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Business models for mini-grid electricity in base of the pyramid markets

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ABSTRACT

This research project develops a business model framework based on the robust management literature on business models and uses the framework to analyze 24 mini-grid business models that serve "base of the pyramid" markets. The framework is based on the four dimensions of a business model that strategy scholars have identified, and is tailored to the unique circumstances of mini-grids that serve BOP customers. The study identifies 29 configurations of elements within mini-grid business models that supply a large—and growing—unmet demand for electricity in these markets. Analyzing these configurations results in a series of observations that pave the way for future research on mini-grid business models, as well as a number of trends within the off-grid electrification sector. The implications of these findings, and areas for further research, are also discussed.

Nearly one in five people around the world—1.26 billion to be precise, living primarily in Sub-Saharan Africa and Southeast Asia—lack access to a reliable source of electricity (International Energy Agency, 2013). The vast majority—85%—of these individuals live in rural areas (International Energy Agency (IEA) and World Bank, 2014). To reach these rural off-grid customers, two approaches are possible: a top-down approach based on extending the main grid, and a bottom-up approach based on household- and village-scale electricity generation. Most countries attempt to implement both, yet main grid extension often remains untenable in the near term for two reasons. First, extending the main grid to remote areas requires a large capital investment that many governments, or utility companies, cannot afford without funding from international donors and lenders (IEA and World Bank, 2014). Second, these investments, even if they were made, would likely not be recuperated financially for decades because utilities in these countries are usually required to charge new rural customers the uniform national tariff, which is hardly ever high enough to allow the utility to recover operating costs, leaving aside capital costs. In the most recent and complete survey of African utility companies to date, the World Bank found that 15 of 21 national utilities in Sub-Sahara Africa operate at a loss because they are required to sell electricity at rates that are below cost-recovery levels (Camos et al., 2008).

Consequently, the World Bank and the International Energy Agency have calculated that only 40% of the electricity required to supply off-grid individuals can feasibly come from extensions of main grids. The remaining 60% of the required electricity must come from "mini-grid and stand-alone off-grid solutions" (IEA and World Bank, 2014, p. 115). These statistics represent not just an international development issue, as lack of electricity access hinders economic growth potential, but also a considerable market opportunity for the private sector to provide solutions in the rural, off-grid electrification sector.

We should not be surprised, therefore, that in rural areas throughout Sub-Saharan Africa and developing Asia, mini-grids are emerging as a solution to provide electricity to off-grid communities. In fact, they are often the preferred method of bottom-up, off-grid electrification because they enable higher levels of electricity-based services at lower costs than solar home systems (Chaurey and Kandpal, 2010; Palit and Chaurey, 2011). In addition, as Ulsrud et al. (2011, p. 294)) assert, "the variety in electricity's uses is potentially higher for mini-grids compared to solar home systems" and "mini-grid systems may also facilitate the set-up of commercial organizations with incentives to keep the system in good working order," both of which make mini-grids important drivers of economic development.

Two important clarification are necessary before moving forward. First, the off-grid areas of low-income countries are not the only places where mini-grids operate. In fact, the most recent and complete assessment of the global mini-grid market to date, conducted by Navigant Research, a research and consulting firm that closely tracks the deployment of mini-grids, highlights that 66% of the total mini-grid installed capacity around the world exists in North America. Applications for these mini-grids include commercial and industrial

Abbreviations: BOP, Base of the Pyramid; GTF, Global Tracking Framework; MGD, Mini-grid Developer.

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complexes, remote communities, and military installations, among others (Asmus et al., 2014). This research project, however, will focus on mini-grids that operate in low-income countries, where 99.92% of the 1.26 billion people without access to electricity live (International Energy Agency, 2013).

Second, mini-grids themselves are not businesses. They are the distribution network that connects an electricity generation source to end users. As we will see in the Prototypical mini-grid business model section, they also can be built, owned, operated, and maintained by different entities. However, we can refer to the business model of a mini-grid because a business model is not tied to a single firm, as we will see in the Business models section, and because the activities surrounding a mini-grid include the elements needed to describe its business model: it has customers, a value chain, and some monetization mechanism. Therefore, in this project I will study mini-grid business models, using data collected from organizations involved in their development, management, and operation.

Mini-grids in low-income countries exhibit a diversity of business models, and there has been a lively discussion, primarily within the investor, practitioner, and international development community, about these business models (e.g., Bardouille and Muench, 2014). However, the many discussions on mini-grid business models in the literature tend to use the term business model loosely, and as a consequence, the business model-specific results and recommendations from these studies are not comparable from one study to the next. In essence, current research on many aspects of mini-grid business models lacks a common understanding of what actually is a business model, and what business models actually exist for mini-grids that serve low-income customers in off-grid areas.

This research project, therefore, sets out to create a foundation for future research on mini-grids and their business models by identifying what the business models are (the building blocks) and what they are made of (the more detailed elements within business models). This project is an exploration of existing mini-grid business models, which leverages academic research on business models in order to identify and understand how different models provide electricity to off-grid consumers in low-income countries. Importantly, the framework that this project develops can be used in future research on any set of mini-grids to determine which business models work best.

In this paper, I first synthesize our current understanding of business models, with a particular emphasis on those models within the Bottom of the Pyramid (BOP) market context where most off-grid customers exist, and mini-grids, with a focus on what has been written about their business models. Next, I construct a business model framework relevant to mini-grids, and use this framework to analyze 24 mini-grid business models that operate in low-income countries. The results identify 29 configurations of elements within mini-grid business models, and build a foundation for further research into the viability of different mini-grid business models that provide electricity to off-grid customers—a market that is estimated to be worth up to $150 billion per year (Bardouille and Muench, 2014), and in which companies and investors have taken a keen interest.

Literature

The aim of this literature review is twofold. First, it contextualizes the research project within recent scholarly work on both business models and mini-grid-based solutions to off-grid electrification. Second, the literature provides the building blocks for the business model framework that I develop in order to analyze the mini-grid business models in the study. This second aim is key: the goal of the paper is to identify what the existing business models are of mini-grids serving the BOP, so I first present and then draw from the robust literature in management on business models in order to develop a robust business model framework that can be applied specifically to mini-grids.

I therefore examine two streams of literature: business models, particularly those in BOP markets; and, mini-grids in off-grid areas of BOP markets. A large and growing body of academic literature on business models exists, and I will leverage the key take-aways from this literature in order to develop the business model framework in the Data and methods section. Scholars have also studied business models within the context of BOP markets, which is of particular relevance to this project since most people without access to electricity reside in these markets. The literature on mini-grids usually addresses the technical aspects of the mini-grid and generator systems, or best practices and ways to ensure long-term success of the mini-grid. Very little academic literature on business models for mini-grids exists, however practitioners and international development agencies have written much on this topic. These reports and studies are sparsely populated by scientifically rigorous analysis, but they do provide insights into the elements contained within the four dimensions of mini-grid business models.

Business models

While the concept of a business model gained traction in academic and popular usage around the early 1990s (as reported by Osterwalder and Pigneur, 2005), no theory of—or one that incorporates—business models yet exists. Early research was characterized by variety in the definitions of business models, and what they are made of—that is, what their dimensions are. As DaSilva and Trkman (2013, p. 4) note, “dozens of definitions and component breakdowns of the business model have been proposed over the last decade.”

As the definitions and dimensions of business models have evolved over the past 15 years, they have begun to coalesce around the definition put forward by Baden-Fuller and Haefliger (2013, p. 419): a business model is “a system that solves the problem of identifying who is (or are) the customer(s), engaging with their needs, delivering satisfaction, and monetizing the value.” Importantly, a business model is a standalone model for understanding these elements, and is not the sum total of all the activities of a firm—so a single company can actually have multiple business models (Baden-Fuller and Morgan, 2010). For example, Amazon operates a business model for its retail marketplace, and a separate business model for its cloud computing, which it sells to tech companies around the world.

Operationalizing this definition first requires a set of clear business model dimensions, each comprised of measurable elements that accurately and completely describe the organization's key value creation, value capture, and profit generating activities (Teece, 2010). The dimensions put forward by Baden-Fuller and Haefliger (2013) represent not only some of the latest thinking in business model research in terms of how to operationalize the concept, but also the most concise and yet still complete description of the firm's business model. These dimensions are:

- *Customer Identification*: Who is the customer? Who is the end user?
- *Customer Engagement*: What is the firm's value proposition? (i.e., What product and/or service does the firm sell?)
- *Value Chain Linkages*: How is customer satisfaction delivered? Is the value chain hierarchical, networked, or integrated?
- *Monetization*: From whom, how, and when is money made?

These four dimensions form the structure of the business model framework I develop in the Literature section.

Business models in BOP markets

Now that we have identified the four dimensions of the business model, let us turn to extant research on business models in the BOP.

This will give us insights as to the various elements in each of the four business model dimensions that have particular relevance to the BOP.

With the publication of Prahalad and Hart's (2002) article and Prahalad's (2006) book of the same title, *The Fortune at the Bottom of the Pyramid*, (Prahalad and Hart (2002); Prahalad (2006)), scholarly interest in business solutions to poverty reduction grew rapidly. Opportunities exist, the authors assert, for businesses to provide goods and services that at the same time help to reduce poverty and generate profit for the business. Many mini-grids are examples of one or more organizations that seek to generate revenues by providing a product (electricity) that helps reduce poverty. Research into "building business models for emerging economies and social uses" has emerged in parallel to the research on business solutions to poverty reduction in low-income countries (Baden-Fuller et al., 2010). Scholars highlight new firms that successfully create new business models to open up new, previously untapped markets (Thompson and MacMillan, 2010), and long-standing social enterprises are providing practitioners with lessons-learned and best practices for how to create economically viable business models that also help to solve a particular social problem (e.g., Yunus et al., 2010).

Customer Identification

During the early period of research into business models to engage with BOP markets, one topics received considerable attention: should, or could, the poor actually be a viable customer? Hart and Christensen (2002), along with Prahalad and co-authors (Prahalad and Hammond, 2002; Prahalad, 2006), argued persuasively that the poor can, and should, be customers—and that firms, in order to be successful, need to create value that is shared by both customers and the firm.

Customer Engagement

London and Hart (2004) demonstrated through their research the importance of creating different product or service options to meet the needs of customers at different income levels, highlighting the fact that BOP markets are not one-dimensional but rather are made up of consumers with varying incomes and willingness to pay. Adding to the notion that firms should create different products or services at different price points, Anderson and Markides (2007) assert that firms should consider broadening their definition of what products can do in order to meet multiple customer needs at prices they can afford. The solar lantern that also charges a cell phone is a good example of a product whose primary definition, a source of kerosene-free light, was broadened to serve an additional need.

Value Chain Linkages

London and Hart (2004) also show the importance of leveraging the existing strengths of the market, rather than focusing solely on overcoming its weaknesses. This, coupled with Prahalad and Hammond's (2002) research, which illustrated the benefits of establishing R&D activities in BOP markets with the specific focus on developing localized innovations, firmly demonstrated the importance of having a physical presence in BOP markets where firms hope to make sales. Adding to the concept of leveraging the existing strengths in a BOP market, Seelos and Mair (2009, p. 51) argue that firms should forge "a multitude of relationships and alliances with local non-traditional BOP partners" such as the local presence of a large company. Similarly, Dahan et al. (2010) recommend that organizations collaborate with NGOs that have complementary capabilities along the organization's value chain.

Monetization

Novel research on pricing and financing has shown the benefits of conducting consumer financing in-house as opposed to relying on external financing entities (Graf et al., 2013), and how "sachet-based pricing" (Anderson and Markides, 2007, p. 86) (i.e., selling smaller portions of a product that is traditionally sold in larger portions) and enabling customers to make small payments over time (Anderson and Billou, 2007) make products with high upfront costs affordable to BOP consumers. A real-world example of this is Simpa Networks, a company that sells solar home systems embedded with mobile phone-based pay-as-you-go technology that allows the customer to make small payments over time with their phones. Once they have paid the full price of the product, the customer owns it outright. These types of pay-as-you-go pricing schemes where the physical asset remains with the customer and can be deactivated in the event of nonpayment is common in the cell phone industry as well.

A few trends emerge from this review of the literature on the elements within the four dimensions of business models that serve BOP markets, which are also relevant for mini-grids. First, BOP business models usually involve selling directly to the end user at prices that the end user can afford. Second, companies are meeting the needs of their customers by offering different products or services at different price points while using the provision of a product or service that a customer needs to enable access to products or services that a customer wants. Third, value chains in BOP markets are not just hierarchical or integrated (i.e., vertically integrated)—they can also be networked, integrating local players such as communities and NGOs as equal partners. Finally, BOP business models often enable customers to make partial payments over time, or pay for small portions of a product, in order to make it affordable.

Mini-grids and their business models

MGDs are often referred to as mini-grids, small power producers, distributed generation, micro-grids, or distributed energy service companies, and the literature reviewed here includes research that uses these different definitions. Mini-grids are typically developed by individual entrepreneurs, a private company or non-profit organization, a community or community organization, or the main utility company (e.g., to serve a small offshore island), who take the initiative to develop a mini-grid. These entities face many of the same issues as more traditional businesses, such as securing start-up capital, preparing a business plan, dealing with regulations, operational issues and policy constraints, etc. (Bhattacharyya and Palit, 2014; Tenenbaum et al., 2014).

The academic research into mini-grids tends to focus on engineering aspects (see, for example, Greacen et al., 2012), or best practices and lessons-learned for operating and developing them (Palit and Chaurey, 2011; Rolland and Glania, 2011). As Ulsrud et al. (2011, p. 293) state, "Off-grid solar power systems in rural areas can be designed and organized in different ways, with different implications for how they work for the communities, how they can be financed, implemented, managed, operated, and kept running." Mini-grids rely on a variety of different energy sources. The most common are diesel, wind, solar, hydro, and biomass. In mini-grids supplied by renewable energy sources, arrays of batteries are often used to provide electricity when the renewable sources are not producing. Multiple energy sources can also be combined in what is called a hybrid system, where a diesel-powered generator provides backup or peaking power[1] (Tenenbaum et al., 2014).

Much of the existing literature on mini-grids and their business models comes from reports and studies by international donor agencies and consultancies, for example the Alliance for Rural Electrification

[1] Backup power refers to power generated by the diesel generator when the renewable energy systems are not producing electricity and batteries cannot meet the grid demand. Peaking power refers to the power needed when there is a surge in demand from customers on the mini-grid. In hybrid mini-grids, a diesel generator would generate the additional power that the renewable sources could not provide.

(Rolland and Glania, 2011), the World Bank (Tenenbaum et al., 2014), the IFC (Bardouille, 2012) and iED (Innovation Energy Développement (iED), 2013). The many discussions on mini-grid business models in the literature tend to use the term business model loosely, often interchangeably with ownership structure (e.g., ACP-EU Energy Facility, 2012) or profit-making status (e.g., Schnitzer et al., 2014). As a result, the results and recommendations from these studies are not comparable from one study to the next. In the following paragraphs, I unpack some of the recent literature on business models in the context of mini-grids. The elements that I identify below, organized by business model dimension, will be used to make the business model framework I develop in the Literature section even more specific to mini-grids that serve BOP customers.

Customer Identification

Mini-grids tend to supply electricity to a variety of customers beyond just households, including shops, television and video game centers, computer and internet cafes, workshops for milling grain, husking rice, and sewing, and a variety of community-related requirements such as street lighting, health centers, schools, community centers, and public offices (Chaurey and Kandpal, 2010; Ulsrud et al., 2011). Furthermore, Chaurey and Kandpal (2010) calculate that a large number (e.g., 500) of densely located connections has a positive influence on the MGD's commercial viability, although sales to an anchor customer such as a tea factory can help commercial viability in the absence of a large or densely populated customer base (Mukherjee, 2013). The mini-grid can also be connected to the main grid, where the mini-grid supplies power at wholesale to the utility company while selling also to retail customers such as nearby households and small businesses (Tenenbaum et al., 2014). For the purposes of this study, a grid and generator that provide electricity only to the main grid—that is, the major utility company is its only customer—is not considered a mini-grid.

Customer Engagement

Mini-grid customers do not want electricity *per se*, they want the services that electricity enables: lighting, phone charging, operating a fan, television, or radio, etc. (Bardouille and Muench, 2014; IEA and the World Bank, 2014). Small solar home systems can provide these services, but only grid-based electricity (main grid or mini-grid) can enable these services *and* productive uses of electricity such as home-based crafts like sewing, or rice husking and milling that add value to agricultural harvests (IEA and the World Bank, 2014). With these services come improved health, cost savings, and income generating activities. Indeed, scholars have argued that off-grid electrification is not an end itself, but a means to achieve the goal of rural poverty reduction by providing access to electricity-enabled services (Erichsen et al., 2013). For example, Kirubi et al. (2009) demonstrate that access to electricity from a mini-grid in a rural, off-grid village in Kenya increased the capacity of residents to generate income. This created a virtuous cycle for the mini-grid, because customers with more income demanded more electricity. However, affordability of the electricity is paramount—and customers tend to benchmark affordability against their current lighting source, typically kerosene or candles (Bardouille, 2012).

Value Chain Linkages

One of the most difficult challenges that all firms in BOP markets face is the delivery—encompassing all links in the value chain—of the product or service. Reaching so-called "last mile" customers is critical for mini-grid developers, and often constitutes one of the greatest supply and distribution chain costs. To overcome the challenges associated with delivering products or services in BOP markets, firms have adopted several strategies, which can generally be categorized as integrated (i.e., "vertically integrated" as per Williamson, 1985), hierarchical (i.e., purchasing services from key partners), or networked (i.e., more loosely organizing service providers, often with status as equal partners within the value chain), as Lorenzoni and Baden-Fuller (1995) describe. For mini-grids, this translates to decisions about who builds, owns, operates, and maintains the mini-grid and its generating source (Peterschmidt et al., 2013).

Mini-grids free individual users from the responsibilities of maintenance and operation as they would have with solar home systems (Chaurey and Kandpal, 2010). However, in cases where the a mini-grid developer contracts with others to build, own, operate, and/or maintain the mini-grid and its generation source(s), these partners play a critical role in the sustainability of the mini-grid (Schnitzer et al., 2014). In one example that Schnitzer et al. (2014) present, a mini-grid owner lost its contract to sell electricity to a telecom company's local cell phone tower—which would have provided a steady stream of income for the MGD—because the contractor the owner hired to conduct maintenance did not provide adequate servicing and the electricity was too unreliable for the telecom tower's needs. Finally, scholars have highlighted the important role that communities can play in designing, constructing, owning, operating, and maintaining mini-grids (Ulsrud et al., 2011), with the caveat that community owned and operated mini-grids are often financially unsustainable (Tenenbaum et al., 2014).

Monetization

The high initial cost of investment to develop a mini-grid is seen as a major barrier to their increased deployment in BOP markets (Alzola et al., 2009). In addition, one of the most significant reasons for a lack of growth in customers that mini-grids face is the high cost of connecting each new customer to the grid (Tenenbaum et al., 2014). As a result of these two upfront investments—one that is expensive for the mini-grid developer and one that is expensive for the customer—how a mini-grid brings in revenues is critically important. Alzola et al. (2009), among other researchers (e.g., Greacen and Tongsopit, 2012) and international development agencies (iED, 2013), have noted that initial capital cost grants and subsidies are often necessary for the successful development of a mini-grid. However, firms are finding ways to make connection costs, as well as the electricity costs, affordable to the end customer. Mini-grid customers are often offered prepaid or postpaid payment plans, or a combination of the two (for example a prepaid connection charge and post-paid monthly billing), and pay tariffs based on energy consumption (kWh), power consumption (kW), a fixed monthly fee, or a combination of these, at levels that they can afford (ACP-EU Energy Facility, 2012). In addition, to help make the electricity affordable, mini-grid customers are cross-subsidized among customer groups (e.g., business customers pay a higher tariff than households), and often have the opportunity to finance their initial connection charge with small payments over time (Tenenbaum et al., 2014).

To summarize, mini-grids can be built, owned, operated and maintained by different types of entities (e.g., community organization or for-profit firm) and they serve a variety of different customers with electricity generated from a variety of different energy sources. They deploy a variety of pricing mechanisms. There is, therefore, a considerable diversity in mini-grid business models.

Data and methods

The analysis in this project occurred in three steps. First, I identified the cases that I would study in this analysis. Then, I developed a framework that can be used to analyze these cases. This framework is essentially the four dimensions of the business model—Customer Identification, Customer Engagement, Value Chain Linkages, and Monetization—tailored to mini-grids that serve BOP markets by including mini-grid specific elements in each of the four dimensions. In the third step, I used this framework to cluster the cases according to their business models and develop insights about mini-grid business models and the industry more broadly.

Step 1: identifying cases

The cases in my study are mini-grid business models that serve BOP customers. In any given country, there may be hundreds of mini-grids, but there will be a smaller number of business models since multiple mini-grids may have the same business model. Typically, one or more organizations are the primary developers of these mini-grids—let us call these organizations Mini-grid Developers (MGDs). By gathering information about mini-grid business models via the organizations that develop them, I was able to efficiently identify a large number of mini-grid business models. For example, a single MGD might develop 100 mini-grids, deploying three different business models, while another MGD might develop three mini-grids, each with different business models. If the business models appeared to be different from each other, I would record this as six cases—that is, six different mini-grid business models.

I identified mini-grid business models using a snowball sampling technique (Biernacki and Waldorf, 1981), which is an effective way to identify cases when no database exists (Bonaccorsi et al., 2006). I started looking for MGDs and the business models of their mini-grids in documents from the World Bank, Alliance for Rural Electrification, HOMER Energy, and Navigant Research—organizations that work with, or conduct research on, a large number of mini-grids. Whenever I came across the name of an organization and/or a description of a mini-grid business model, I added it to the list and researched it through a series of keyword searches on Google in order to capture general information about the mini-grid business model (date of first mini-grid or MGD founding date if that was unavailable, country or countries of operation, type of energy source, customers, tariffs, etc.). This often led to other sources such as news articles, reports, and studies that mention other MGDs or mini-grids in addition to the one I was searching for on Google. I stopped searching for new mini-grid business models when new sources did not mention any new MGDs or new business models. In this way, I had identified 78 different mini-grid business models that operate in the off-grid areas of low-income countries, and had collected preliminary information on each of the business models.

Step 2: developing a mini-grid-specific business model framework

In order to analyze the mini-grid business models (the cases to be studied), I used the four dimensions of the business model that have been identified in management literature—Customer Identification, Customer Engagement, Value Chain Linkages, and Monetization. Within each of these dimensions, I further developed the framework by identifying certain business model elements from the literature that we would expect to see in mini-grids, presented above in the Business models in BOP markets and Mini-grids and their business models sections, and other business model elements from an initial read-through of the data, as I explain below.

For each of the 78 mini-grid business models I had identified, I created a separate table to capture information about its four dimensions. I carefully researched each of the 78 cases and collected data from a variety of sources, including the MGD's websites, recorded or transcribed interviews with individuals familiar with the mini-grid business model, press releases, articles in the press, and reports and case studies from authoritative entities like the World Bank. I then downloaded these files—including webpages converted to PDFs—to my computer. From these data, I copied passages that contain information relevant to the business model directly into the table for each organization—with a reference to the filename from where the data came. In this way, I was able to develop a snapshot of the business model, with a traceable connection between each passage and the document from which it came.

Once I had this initial data for each mini-grid business model, I went back through each of the cases to identify elements within each of the four business model dimensions that were recurring across multiple cases. I then checked these elements against what has been discussed in the literature related to mini-grid business models as well as business models for doing business in BOP markets. Checking back with the literature enabled me to include any critical business model activities that I missed from an initial read-through of the data. From an initial reading of the data and by revisiting the literature, I developed the following Framework for Mini-Grid Business Models:

L&D: Elements identified in the literature and though initial reading of the data; L only: elements identified in the literature only.

The process of first identifying business model elements directly from the data, then supplementing these with business model elements from the literature, ensured that I had a robust and thorough (i.e., complete) framework by which to compare the mini-grid business models.

Step 3: analyzing mini-grid business models using the business model framework

With this framework, I returned to the data I had collected on the 78 mini-grid business models. Of these cases, two were eliminated because they sell electricity only to the main grid—in other words, they are what the energy industry refers to as independent power producers. Nine were eliminated because they were business models of organizations that sold or developed mini-grids and did not earn any revenue from the actual production and sale of electricity. A further 46 were eliminated because sufficient data across all business model elements could not be found from secondary sources. This resulted in 24 different mini-grid business models from 23 different MGDs (one of the MGDs developed some mini-grids with one business model, and some with another business model). For each of the 24 mini-grid business models, I collected

Table 1
Framework for analyzing mini-grid business models.

Business model dimension	Business model elements from literature and data
Customer Identification	• (L&D) whether or not the mini-grid also connects to the main grid; • (L&D) whether the paying customers are the end users of the electricity, or some intermediary (such as the main utility or a local entrepreneur), or both; • (L&D) what types of end users the mini-grid serves—just households, or households and small businesses, and whether there was an anchor customer
Customer Engagement	• (L&D) whether or not the electricity is cheaper than kerosene (or some other non-electric lighting source) • (L only) whether or not the organization offers different services at different price points; • (L only) whether or not the electricity provided is enough to enable services beyond lighting such as the operation of small appliances
Value Chain Linkages	• (L&D) which entity is responsible for the building, owning, operating, and maintaining of the mini-grid and its generator—options ranged from the MGD, a third party provider, or the community or a community organization
Monetization	• (L&D) when payment is made—prepaid, postpaid, or both; • what type of tariff the MGD uses—energy (per kWh), power (per kW), a combination of energy and power, or a flat tariff • (L only) whether the MGD earns revenue from the sale of electricity (hence the different tariff types as previously identified), or from the construction of the mini-grid and generator(s); • (L only) whether the MGD offers customers the ability to pay over time for the cost of connecting to the grid, and whether the MGD cross-subsidizes different customer groups by charging one customer group higher prices to subsidize lower prices for lower-income customers

Note: L&D: Elements identified in the literature and though initial reading of the data; L only: elements identified in the literature only.

Table 2
Business model cases for analysis.

Business model case name	First mini-grid (or MGD founding)	Country	Energy source[a]
Andoya Hydropower	2011	Tanzania	Renewable
Bonny Utility Company	2006	Nigeria	Fossil
CarbonX Energy	2011	Tanzania	Renewable
Comisión Federal de Electricidad	1999	Mexico	Hybrid
CREDA	2001	India	Renewable
DESI Power	1996	India	Renewable
Devergy	2010	Tanzania	Renewable
Dothaluoya Village Hydropower Consumers Welfare Society	2007	Sri Lanka	Renewable
Earthspark	2012	Haiti	Hybrid
Electricite d'Haiti	1986	Haiti	Fossil
Gram Power	2013	India	Hybrid
Husk Power Systems Model 1 ("BOM")	2008	India	Renewable
Husk Power Systems Model 2 ("BOOM")	2008	India	Renewable
Inensus West Africa (now Enersa)	2008	Senegal	Hybrid
Korayé Kurumba	2006	Mali	Fossil
LUMAMA Electricity Association	2011	Tanzania	Renewable
Mera Gao Power	2011	India	Renewable
MeshPower	2013	Rwanda, India	Renewable
Mutanda Electricity Utility	Mid-1990s	Zambia	Renewable
OREDA	2002	India	Renewable
Rift Valley Energy/Mwenga Hydro	2012	Tanzania	Renewable
Sunlabob Model ("B-to-U")	2001	Laos	Hybrid
WBREDA	1993	India	Renewable
Yeelen Kura	2001	Mali	Hybrid
Median Founding Date	2008		
Total Number of Countries		11	
Number of Each Case's Energy Source			15 Renew.
6 Hybrid			
3 Fossil			

[a] Renewable includes hydro, biomass, solar, and wind. Fossil includes natural gas and diesel. Hybrid is a combination of renewable and fossil sources.

passages totaling an average of 817 words describing business model elements, copied from an average of 6 sources per case, in order to create a detailed business model snapshot. Appendix A presents an example of a business model snapshot. Table 2 presents the final cases I used in my analysis. As Table 2 demonstrates, I was able to achieve diversity in cases in terms of age, geography, and energy source. Note that each case name is the name of the MGD, but data is collected about one or more of the specific mini-grids that it developed. (See Table 1.)

In order to apply the framework to each case as a way to systematically compare the cases, I developed a coding system whereby each business model element in Table 3 was assigned a consecutive integer value, starting with 0 or 1. I selected consecutive integer values as the coding system for each of the business model elements, but could have used letters or symbols as ways to code each case, however I found consecutive integer values easier to work with in Microsoft Excel. I then coded the cases by assigning every business model element within each case the appropriate numerical value based on a careful inspection of the data I had assembled for each case. Each case therefore had a unique sequence of numbers according to the elements in its business model. We can think of this like a unique "bar code" for each case. As an illustrative example, Appendix B provides the numerical value assigned to the business model for Carbon X Energy that resulted from a careful inspection of its business model data. Table 3 below presents the final business model framework, with each element and its assigned numerical values.

To systematically compare the cases, I grouped them according to the configuration of their codes along each business model element using Microsoft Excel, with rows representing business model cases

Table 3
Mini-grid business model framework for clustering analysis.

Business model dimension	Elements within the business model dimension	Assigned numerical values
Customer/User Identification	Whether or not the mini-grid is connected to the main grid	1 = Stand-alone; 2 = Main Grid Connection
	Whether the paying customers are the end users of the electricity, some intermediary, or both	1 = End User; 2 = Intermediary and End User; 3 = Intermediary Only
	What types of customers the mini-grid sells to	1 = Just Households; 2 = Households & Businesses; 3 = Presence of Anchor Customer(s)
Customer/User Engagement	Is the electricity cheaper than kerosene (or some other non-electric lighting source)	1 = Yes; 2 = No
	What level of services the electricity enables	0 = < "Tier 3"; 1 = "Tier 3"; 2 = > "Tier 3" (*see Note below*)
	Does the organization offer different products or services at different prices	1 = Yes; 2 = No
Value Chain Linkages	Which entity is responsible for the building, owning, operating, and maintaining of the mini-grid and its generator	1 = MGD itself; 2 = Non-Community Third Party; 3 = Community or Community Organization
Monetization	When customers make their payments	1 = Prepaid; 2 = Both Pre- and Post-paid; 3 = Post-paid
	What type of tariff the MGD uses or if the MGD earns revenue instead from the construction of the mini-grid and its generator	1 = Energy Tariff (per kWh); 2 = Combination Energy and Power Tariff (per kW); 3 = Power Tariff; 4 = Fixed Tariff; 5 = Payment for Installation/Construction Only
	Whether the MGD enables customers to pay for the cost of connecting to the mini-grid over time, or if the MGD cross-subsidizes customer groups	1 = Neither; 2 = connection cost financing; 3 = Cross-subsidization; 4 = both 2 and 3

Note: Calculating what level of services the mini-grid provided proved to be a challenge. I needed a way to codify energy access in terms of services enabled by electricity. I used the multi-tier framework for energy access developed by the World Bank and the International Energy Agency to produce such a codification. As part of the United Nation's Sustainable Energy for All initiative (http://www.se4all.org/), these organizations have identified the different services that are possible with different levels of access to electricity. For this initiative's Global Tracking Framework Report, the traditional "energy ladder" is replaced by a multi-tier framework, as shown below in Table 4. The data I focused on were "peak available capacity" and "duration" in order to calculate Watt-hours of availability per user, as these data were more readily available for a larger number of the mini-grids I was researching. For some of the mini-grids, it was stated how many Watts each connection had access to, and for how many hours per day electricity was available. For others, this data had to be calculated using other information that was available—for example dividing the total capacity of the generator in Watts by the total number of connections, or dividing the total number of kilowatt-hours produced annually by 365 to find the number of hours electricity was available on average per day throughout the course of the year. It's important to note that one of the issues that has been raised about the multi-tier framework is its emphasis on capacity and consumption thresholds that ignore energy efficiency. Thus, it in effect penalizes uses of electricity that are energy efficient. For the purposes of this study, however, it was necessary to compare cases at the level of the mini-grid, and not at the level of how the mini-grid electricity was used, so the energy per user metric (Watt-hour per user) proved to be the most appropriate.

and columns representing each of the business model elements. I conducted four rounds of clustering analyses—one for each dimension of the business model.

Because I had only 24 cases in my sample, I wanted to err on the side of too many configurations rather than too few so as to be sure I was capturing as much of the natural variation in the population that I could and not artificially missing some configurations defined by only a small number of cases. For this reason, many of the configurations have just one or two case in them.

Table 4
Multi-tier framework to define access to electricity services.

Attributes	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Peak available capacity (W)	–	>1	>50	>500	>2000	>2000
Duration (hours)	–	≥4	≥4	≥8	≥16	≥22
Resulting W-h per User	–	*>4*	*>200*	*>4000*	*>32,000*	*>44,000*
Evening supply (hours)	–	≥2	≥2	≥2	≥4	≥4
Affordability	–	–	✓	✓	✓	✓
Legality	–	–	–	✓	✓	✓
Quality (voltage)	–	–	–	✓	✓	✓
Use of electricity services	–	Task lighting, and phone charging (or radio)	General lighting, television, and Fan	Tier 2, and any low-power appliances	Tier 3, and any medium-power appliances	Tier 4, and any high-power appliances
Typical electricity delivery mechanism	Batteries	Lanterns & Solar Home Systems	Solar Home Systems	Mini-Grids & Main Grids	Mini-Grids & Main Grids	Mini-Grids & Main Grids

Source: *IEA and the World Bank*, 2014.

Results

This section presents the results of my analysis. I first present the most common configuration of business model elements within each dimension—thus identifying what could be considered the prototypical mini-grid business model. I then present the results of four clustering analyses, one for each dimension of the business model, as a way to gain insights into which business model elements are most commonly found together. For example, given a particular configuration of elements in the Customer Identification dimension, what other business model elements do we see, or not, in the other business model dimensions, and what conclusions can we draw from this? Finally, I present the results of an analysis of comparing mini-grid business models and the date they were founded to reveal trends in the industry.

It would be tempting to draw decisive, sector-wide conclusions from the data I collected, but a sample of only 24 cases means that I can only present observations that can guide future research using larger samples. Appendix C presents the four clustering analyses in Microsoft Excel format to give the interested reader fuller access to the underlying data.

Table 5
Business model elements observed in the data.

Business model dimension	Elements within the business model dimension	Number of cases
Customer/User Identification	Stand-alone Mini-grid	22
	Connected to the Main Grid	2
	End User is Paying Customer	19
	End Users and Intermediaries are Paying Customers	3
	An Intermediary is Paying Customer	2
	Homes and small businesses are end customers	15
	Homes, small businesses and an anchor customer are customers	5
	Homes are the end customers	4
Customer/User Engagement	Electricity is cheaper than substitute lighting source	21
	Electricity is not cheaper than substitute lighting source	3
	Electricity production < GTF Tier 3	15
	Electricity production = GTF Tier 3	7
	Electricity Production > GTF Tier 3	2
	Mini-grid offers different service levels at different prices	16
	Mini-grid does not offer different service levels at different prices	8
Value Chain Linkages	Constructing the Mini-grid: MGD	17
	Constructing the Mini-grid: 3rd Party	7
	Constructing the Mini-grid: Community	0
	Owning the Mini-grid: MGD	21
	Owning the Mini-grid: Community	3
	Owning the Mini-grid: 3rd Party	0
	Operating the Mini-grid: MGD	15
	Operating the Mini-grid: Community	7
	Operating the Mini-grid: 3rd Party	2
	Maintaining the Mini-grid: MGD	19
	Maintaining the Mini-grid: 3rd Party	4
	Maintaining the Mini-grid: Community	1
Monetization	Customers Prepay	11
	Customers Postpay	9
	Customers Prepay and Postpay	4
	Customers pay Energy Tariff	10
	Customers pay Combination Energy and Power Tariff	6
	Customers pay a Fixed Tariff	5
	Customers pay Power Tariff	3
	No customer financing is offered	12
	Customers are cross-subsidized	6
	Customers can finance their connection charge	3
	Customers are both cross-subsidized and can finance connection	3

Note: Underlined data signify elements that appeared most often in the cases.

Table 6
Configurations of customer identification.

Configuration	A	B	C	D	E	F
Number of Cases	14	4	2	1	1	2
Main Grid Connection?	Stand–Alone	Stand–Alone	Stand–Alone	Stand–Alone	Stand–Alone	Grid–Connected
Paying Customer	End–User	End–User	Inter–mediary	End User & Intermediary	End User	End–User& Intermediary
Types of Customers	Homes & Small Businesses	Homes	H, SB, and Anchor Customer(s)	Homes & Small Businesses	H, SB, and Anchor Customer(s)	H, SB, and Anchor Customer(s)
Cheaper than Kerosene	Yes	Yes	Yes	Yes	Yes	Yes
Energy Service Tier		< Tier 3		Tier 3	< Tier 3	
Service Differentiation	Yes			No	Yes	
Build			MGD	MGD	MGD	MGD
Own	MGD	MGD		MGD	MGD	MGD
Operate		MGD	Comm.	Comm.	Comm.	MGD
Maintain	MGD			MGD	MGD	MGD
When Payments are Due		Postpay		Postpay	Prepay	
Revenue Scheme		Fixed Tariff		Energy Tariff	Energy & Power Tariff	Energy Tariff
Customer Financing		None		Cross–subsidy	None	

Note: *Blanks represent elements for which there was considerable difference between cases in the configuration, so we cannot draw conclusions about that particular element from the clustering analysis.*

Prototypical mini-grid business model

Table 5 presents the business model elements that were observed across the cases.

As Table 5 shows, the prototypical mini-grid business model that serves off-grid customers in low-income markets would be a stand-alone mini-grid that sells directly to end users, who are nearby households and small businesses. The electricity would be cheaper than a lighting alternative (e.g., kerosene), the capacity-per-user would be the equivalent of less than the Global Tracking Framework's Tier 3, and customers would be offered different levels of service at different prices. The mini-grid would be constructed, owned, operated, and maintained by the mini-grid developer, and customers would prepay an energy tariff, without the option of financing their connection charge or having their tariffs cross-subsidized.

In my sample, however, no single business model matched this prototype across every element. As a result, it is important to analyze which elements we tend to find together—for example, if a stand-alone mini-grid sells directly to end users, which type of monetization scheme will be in place? The next four sections conduct this analysis by identifying different configurations of business model elements given different starting conditions in each business model dimension.

Table 7
Configurations of customer engagement.

Configuration	A	B	C	D	E	F
Number of Cases	9	5	4	2	1	3
Main Grid Connection?	Stand–Alone	Stand–Alone	Stand–Alone	Stand–Alone	Stand–Alone	Stand–Alone
Paying Customer	End User				End User	End User
Types of Customers				Homes & Small Business	Homes & Small Business	
Cheaper than Kerosene	Yes	Yes	Yes	Yes	Yes	No
Energy Service Tier	< Tier 3	< Tier 3	Tier 3	Tier 3	> Tier 3	
Service Differentiation	Yes	No	Yes	No	Yes	
Build	MGD		MGD	MGD	MGD	MGD
Own			MGD	MGD	MGD	MGD
Operate					MGD	
Maintain	MGD	MGD		MGD	MGD	MGD
When Payments Due					Prepay	
Revenue Scheme				Energy Tariff	Energy & Power Tariff	
Customer Financing				Cross Subsidy	Connection	

Note: *Blanks represent elements for which there was considerable difference between cases in the configuration, so we cannot draw conclusions about that particular element from the clustering analysis.*

Customer Identification

The mini-grid business models that I analyzed fell into seven different configurations based on customer identification elements, presented in Table 6 below.

Several interesting trends emerge from an analysis of the configurations of business model elements when they cases are clustered according to their customer identification characteristics. First, the dominant configuration consists of a mini-grid business model in which a stand-alone mini-grid serves households and small businesses, or just households, as the paying customers. The electricity is cheaper than kerosene, and the mini-grid developer owns the mini-grid. When the mini-grid sells just to nearby households and there are no small business customers, the monetization scheme tends to be a model we might associate with older utility companies: it is a post-paid fixed tariff without any customer financing. The difference between configurations A and B, therefore, are driven by the presence of small businesses—which likely push the mini-grid developer, who owns the mini-grid, to not only maintain it but also to try different monetization schemes. This leads us to our first observation:

> *Observation 1*: *The presence of small business as paying customers for a mini-grid can be a source of innovation in the monetization dimension of the mini-grid business model.*

Second, selling electricity to an intermediary as the end customer coincides with the mini-grid developer not owning the mini-grid. Intermediaries could be a local entrepreneur who buys bulk energy credits and resells them to nearby households, or another type of entity that purchases electricity from the mini-grid and then resells it. This configuration is likely the result of a broader strategy to avoid the costs associated with maintaining a significant presence in the local area where the mini-grid is located. If a mini-grid developer has decided that it does not want to become "embedded" within the local area, or at least minimize its embeddedness, it will give up ownership of the mini-grid by selling it to the local community or to a 3rd party (e.g., a local entrepreneur), which then becomes the intermediary through which electricity sales to the end user are conducted. We might therefore observe that:

> *Observation 2*: *Selling electricity through an intermediary and not owning the mini-grid can be effective complementary strategies to reduce costs and potentially increase the mini-grid developer's financial viability.*

Third, mini-grid business models in which an anchor customer is present tend to have the mini-grid developer responsible for building the mini-grid. This is likely because anchor customers represent attractive targets for mini-grid developers that have the capabilities to build a mini-grid, and I suggest the following:

> *Observation 3*: *If an anchor customer is served by a mini-grid, the mini-grid will be more likely to have been constructed by the mini-grid developer than by the community or a 3rd party.*

Finally, only two mini-grid business models include the main grid as a customer. That there were only two mini-grids with connections to the main grid might seem to suggest that this is a rare occurrence. However, one wonders why mini-grids would be extended to sell electricity to nearby households and small businesses at all, if the main grid can serve as a

Table 8
Configurations of value chain linkages.

Configuration	A	B	C	D	E	F	G	H
Number of Cases	8	3	2	2	5	1	2	1
Main Grid Connection?	Stand–Alone	Stand–Alone	Stand–Alone	Stand–Alone	Stand–Alone	Stand–Alone	Stand–Alone	Stand–Alone
Paying Customer	End User		End User		End User	End User		End User
Customer Types					Homes & Small Business	Homes & Small Business		Homes
Cheaper than Kerosene	Yes	Yes	Yes	Yes		No	Yes	Yes
Energy Service Tier			< Tier 3	Tier 3		> Tier 3	< Tier 3	< Tier 3
Service Differentiation			Yes	Yes		Yes		No
Build	MGD	MGD	MGD	MGD	3rd Party	3rd Party	MGD	3rd Party
Own	MGD	MGD	MGD	MGD	MGD	MGD	Comm.	Comm.
Operate	MGD	Comm.	MGD	Comm.	MGD	Comm.	Comm.	3rd Party
Maintain	MGD	MGD	3rd Party		MGD	MGD	MGD	3rd Party
When Payments are Due	Prepay			Postpay		Postpay		Postpay
Revenue Scheme						Energy Tariff	Energy Tariff	Fixed Tariff
Customer Finance			None	None		None		None

Note: *Blanks represent elements for which there was considerable difference between cases in the configuration, so we cannot draw conclusions about that particular element from the clustering analysis.*

customer that provides steady revenues. I suspect that three factors are behind this result: 1) Tanzania has favorable policies and regulations for MGDs that wish to connect their mini-grid to the utility's main grid while also serving nearby households and small businesses (EWURA, 2012; United Republic of Tanzania, 2008); 2) hydro-powered mini-grids generally have a greater ability to produce electricity continuously and cheaply than mini-grids powered by other renewable sources or a combination of renewable and fossil-based energy sources (Greacen, 2004); and, 3) Tanzania's Rural Electrification Agency gives a grant of $500 to an MGD for every household or small business it connects to the mini-grid (Tenenbaum et al., 2014). Because there were only two cases in my sample, I cannot draw any definitive conclusions, but this presents an interesting line of research for scholars, and suggests the following observation:

Observation 4: *A favorable policy regime, an energy source that enables the provision of electricity continuously and cheaply, and subsidies that incentivize the MGD to connect nearby retail households and small businesses when it already plans to connect to the main grid, are necessary—but not sufficient—factors for an MGD to connect its mini-grid to both the main grid and nearby households and small businesses. These factors are in addition to the obvious need to have household and small business customers located near enough to the main grid to be served by the MGD's main grid-connected mini-grid.*

Customer Engagement

The mini-grids that I analyzed exhibited six different configurations of customer engagement elements within their business model, as shown below in Table 7.

In the clustering analysis above, we see that all but three cases of mini-grid business models were able to sell electricity that was at least as cheap as kerosene (or whichever non-electric light source would be the substitute). By analyzing the results, we can see that relatively expensive electricity coincides with the mini-grid developer building, owning, and maintaining the mini-grid, except when customers are charged an energy tariff and they are cross-subsidized. This leads me to observe the following:

Observation 5: *If a mini-grid developer builds, owns, and maintains the mini-grid, it risks not being able to sell electricity that is cheaper than an alternative energy source. This risk can be mitigated if it cross-subsidizes across different customer groups and charges an energy tariff (which encourages energy efficiency among customers).*

We also observe that mini-grid business models in which the MGD builds and owns the mini-grid correspond with higher capacity per user. This is likely a reflection of the fact that the incentives to build a mini-grid with larger capacity are stronger when the builder is also the mini-grid owner, whose ability to repay any capital costs incurred from constructing the mini-grid rest on being able to sell electricity to a large number of customers. We might therefore say that:

Observation 6: *Having the same entity responsible for building and owning a mini-grid creates positive incentives to develop more capacity per customer.*

An important caveat to the above observations is that it is likely that many MGDs are able to offer low tariffs because their capital expenditure costs were partially or completely covered by donor grants, although I was not able to find reliable data on this for most of the cases in my sample. However, research has shown that without subsidies or regulatory mandates, mini-grid-based electricity is often more expensive than kerosene when tariffs must cover capital and operating expenditures while also earning a profit (Tenenbaum et al., 2014).

No single element within a mini-grid's business model determines whether or not the mini-grid will be able to sell electricity that is cost competitive with *unsubsidized* kerosene. Instead, what the results are indicating is the following:

Observation 7: *Some combination of creative monetization models, efficient operations through a well-designed value chain, appropriate fuel choice, and external funding (grants, equity, debt, etc.) are needed to produce electricity that can compete on cost with unsubsidized kerosene.*

Value Chain Linkages

The value chain linkages of the cases that I analyzed differ considerably between firms. I identified nine configurations based on the different types of organizations that are responsible for the activities in the mini-grid's value chain, shown below in Table 8.

As the table above shows, there is considerable variety in the value chain linkages of mini-grids that serve BOP customers. It is likely that if I had analyzed more cases, I would have seen even more diversity in value chain linkages. There are at least three interesting trends in my sample, though. First, the most common role for the mini-grid developer was to own the mini-grid. This accounted for 21 of 24 cases. The fact that other entities commonly play important roles in the value chains of mini-grids is itself an important observation, and should be heeded by policymakers and others who study mini-grids:

Observation 8: *There is no single, well-defined role that a mini-grid developer can play in the mini-grid business model. Instead, the value chain of a mini-grid entails the local community and other 3rd parties as important actors for building, owning, operating, and/or maintaining the mini-grid.*

The second observation that we can draw from the table above is that the mini-grid business model in which the MGD builds, owns, operates, and maintains the mini-grid is also characterized by prepayments from the customers. This likely reflects the fact that prepayments are an important tool to ensure customers are paying for the electricity that they use, which is particularly important for MGDs who need to recoup the capital and O&M costs from electricity sales. In fact, in the business models where postpay was used, the MGD was not responsible for operating the mini-grid, which might indicate that prepaid tariffs are primarily a technique used to recover O&M costs. Whatever the underlying motivations may be, we can observe:

Table 9
Configurations of monetization.

Configuration	A	B	C	D	E	F	G	H	I
Number of Cases	4	2	2	2	2	3	3	3	3
Main Grid Conn.?	Stand–Alone	Stand–Alone	Stand–Alone	Stand–Alone		Stand–Alone		Stand–Alone	Stand–Alone
Paying Customer	End User	End User		End User	End User & Intermediary			End User	End User
Customer Types	Homes	Homes & Small Business		Homes & Small Business					
Cheaper than Kerosene	Yes		Yes	Yes	Yes	Yes		Yes	Yes
Energy Service Tier	< Tier 3		Tier 3	< Tier 3	Tier 3			<Tier 3	
Service Differentiation	No	Yes	Yes	Yes					Yes
Build	3rd Party		MGD	MGD	MGD	MGD			MGD
Own	MGD		MGD	MGD	MGD		MGD	MGD	MGD
Operate	MGD	Comm.	Comm.				MGD	MGD	
Maintain		MGD		MGD	MGD	MGD	MGD	MGD	
When Payments are Due	Postpay	Postpay	Postpay	Prepay & Postpay		Prepay	Prepay	Prepay	Prepay
Revenue Scheme	Fixed Tariff	Energy Tariff		Energy & Power Tariff	Energy Tariff	Energy Tariff	Energy Tariff	Power Tariff	Energy & Power Tariff
Customer Finance	None	None	None	None	Cross Subsidy	Cross Subsidy	Connect. & Cross Subsidy	Connect.	None

Note: Blanks represent elements for which there was considerable difference between cases in the configuration, so we cannot draw conclusions about that particular element from the clustering analysis.

Observation 9: mini-grid business models in which the MGD builds, owns, operates and maintains the mini-grid are likely to include prepayment as part of the monetization dimension, whereas mini-grids in which the MGD does not operate the mini-grid are likely to include post-payment as part of the monetization dimension.

Monetization

How to monetize the mini-grid is a critically important dimension to their business model. There was a surprising amount of variation in the way mini-grids in my sample were monetized, as reflected in the eight configurations revealed by the clustering analysis, shown below in Table 9.

Table 10
Trends by MGD age.

Business model dimension	Business model element	Most common observation pre-2000	Most common observation 2000–2004	Most common observation 2005–2009	Most common observation 2010–2014
Customer Identification	Location of Generation	Stand-Alone	Stand-Alone	Stand-Alone	Stand-Alone
	Paying Customer	End User	End User	End User	End User
	End User Identification	Homes & Small Businesses	Homes	Homes & Small Businesses	Homes & Small Businesses
Customer Engagement	Electricity Cheaper than Kerosene	Yes	Yes	Yes	Yes
	GTF Tier	<Tier 3	<Tier 3	<Tier 3	<Tier 3
	Services Offered at Different Prices	Yes	Yes	Yes	Yes
Value Chain Linkages	Builder	MGD	MGD	MGD	MGD
	Owner	MGD	MGD	MGD	MGD
	Operator	Community	MGD	MGD	MGD
	Maintenance	MGD	3rd Party	MGD	MGD
Monetization	When Payment is Due	Postpay	Postpay	Prepay	Prepay
	Type of Tariff	Energy Tariff	Fixed Tariff	Energy & Power	Energy Tariff
	Customer Financing Offered	None	None	None	Cross-Subsidies

One of the first observations we can make from the table above is that postpaid tariffs tend to coincide with no customer financing while prepaid tariffs tend to coincide with some form of customer financing. This might reflect the fact that postpayment is in itself a form of financing—energy is provided first, and payment comes later—so adding additional customer financing would place an even greater financial burden on the mini-grid owner/operator. Thus:

Observation 10: *Mini-grids in which customers post-pay for their electricity are less likely to offer customer financing than mini-grids in which customers prepay for their electricity, likely because the combination of post-payment and customer financing places too much of a financial burden on the mini-grid owner/operator(s).*

The second observation we can make is that mini-grid business models in which customers pay an energy or power tariff are more common than mini-grid business models in which customers pay a fixed tariff. This makes sense in the context of mini-grids needing to survive as economically viable entities—fixed tariffs make it more difficult for the mini-grid to earn revenues that are tied to its electricity production, creating a misalignment of incentives not only to generate more electricity which could be used to supply more customers and/or productive uses of electricity, but also to encourage energy efficiency in end-uses of electricity. This leads me to observe the following:

Observation 11: *The misalignment of incentives between mini-grid customers and mini-grid owner/operator(s) that result from a fixed tariff scheme means that we are more likely to observe mini-grid business models that rely on energy or power tariffs, or combined energy and power tariffs, if allowed by the regulator.*

Industry trends

In addition to identifying 29 configurations of elements within mini-grid business models, my data also enabled me to consider what trends appear to be emerging in the off-grid electricity sector. When I compared mini-grid business models (the cases) by the date of the first mini-grid with that model, or the founding date of the mini-grid developer deploying that model, I was able to identify shifts within the industry. These shifts are presented below in Table 10.

The table above highlights the following key industry trends:

First, most mini-grid business model innovation has occurred within the value chain linkages and monetization dimensions. This makes sense since we would not expect the general customer orientation and value proposition of mini-grid business models that target BOP customers to change.

Second, within the value chain dimension, there has been a shift in developing a business model around a community operated mini-grid, and towards a more vertically oriented value chain in which the mini-grid developer is responsible for mini-grid construction, ownership, operation and maintenance. This likely reflects one of the limitations inherent to running an organization in BOP markets: suitable partners for value chain activities like operating the mini-grid are difficult to find when the end goal is to run a financially viable mini-grid.

Third, within the monetization dimension, we see a clear shift away from postpaid tariffs and no customer financing towards prepaid tariffs and cross-subsidizing different customer groups. I suggest that this is occurring for two reasons. First, as more mini-grid business models have the mini-grid developer as the operator, developers are seeking more creative monetization mechanisms to be able to offer affordable electricity. Second, as cell phones have become ubiquitous in BOP markets, customers are more comfortable with prepaying for cellphone services and companies are becoming more comfortable with cross-subsidizing customer groups based on how many minutes and/or how much data they use. Mini-grid developers have likely noticed these trends and are adopting similar strategies.

Discussion

The analyses above have provided several important insights, presented as observations that can guide future research on mini-grid business models. We summarize these here and suggest their implications for policymakers and for the success of mini-grid business models.

Implications for policymakers

First, while only two mini-grid business models in my study included the main grid as a customer, they were both located in Tanzania, and we can develop some preliminary insights into what it takes to incentivize a main-grid-connected mini-grid to connect to nearby offgrid customers. Based on the conditions present in Tanzania which enabled these business models to emerge, I suggest that a favorable policy regime and tariff premiums on sales to the main grid, and/or connection cost subsidies, are necessary to incentivize the mini-grid to connect nearby retail households and small businesses when it already plans to connect to the main grid. These factors are in addition to the obvious need to have households and small businesses located near enough to the main grid to be served by the mini-grid.

Second, subsidies targeting mini-grid tariffs may not be necessary if subsidies on electricity alternatives (e.g, kerosene) are removed, if some form of capital cost and/or connection cost subsidy is available, and if mini-grid business models can combine creative monetization mechanisms, efficient operations through a well-designed value chain, and appropriate fuel choice. In addition, the regulator needs to allow mini-grid business models the flexibility to charge tariff schemes that incentivize the connection of new customers and energy efficiency on the end uses of electricity (Tenenbaum et al., 2014).

Third, there was no single role that mini-grid developers always played across all business models in my study. Instead, the value chain of a mini-grid business model often entails the local community and other 3rd parties as important actors for building, owning, operating, and/or maintaining the mini-grid. This has important relevance for scholars and policymakers alike. While most of the attention in policy and academic work relating to mini-grids focuses the attention on the mini-grid developer, likely because they are the most common owners of mini-grids, attention should also be placed on the communities and other 3rd party entities that play valuable roles in mini-grid value chains—and hence the economic viability of the mini-grid. Tenenbaum et al. (2014) begin to address this by noting the common practice among community-operated mini-grids to charge tariffs that do not cover O&M costs.

Implications for mini-grid business model success

First, the presence of an anchor customer, an intermediary that can purchase and on-sell the mini-grid's electricity, and/or small business customers, will impact the design of the mini-grid business model. When small businesses are present, monetization mechanisms tend to be more creative (i.e., not a postpaid or fixed tariff). This can in turn benefit non-business customers, suggesting that a combination of small businesses and households as paying customers is a better combination to catalyze innovation in the monetization dimension of a mini-grid business model than households alone.

Second, if there is a potential anchor customer present, the mini-grid developer is likely to take responsibility for constructing the mini-grid. The mini-grid, therefore, is built to the specifications required by the anchor customer, which may impact its ability to effectively and economically serve nearby households and/or small businesses. This suggests that mini-grids serving an anchor customer must take extra care—in design and monetization especially—to balance the needs of the anchor customer with those of other customers.

Third, there appear to be several ways that mini-grid developers can reduce their costs and increase their financial viability. One option is to sell the mini-grid electricity through an intermediary, thereby taking a more hands-off approach to owning and managing the mini-grid. Another option is to avoid combining post-paid tariffs with consumer finance—or offering some form of consumer finance only when tariffs are prepaid—as a way to minimize burdens on working capital. Prepaid tariffs are also common among mini-grid business models in which the mini-grid developer builds, owns, operates, and maintains the mini-grid, suggesting that prepayment is also important when the value chain is vertically integrated. Finally, to mitigate the risks of not being able to keep electricity prices affordable and recoup the costs associated with building, owning and maintaining the mini-grid, developers can cross-subsidize customer groups and charge an energy-based tariff.

Finally, it appears that most of the potential for mini-grid business model innovation exists in the value chain and monetization dimensions. This could include new ways of charging customers for electricity and offering financing or cross-subsidizing across customer groups, or new configurations of partners along the value chain.

Conclusion

One of the primary contributions of this article is to demonstrate the utility of a business models framework for studying mini-grids. Prior research and discussions of mini-grid business models typically take too narrow a view of what is a business model, or conflate it with other concepts like ownership. These views not only lack a theoretical understanding of what is a business model, but also miss important opportunities to study the interactions between the different dimensions of the business model. With large enough datasets and access to the performance data of various mini-grids, researchers could even begin to understand which mini-grid business models work best in which situations. The results of this study suggest that the configuration of elements across the four dimensions of a business model is an important variable to consider when studying what makes mini-grids successful.

This project has used the business model framework as a way to study the configurations of different elements within mini-grid business models that serve BOP customers. Although my sample size was small, I was still able to capture 29 different configurations across the four dimensions of a business model. The main observations and findings, summarized above, have important implications for MGDs, policymakers and regulators, and researchers.

This paper paves the way for a number of different research areas that scholars can pursue. Some of the more interesting include linking the configuration of business model elements with different mini-grid outcomes, such as profitability, number of customers, etc. In addition, while this research project focused just on business models, these do not exist in a vacuum. They require internal capabilities to enact them, and they interact with the external environment, including competition, policy and regulations, and the international development and aid community. Future research on mini-grid business models should incorporate these important factors.

As with all scientific endeavors, this project has its limitations. First, the findings, for the most part, are specific to the off-grid electrification sector. While certain parallels can be drawn to conducting business in BOP markets more broadly, these are generally limited to specific elements within business model dimensions (for instance prepayment, cross-subsidization, and financing of large upfront costs are monetization strategies that many firms in BOP markets deploy). Second, my sample size is relatively small compared to the total population of different mini-grid business models. After thorough research, the only database of mini-grids I was able to identify is a closely guarded proprietary database held by Navigant Research. Future research, however, could find ways to collaborate with Navigant Research, perhaps through a survey of MGDs in its database, to produce insights that have both scholarly and commercial value. Third, the data come from secondary sources. While I carefully selected my sources, including company websites and reports written by agencies with expertise in off-grid electricity, I cannot rule out the possibility that some configurations are based on input values that are incorrect. Future research could survey and interview other MGDs in order to obtain data from primary sources. Ultimately, however, I have a high degree of confidence in the main findings of this project, and I believe that they can serve as useful insights for scholars and practitioners alike.

Conflicts of interest

In addition to being an academic researcher, the author has consulted for the US Department of Energy and the World Bank on topics related to mini-grids. He is also co-author of a World Bank book on policies and regulations to support mini-grids. He has not worked with or consulted for any of the organizations in this study. The author's consulting work does not present a competing interest to this research project.

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Appendix A. Business model snapshot for Carbon X energy

Customer/User Identification	"Carbon X's mission is not to supply the main grid, but to stimulate economic development through rural electrification." File: CarbonX Company Profile "Carbon X discourages large customers." File: CarbonX WBGIC "The pre-paid metering system allows for villagers and businesspeople to buy electricity at their leisure, and reduces Carbon X's risk in tariff collection" File: CarbonX Company Profile
Customer/User Engagement	"Carbon X has developed its electricity delivery model around a less costly budget than that of kerosene. This will produce considerable savings and increase the overall purchasing power of the community." File: CarbonX Project Benefits "Electricity from the solar mini-grid system will enable the use of better quality lighting and students will no longer be forced to study directly beside a polluting light source. The use of electricity will also allow students and other members of the villages to gain access to electronic media through radios, television sets, and the Internet." File: CarbonX Project Benefits "Customers choose between 50 W, 100 W, and 200 W supply, for 18 h per day, at costs of TSh 12,000, TSh 24,500, and TSh 50,000/month ($7.30, $14.90, and $30.30/month). A 50 W connection is just enough to power a 14-in. television plus one lightbulb; to use more lights or a radio, the television must be off." File: CarbonX WBGIC "With the mini-grid, the poorest households can save nearly 40% in monthly energy expenditures, while enjoying cleaner, better lighting and more convenient phone charging (having previously needed to leave their homes to charge their phones)." File: CarbonX WBGIC "Once employed the project will provide over 500 kWp electricity to more than 2500 homes and businesses spanning across 6 villages in the area." File: CarbonX Company Profile "It has 37 customers: 30 on the 50 W plan, 4 on the 100 W plan, and 3 on the 200 W plan" File: CarbonX WBGIC

Value Chain Linkages	"The Carbon X mandate is to provide conventional 230 V AC electricity to isolated rural communities through the use of solar-PV and hybrid mini-grid systems." File: CarbonX Mission Statement "For its pilot projects, Carbon X will assume the responsibility of building and running both the mini-grid and the power generation station" as well as ongoing maintenance—File: CarbonX Company Profile "Carbon'X' is currently applying for grant-based funding to help finance the construction of 'much larger multi-village rural electrification project in the Rufiji District" File: CarbonX Company Profile
Monetization	"Through various financing options, villagers will be offered an affordable and safe installation package to meet the needs of' their household." File: CarbonX Company Profile "The pre-paid metering system allows for villagers and businesspeople to buy electricity at their leisure, and reduces Carbon X's risk in tariff collection." File: Carbon X Company Profile "Through various financing options, customers in the village purchased an installation package that included a ready-board, a load-limiting meter, and two to four energy-efficient LED (light-emitting diode) lights." File: CarbonX WBGIC "Customers choose between 50 W, 100 W, and 200 W supply, for 18 h per day, at costs of TSh 12,000, TSh 24,500, and TSh 50,000/month ($7.30, $14.90, and $30.30/month). A 50 W connection is just enough to power a 14-in. television plus one lightbulb; to use more lights or a radio, the television must be off." File: CarbonX WBGIC "10kWp in Serengeti, developed by Carbon X, connections with load limiters at 50 W (12,000 TZS/mo), 100 W and 200 W." File: CarbonX AHK "Monthly income is estimated to be TSh 608,000, or $380. This is much lower than the commercial breakeven monthly equivalent of $1290/month (which is based on the capital expenditure amount, a conservative 15% discount rate, and a 10-year payback period)." File: CarbonX WBGIC "It has 37 customers: 30 on the 50 W plan, 4 on the 100 W plan, and 3 on the 200 W plan" File: CarbonX WBGIC "As the system is modular, scaling it up with higher numbers of customers or heavier loads will not significantly increase profitability. Although the Masurura project is not intended to generate a return on capital, Carbon X does intend to roll out similar projects that do make profits across Tanzania. From the analysis here, it is not clear that this will be possible unless the company finds significant further efficiencies in service delivery, charges much higher tariffs, or continues to use grant funding." File: CarbonX WBGIC

Appendix B. Input values for CarbonX energy

Activities within the business model dimension	Input value
Generation Location: 1 = Stand-Alone; 2 = Grid Connection	1
Paying Customer: 1 = End User; 2 = Two-Way; 3 = Intermediary Only	1
End User Identification: 1 = Homes; 2 = Home & Business; 3 = Home, Bus. & Anchor	1
Electricity Cheaper than Kerosene: 1 = yes; 2 = no	1
Total Connections per Generator	
Retail Capacity per Generator (W)	
Average Peak W/Connection	200
Hours/Day	18
Average Wh/day per Connection	3600
Global Tracking Framework (GTF) Tier	2
Resulting GTF Tier Score: 0 = <3; 1 = 3; 2 = >3	0
Offer Different Services at Different Prices: 1 = yes; 2 = no	1
Build 1 = PD; 2 = 3rd Party; 3 = community; 4 = utility; 5 = gov.'t	1
Own 1 = PD; 2 = 3rd Party; 3 = community; 4 = utility; 5 = gov.'t	1
Operate 1 = PD; 2 = 3rd Party; 3 = community; 4 = utility; 5 = gov.'t	1
Maintain 1 = PD; 2 = 3rd Party; 3 = community; 4 = utility; 5 = gov.'t	1
Payment 1 = Prepay; 2 = Both; 3 = Postpay	1
Payment Type: 1 = Energy Tariff; 2 = Combo Tariff; 3 = Power Tariff; 4 = Fixed Tariff; 5 = Installation	3
Customer Finance: 1 = None; 2 = Connection; 3 = Cross-Subsidy; 4 = both	2

Appendix C. Final clustering analyses in Microsoft Excel format

C.1. Configurations based on customer identification cluster analysis.

Mini-Grid Business Model Case Name	Cluster	Generation Location: 1=Stand-Alone; 2=Grid Connection	Paying Customer: 1=End User; 2=Two-Way; 3=Intermediary Only	End User Identification: 1=Homes; 2=Home & Business; 3=Home, Bus. & Anchor	Electricity Cheaper than Kerosene: 1=yes; 2=no	Resulting GTF Tier: 0 = <3; 1 = 3; 2 = >3	Offer Different Services at Different Prices: 1=yes; 2=no	Build: 1=MGD; 2=3rd Party; 3=community	Own: 1=MGD; 2=3rd Party; 3=community	Operate: 1=MGD; 2=3rd Party; 3=community	Maintain: 1=MGD; 2=3rd Party; 3=community	Payment: 1=Prepay; 2=Both; 3=Postpay	Payment Type: 1=Energy Tariff; 2=Combo Tariff; 3=Power Tariff; 4=Fixed Tariff;	Customer Finance: 1=None; 2=Connection; 3=Cross-Subsidy; 4=both
West Bengal Renewable Energy Development Agency (WBREDA)	A	1	1	2	1	1	1	1	1	3	2	3	3	1
Yeelen Kura	A	1	1	2	2	0	1	2	1	1	1	2	1	4
Bonny Utility Company, Nigeria	A	1	1	2	1	0	1	1	1	1	1	1	1	3
MeshPower	A	1	1	2	1	0	1	1	1	1	2	1	1	1
Mutanda Electricity Utility, Zambia	A	1	1	2	1	0	2	2	1	1	1	3	4	1
LUMAMA Electricity Association	A	1	1	2	1	1	1	2	1	1	1	1	2	4
Mera Gao Power	A	1	1	2	1	0	2	1	1	1	1	1	4	2
Husk Power Systems BOOM Model	A	1	1	2	1	0	1	1	1	1	1	2	2	1
Korayé Kurumba	A	1	1	2	1	0	1	2	1	1	1	1	3	3
Husk Power Systems BOM Model	A	1	1	2	1	0	1	1	1	2	1	2	2	1
Earthspark	A	1	1	2	1	2	1	1	1	1	1	1	2	2
Electricite d'Haiti	A	1	1	2	1	0	1	1	3	3	1	3	1	1
Comisión Federal de Electricidad, Mexico	A	1	1	2	2	2	1	2	1	3	1	3	1	1
Devergy	A	1	1	2	1	1	2	1	1	1	1	1	1	3
Orissa Renewable Energy Development Agency (OREDA)	B	1	1	1	1	0	1	1	1	1	2	3	4	1
CREDA, India	B	1	1	1	1	0	2	2	3	2	2	3	4	1
Dothaluoya Village Hydropower Consumers Welfare Society	B	1	1	1	2	1	2	2	1	1	1	3	4	1
CarbonX Energy	B	1	1	1	1	0	1	1	1	1	1	1	3	2
Gram Power	C	1	3	3	1	0	2	1	3	3	1	1	1	3
Sunlabob Renewable Energy Ltd. B-to-Government/Utility	C	1	3	3	1	1	1	1	1	3	3	3	2	1
DESI Power, India	D	1	2	2	1	1	2	1	1	3	1	3	1	3
Inensus West Africa (now Enersa)	E	1	1	3	1	0	1	1	1	3	1	1	2	1
Andoya Hydropower, Tanzania	F	2	2	3	1	1	1	1	1	1	1	2	1	3
Rift Valley Energy / Mwenga Hydro 4MW, Tanzania	F	2	2	3	1	0	2	1	1	1	1	1	1	4

Note: *Black boxes represent the defining characteristics of a particular cluster.*

C.2. Configurations based on customer engagement cluster analysis.

Mini-Grid Business Model Case Name	Cluster	Generation Location: 1=Stand-Alone; 2=Grid Connection	Paying Customer: 1=End User; 2=Two-Way; 3=Intermediary Only	End User Identification: 1=Homes; 2=Home & Business; 3=Home, Bus. & Anchor	Electricity Cheaper than Kerosene: 1=yes; 2=no	Resulting GTF Tier: 0 = <3; 1 = 3; 2 = >3	Offer Different Services at Different Prices: 1=yes; 2=no	Build: 1=MGD; 2=3rd Party; 3=community	Own: 1=MGD; 2=3rd Party; 3=community	Operate: 1=MGD; 2=3rd Party; 3=community	Maintain: 1=MGD; 2=3rd Party; 3=community	Payment: 1=Prepay; 2=Both; 3=Postpay	Payment Type: 1=Energy Tariff; 2=Combo Tariff; 3=Power Tariff; 4=Fixed Tariff;	Customer Finance: 1=None; 2=Connection; 3=Cross-Subsidy; 4=both
Orissa Renewable Energy Development Agency (OREDA)	A	1	1	1	1	0	1	1	1	1	2	3	4	1
Bonny Utility Company, Nigeria	A	1	1	2	1	0	1	1	1	1	1	1	1	3
Korayé Kurumba	A	1	1	2	1	0	1	2	1	1	1	1	3	3
MeshPower	A	1	1	2	1	0	1	1	1	1	2	1	1	1
Husk Power Systems BOOM Model	A	1	1	2	1	0	1	1	1	1	1	2	2	1
Inensus West Africa (now Enersa)	A	1	1	3	1	0	1	1	1	3	1	1	2	1
Husk Power Systems BOM Model	A	1	1	2	1	0	1	1	1	2	1	2	2	1
CarbonX Energy	A	1	1	1	1	0	1	1	1	1	1	1	3	2
Electricite d'Haiti	A	1	1	2	1	0	1	1	3	3	1	3	1	1
Mutanda Electricity Utility, Zambia	B	1	1	2	1	0	2	2	1	1	1	3	4	1
Rift Valley Energy / Mwenga Hydro 4MW, Tanzania	B	2	2	3	1	0	2	1	1	1	1	1	1	4
CREDA, India	B	1	1	1	1	0	2	2	3	2	2	3	4	1
Gram Power	B	1	3	3	1	0	2	1	3	3	1	1	1	3
Mera Gao Power	B	1	1	2	1	0	2	1	1	1	1	1	4	2
Sunlabob Renewable Energy Ltd. B-to-Government/Utility	C	1	3	3	1	1	1	1	1	3	3	3	2	1
West Bengal Renewable Energy Development Agency (WBREDA)	C	1	1	2	1	1	1	1	1	3	2	3	3	1
LUMAMA Electricity Association	C	1	1	2	1	1	1	2	1	1	1	1	2	4
Andoya Hydropower, Tanzania	C	2	2	3	1	1	1	1	1	1	1	2	1	3
Devergy	D	1	1	2	1	1	2	1	1	1	1	1	1	3
DESI Power, India	D	1	2	2	1	1	2	1	1	3	1	3	1	3
Earthspark	E	1	1	2	1	2	1	1	1	1	1	1	2	2
Yeelen Kura	F	1	1	2	2	0	1	2	1	1	1	2	1	4
Dothaluoya Village Hydropower Consumers Welfare Society	F	1	1	1	2	1	2	2	1	1	1	3	4	1
Comisión Federal de Electricidad, Mexico	F	1	1	2	2	2	1	2	1	3	1	3	1	1

Note: *Black boxes represent the defining characteristics of a particular cluster.*

C.3. Configurations based on value chain linkages cluster analysis.

Mini-Grid Business Model Case Name	Cluster	Generation Location: 1=Stand-Alone; 2=Grid Connection	Paying Customer: 1=End User; 2=Two-Way; 3=Intermediary Only	End User Identification: 1=Homes; 2=Home & Business; 3=Home, Bus. & Anchor	Electricity Cheaper than Kerosene: 1=yes; 2=no	Resulting GTF Tier: 0 = <3; 1 = 3; 2 = >3	Offer Different Services at Different Prices: 1=yes; 2=no	Build: 1=MGD; 2=3rd Party; 3=community	Own: 1=MGD; 2=3rd Party; 3=community	Operate: 1=MGD; 2=3rd Party; 3=community	Maintain: 1=MGD; 2=3rd Party; 3=community	Payment: 1=Prepay; 2=Both; 3=Postpay	Payment Type: 1=Energy Tariff; 2=Combo Tariff; 3=Power Tariff; 4=Fixed Tariff;	Customer Finance: 1=None; 2=Connection; 3=Cross-Subsidy; 4=both	Cluster
Mera Gao Power	A	1	1	2	1	0	2	1	1	1	1	1	4	2	A
Rift Valley Energy / Mwenga Hydro 4MW, Tanzania	A	2	2	3	1	0	2	1	1	1	1	1	1	4	A
Earthspark	A	1	1	2	1	2	1	1	1	1	1	1	2	2	A
Husk Power Systems BOOM Model	A	1	1	2	1	0	1	1	1	1	1	2	2	1	A
CarbonX Energy	A	1	1	1	1	0	1	1	1	1	1	1	3	2	A
Devergy	A	1	1	2	1	1	2	1	1	1	1	1	1	3	A
Andoya Hydropower, Tanzania	A	2	2	3	1	1	1	1	1	1	1	2	1	3	A
Bonny Utility Company, Nigeria	A	1	1	2	1	0	1	1	1	1	1	1	1	3	A
Husk Power Systems BOM Model	B	1	1	2	1	0	1	1	1	2	1	2	2	1	B
DESI Power, India	B	1	2	2	1	1	2	1	1	3	1	3	1	3	B
Inensus West Africa (now Enersa)	B	1	1	3	1	0	1	1	1	3	1	1	2	1	B
MeshPower	C	1	1	2	1	0	1	1	1	1	2	1	1	1	C
Orissa Renewable Energy Development Agency (OREDA)	C	1	1	1	1	0	1	1	1	1	2	3	4	1	C
Sunlabob Renewable Energy Ltd. B-to-Government/Utility	D	1	3	3	1	1	1	1	1	3	3	3	2	1	D
West Bengal Renewable Energy Development Agency (WBREDA)	D	1	1	2	1	1	1	1	1	3	2	3	3	1	D
Mutanda Electricity Utility, Zambia	E	1	1	2	1	0	2	2	1	1	1	3	4	1	E
Yeelen Kura	E	1	1	2	2	0	1	2	1	1	1	2	1	4	E
Dothaluoya Village Hydropower Consumers Welfare Society	E	1	1	1	2	1	2	2	1	1	1	3	4	1	E
Korayé Kurumba	E	1	1	2	1	0	1	2	1	1	1	1	3	3	E
LUMAMA Electricity Association	E	1	1	2	1	1	1	2	1	1	1	1	2	4	E
Comisión Federal de Electricidad, Mexico	F	1	1	2	2	2	1	2	1	3	1	3	1	1	F
Electricite d'Haiti	G	1	1	2	1	0	1	1	3	3	1	3	1	1	G
Gram Power	G	1	3	3	1	0	2	1	3	3	1	1	1	3	G
CREDA, India	H	1	1	1	1	0	2	2	3	2	2	3	4	1	H

Note: *Black boxes represent the defining characteristics of a particular cluster.*

C.4. Configurations based on monetization cluster analysis.

Mini-Grid Business Model Case Name	Cluster	Generation Location: 1=Stand-Alone; 2=Grid Connection	Paying Customer: 1=End User; 2=Two-Way; 3=Intermediary Only	End User Identification: 1=Homes; 2=Home & Business; 3=Home, Bus. & Anchor	Electricity Cheaper than Kerosene: 1=yes; 2=no	Resulting GTF Tier: 0 = <3; 1 = 3; 2 = >3	Offer Different Services at Different Prices: 1=yes; 2=no	Build: 1=MGD; 2=3rd Party; 3=community	Own: 1=MGD; 2=3rd Party; 3=community	Operate: 1=MGD; 2=3rd Party; 3=community	Maintain: 1=MGD; 2=3rd Party; 3=community	Payment: 1=Prepay; 2=Both; 3=Postpay	Payment Type: 1=Energy Tariff; 2=Combo Tariff; 3=Power Tariff; 4=Fixed Tariff;	Customer Finance: 1=None; 2=Connection; 3=Cross-Subsidy; 4=both	Cluster
Mutanda Electricity Utility, Zambia	A	1	1	2	1	0	2	2	1	1	1	3	4	1	A
Orissa Renewable Energy Development Agency (OREDA)	A	1	1	1	1	0	1	1	1	1	2	3	4	1	A
CREDA, India	A	1	1	1	1	0	2	2	3	2	2	3	4	1	A
Dothaluoya Village Hydropower Consumers Welfare Society	A	1	1	1	2	1	2	2	1	1	1	3	4	1	A
Comisión Federal de Electricidad, Mexico	B	1	1	2	2	2	1	2	1	3	1	3	1	1	B
Electricite d'Haiti	B	1	1	2	1	0	1	1	3	3	1	3	1	1	B
Sunlabob Renewable Energy Ltd. B-to-Government/Utility	C	1	3	3	1	1	1	1	1	3	3	3	2	1	C
West Bengal Renewable Energy Development Agency (WBREDA)	C	1	1	2	1	1	1	1	1	3	2	3	3	1	C
Husk Power Systems BOM Model	D	1	1	2	1	0	1	1	1	2	1	2	2	1	D
Husk Power Systems BOOM Model	D	1	1	2	1	0	1	1	1	1	1	2	2	1	D
Andoya Hydropower, Tanzania	E	2	2	3	1	1	1	1	1	1	1	2	1	3	E
DESI Power, India	E	1	2	2	1	1	2	1	1	3	1	3	1	3	E
Devergy	F	1	1	2	1	1	2	1	1	1	1	1	1	3	F
Gram Power	F	1	3	3	1	0	2	1	3	3	1	1	1	3	F
Bonny Utility Company, Nigeria	F	1	1	2	1	0	1	1	1	1	1	1	1	3	F
Rift Valley Energy / Mwenga Hydro 4MW, Tanzania	G	2	2	3	1	0	2	1	1	1	1	1	1	4	G
Yeelen Kura	G	1	1	2	2	0	1	2	1	1	1	2	1	4	G
LUMAMA Electricity Association	G	1	1	2	1	1	1	2	1	1	1	1	2	4	G
CarbonX Energy	H	1	1	1	1	0	1	1	1	1	1	1	3	2	H
Mera Gao Power	H	1	1	2	1	0	2	1	1	1	1	1	4	2	H
Korayé Kurumba	H	1	1	2	1	0	1	2	1	1	1	1	3	3	H
MeshPower	I	1	1	2	1	0	1	1	1	1	2	1	1	1	I
Earthspark	I	1	1	2	1	2	1	1	1	1	1	1	2	2	I
Inensus West Africa (now Enersa)	I	1	1	3	1	0	1	1	1	3	1	1	2	1	I

Note: *Black boxes represent the defining characteristics of a particular cluster.*

References

ACP-EU Energy Facility. *Sustainability—Business Models for Rural Electrification* (Thematic Fiche No. Thematic Fiche no. 7). Brussels, Belgium: European Commission; 2012.

Alzola, J. A., Vechiu, I., Camblong, H., Santos, M., Sall, M., & Sow, G. (2009). Microgrids project, Part 2: Design of an electrification kit with high content of renewable energy sources in Senegal. Renew. Energy, 34(10), 2151–2159. http://dx.doi.org/10.1016/j.renene.2009.01.013

Anderson, J., & Billou, N. (2007). Serving the world's poor: innovation at the base of the economic pyramid. J. Bus. Strateg., 28(2), 14–21. http://dx.doi.org/10.1108/02756660710732611

Anderson J, Markides C. Strategic innovation at the base of the pyramid. MIT Sloan Manag. Rev. 2007;49(1):83–8.

Asmus P, Embury T, Lawrence M. *Microgrid Deployment Tracker 2Q14* (Research Report). Boulder, CO: Navigant Research; 2014.

Baden-Fuller C, Haefliger S. Business models and technological innovation. Long Range Plan. 2013;46:419–26.

Baden-Fuller, C., & Morgan, M. S. (2010). Business models as models. *Long Range Plan.*, *43*(2–3), 156–171. http://dx.doi.org/10.1016/j.lrp.2010.02.005

Baden-Fuller C, Demil B, Lecoq X, MacMillan I, editors. Editorial., *43*(2–3) *Long Range Planning*; 2010. p. 143–5.

Bardouille, P. (2012). *From Gap to Opportunity*: *Business Models for Scaling Up Energy Access*. Washington, DC: International Finance Corporation.

Bardouille P, Muench D. How a New Breed of Distributed Energy Services Companies can Reach 500 mm Energy-poor Customers Within a Decade: A Commercial Solution to the Energy Access Challenge. International Finance Corporation and Persistent Energy Partners; 2014 (June).

Bhattacharyya SC, Palit D, editors. *Mini-Grids for Rural Electrification of Developing Countries*. Switzerland: Springer International Publishing; 2014.

Biernacki P, Waldorf D. Snowball sampling: problems and techniques of chain referral sampling. *Sociol. Methods Res.* 1981;10(2):141–63.

Bonaccorsi, A., Giannangeli, S., & Rossi, C. (2006). Entry strategies under competing standards: hybrid business models in the open source software industry. Manag. Sci., 52(7), 1085–1098. http://dx.doi.org/10.1287/mnsc.1060.0547

Camos D, Shkaratan M, Ouedraogo F, Briceño-Garmendia C, Foster V, Eberhard A. *Underpowered* : *The State of the Power Sector in Sub-Saharan Africa* (Background Paper No. 6). The World Bank. 2008. Retrieved from https://openknowledge.worldbank.org/handle/10986/7833.

Chaurey, A., & Kandpal, T. C. (2010). A techno-economic comparison of rural electrification based on solar home systems and PV microgrids. Energ Policy, 38(6), 3118–3129. http://dx.doi.org/10.1016/j.enpol.2010.01.052

Dahan, N. M., Doh, J. P., Oetzel, J., & Yaziji, M. (2010). Corporate-NGO collaboration: co-creating new business models for developing markets. *Long Range Plan.*, *43*(2–3), 326–342. http://dx.doi.org/10.1016/j.lrp.2009.11.003

DaSilva, C. M., & Trkman, P. (2013). Business Model: What It Is and What It Is Not. Long Range Plan., 1–11. http://dx.doi.org/10.1016/j.lrp.2013.08.004

Erichsen T, Sauar E, Roine K, Skogen A. *The Way Towards Universal Access*: *Putting Value on Electricity Services* (Summary for Policymakers). Oslo, Norway: Differ; 2013.

EWURA. Detailed tariff calculations for year 2012 for the sale of electricity to the maingrid in Tanzania under standardized small power purchase agreements in Tanzania. 2012. Retrieved from http://www.ewura.go.tz/pdf/SPPT/2012/2012%20SPPT%20Calculation%20for%20Main%20Grid.pdf.

Graf J, Kayser O, Klarsfeld L. *Marketing Innovative Devices for the Base of the Pyramid*. Paris, France: Hystra; 2013.

Greacen C. *The Marginalization of* "*Small is Beautiful*": *Micro-hydroelectricity*, *Common Property*, *and the Politics of Rural Electricity Provision in Thailand* (Ph.D.). Berkeley: University of California, Berkeley; 2004 (Retrieved from http://palangthai.org/docs/GreacenDissertation.pdf).

Greacen C, Tongsopit S. *Thailand's Renewable Energy Policy*: *FiTs and Opportunities for International Support*. Palang Thai. 2012. Retrieved from http://www.palangthai.org/docs/ThailandFiTtongsopit&greacen.pdf.

Greacen C, Engel R, Quetchenbach T. A Guidebook on Grid Interconnection and Island Operation of Mini-Grid Power Systems Up to 200 kW. Lawrence Berkeley Laboratory; 2012.

Hart SL, Christensen CM. The Great Leap: Driving Innovation from the Base of the Pyramid. MIT Sloan Manag. Rev. 2002;51–56.

Innovation Energy Développement (iED). *Low Carbon Mini Grids*: "*Identifying the Gaps*; *Building the Evidence Base*". (Support Study for DFID No. *ARIES* PO number: 40062121). Francheville, France: Innovation Energie Développement; 2013.

International Energy Agency. *World Energy Outlook 2013*. Paris, France: Organization for Economic Cooperation and Development; 2013.

International Energy Agency (IEA), the World Bank. *Sustainable Energy for All 2013–2014*: *Global Tracking Framework Report* (No. 85415). Washington, DC: The World Bank; 2014.

Kirubi, C., Jacobson, A., Kammen, D. M., & Mills, A. (2009). Community-based electric micro-grids can contribute to rural development: evidence from Kenya. World Dev., 37(7), 1208–1221. http://dx.doi.org/10.1016/j.worlddev.2008.11.005

London, T., & Hart, S. L. (2004). Reinventing strategies for emerging markets: beyond the transnational model. J. Int. Bus. Stud., 35(5), 350–370. http://dx.doi.org/10.1057/palgrave.jibs.8400099

Lorenzoni G, Baden-Fuller C. Creating a strategic centre to manage a web of partners. Calif. Manag. Rev. 1995;37(3):146–63.

Mukherjee M. *Private Sector Led Off-Grid Energy Access*: *The A-B-C Business Model and How Third Parties Can Support the Development of Mini-Grids*. PowerPoint Presentation presented at the Incubating Innovation for Off-Grid Rural Electrification: London Investor's Conference, London, United Kingdom.; 2013. (March).

Osterwalder A, Pigneur Y. Clarifying business models: origins, present, and future of the concept. Commun. Assoc. Inf. Syst. 2005;16(1):1–25.

Palit, D., & Chaurey, A. (2011). Off-grid rural electrification experiences from South Asia: status and best practices. Energy Sustain. Dev., 15(3), 266–276. http://dx.doi.org/10.1016/j.esd.2011.07.004

Peterschmidt N, Neumann C, von Flotwo P, Friebe C, Springmann J-P, Schmidt-Reindahl J. *Scaling up Successful Micro-Utilities for Rural Electrification*. Oestrich-Winkel, Germany: Sustainable Business Institute; 2013.

Prahalad CK. *The Fortune at the Bottom of the Pyramid*. Upper Saddle River, N.J: Wharton School Publishing; 2006.

Prahalad CK, Hammond A. Serving the world's poor, profitably. Harv. Bus. Rev. 2002:4–11.

Prahalad CK, Hart SL. The Fortune at the Bottom of the Pyramid. *Strategy + Business*, (26). 2002. Retrieved from http://www.cs.berkeley.edu/~brewer/ict4b/Fortune-BoP.pdf.

Rolland S, Glania G. *Hybrid Mini-Grids for Rural Electrification*: *Lessons Learned*. Brussels, Belgium: Alliance for Rural Electrification; 2011. p. 72.

Schnitzer D, Lounsbury DS, Carvallo JP, Deshmukh R, Apt J, Kammen DM. *Micrograms for Rural Electrification*: *A Critical Review of Best Practices Based on Seven Case Studies*. Washington, DC: United Nations Foundation; 2014.

Seelos C, Mair J. Profitable business models and market creation in the context of deep poverty: a strategic view. Acad. Manag. Perspect. 2009;49–63.

Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Plan.*, *43*(2–3), 172–194. http://dx.doi.org/10.1016/j.lrp.2009.07.003

Tenenbaum B, Greacen C, Siyambalapitiya T, Knuckles J. *From the Bottom Up*: *How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa*. Washington, DC: The World Bank; 2014.

Thompson, J. D., & MacMillan, I. C. (2010). Business models: creating new markets and societal wealth. *Long Range Plan.*, *43*(2–3), 291–307. http://dx.doi.org/10.1016/j.lrp.2009.11.002

Ulsrud, K., Winther, T., Palit, D., Rohracher, H., & Sandgren, J. (2011). The Solar Transitions research on solar mini-grids in India: Learning from local cases of innovative socio-technical systems. Energy Sustain. Dev., 15(3), 293–303. http://dx.doi.org/10.1016/j.esd.2011.06.004

United Republic of Tanzania. Electricity Act, 2008, Pub. L. No. No. 10 of 2008. 2008. Retrieved from http://polis.parliament.go.tz/PAMS/docs/10-2008.pdf.

Williamson OE. *The Economic Institutions of Capitalism*: *Firms*, *Markets*, *Relational Contracting*. New York: Free Press; 1985.

Yunus, M., Moingeon, B., & Lehmann-Ortega, L. (2010). Building social business models: lessons from the grameen experience. Long Range Plan., 43(2–3), 308–325. http://dx.doi.org/10.1016/j.lrp.2009.12.005