Locally Managed Microgrids for Near Term Energy Solutions in Small Island Developing States (SIDS): A Case Study of São Tomé

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Abstract

Rural electrification can play a vital role in issues of healthcare, education, and other socio-economic development needs, but it is rarely financially attractive in the short term. A large part of this financial burden comes from the cost of extending an existing national network of medium voltage transmission lines to connect scattered population pockets. However, a unique opportunity exists in aggregated settlements to provide near-term low cost, life-line scale energy that can be locally managed and maintained, even providing momentum toward local organization and capacity building in adjacent development issues.

A rural electrification project was carried out in 2005 and 2006 in Uba Budo, São Tomé. Special attention was paid to installation and local management practices to promote scalability and sustainability. The focus of this research was to highlight practical strategies for community level management of rural electrification.

Introduction

Small Island Developing States (SIDS) generally suffer from inadequate energy infrastructure. Complex issues of size, remoteness, environmental fragility, colonial history, and external dependence weave together to make energy infrastructure expansion very difficult. In the last decade the United Nations has organized two important conferences articulating the issues faced by SIDS and proposing a general program of action to further investigate solutions to these issues[11,12]. In the area of energy specifically, Weisser has investigated institutional level solutions involving power sector reform, electricity supply chains and economics for renewable energy potentials[15-17]. Even with this recent attention, there is a need for specific case studies of community level programs detailing practical implementation strategies. Such localized efforts have potential to compliment and inform how energy policy and technology decisions are made at the national institutional level. This paper details one such community level case study.

SIDS

There is no single, universally recognized definition of what a Small Island Developing State (SIDS) is. The United Nations list of SIDS includes 45 countries[14], but this list has been fluid over the years. (39 states were included in 1991 Alliance of Small Island States (AOSIS) list, 41 states were recognized as SIDS by the United Nations in 1994 [18], SIDSnet.org currently identifies 43 constituents). Regardless of the exact list, SIDS exhibit unique characteristics that impact energy resource evaluation and planning. These very characteristics paint a definition of what it is to be a SIDS. The following three sections are a presentation of these characteristics.

Small Size, Remoteness and Insularity

Economies of scale are the reduction in cost per unit of a given good or service resulting from increased production from operational efficiencies. In other words, an economy of scale is occurs when production increases reducing the cost of each additional unit.

Country size is an important factor in developing economies of scale. But SIDS are small. Most SIDS have a population of only a few hundred thousand (see figure 1). This small size impacts energy infrastructure. Weisser notes that "low and medium speed diesel generators, most commonly used on SIDS for electricity generation, gain economic efficiency with increased scale"[15]. In a study of diesel generation in island states, Mayer found that 9 MW generators are the minimum threshold where economies of scale begin to be achieved[8]. Most SIDS find themselves below this threshold, having no access to an economy of scale in power production [15]. With an entire diesel generation capacity of only 9.2 MW spread out across multiple generators São Tomé is no exception.

Similar to economies of scale, specialization can also be difficult for SIDS to obtain, and due to size limitations it can be a trade-off with diversification[1]. If specialized industries do become successful at the expense of a diversified production base, SIDS may become less resilient to economic crisis brought on by market fluctuations.

Economic issues become further complex when considering cultural interactions. Pelling notes that a transition from folk economies to mixed economies can considerably lessen a society's ability to cope with economic shocks: "as traditional social supports are neither kept up in the face of capitalist incursions nor adequately replaced by welfarist support systems" [10].

Because a SIDS is by definition an island, they are often remotely located as well as isolated, resulting in high transportation costs. Take for example São Tomé. With a small airport with very infrequent flights, yet no deep harbor port, most imports come by sea but require special unloading from larger ships to smaller ships before landing. This greatly increases import/export cost. Furthermore, if road and transport systems within the country itself are also lacking (which in many cases they are), in-country transportation costs contribute further to issues of remoteness and insularity.

Vulnerability and Environmental Fragility

Sadly, SIDS are often the countries that contribute the least to global climate change and sea level rise, yet suffer the most from the consequences of each because their population, agricultural land and infrastructure tend to be concentrated on the coast [11]. Their very nature of being an island state closely ties them to these issues. Further proneness to additional natural disasters only magnifies their vulnerability, as SIDS bare more than their fare share of disasters: at least 13 of the 25 most disaster-prone countries are small island developing States [11].

Water resource and waste management are two more significant environmental issues SIDS face due to their often small land mass. Closely tied to issues of water and waste are issues of tourism and biodiversity. "Eco-tourism" and "sustainable tourism" have the opportunity to positively impact SIDS economies, but they must first gain popularity and become more common. (Eco-tourism is currently less than 5% of all tourism [3], even though, as Gossling shows, tourism steadily grew in developing countries during the 1990s [3]). But the expansion of tourism provides SIDS with a catch 22: too much reliance on their environmental resources to foster economic growth could risk major economic shocks from potential further rises in sea-level or other environmental degradation factors outside of an individual SIDS direct control; but if sustainable tourism is not practiced and other economic stimulus are focused on, then they will quickly lose the rich beaches and wildlife that are often SIDS greatest strengths and the very thing that attract tourists. Lockhart notes that tourism is perhaps the only economic sector where there are genuine comparative advantages for SIDS[7].

Colonial Heritage and External Dependence

Most SIDS are former colonial territories and many are still attached by some formal ties to their former colonial overseer [13]. Indeed, independence has come recently for most SIDS. The vast majority of SIDS listed in figure 1 received independence after 1960. Colonialism has led many SIDS to become single commodity producers and single market exporters[6]. It has also resulted in the marginalization of native production, decreasing returns from village agriculture, environmental degradation, and increasing peripheral position on world markets[7]. SIDS who are not heavily dependant on their former colonial tie, are often still heavily dependant on import from and external dependence on other countries for the economic issues discussed above. These dependencies are starkly illustrated in energy infrastructure, as will be shown in this case study.

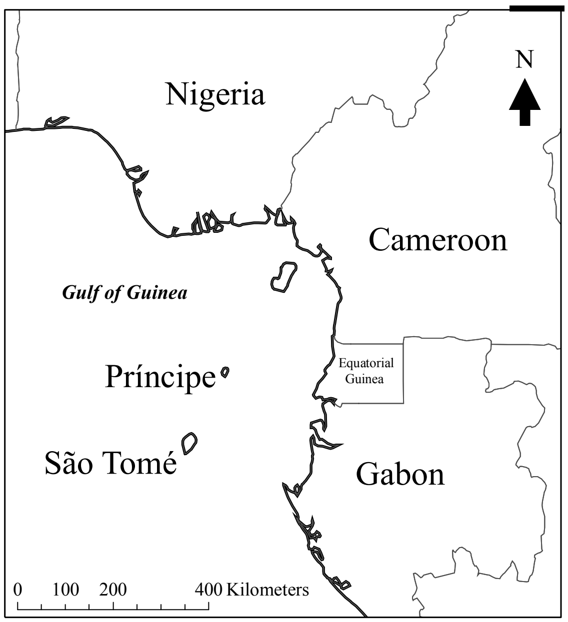
Figure 1: SIDS Comparison [14]

SIDS	Population (2002)	Population Density (per km^2)	GDP (per capita USD)
Antigua and Barbuda	65,000	152	10,204
Aruba	108,000	489	--
Bahamas	312,000	22	14,856
Bahrain	663,000	944	12,012
Barbados	269,000	622	9,255
Belize	236,000	10	3,123
Cape Verde	446,000	106	1,259
Comoros	749,000	316	278
Cook Islands	20,000	81	4,388
Cuba	11,273,000	101	2,545
Cyprus	793,000	86	11,504
Dominica	70,000	95	3,367
Dominican Republic	8,639,000	172	2,500
Fiji	832,000	45	2,046
Grenada	94,000	270	4,682
Guinea-Bissau	1,257,000	33	174
Guyana	765,000	4	936
Haiti	8,400,000	293	431
Jamaica	2,621,000	234	2,990
Kiribati	85,000	113	468
Maldives	309,000	976	1,806
Malta	393,000	1,234	9,245
Marshall Islands	53,000	343	1,938
Mauritius	1,210,000	615	3,779
Micronesia, Federated States of	129,000	165	2,215
Nauru	13,000	524	2,500
Netherlands Antilles	219,000	269	12,149
Niue	2,000	--	--
Palau	20,000	40	6,179
Papua New Guinea	5,032,000	10	545
Saint Kitts and Nevis	38,000	149	6,396
Saint Lucia	151,000	238	4,994
Saint Vincent and the Grenadines	115,000	289	1,940
Samoa	159,000	56	1,402
Sao Tome and Principe	143,000	149	312
Seychelles	83,000	177	7,850
Singapore	4,164,000	6,075	20,544
Solomon Islands	479,000	15	760
Suriname	441,000	3	1,965
Tokelau	1,400	--	--
Tonga	100,000	151	1,284
Trinidad and Tobago	1,306,000	252	6,817
Tuvalu	10,000	423	1,342
US Virgin Islands	124,000	271	--
Vanuatu	207,000	16	1,085
Total	52,598,400	16,628	184,065
Average	1,170,000	387	4,490

São Tomé e Príncipe

São Tomé e Príncipe (STP) is made up of two primary islands off the west coast of Africa in the Gulf of Guinea, on the equator (see figure 2). The larger of the two islands, São Tomé, contains most of the population and infrastructure. The scope of this case study focuses on the island of São Tomé and its electricity infrastructure.

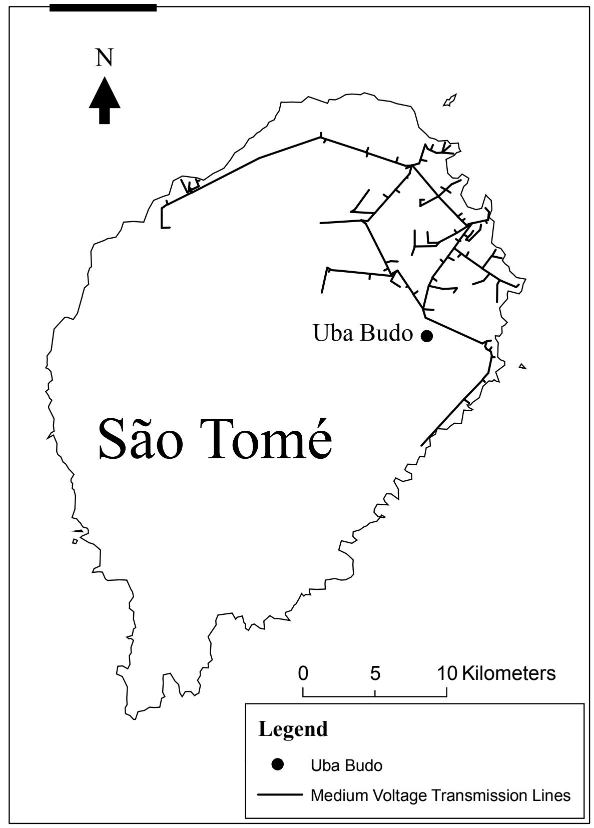
Figure 2: São Tomé e Príncipe and the Gulf of Guinea



Empresa de Agua e Electricidade (EMAE) is the national electricity provider in São Tomé. EMAE is a public-private company (51% government owned and 49% privately owned) under the jurisdiction of the Ministry for Natural Resources and the Environment's office of Energy and Natural Resources. EMAE provides electricity to approximately 60% of the population, leaving 40% of households in STP with no access to electricity[9].

EMAE's total generation capacity in STP is 11.6 MW. 9.2 MW is from diesel generators and 2.4 MW from hydro electric plants. In 2003 EMAE generated 35 GWh. Figure 3 shows the São Tomé electricity network. EMAE pays 7,000 dobra per liter of diesel (0.56 USD/liter), and buys 51% of the diesel imported to STP[9]. Electricity clients who use less then 40 kWh per month pay a special "lifeline" price of 1150 STD per kWh[1], while the average rate paid by other EMAE clients is 1500 STD per kWh[2].

Figure 3: São Tomé Electricity Network



STP's recent colonial past has left a significant portion of the country still residing in very aggregated communities as a result of the former plantation system. Figure 4 shows a picture of a typical former plantation "slave quarters." Long blocks of one room homes line compact streets. A former plantation community will consist of half a dozen, or more, of these long buildings, each housing 10's of households. These structures can be in disrepair; make-shift shacks have been built onto sides of some of the homes to extend the tiny living spaces or to house small shops, sheds, or other small businesses. Such aggregated housing does offer an advantage in electrification: the overall local electric network cost is considerably lower then a less aggregated community, because, at the very least, the length of the transmissions lines required is minimal.

[1] 2004 lifeline prices, equivalent to 12 cents USD
[2] 2004 average rate prices, equivalent to 15 cents USD

Figure 4: Uba Budo Streets

The Case of Uba Budo

Most of the population of São Tomé (about 85%) live in communities greater then 200 people in size. About 10% of the total population live in un-electrified communities between 200 and 500 residents in size. This means that Uba Budo is representative of at least 25% of the overall un-electrified population in São Tomé.

Uba Budo is located just over a 1 kilometer from the medium voltage transmission line network (see figure 3). EMAE has estimated the cost of 63,000 Euros per kilometer to extend medium voltage electric lines and a transformer cost of between 16,000 to 30,000 Euros to step down to low voltage levels. This means, even though Uba Budo is relatively close to the existing grid it would cost between 79,000 to 93,000 Euros to connect Uba Budo to the national electric network. But even if the grid was extended to Uba Budo, EMAE requires an average connection fee equivalent to approximately 150 USD of each household being connected to cover the cost of low voltage transmission wiring, outlets, etc. [9]. 60% of Uba Budo households make less then the equivalent to 40 USD per month. A connection fee of 1/3 of their annual income is likely to be unmanageable for most residents.

Instead of connecting Uba Budo to the national electric network, this case study examines the potential for micro-electric grids. A micro-electric grid, for the purposes of this study, can be defined as an isolated network of connected low voltage lines powered through a local electric generator system exclusively connected to the isolated network (i.e., low voltage, isolated, distributed power).

Choosing a Generation System

A very large range of electricity generation technologies exist. Many interconnected factors affect the appropriateness of one technology versus another. Key factors considered when choosing a generation system for this case study included implementation time, existing infrastructure, scalability, initial investment costs, recurring maintenance & operation costs, reliability, and human capacity.

Precarious dependence on imported fossil fuel combined with high costs for transporting the fuels, result in expensive, and potentially unreliable energy for most SIDS. In the isolated settings that characterize SIDS, Renewable Energy Technologies (RETs) have potential to offer advantages over traditional fossil fuel technologies. Furthermore, many SIDS are located near the equator, receiving high solar insolation, making both solar and biomass technologies strong RETs candidates.

Biodiesel, a vegetable oil derived fuel, could be used in many SIDS to offset petrol diesel imports. At 2760 liters/hectare, oil palm is the highest oil yielding plant used as a biodiesel feedstock and is common in the Gulf of Guinea[2]. The cold flow properties of oil palm make it unappealing for temperate climates, but are not relevant for use in tropical SIDS.

In 1979 EMOLVE, a palm oil plantation and factory, was built in São Tomé. Originally 1500 hectares were used for growing *Tenera* a variety of the oil palm species *Elaeis Guineensis*. EMOLVE was founded by European investors to experiment with *Tenera*, which originated as a hybrid from the Ivory Coast that combined both *Dura* and *Pesifera* varieties of *Elaeis Guineensis*. In 1989 São Tomé obtained ownership and management of EMOLVE. Following a series of administrative and technical problems EMOLVE went bankrupt in 2004. When the author visited EMOLVE in November of 2005 only 169 hectares were still being actively cultivated and harvested, providing a relatively low yield of about 6,000 liters a week. At that time EMOLVE was selling the processed oil to local distributors at 0.90 USD/liter equivalent. The distributors then sold the oil into São Tomé food markets for between 1.20 and 1.80 USD/liter equivalent.

Feedstock costs generally represent 75% of the overall cost of biodiesel production[4]. Even if EMOLVE could produce palm oil at 0.45 USD/liter (meaning current distribution prices include a liberal 50% profit margin), the end cost of production would be 0.60 USD/liter, which is still higher then the price EMAE pays for its petrol diesel fuel. However, if significant investment could be made into EMOLVE to restore production levels and yields, resulting price reductions in the vegetable oil could potentially make biodiesel a competitive option in STP

The potential for wind and solar based RETs have been briefly evaluated for São Tomé. Modi and Trancik found that "São Tomé e Príncipe is unlikely to be a high potential wind energy site" and that the high cost of PV solar would require private duty-free import to become potentially competitive[9].

A complete, detailed comparison of all RETs and their appropriateness for SIDS goes well beyond the scope of this study. However, several evaluations of specific RETs do exist. For example, Kaldellis, et. al.*'s Evaluation of wind-hydro energy solutions for remote islands* describes an extensive numerical algorithm based model for performing a parametrical analysis on a techno-economic basis for hybrid wind-hydro-diesel (and desalination) systems in the Greek archipelago [5]. An important conclusion of the study shows a 20 year cost advantage for the technology, but at the expense of a first installation cost of more then 5 to 10 times the annual maintenance & operation costs of existing fossil fuel systems on the islands. This is somewhat representative of many RETs solutions for SIDS: long term advantages exist, but at the expense of high short term installation costs.

The greatest barrier to SIDS' utilization of RETs is related to local human capacity. Weisser explains that:

> the fundamental prerequisite of creating policies that would allow RETs to compete on equal footing [to fossil fuel technologies]…requires strengthening of human capacity of both the electricity industry and government bodies. Presently, the lack of expertise poses a serious barrier to analytically and strategically assess RETs for power capacity expansion [16].

In considering these factors of installation, fuel & maintenance costs, existing infrastructure, as well as implementation time, diesel generation was chosen because it offers the lowest installation cost, the most easily near term scalable or transitionable method, it can be installed quickly, operating costs are low at the low consumption levels for this particular case study, and local resources can easily install and service/ maintain it.

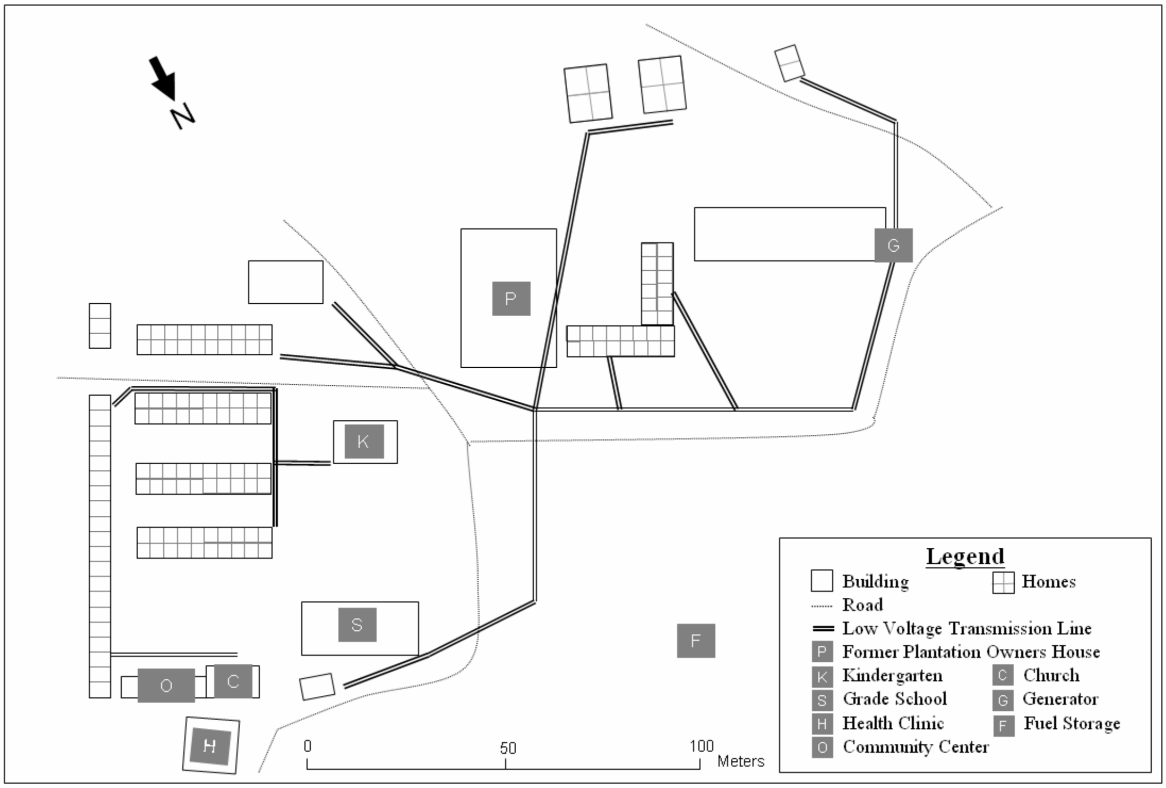
After one to two years, a second phase could be implemented to transition energy generation to a biomass based or other RET based system. Not only is São Tomé extremely well suited for biomass, but the method also offers several other benefits including local income through the production/collecting of fuel. Another option for a second phase could be the transition to hydropower or integration into the existing EMAE grid. But before a 2nd phase is implemented it will be important for the community to successfully self-organize to financially/operationally manage the initial diesel generator system, or order to promote capacity building toward long term sustainability. The skills and abilities that gained by the community will be very useful for later energy transitions as well as further development in areas of water, agriculture, transportation, education, and healthcare.

Sizing the System

This case study limited electricity use to lighting at the household level with some allowance for small appliances at the community level in the local school and health clinic. In initial meetings with the community it was determined that the average amount of money spent on kerosene for lighting was significantly higher then the cost for fuel and routine maintenance for a diesel generator system. Additionally if small (7 watt) efficient light bulbs (CFLs – compact fluorescent lamps) were used, not only could financial savings be realized, but the amount of light provided could be significantly higher then the status quo as well. It was assumed that a lighting only system would be the most appropriate and sustainable system because it would provide an incremental step toward complete electrification, realizing immediate and significant benefits, while not exceeding the means of local residents to participate and manage the system.

Uba Budo consists of 138 households. 15 households live illegally in the abandoned former plantation owner's house and were not able to be included in this case study's installation, leaving 123 participating households. 7 watt CFLs were installed in each room of these 123 households (several families that are large have more then one room), the health clinic, the school, and community center meeting area. There were a total of 208 7 watt CFLs installed. The health clinic, the school, and a community center also received outlets for use with small appliances. A television was also installed in the community center, for community use. Figure 5 shows a map of the community, the household distribution, and the installed transmission lines.

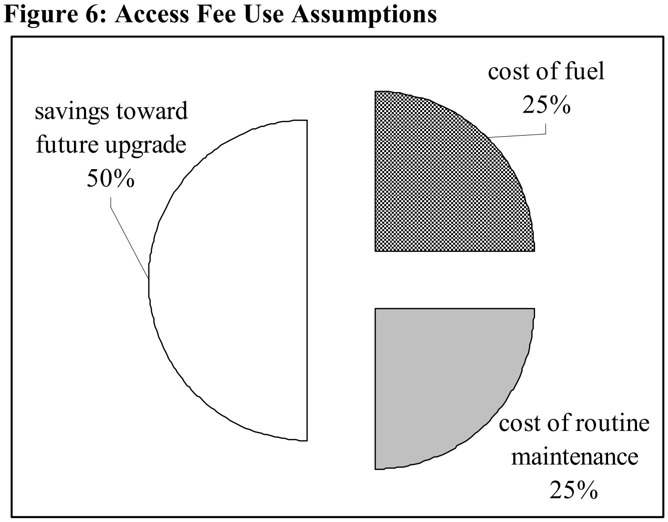
Figure 5: Uba Budo Household Distribution and Transmission Line Map



Most households in Uba Budo work away from their home (53% in agriculture). As such, the primary lighting load was determined to occur in the early evening. In the bylaws the community wrote for managing their system they determined to only operate the generator each night from 6 to 10pm. This would also provide a financially manageable monthly fuel requirement of about 120 liters of fuel per month, translating into the equivalent of about 0.50 USD of fuel costs per household per month. (This calculation assumed a diesel cost of 0.50 USD equivalent, a fuel efficiency of 0.5 liters per kilowatt-hour, and 120 hours of monthly generator use at a conservatively high average load of 2 kilowatts.)

Instead of EMAE directly billing residents for their electricity use, it was determined more practical and financially viable for the community to collect “access fees”. A more traditional “use fee” approach would have required a detailed metering and monitoring system. The cost of the meter and monitoring would be equivalent to the use fee collected from each household over a 6 year period! (This assumes EMAE’s cost of 16 USD equivalent per meter, plus charges for monitoring, and the above mentioned load estimates.) Instead, an access fee approach was articulated in the community’s bylaws and carried out by elected community members. Each participating household was charged an access fee of 25,000 dobra per month (equivalent to 2 USD). It was assumed that this charge would more then cover the cost of fuel and routine maintenance required by the system, providing a mechanism to also save[3] toward a future upgrade for further electricity access. Figure 6 breaks down the different uses of the access fee.

Figure 6: Access Fee Use Assumptions



[3]The communities elected leaders opened a bank account for the community to deposit monthly savings.

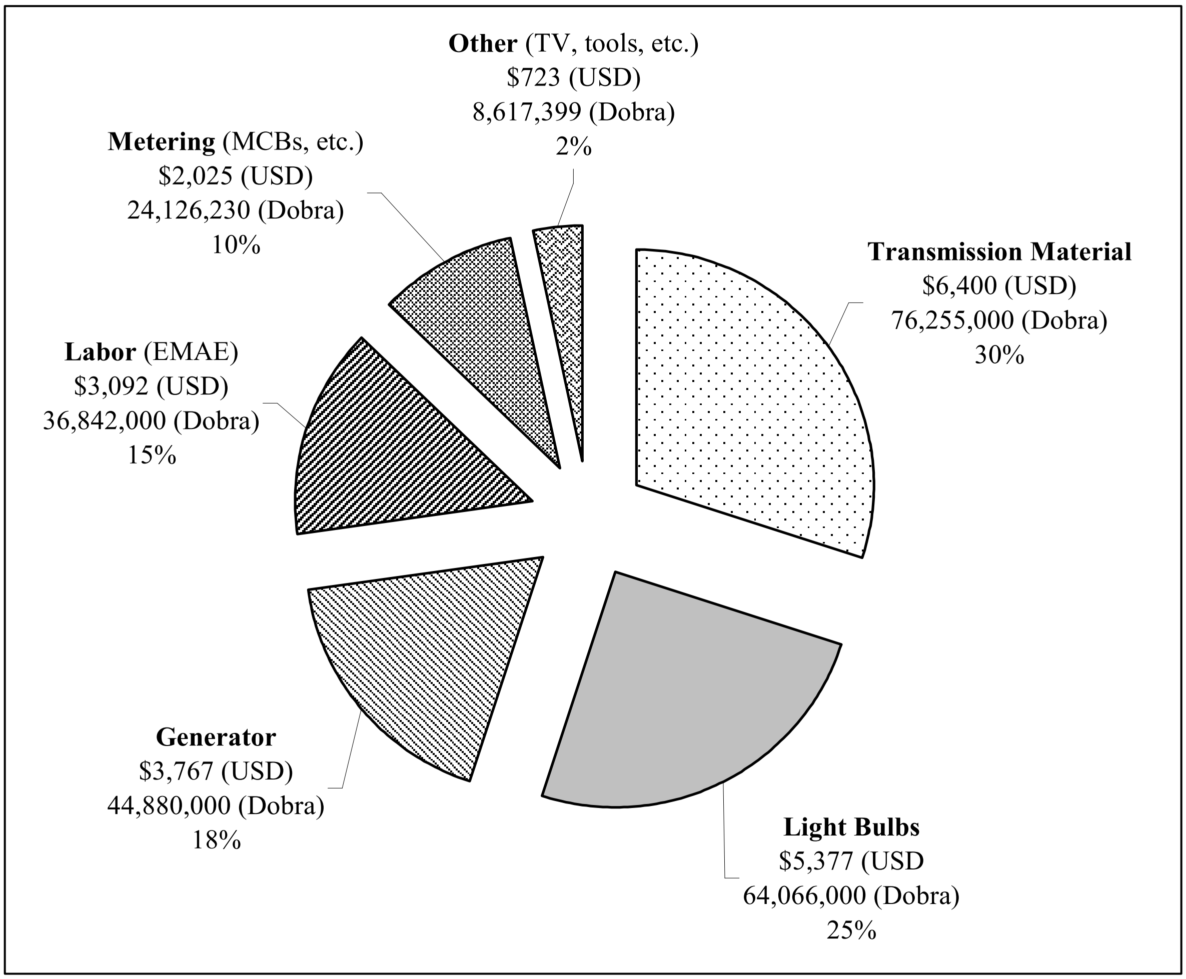
Even though power meters were determined to be too expensive, there still needed to be a way to manage and monitor system use. Mini-Circuit Breakers (MCBs) were employed to restrict the household use of electricity to the designated 7 watts per room, providing both a use ceiling as well as an important safety mechanism. 50 watt MCBs were installed several feet above the door ways of homes. The threshold of 50 watts was chosen so that multiple households shared the same MCB – further reducing the likelihood of tampering or system misuse because of the communal accountability of shared MCBs.

Results

Financial Analysis

The budget for the case study was donated by EMAE, Taiwan, and the Earth Institute at Columbia University. Installation was completed by EMAE. Figures 7 summarize the expenses.

Figure 7: Uba Budo Expenses (Total: $21,386 USD equivalent)



The amount of money spent acquiring light bulbs is extremely high because several sets of CFLs were first purchased locally before importing 500 bulbs. The locally purchased bulbs were of poor quality and a large percentage did not work. Future projects of comparable size and scope would require roughly $^1/_3$ to $^1/_2$ the light bulb cost shown in figure 7.

Labor costs for the Uba Budo system are low for two reasons: several technicians donated their services without full compensation, and a large amount of transmission material was already present in Uba Budo, reducing both the labor and material costs. Future projects of comparable size and scope, without similar existing transmission infrastructure, would require roughly double the labor costs and an additional 50% transmission material cost.

Power Generation Analysis

A data logging power meter (Brand Electronics *ONE meter*) was installed on the generator to track the energy accumulated, per phase, every 15 minutes the generator was on. The system installation was completed and inaugurated mid March of 2006. However, for the first several months that the system was in operation leaders did not enforce collection of "access fees" resulting in a lack of funds to buy fuel and irregular generator use. New community leadership began managing the system on July 1st, 2006. Figure 8 shows the total accumulated energy of the system. Management practices by the new community leaders have resulted in remarkably uniform operation, as shown by figure 9.

Figure 10 shows the daily hours of system operation for July and August (the period since the leadership has taken over system management). The average operation period is 4.1 hours.

Figure 11 shows the daily average power each day. At an averaged 1.23 KW, this shows that the average system load is about 80% of the total available load (208, 7 watt light bulbs and one community TV). This also shows that the generator is providing only about ¼ of its 4.2 kVA capacity.

Figure 8: Total Accumulated Energy

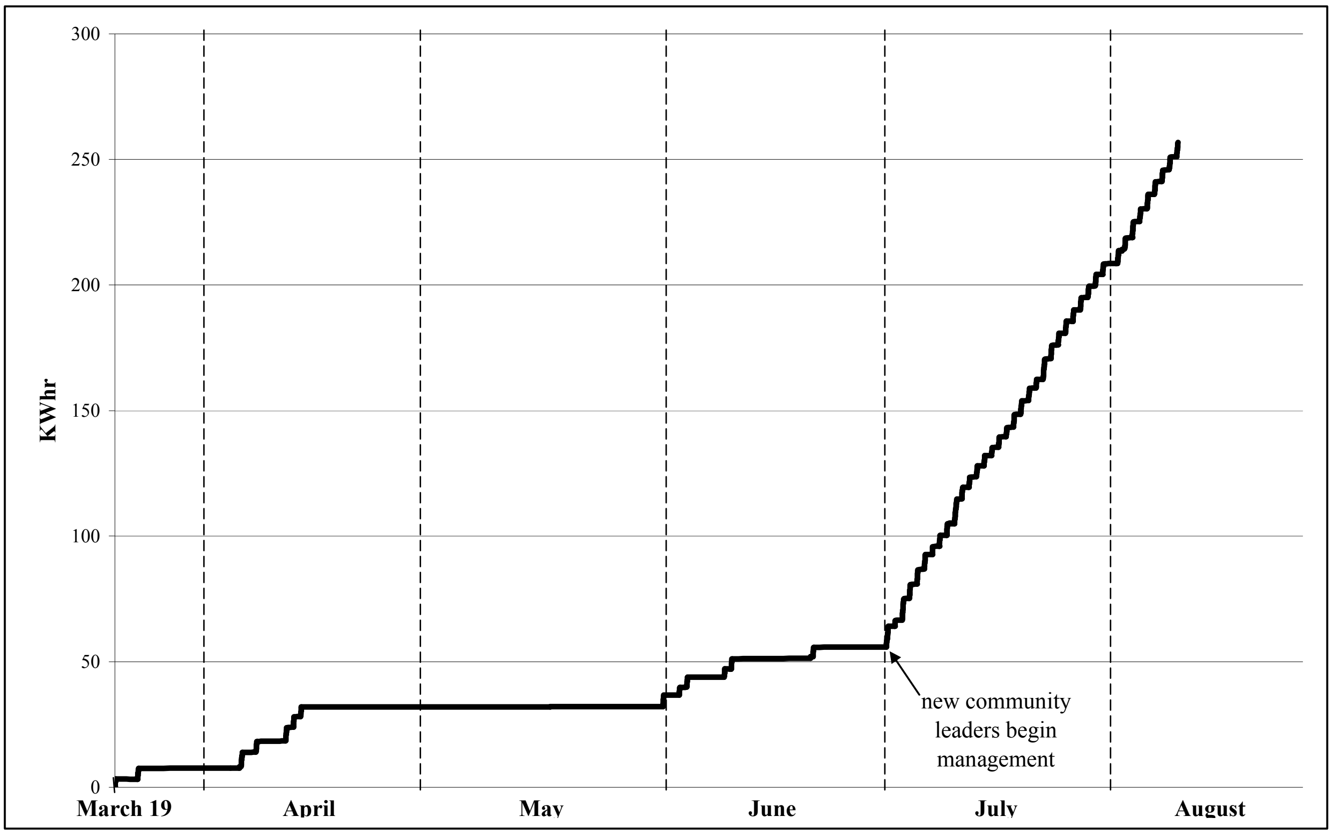


Figure 9: Total Accumulated Energy June 31st – August 9th

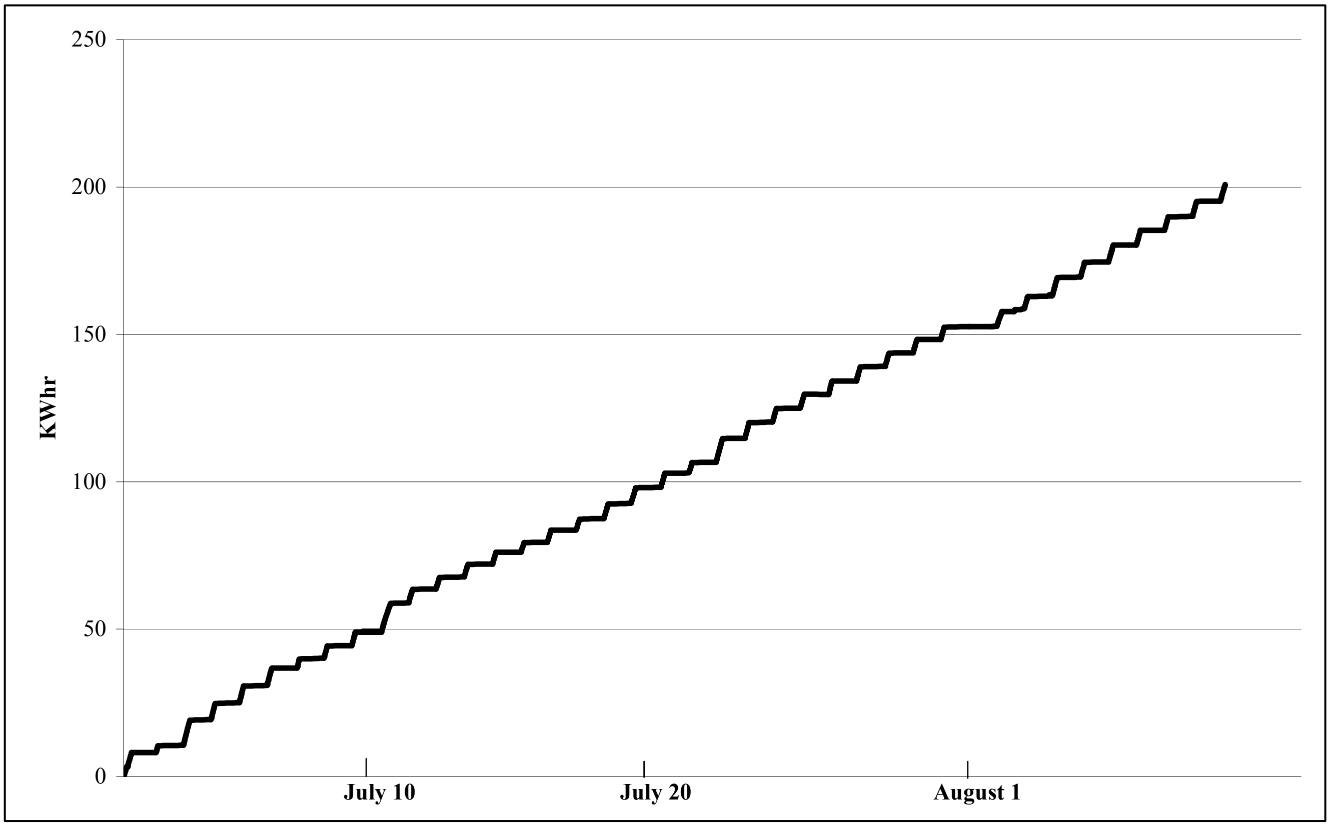


Figure 10: Daily Hours of System Operation (4.1 hours)

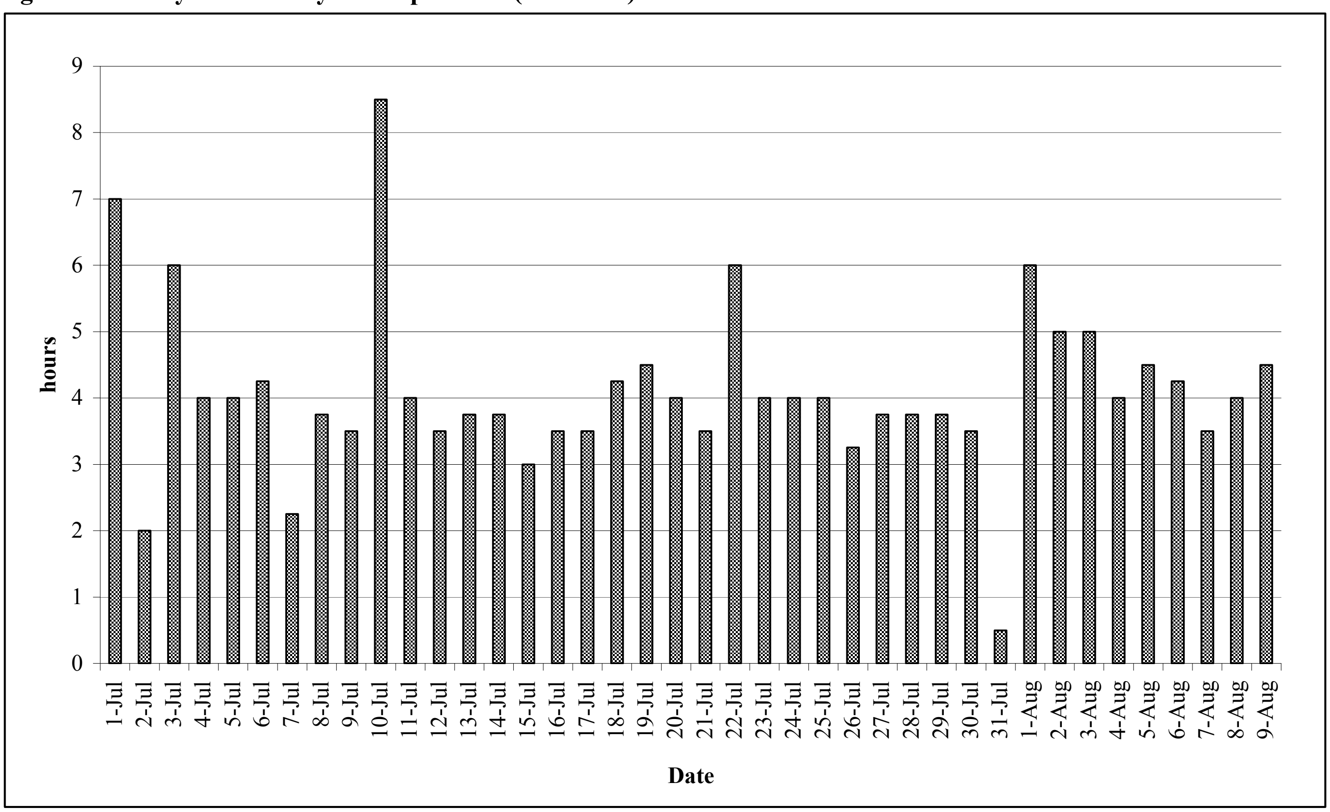
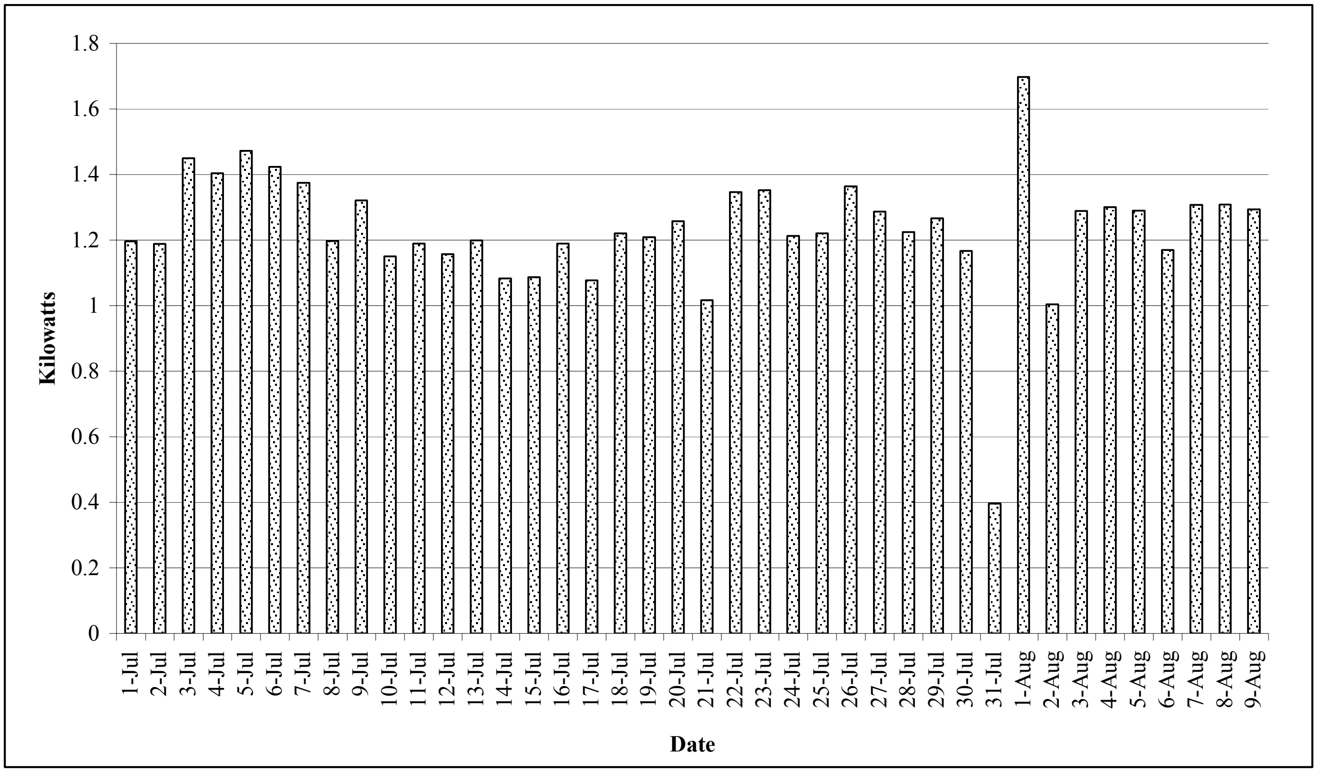


Figure 11: Daily Averaged Power (1.23 KW)



Survey Highlights

Following the installation and after several months of operation, the residents of Uba Budo were surveyed in order to gain insight into detailed community demographics and the appropriateness of the installation technology as well as management practices. 78 households participated in the survey (approximately a 63% sample size). Below is a list of survey result highlights:

- The occupation of the majority of heads of households (53%) is agriculture (farming their own small plot).
- 94% of households surveyed are connected to the microgrid system and successfully making the monthly access fee payment. (The community leadership's records reported that 110 out of the 123 households, or 89% of the total community, are connected and successfully making access fee payments.)
- 83 % of the total number of rooms belonging to households surveyed had a light bulb connected to the system. (Some larger households with multiple rooms do not have light bulbs in all rooms.)
- 66% of households surveyed have an income greater than ~$20 USD per month (40 % have an income greater than ~$40 USD per month).
- 51% of households surveyed already own a TV, but only a few are battery powered. 88 % of those surveyed would like electric lighting access 24 hours a day.
- The amount of money spent on lighting each month that is saved by those participating in the system averages ~$3 USD.
- Only 3 homes reported any MCB tripping, and the cause was not due to a changed bulb or tampering, but a wiring issue that EMAE quickly resolved.
- All households surveyed, except one, had electric lighting for 30 out of 31 days last month, and that household had a loose bulb that once tightened worked correctly.
- No homes reported bulb failure, or breakage.
- 25 % of households spend money on batteries each week. The average amount of money spent each week on batteries, by households that buy batteries, is $2.10 USD (27,000 Dobra).
- 61 % of homes use self made lanterns.

Survey Results Details

Figure 12: Age Distribution

Years old	%
< 10	28%
10 to 19	30%
20 to 29	18%
30 to 39	10%
40 to 49	9%
50 to 70	3%
> 70	3%

Figure 13: Miscellaneous Household and Occupation Statistics

Average number of people per household	4
Average number of people per room	3
Percent of households with greater than 3 people per room	40%
Percent of households with only one person per room	18%
Percent of households with more than five people per room	9%
Percent of head of households having Agriculture as their primary occupation	40%
Percent of head of households that are retired	18%
Percent of head of households that are unemployed (but not retired)	6%

Figure14: What has the new lighting allowed households to do that they weren't able to do before?

increased social activity	33%
watch community TV	26%
no difference	26%
easier to prepare evening meal	16%
increased study time, reading and/or writing time	14%
saved money compared to previous lighting	12%
decreased indoor smoke	9%
increased work time	5%
increased time for house work	5%
joy/happiness	5%

Figure 15: Use of System: Percent of households that on average use the system lighting for:

all 4 hours	75.3%
3 hours	12.3%
2 hours	9.6%
1 hours	1.4%
<1 hours	1.4%

Figure 16: If households had access to further electricity, what would it be used for?

personal appliances - TV, radio, refrigerator, etc.	77%
small business - making/selling baked goods	14%
small business - making/selling ice-cream/ yogurt	9%
enhance work	5%
enhance study	2%
small business - involving film projection	2%

Figure 17: Satisfaction level concerning the current system:

very satisfied	51%
somewhat satisfied	47%
neither unsatisfied or satisfied	2%
not sure, undecided	0%
very unsatisfied	0%
somewhat unsatisfied	0%

Figure 18: What recommendations or concerns are there for the system?

want outlets for appliances	93%
want extend the hours of operation	7%
none	5%
want to lower cost	2%
more punctual service	2%
additional lighting	2%

Figure 19: Income

Percentage of monthly income spent on lighting fee	(monthly income in equivalent USD)	Results
< 5%	greater than $40	40%
5-10%	between $40 and $20	26%
10-20%	between $20 and $10	6%
20-50%	between $10 and $4	15%
>50%	less than $4	13%

Figure 20: Appliances already owned by households

% of Households	Appliance	currently battery powered?	currently not powered
51%	TV	8%	92%
36%	Radio	65%	35%
15%	Cell Phone	100%	0%
11%	Iron	0%	100%
9%	Fan	0%	100%
6%	oven or heating device	0%	100%
6%	Refrigerator	0%	100%
2%	Mixer	0%	100%

Figure 21: Non-electric lighting sources

	Before	After
Percentage of households using candles	30%	11%
Percentage of households using kerosene	85%	46%
Percentage of households using private gasoline generator	4%	0%

Figure 22: Spending per month, averaged across all surveyed households

	Before (Dobra)	After (Dobra)	Savings (Dobra)
Candles for lighting	18,500	2,700	
Kerosene for lighting	58,800	17,400	
Gasoline for lighting via private generator	7,800	0	
TOTAL lighting	85,100	20,100	38,900

	Before (USD)	After (USD)	Savings (USD)
Candles for lighting	$1.5	$0.2	
Kerosene for lighting	$4.6	$1.4	
Gasoline for lighting via private generator	$0.6	$0.0	
TOTAL lighting	$6.7	$1.6	$3.1

Figure 23: Candles and kerosene, before and after

	Before	After
Number of candles used per week, averaged across all surveyed households	1.9	0.3
Number of liters of Kerosene used per week for lighting, averaged across all surveyed households	1.6	0.4

Figure 24: Non-electric lighting costs

	Min (Dobra)	Max (Dobra)	Average (Dobra)	Min (USD)	Max (USD)	Average (USD)
Cost of 1 Candle	1,500	2,500	2,300	$0.1	$0.2	$0.2
Cost of 1 liter of kerosene	4,000	19,000	8,200	$0.3	$1.5	$0.6
Cost of 1 liter of gasoline	16,000	17,000	16,500	$1.3	$1.3	$1.3
Cost of 1 kerosene lantern (for non self made lanterns)	2,000	70,000	11,100	$0.2	$5.5	$0.9

Figure 25: From the head of household's understanding, who is believed to be responsible for the generator/lighting?

70%	Columbia University
43%	EMAE
20%	Community Association
7%	Government
5%	unknown/don't care

Figure 26: Which organization or organizations are expected to be responsible for these future development projects?

75%	Columbia University
30%	Community Association
20%	EMAE
16%	Government
7%	unknown/don't care
2%	Other

Figure 27: What are the expectations for future development projects in Uba Budo?

100%	increased electricity access (outlets)

Non-electricity development projects involving:

59%	housing	7%	emergency transport
43%	roads	5%	clean up the yard
36%	water	5%	healthcare
25%	job creation	2%	tools
16%	toilets	2%	telephones
		2%	increase agriculture prod.

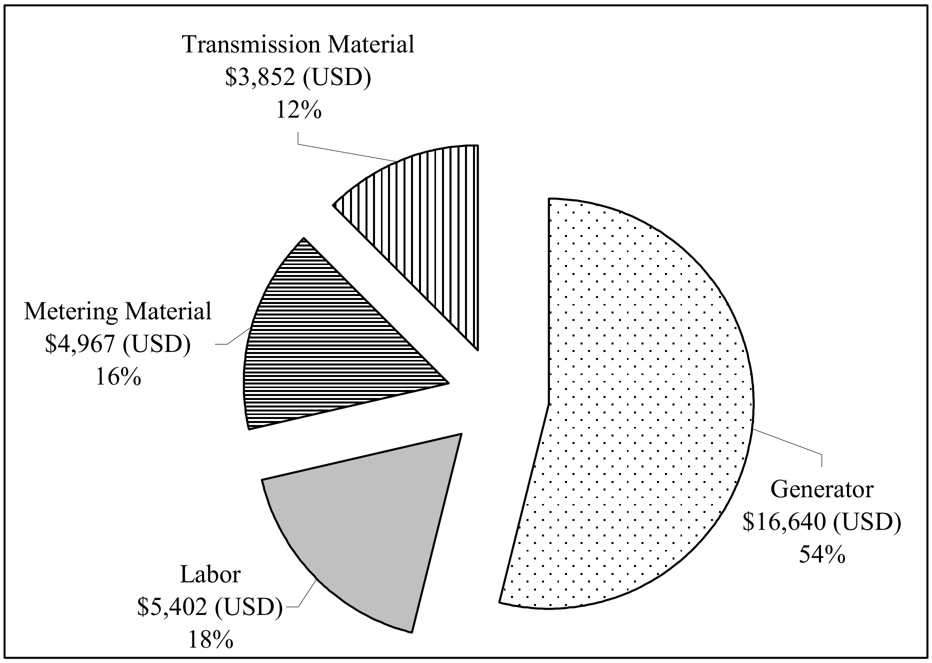
Looking Forward

Even with high import prices, the low installation cost of about 50 USD/capita was obtained in this case study. Post installation, all operating costs were bore by the community. MCBs provided a unique low cost access metering method through communal accountability. Local leaders successfully managed and operated the system, and a significant portion of the monthly money collected was designated toward saving for future expansion.

The cost of a next phase electricity system has been estimated to be about $30,000 USD (see Figure 28). Even if Uba Budo was able to successfully save 50% of all collected access fees, it would take nearly a decade and a half to save enough money to afford the installation, without outside assistance.

An important qualitative outcome of the installation in Uba Budo was the capacity building in local leadership. Uba Budo households are in close physical proximity to one another as a result of the colonial plantation system, but the unfortunate irony is that the nature of the households under colonial rule was that families or individuals were transplanted to Uba Budo and no significant social network formed to bind the individual households together as a cohesive community. The electrification project however had a positive peripheral impact in this area. Elected leaders of the electrification project used the momentum from the energy system to organize the community to begin to address issues of emergency transport, sanitation, and housing repair. Further work is needed in each of these areas and outside assistance is essential, but it is valuable to note that when local resource management is included in the promotion of development of one resource area (i.e., energy), it can often positively impact peripheral resource development areas.

Figure 28: Uba Budo 2nd Phase Installation Costs ($30,860 USD)



Conclusions

This case study illustrates how micro-grids utilizing an MCB based "access-fee" local management approach can provide aggregated communities with low cost lighting, and be a useful step toward expanded electrification. Though Uba Budo was able to both successfully manage and operate the system, and even save money and build capacity toward further scaling and expansion, it is likely that further assistance will still be required to realize additional electricity access. For these reasons it is clear that both country level action (or large institutional level action) as well as community level programs are essential moving forward. Remnants of the former plantation system and its aggregated settlements have provided conditions where low cost, life-line scale systems can be quickly implemented, but both community and national capacity building will still be necessary in order to promote sustainable electrification.

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