



# Framework for Achieving Sustainable Micro Grid Systems in Rural Communities

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## Abstract:

This paper presents a concise framework for achieving sustainable and well-grounded mini-grid system across rural communities by interpreting various critical determinants which directly/indirectly affect a localized energy grid and draws a co-relation between them. The end product is a matrix that guides private sectors to rate an area in terms of its viability to cater an autonomous energy generation system by blending technology with economic and social aspects. More importantly the framework also addressed methodology for scaling a plant – circumstances such as post-grid arrival, rise in energy demand, conjunction with new generation plants required to meet the rise. Furthermore, the paper provides a commentary on business models and blend of financial indices suitable for decentralized system for long term financial viability for private sectors. GoN has been supporting rural micro-grids through Alternative Energy Promotion Centre (AEPIC). Until recently, rural off-grid areas of Nepal had community led projects that would become defunct after arrival of national grid, fragmented planning, substandard technology, O&M issues etc. Now, with concept of private sector led projects opening up, the paper provides a skeleton for establishing mini-grid systems designed by negating those downsides that are practically feasible.

This study was performed in various micro-grid sites in Makawanpur District. Research was carried out beforehand via online technology. This was to gain a sense of understanding before visiting the district. A field visit took place from April 24-26, 2018 to verify the research and to perform further analysis. Details were gathered firsthand through empathizing with locals, who filled out a questionnaire set Benchmarks were established in relation to technology, economics and social factors. Analysis was carried out, with the villages ranked against each other.

**Keywords:** Micro-Grid, Off-grid Energy, ABC Business Model

## 1 Introduction

### 1.1 Background

During this study, four off-grid villages in the Makawanpur District of Nepal were selected to generate an archetypical quantification model for micro grids as an essential tool to assess mini grid sites. The Makawanpur District is a diverse area consisting of ample hilly regions and plain land. Most of the areas have not been electrified. Consequently, this study will conclude by comparing four potential micro-grid sites in this area using that model.

Primary focus of the study was established around Anchor Business Community (ABC) business model for off-grid micro grid systems. BTS telecom towers had been considered as crucial anchor loads. For this reason, the study sites were strategically selected to have a mix of

locations with and without anchor loads. To be able to install micro-grids that are financially viable, correct sizing of the system is required. The business model that has been used in most micro-grid projects is the Anchor-Business-Community model (ABC). This works by providing power to an anchor source that requires electricity for the entire or a large portion of the day. Businesses are the next largest consumer, powering buildings that require larger loads. i.e. hotels, hospitals, and restaurants. The community is last but largest demand by population. The aim is to provide the anchor with the highest rate, and then subsidize costs for community consumers, and is especially important in communities that have a low economic status. The business model must also be profitable. Costs must be reduced where possible, while still allowing for consumers to afford the tariff rate. Criteria such as economics, environmental, and social

aspects are important to consider in energy planning (Beccalli, 2003).

**Table 1: Study Area**

S.N.	Location	Latitude	Longitude
1	Kalikatar, Ward - 3, Kailash Rural Municipality	27.587122° N	84.919985° E
2	Litche, Ward-4, Kailash Rural Municipality	27.574032° N	84.921727° E
3	Sarikhet Ward. 2, Raksirang Rural Municipality	27.521340° N	84.858070° E
4	Silinge, Raksirang Rural Municipality	27.634843° N	84.741016° E

A micro-grid system needs to have a balance between different techno-commercial aspects alongside the socio-economic as well as infrastructural aspects of any general location. Importantly, collecting information, which not already available, for specific sites isn't always a practical approach. Therefore, this study develops an open source toolkit for pre-assessment of micro grid systems based on various influential factors. The final outcome i.e. a selection matrix helps profitable as well as not for profit organizations to rank a potential site in terms of averaged scores out of weighted scores of different criteria falling under the scope of technology, business model, infrastructure, social aspects and economical status.

## 1.2 Study Area

Makawanpur District has been diversified by the recently updated provincial political boundary. On the booming end industrial cities like Hetauda has spiked the economic potential for developing rural communities. However, on the flip side existence of primitive and tribal communities can also be found within the district. The study area was selected in Makawanpur to get comprehensive understanding of these communities in terms of possibilities to establish commercial and public oriented energy solutions for the vast number of off-grid areas.

The four study sites, as outlined in table 1, were selected as the study area. Detailed Description of the Study Area

This section of the report will go into details for each village. A majority of this information was gathered whilst visiting each respective village. Information stated in each subsection is accurate as of the publish date of this report.

### 1.2.1 Kalikatar

#### Introduction

Kalikatar-3 is located in Kailash Gaupalika, west of Namtar. The site is approximately 100 Km from

Kathmandu valley. The route from our starting point in Kathmandu, to Kalikatar. With favourable weather conditions (no rain), it should take between 4 to 5 hours to reach Kalikatar from the capital.

There are approximately 250 households spread across the village in small clusters. The houses use small solar home systems. There are two government offices, two health posts, one middle school, and a few convenient stores and hotels in the area. There is also a bus stop and local eateries. The total population of the village is approximately 1,500. The ethnicity of the village includes Tamang, Chetri, Bahuns and Chepang.

#### Electrification Status

The village had a community owned 4 kilowatt peltric system supplying electricity eight years ago. Presently, the peltric system has not been able to meet the demands and is only able to provide electricity during the night time. The electricity provided is only just enough for lighting three bulbs and a mobile phone charger per household. To combat this, the local population has installed small Solar Home Systems of 20-50 watts. The government offices and other institutions have up to 1 kilowatt solar home systems installed. The current electricity is nowhere near enough to meet the present demand. This opens up potential for us to provide a new solution. The NEA has installed transmission lines up to Namtar, which is 10kilometres from Kalikatar-3. Thus, the village can be considered an off-grid site. After the introduction of Peltric system, the villagers had invested in Dish TVs, refridgerators, lighting and other facilities powered by electricity. Currently, they also have water powered mechanical mills. Each household consists of at least three light bulbs and mobile charging stations.

The 4-kilowatt peltric system simply does not meet the demand, and villagers are limited to a few light bulbs and chargers during night. Our proposed solar micro-grid would complement the existing peltric system, if such an integration is possible. The electricity supplied from Peltric system was single-phase AC current. The single-phase network of poles is widely distributed throughout the ward. This would allow a saving on installing transmission poles to the area.

#### Economy

The main source of income of the village is agriculture. Almost everyone practices farming in a conventional way. Maize, millet, wheat, vegetables and fruits are most commonly farmed in the village. There is also a water-powered grinding mill to grind their harvest. Animal husbandry and fish farming are also common here. The

Agriculture Development Committee is also actively involved in making farming more efficient for the productive end uses. The income of the place is seasonal. They sell their harvest during season. Whilst in the off-season they practice vocational works. This includes making clothes, small handicraft and furniture. There are also small commercial stores present. Locals from the surrounding villages travel to Kalikatar in order to use the mills and health facilities. Recently, people have been acquainted with mobile phones and internet provided by NTC. The village has an active economy and people are demanding an upgrade. They were willing to pay the monthly costs. According to our analysis and communication with the Ward Chief, they were optimistic to set up the project with some subsidy from the government. They certainly cannot finance the whole project without some outside help.

### **Anchor Load**

The downside is that there are no telecom towers to act as the anchor. In order to solve this problem, we have to search for alternative anchors like some other established institutions.

### **1.2.2 Litche**

#### **Introduction**

The Litche village is located in Kalikatar, Ward no. 4 of Kailash Rural Municipality. It lies on top of a hill which can be reached by hiking for 2 hours from Kalikatar. A road is also being constructed by a cement company because that leads to limestone mines. It might take a year for the road to be complete. Till then, the village is only accessible by foot.

There are around 100 houses, which are primarily made of mud, clay, wood, and tin. This is typical for villages in Nepal. Almost all of the people own farms and have sheds to house their animals. They cultivate different kinds of crops such as maize and millet. The houses are not clustered; they are spread all around the hill. According to the ward chief of the village, Mr. Tilak Bahadur Moktan, the village presently holds around 1,000 people. They are mainly children and elderly people as most of the youths have been away working in other places. The people are mostly of Tamang and Chepong ethnicity.

#### **Electrification Status**

The village is not connected to the national grid and it is highly unlikely that the grid will arrive within a decade. It also lacks any kind of micro-grids for electrification. Each villager owns a small solar home system with a rated

power of 20 watts. The system consists of a small battery, and a charge controller. It is sufficient enough to power light bulbs and charging mobile phones. From the survey, we found that no villager owns any other equipment such as television, refrigerator or fans that consume a larger amount of electricity. The load demand of the village is high during morning and night due to use of the light bulbs. They also use it to charge their phones mostly during the day. The current daily estimated demand for the whole village is around 1.5-kilowatt hour.

### **Economy**

The main source of income is agriculture. People have cultivated a range of crops such as barley, millet, and maize. They also own different kinds of livestock including chicken, goats, and cows. The village currently lacks any kind of business or any prospects for trade. The willingness to pay for electricity was quite high among the villagers. They were very enthusiastic to support any electrification project. However, because of their low economic status, they are unable to pay high prices for electricity. The cost of the project would also be very high due to problematic accessibility. Therefore, a large amount of subsidy would be required to install a new electrification project.

### **Anchor Load**

A Nepal Telecom BTS tower in the village provides the mobile network to the people continuously. The tower runs on the electricity provided by the solar PV system... The system has 14.5 kW PV array in conjunction with battery storage. All other balance of systems; batteries, charge controllers, inverters were housed inside a container that was inaccessible at the time. The system is working without any major incidents or failures.

### **1.2.3 Sarikhet**

#### **Introduction**

Sarikhet Ward no. 2 is located in Raksirang Gaupalika, next to Namtar. Sarikhet Palasi can be reached via two routes. One route lead from Kalikatar-3 and another route is through Beluwa from the East West. Sarikhet Palasi region, is the only off-grid site in the region. The rest of the wards, 1 and 3 which lies in Sarikhet region have grid access from NEA.

There are about 200 households that are traditionally built of mud and wood. The location is quite remote and people live in a traditional way. There are few convenient stores and a ward office. The village is composed of approximately 1000 people. Majority of the population is

of Chepang and Tamang ethnicity. Almost everyone practices farming. The local harvest includes maize, millet, wheat and fruits and vegetables. A typical household consists of a farmland, animal shed and a residence. Households are made from mud, wood and tin.

### **Electrification Status**

There was no grid electricity available around a radius of 1 km from the village. There have been attempts to electrify the region before. A peltric system had been introduced at the region which had completely been shut down after the nearby stream dried up. According to the locals, the stream started to dry up after the earthquake of 2015. The transmission poles of the peltric system was still present throughout the village. The peltric system had malfunctioned earlier and now, it has been completely shut off. Small solar home systems ranging from 20-50W have been implemented by the locals in order to meet the primary lighting needs. There is a strong possibility of NEA integration as well.

### **Economy**

The main source of income for the villagers is agriculture and animal husbandry. Poultry farms are also very popular in the region. The village also includes small convenient stores. Recent water scarcity has highly affected the region. The income of the village has been highly affected by these factors and is quite low at the moment. Majority of the youth have migrated to bigger cities while locals are still practicing the conventional way of living which is quite self-sustaining. The villagers were struggling to pay Rs. 80/month for the peltric system. People are willing to pay but they simply lack the capacity to pay in their current situation.

### **Anchor Load**

There is an NTC telecom tower in the village. It is powered by a 15 KW solar powered system. Currently, all of its demand was met by dedicated solar system Thus, we need to promote various PEU industries to act as anchor to make our micro-grid business model successful.

#### **1.2.4 Silinge**

The village Silinge lies in Kankanda, ward no. 6 of Raksirang rural municipality. Silinge can be reached from Bhandara which is 50 km away from Hetauda along the East-West Highway. The road is not well maintained and consists of unpaved stones, river crossings and slippery soil.

There are around 250 houses in Silinge. The houses are made of mud, clay, tin, and wood. The houses are not

clustered in a specific area but loosely spread within 2 kilometers across the hill. The population of the area is around 1,500 people. Most of the people belong to Tamang and Chepang ethnicity.

### **Electrification Status**

The village already contains a peltric set of 16 kW. The electricity is distributed by 3 phase transmission poles throughout Silinge. The peltric set is community owned and was established 8 years ago but the supply of electricity began just a year ago. People were able to use electricity without any load limit for a monthly price of Rs.100. Most of the people own a television and fans in addition to light bulbs and phone chargers. Some of the households and cafes also own refrigerators. The village also has a mill that was electrified by the peltric system, with a diesel generator as back up. Currently however, the peltric system is not functioning as its piping system was damaged due to the construction of road. The peak load demand is in morning and night time People also use televisions and refrigerators during the daytime. Hence, there is constant demand, with slightly lower demands in the morning and night than the during the day. A few isolated houses contained small solar home systems of 20 watts that is sufficient only for light bulbs and phone chargers.

### **Economy**

The main source of income is agriculture. People grow wheat, maize, millet, and barley. There are about 5-6 shops and small cafes. The willingness to pay is low among the people because of the low cost of electricity provided by the peltric system. The affordability is moderate and most of the people can pay from Rs. 500 to Rs. 1000 per month with ease. The village is near to the highway and so we can see glimpses of modernization. Thus, there is a desire among people to integrate more electrical devices provided they get enough electricity.

### **Anchor Load**

The village contains two telephone towers that are about 2 kilometers apart. One which is owned by NCELL, and the other by SMART CELL. According to the villagers both of these towers are working without any disruptions to service. The towers are solar powered and fully automated. The NCELL tower contains 4.5 kilowatts for the system. The balance of system was housed in an inaccessible container provided by Huawei.

## **2 Selection Matrix**

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The selection matrix is used to score each village and subsequently compare them against each other. Each village is given a score between 1 and 5. One being the worst, and 5 the best for our goals. The village with the highest score theoretically should be considered first. However, a weighted score must be considered. Some criteria are more important than others, and are thus weighted more. This is incorporated to level out the comparison between villages, making it fairer for villages that are better or worse in a particular area. Thus, once weighting is considered, then comparison may take place. The total score, between 0-100, represents how probable a village could support a micro-grid. The weighted score is for the purpose of selecting what village to visit and install first. Once the feasibility and importance of a micro grid solution to a particular village is established, the next stage can commence: sizing the micro-grid.

## 2.1 Criteria

The following criteria are used in the ranking matrix. Each criterion comes under the scope of economics, social and technology. Twenty criteria were deemed necessary to score each village. Most of these criteria have been sourced from previous research from international best practices. While some are unique, such as geographical location due to the rugged terrain that exists around Nepal.

1. **Accessibility:** This criterion ranks the level of difficulty in accessing the village. Ranging from no access, up in increments of vehicle access, to total access. This only takes into consideration the accessibility into the village regardless of geographical location.
2. **Geographical Location:** The geographical location relates to where the village is situated relative to a hill.
3. **Distance from Highway:** The distance from a major highway concerns logistics and accessibility associated with project. The closer they are, the more accessible the village is in terms of time taken from a major country town and directly affects project financials.
4. **Average Monthly Income** This criterion summarizes the economic status of the village. Determining whether they will be able to afford the tariffs, and correspondingly how the tariff structure is modelled.
5. **Past Projects:** Past projects primarily relates to the current electrification of a village. Whether the project was or is still successful in providing the load demand, in addition to what type of system it is
6. **Population:** Simply the number of people present in the village. The more people, the more customers there are. This number will affect the load demand
7. **Households:** The number of households in the village directly affects how many customers the system will have, as well as the load demand profile and tariff structure.
8. **Ability to Pay:** A consumer's ability to pay for the electricity. This will depend on their financial situation. Subsidizing will most likely come into effect since we are dealing with large community bases.
9. **Willingness to Pay:** The willingness of a consumer to pay for the electricity. This will depend on their finances as well as personal opinion on the tariff structure.
10. **Institutions and Businesses:** How many institutes and businesses are in the village. This includes hospitals, pharmacies, kiosks. And restaurants. These will be our second biggest demand.
11. **Energy Resource Assessment:** Primarily, the renewable energy sources most viable in Nepal are Solar followed by Wind.
12. **Infrastructure:** What is in place that will help with the installation of a micro grid. This includes transmission poles, and laid out roads for the poles to follow.
13. **Utility Grid Connection** How soon until the NEA will connect the village to the national grid. One of two outcomes can happen:
14. **Presence Anchor Load:** Whether there is an anchor load present, and if it is currently being supplied with power. Anchor load substantially helps in increasing plant factor.
15. **Anchor Power Requirement:** Anchor Power Requirement determines the fraction of load demand
16. **Distance from Anchor Load** Distance to the anchor can be directly associated with the length of transmission line required. Generally, anchor loads are present further from power houses.
17. **Existing Electricity Status:** What the village currently has for power. If none present, then refer to ability to pay since this will relate to how much the tariff can supply.
18. **Load Profile:** This is the load the village currently has, and whether it is economically viable to invest in supplying them the amount they need, plus some more if demand increases.
19. **Productive End Users:** Whether the village has a productive machinery etc. What the village could gain by the installation of a micro-grid.

**20. Availability of Land for Project Construction:**

Land is needed to run the micro-grid. This criterion outlines whether there is scarcity, land to be sought, or a villager donating their property to run the plant.

**21. Revenue Stream:** This categorizes where the majority of the revenue will come from. It ranges from just community, to include productive end uses and business.

**2.2 Weighting Scheme & Matrix Scoring**

The weighting scheme has been based upon the pedigree of different criterion in determining success of a micro-grid project.

**2.2.1 Weighting Scheme**

**2.2.2 Scoring Schemes based on Criteria**

Different scores were given to different criterion based on the scenario of a particular criteria.

**2.2.3 Benchmarking**

After performing the selection matrix on the four villages, a pass mark was established to determine whether or not a village should be considered for a micro-grid system. It was deemed that a weighted score pass mark of 55% was suitable. A score above 65% was also deemed as ultimately necessary to install. This thus divides the four villages in two. Litche is in the bottom bracket, then Sarikhet in the middle tier, and finally Kalikatar-2 and Silinge at the top.

**Table 2: Weighting Scheme**

Importance Factor		
Criteria	W. Score	Percent
Accessibility	5	100%
Location	3	60%
Distance from Major Highway	3	60%
Ave. income/month	5	100%
Past Projects	2	40%
Population	3	60%
Households	4	80%
ATP	5	100%
WTP	5	100%
Institutes in village	4	80%
Solar Irradiance	4	80%
Infrastructure	3	60%
NEA connection	5	100%
Anchor power status	5	100%
Anchor power requirement	4	80%
DTA	4	80%
Electricity status	5	100%
Load profile (revenue)	4	80%
Productive End Use	5	100%
Availability of Land	3	60%
Revenue Stream	4	80%
<b>TOTAL</b>	<b>85</b>	<b>80.95%</b>

**Table 3: Scoring Scheme**

S.N.	Criteria	Score				
		1 Point	2 Points	3 Points	4 Points	5 Points
1	Accessibility	Inaccessible	Access by walking trail	Access by bike	Access by car	Accessible by all sources
2	Location	High Peak	Along ridge of hill	Mid Hill	Foot Hill	Valley
3	Distance from Major Highway	>50km	<50km	<20km	<10km	<5km
4	Avg. income/month	Low		Moderate		High
5	Similar Projects in the Past	Successful	Working most of time	Working on the threshold	Needs upgradation	No system in place
6	Population	<100	<250	<500	<1000	>1000
7	Households	<25	<50	<250	<500	>500
8	Ability to Pay	Not able		Moderately able		Highly Able
9	Willingness to Pay	Not willing		Moderately able		Highly Willing
10	Institutes in village	<2	<4	<6	<8	>8

11	Solar Irradiance	<3kWh/kWp	<4kWh/kWp	<5kWh/kWp	<5.8kWh/kWp	>5.8kWh/kWp
12	Infrastructure					
13	NEA connection	On-grid	Arriving in <2 years	Arriving in <5 years	Arriving in <10 years	Arriving in >10 years
14	Anchor power status	Already Supplied		Moderate		No Power Supplied
15	Anchor power requirement	<2kW	<5kW	<10kW	<15kW	>15kW
16	DTA	>10km	<10km	<5km	<2.5km	<1km
17	Electricity status	Supplied by NEA	Enough Supplied	Moderately Supplied	Meagerly Supplied	No Supply
18	Load profile (revenue)	Low		Moderate		High
19	Productive End Use	Non-existent	Existing, not in use	Existing, Mechanical	Existing, electric power required	Upgradeable
20	Availability of Land	No Land	Land to be sought	Land Available w/o infrastructure	Land Available with infrastructure	Land donated by village committee
21	Revenue Stream	No Stream	Community	C+PEU	C+PEU+Business	Anchor+C+PEU+B

Table 4: Benchmarking

Criteria	Litche		Kalikatar		Sarikhhet		Silinge	
	Score	W. Score	Score	W. Score	Score	W. Score	Score	W. Score
Accessibility	1	1	4	4	4	4	3	3
Geographical location	1	0.6	5	3	2	1.2	3	1.8
Distance from Highway	3	1.8	3	1.8	4	2.4	3	1.8
Ave. income/month	1	1	3	3	2	2	3	3
Past Projects	5	2	3	1.2	4	1.6	3	1.2
Population	4	2.4	5	3	4	2.4	5	3
Households	3	2.4	4	3.2	3	2.4	3	2.4
ATP	1	1	4	4	2	2	3	3
WTP	4	4	4	4	2	2	2	2
Institutions& Businesses	1	0.8	3	2.4	1	0.8	4	3.2
Solar Irradiance	5	4	4	3.2	5	4	4	3.2
Infrastructure	1	0.6	5	3	4	2.4	5	3
NEA connection	5	5	3	3	3	3	3	3
Anchor connection	1	1	5	5	2	2	2	2
Anchor load	3	2.4	1	0.8	4	3.2	4	3.2
DTA	5	4	1	0.8	5	4	4	3.2
Electricity status	4	4	2	2	4	4	4	4
Load profile (revenue)	3	2.4	2	1.6	2	1.6	4	3.2
PEU	1	1	4	4	2	2	3	3
Land available for powerhouse	2	1.2	2	1.2	2	1.2	2	1.2
Revenue stream	3	2.4	4	3.2	3	2.4	4	3.2
TOTAL	57	45	71	57.4	64	50.6	71	56.6
WEIGHTED TOTAL	54.3%	52.9%	67.6%	67.5%	61.0%	59.5%	67.6%	66.6%

### **3 Conclusion**

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The extension of the grid to electrify the entirety of Nepal is an arduous task. Unfortunately, there are many places that are not feasible economically for grid connection. Hence there is a high necessity to establish micro-grids in remote areas around Nepal. However, it is difficult to identify sites that will be profitable for a private company to invest in. Establishing a micro-grid might seem like a noble and an easy task, but its success depends upon a complex number of factors. Throughout this report, we analyzed the potential for micro-grids in four villages in the Makawanpur District. The data was collected from initial research as well as our field trips to the area. We have incorporated as many factors as possible into our selection criterion, such that we would have an adequate ranking system to identify the best location. Our analysis has led us to conclude that Kalikatar Ward No. 3 is the best location for establishing a pilot solar micro-grid project. Silinge would be the next best candidate. Sarikhet and Litche were lower in the ranking due to their accessibility and economic status. It is recommended to still consider these areas, however in the nature of a business, profit must ensue.

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