Feasibility Study for the Electrification of a Village in Pyinsalu, Myanmar

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Abstract

Currently around 1.5 billion people worldwide still do not have access to electricity in their homes. An estimated 80% of these people live in rural areas and most have low possibility of gaining access to electricity in the near future. Mini-grid systems are the most promising way to accelerate the access to reliable energy sources, where the distance from the national grid is too long and the demand not enough to reach critical mass. Nevertheless, mini-grid solutions often lack a deep understanding of the socio-cultural context, compromising the ability to provide sustainable solutions to energy poverty and improving livelihoods. Community participatory strategies can gain a more holistic understanding of the community and enable a more inclusive approach to community energy design and planning, in a common effort towards sustainability. The case-study described shows how such approach has created a two-ways collaboration that has facilitated the collection of information and the engagement of the community members. In particular, The Minigrid game, developed by Energy Action Partners, has achieved enthusiastic participation and increased community understanding of energy-related concerns. However, the economic assessment of proposed solutions has highlighted the unviability of the project for private investors, as well as with incentives partially covering the capital costs. The best scenario is represented by a mini-grid fully donated by a public entity or a donor. In this case, the community would be able to sustain the cost of operation, maintenance and replacement, although paying an electricity tariff higher than usual Myanmar's prices.

Keywords: Electrification, Mini-grid, Community Participatory Approach, The Minigrid Game, RETs.

Introduction

Currently around 1.5 billion people worldwide still do not have access to electricity in their homes [1]. By 2030, according to International Energy Agency projections, this number is not likely to drop because of population growth. An estimated 80% of these people live in rural areas [1] and most have low possibility of gaining access to electricity in the near future. Reliable access to electricity is crucial for improving people's living conditions in rural areas, for enhanced healthcare and education, and for growth within local economies. The international community is taking actions to minimize this inequality of energy services between developed and developing countries.

The new energy era is characterized by the concept and framework for global action known as “energy trilemma”. Actions need to address simultaneously three key policy drivers: energy security, climate change mitigation and energy equity, to ensure long-term sustainability of global energy systems [2]. Deep structural changes to energy systems will be required to align technology, infrastructure, policy, scientific knowledge and social and cultural practices towards achieving the same goals. Renewable energy technologies (RETs) have been identified as potential tools to address all three forces constituting the trilemma.

Since the poorer communities are the most vulnerable to the increasingly evident consequences of anthropogenic climate change, energy poverty has become an increasingly important issue on the international institutions’ agenda. Therefore, a dedicated industry has grown to address the tripartite challenge to accelerate energy access for the world’s poorest communities: appropriate technology, scale and financing.

Several technological solutions have been tested and implemented. The first approach is simply to extend the national grid. In many countries, however, this solution is usually unfeasible because of the high cost of extending the transmission lines to rural areas far from the national grid [1], low demand and political conflicts of interests. Therefore, where the distance from the national grid is too long and the demand is not enough to reach critical mass, off-grid systems are the most cost-effective solution. Energy Home Systems (EHS) are very small solution that can be installed at the household level. This solution is taken into consideration mainly depending on the dispersion of the households and the types of load required. Where the population is scattered on a large area, stand-alone solutions can be a better solution, providing energy access to isolated households and eliminating transmission and distribution costs. Nevertheless, the lack of economies of scale hinders the decrease of the total cost of energy and the limited power capacity often do not support income generating activities, which enable a village to create productive services and jobs [1]. Mini-grids are small centralized system where the electricity is generated at a local level, creating a village-wide distribution network. Mini-grids are the most promising technological approach to accelerate rural electrification, since capacity is provided for both domestic and productive use, enhancing the community living conditions and supporting local businesses and economic development. Electricity can be generated via renewable energy technologies, such as PV, wind or small hydro power, advantage of low running costs, greater energy security, and lower environmental pollution.

However, the deployment of mini-grids has resulted to be extremely challenging and many projects have turned out to be unsuccessful after the installation. The bottlenecks for the sustainable success of mini-grids are often not technological, but financing, management, business models, sustainable operations, maintenance, and socio-economic conditions [1]. Each community is described by a complex set of characteristics and interests that determine technical and strategic solution according to local financial, social, and environmental terms. For this reason, it is important to pay attention to the specificities of the local context to design appropriate technologies. Site-visits and community surveys are necessary to gather preliminary information that are crucial for the development of a feasibility study. Community engaged strategies and participatory methods can help to enable a direct engagement, to increase understanding and participation on the community’s side and elicit community needs.

Participatory Energy System Design

Developing an appropriate energy system is one of the key challenges to accelerate a sustainable access to reliable and resilient electricity supply. The long term sustainability of a solution not only depends on the standard and integrity of its technical design and installation, but additional attention must be given to the socio-economic and cultural context of the environments in which these systems are installed and operate [3].

Electrification of rural communities has been often framed within “a top-down technologically-driven framework” [4] that compromise the ability to provide sustainable solutions to energy poverty and improving livelihoods. Key actors in the sector often imagine and construct energy projects according to a set of universalized energy futures, developed via particular sociotechnical imaginaries, rather than particular energy needs/aspirations of individual communities. Each community is described by a complex set of characteristics and interests that determine technical and strategic solution according to local financial, social, and environmental terms. For this reason, it is important to pay attention to the specificities of the local context to design appropriate technologies. Site-visits and community surveys are necessary to gather preliminary information that are crucial for the development of a feasibility study.

Participatory energy planning can improve the quality of the data collection, overcoming social, cultural and educational barriers that often compromise the truthfulness of basic structured interviews and community surveys. Local communities should not be viewed as just targeted beneficiaries, but as important partners in the development process. Active involvement of the community in program planning gives to people the opportunity to express also their willingness to participate and the level and type of benefit they require to ensure satisfaction and commitment. In such a way, “the implementation evolves into a process of realizing a goal that has emerged as a genuine response to a felt need” [5].

Meetings with local government leaders and public consultation meetings with household heads cannot be considered as community involvement. In fact, this type of activity often remains a one-time event to delivery provide information that are too technical and conveyed using communication methods and language that are hardly understandable for poor rural people [6]. Participatory activities are more than a public consultation meeting, they need to actively engage the community in a two-way communication, which is crucial for building mutual trust, and forms the foundation for cooperation and contribute to project effectiveness and sustainability [6]. The mini-grid project developer should organize regular participatory meeting with community members, invest on existing local organizational structures, and establish a community committee to manage the project and the system operation after it is installed [6]. Governments and NGOs should work to ensure that as the community’s capacity increases, the external groups will withdraw from their active role and finally assume the role of a facilitator, offering information or guidance to the community-operated mini grid [5].

Preliminary Study Methodology in Ar Wa Karr Village, Pyinsalu Island, Myanmar

A community mapping approach was used to ensure a more inclusive and participatory approach to community energy design and planning. Three different methods have been used.

First, semi-structured interviews have been conducted within the village. The team has visited each house of the village to personally make the survey. A questionnaire has been prepared to guide the interview, despite it has not been strictly followed. Conducting the conversation freely let the households express their concerns, problems and familiar situations.

Then, participatory mapping activities have been organized to collect information about social structures, economic activities, services and lifestyle in the village. Such activities also help to confirm data about the size of the community and the dispersion of the households in the territory. The participants (about 25 community members) have been divided in groups and a different topic has been assigned to each of them. The topics assigned were the following [7]:

- Institutional map: existing groups, associations, organizations operating in the community and,
- Seasonal calendar: a calendar showing seasons, major events, festivities in a year and,
- Time use diary: daily activities according to gender, age and job and,
- Income and expenditure map: average income of jobs and usual household expenses and,
- Geographic map of the village: location of services and infrastructures and,
- Mobility map: movement in the village, available transportation with relative duration and price.

Each group has presented its results in front of the others, leading to a constructive debate within the community that help clarify and correct the output of each group.

Finally, a session of the Mini-grid Game, developed by Energy Action Partners, has been conducted following the participatory mapping activities. Around 30 inhabitants of all ages participated to the game session, grouped into smaller teams of 3 to 4 people. The game simulates a micro-grid setup, enabling real-time discussions around energy-related decisions of both household and community. In the game, the participants purchase the appliances needed and run them during a networked simulation as they wish. A game facilitator plays the role of ‘system operator’ and at the end of the simulation each household receives an electricity bill related to the selected appliances and the use of them. Between the simulations the users can modify their daily energy behavior according to their financial situation [7]. Therefore, after few simulations the electricity bill of each user will tend to converge to their actual willingness-to-pay.

Preliminary Study Results

The methods used in this approach enabled the project team to gain a better and more holistic understanding of the local context and energy needs in the community. Through the semi-structured interviews and group mapping exercise, the project team were able to gather information about the various stakeholders, their roles in the energy system, and the community's available resources. The game actively engaged the participants collecting information about their daily energy routine, energy needs and their willingness to invest money for electricity services. The Minigrid Game workshop successfully increased participants understanding of the different power ratings of appliances, giving a visual representation of the consumption related to each of them. They were also able to see that their own peaks in household loads corresponded with higher usage of cooking appliances. Through The Minigrid Game, participants were able to view the costs associated with their individual electricity consumption and adjust their usage based on their willingness to pay.

The village Ar Wa Karr is located in the South East part of the island Pyinsalu, Ayeyarwaddy region, Myanmar. It has 25 households, accounting for 109 people equally divided between male and female. The village is divided into two main parts, one located along the shoreline, and the other along the main road. The majority of the community lives permanently on the shore.

The main sources of income are farming (rainy season), fishing (dry season) or running small shops. Complementary incomes come from trapping and selling crabs and fishes, making traps and selling tiger prawn hatchlings. The villagers would sometimes sell their domestic animals mainly cows, pigs, chicken, ducks and goats as well as engage in casual labor for additional income. According to the households interviews, the average income of a family in the village is around 233,000 MMK per year. 76% of the households rely on a loan from an investor living in a close-by island. The interests range between 1% and 20-30%. These families are forced to sell the fish exclusively to the lender and, in case they are unable to repay their loan, the lender controls the price of their catch, typically setting lower prices than market rates. The majority of the jobs are seasonal and when it is not the job season most of the families heavily relies on the loan to survive.

The island currently does not have access to the national electricity grid and there are no governmental plans to connect it in the future, due to the considerable distance from the main land. The majority of the community relies on rechargeable lead-acid batteries, mainly for lighting. As many as 11 households currently use solar home systems. Only 7 of them have PV system with inverter and batteries large enough to power also a television. Small generators are used by three households. The remaining would charge at the homes of friends and family (sometimes a small fee is charged).

Two different community load profiles have been estimated. The first represents the current situation of the village. Existing domestic load are mostly lighting, televisions and DVD players, and there are no productive loads. The profile peak is 2.4 kW and the daily energy consumption is just 15.56 kWh. Figure 1 shows the daily trend.

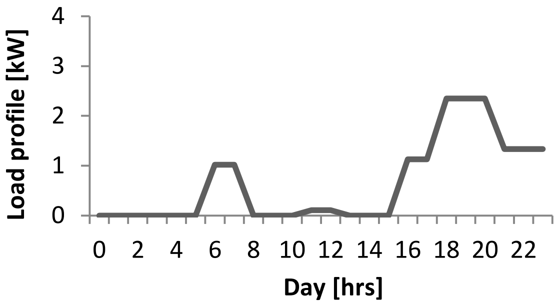


Figure 1
Current Community Load Profile

The second estimates the future purchase of cooking tools, better lighting and some freezer or refrigerators. The penetration rates of TV, fridge, radio, rice cooker and fan have been assumed respectively 60%, 28%, 72%, 52% and 60%. In this case, the peak power is much higher, accounting for 10.9 kW, and the daily energy consumption is 88.02 kWh. Figure 2 shows the daily trend.

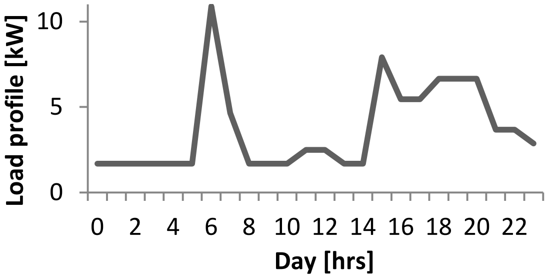


Figure 2
Potential Future Community Load Profile

The community is in need of better and more reliable access to electricity in order to use electricity productively and create more income-generating activities. Members are willing to use and accept a solar micro-grid with possibly lower reliability compared to grid electrification. Although the average expressed willingness-to-pay from the interview resulted 7,720 MMK (4.98 USD) per month, after the last Minigrid Game session they converged on 20,000MMK (12.90 USD).

In order to afford new energy services, community members must not only increase their livelihoods, but also obtain more regular income throughout the year to pay for monthly services. Additional support is needed to facilitate the creation of new enterprises and income-generating opportunities within the village. This could take the form of attracting investment and businesses to set up processing and production of seafood products on Pyinsalu Island, or developing small-scale processing by villagers and enabling access to outside markets. Any enterprise creation will require energy services, which also benefits the community by creating additional energy demand.

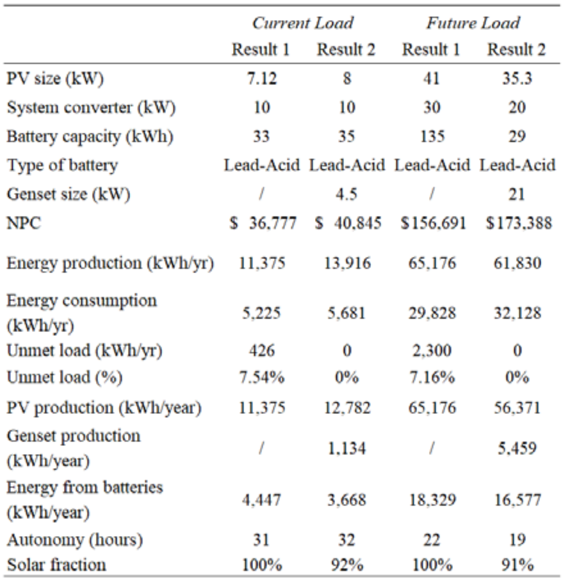
Other than the community's Decision-Making Committee, the community has no other governance structure. The village also does not have many community-owned assets or resources, and have limited experience with community-based management of common resources. A community-based micro-grid system would require careful, participatory design and planning with the community in order to determine the most appropriate ownership and management model for the community. The project team's participatory approach as demonstrated in this report was well-received by the community, project partners and is well suited for high levels of community engagement.

However, there are several unique issues to consider that need a further consultation and study of the community. Strong cooperation and agreement from the community will be required to relocate the members to only one general area, reducing seasonal migration. Increasingly frequent natural catastrophes should be carefully taken into consideration. An energy system or distribution lines on the shore are more exposed to storm and cyclones that can cause severe damages and failures. Finally, low energy demand and low purchase power as well as low incomes complicate the sustainability of the mini-grids, discouraging private investors.

Proposed Solutions

The size of the different cases has been estimated and optimized with the software Homer Pro, inputting the two load profiles estimated in the preliminary study. The unmet load has been limited to 10% per year, in order to provide high system reliability. The flexibility of the load profile has been set to 5%. The components considered by the software have been limited to generic PV panels, lead-acid batteries and auto-sizing generator.

Table 1
Homer Simulation Results



	Current Load		*Future Load*	
	Result 1	Result 2	Result 1	Result 2
PV size (kW)	7.12	8	41	35.3
System converter (kW)	10	10	30	20
Battery capacity (kWh)	33	35	135	29
Type of battery	Lead-Acid	Lead-Acid	Lead-Acid	Lead-Acid
Genset size (kW)	/	4.5	/	21
NPC	$ 36,777	$ 40,845	$156,691	$173,388
Energy production (kWh/yr)	11,375	13,916	65,176	61,830
Energy consumption (kWh/yr)	5,225	5,681	29,828	32,128
Unmet load (kWh/yr)	426	0	2,300	0
Unmet load (%)	7.54%	0%	7.16%	0%
PV production (kWh/year)	11,375	12,782	65,176	56,371
Genset production (kWh/year)	/	1,134	/	5,459
Energy from batteries (kWh/year)	4,447	3,668	18,329	16,577
Autonomy (hours)	31	32	22	19
Solar fraction	100%	92%	100%	91%

The results of the software simulations are presented in Table 1. Two different configurations have been taken into consideration, the first without a backup diesel generator, while the second includes it. Although the NPC increases by 10%, it can be noticed that the addition of a generator in the system maximizes the reliability of the system, meeting 100% of the load. Furthermore, it allows the system to operate also in case of a temporary failure of the PV components. For this reason, hybrid mini-grids are usually preferred for remote areas.

Alternatively, a 200W Solar Home System can meet the household requirements, providing power for lighting and recharge of portable devices, such as smartphones, speakers or radio, and small TV, decoder and DVD players. It is important to provide high quality items to guarantee the longevity and avoid to decrease the trust of the client in small photo voltaic products.

The cost of a SHS ranges between 200 and 600 USD. It can be donated by a public entity or a donor or sold to the community members through dedicated business models. Pay-as-You-Go solutions allows to reduce the upfront cost, relying on digital finance platforms. The user pays a monthly fee for the rental of the product or only pays for the amount of energy used.

Assuming a price of 300 USD per product, the Ar Wa Karr community would only require an investment 7,500 USD, which is much lower than the capital cost of a mini-grid. Nevertheless, the service would be limited to domestic consumption and it would not improve productive use of energy and the household incomes.

Economic Assessment

The economic assessment of a potential mini-grid project is crucial for evaluating the long term sustainability. Private companies and investors should carefully study project-related capital costs, O&M costs and revenues in order to understand whether to invest on it or not. Different economic parameters can help to predict the cash flows throughout the system lifetime. In particular, computing the Levelized Cost of Electricity (LCOE) allows to estimate which electricity tariff would make the project viable and profitable and to compare different strategies and business models.

In this assessment, three different scenarios have been taken into consideration and simulated. Table 2 shows the rates, costs and parameters that have been assumed. System costs have been assumed considering capital investments of existing projects installed by a local installer company. These costs include T&D lines installation expenses. Tax and interests rates have also been assumed according to existing projects.

Case 1 simulates a private-owned mini-grid where a private investor pays to install, operates and maintains the system. Companies usually access debt capital to cover the capital cost. In this case, the commercial loan has been assumed covering 80% of the initial investment, 10 years to pay it back and 3% of interest. The electricity tariff has been set to 0.25 USD/kWh (387MMK/kWh), which is a quite high price for Myanmar.

Case 2 simulates a private-owned mini-grid with incentives covering 80% of the upfront costs. The company pays only 20% of the CAPEX to install the system, relying on a commercial loan to cover it. The loan conditions are, like in Case 1, 10 years to pay it back and 3% of interests. The system is owned, operated and maintained by the private actor. The electricity tariff has been set to 0.25 USD/kWh (387MMK/kWh).

Case 3 simulates a community-owned mini-grid fully donated by a public entity or a donor, providing grants or financial assistance to an outside organization which design and install the system. The local community takes care of tariff collection and operation and maintenance. The revenues from the electricity sold should cover all the O&M expenses in order to be autonomous and sustainable. The electricity tariff has been set to 0.32 USD/kWh (496MMK/kWh), which is a very high price for Myanmar.

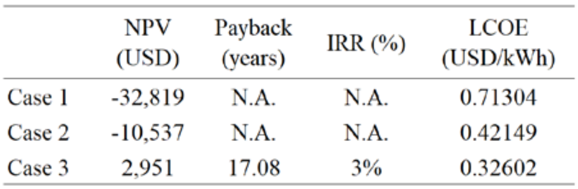
The village load profile has been assumed equal to the current load profile resulted from the preliminary study. The optimal system configuration given by Homer simulations consists in 8 kW PV system with electrochemical storage and backup diesel generator. Considering a demand growth rate of 6% for 10 years, the cumulative annual electricity demand will raise from 5,680 kWh/year to 10,172 kWh/year. To

Table 2
Parameters Assumed for the Economic Assessment

System Inputs			
System Size (kW-DC)	12	Tax Rate	20%
Annual Energy Yield (kWh/kWp)	1,400.00	Discount Rate (%)	10%
Annual System Degradation Rate	0.90%	Residual Value (%)	10%
System Availability (%)	99%	Residual Value ($)	4,800.00
First Year Production (kWh)	16,632	Depreciation term (Years)	6
System Cost ($/kW)	4000	Annual Depreciation ($)	7,200.00
Initial Investment ($)	48,000.00	Annual Depreciation Rate (%)	15%
Loan to value ratio	20%	Electricity Tariff ($/kWh)	0.25
O&M Cost ($/kW)	100	Electricity Price Escalation	1.50%
Inflation (%)	5%	Annual Load/Demand Growth Rate	6%
Inverter Replacement Cost ($), on year 12	3,000.00	Electricity Demand (kWh) per annum	5680
Insurance (% of Initial Investment)	0.80%	Years of growth	10
Loan Duration (Years)	10	Donor ratio	80%
Loan Interest (%)	3%	System Lifetime	25

face the increasing request, the system size has been expanded to 12 kW.

Table 3
Economic Assessment Results



	NPV (USD)	Payback (years)	IRR (%)	LCOE (USD/kWh)
Case 1	-32,819	N.A.	N.A.	0.71304
Case 2	-10,537	N.A.	N.A.	0.42149
Case 3	2,951	17.08	3%	0.32602

The results of each case are shown in Table 3. It can be noticed that Case 1 is not viable with the parameters taken. The NPV is negative, consequently IRR and PBT cannot be calculated. The LCOE value shows that the electricity tariff should be higher than 0.713 USD/kWh to be economically sustainable. Nevertheless, such price is not affordable at all for the community. Case 2 is also not viable with the parameters taken. The NPV is negative, consequently IRR and PBT cannot be calculated. The LCOE value shows that the electricity tariff should be higher than 0.42 USD/kWh to be economically sustainable. Nevertheless, such price is not affordable for the community. Finally, case 3 is viable. The IRR and NPV result respectively 3% and 2,951 USD. The community can sustain the mini-grid that has been provided with. Nevertheless, the tariff set is high for the community and may lead people to avoid consumptions, turning the project to unsustainable.

Conclusions

Community participatory strategies successfully achieved to facilitate and enhance the collection of data and information about the local context and the community energy needs. This approach was well-received by the community, project partners and is well suited for high levels of community engagement. In particular, during The Minigrid Game sessions the participants show enthusiastic engagement and an increased understanding of the different power ratings of appliances and their impact on the monthly electricity bill, that allow them to converge to a more realistic willingness to pay.

The Ar Wa Karr community has a poor and unreliable access to electricity and it would benefit greatly from improved energy services. However, there are several unique issues to consider that need a further consultation and study of the community. Strong cooperation and agreement from the community will be required to relocate the members to only one general area, reducing seasonal migration. Furthermore, low energy demand and low purchase power complicate the sustainability of the mini-grids, discouraging private investors. This issue is highlighted in the economic assessments. The results of the computations show that the investment would be unsuccessful for a private company, also in case of access to a commercial loan. The results slightly improve if the capital cost of the system is partially covered by incentives. Nevertheless, the LCOE is still too high and the tariffs settings to reach the sustainability would be too high for the users. The best scenario is represented by a mini-grid fully donated by a public entity or a donor. In this case, the community would be able to sustain the cost of operation, maintenance and replacement, although paying an electricity tariff higher than usual Myanmar's prices. Creating and forming community electricity cooperatives or other local organizations to manage and operate the system may lower the O&M costs, reducing consequently the LCOE and the electricity tariffs.

As future steps, in order to afford new energy services, community members should obtain more regular income throughout the year to pay for monthly services. Micro-finance projects and investments are necessary to facilitate the creation of new enterprises and income-generating opportunities within the village. This could take the form of attracting investment and businesses to set up processing and production of seafood products on Pyinsalu Island, or developing small-scale processing by villagers and enabling access to outside markets. Any enterprise creation will require energy services, which also benefits the community by creating additional energy demand.

In conclusion, it would be beneficial to deploy The Minigrid Game several more times to converge on other mini-grid design-related parameters, continue community engagement and gain further community acceptance of the difference configurations, and collaboratively put in place a long-term community management plan. Multiple sessions would also enable larger numbers of community members to participate. This would all help ensure substantive community engagement throughout the entire project lifecycle.

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