International Journal of Social Sciences and Management Review

Volume: 02, Issue: 01 " January-February 2019"

ISSN 2582-0176

INTRODUCING ELECTRICITY AND RENEWABLE ENERGY PLATFORMS IN RURAL UGANDA: A CASE STUDY ON LAKE BUNYONYI

MATT VANDERWERKEN
Colorado State University
145 Bryant St, Apt 2
North Tonawanda, NY 14120
+1 315 418-5404

JERRY AMANYA
Global Livingston Institute
Wandegeya, Makerere, P.O. Box 7062, Kampala, Uganda
+256 774 489 112

EVAN FUELLENBACH
Colorado State University
329 Wood Street, unit b
Fort Collins, CO 80521
+1 719 466 1437

KENI HERMAN
Colorado State University
504 Skyline Drive
Fort Collins, CO 80526
+1 352 638 2562

THOMAS KARREL
Global Livingston Institute
59 Center Street, Westport, CT 06880
+256 770 943 614

WILL TESCONI
Global Livingston Institute
3001 Brighton Boulevard, Suite 2662, Denver, Colorado 80216
+1 707 483 1249

JAMES M. VAN LEEUWEN
Global Livingston Institute – Wilson Center Public Policy Fellow
3001 Brighton Boulevard, Suite 2662, Denver, Colorado 80216
+1 720 272 4886

ABSTRACT

While the limited access to modern energy used for electrification and cooking can be addressed by kerosene and non-renewable, rampant electrification measures considered viable solutions for developing communities are harmful to the environment and will further exacerbate current environmental and health issues. This study addresses the challenges of

limits to energy in remote areas of developing countries. Our research team spent six weeks collecting data in areas surrounding Lake Bunyonyi in Southwestern Uganda, shadowing a microgrid business in Kigali, Rwanda, and meeting with local and national government representatives and agencies. Data were collected through focus groups, interviews, and surveys to capture energy consumption habits from a broad range of small-scale economics. We conducted 34 in-depth interviews and distributed 35 surveys. The research assessed the ability and willingness of rural communities to pay for electrical access to their homes and shops; this reflected that, on average, local community members were willing to contribute 20 per cent ($5 USD on average) of their monthly income for access to electricity. We conclude that while it may be difficult to overcome the hurdles of lighting a rural population, the demand and usage are high enough to enable a premium return on investment (ROI).

Keywords: Solar, Rural, Uganda, Micro grid, Renewable Energy, Sustainability, Entusi

1.0 INTRODUCTION

There are 1.2 billion people around the world living without safe, efficient access to modern energy for electrification and cooking. Additionally, progress in electrifying urban areas has outpaced that in rural areas two-to-one worldwide (Global Energy Trends to 2040, 2015). Rural communities that lack electricity options experience limitations to development, productivity, and income inequality. The absence of an affordable source of electricity prevents the creation of many new jobs, on both community and national levels, and can be seen as a loss of GDP potential (GEA, 2012). A recent study of sub-Saharan countries showed as much as 6.5 per cent of GDP lost in Malawi due to unreliable access to electricity (GEA, 2012). These communities also suffer from lower access to quality education and increased health risks. Specifically, people using kerosene fuel for lighting have a substantially higher risk of eye irritation and vision impairment, along with difficulty breathing, pneumonia, and other respiratory illnesses (Mills, 2012). Electricity can improve education through access to otherwise unavailable forms of electronic information and the ability for students to study in the evenings at home. The current systems are not reaching significant portions of populations due to the cost of infrastructure development and geographic obstacles. However, there are promising business and technology solutions that address this challenge to create a large-scale, sustainable impact.

2.0 LITERATURE REVIEW

There are many systems involved in the limitations of modern energy access: governmental, socioeconomic, natural resource, cultural, and religious systems and all play a part in shaping energy access. Most governments of more developed countries have systems in place to distribute and provide energy to the masses through government-subsidized monopolies known as utility companies, while developing countries may not possess this established infrastructure. Socio-economic and market mechanisms limit energy access to finance and trading systems. People living without energy access likely do not have access to traditional banking. Natural resource systems and pricing all directly impact the supply and demand for direct and alternative energies. Cultural systems shape the societal outlook on acceptable forms of energy, and even religious systems which might limit or give preference to certain energy use.

Bringing renewable energy to rural, off-grid communities affects numerous stakeholders including residents, local businesses, and suppliers of other energy sources (ex: kerosene, coal, etc.). While not all energy use can be addressed by an enterprise, the challenge of limited access to modern energy is amendable by enterprise-based approaches due to certain key characteristics. One characteristic, inherent in rural limits of modern energy, is the need for energy to aid in income generation in rural communities. Government intervention in many developing countries has been ineffective and apathetic in providing energy to its citizens, while enterprise opportunities exist as an attractive alternative as a result of the low cost of acquiring a 'wide pool' of new customers. Businesses that provide electricity to marginalized groups have the ability to make substantial profits by addressing the needs of a large number of people.

Providing clean, renewable energy to rural communities has some notable social impacts. Kerosene is currently one of the only options for many of the 1.2 billion people without electricity and releases harmful particulates into the air that can affect eyes and lungs (Lam, 2012). Eliminating its use with clean alternatives would result in quick and measurable health improvements. Community surveys done in Vietnam show immediate attendance increases in rural schools after the introduction of electricity options; this allows for the use of televisions and safe lighting for studying, socializing, and other activities. Additionally, income generation is made possible with new opportunities for home-based small businesses and potential global connectivity (Khandker, Barnes, Samad, & Huu Minh, 2009).

In Uganda, roughly 18 per cent of the population has access to electricity; that figure reduces to about 8.01 per cent in rural areas. There has been a push for more solar products in Uganda over the last decade, although primarily coming from non-governmental organizations (NGOs) that are internationally-based. Yet, there has not been an abundance of investment funds for large-scale solar products, or for microgrid development in Uganda. This leaves rural Uganda with few viable options for electricity. Electricity has the power to help people become entrepreneurs, boost their earning capacity, increase time spent studying, and alleviate health problems that result from the use of kerosene. This microgrid research examines productive use and how people can use electricity and renewable energy in a rural setting. This case study can inform other NGOs working in developing countries to introduce renewable energy in similar rural communities.

The Global Livingston Institute (GLI) is a community-based research institute co-located in Denver, Colorado, Kampala, Uganda and Kabale, Uganda that develops strategic partnerships in both East Africa and the United States with a focus on education, job creation, and social impact. The Entusi Resort and Retreat Center (Entusi) was opened in 2012 on Lake Bunyonyi in Kabale as a space to cultivate GLI's innovative community development work in rural Uganda. Entusi employs 25 full-time Ugandans and acts as a forum for the growing dialogue in social and economic progress within the local and international community (The Story of Entusi, 2017). This research focused on the communities neighbouring Entusi around Lake Bunyonyi.

3.0 METHOD

This research was guided by five hypotheses:

I. The range of individual income within the local economy is enough to support electricity distribution.

II. There is an anchor productive use model with a 1kw system for 25 households that allows for profit.
III. A revenue-based business model is possible (i.e. municipal oversight, cooperative, or hybrid).
IV. The Ugandan government, corporate subsidies, and/or other partnerships exist to help develop rural microgrids.
V. The business model will work if 100 microgrids are installed in three years.

The primary focus of the research was to determine if job creation and revenue generation are possible with increased electrical capacity at Entusi. We drew our data from a convenience sample of the Entusi manager and staff and looked for gaps in services that could be resolved with the addition of increased electrical capacity.

Using in-depth individual interviews, group interviews, and surveys to determine our customer segments and the perceived value of electricity, our research team tapped into customer type, customer demographics, geographic area, willingness to pay, customer segment income, and standard payment methods. Through selective sampling, the staff at Entusi directed us to the areas without electricity and provided translation as needed. We cross-referenced translations in order to verify the integrated data collected through interviews. Through descriptive research methods, we assessed the direct competitors operating in Uganda and Rwanda by interviewing corporate and governmental subjects, the major entity being the Rural Electrification Agency (Turyahikayo, 2017). Using snowball sampling, we leveraged our convenience sample to put us in contact with government officials. We used non-participant observation and surveys to recommend an appropriate sized photovoltaic (PV) system to be built. The survey information helped determine the need for electricity from participants; however, electrical distribution to homes was unfamiliar to the sample. As a result, much of the research was informed by personal observations of daily routines in the non-electrified villages compared to electrified towns to assess how the use of electricity could be vital. On-site weather recording devices, provided by the Smart Village Microgrid team from Colorado State University’s PowerHouse, was used to analyze whether and smog patterns. We also analyzed the cost structures to provide electricity to the highest number of people.

Our research generated ethnographic and quantitative data from interviews collected across nine villages around Lake Bunyonyi. We conducted 34 in-depth interviews, distributed 35 surveys, led six group interviews which involved 120 villagers, met with five government officials, and learned from nine experts in the fields of solar, finance, and technology. Given existing language barriers, we used a local translator to help conduct most interviews. Our research was supported and informed by the Entusi staff who are familiar with and grew up in the villages around the lake. For comparison purposes, we spent three days in the local urban town of Kabale to determine the energy usage of people on the national grid, and to identify locally available products and their price points.

4.0 RESULTS & DISCUSSION

All but one person interviewed in the villages had home solar systems which were built through a one component at a time purchase model. These systems run on DC power and do not have an inverter. To assess the demand for electricity for product use, we surveyed people on desired appliances for personal and income-generating activities. 38 per cent of

International Journal of Social Sciences and Management Review

Volume: 02, Issue: 01 " January-February 2019”

ISSN 2582-0176

individuals surveyed are interested in using electricity for their radio; 32 per cent of people were interested in cooking. Subjects also expressed interest in televisions, refrigeration, and electric razors.

To better gauge the demand for off-grid electricity in rural Uganda, we used the following methods: card sorting, collaging, expert interviews, depth interviews, natural experiments, observations, and surveys. Data regressions and analysis revealed that access to electricity is not only needed, but desired. 100 per cent of individuals interviewed identified that if they did not already have a solar PV system to charge their products and light their homes, they would greatly desire electricity. Our findings estimate potential monthly income at 110,000 UGX (~$29.85 USD) and a willingness to pay for electricity at 20,000 UGX (~$5.43 USD). Our interviewees’ willingness to pay is therefore roughly 20 per cent of their monthly income.

Survey data suggests that the most desired use for electricity is lighting, followed by phone charging and personal use.

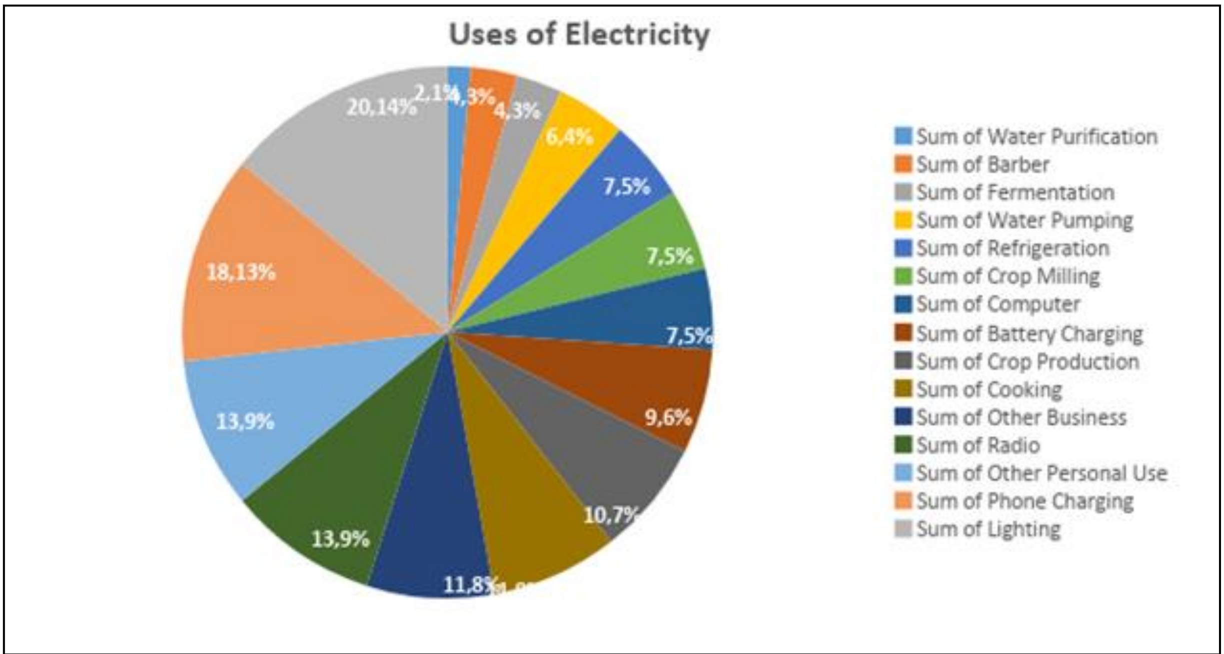
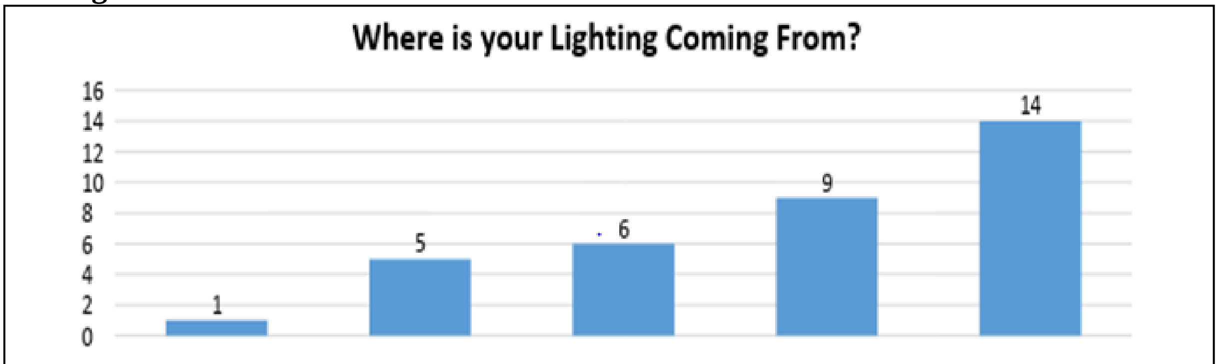


Figure 1: Desired Uses of Electricity

Kerosene lamps are the largest provider of in-home lighting, followed by candles and flashlights/torches.



Volume: 02, Issue: 01 " January-February 2019"

ISSN 2582-0176

Figure 2: Common Source of Electricity

Farming/livestock and non-agricultural business or retail stores are the two primary sources of income in the region. The group interviews validated the aggregate level of income and willingness to pay at around 110,000 UGX and 20,000 UGX, respectively.

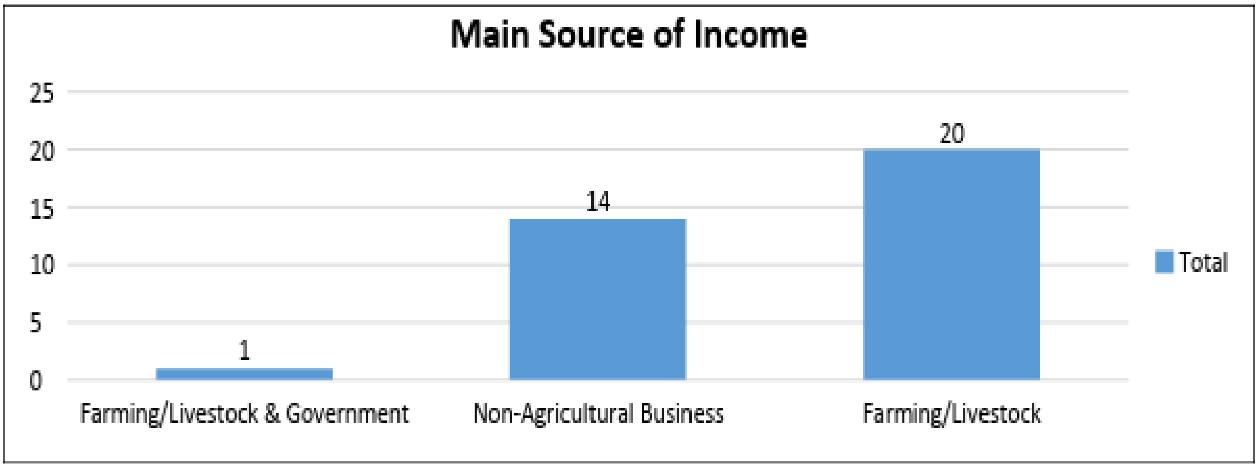


Figure 3: Primary Income Source

Hypothesis I: The range of individual income within the local economy is enough to support electricity distribution.

With a willingness and ability to pay per household of roughly 20,000 Ugandan shillings, or around $5 USD a month, a distribution model is possible. Using PV solar generation, the cost of electrical production is relatively cheap and scaled easily. The largest cost component of an electrical distribution system is the capital infrastructure necessary to transport the electricity from the source to homes. This includes the distribution grade wires, poles, and customer boxes within the home. Macro-distribution systems that satisfy national services and most micro-scale distribution systems rely on 240V AC. This electrical transportation is costly. The findings suggest that a price point at the willingness to pay, rudimentary solar generated 48 DC system could satisfy small villages with distribution to homes in a 200-meter radius away from a centrally-located base station with a minimum of 50 participating homes.

Hypothesis II: There is an anchor productive use model with a 1kw system for 25 households that allows for profit.

This hypothesis is not supported by the research conducted. Most villages do not have the economy to support the purchase or overhaul of current productive use machines to electric from diesel (corn and sorghum mill), or hand operated (sewing machine). The upfront costs are likely not within a local business person's means; however, a productive business model centred on access to productive use machines could be studied for viability. The 1kw system would not produce enough electricity for both the productive use devices in addition to 25 households. We estimate that an increase in electricity production, closer to 5kw, would

accommodate at least 50 to 75 households to help shift the total cost burden of the businesses utilizing daytime electricity for productive use. Households would then utilize stored power off batteries, typically in the evening hours.

Hypothesis III: A revenue-based business model is possible (i.e. municipal oversight, cooperative, or hybrid).

Though local municipalities are in favour of village-level electrical distribution, they are not in a position, organizationally or financially, to assist in their development. The findings do not indicate that any village-scale, revenue-based business models can develop from municipal oversight.

A cooperative model can only work on a case-by-case basis. Currently, there are groups in place on the village level called savings groups or ‘saccos’. These function as a community credit union where villagers pool their money and distribute it to one individual per cycle. They have high potential as a cooperative model as there is already a village-wide system of money gathering and distribution in place. However, many social and business organizations that exist in rural communities do not extend beyond the village borders. This means that each new microgrid solution would require negotiations and intense, ongoing communication with community groups increasing sales costs and organizational overhead. In order to scale to profitability, several hundred villages systems would need to be brought on board over time, which causes nearly insurmountable communication issues.

With a business organization supporting local cooperation, a hybrid model could work, although it would be subject to the same pitfalls of a pure cooperative structure as well as have limited scalability due to the informality of local cooperatives.

A for-profit, revenue-based, the subscription model is possible and highlighted in Hypothesis V. Further research is necessary, but with the growing opportunities in impact investing, start-up challenges for this model are eased.

Hypothesis IV: The Ugandan government, corporate subsidies, and/or other partnerships exist to help develop rural microgrids.

The Ugandan government is in support of the development of microgrids in rural locations. They will provide infrastructure associated with the microgrids as a form of subsidy. However, the infrastructure provided would lead to a larger system that has been determined necessary. The system would be 240 volt AC distribution. Even with the subsidy, the size of the system would make it difficult to maintain and would be unnecessary for the assessed needs of the villagers. Any business would also need to rely on the government to fix issues with the wires or poles. This could lead to extreme delays in service and large-scale power outages.

A long-term partnership with a Rwandan company, Mesh Power, would allow for further expertise and technical assistance to be brought to Ugandan villages. Mesh Power is currently operating in75 villages in Kigali, Rwanda, and neighbouring areas, and directly south of Uganda. This partnership would allow expansion into a new market while benefiting from the research that has been conducted. Additionally, no corporate subsidies were discovered throughout the research.

Hypothesis V: The business model will work if we install 100 microgrids in three years.

Volume: 02, Issue: 01 " January-February 2019"

ISSN 2582-0176

A business model can work if we install 100 microgrids in three years if austerity measures in both physical and organizational infrastructure are in place. Also, there need to be at least 50 homes subscribed to services and a secondary revenue stream established with small DC electrical devices. The bootstrapping is a critical component to reduce the overhead of initial operations for a business that is servicing low-income households in developing countries. Initially, a single administrator can be on payroll with the rest of the foreign staff donating time and in-country staff utilizing local expertise. As mentioned previously, the physical infrastructure costs can be minimized by employing local wood for poles and 48V, touch safe wires for electricity distribution. Extrapolating from our interviews and the consensus of not only need but expressed desire of electricity, a 50-home minimum is easily within reach for many village communities. DC device sales would be a necessary component of the business. Small DC devices include flashlights, radios, small televisions, and razors. These devices are a central backbone to solar lamp system organizations that promote the lighting feature of their products and then upsell customers with different devices that work on a proprietary basis with their systems.

	Feasibility	Viability	Desirability	Total Points	Ranking
DC Devices	3	1	1	5	**3**
Mesh Uganda	2	2	3	7	**1**
Water Pumping	1	3	2	6	**2**

Figure 4: Business Model Decision Matrix

5.0 CONCLUSION

We established a baseline understanding of electricity needs in a rural community that can inform future efforts to engage communities in adopting electricity and renewable energy platforms. Government officials provided critical insight into the rules and regulations of operating a DC microgrid in the Lake Bunyonyi region of southern Uganda. These regulations limit the use of solar running of direct current, thus making the inverter a necessary addition to microgrid operations. Because of the subsidization efforts from the Ugandan government, the system would need to be 240 volts, which is not economically feasible for the microgrid operation that was originally recommended.

Through this research, there may be opportunities to leverage connections and existing relationships to develop a pilot project. This research demonstrates that the demand and usage for sustainably electricity is high enough to enable a premium ROI, despite various systematic hurdles involved in lighting a rural population.

6.0 REFERENCES

ERA. (2013). *Electricity Regulatory Authority, Energy Generation Statistics*. Retrieved from: https://www.era.or.ug/index.php/stats/generation-statistics/energy-generated

GEA. (2012). *Global Energy Assessment - Toward a Sustainable Future*. Cambridge, UK and New York, NY, USA: Cambridge University Press, and Luxemburg, Austria: the International Institute for Applied Systems Analysis.

Global Energy Trends to 2040. (2015). *World Energy Outlook 2015*, 107. Doi: 10.1787/weo-2015-en

Khandker, S. R., Barnes, D. F., Samad, H., & Huu Minh, N. (2009, September). Welfare Impacts of Rural Electrification: Evidence from Vietnam. *Impact Evaluation Series*, 38. Washington, D.C.: The World Bank.

Lam, N. L., Smith, K. R., Gauthier, A., & Bates, M. N. (2012). Kerosene: A Review of Household Uses and their Hazards in Low- and Middle-Income Countries. *Journal of Toxicology and Environmental Health, Part B,15*(6), 396-432. doi:10.1080/10937404.2012.710134

Mills, E. (2012). *Health Impacts of Fuel-Based Lighting*. University of California, Lawrence Berkeley National Laboratory. Berkeley: University of California.

The Story of Entusi. (2017, April 22). Retrieved May 2, 2017, from Global Livingston Institute: http://globallivingston.org/entusi/

Turyahikayo, G. (2017, May 1). *The Peoples Electricity Link*. Retrieved from Rural Electrification Agency: http://www.rea.or.ug/#

World Bank. (2014). *Electric power consumption (kWh per capita)*. Retrieved from The World Bank: http://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC?year_high_desc=false

