Accelerating Widespread Adoption of Distributed Energy: Solutions Targeting Small & Medium-sized Enterprises

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Abstract

Distributed energy\(^1\) is a critical driver for new business creation and the growth of small and medium-sized Enterprises (SMEs)\(^2\) in the developing world; the SME sector is also an engine for driving adoption of distributed energy solutions. SMEs provide the majority of jobs in developing countries. Combining productive use, reducing costs, and improving financing of energy solutions for SMEs can accelerate adoption of distributed energy essential for economic growth in the developing world. We propose designing energy solutions that match a SME’s productive use, and linking these solutions to appropriate energy financing.

\(^1\) The National Renewable Energy Lab defines distributed energy as “small, modular power generation technologies that can be combined with load management and energy storage systems to improve the quality or reliability of the electricity supply. They are ‘distributed’ because they are placed near the point of energy consumption, unlike traditional ‘centralized’ systems, where electricity is generated at a remotely located, large-scale power plant and then transmitted down power lines to the consumer.” National Renewable Energy Laboratory (NREL) (2012, December 3). Distributed Energy Basics. Retrieved July 20, 2013, from http://www.nrel.gov/learning/eds_distributed_energy.html

\(^2\) Defining SMEs is difficult due to the fact that country specific conditions often result in different definitions. A common definition of an SME is a formal business with no more than 250 employees with a minimum of $3 million and a maximum of $15 million in assets and annual sales.

Introduction
Energy for the Underserved

According the United Nations Foundation, 1.4 billion people worldwide lack any access to electricity, and 1 billion more have only unreliable access\(^3\). Energy not only lights up homes and communities; it is necessary to alleviate the pressing problems of poverty. Appropriate and sustainable energy sources enhance human health, improve education, enable provision of clean drinking water, afford physical safety, and stimulate economic development. Empirical examples of the positive effects of clean and affordable modern energy sources for the poor are proliferating, yet we are far from achieving universal access. What prevents the world’s entire population from accessing the energy needed to live and to grow its economies?

In a recent speech at the University of Cape Town, President Obama emphasized the need for energy in developing countries: “[W]e believe that nations must have the power to connect their people to the promise of the 21st century. Access to electricity is fundamental to opportunity in this age. It’s the light that children study by; the energy that allows an idea to be transformed into a real business. It’s the lifeline for families to meet their most basic needs. And it’s the connection that’s

needed to plug [...] into the grid of the global economy." 

Grid expansion is a core element of many national electrification strategies and global initiatives that seek to address energy poverty. India’s massive power outage in 2012 illuminated serious questions about the adequacy of grid energy distribution; disruption of grid service occurs on a daily basis, interrupting power supplies to hundreds of thousands of SMEs and millions of households. Grid infrastructure is expensive to implement and maintain. The cost to upgrade India’s grid, for instance, is estimated to be around $200 billion. Globally, the annual grid infrastructure investment is estimated as $700 billion over the next 10 years. In developing countries, 34% of generated grid power is wasted on the way to end users due to transmission and network losses and unauthorized tapping (see Figure 1); this level of loss is three to four times higher than


FIGURE 1

A typical ‘spider’s web’ of wires in Delhi created by unauthorized tapping of the grid.
in developed countries\textsuperscript{9}. These considerations call into question whether grid expansion is the best investment to solve the persistent problems of disrupted or unavailable energy service in rural, peri-urban, and urban areas.

The International Energy Agency finds that grid expansion strategies are not keeping pace with population growth, particularly in sub-Saharan Africa\textsuperscript{10}. Distributed energy generation may provide a viable alternative, but has not yet reached scale. Cost does not appear to be the primary constraint. In early 2013, the Indian states of Maharashtra, Delhi, and Kerala reported that the cost of unsubsidized off-grid solar is at parity with the grid\textsuperscript{11}. Nor does technology: in India and elsewhere, companies are starting to take advantage of lower costs to create technology solutions that can meet the growing demand for distributed energy systems. However, while numerous solutions including solar powered lanterns, solar home systems, and village-scale microgrids have been developed to address the lack of modern energy services, no single one has reached a meaningful level of adoption relative to the scale of the unmet need. For example, while the distributed home energy solutions provided by Grameen Shatki\textsuperscript{12} are often considered a viable alternative to grid infrastructure, Grameen Shatki will have distributed only 2 million systems over a 20-year period by 2016.

Market size is not a limiting factor: the opportunity for serving the world’s poor with modern energy is enormous, with substantial portions of household income already dedicated to purchasing inferior and unhealthy sources of energy, particularly in rural areas\textsuperscript{13}. According to a recent report from the IFC, the global poor spend $37 billion on inferior energy solutions. From careful analysis of business models, this same report suggests that “pioneering companies are already making money from selling superior energy access options” to the energy impoverished. It concludes that challenges to scaling energy access solutions can be overcome


by addressing a combination of ecosystem factors, including: investment in SMEs delivering these energy solutions; smart policy frameworks that address subsidies and tariffs; and attention to overcoming barriers to market access\textsuperscript{14}. Multi-lateral agencies such as the IFC and the United Nations have recently articulated mechanisms to address these ecosystem conditions by supporting SMEs that provide energy access solutions to the poor.

We agree that serving poor households with sustainable, affordable, and appropriate energy solutions is essential. Based on our work with more than 60 social enterprises in this sector, we propose that designing energy solutions to support specific productive uses by SMEs that employ the poor could accelerate adoption of distributed energy and stimulate economic growth. Without access to reliable power, SMEs cannot operate profitably and provide local talent with predictable income-generating opportunities.

### Driving Growth through SMEs

Targeting distributed energy solutions to serve existing SMEs presents a tremendous opportunity for social and economic impact. Under the right conditions, SMEs create jobs and have a multiplier effect on the global economy\textsuperscript{15}.

SMEs play a critical role in national economies across the world, contributing to job creation and GDP. According to the IFC,

\textit{“For an impoverished family in a developing country, establishing a small- or micro-enterprise often represents the first tentative step toward self-sufficiency. The SME sector as a whole can galvanize an entire economy, creating jobs and spurring growth.”}

\textit{In much of the developing world, the private economy is almost entirely comprised of SMEs. In Ecuador, for example, 99 percent of all private companies have no more than 50 employees. Bottom line? SMEs are frequently the only realistic employment opportunity for millions of poor people throughout the world.”}

\textbf{WORLD BANK GROUP}


SMEs account for up to 90% of all businesses in sub-Saharan Africa\textsuperscript{16}. In India, SMEs employ 40% of the workforce, and account for 45% of manufacturing output\textsuperscript{17}. On average, SMEs account for 66% of full-time, permanent employment in the developing world and over half of all formal employment worldwide\textsuperscript{18}.

However, SMEs face substantial challenges that impede their growth: financing, a lack of human capital, and infrastructure. Highest among the infrastructure needs is access to reliable energy necessary to produce goods and services.

Respondents to a recent Omidyar Network / Monitor Group survey indicated that “access to constant electrical power” was the biggest barrier to growth for SMEs in sub-Saharan Africa\textsuperscript{19}. A World Bank survey found that electricity was the second biggest concern for entrepreneurs\textsuperscript{20}. The Aspen Network of Development Entrepreneurs (ANDE) reports that after finance, access to electricity is the biggest obstacle to growth\textsuperscript{21}.

Unreliable power supplies tax the profits of SMEs in several ways. First, by limiting the output of the SME, power outages reduce the number of units that can be produced and sold. Second, the effective capacity of fixed assets is decreased, reducing return on capital. Third, because the length of a power outage is frequently unpredictable, the owner or manager may continue to pay an idle workforce for some period of time in case the power comes back on. A decision to release the workforce may mean that employees and their families must skimp on meals, school, healthcare, or other vital needs.

In response, many SMEs have purchased individual diesel generators to back-up unreliable grid power; the cost of this source of power generation is 2-4 fold higher than grid electricity, and SMEs must deploy scarce working capital to purchase diesel generators.


\textsuperscript{17} The Economic Times (2013, June 9). SMEs employ close to 40% of India’s workforce, but contribute only 17% to GDP. Accessed July 25 \url{http://articles.economictimes.indiatimes.com/2013-06-09/news/39834857_1_smes-workforce-small-and-medium-enterprises}


and costly fuel inventories, decreasing output capacity and profits\textsuperscript{22}. Enterprises without the means to purchase a generator lose sales; nearly 5\% of sales are lost due to unreliable power for SMEs worldwide, 12-15\% in India, and as high as 25\% in parts of Africa and South Asia according to a recent World Bank survey\textsuperscript{23}.

Sustainable and affordable distributed energy solutions for SMEs are constrained by cost, price-performance trends of extant solutions, and distribution mechanisms. In the case of solar solutions that may comprise photovoltaic (PV) panels, battery, inverter, charge controller, and energy efficient appliances such as LEDs or low-energy consumption tools, a number of favorable trends exist. However, the technology solution for SMEs must be integrated and holistic. We believe successful energy solutions targeted to SMEs must:

1. Provide distributed rather than centralized energy solutions;
2. Tie distributed energy generation directly to productive energy use; and
3. Make it easy to pay for distributed energy generation through asset financing.

These core components for distributed energy solutions already exist, and are well described. How can they effectively be integrated into solutions that target SME business growth?

### Distributed Energy

#### Targeting SMEs

Productive Use, Optimized Cost, and Financing

India’s SELCO is leveraging its nearly twenty years of experience in distribution of solar home systems in India to package energy systems with low-power sewing machines for textile production. In Uganda, Solar Sister, a distribution channel for solar lanterns and other distributed energy products, has identified a need for self-powered entertainment services that could be integrated into shops or restaurants. Each solution could be made available to SMEs and micro-entrepreneurs as a “business in a box” that stimulates local economic development; each business could be replicated in other regions or countries in a massively parallel fashion.

How can distributed energy solutions best serve SMEs? While there are many factors to


consider for each enterprise, any solution must integrate three fundamental factors:

1. The productive energy use;
2. The optimized cost of the solution; and
3. Financing the purchase of the solution.

Consider Sapna, an entrepreneur in an off-grid village who wants to expand the neighborhood store she owns by adding refrigerated foods and drinks. To achieve new profits and avoid losses due to spoilage, she needs a reliable and affordable refrigeration solution. Typically, she would be on her own to select a small refrigeration unit and a solar panel system to power it. This scenario could lead to her purchasing a sub-optimal system, perhaps spending more than necessary on the system components or economizing, but having an unreliable system that incurs downstream costs to her business. Because of the complexity of evaluating technology solutions, upfront costs, and risk, the most likely outcome is that Sapna will not expand her business.

Now suppose another entrepreneur, Amira, wants to create a regional business that services entrepreneurs like Sapna. How would Amira integrate the three fundamental factors into an appropriate distributed energy solution she offers to Sapna?

1. **Productive Use**
   To supply the best solution, Amira needs to understand the detailed specifications for refrigeration in Sapna’s store. For example, required refrigerator capacity, peak power draw, average energy use, and energy efficiency of the refrigerator will impact the design requirements for the energy solution Amira offers Sapna.

2. **Optimized Cost**
   The ideal solution balances the cost and efficiency of different refrigerators against the cost of the energy supply. A slightly more efficient refrigerator might be worth buying if it cuts the cost of the energy supply. Costs need to be optimized over the life of the asset. Amira needs to understand these trade-offs.

“People’s lives can change by addressing that sweet spot: that point where people can make economic decisions to improve their own lives. This is especially true when we look at small businesses. No one lifts out of poverty without access to clean energy.”

**KATHERINE LUCEY,**
**FOUNDER & CEO**
**SOLAR SISTER**
offs from Sapna’s perspective, and the required lifetime of the solution Amira offers Sapna.

3. Financing the Purchases
In many cases, the optimized solution will require a higher up-front investment than a sub-optimal solution. Even if Sapna recognizes the long-term benefit, she is not likely to have sufficient cash available to purchase the optimized refrigeration and energy solution outright. Amira needs to provide a financing solution for Sapna that fits her capacity to pay and her appetite for risk.

Three additional examples of regional or global business opportunities to provide power to SMEs are briefly described in Appendix 1; many more certainly exist.

The Particular Challenge of Optimized Cost and Financing

We believe that integrated energy solutions that address productive use, cost, and financing for SMEs would accelerate widespread adoption of distributed energy and power income-generating activities in poor communities around the planet. Many of the entrepreneurs with whom we and others work highlight the challenge of finding appropriate distributed energy solutions that are affordable and can be financed\textsuperscript{24, 25}.

To gauge the potential of a given solution, we apply the Levelized Cost of Energy (LCOE), which is used by energy practitioners to analyze how three primary factors affect user costs:

- The lifetime of the power source (L);
- The cost to generate the power (C); and
- The cost of financing (F)

In the case of Amira’s business solution for Sapna, if Amira is going to finance an energy supply, she must understand not only how much the energy supply costs (C), but also the number of years for the financing, which depends on the lifetime of the energy asset (L). Finally, she must understand the interest rate and other terms (F) of the loan she provides Sapna.

There are well-established formulae to calculate these factors and how they combine to influence the relative merit of alternative solutions. For the purposes of this paper, we

\textsuperscript{24} Omidyar Network (2013). \textit{Accelerating Entrepreneurship in Africa}.

create an estimate of merit $E$, where $E$ is a function of $L$, $C$, and $F$.

$$E = f(L,C,F)$$

This functional dependence can be quantified according to a simplified Levelized Cost of Energy (sLCOE) formula such as the one from Black and Veatch (discussed in Appendix 2). E is then normalized by calculating the ratio of the sLCOE for the distributed solution divided by the sLCOE for the grid. When $E = 1$, then the cost of power from the distributed energy solution is equal to the local price of grid electricity, a condition known as grid parity.

**Grid Parity and LCOE**

Grid parity is an economic concept that designates the cost competitiveness of disparate technologies in providing energy. Electricity generating technologies have significantly different cost and performance structures that make direct comparisons difficult. Fossil fuel based systems may have lower initial investments, but have significant ongoing operating costs in the form of fuel purchases. Renewable technologies avoid ongoing fuel costs, but typically require higher initial investments. Additionally, the actual performance of renewable technologies must be factored in since power production is rarely at the full capacity of the renewable technology. For instance, PV panels rely on actual sunlight available and as such are exquisitely sensitive to location, orientation, and weather conditions.

The concept of LCOE is used to compare competing energy production technologies. The intent is to account for all factors to install, generate, and maintain an electricity-producing asset. The calculation includes the capital, operating, and maintenance costs; a depreciated cash flow is used in the most rigorous variants. For communities that have grid power available as a benchmark, grid parity is achieved when the LCOE of an alternative power source equals the price of the power from the grid. The point of grid

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parity is not fixed; it varies even within a single system.

The point of grid parity can be determined for each of the three broad constituents in power generation and consumption: grid power producers (i.e., energy companies), large-scale users, and residential consumers. The difference in calculating grid parity depends on the marginal price that each party pays for electricity. Grid power producers compare the cost of PV electricity generation relative to other technologies such as coal or nuclear; this is the most cost stringent point of grid parity, since the producer’s cost is the lowest. On the other end of the spectrum is the residential consumer, whose unsubsidized price for grid power includes transmission costs and losses, as well profit for the all the necessary parties in the supply chain. In the absence of significant subsidies, grid parity is most easily achieved for this constituent. Large-scale users, such as manufacturing firms, lie in between; they often receive preferential pricing from energy producers. SMEs, particularly in the developing world, fall relatively close to residential consumers on the spectrum, especially for smaller enterprises.

Grid parity should thus be calculated relative to the entity purchasing energy assets, with asset life and financing costs included in the calculation of grid parity.

Using E to Target Solutions for SMEs

At present, grid power generation can be added by governments and established power companies for $2.50/watt in India. This cost is expected to drop to $2.00/watt over the next few years. This grid energy is financed over 20 years at a rate of 12%.

If Amira wishes to price and finance a distributed energy source, such as a local hybrid solar energy generator, then the cost and financing can be increased by 34%, because her distributed energy solution will not be subject to 34% grid losses. Amira can thus offer a solution with an estimate of merit $E = 1.3$. We define this condition of $E = 1.3$ as point of use grid parity. Using the sLCOE model, $E = 1.3$ can be achieved if, for example, Amira chooses an energy source that costs $2.00/watt, and can be financed over 10 years at a rate of 15%. In this instance, the higher interest rate of 15% relative to the 12% grid energy figure is offset by the shorter loan term and the lack of transmission losses.

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Figure 2 plots the results of the sLCOE formula for different interest rates (F) and installed energy costs (C). Amira could achieve point-of-use grid parity of 1.3 under various conditions; for example, a 20% interest rate at $1.70/watt or 10% interest rate at $2.50/watt also yield E = 1.3, assuming the same lifetime (L) of 10 years. Plots can of course be constructed using different lifetime values (L) or holding either interest rates (F) or installed energy costs (C) constant. Three Asset Life animations have been created and are available online to show how changing each variable affects the other two.

The power of this integrated approach is that it allows Amira to consider a range of lifetime, financing, and asset costs in order to hit the point of use grid parity benchmark. Appendix 3 describes ways the L, C, and F can be modified for a given business case.

Implications for System Design

The specific productive use of a power supply by an SME will influence system design.

28 The Asset Life video is part of this paper and available on the Energy Map website at: http://energymap-scu.org/insights/
and optimization. Figure 3 illustrates three scenarios for energy demand by an SME over a one-day period relative to PV generation potential.

The simplest case is “Commercial/Retail with Working Hours usage”. Demand follows available sunlight with straightforward and predictable usage. An example is a sewing/tailoring establishment where the power requirements from a sewing machine are modest. The energy source can be limited to simple panels; batteries may be added to extend working hours past available sunlight. However, this SME could benefit from a holistic approach in designing the power supply while considering the essential tools of the business. If the tools can be driven solely from DC electricity, then the PV system can be designed without an inverter, a sizable portion of the total PV system cost.

The “Commercial/Retail with 24 Hour usage” case is slightly more complex; SMEs that require constant refrigeration to store foodstuffs or medicine are examples. The

FIGURE 3
Implication for System Design
Three examples matching energy supply requirements to productive use by SMEs.
energy system must include a battery or other storage mechanism to provide power when PV generation (i.e., sunlight) is not available. Again, a holistic approach can be beneficial. For example, refrigerators produced for the on-grid market may not include energy efficiency as a key design objective. Refrigerated units specifically designed for low energy consumption could reduce the total system cost because the PV panels, batteries, and other system components could be smaller and hence lower cost.

The “Manufacturing/Processing with Induction Motors” case is the most complex of these three examples. Induction motors are the technology of choice when higher power, typically greater than ½ horsepower, is required. Power system design requirements are adversely affected by another characteristic of induction motors: in the turn-on phase, power requirements can easily exceed 5-6 times the steady state requirements. During this turn-on phase, the voltage supplied to the motors must not drop below 80% of the rated value or the motor could be damaged. This requirement puts significant incremental demands on the power system. Extra power sources must be included in the system, though their usage will only be for a fraction of the total operating time. One way to mitigate these extra capacity costs would be to sell the incremental power to other entities.

Asset Life and Financing Strategies

Designing the distributed energy system to match the power requirements is only the first step in enabling a successful business. The system cost must be factored in along with the asset life and interest rate to achieve a value for E that will make the system a competitive investment. To an entrepreneur in the developing world, keeping E competitive, e.g., under the 1.3 threshold calculated above, may seem like a daunting task, but careful application of the formula for each business case will lead to an optimized solution.

Asset life turns out to be a major enabler for businesses powered by distributed energy since spreading the installed cost over a longer period of time can make a business viable, even with high interest rates. As can be seen in the Asset Life video, a system with a five-year life would need to have an installed cost of less than $1.70/watt and an interest rate around 5% to be competitive. Neither of these is possible in the developing world. However, a ten-year asset life permits achieving grid parity at a $2.00/watt installed cost and a modest 15% interest rate. A

29 The Asset Life video is part of this paper and available on the Energy Map website at: http://energymap-scu.org/insights/
fifteen-year asset life opens even more possibilities, with viable solutions at $2.00/watt and 18% interest or $2.30/watt and 15% interest.

Defining the asset life therefore determines the maximum permissible interest rate to keep the distributed energy solution cost competitive with grid solutions. Obtaining finance at 15% to 18% rates is currently challenging in many parts of the developing world. The latest impact report from ANDE documents that access to finance is the most reported barrier to growth for enterprises in low and lower-middle income countries: 60% of micro enterprises and SMEs in emerging markets are un-served or underserved by banks\textsuperscript{30}. Yet, there is a $700 million to $850 million credit gap for SMEs, which could create $170 million of annual profits for banks\textsuperscript{31}. ANDE is working to unlock capital for the SME sector through research and pilot initiatives like the Entrepreneurial Finance Lab to identify high potential, creditworthy entrepreneurs.

**Catalyzing New Businesses**

We believe that the methodology described in this paper will enable distributed energy entrepreneurs throughout the developing world to identify viable business opportunities that create jobs while increasing adoption of distributed energy. Technical, business, and financial tools as well as support will be necessary to ensure the success of distributed energy entrepreneurs targeting solutions to SMEs. Multi-lateral institutions, for instance, could deploy concessionary loans to SMEs to enable purchase of distributed energy solutions that increase their effective capacity and therefore increase output and profits. Low-interest loans could be provided to SMEs to help them finance off-grid, clean energy solutions tailored to productive uses. These distributed energy business opportunities could accelerate economic growth and improve the lives of the poor in the developing world.

Santa Clara University’s Center for Science, Technology, and Society has an ongoing commitment to accelerating distributed, sustainable energy adoption in developing countries to drive economic growth and alleviate poverty. We are collaborating with social entrepreneurs in our network and US-based business and technical practitioners to implement leading-edge action research projects that empirically test this integrated framework “on the ground.” Our intention is to catalyze new business opportunities that

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can grow and thrive on distributed clean energy. You may join our efforts by contacting: 
cs.tenergy@scu.edu.
Appendix 1
Additional Examples of Potential Businesses Enabled by Distributed Energy Solutions

The example of Sapna and Amira is one of many ways that distributed energy can enable new businesses, which in turn drives the adoption of distributed energy. Here are other examples being developed and piloted by SELCO and Solar Sister:

**Garment Production**
Many apparel SMEs in India and Africa produce small batches of garments made of thin fabric that do not require high power sewing machines. A sewing machine that can operate on less than 100 watts that could be used for such thin fabric garments, and be financed along with an appropriate power supply. By enabling the garment producers to work from home, costs are lowered.

**Crop Irrigation**
In geographies with shallow ground water, low power DC water pumps could be run with solar panels. These pumps could be used for irrigation, enabling smallholder farmers the opportunity to grow additional higher value crops.

**Integrated Energy Centers**
Off-grid villages can be well served by an Integrated Energy Center that offers a variety of basic services like solar lantern rental, mobile phone charging, and battery charging. These centers are ideally co-located in a community center such as an education or health facility which has high foot traffic by the business and residential customers who need these energy services.
Appendix 2
The sLCOE Model

While there are many detailed LCOE models, the simplified levelized cost of energy (sLCOE) model from Black and Veatch is sufficient for the framework we propose in this paper. In that model:

\[ sLCOE = sLCOE_{\text{capital}} + sLCOE_{\text{variable}} \]

where

\[ sLCOE_{\text{capital}} = \frac{[(\text{capital cost} \cdot \text{CRF}) + \text{fixed O&M cost}]}{(8.76 \cdot \text{capacity factor})} \]

and where

\[ sLCOE_{\text{variable}} = (\text{variable O&M cost} \cdot \text{output}) \]

and where capital cost is the initial capital and “first-in” cost of the asset, CRF is the capital recovery factor for a given interest rate (i) and payback period (n) defined as:

\[ CRF = \frac{i(1+i)^n}{[(1+i)^n]-1} \]

The fixed O&M cost is the operating and maintenance costs tied to the asset, and variable O&M is the operating and maintenance costs tied to the actual usage. The capacity factor is the ratio of actual to potential power output.

To calculate E for grid parity in India, we use the sLCOE formula with the assumptions of a capacity factor of 0.15, common to solar, i of 10%, and n of 20 years. If we assume that we can accept higher costs for distributed energy due to the fact that we eliminate 34% loss due to transmission when installing the source of power at the point of use, E can be increased to 1.3 for point of use grid parity.

In practice, any distributed solution will have fixed and variable O&M costs that would either be factored into the financing or be carried by the end customer. In the discussion thus far, we have effectively assumed that the O&M costs are zero in order to compare with the install costs and transmission losses of grid electricity. An entrepreneur like Amira who uses this formula would need to consider the full cost of the solution including O&M costs, and compare that with the cost of electricity per kilowatt hour at the power receptacle in Sapna’s store. Often, however, the O&M costs are small relative to the other costs in the sLCOE calculation.
Appendix 3
Improving L, C and F for Distributed Energy Systems

(L) Increasing Lifetime for Productive Use
By increasing the lifetime, \( E \) improves due to the longer period over which the asset is amortized. In developing markets, one can imagine increasing lifetime by enhancing the quality and reliability of the energy supply as well as its security. In other words, both ensuring that the asset cannot be stolen or tapped into, and also making sure that it stays up and running for an extended period of time, will lengthen \( L \) and thereby reduce \( E \), all other factors remaining constant.

By integrating a SME’s energy system with its productive use, the lifetime of the asset will likely increase due to several factors:

1. The asset owner has strong incentives to keep the power supply well-secured and in working order because its operation is directly tied to the success of the asset owner’s business and livelihood;
2. Remote monitoring of the asset can be used to determine usage and billing, but also provides status reports of system performance and needs for servicing, increasing its reliability; and
3. The design of the power supply can be tailored for longer life according to the needs of the productive use. For example, the power cycles, length of use per day, and burst power requirements can be factored into the design requirements.

(C) Decreasing the Cost to Generate Power for Productive Use
The most widely available source of distributed power in these markets today is diesel generation\(^{32}\). The reason diesel generators have not been widely accepted as a viable productive use parity energy source is because the operating costs are high and continue to rise, driven by the price of diesel (Figure 4). While SME’s often use diesel generation for backup power, it is too expensive to be a primary source of energy. Moreover, it is environmentally damaging, which has long-term negative economic consequences, particularly in the developing world.

Exploring alternative power supplies, such as solar-battery hybrids, could provide a feasible way to separate energy costs from the price of diesel. The “balance of system costs” including the battery usually account for a significant portion of the total material costs\(^{33}\) of these alternative power supplies; these costs can


often be reduced by effectively pairing the supply to the specifics of productive use. For example, in DC applications, inverter costs can be minimized or eliminated. In other applications, an on-board battery can be charged when the grid is available. By adopting a productive use design approach, the appropriate amount of energy can be generated for what is efficiently needed at any given time with minimal waste.

There are cases where despite excellent design, the source provides more energy than the average demand. Excess energy can almost always be turned into an additional source of revenue for a SME. For example, battery charging for mobile devices and tools is a rapidly growing industry of its own.

Finally, developing distributed energy solutions globally rather than locally can help reduce costs. Companies can begin to achieve economies of scale for the power supply components and distribution from production centers to the major channel points in each country. In this way, materials and distribution costs can be lowered, with savings being passed along to SMEs, effectively lowering the cost to generate power (C).
(F) Improving Financing for Productive Use

By coupling the asset to the productive use, and securing it well both in the design of the generator and through remote monitoring, there is potential to drive down the cost of capital for financing the power source.

Remote monitoring technology solutions are becoming widespread and can reduce the cost of financing. With remote monitoring technology, financial institutions providing credit can assess both the power use and the productivity of the business, which lowers their risk to capital. In addition, remote monitoring can also be used as part of a solution to secure the asset and ensure the power is not tapped without payment.

Also, global aggregation and capitalization of a company could potentially enable lower base interest rates, either from the market or from international development agencies that hesitate to fund small, one-off efforts due to overhead costs.

Finally, large global companies can ensure the stable and rapid flow of funds as they manage the financing risk over a significant number of distribution channels.
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About the Center for Science, Technology, and Society

The mission of the Center for Science, Technology, and Society is to accelerate global, innovation-based entrepreneurship in service to humanity. Through an array of programs including its signature Global Social Benefit Institute (GSBI®), the Center engages an international network of businesses, investment capital, and technical resources to build the capacity of social enterprises around the world. As a Center of Distinction at Santa Clara University, the Center leverages its programs to inspire faculty and students with real-world case studies, distinctive curricula, and unique research opportunities, advancing the University's vision of creating a more just, humane, and sustainable world. A pioneer and leader in social impact, the Center has worked with over 196 social impact enterprises around the world. Over 90% are still in operation impacting the lives of 100 million people.

About Santa Clara University

Santa Clara University, a comprehensive Jesuit, Catholic university located 40 miles south of San Francisco in California's Silicon Valley, offers its more than 8,800 students rigorous undergraduate curricula in arts and sciences, business, theology, and engineering, plus master’s and law degrees and engineering Ph.D.s. Distinguished nationally by one of the highest graduation rates among all U.S. master’s universities, California’s oldest operating higher-education institution demonstrates faith-inspired values of ethics and social justice.
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Stella Tran, Brand Manager & Energy Map lead

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