantify household air quality, specifically fine particulate matter ($PM_{2.5}$) and carbon monoxide;

3. quantify household fuelwood usage; and
4. explore the relationship between these energy and environmental measures and human cardiovascular and respiratory health.

In this case study, we present the results of these efforts and—drawing on qualitative information collected from study participants, local partners and other key stakeholders—formulate recommendations for future interventions to address energy poverty and its associated human and environmental impacts in rural Madagascar.

The Setting

Mandena is a small village located in the SAVA (Sambava-Andapa-Vohemar-Antalaha) Region of Madagascar (Figure 10). It is located about 70 kilometers (road distance) from the city of Sambava, in a sparsely populated area. The total population is about 2,200 people (based on personal communication from the village President). The majority of community members are farmers, engaging in slash and burn agriculture for food and income. The typical household has five members, and around a third of households have at least one child under five years of age. The full range of Malagasy wealth quintiles, as defined by the 2008/09 Demographic and Health Survey, are represented in Mandena. The village lies a few kilometers southeast of Marojejy National Park, which is home to flora and fauna endemic to Madagascar. This national treasure is a draw for tourist and a source of employment for Mandena's residents. The village is not connected to the national electricity grid, though many households use electric lighting and mobile phone rechargers that are powered by small solar home systems, dry-cell batteries, or diesel generators. The remoteness of the village, poor road quality and low demand in the community are all barriers that make it difficult for other forms of modern energy, such as liquefied petroleum gas (LPG) or even improved cookstoves, to reach the community on a regular basis and at a cost that the majority of households can afford. Most households rely on fuelwood collected in the area for cooking. At the same time, community members recognize the importance of forest conservation both for preserving environmental quality and as a source of income from eco-tourism.

Figure 10: Map of field site indicating (a) Mandena's location within Madagascar and (b) proximity to Marojejy National Park, as well as (c) bird's-eye view of the village

Data Collection

This case study relies on qualitative and quantitative data collected in July 2016 by a group of student researchers from the United States, Madagascar, and Turkey. The data are at the household and individual level and were collected with funding from Duke University's Bass Connections in Global Health program.

The household sample consists of 24 households, randomly selected from the full population of households in the village. We collected individual-level health data, including height, weight, blood pressure, pulse, current body temperature, and spirometry measures, from individuals in the 24 randomly-sampled households and from an additional group of individuals who self-selected into the study. Finally, data regarding fuelwood consumption was collected in households, different from the 24 randomly-selected households. The households for fuelwood consumption data collection were chosen via purposive sampling, based on the likelihood that a primary cook would be home with enough cut fuelwood to estimate daily consumption.

Household Energy-Use Patterns

As elsewhere, energy satisfies a variety of needs for households in Mandena, including cooking, lighting, and entertainment. Cooking is by far the most energy intensive of these needs. Households primarily rely on fuelwood for cooking, using traditional stoves such as metal tripods, brick stoves or three-stone fires (Figure 11). Residents are aware of the existence of improved cookstoves, like the ADES stove, that are designed to produce less smoke; while a few of these devices are present in the village, they appear to be rarely used.[22] There is significantly less awareness about types of cooking fuels (such as LPG) that produce less smoke. While wood was the exclusive cooking fuel reported to be used during the month of July, some households vary their cooking fuel over the year, relying on charcoal when it is available and affordable. Charcoal is scarce during the season of the vanilla harvest, which starts mid-June and typically lasts a few months, as charcoal manufacturers are primarily engaged in harvesting, processing, and transporting vanilla—a major cash crop in Mandena. Kitchen location varies, with most households cooking in a location separated from the sleeping area—either a separate room or a completely separate building. The few households that cooked directly in the sleeping area claimed it was because they could not afford to construct a separate kitchen. Most households cooked indoors, though many had a window or space between the wall and ceiling to allow some smoke to escape. Additionally, about half of respondents reported having other family members present in the kitchen while cooking. In the majority of these cases, these included children. Around forty percent of respondents reported having to leave the kitchen often while cooking due to poor air quality. From discussions with household members, we learned that having a closed, built room as a cooking area was important both for security reasons (i.e., locking the doors and windows to protect pots, utensils and food from theft) and as a symbol of wealth and prosperity. In all households with at least one female member, the primary cook was a woman, with a mean age of 39. Fuelwood collection was done mainly by men, who collected fuelwood between 1-7 times weekly. We accompanied two individuals during fuelwood collection. Both traveled between 2-2.5 kilometers in total and collected wood from

[22] ADES is the Association pour le Développement de l'Energie Solaire, a nonprofit based in Switzerland and Madagascar that develops and distributes improved cookstoves.

family-owned plots. Many residents prioritize collecting wood that is nearby (as opposed to targeting specific tree species), and most report that fuelwood is getting more difficult to find. A handful of local residents engage in reforestation, but we did not see evidence that the practice is widespread in Mandena.

Figure 11: Cookstoves (from left to right: metal tripod, ADES stove, brick stove, three-stone)

To meet their lighting needs, households in Mandena rely primarily on kerosene, while around a quarter report using cleaner alternatives, such as solar home systems, outdoor diesel generators, or battery-powered flashlights. While heating is not a primary energy service in Mandena due to the climate, a handful of households reported spending more time in the warm kitchen during the colder season, potentially increasing air-pollution-exposure levels during this time.

Environmental Impacts

Air Quality

To assess air quality, we monitored $PM_{2.5}$ and CO levels in cooking and sleeping areas for 24-hour periods. Exposure to both $PM_{2.5}$ and CO is known to produce negative health effects, including respiratory illness, pregnancy complications, nausea, dizziness and even death (Bruce et al., 2014). Recognizing this, the World Health Organization has set concentration limits, which—if exceeded—constitute a health hazard. CO in Mandena's kitchens reached high concentration levels during breakfast (6 a.m.), lunch (12 p.m.) and dinner (6 p.m.) times, with peaks lasting up to twenty minutes in the most poorly ventilated cooking areas (see Figure 12, left panel). CO also displayed three daily peaks in the sleeping areas, but at lower and safer concentrations.[23]

Unlike carbon monoxide, $PM_{2.5}$ did not create distinguishable peaks throughout the day, though concentrations still regularly exceeded WHO limits (see Figure 12, right panel).[24] This is likely because $PM_{2.5}$ disperses less quickly than CO, and is also produced by other household and ambient sources like kerosene lamps and agricultural burning. Amongst residents, there are varied beliefs about the impact of cooking on air quality, with some residents believing it has no impact and others believing it has a large impact.

[23] The WHO standards for CO are limiting exposure below 200 ppm. At 800 ppm, CO is linked to headaches, nausea, and dizziness after 45 minutes of exposure. After one hour of exposure, one could become unconsciousness (WHO, 2016a).

[24] The WHO recommends exposure should not exceed a mean of 25 $\mu g/m^3$ over 24 hours. However, because even small concentrations of PM are known to cause adverse health effects, the WHO 2005 guideline limits are "aimed to achieve the lowest concentrations of PM possible."

Deforestation

In our survey, we focused on fuelwood usage as a proxy for deforestation pressures due to energy-use patterns. We found that all households reported

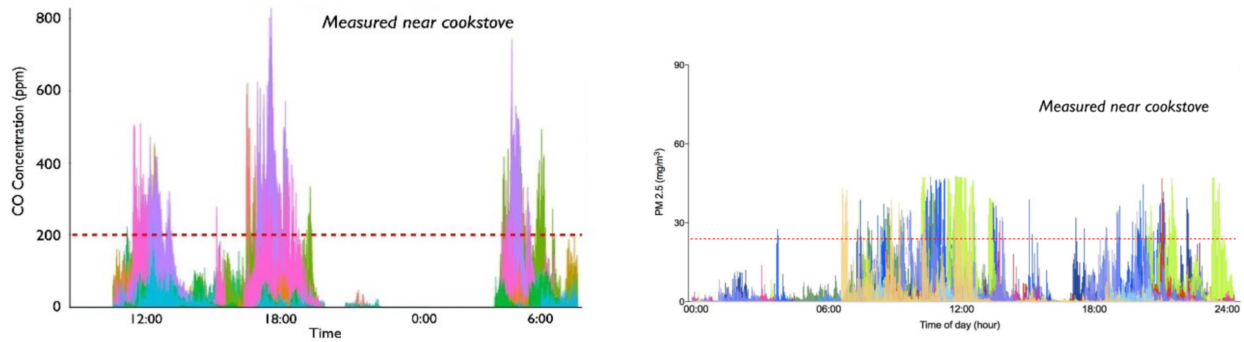


Figure 12: Daily concentration of CO (left) and $PM_{2.5}$ (right)

using a variety of different types of fuelwood concurrently. Cooks reported using the same amount of wood for lunch and dinner, but less for breakfast. Our measures of fuelwood weight were consistent with these reports, with households using an average of 1.5 kg for breakfast and 3.6 kg each for lunch and dinner (see Figure 13). Assuming these values are representative of the amount of daily fuelwood used across a calendar year, we estimate that families living in Mandena each require, on average, 3,204 kg of wood for cooking.

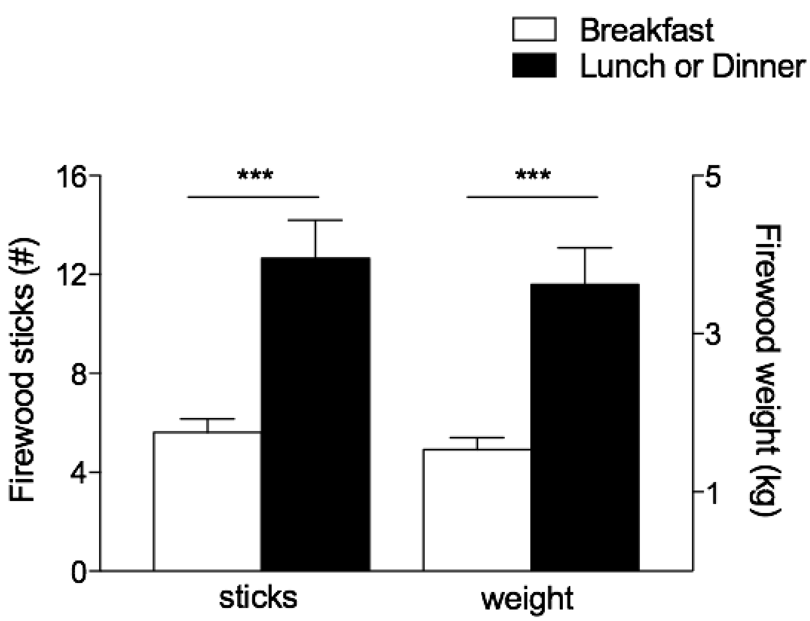
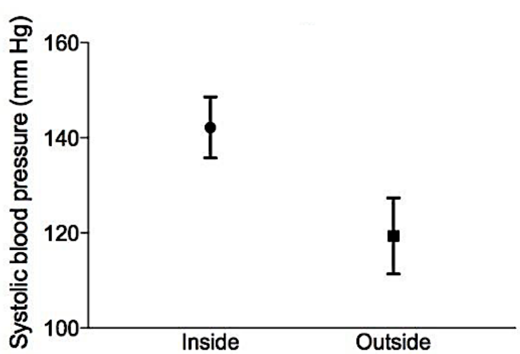


Figure 13: Comparison of fuelwood used for breakfast and lunch/dinner

Residents of Mandena recognize the value of the nearby forest. They cite many services provided by the forest, including clean air, good weather and rain, clean water, shade, animal habitat, and fuelwood. Residents also recognize the value of planting hardwood, fast-growing trees for both the economic (fuelwood, construction, furniture, charcoal, and agricultural) and environmental (weather/rain, water, and clean air) benefits, as well as the importance of forests as an asset for future generations. Like air quality, the awareness of the impact of cooking practice on environmental health in Mandena is varied, with some residents believing that current cooking practices have a large impact on the environment and others believing there is no link.

Health impacts

Within our study population, there is evidence of a link between cooking practices and health. There were high rates of hypertension in general, but these rates are higher amongst women who cook inside (i.e., those with higher exposure to CO and $PM_{2.5}$) as compared to those who cook outside (see Figure 14). Additionally, over 90 percent of study participants had less than healthy lungs, measured via forced expiratory volume in the first or sixth second of a forced breath (FEV1 or FEV6). Of subjects with unhealthy lungs, the majority are the primary cooks in their households. These findings are supported by self-reported data, with more than half of households reporting that at least one household member had a cough or runny nose in the two weeks preceding the interview. Female cooks and children were most often reported to have been ill. These health effects are a significant burden on Mandena's residents. On top of the pain and suffering associated with illness, the average household spent around USD 13 to get treatment for household members who fell ill. This is a significant cost considering Madagascar's annual GDP per capita was estimated to be USD 402 in 2015 (World Bank, 2017). Most of Mandena's residents perceive a medium to large link between cooking practices and health, although some believe that cooking practices have no impact on health.



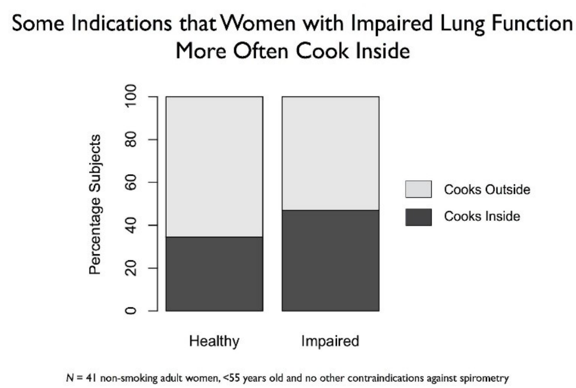


Figure 14: Comparison of blood pressure between cooks who report cooking outside and inside (left) and cooking locations between those with healthy and impaired lung function (right)

The Way Forward

Lying in the shadow of Marojejy National Park, the village of Mandena is rich in beauty and natural resources. Despite this wealth, the residents of Mandena live with the reality of energy poverty—a reality that has implications for both human and environmental health. Although this case study has focused on documenting the relationship between energy poverty, human health, and local environmental impacts, a goal of the larger project is to produce a solution for the harmful impact of open-fire cooking that will benefit the health of humans, their environment, and biodiversity.

A range of interventions could target these outcomes. Within our team, we have discussed a number of possibilities at both the household and community levels. These interventions could involve bringing in new technologies, such as renewable energy microgrids, a connection to the national electric grid, a kerosene lamp buyback program, and/or improved cookstoves, both biomass and LPG burning. They could also involve promoting behavior change, for example keeping children out of the kitchen to avoid exposure to harmful pollutants, increasing the ventilation in the cooking space, educating community members to raise awareness of the costs of current energy use patterns, and/or a community reforestation effort to alleviate environmental harms and increase access to biomass fuels. The task ahead involves designing a program that can be initiated in the near term, addresses as many outcomes as possible, accounts for the diverse needs of Mandena's citizens, and is self-sustaining and self-perpetuating in the long run.

In this spirit, as we reflect on the current state of household energy use patterns presented above, we discuss a set of guiding principles—identified by both our own team and other case studies in this volume (e.g., those focusing on the experiences of United Solar Initiative or of WindAid) that we hope will inform future policies and programs to improve access to clean, affordable, and sustainable energy sources in Mandena.

Stakeholder engagement

For most interventions, at both the community and household levels, the consultation of and buy-in from the full set of key stakeholders is important when designing a program or selecting new technologies. In Mandena, this means involving both men and women, as men are often the primarily fuel collectors and women do the majority of the cooking. A community-level reforestation campaign would need to engage those involved in fuelwood collection but also consider other land users who may be impacted by the program. Without these consultations, issues important to the citizens of Mandena, like the importance of securing cooking assets in an enclosed kitchen—which we learned about through our discussions with community members—would not come to light.

Along with the choice of which groups to involve at the design and implementation stages, we and other planners must consider at which level to conduct engagement and consultation activities. Given the heterogeneous family structures, income levels, values, preferences, and priorities in Mandena, it may be more practical to engage with stakeholders at the household level. In contrast to community level interventions, where one form of technology or program strives to meet as many community members' needs as possible, household interventions can be tailored at finer scales to meet diverse needs. For example, instead of selecting one technology or intervention design to implement in all households, a bundle of options can be presented, with stakeholders in each household choosing the option that best fits their needs (Bensch and Peters, 2012; Jeuland et al., 2015; Mobarak et al., 2012). This would suggest that household-level technologies like larger solar home systems or improved cookstoves may be more successful in Mandena than community-level technologies. Presenting households with a set of options from which to choose can also help to foster a sense of ownership, important for the continued use and maintenance of new technologies.

Finally, early stage community and individual consultations, some of which our team has already initiated, can help to avoid program design errors and the associated reputational damage, as well as the time and capital costs needed to rectify any problems.

Participant selection

Another important question to consider is which households to target with energy programs. As evidenced in other cases in this volume, engaging with groups or households who self-select into the program is one way to ensure the program reaches interested parties. This practice can also help to promote ownership, as households self-selecting into the program have borne the costs, in the form of time and/or money, to seek out information and/or access to services. In the case of Mandena, however, this strategy may prevent the program from reaching households where the negative effects of energy use patterns are high. For example, households with low awareness of the links between cooking fuels and health, who are likely doing little to avoid exposure to indoor air pollution, may not self-select into the program. So, while reliance on self-selection may improve the uptake or usage of a technology or the cost-effectiveness of an intervention, it may leave some households behind. Depending on the relationship between health awareness and income, a self-selection program may exacerbate existing inequalities within targeted communities. Depending on program goals and resources, there may be a role for more intensive (and expensive) educational initiatives (e.g., those that seek to inform households or alter beliefs about the relation between indoor air pollution and personal health).

Marketing and promotion

As discussed above, residents of Mandena are more aware of the high fuel costs associated with current energy use patterns than the related health effects. This is partially due to the fact that fuelwood collection is becoming increasingly time consuming and other fuels are prohibitively expensive or not available. Emphasizing the fuel efficiency aspect of a new technology may increase demand for the product or service, more than a program that emphasizes the health benefits of improved technologies. Even though illness from indoor air pollution is costly for households, many are not fully aware of the link between energy use and health. This is not to say that a program or policy must exclusively focus on fuel efficiency or health, but a health-focused program would need to be preceded by an education campaign to inform residents about the links between fuelwood use and health. Nevertheless, a small share of Mandena's residents are already highly aware of the link between energy use and health; education campaigns, possibly with friends or neighbors recruited as teachers, could be one part of expanding this awareness. An example of successful awareness building is WindAid's "energy usage" information sharing program in Peru, aimed at increasing demand for wind turbines by making consumers more aware of the costs of their current energy consumption patterns.

Regular follow-up

At the most basic level, follow-up is important to ensure that technologies or programs are operating as planned. If technologies break or newly-formed institutions collapse, Mandena's residents may be less willing to participate in energy programs again in the future. But this follow-up should not be just for repair. It is also an opportunity to assess how residents' preferences are changing in response to new technologies and information, and to shift or expand programming accordingly. Energy transitions are a dynamic progression toward clean, affordable and sustainable energy access and use—not a static, one-time fix. As communities change, so too must policies and programs.

Next steps

Mandena, currently classified as energy poor, is undergoing a period of significant transition and modernization. Small solar panels adorn many houses, dry-cell batteries are increasingly used for light, a handful of diesel generators are present in the village, and most residents have access to communication technology and the internet via cell phones. The persistent and widespread reliance on fuelwood or charcoal for cooking, however, remains a serious concern for both local forest cover and human health. Ultimately, energy limitations do not exist within a silo. They are part of a complex system of ever-changing community life that extends to security issues, time and financial management, and cultural history. Our team will take these facets of rural life into consideration as we seek to engage the community in improving local human and environmental health in the future.

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Electrifying Rural Indonesia: One NGO's Approach to Community Empowerment

Tyler Wakefield

Tyler Wakefield (tyler.wakefield@duke.edu) is an undergraduate student at Duke University.

In 2011, an Indonesian NGO with decades of experience in rural electrification worked with inhabitants of Kamanggih Village in East Sumba Island, Indonesia to construct a 37 kW micro hydro plant (MHP) and provide the village with reliable electricity for the first time. The NGO IBEKA—*Institut Bisnis dan Ekonomi Kerakyatan*, or the People-Centered Business and Economy Institute—returned in 2015 to construct an 11 kW hybrid wind and solar farm, which electrified the majority of the households that were not electrified the first time around. The projects were designed and funded by IBEKA, constructed by community members, and are owned by the Kamanggih Cooperative—an institution managed and staffed by Kamanggih residents that offers a variety of economic, material, infrastructural, and educational services to Kamanggih residents. Kamanggih—the largest village in the region, with approximately 345 households and 1,900 residents—serves as a model for other villages for how to successfully operationalize electrification for community empowerment. As part of the Sumba Iconic Island Initiative[25], IBEKA and partner organizations continue to electrify surrounding villages in East Sumba in their goal of electrifying all communities in Sumba using only renewable sources, and Kamanggih residents are working alongside IBEKA staff to help gather community support and long-term commitment for responsible energy resource ownership and management.

In June 2016, a fellow Duke undergraduate (Connor Guest) and I traveled to Kamanggih to assess the impacts of the electrification projects on community empowerment. We lived in this community for two months, and studied how electrification affected health, education, social structures, household income, and economic development. With the help of a translator, we conducted fifty-five randomized household surveys over the course of six weeks. I compiled these findings into an impact assessment report for IBEKA, which included suggestions for improvement in future iterations.[26] This case study draws on this report and general observations to describe the unique process of electrification in Kamanggih, including challenges, results, and outlook for the future.

[25] http://sumbaiconicisland.org/sumba-iconic-island-100-renewable-energy/

[26] Wakefield, T. (2016). Empowering Communities: Results from Community Electrification in Kamanggih, Sumba Island. http://bit.ly/2qs6xZF

Site Background

Kamanggih Village is located on East Sumba Island, Indonesia (see Figure 15). It is the capital of East Sumba Sub-District, Kahaungu Eti. Kamanggih is organized into five hamlets, loosely arranged in a circle with a radius of approximately 1.5 km. One road—part pavement, part gravel—connects all the hamlets and can be traversed by car, motorbike, horse, or foot. The five hamlets were traditionally separated by lineage, though resettlement across hamlets is now more common. Two of the five hamlets serve as a village center of sorts, where the schools, biggest stores, market space, and Kamanggih Cooperative office are located. Thus, many Kamanggih residents from other hamlets visit the village center often. However, the poorest households tend to be furthest away from the village center, and tend to have both fewer reasons to travel from their homes and fewer resources with which to do so.

Figure 15: Sumba's Location in the Indonesian Archipelago (left) and Kamanggih's Location on Sumba (right)

The largest city on Sumba, Waingapu, lies on the north coast and has a population of approximately 53,000, as well as an airport and a seaport. Prior to 2016, travel over the 100 km from Kamanggih to Waingapu would take anywhere from 1.5 to 3.5 hours depending on the vehicle's ability to traverse the degraded and pot-holed road. However, recent road repair and expansion has reduced travel time to 1-2 hours depending on the vehicle. The road descends from Kamanggih, and winds through open land, much smaller unelectrified villages, and relatively isolated clusters of houses. Every Wednesday, vendors from Waingapu and surrounding areas bring their goods to sell in the Kamanggih Market, and some Kamanggih residents sell their own produce and crops. A private bus provides round-trip service between Kamanggih and Waingapu once per day, and residents often find rides in the back of trucks in both directions.

The village of roughly 1,900 people is comprised of mostly farming households. Livestock such as cattle and pigs represent both literal and cultural wealth, though they are traditionally not sold, but rather slaughtered and consumed for ceremonies such as weddings, funerals, and holidays. Wealthier households are more likely to own livestock, while most farming households grow a combination of subsistence crops (cassava, assorted vegetables, fruit, and corn) and cash crops (betel nut, areca leaf, tobacco, corn) and have several chickens. While some households exclusively farm for their subsistence and income, most households conduct other income-generating activities in addition to farming. Common occupations include motorbike mechanic, teacher, health clinic staff, weaver, shop owner, carpenter, and stonemason. Sumba is well-known for its textiles, and many women weave purely for cultural and personal use, while others sell their products. While almost all households either raise livestock and or grow crops, few are able to subsist entirely from their own production. Many households receive free seeds and rice from the government, and the poorer households receive government support for buying food as well. Some households do not own arable land. Land is normally owned communally within an extended family and is divided unofficially for use among households. In some families, the household responsible for a certain plot will retain the harvest, while in other families, the harvests are owned in common.

Kamanggih is home to three elementary schools, a junior high school, and a senior high school. As the only village in the region with a junior and senior high school, many students from the smaller surrounding villages live in Kamanggih during the school year with an extended relative or host family. One USD was valued at an average of 13,333 Indonesian rupiah (IDR) during June and July 2016. In Kamanggih, 10,000 IDR ($0.75) can purchase a pack of upper-tier cigarettes, a full meal, or a liter of gasoline.

Wealth among Kamanggih households is difficult to measure and observe for several reasons. A three-tiered caste system persists in Kamanggih with significant consequences for socio-economic equality, education, and upward mobility.[27] Some of the ostensibly wealthy households at the top of the caste system may have access to free coerced labor, guaranteed food security, livestock, and items of high cultural value, yet at the same time may have very little income or measurable liquid assets. Conversely, households towards the bottom of the caste system may own appliances, a cellphone, a motorbike, and have an income from various jobs, yet have restricted independence and upward mobility. Additionally, in my conversations with Kamanggih residents, I found that few people keep records of their financial information, and that many people were apprehensive about providing me with information on their finances and assets due to complex social norms. Both in relation to and irrespective of the caste system, communal labor is often used for large-scale projects such as house construction, harvests, or infrastructure with laborers receiving meals in addition to an expectation of reciprocity.

[27] While many Kamanggih residents consider their community to be more progressive than other villages in terms of the caste system, social stratification is often visible and some residents were described as "slaves." For additional information, see Barokah (2016).

Figure 16: A pseudo-traditional home of an upper-caste family

That said, there are some observable characteristics that distinguish households by assets or income. The wealthiest households in Kamanggih tend to have more assets—larger homes (Figure 16), a car or truck, at least one motorbike, agricultural land, appliances such as computers, and televisions and rice cookers—and tend to travel to Waingapu more frequently. The poorest families in Kamanggih reside in a one- or two-room wooden hut, have no appliances, farm for a living, receive government assistance, and likely do not send their children to school.

Kamanggih residents elects a Village Chief every two years (see Figure 17) who works with local and regional government staff. During the summer of 2016, the most pressing issues discussed during the election by the candidates were how to allocate government money to support poor households, how to best provide loans and support for high value crop growing, and how to combat corruption within the local government. Almost all adults who are physically able to travel to the village center cast a vote.

Figure 17: Residents await village chief election results

Electrification Background

Prior to IBEKA's electrification projects, Kamanggih's electricity needs had been reported to be inadequately served by a Chinese foreign aid project and the Indonesian national electric utility (Perusahaan Listrik Negara, or PLN). In 1997, a Chinese organization working with local cooperatives constructed wind turbines for individual households in the two hamlets of Kamanggih that constitute the village center. These turbines were unreliable, however, as they frequently broke down, provided energy for only part of the day when they did work, and were all out of service within one year. IBEKA first came to Kamanggih in 1999, when it worked with the community to install a solar-powered water pump to provide easier access to river water for the village center. That system is still functioning, albeit less efficiently. In 2005, PLN installed two diesel generators and a microgrid that provided nightly electricity for the village center (approximately fifty homes at the time), but this service was unreliable as well and blackouts were frequent.

Complete electrification of Kamanggih presented economic and logistical challenges such as distance from nearest grid access (30 km), poor road infrastructure, cost of transportation between manufacturing centers and Sumba Island, relatively low incomes among households in the village, low population density, and difficult topography. While rural electrification was a priority for PLN, the organization was not able to adequately serve Kamanggih's needs. PLN dedicated more of its resources to projects in other regions that faced lower costs or barriers.

Renewable potential in Kamanggih and the surrounding region is very high. Due to its topography and climate, micro hydro generation is widely available year-round. These systems exploit natural flowing water along altitude differentials to generate electricity. The flowing water is not dammed completely—allowing a natural flow of water—while some water is directed into a penstock that allows gravity to force water into the generator below. In addition, Kamanggih has high potential for solar.[28] Lastly, Kamanggih and the surrounding hilly region provide wind potential on hill peaks. IBEKA's solution was a mix of all three.

[28] Bali, the nearest island for which solar insolation data could be found, has an average radiation of 5.34 kWh/(m^2-day) (Fathoni et al., 2014).

Electrification Process

Several years after IBEKA installed the solar water pump in 1999, Kamanggih's first college graduate began working for IBEKA as a civil engineer. This connection brought IBEKA back to Kamanggih to begin discussions with the community about the potential for community owned and managed electricity in Kamanggih. Before IBEKA begins designing any electrification project, they begin lengthy conversations with community leaders and citizens to educate the community on the resources available, potential for empowerment, and expectations. IBEKA conducts workshops in which community members identify desired outcomes from an electrification project and collectively commit to helping with construction, as well as responsible ownership and management of potential electricity resources.

After receiving social buy-in from Kamanggih residents, IBEKA designed plans for a 37kW MHP (Figure 18) around the existing river's potential. The construction capital came from grants and donations received by IBEKA and its partner organization Hivos. In January 2011, the construction process began with the community constructing an asphalt road for the trucks needed to transport construction material to the micro hydro site. The construction process of the plant and additional grid infrastructure took roughly nine months, and 92 percent of households surveyed helped by providing labor or material

Figure 18: Kamanggih's 37 kW micro hydro generator house

support in some way. When the MHP was completed in November 2011 with a total cost of roughly USD 200,000 (excluding grid and connection costs), reliable 24/7 electricity was provided to four out of the five Kamanggih hamlets (approximately 275 households).

Initially, the Kamanggih Cooperative took ownership of the MHP and sold electricity from the MHP to households. In 2013, IBEKA helped facilitate an agreement by which the Cooperative sells electricity to PLN for distribution via an Independent Power Producer License. A PLN staff member operates the plant, but maintenance expenses are covered by the Cooperative. Most evenings during the dry season (approximately June–December), PLN deploys a diesel generator to cover the demand not met by the MHP during the night. Households are connected via a meter, and residents pre-pay PLN for their electricity. The Cooperative sells electricity to PLN at a rate of 475 IDR/kWh ($0.04/kWh). Households pay about 850 IDR/kWH ($0.06/kWh) and on average consume 36 kWh per month, for a total (average) monthly cost of 30,377 IDR ($2.28). After years of operating below the expected price-point and as the result of a compromise reached in negotiations between the Cooperative, IBEKA, and PLN, the Cooperative expects to raise the price it charges to PLN, to 850 IDR/kWh ($0.06/kWh) in 2017. This rate hike will, in turn, increase the rates that the PLN charges to households.

IBEKA returned in 2015 to build an 11 kW hybrid wind-solar farm with battery storage (Figure 19). The project was given similar community support, although it was a much quicker and easier construction process. It provides 24/7 electricity for more than half of households (approximately twenty-five) in Kalihi, the one hamlet that did not receive electricity in 2011. The wind turbines and panels are connected to a storage system which moderates flow to the grid. Household connections were established by IBEKA and are maintained by the Cooperative. Unlike customers in other hamlets, who pay use-based rates to the PLN, residents in this hamlet pay a flat monthly fee of 20,000 IDR ($1.50) to the Cooperative. Households in this hamlet are typically poorer and only use a few light bulbs and maybe charge cellphones. In addition, not all households in this hamlet were connected, due to more extreme topographical limitations. The Cooperative plans to connect the remaining households as funds become available from their electricity sales.

Figure 19: 11 kW Hybrid Farm in Kalihi

The Cooperative uses revenue from electricity sales for maintenance, to provide household loans, to support small trade groups such as weavers, and to fund other infrastructure projects such as household water service and road repair. See Figure 20 for a schematic of the stakeholders and resource flows.

Typical household electricity use and impacts

As noted in the introduction to this case study, I developed an impact assessment report from surveys I undertook in summer 2016. The following results are taken directly from that study. I found that households vary greatly in their electricity use, ranging from nonexistent to powering several refrigerators, lights, televisions, and power tools. The vast majority of households use electricity only for lighting and charging cellphones, as additional appliances are prohibitively expensive to obtain. These households contain 2-4 bulbs (a total that includes both indoor and outdoor use) for their cooking and washing stations. Cost of electricity does not seem to be a concern for most households (only 12 percent of households reported electricity payments being a “burden”), and the average household reports a net savings on monthly lighting expenses after switching to electricity from candles, oil lamps, and battery powered lights. Wealthier households use televisions, radios, and computers in addition to lighting and phone charging. The wealthiest households also have rice cookers, electric water pumps, computers, and power tools. Larger convenience stores have refrigeration, while the smaller shops will only have lighting.

Household electricity access appears to have led to significant improvements in reported health outcomes. These may be due to residents replacing dirty oil and kerosene lamps with light bulbs, as well as due to the enhanced availability of refrigerated medicine at the community health center. In particular, after

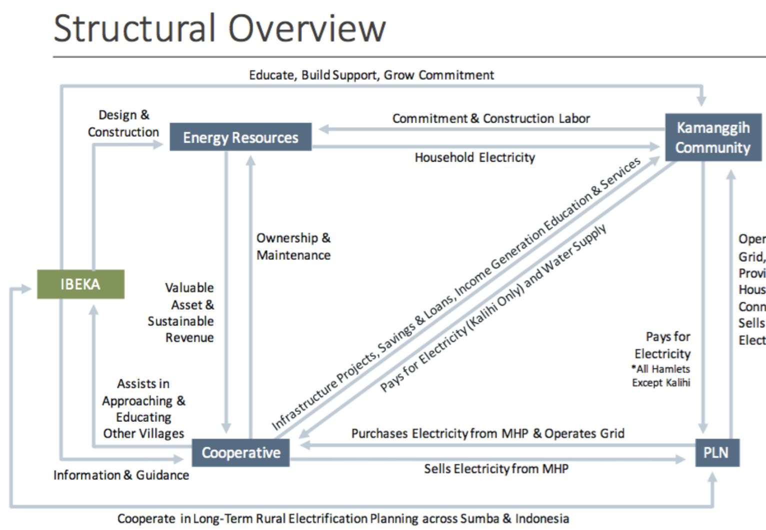

Figure 20: Stakeholder and resource flow map

having been electrified:

- Nearly 90 percent of households report being less worried about health security
- Over 50 percent report receiving services from the health clinic that they did not or could not receive before
- Over 80 percent of households experiencing persistent coughs prior to being electrified report feeling better

Reported access to information technology services (such as televisions, cellphones, or the Internet) exhibited similar dramatic increases. For instance, nearly a quarter of households reported now having access to Internet services. Finally, parents in nearly all households reported that children's attentiveness with respect to schoolwork had increased. The extent to which such improvements translate into better educational outcomes remains to be seen.[29]

[29] Other trends and patterns were also observed, and are discussed in greater detail below in the section on "Broader Impacts" as they are likely tied to a combination of electricity access, infrastructure improvements made possible by electricity access, and social impacts from the collective participation in the electrification process.

Electricity As Infrastructure Catalyst

The newly available and reliable electricity availability has accompanied major development in water infrastructure in Kamanggih. While IBEKA had installed a solar-powered water pump in 1999, its capacity hardly met the demand of more than a few dozen homes, and it has degraded. The Kamanggih Cooperative reports having used the revenue from electricity sales to fund the construction of a pumping house and household piping infrastructure to increase water services. Only three of five hamlets currently have water pumped to the household, yet further development is likely to continue as funds become available. The Cooperative charges each serviced household a usage-based monthly fee to cover further costs. Most households use this water for drinking (after boiling), cooking, cleaning, and bathing, while a few households use it for small-scale irrigation.

Broader Impacts

The aforementioned asphalt road constructed prior to electrification and the ongoing development of water infrastructure contribute—along with electricity access—to a climate conducive for socio-economic development and growth.

For instance, households near the village center report spending over two fewer hours collecting water for household-level uses relative to households without comparable water infrastructure; all households with access to pumped water also report having access to improved sanitation. Similarly, approximately eighty percent of households reported being able to create a new income-generating activity or expand an existing one; respondents largely attributed this to electrification. For the small sample of fifteen households that were able to recall and report incomes before and after electrification, incomes rose on average by over 75 percent. More broadly, nearly 90 percent of households in the community reported feeling more "financially secure."

Needless to say, these statistics should be viewed with great caution. Formal records for household finances are rarely maintained; even if they were, it would be challenging to attribute economic improvements to distinct factors without a more rigorous analysis. Nevertheless, these data do suggest—at the very least—the presence of a community-level sense of economic optimism and perhaps opportunity. In addition, while the staggered roll-out of the electrification program in Kamanggih may have exacerbated pre-existing inequality (relatively wealthier households living in the center of the community received electricity and pumped water first), this does not appear to have resulted in community-level resentment or disagreements.

Defining Empowerment, Defining Success

IBEKA does not view electrification as empowerment in itself. They merely view it as a powerful tool for communities to achieve empowerment with. Thus, they do not blindly pursue or push any external development goals, but rather work with communities to establish their own vision and path forward. This flexible and democratic process is well practiced and seems to have worked well in Kamanggih. Residents feel that the Kamanggih community is now more supportive, more aware of the issues it faces, better able to seek assistance for those issues, and better able to address those issues.

While electricity itself may have had a profound impact on Kamanggih, the lasting effects of the collective effort required to complete their project cannot be understated. With frequent village-wide conversations and construction projects during the electrification process, many in the community felt that the organizing facilitated by IBEKA helped establish better social and political relations in the village. Indeed, since being electrified:

- 93 percent of respondents feel that Kamanggih is a more supportive community, and is better organized to address community-level challenges
- Approximately half report they have have a greater influence in solving Kamanggih's problems
- Nearly ninety percent also feel empowered to address household-level challenges

Anecdotal conversations with local students also suggest a desire to pursue higher education, particularly after having seen the efforts of IBEKA engineers.

Future Outlook

Electrification has led to some minor improvements in income generation, yet there remains great potential for advancement. While electricity provides nighttime lighting that increases productivity for weavers, most residents lack a trade that can greatly expand with electricity access alone. The greatest potential seems to be for export of textiles and value-added food products to other areas of Indonesia and other countries. The Kamanggih Cooperative is already helping weaving groups market their products and decrease production costs, yet it intends to invest in community-owned food processing equipment as individual households lack the capital to purchase equipment on their own. As the water infrastructure expands, well-designed irrigation can improve crop yields during the dry season. A community-owned cattle farm made possible by electric water pumping with US-based investor support is currently being developed with the intention of funding college scholarships for Kamanggih students.

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