Understanding and Contextualizing Micro-Hydro Plant Sustainability in Nepal

Prepared By: Caitlin Bonney, Ian Ferguson, Gigil Ghosh, Gordon Li

Advisor: Dr. Robyn Meeks

Nicholas School of the Environment, Duke University

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Contents

Glossary

ADB/N - Agricultural Development Bank, Nepal

AEPC - Alternative Energy Promotion Center (of Nepal)

ARE – Alliance for Rural Electrification

BBC - British Broadcasting Corporation

BFI - Banking and Financial Institutions

CPA - Comprehensive Peace Agreement

CPN - Communist Party of Nepal

CREF - Central Renewable Energy Fund

DDC - District Development Council

HV – High Voltage

IAD - Institutional Analysis and Development

IDA - International Development Association

I-REC – International Renewable Energy Credit

K – Thousand

kW – Kilowatt

LV – Low Voltage

ME - Ministry of Energy

MHP – Micro-Hydro Plant

MHVE – Micro-hydro Village Electrification

MW – Megawatt

MWh – Megawatt hour

NCP - Nepali Congress Party

NGO – Non-governmental Organization

NPR – Nepalese Rupee

NRREP – National Rural Renewable Energy Programme

NVMHP - Nepal Village Micro Hydro Project

O&M – Operations and Maintenance

PAP - Poverty Alleviation Project

PDDP - Participatory District Development Programme

PM - Prime Minister

PPA – Power Purchase Agreement

PV - Photovoltaic

REC – Renewable Energy Credit

REDP - Rural Energy Development Programme

RERL - Renewable Energy for Rural Livelihoods

RVWRMP - Rural Village Water Resources Management Project

SDG – Sustainable Development Goals

T&D – Transmission and Distribution

UNDP - United Nations Development Program

VDC - Village Development Committee

VDF – Village Development Fund

1.0 Executive Summary

The goal of this report is two-fold. We hope to both understand why run-of-the-river micro-hydro plants in rural Nepal are failing prematurely and to propose recommendations for future operational success of existing and future micro-hydro plants. This project was completed by Master of Environmental Management students at Duke University's Nicholas School of the Environment. The report is prepared for the Alternative Energy Promotion Center (AEPC), which is part of the Government of Nepal.

Since 1996, the Government of Nepal has installed over 1,000 micro-hydro plants, ranging from 10 to 100 kW, to support off-grid electrification of rural Nepal. As of 2019, one-third of Nepal's existing micro-hydro plant infrastructure is untenable, with an additional third at risk of faltering in the coming years. The problem was analyzed from technical, cultural, and economic viewpoints.

In May of 2018 the research team traveled to six sites in the in the Achham District of Nepal. These sites were chosen because they are representative of both successful and faltering sites and are in a territory that has not been researched recently. Formal data were collected through in-person surveys, with additional insights gleaned through on-site observation and anecdotes.

The project team conducted in-country data collection, site visits, literature reviews, and technical analysis to understand the current situation and propose recommendations to AEPC for future operational success of the existing and new micro-hydro plants.

The bulk of the report is comprised of four separate sections, each of which addresses an important aspect of the micro-hydro plant ecosystem in Nepal. The Glossary, Executive Summary, Recommendations, and Works Cited can also be found within the report, as per the Table of Contents above. The primary four sections, and brief descriptions of their contents, are as follows:

1. Institutional Analysis Report - This analysis focuses on the interplay between governance at both local and federal levels and the production of micro-hydro power in the country. It builds understanding of the environment in which the plants operate, providing a critical lens for further analysis.
2. Case Studies - Case studies included from target sites in the Achham District of Nepal highlight some of the more prevalent concerns and potential solutions for future planners dealing with Nepalese micro-hydro power.

3. Technical Analysis Report - In this report, readers encounter a comprehensive breakdown of the operations and maintenance of sites in the Achham District. Analysis was conducted on every stage of plant operation, painting a holistic picture of strengths and concerns in the technical sphere.
4. Micro-Hydro as an Enterprise Asset - The final major report in this compilation deals with potential strategies to promote financial independence for micro-hydro plants, especially in rural regions where more traditional government subsidization is difficult.

Generally, the project team identified three overarching problems with micro-hydro plants in Nepal that are cause for failure. Those are:

1. Lack of Revenue
2. Inconsistent Electricity Production
3. Poor Communication

Six solutions were identified that can address at least one of those causes for failure, if not more. Those six solutions are:

1. Adoption of a Standardized Tariff Structures
2. Consistent Bookkeeping
3. Improved Operator Training
4. Increased Role of Community Enablers
5. Implementation of Anchor Customers
6. More Effective Financing Methods

Each site is unique, and the situation is complex, but some combination of these solutions can provide help in ensuring that rural communities of Nepal have access to reliable electricity and the many benefits that it provides.

2.0 Data Collection Methodology

In May 2018, two of the team members, Ian Ferguson and Gigil Ghosh, traveled with a community mobilizer and translator. Data were collected through in-person, face-to-face surveys at six micro-hydro plant sites in the Kailash Khola Valley in the Achham District of Nepal. The respondents were not randomly selected, but rather the community enabler arranged the interviewees. There were three total surveys -- one for community leaders, one for community members, and one for micro-hydro plant operators. In total 19 community leaders, 44 community members, and 11 micro-hydro plant operators were surveyed. In this report, the site names are referred to as generic names (eg Site 1) rather than the Village name in order to preserve anonymity.

It is important to note that in the below representation of data, operators interviewed are listed arbitrarily - there is no underlying status associated with titles such as "Operator 1," "Operator 2," or "Operator 3". The same is true for site name.

Due to the relatively small sample size, the responses should not be taken as indicative of all micro-hydro plant projects. Rather, the data should be taken as a sample representing relative wellness of the larger micro-hydro project. Additionally, substantive value was gained through on-site observation and anecdotes that were not recorded in the surveys. These insights are reflected in the analysis, recommendations, and case studies.

3.0 Institutional Analysis Report

3.1 Introduction

This report is meant to offer background information surrounding Nepal's institutional landscape, particularly in reference to relevant institutions for micro-hydro plant development and management. It is by no means comprehensive in comparison to the country's vast history, but it offers necessary background to engage in a discussion surrounding the intricacies of the micro-hydro plants and institutions that affect them in 2019 and the years prior.

3.2 Governance

3.2.1 Historical Government Structure

Many of the important instances of institutional development in Nepal discussed in this report coincide with historical events in the country's recent history. Table 1 below provides an outline of important political events paralleled with actions by AEPC. Since its first election in 1959, the political history of Nepal has been fraught with power struggles between the Monarchy, the Government, and the Maoist Party. There has been a repeated history of multi-party politics contending for influence, only to be suppressed by the might of the monarchy (Nepal Profile - Timeline, 2018). This trend was shattered in 1996, which was coincidently the same year that the AEPC and the Rural Energy Development Programme (REDP) began working together.

Year	Political Situation	Action by REDP/AEPC
1996	The Communist party of Nepal(Maoist) started violent insurgency in more than 50 of the 75 districts of Nepal	REDP initiative with United Nations begins.
1997	Revolution Continues, furthering political instability	MHP at Site 3 starts Construction
1998	Revolution Continues along political instability	Site 3 Chairman is Abducted, stopping construction
2000	9th government to control the country since 1991 elected. Over 13000 people have died conflict	Site 3 construction completes after Chairman returns
2001	Royal family is murdered, triggering a national emergency	
2006	Return of despotic Monarchy	Site 2 and Site 5 Start Construction
2007	End of Monarchy, Maoist government is Established	REDP Program Ends, AEPC takes over. Site 1 starts Construction.
2009	Maoist Prime Minister leaves position, leaving a vacuum	Site 4 starts construction
2010		Site 5 Construction is completed
2013	Impasse in government over constitution	Site 6 starts and Site 4 ends construction
2015	Repeated changes in PM. Devastating 7.8 magnitude earthquake occurs	Sites 1,2 and 6 and start production
2018	K.P Oli Elected as PM for the second time	

Table 1: Timeline showing major political events and milestones for AEPC projects.

There are two distinct phases in the development of the MHP sites in the Achham District that have significant parallels with the political climate of the country.

As per a discussion with its chairperson, the construction of the pilot site, Site 3, started the same time as the insurgency. As the Maoists held sway in Achham district, the construction was halted for a year.

It was, however, completed in 2000 thanks to a determined effort from the chairperson and community members. The murder of the Royal Family induced a significant change in political atmosphere, exacerbating political tensions (Nepal Profile - Timeline, 2018). Even in that tumultuous environment, REDP was successful in starting construction of Site 5 within a year of the incident.

In 2007, AEPC began construction of their solo pilot site, Site 1. In the same year, a Maoist government was elected freely, and the Monarchy was abolished for good. This constitutes the second phase in the country's political history, as well as in the construction of MHPs. From 2007 until 2015, AEPC oversaw the construction of four more of our subject sites, among many others throughout the country. The newfangled government, on the other hand, saw changes in power every year due in the main to 'no confidence' votes.

3.2.2 Current Government Structure

Based on the new Constitution of Nepal in 2015, all previous municipal structures were abolished to form seven Provinces, consisting of 77 districts (Nepal Government, 2018). The structure is illustrated in the following diagram:

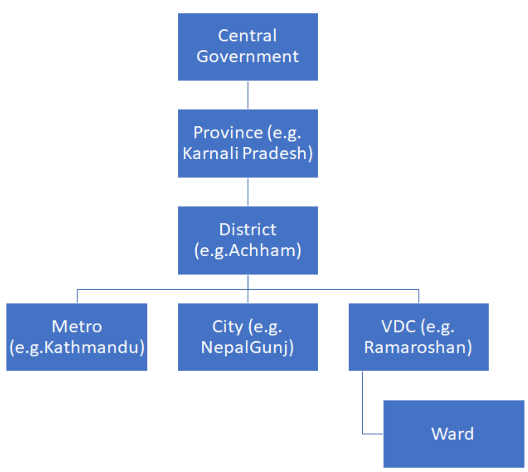


Figure 1: Current Administrative Divisions in Nepal.

The seven provinces of Nepal are simply named "Province No." followed by "1-7". Province No. 4 is also known as Gandaki Pradesh, Province No. 6 is known as Karnali Pradesh, and Province No. 7 is known as

Karnali Pradesh (Nepal Government, 2018). These provinces were formed by grouping together already-existing districts.

A village development committee (VDC) in Nepal is the lower administrative part of its Ministry of Federal Affairs and Local Development. Each district has several VDCs, which are similar to municipalities but with greater public-government interaction and administration. There are currently 3,157 village development committees in Nepal. Each VDC is further divided into several wards, depending on the population of the district. The average number of wards in a VDC is nine. Achham district, the region of study for this project, consists of 77 VDCs (Nepal Government, 2018).

3.2.3 Local Governance

The Alternative Energy Promotion Center made a conscious effort to "adopt community mobilization as an essential vehicle for self-governance to ensure active participation of local people to manage and operate rural energy system, primarily micro-hydro, and other community development initiatives in sustainable manner" (Rural Energy Development Programme, 1997). Unfortunately, in certain regions, local governance can be quite informal, especially in comparison to the more stringent regulatory structures in the capital city Kathmandu.

While the state government plays a substantial role in rural operations, the day-to-day governance in those areas more closely mirrors the traditional feudal structure of the past. Traditionally, feudal landlords held major sway in Himalayan villages. As often occurs in unchecked power structures, though, abuses were rampant. A confluence of events, including latent support by the central government of abusive feudal landlords, inspired the start of ten years of armed conflict in 1996. During this tumultuous period, the Communist Party of Nepal (CPN) led a bloody revolution against the standing power structures in the country (Upreti, Sharma, Pyakuryal, & Ghimire, 2010). The epicenter of the revolution was the Achham District – the capital of Mangalsen was the site of the most violent coup in the entire conflict, where 129 targeted policemen, soldiers, and civilians were killed by Maoist rebels (McCarthy, 2002). The Achham District represented something of a perfect storm for rebels, embodying the aspects that inspired the violent revolution: a strict caste system, scarce institutional support, and a dearth of viable options for livelihood.

Interestingly, in our research we saw echoes of the Maoist revolution throughout the river valley. By the time we arrived in Nepal, governance had seemed to revert to a feudal structure in lieu of consistent interaction with the government in Kathmandu. Although anecdotally national governing structures have been present to a greater degree than they were prior to the revolution, rural villages appeared to find it more effective to adopt traditional feudal structures than to rely solely on institutional support from the capital. That said, the feudalism present today is more muted, adopting tenets of Maoist thought rather than the strictly defined hierarchical power structure of the past. Through our interviews we found anecdotal evidence that although there is in the main an uneasy agreement to work together, both sides of the revolution still harbor strong feeling about their respective roles in the conflict. The river valley region is still healing. Without careful acknowledgement of the past, the grievances that led to the first revolution could again come to light, albeit in a likely less-drastic way – an incidence that even then would benefit nobody, and one about which we hope AEPC stays actively aware as they work to improve community relations and governance structures.

3.3.0 Alternative Energy Promotion Center

3.3.1 History of AEPC

In 1996, the Alternative Energy Promotion Centre was created to develop renewable sources of energy in Nepal in order to improve standards of living in off-grid communities (Alternative Energy Promotion Centre, n.d.). The United Nations Development Programme (UNDP) has worked with the government of Nepal through AEPC since 1996, beginning with an initiative called the Rural Energy Development Programme. This partnership between AEPC, REDP and the World Bank ran until 2007. During that time, the program set up systems in 300 remote villages, including 185 micro hydro plants with 2.47 total megawatts (MW) of capacity (Dutta, Singh, & Thakali, 2007).

The REDP was built around the idea of decentralized governance (Dutta, Singh, & Thakali, 2007). The 2007 Terminal Review Report conducted by the UNDP states that the "micro-hydro schemes set up in villages rank high on sustainability," but our recent research indicates that in reality this is not the case in every village. The micro-hydro plants (MHPs) were set up so that the District Development Council (DDC) and local communities would be responsible for owning and running the plant. This is an example of community ownership, an effective tenet in efforts meant to be sustainable long after the original benefactor leaves a given location. Unfortunately, because local ownership was not inspired well in every village, the hands-off approach of the central government is one of the main reasons that the REDP has not seen continued success. The community enabler, a government-supported role, is meant to initiate the program and help the community for the first two years of its development. The UNDP report finds that the community programs significantly decline once the community enabler leaves (Dutta, Singh, & Thakali, 2007).

In 2003, the micro-hydro Village Electrification (MHVE) program was started through the REDP with support from the International Development Association (IDA) as part of the national Power Development Project (Microhydro Village Electrification in Nepal, n.d.). Its goal was to increase financing and provide electricity to rural citizens that were unlikely to obtain national electrical grid access in the foreseeable future. This both supported earlier REDP work and led to the construction of new MHP systems. The average system size for these projects were 25kW to 30kW (Microhydro Village Electrification in Nepal, n.d.). The MHVE required local communities to donate land and labor to the projects in their village. The local Microhydro Functional Group set and collected tariffs. However, this system has proved to be unsuccessful and potentially to the demise of the sustainability of the MHPs. Due to the low levels of electricity consumption, the tariff system was ineffective. Revenue generated was not enough to cover the operational costs associated with metering and collection (Sovacool, Bambawale, Gippner, & Dhakal, 2011).

Another commonly cited problem is a lack of skilled technicians to operate and repair the systems (Sovacool, Bambawale, Gippner, & Dhakal, 2011). It is important to note that a key success of the REDP was the creation of the Rural Energy Policy in 2006. The formal goal of this policy is "to contribute to rural poverty reduction and environmental conservation by ensuring access to clean, reliable and appropriate energy in the rural areas" through small-scale systems (Rural Energy Policy, 2006). AEPC sets up MHPs in areas that are hilly and remote, and therefore unlikely to have grid access. Fortunately, the chosen areas do have the water resources to generate their own electricity, predominantly by means of run-of-the-river turbines. AEPC understands the benefits of clean electricity access, and targets districts that rank low on the Human Development Index (Dutta, Singh, & Thakali, 2007).

The successor to REDP, UNDP's Rural Energy for Rural Livelihood, has worked with AEPC since 2014. It is part of the National Rural Renewable Energy Programme (NRREP). The program, known as the Renewable Energy for Rural Livelihoods (RERL), has a goal to "to remove barriers for scaling up of interventions which promote less-disseminated larger renewable energy systems such as mini hydro, large micro hydro and.... attainment of financial sustainability through promotion of productive energy uses" (Renewable Energy for Rural Livelihood, n.d.). RERL is working with AEPC to use the MHPs for commercial operation. This is seen as a solution to some of the shortcomings of the initial implementation of MHPs. The thinking is that if the MHPs are used to start businesses that will be able to increase revenue, allowing communities to pay for and maintain their systems (UNDP, 2017). Productive energy usage is the key to building and maintaining sustainable MHPs. The RERL program is planned to go until 2019 and install 10 MW of small scale hydro plants (Renewable Energy for Rural Livelihood, n.d.).

The Central Renewable Energy Fund (CREF) and RERL are working to inspire private investment in rural projects by reducing risk and increasing returns for Banking and Financial Institutions (BFIs). By supporting projects that will create productive uses of energy, more revenue will be generated and risk associated with returns will be lower (UNDP, 2017). RERL has been helping construct demonstration projects, including the 83 kW Site 1 in Achham District (UNDP, 2017). MHP as an enterprise is seen as one of RERL's keys to success, but there is still a lot of work to be done to get the communities and systems to a place where this can be achieved.

Another key reason the first iteration of MHP projects have not seen continued success correlates directly to the dilemma of common property, otherwise known as the tragedy of the commons. This has led to AEPC's focus on the Institutional Analysis and Development (IAD) framework in the second iteration of their MHP projects.

3.3.2 AEPC Ideology – Institutional Analysis and Development

In their current work, AEPC focuses intently on the Institutional Analysis and Development framework, an approach to institution building conceived in the 1980's by Nobel Prize winner Elinor Ostrom. Ostrom challenged what were (and often still are) commonly held beliefs regarding the necessity of high-level government regulation for development of successful local institutions.

While certainly not perfect, the IAD Framework allows researchers to look "at the motivation of participation or non-participation in open initiatives, and how openness itself should be seen as a dynamic or situational phenomenon" (The IAD Framework, n.d.). This is especially important for AEPC given the mixed results they saw in their primary initiative to inspire electrification in rural areas of the country. Approaching the problem with a holistic and inclusive mindset has allowed them to more appropriately identify how to initiate community-focused endeavors surrounding the microgrid. In our personal research, Site 1 was the token community for a successful rollout and maintenance plan for micro-hydro power in the Achham District.

Interestingly, although it is referenced no less than three different times as an overarching concept, the IAD ideology is never explicitly defined in the 2017 inception report circulated by AEPC regarding the electrification of rural Nepal (Universal Consultancy Services Pvt. Ltd, 2017). We saw this as indication that although the IAD Framework was clearly considered in the planning stage, there may be some discontinuity among AEPC workers regarding its actual application. Given this observation, we recommend that workers in both Kathmandu and the field become more intimately familiar with Ostrom's framework, with special consideration as to how it might be applied in reference to Nepal's MHPs.

A starting point for this education could be a breakdown of points detailing the robustness of the intended systems in the Himalayas. For example, the emphases on congruence, collective choice, defined system boundaries, and autonomy acted as effective baselines from which we began to understand how the IAD Framework might have influenced longstanding decisions (Nepal Government, 2018). Further, theoretical conflict resolution mechanisms regarding water use are helpful tools, if perhaps tools that appeared to be only obliquely applied during our time in the Khailash Khola River Valley due to minimal internal conflict surrounding water resources. Finally, the focus on nested enterprise is critical. In order to understand microgrids as microfinance institutions, the most likely road to MHP sustainability, an understanding of functional groups and the roles of differing community organization is incredibly helpful (Singh & Chaulagain, 2009). These roles are explored in more detail in the MHP as An Enterprise Asset Report below.

3.4.0 Land Rights and Resource Management

Nested in the shadows of the highest mountain range in the world, precipitous terrain dominates the Nepalese countryside. The country is oblong, spanning lengthwise from east to west, with the Himalayas acting as a natural border to its neighbor China in the north. Generally, the landscape becomes adopts a more gradual slope as it descends southward. The mountain range forces air to rise and eventually precipitate, offloading most of its moisture content into the slopes of the Himalayas. There, snow and ice collect into vast reservoirs. Meltwater draining down from the mountains supply the country with abundant water year-round. Unlike many Asian countries in monsoon areas, Nepal is blessed with a perpetual source of water that mitigates the effects of its intermittent dry seasons.

It is estimated that Nepal has the potential capacity of 83,000 MW through hydropower, with 42,000 MW deemed economically viable (Devkota, 2014). However, hydropower only accounts for 1% of total energy consumption. Currently, only 5% of the rural population are connected to the national grid; it could take many years for before the rest of the country gains access (Singh, 2009). Hydropower proves to be a solution to provide first-tier energy access to the dispersed communities scattered throughout the countryside that rely primarily on biomass for lighting and cooking. With access to an intricate network of rivers and streams, these communities are naturally located within comparable distance to water sources primed for hydropower development (Legros, Rijal, & Seyedi, 2011). With an increasing number of micro-hydro power projects in development, plans to form microgrids by synchronizing locally between integrated energy and irrigation applications are within reach (Devkota, 2014). This perspective of multipurpose use of water resources could offset financial constraints that would otherwise make a given plant uneconomical.

In rural regions, communities are primarily involved in agriculture, an industry that is water intensive and constrains most settlements to a short distance from a steady water source that can be diverted for crop irrigation. It is micro-hydro systems' ability to leverage this existing geographical and infrastructural attribute that gives it a competitive edge over other renewable energy generation sources. Water catchment systems, which are needed for hydropower electricity generating systems, can also be used to manage water for drinking, irrigation, and other applications (Legros, Rijal, & Seyedi, 2011). Additionally, water from the power canal that feeds and turns the generator can be further diverted and made available for irrigation (Legros, Rijal, & Seyedi, 2011). The shared usage of infrastructure lowers the chance of pushback for existing and new projects as people in these communities often view the development of micro-hydro plants as beneficial in one or many aspects of their livelihood.

Unlike most parts of the world where the water supply fluctuates between dry and wet seasons, much of Nepal is privileged to experience a constant supply of water that feeds into its streams and rivers from the Himalayas. The mountainous terrain becomes an asset, as water canals that feed into generators require sufficient height for the diverted water to gain enough momentum and pressure to spin its turbines. Actual siting of micro-hydro plant location is mainly a function of physical attributes such as ground/soil integrity on which the actual plant and water canal will be built. The Maha Khola Plant (another micro-hydro plant in the country) was shut down because of a landslide the occurred near the canal (Sustainable Energy and Technology Management, 2014). In late of that disaster, ground stability under and adjacent the main and ancillary structures must be carefully inspected before construction. However, geographical attributes should also be considered as problems arise when these factors are overlooked. Although most of Nepal has no shortage of water, there are drier regions in some parts of the country that are more favorable for other renewable energy resources such as solar photovoltaic (PV) panels.

Land ownership varies from village to village and case by case. However, the MHP Committee must retain the legal ownership of the land for the required infrastructure to qualify for assistance from the Government of Nepal. Our field visits suggest that the communities are generally open to development on private lands. For example, at Site 1 the MHP expansion canal passes through private land. That said, a more common practice is that the MHP Committee takes ownership of the once private land, either in form of payment, tariff reduction, or compensation through various means (including guaranteed work positions in the plant itself). Some land parcels are easier to transfer than others. In Kailash Khola, the land where the plant was built was public property before it was claimed by the MHP Committee. In a single village, land for the project could originate from multiple parties. For example, at Site 5, the operator that owned the land on which the plant was built was offered work in exchange for a permanent position. The committee leader previously owned the land where the diversion water canal now resides.

Bank loans from the Agricultural Development Bank (ADB/N) are subjected to further qualifying factors such as a legally-signed land transfer agreement from the previous land owner to the MHP Committee. These documents include land tax clearance papers and land transfers (Singh, 2009). The land requirement for micro-hydro plant projects extend well beyond the canal and the housing for the generator and must encapsulate the planning of other civil structures and transmission lines. Although not always a required factor, it is highly recommended that the MHP Committee have full rights of the land. Given the extent and economic cost of these projects, multi-party collaboration is essential to gain access to the widest array of funds available.

3.5.0 Funding

3.5.1 Previous Funding for MHPs

The Micro Hydro Village Electrification program received a US$19.36 million IDA Grant. The Nepal Village Micro Hydro Project (NVMHP) received US$1.96 million (funded by a Trust Fund) between 2007 and 2015 (Nepal - Village Micro Hydro, 2018). The World Bank provides the funding amounts from many sources for AEPC micro-hydro projects. The total between 2007 and 2018 was US$59.1 Million (Nepal - Village Micro Hydro, 2018). The funding details are as follows:

Financier	Amount (US$ Million)
Denmark: Danish Intl. Dev. Assistance (Danida)	14,300,000
International Development Association (Ida)	9,400,000
Un Development Programme	3,600,000
Local Communities	26,900,000
Local Sources Of Borrowing Country	700,000
Borrower	2,300,000
Prototype Carbon Fund	1,900,000

Table 2: Funding sources for AEPC projects between 2007 and 2018.

3.5.2 Current Funding for MHPs

As per the 2017 RERL annual report, the projects have received support from the following sources as of 2017 (all amounts in USD): (UNDP, 2017)

- UNDP: 2,000,000
- Nepal government: 30,312,500
- Other aggregated sources: 24,249,600
- Global Environment Facility 3,000,000
- Norwegian: 378,000
- Korean: 99,269

The project has a total budget of US$35,312,500, of which, US$244,930 remains unfunded (UNDP, 2017).

3.6.0 Current Energy Situation

Since its formation in 1996, the Rural Energy Development Programme has been operating to "realize the goal of alleviating poverty in rural areas and reduce dependency on fossil fuels" (Singh, 2009). As of 2001, REDP had successfully commissioned 76 micro hydro schemes connecting 60,000 people across 15 districts: Baitadi, Dadeldhura, Achham, Bajura, Dailekh, Pyuthan, Baglung, Parbat, Myagdi, Tanahun, Kavrepalanchok, Sindhualchowk, Dolkha, Okhaldhunga, and Tehrathum (Singh). By 2009, REDP had installed a total of 267 micro-hydro plants, totaling 44.53 MW, in addition to 5,440 toilet-attached biogas plants, 2,410 solar PV home systems, and 11,757 improved cooking stoves. At the same time, programs executed by the Alternative Energy Promotion Center installed biogas plants (214,000), micro-hydro power (13.5 MW), improved cooking stoves (300,000), solar PV home systems (18,000), solar tuki sets (59,120), and improved water mills (5,500) (Legros, Rijal, & Seyedi, 2011).

The primary source of energy in the country comes from biomass, which accounts for 86% of total consumption (Legros, Rijal, & Seyedi, 2011). Consuming biomass, mainly for cooking and heating, takes an enormous toll on the environment and an overdependence on firewood collection adversely affects the surrounding ecosystem. Still, only 15% of the population, mostly those residing in urban centers, have access to electricity (World Bank Group, 2015). Coupled with the fact that the population of Nepal remains one of the poorest and most isolated in the world, programs like REDP can catalyze enormous impacts on the livelihood of the people it affects.

Although REDP states that it does not believe that energy is a basic need, it does consider access to electricity an important precondition for development (Singh, 2009). REDP believes that it is an essential ingredient for socio-economic development and therefore the objective of rural energy systems should be to provide energy to reduce drudgery, conserve and efficiently utilize resources, generate employment, and increase income (World Bank Group, 2015). In 2012, AEPC activated the National Rural and Renewable Energy Programme. The goal of improving the livelihood of these rural communities through clean energy generation has attracted the attention and funding of world humanitarian organizations, including the United Nations Development Programme, United Nations Capital Development Fund, and the World Bank. It has also attracted financial support from national governments and other relevant organizations including the Government of Denmark, Norway, Germany, and the UK. Additionally, 80 private companies are working in the micro-hydro power development sector in Nepal by July 2014.

3.7.0 Institutional Analysis Report Conclusion

Much like comparable situations in other developing countries, Nepal's institutional structures have been shaped by the complicated interplay between local customs and external influences. At a broad scale, ideas from India and China have influenced the national and local governance of the country, though it would be remiss to say that Western powers in Europe and the Americas have not played a role as well. Even further, local ideals and traditions are substantive in the formation of the geopolitical environment in which energy access work must thrive. In order to properly address the challenges of micro-hydro development and management, it is critical to understand the complicated interplay between the institutions and acknowledge the needs of the local people in spite of (and often because of) the difficulties they face.

4.0 Site Case Studies

4.1.0 Introduction

In order to attain a thorough understanding of the sites analyzed in the future sections of this report, case studies will allow the socio-economic dynamics of the individual sites to become more clear. The following segment contains case studies for Site 1 and Site 3 due to their unique characteristics.

4.1.1 Case Study – Site 3

Of all the sites surveyed, Site 3 was particularly noteworthy, mainly because of the observed apathy of community members towards the MHP. As the prototype project by REDP that began construction as early as 1997, this site saw some major advantages in relation to later products. First, the NPR 1 Million in debt was paid off by AEPC. Second, the MHP was given spare equipment parts by Nepal Machine and Steel Structure Private Limited to reduce future maintenance costs. Third, further aid of NPR 700 Thousand (K) was given by parliament members in 2016 to cover Operations and Maintenance (O&M) expenses.

Operation of the site is dictated by the MHP chairperson (akin to the village patriarch) as well as the only person to hold the post of chairperson since the inception of the MHP. It is unclear what prompted his initial election, but he survived a Maoist abduction during the revolutionary period that raised his overall social standing immensely. Presently, the survey respondents reported that while they do disagree with him on how the MHP should be run, nobody wants to be the person that has to contradict him. From the conversations with him and other community members, it could be assumed that the chairperson is fairly confident in his beliefs, and at times acts according to them rather than consulting the MHP committee or community members.

For example, he does not allow the plant to operate more than seven hours a day because he believes electricity is a luxury and is only needed in the evenings when the children study and the women do chores. The government no longer provides the funds necessary to run the plant, and the chairperson feels that it is not the community's responsibility to foot the bill for a plant that REDP installed. The chairperson reported petitioning for funds to AEPC, though to no avail. He also insisted that there is no demand for electricity and there is no foreseeable need for electricity for businesses in the future. These claims, however, are contrary to the findings stated in this report indicating that there is sufficient demand. Further, the chairman claims that the average community member is too poor to pay any more than NPR 45 every three months. This is also contradictory to the findings discussed later in this document.

The information provided by the chairperson and the operators illustrates a large difference in approximated annual O&M costs. While the chairperson approximated annual repair costs to be NPR 50K per year, operators reported it to be NPR 200K per year. Due to the lack of revenue and high O&M costs, some of the operators stated they use their salaries to pay for maintenance and repairs.

Beyond anecdotal information from surveys, analysis of quantitative data shows some very interesting facts that directly contradict the chairperson's assertions. The survey of this site encountered the second largest number of entrepreneurs among all sites. As these are mostly hotels and grocery stores, they would definitely benefit from being able to refrigerate their goods. This, added with the dissenting opinions reported previously, indicates that the chairperson's assertions regarding no demand or necessity for electricity in business are suspect. It was also found that the percentage of businesses that reported using electricity to aid their business was the second largest among all surveyed sites. This site also displayed a healthy electricity consumption profile, indicative of the ability to pay more reasonable rates than those they are currently charged. In short, the community has entrepreneurs eager to make use of electricity for their business and take on the role of anchor customers.

It is AEPC policy to try to allow the communities to be independent. But in this case, the leadership has closed itself off to AEPC. The chairperson himself reported no communication with AEPC in the last six years, after his request for further funding supposedly fell on deaf ears. Unfortunately, it is our belief that direct advice or mandate might be considered meddling. Bridging the gap in communication by employing more community enablers would allow AEPC to convey best practice ideas to the communities will be better accepted than a strict command. It is worth mentioning too that such enablers have a better grasp of best practices than operators therefore making use of their experience to frame policy is advisable.

4.1.2 Case Study – Site 1

In many respects, Site 1 was the most successful site visited in Achham district by the project team. Initially, the community elected a committee that reportedly mishandled MHP finances and operations. According to the current community leader, his predecessors had no management accountability and kept no financial documentation of MHP operation. Further, their handling of funds was suspect. Frustrated, villagers from 9 wards unanimously decided to reform the committee and switch to the cooperative system employed in the present day. The cooperative was established with a goal of attributing the ownership and operation of the micro-hydro plant to the entire community and allowing its members to share the profits or benefits. Beyond that, the cooperative was to have a stable revenue stream, a fund that could be diverted to the needs of the community or plant on a needs basis, and would have the capacity to give out loans until the returns from the three strategies paid for the entire system. This venture has seen remarkable success so far, paying off 2.3 Million NPR of their initial 5.5 Million debt so far.

Switching to the cooperative model earned enough revenue for the micro-hydro plant to allow expanding distribution to the adjacent Kalagaon Village, opening up an additional revenue stream.

A defining characteristic of this site is the micro-financing aspect of the co-operative, which is run solely by women. Micro-financing allows for small short-term loans to be offered to community members at a low interest. Women are capable of saving anywhere between 100 to 500 NPR per month, allowing for a substantial O&M contingency fund. Beyond that, the fund is used to disburse zero interest funds for the community members in case of emergencies such as death or injury.

Based on the people interviewed across all sites, Site 1 has the largest number of entrepreneurs among those individuals interviewed across all sites. A total of 7 respondents reported 10 businesses amongst them, with three reporting ownership of multiple businesses. This was credited directly to the improvement of the entire community's financial state.

Similarly, Site 1 took the lead in the number of entrepreneurs that made use of the MHP to bolster their business. This is further described in the 'In-Community Anchor' Section of the *MHP as an Enterprise Asset* report.

Site 1 also had the healthiest electricity profile of all the sites, reporting an average of 3.8 appliances per household, well above the average of 2.5, a comparison shown in Table 3.

Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 1
Average number of appliance per household	**3.9**	1.8	2.1	2.5	2.5	2	2.5

Table 3: Average number of appliances per household. Data is a direct average of reported appliance ownership. Note: Mills were not included as household appliances.

Site one's success can be attributed to the fact that it has high electricity consumption, the tariff rates are reasonable, and bill collection is centralized and computerized. The tariff rate, despite being high, was proportionate to the site's consumption and did not overcharge the consumers. It is of significance that people of this community put greater faith in digitized legers as compared to physical legers, reducing operator labor in bill collection significantly.

The success of Site 1 was inspired by visiting a similarly successful MHP at Surkhet, in the Karnali district of Nepal. In addition to AEPC directly suggesting changes at other sites, it might be worthwhile to organize visits from community leaders of faltering MHP sites to exemplary sites like Site 1 or Surkhet.

During their stay in Achham district, the project team noted that community enablers (liaisons between the AEPC and the communities) like Mr. Laxmi hold intimate knowledge of each site and that members of the communities regard them with respect, heeding their advice on policy decision. It was Mr.

Laxmi's advice that the Site 1 community leaders took when switching to co-operative mode, which has proven to be a major reason for success.

Of all the sites, Site 1 seems to have the best-kept financial records, as they had learned from the mistakes of their previous committee. Details of financial success were not just well-kept, but well-advertised. This bolstered the community members' confidence when investing in the microfinance scheme. Sites like Site 2, on the other hand, struggled to find detailed documentation when asked. It is important to realize just how much this sense of community pride helped foster the sense of community ownership of the MHP; an integral piece of AEPC's model.

As a result of having a reliable electricity source and the cooperative financial infrastructure, Site 1 has cultivated entrepreneurs who make regular use of electricity in their businesses. This leads to a stabilized cash flow, routine maintenance and system expansion, and the attraction of more electricity consumers, which in turn leads to more revenue. The section titled 'In-Community Anchors,' within the *Micro-Hydro as an Enterprise Asset Report*, will further emphasize the importance of utilizing such entrepreneurs.

5.0 Technical Analysis Report

5.1.0 Introduction

5.1.1 Background

Over the last two decades, the Government of Nepal installed micro-hydro plants throughout the mountainous nation, but due to the challenging terrain and rurality of the sites, limited data and general information as to how the equipment is operating are available. As such, this report aims to provide insight into the current operational status of the generating equipment, in addition to details about the people who operate the plants. The objective of this report is to equip decision-makers with data and insights on the status of equipment and electrical output at a sampling of the sites.

The goal of the surveys and resulting analysis is to understand the current technical status of the micro-hydro plants and understand that said status differs from initial expectations. With that difference identified, the hope is that Nepalese officials will be able to initiate plans to improve the operation of sites lagging behind their expected functionality.

5.2.0 Micro-Hydro Plant Design

5.2.1 Micro-Hydro Plant Analysis - Specifications vs. Reported Attributes

This section summarizes the six sites studied. It provides an overview of each site's generation capacity, reporting the technical specifications of the plants, the status of the plants during this team's fieldwork in May 2018, and ,where possible, the differences between these two.[1] Specific micro-hydro plant attributes are explored in greater depth later in the document. Data for the following six tables is summarized from equipment specifications and technical interviews conducted.

	Site 1		
	Specifications	*Reported (Average of MHP Operators Responses)*	*Delta (Specifications - Reported)*
Generation Capacity(kW)	128	83	45
Capacity factor	88%	47%	41%
Head height(ft)	Unknown	164	Unknown
Flow rate(gal/min)	Unknown	7,069	Unknown
Efficiency	100%	91%	9%
Load (kW)	76	69	7
HV Length(km)	Unknown	4	Unknown

[1] The difference between the specifications and actual responses is calculated where such calculation is possible, but that was not always the case. Further, in the chart, the term "Unknown" indicates when the interviewed plant operators could not provide such information rather than a lack of data collection on the part of the project team.

LV Length(km)	Unknown	4	Unknown
Max Maintenance Cost (NPR)	67,500	35,000	32,500
Wooden Pole Count	Unknown	Unknown	Unknown
Annual O&M Cost (NPR)	35,000	30,000	5,000
Contingency Fund (NPR)	220,000	280,000	-60,000

Table 4: Site 1 MHP Technical Specifications versus Reported Attributes.

	Site 2		
	Specifications	*Reported (Average of MHP Operators Responses)*	Delta (Specifications - Reported)
Generation Capacity(kW)	100	60	40
Capacity factor	88%	23%	65%
Head height(ft)	Unknown	Unknown	Unknown
Flow rate(gal/min)	Unknown	Unknown	Unknown
Efficiency	100%	58%	42%
Load (kW)	60	35	25
HV Length(km)	Unknown	6	Unknown
LV Length(km)	Unknown	5	Unknown
Max Maintenance Cost (NPR)	12,000	406,000	-394,000
Wooden Pole Count	Unknown	Unknown	Unknown
Annual O&M Cost (NPR)	Unknown	Unknown	Unknown
Contingency Fund (NPR)	Unknown	60,000	Unknown

Table 5: Site 2 MHP Technical Specifications versus Reported Attributes.

	Site 3		
	Specifications	*Reported (Average of MHP Operators Responses)*	*Delta (Specifications - Reported)*
Generation Capacity(kW)	16	16	0
Capacity factor	88%	22%	66%
Head height(ft)	Unknown	92	Unknown
Flow rate(gal/min)	Unknown	3,963	Unknown
Efficiency	100%	75%	25%
Load (kW)	16	12	4
HV Length(km)	Unknown	Unknown	Unknown
LV Length(km)	Unknown	5	Unknown
Max Maintenance Cost (NPR)	Unknown	150,000	Unknown
Wooden Pole Count	Unknown	9	Unknown
Annual O&M Cost (NPR)	12,000	12,000	0
Contingency Fund (NPR)	50,000	60,000	-10,000

Table 6: Site 3 Technical Specifications versus Reported Attributes.

	Site 4		
	Specifications	*Reported (Average of MHP Operators Responses)*	*Delta (Specifications - Reported)*
Generation Capacity(kW)	60	35	25
Capacity factor	88%	19%	69%
Head height(ft)	Unknown	Unknown	Unknown
Flow rate(gal/min)	Unknown	Unknown	Unknown
Efficiency	100%	51%	49%
Load (kW)	35	18	17
HV Length(km)	Unknown	Unknown	Unknown
LV Length(km)	Unknown	Unknown	Unknown
Max Maintenance Cost (NPR)	150,000	400,000	-250,000
Wooden Pole Count	Unknown	400	Unknown
Annual O&M Cost (NPR)	Unknown	360,000	Unknown
Contingency Fund (NPR)	Unknown	Unknown	Unknown

Table 7: Site 4 Technical Specifications versus Reported Attributes.

	Site 5		
	Specifications	*Reported (Average of MHP Operators Responses)*	*Delta (Specifications - Reported)*
Generation Capacity(kW)	50	28	22
Capacity factor	88%	13%	75%
Head height(ft)	Unknown	62	Unknown
Flow rate(gal/min)	Unknown	4,755	Unknown
Efficiency	100%	50%	50%
Load (kW)	40	20	20
HV Length(km)	Unknown	2	Unknown
LV Length(km)	Unknown	6	Unknown
Max Maintenance Cost (NPR)	Unknown	Unknown	Unknown
Wooden Pole Count	Unknown	100	Unknown
Annual O&M Cost (NPR)	60,000	300,000	-240,000
Contingency Fund (NPR)	400,000	400,000	0

Table 8: Site 5 MHP Technical Specifications versus Reported Attributes.

	Site 6		
	Specifications	*Reported (Average of MHP Operators Responses)*	*Delta (Specifications - Reported)*
Generation Capacity(kW)	64	45	19
Capacity factor	88%	11%	77%
Head height(ft)	Unknown	649	Unknown
Flow rate(gal/min)	Unknown	1,601	Unknown
Efficiency	100%	38%	62%
Load (kW)	64	24	40
HV Length(km)	Unknown	1	Unknown
LV Length(km)	Unknown	7	Unknown
Max Maintenance Cost (NPR)	Unknown	150,000	Unknown
Wooden Pole Count	Unknown	0	Unknown
Annual O&M Cost (NPR)	150,000	400,000	-250,000
Contingency Fund (NPR)	Unknown	Unknown	Unknown

Table 9: Site 6 MHP Technical Specifications versus Reported Attributes.

5.3.0 Transmission and Distribution System

Knowledge of the sizing of a Transmission and Distribution (T&D) system is important for multiple reasons. First, it directly adds to installation costs and poses a regular maintenance expenditure. T&D infrastructure are regularly damaged or knocked down during Nepal's monsoon season. An efficiently designed T&D system can reduce ongoing maintenance costs. This section details available information on the T&D system sizing and maintenance for the studied sites.

5.3.1 Length of Transmission and Distribution Wires

Operators at each site provided information regarding the length of both high voltage (HV) and low voltage (LV) transmission wires. Figure 2, shown below, depicts the answers from the 11 operators surveyed. Lack of data and technical knowledge of the extent of the T&D is a recurring theme. It is also important to note most operators in the same site were unable to agree on the exact length of the T&D system. Distribution wires run at a lower voltage than transmission wires. Therefore, it is also important to note that in distribution wires, greater length results in greater loss of electrical power. Different sites will require different quantities of high and low transmission infrastructure dependent upon geography and customer demand. Minimizing power loss can be done by strategic planning during the pre-construction phase of infrastructure buildout.

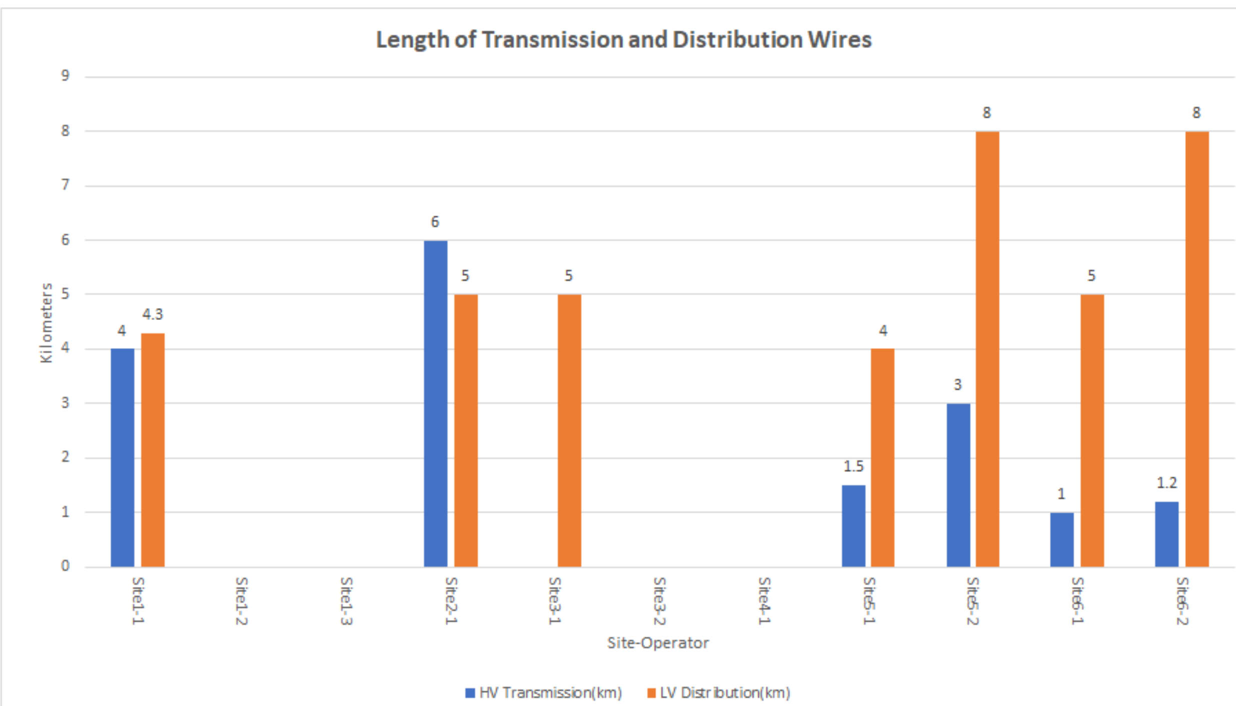


Figure 2: Length of Transmission and Distribution Wires. Data sourced from operator interviews. Disagreeing numbers for same site or the lack of numbers is to be noted.

5.3.2 Quality of Transmission Poles

Transmission infrastructure varies wildly in quality, minimizing grid resiliency. Addressing the problem is capital intensive, requiring notable investment to replace infrastructure such as wooden transmission poles and to upgrade essential equipment. While more stable poles of different materials are used in a few areas, the majority are constructed out of wood due to financial constraints. At times, wires are even circled around trees to act as makeshift poles. Unfortunately, wooden poles can act as fuel in case of electrical fires and are easily damaged and toppled during the monsoon season. Fallen poles can be dangerous, and they pose a serious risk for electrocution for villagers and their livestock. The risk is magnified as transmission poles often topple during monsoon season, increasing the possibility of electrocution as live wire are struck with rainwater.[2]

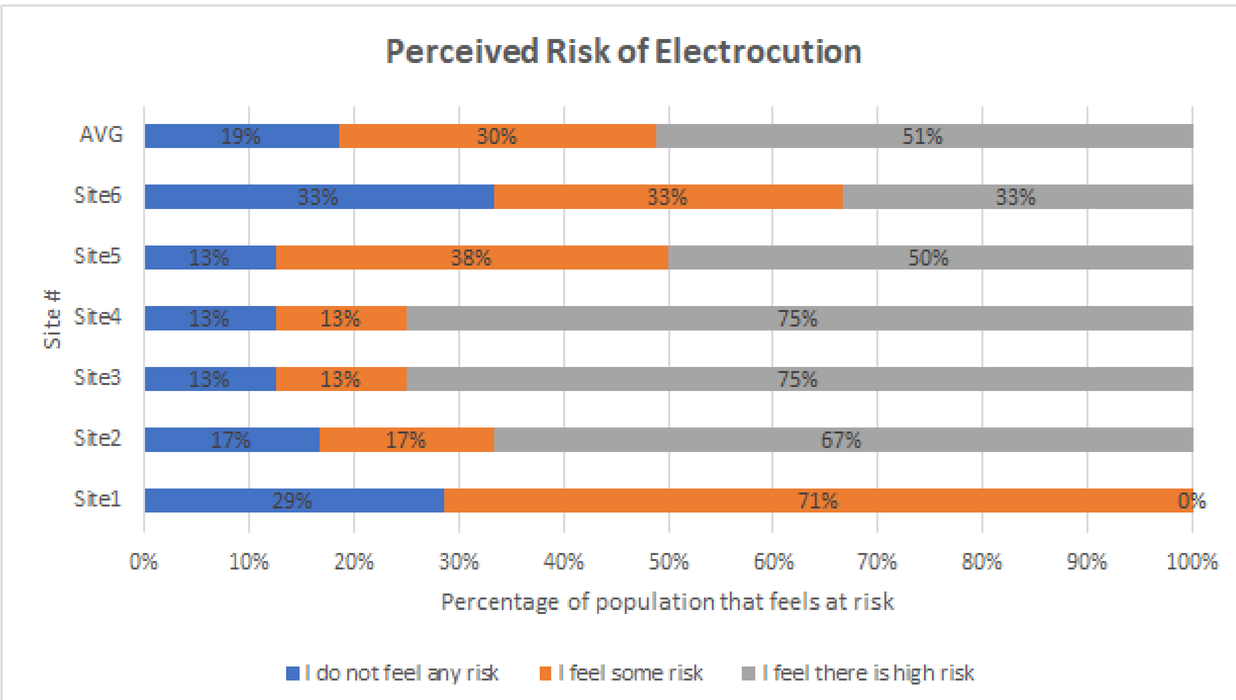


Figure 3: Perceived Risk of Electrocution. Data sourced from operator interviews.

[2] Figure 3, found below, illustrates the perceived risk of electrocution by the community of each village. It is no surprise that Site 1 performs best, with its inhabitants feeling the least amount of risk from the dangers of electrocution. In all other sites, the perceived risk appears correlated, to some degree, to the stability of the transmission infrastructure and the availability of a funding pool to carry out maintenance.

Images 1 and 2: Wooden Transmission Poles. Images taken while on-site

5.4.0 Financials

Implementation of a successful and sustainable micro-hydro scheme requires a large initial investment, followed by continuous maintenance funding through design life. Failure to fund regular operations and maintenance procedures will result in technical failures and loss of confidence in the value of a micro-hydro project. Financial success is an important indicator of the future success of micro-hydro plants. This section documents the following:

1. Initial funding granted to each site along with the investment's efficiency in terms of generation.
2. Availability of maintenance funds to each site.
3. Information on established billing system for each site, which is the primary source for O&M reserves for the sites.
4. A financial feasibility analysis that compares the sites surveyed to other micro-hydro sites in Nepal.

5.4.1 Installation and Operation Costs

The capital cost of a new a micro-hydro plant is expensive. Installation costs, operation costs, and expected revenue are valuable metrics to estimate earnings and costs associated with the project. The following section contains information regarding installation cost as well as the efficiency of capital invested.

The data about the cost of installing the micro-hydro plants (visualized in Figure 4) came from a collection of community leaders surveyed in the target sites. Initial cost is compared to actual generation in the figure to demonstrate relative production in relation to the initial investment.[3] Site 1 performed the best in relation to the cost efficiency ratio for a couple reasons. First, it was built in the late 1990s, when costs were generally cheaper. Second, it benefited from an enormous pool of free labor, afforded by the relative excitement of the local community for what at the time was an innovative approach to local electricity generation. Although Site 1 saw relatively high returns in relation to the up-front capital, because their charged price/kW to the customer is so minuscule they are still economically unviable by this metric.

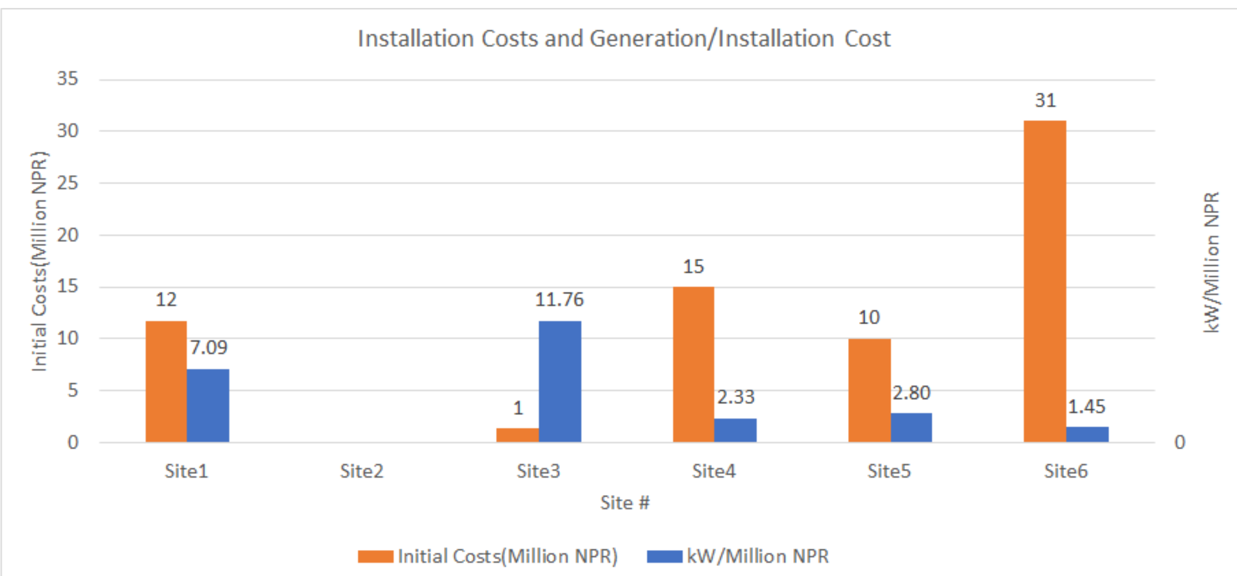


Figure 4: Installations Costs and Generation/Installation Cost Ratios. Data sourced from operator interviews.

[3] A higher number in this metric indicates a more efficient use of initial investment. It is important to note that although this could be considered an indicator of fiscal health, it is not foolproof and should not be the only measure of relative financial well-being.

5.4.2 Availability of Maintenance Funds

Revenue from the sale of electricity should contribute directly to the maintenance fund of micro-hydro plants. The availability of a funding reserve is used to support operations and make immediate repairs should any part of the system malfunction or becomes damaged. However, our surveys suggest that villages charge vastly different rates for each kilowatt of electricity. For example, at Site 1 and Site 3, funds are explicitly dedicated for maintenance. Site 6, however, has no explicit funds for maintenance, while Site 1 siphons operator salary for maintenance cost when required. That disparity is critical to understand in addressing the persistent lack of funding at different sites throughout the country. Unfortunately, there is also substantial variation and a general lack of knowledge among micro-hydro plant operators about how much funding is available for their operations.[4] It is important to ensure that maintenance funds are independent of funds allocated for operator salaries. Otherwise operators are incentivized to ignore routine maintenance to ensure their earning is not compromised.

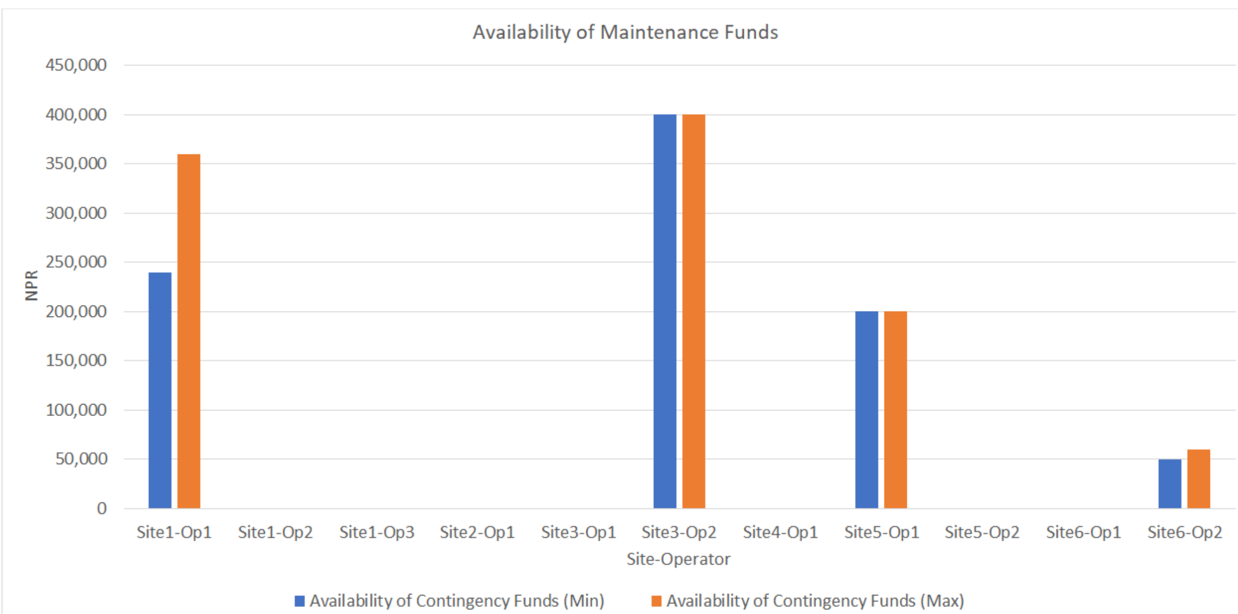


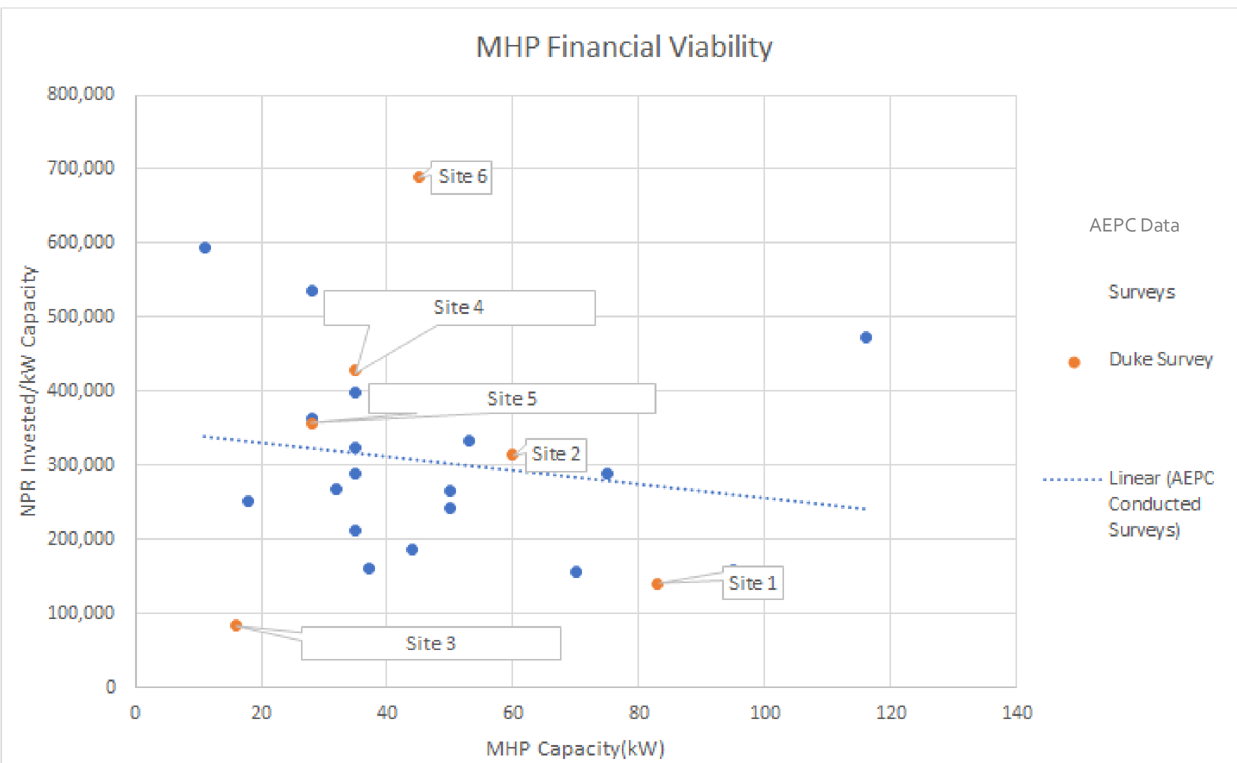
Figure 5: Availability of Maintenance Funds. Data sourced from operator interviews.

[4] The data is based on the operators' engineering estimates. It is important to note too that sites in the below graph (Figure 5) with no data are an indicative of sites at which the operators did not know or track how much money was available for maintenance rather than a situation in which NPR is not available.

5.4.3 Micro-Hydro Plant Financial Viability

The cost per kilowatt of capacity for a micro-hydro plant allows for a comparison of financial viability across micro-hydro plants across Nepal. Generally, the lower the cost per kilowatt, the better the plant compares to its cousins. The chart below illustrates the relationship between the cost to install the micro-hydro plant and the plants' respective electricity output. It offers a unique representation of the idea of economies of scale. As plants increase their output, unit cost generally decreases. Therefore, it is advisable to install capacity to the greatest degree a budget allows.

There is considerable variation among the micro-hydro plants' capacities, for reasons related to maintenance practices, consumer demand, and geography.[5] The dotted line indicates the mean value of the AEPC data included, allowing for a very cursory comparison of relative output and capacity amongst a sample set of plants. Plants below the trend line are considered relatively successful in relation to other plants in the study. For example, Site 2 is relatively unsuccessful in relation to Site 1 because it is more expensive and outputs a relatively low kW production.



[5] Data for the below chart (Figure 6) was sourced from surveys conducted for AEPC (Universal Consultancy Services Pvt. Ltd. and Nepal Energy Foundation (NEF) 2017). Target groups surveyed by Duke University researchers included for comparison.

Figure 6: Relationship Between Cost to Install Micro-Hydro Plants and Electrical Output for Data Collected by AEPC and surveys for this report.

5.4.4 Rating System

Table 10 delineates up-front, metered, and, where appropriate, appliance-based charges for electrification over the six sample sites researched in the Kailash Khola Valley. Its purpose is to highlight the differences in rate structures between the different sites, especially considering the stark differences from location to location.[6]

Generally, metered communities were consistent in their payment mechanisms. However, not all residents purchased meters. In the case of an electricity consumer without a meter, a fixed rate was levied on a monthly basis. Just as with the primary and secondary metered rates, the fixed unmetered rate differed enormously from site to site. In this singular instance (Site 5), unmetered customers are charged a flat rate per appliance in their homes. Every household was charged the same rate in this structure, regardless of the appliances' electricity requirements. This inconsistency can explain many of the issues associated with funding on a community level. It would benefit AEPC to offer some guidance to local communities in reference to an appropriate, sustainable and just method to set electricity tariffs.

	Connection Rate (NPR/kWh)	**Metered Rate (NPR/kWh)**	**Fixed Unmetered Rate (NPR/Month)**	**Appliance Based Unmetered Rate (NPR/Appliance)**
Site 1	5	7	160	-
Site 2	12	10	-	-

[6] The first column in Table 10, "Connection Rate," measures the up-front charge for a connection to the respective microgrid in relation to the kWh offered to the customer. The second column, "Metered Rate," defines the subsequent use rate in NPR per kWh. In other words, the "Metered Rate" is the price the customer pays based on his or her meter reading. The final column, "Appliance Based Unmetered Rate," offers an alternative to the fixed unmetered rate used in three communities.

Site 3	-	0.05	45	-
Site 4	-	7	80	-
Site 5	-	8	-	12
Site 6	-	-	-	-

Table 10: Rate Structure at Surveyed Sites. Data sourced from a combination of Operator and Community leader Surveys.

5.5.0 Micro-Hydro Plant Performance

A micro-hydro plant's revenue stream is directly tied to the delivery of consistent and reliable electricity. Micro-hydro plants should be running night and day without interruption to supply the demand for electricity. The following are factors that affect electricity production are described in detail in the section below:

1. Plant Capacity: Straightforward, this describes the plant's capacity to generate power.
2. Efficiency: Based on the water inflow and capacity, this ratio indicates how efficiently the device is generating electricity.
3. Load Serving Efficiency: This metric describes the ratio of the actual load a plant currently serves with respect to the load that the plant was originally intended to serve.
4. Operation Hours: This details how many hours of day the plant is active. It is significant because these are industrial plant that are intended and rated to run 24 hours a day.

5.5.1 Micro-Hydro Plant Capacity

The capacity of the micro-hydro plant at each of the six sites was obtained from survey data provided by plant operators. Generators over the six sampled sites are rated from 16 kW to 83 kW – a range of 67 kW. Plants are sized according to budget, installation dates, and demand at the time of construction. It is not uncommon for a larger plant to require a different type of strategy than smaller plants. The large range of nameplate capacities could become a major challenge in determining a scalable solution to sustainable micro-hydro plant operation.

Nameplate capacity inconsistency in relation to actual performance is unlikely a cause of micro-hydro plant failure, but it does highlight a challenge that AEPC must address: the lack of record keeping. In Site 1, a site that is relatively successful, there appears to be a large disparity between rated nameplate capacity and reported capacity. The lack of operator training or education can explain that discrepancy. However, in the circumstances that the generators are running at maximum power, the supply chain and supply partners ought to be contacted to check their product's legitimacy.

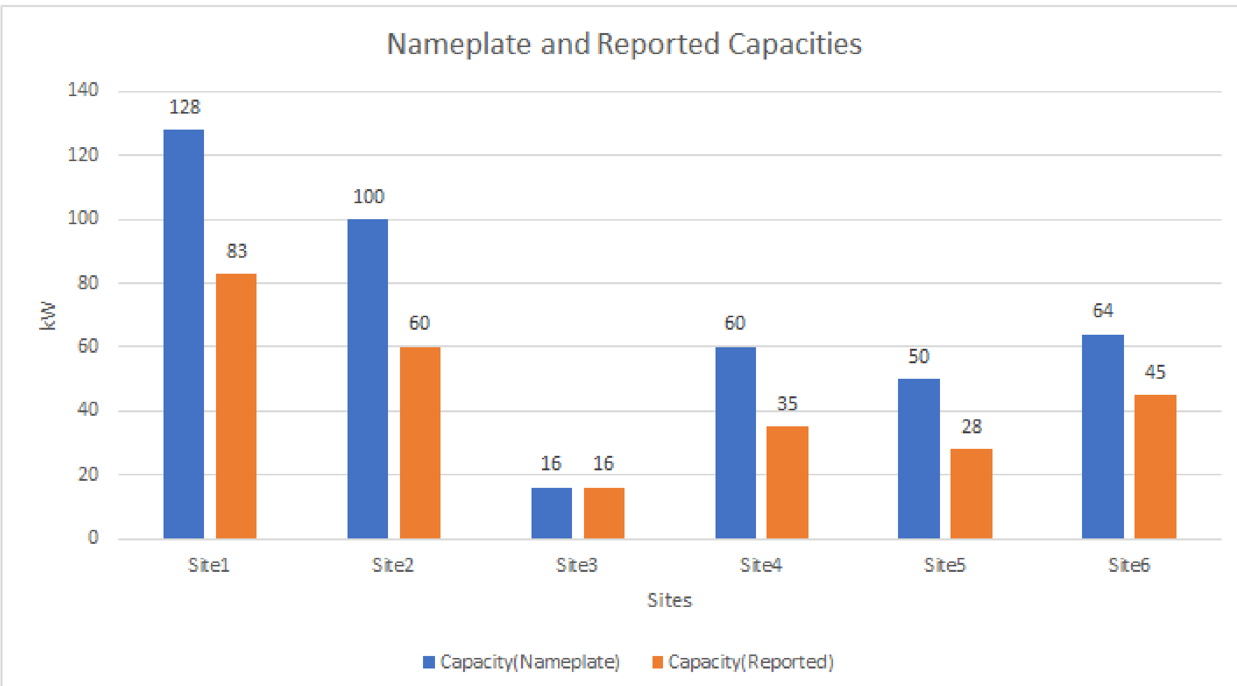


Figure 7: Nameplate Capacity and Capacity Reported by Operators. Data sourced from Operator Interviews.

5.5.2 Production Efficiency in Relation to Hydrokinetic Potential

This section highlights the efficiency of each plant based on a range of physical characteristics that are important to generate electricity from the diverted stream water.[7] Importantly, the efficiencies in this graph ought to be considered indicators rather than hard calculations of the plants' respective capabilities.

The data is important in emphasizing the enormous differences in capacity between sites. It is an important note in reference to maintenance scheduling and operator training - without a greater

[7] The two sites that are not present Table 11 are omitted because operators did not provide enough data for calculations to be made.

emphasis on standardized practice and adequate education, it is likely that operators will continue to demonstrate confusion regarding duties essential to effectively running a micro-hydro plant.

Site Name	Head of Water (ft)	Flow Rate of Water (gal/min)	Constant (gal*ft/min*kW)	Nameplate (kW)	Reported Generation (kW)	Efficiency
Site 1	164	7,069	5,310	218	83	38%
Site 3	92	3,962	5,310	68	16	23%
Site 5	62	4,755	5,310	55	40	72%
Site 6	649	1,600	5,310	195	45	23%

Table 11: Micro-Hydro Plant Efficiency Calculations. Data sourced from Operator Interviews from the field.

5.3 Comparison of Expected and Actual Load

Plants are installed based on the expected consumer energy demand in the micro-hydro grid service area. Lower load capacities are caused by several factors. Differing minimum expectations for maintenance between sites and a lack of funding contributing to defective or unsuitable infrastructure – such as wooden power poles – are the predominant culprits for poor plant performance. These poles are susceptible to monsoons and fires, leading to concerns regarding their reliability. A representation of this data is included below.[8]

[8] It is important to note too that the reported values used for calculations in Figure 8 and Table 12 are the highest values offered by the combination of interviewed operators at their respective sites.

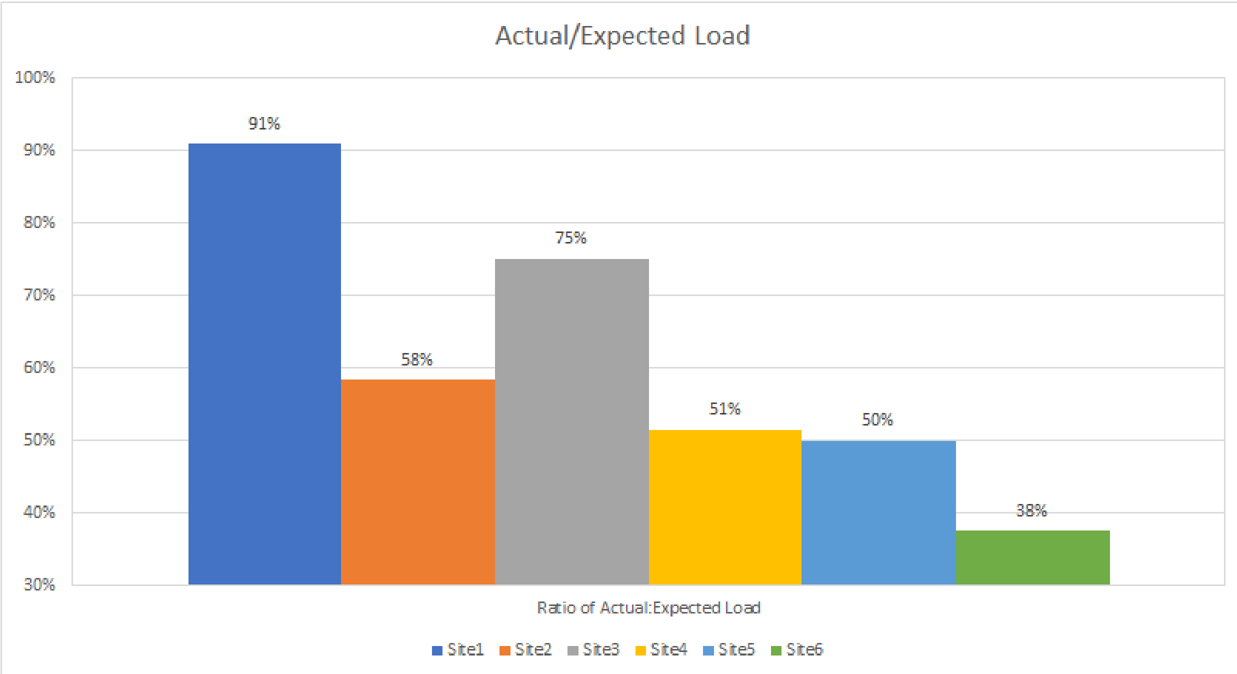


Figure 8: Actual Electrical Output in Relation to Expected Actual Output. Data sourced from Operator Interviews.

Site Number	Gross Predicted Load/hour (kW)	Present-day Load/hour (kW)	Actual/Expected Load
Site 1	76	69	91%
Site 2	60	35	58%
Site 3	16	12	75%
Site 4	35	18	51%
Site 5	40	20	50%
Site 6	64	24	38%

Table 12: Actual Electrical Output vs. Predicted Electrical Output. Data sourced from Operator Interviews.

5.5.4 Micro-Hydro Plant Operating Hours

The number of hours and time of day that each micro-hydro plant operates is key to the success of the plant. Supply and demand of electricity is delineated by hour, and meeting that demand is considered the top priority for electricity generating devices. However, at each of the six sites the MHPs are not operated continuously throughout the day. There are a few reasons for this, including but not limited to: a necessity for some operators to farm for food, a fear of "overworking" the plant machinery, and general negligence. In particular, the thought that the machines would overheat was a consistent misunderstanding of the capabilities of the equipment. In each surveyed location, the equipment was rated to operate 24 hours a day. As such, a comprehensive education program ought to be utilized so the operators have a greater understanding of their equipment and its abilities.

Most of the plants are operational during the early morning and evening hours, as that is when there is demand for lighting. Some of the plants are shut down during the day due to a lack of demand. As a case study, it is interesting to note the operating hours of Site 1 because it is considered a highly functional site. It continues to run for 21 hours a day, much more than all other nearby micro-hydro plants. In fact, it is not operational for only three hours per day (hour 1, hour 9, and hour 17), a practice that is effectively unavoidable due to shift changes and maintenance duties. However, sites throughout the country could emulate Site 1's framework, particularly if they could secure the demand necessary to justify the extended operation.

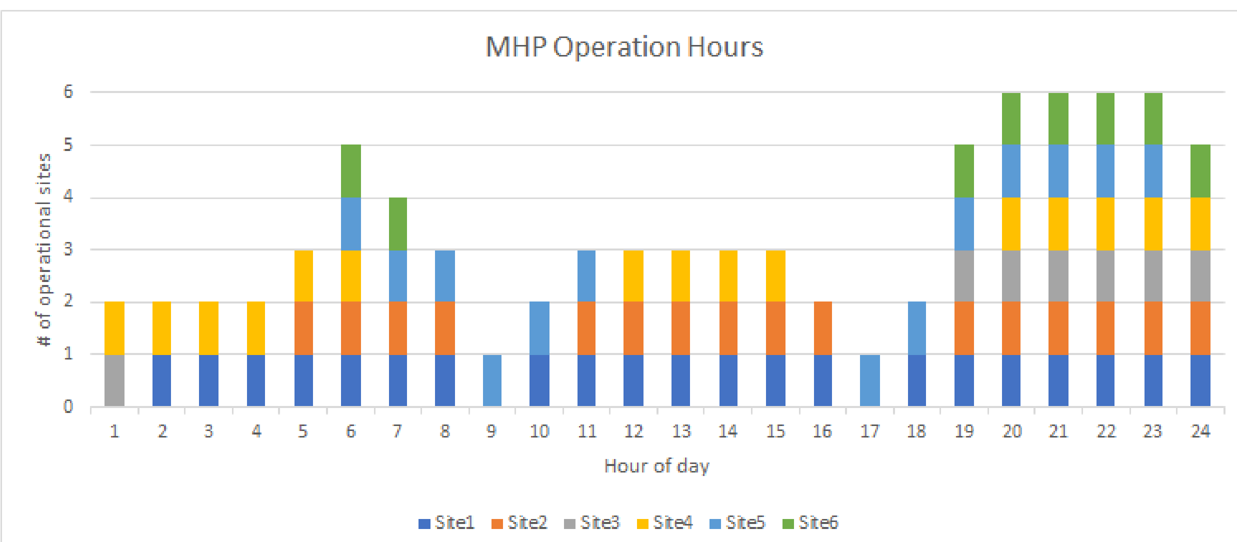


Figure 9: Micro-Hydro Plant Operation Hours. Data sourced from Operator Interviews.

5.5.5 Capacity Factor

A high capacity factor is favorable to a lower one. A high capacity factor indicates that the plant is being utilized more and therefore is closer to obtaining its full potential. The low capacity factors at the sites are attributable to the fact that they are not operating 24 hours a day and the fact that the actual output is much lower than the nameplate capacity. The capacity factor is calculated as the average energy production divided by the total possible energy production. The numerator is the actual kW output times the number of operational hours a day. The denominator is the nameplate capacity times 24 hours. In the chart (Figure 10), the first bar shows the "Ideal" capacity factor. This was calculated by using Site 1 as a sample site, with actual generation meeting its nameplate capacity for 21 out of the 24 hours in the day.

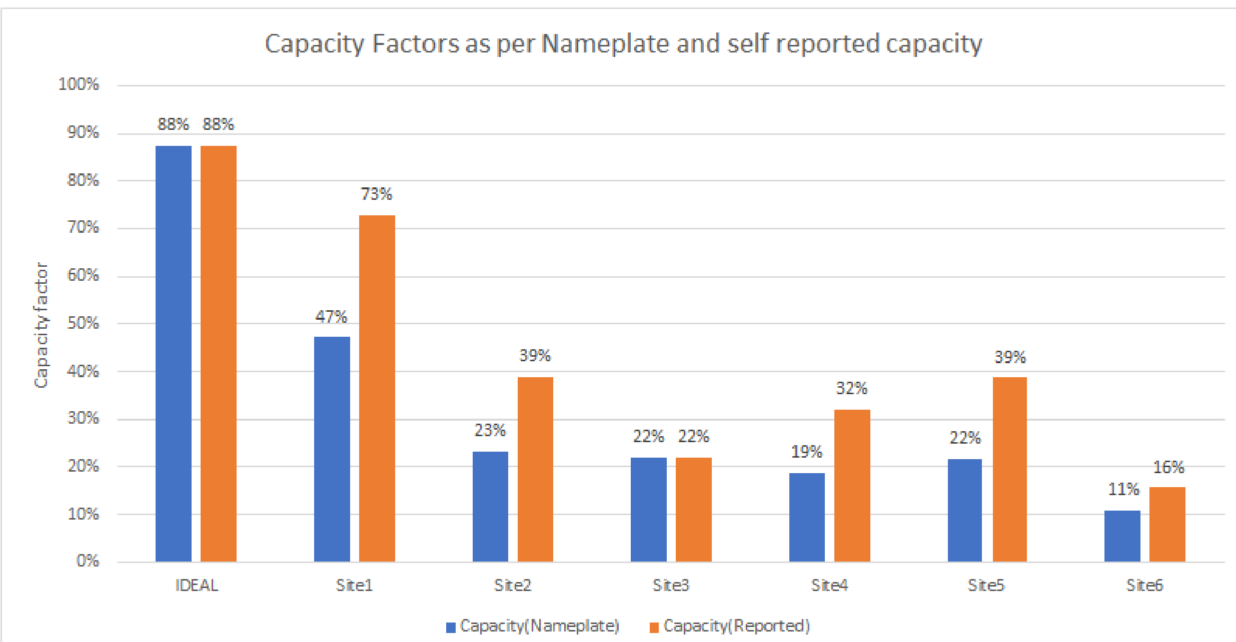


Figure 10: Plant Capacity Factors. Data sourced from Operator Interviews.

5.6.0 Operation and Maintenance

Operation and maintenance are perhaps the most vital part of a sustainable micro-hydro plant. To prevent untimely breakdowns, O&M procedures must be planned and utilized from the very first day of a plant's operation. This includes proper training for operators, proper funding for projected O&M costs, maintenance schedule and log book preparation, and operation policy. The following section outlines how the different sites surveyed undertook operation and maintenance.

5.6.1 Operator Education

Education level for plant operators was determined based on survey answers. Although the sample size of eleven operators is small, it still highlights an important disparity in education. The inconsistency in relative understanding of the systems the operators were tasked with maintaining became clear in interviews in which operators did not understand concepts as necessary as the difference between single phase and three phase transmission, pointing to a need for more in-depth education and training for operators in the future. Only 54.5% of the operators at the respective sites received at least a tenth-grade education. This indicates that likely they have little to no educational background regarding engineering. Though they have been innovative in solving problems, additional education would go a long way toward effective practice in coming years.

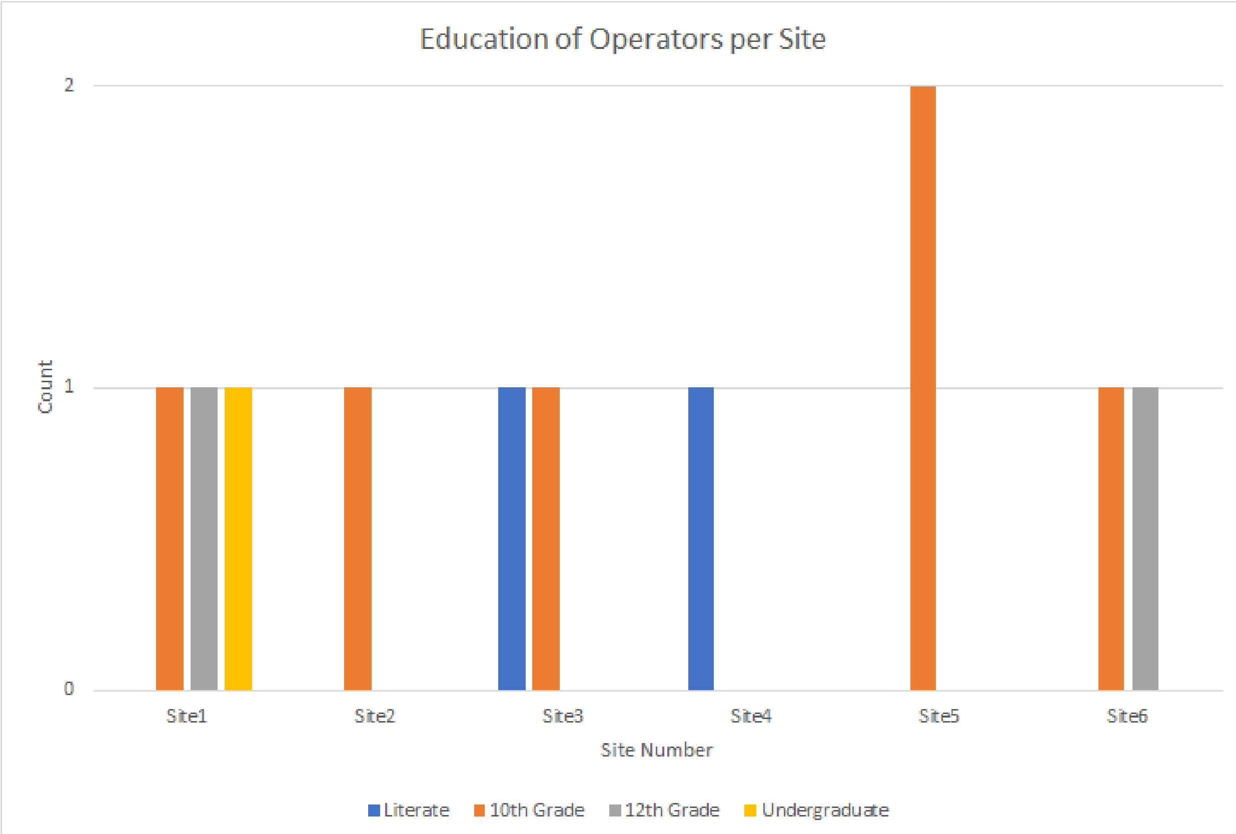


Figure 11: Micro-Hydro Plant Operator Education Attainment. Data sourced from Operator Interviews.

5.6.2 Operation and Maintenance Costs in Relation to Available Funds

The below chart (Figure 12) highlights two important aspects of research in the target communities. The first is that responses differed between operators at the same site. Although the values were relatively similar when asked questions, the oft-differing perspectives of operators offer further evidence that it is necessary to implement official training and guidance. Missing data points also supports the fact that some operators do not know vital information about their own site. Finally, the chart itself demonstrates a drastic need for funds in order to properly maintain sites. During site visits, highly unsafe solutions to technical issues, born mainly from a need to coax equipment to operation due to a lack of adequate funding, were observed.[9] Images of some of these issues can be found below, in Image 3 and Image 4.

[9] A response of "#N/A" in Figure 12 indicates a response of "Do Not Know" from the relevant operator. A response of "0" indicates a response reporting a dearth of any maintenance funds in the case of an emergency. At some sites, operators reported different data regarding maintenance funds. Of that data, higher values were used for calculations.

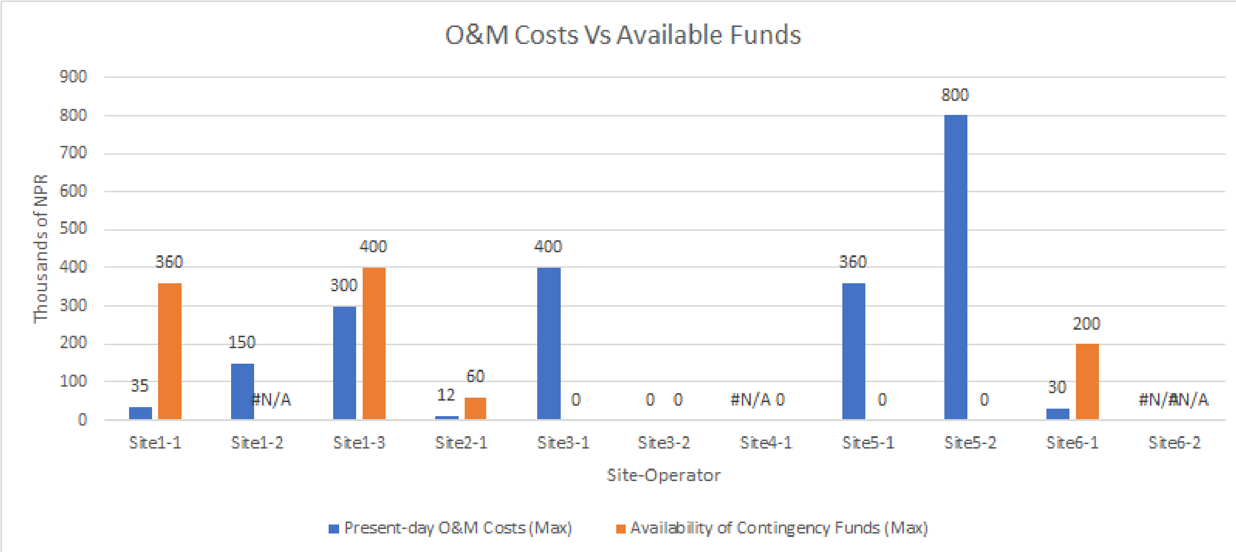


Figure 12: Operations and Maintenance Funds in Relation to Available Funds. Data sourced from Operator Interviews.

5.6.3 Micro-Hydro Plant Success Factors

In gathering the data for Figure 13, the micro-hydro plant operators were asked "What aspects would you contribute to the success of the MHP?" and were given 5 choices: Social, Technical, Economic, Environment, and Policy. They chose all the responses that they felt applied and did not rank them. This often led to multiple response by one operator, explaining the discrepancy in number between their responses and the total number of operators surveyed.

Social, technical, and policy were the most common responses to this question by operators. The term "social" refers to community members' participation in the construction of the project, as well as the fact that there was a discussion between AEPC and the community. "Technical" refers to how well equipment was installed and performed. A response that "policy" was a critical component indicates an opinion about the rules and guidelines that the community leaders established to operate the plant. A fourth opinion, "environment," refers to the local geography. Very few operators cited the environment as a factor that led to success because the terrain of the sites is not favorable in accessing canals or installing and maintaining transmission lines. Economic factors include the availability of funds to pay workers and perform repairs. In line with other findings in this report, economic factors were not commonly cited as a driver of success.

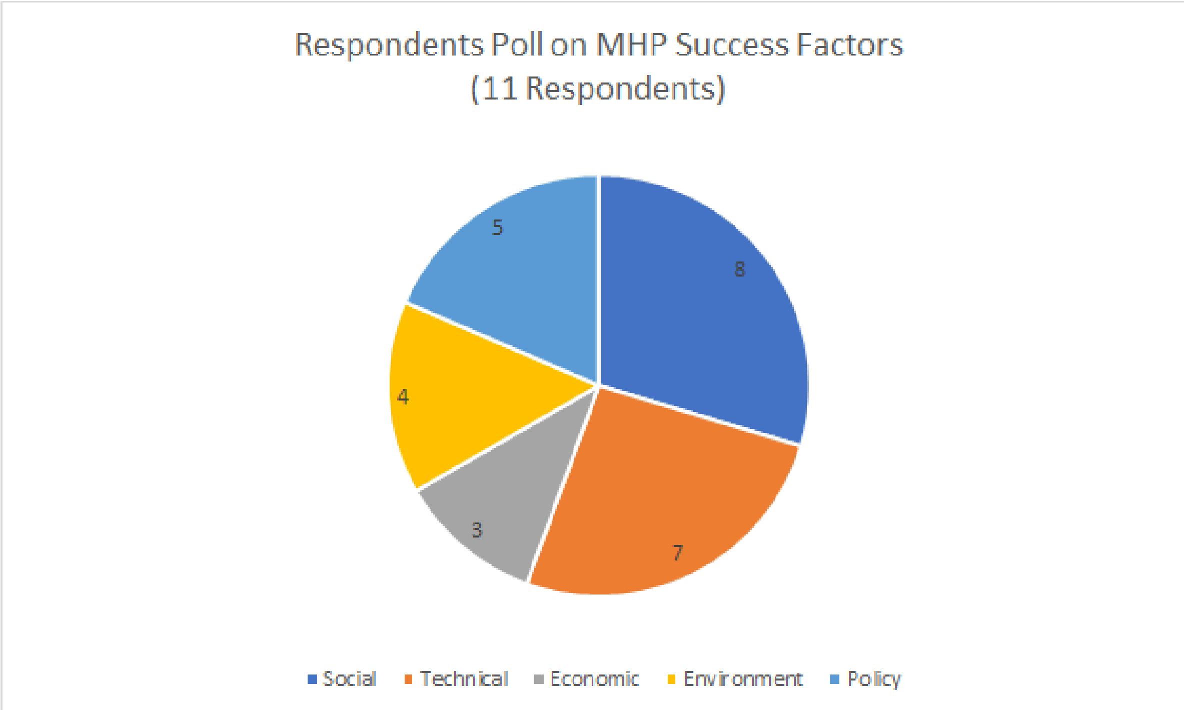


Figure 13: Micro-Hydro Plant Success Factors. Data sourced from Operator Interviews.

5.6.4 Micro-Hydro Plant Component Maintenance Schedule

The chart below (Table 13) offers an aggregate of the frequency with which different components of micro-hydro plants are maintained on a regular basis. Maintenance appears to be spontaneous, rather than routine. The schedules were effectively created by operators at each respective site, a fact reflected in the varying commercial successes of those sites.

	Count of Responses										
	Penstock	Weir & Intake	Flood Control Gates	Valves	Joints	Turbines	Governor	Drive System	Generator	Switchgear	Transmission Lines
Never	0	0	0	0	2	0	2	0	2	0	0
Every other year	0	0	0	0	0	0	0	0	0	0	0
Annually	1	0	0	0	1	0	1	0	0	0	0
Every other month	1	1	1	0	1	1	0	1	0	0	1
Monthly	4	1	0	0	2	0	0	0	1	1	1
Every few weeks	0	0	1	0	1	3	0	0	0	0	0
Weekly	2	2	3	1	2	1	0	0	1	0	1
Every few days	0	1	0	0	0	0	1	0	1	0	0
Daily	1	4	3	7	0	3	1	6	2	6	0
As per breakdown	0	0	0	0	0	0	0	0	0	0	0

Table 13: Maintenance Schedule by Equipment Type. Data sourced from Operator Interviews.

5.6.5 Causes of Equipment Malfunction

Equipment malfunction is a major cause of micro-hydro plant downtime. Table 14 depicts reasons for malfunction by their component.[10] While there is little consistent reason, we know that the micro-hydro plant and transmission system is especially vulnerable to storms. In some sites, the lack of maintenance pushed operators to experiment with dangerous, temporary fixes like wedging a stick into a spinning turbine or using large rocks to stabilize equipment.[11]

	Count of Responses										
	Penstock	Weir & Intake	Flood Control Gates	Valves	Joints	Turbines	Governor	Drive System	Generator	Switchgear	Transmission Lines
Silt/mud	2	4	2	0	0	1	0	0	1	1	0
Leaves	0	0	0	0	0	0	0	0	0	0	0
Monsoon	1	2	1	2	1	0	0	0	0	0	0
Short	0	0	0	0	0	0	1	0	0	1	1
Hardward Issues	2	0	2	1	1	1	1	1	2	1	0
Rust	1	0	1	0	0	0	0	0	0	0	0
Wear and tear	0	0	0	1	0	0	1	1	0	0	0
Other	2	1	0	1	1	1	0	2	0	1	2
Don't know	4	5	6	7	9	9	9	8	9	8	9

Table 14: Cause of Equipment Malfunction. Data sourced from Operator Interviews.

Images 3 and 4: Dangerous Solution to Equipment Malfunction. Images Taken while onsite.

[10] The counts included in Table 14 are tallies of the primary cause of malfunction as identified by the operators and do not reflect secondary/tertiary/etc. causes for malfunction.

[11] Two of these dangerous practices are included as images 3 and 4.

5.7.0 Technical Analysis Report Conclusion

Our survey of micro-hydro plant operators from six sample sites revealed technical, mechanical, and human capacity factors that play a significant role in the success of micro-hydro plants. The varying degree of responses in plant and grid specifications – such as the length of transmission lines – seem to point to gaps in knowledge in the workforce. Though it is not necessary that all operators are well-versed electrical engineers, they should have a sense of essential plant information, be knowledgeable about the basics of electricity, and possess the ability to perform rudimentary maintenance.

The data also suggests that there is an urgent need for a more stringent quality assurance process and due diligence before receiving electrical generation equipment from its manufacturer and supplying partners. In all sample cases, not a single generator lived up to the device's stated production capacity. Complete and accurate information is necessary to estimate peak loads that the micro-hydro plant can supply and plays a crucial role in estimating the correct tariff structure for electricity. Additionally, record keeping guidelines and procedures are important to ensure that proper accounting of assets is available when needed.

The success of micro-hydro plants is dictated by its ability to provide quality and reliable electricity at a price that will not hinder the plant's ongoing operations. The availability of maintenance funds that finance the micro-hydro plant's upkeep varied widely. This indicates that more capacity building work is needed to provide support for a sustainable and just rate structure. These funds are vital, and without them, a negative spiral of decreasing asset performance and eventual failure is all but inevitable. In regions that experience seasonal climatic events such as monsoons, a pool of excess maintenance funds is fundamental to the micro-hydro plant's ability to recover from potential disasters.

Of the six sample sites, only two were financially viable when compared to the national average of Nepalese Rupees (NPR) divided by plant capacity. In general, a successful micro-hydro plant would sit below the national average trend line, meaning that the per kilowatt capacity during the plant's installation is on average less expensive than its peers. This metric provides an important first glance at value but is in no way a final determinant of a plant's financial viability. It is hard to say whether a success a micro-hydro plant is successful based on one metric alone. Only when complemented by other indicators – building workforce capacity, clear asset accounting, and guidelines and support in setting a feasible tariff structure – can success be measured holistically.

6.0 Micro-Hydro Plant as an Enterprise Asset Report

6.1.0 Introduction to Micro-Hydro as an Enterprise Asset

While micro-hydro projects in Nepal represent a solution with high potential for electrifying rural villages, they also represent a real risk of long-term unsustainability. As of 2019, according to internal AEPC documentation, nearly one-third of Nepal's existing micro-hydro infrastructure is untenable, with an additional third at risk of faltering in coming years. While the reasons for failure are diverse, lack of long-term funds present the biggest challenge. In this report, several financing options are explored in the context of what development practitioners have coined the Anchor, Business, Consumer (ABC) Framework. Those options are explicitly tailored to the micro-hydro plant situation in Nepal. With these recommendations, the hope is that AEPC may be able to reform and revisit failing sites to motivate their financial efforts and stimulate the possible benefits of having micro-hydro facilities in rural villages without a reliance on subsidization.

This analysis explores a number of feasible options microgrids can utilize to stabilize funding and become autonomous without the use of continued subsidies. Each solution does not apply to every micro-hydro project, but with some support, a mix of the potential remedies could help floundering sites in Nepal. The report is separated into four major sections:

1. In-Community Anchor Customers
2. Out-of-Community Anchor Tenants
3. Micro-Hydro as a Microfinance Institution
4. Suggestions for the Future
    a. Leveraging grants and low-interest funds
    b. Recommendations on rate structure
    c. International Renewable Energy credits

Each of these sections deals with a facet of micro-hydro financing that could be utilized in pursuit of sustainable, business-oriented goals in an attempt to avoid reliance on subsidies. The sections will also emphasize methods by which the microgrids can become more consistent in their management; a facet that proved to be deleterious in communities targeted for research.

6.2.0 ABC Framework

The ABC Framework is a method of electrification deployment implemented predominantly with microgrid projects in different regions of the world. It has been utilized successfully in both India and Africa, providing substantive evidence that it has the potential for useful implementation in Nepal as well. The ABC Model is based on serving first anchor clients, then local businesses, and finally the residences of the local community to promote financial stability (Frankyln, 2016). While generally used for the rollout of new microgrid projects, the prioritization of the different clients championed by the ABC Method is a useful echo of recommendations made in this report.

6.3.0 In-Community Anchor Customers

6.3.1 Introduction

In the report "Hybrid Mini-Grids For Rural Electrification: Lessons Learned", The Alliance for Rural Electrification posits that in order for a renewable energy system to be able to be sustainable, it is required to address three major issues (Electrification, 2014). The first of these is end-user financing. Community end users should have enough financing support to afford an electricity connection and the purchase of electricity appliances. The second pertains to business finance, which involves small businesses of the community achieving connectivity and being able to afford electricity necessary to enhance their earning capacity. This is vital in order to secure steady revenue, as well as consistent demand for electricity. The third is project financing and capital investment. The "In-Community Anchor Customers" section below addresses the second level - small enterprises that provide sufficient cash flow as well as electricity demand to allow the micro-hydro project to be sustainable. These entities are addressed in this section as in-community anchors.

6.3.2 When Subsidies are Not Enough

As stated above, this section shall pertain to addressing how a community can sustain its micro-hydro plant grid through achieving significant subscriptions from small businesses. In section 5.6.2 the groundwork has been laid for the financial analysis required to understand the problem.

A significant takeaway from the technical analysis of this project was the chronic shortage of maintenance funds to sustain the micro-hydro plants. Below, Table 15 emphasizes how there is often little contingency funds allocated for Operations and Maintenance because of low revenue.Table 15: A comparison of predicted and present-day O&M costs, accompanied by contingency fund availability.

Site	Predicted O&M Costs (Minimum)	Predicted O&M Costs (Maximum)	Present-day O&M Costs (Minimum)	Present-day O&M Costs (Maximum)	Availability of Contingency Funds (Minimum)	Availability of Contingency Funds (Maximum)
Site 1	50,000	100,000	30,000	**35,000**	240,000	360,000
Site 2	Unknown	Unknown	Unknown	Unknown	**0**	**0**
Site 3	10,000	12,000	10,000	12,000	50,000	60,000
Site 4	Unknown	Unknown	Unknown	360,000	**0**	**0**
Site 5	50,000	60,000	**250,000**	**150,000**	400,000	400,000
Site 6	Unknown	150,000	**300,000**	**400,000**	**0**	**0**

These predictions are reported in the Feasibility Study and the Operation and Maintenance Study conducted by AEPC before construction of the MHPs. The table was compiled by choosing operator responses that provided the most complete set of data. An 'Unknown' field indicates that the information was unknown to all surveyed operators at the site.

Although all locations received varying amounts of funding and subsidies from NGOs, the government, and equipment providers, our fieldwork indicates only one of the sites surveyed managed to attain economic sustainability based on a basic economic analysis. Multiple respondents at several sites displayed a conviction that the government should provide continuous, indefinite aid towards device O&M, which is in stark contrast to the actual intent of AEPC to encourage these communities to be self-sufficient.

Figure 14 is an indicator of why prudence should be observed in offering subsidization to a site. The revenue of a site is in part the product of its bill and monthly usage profile. As the two are scaled equivalently in the figure, an ideal bill should be positioned near the top edge of the usage bar, without exceeding it. A monthly bill above the usage profile indicates pricing beyond the community's means, and one below the edge of the usage profile indicates revenue that is not realized explicitly from the tariff. Calculations, and a further description of the calculations necessary to understand Figure 14, are included in the figure description.

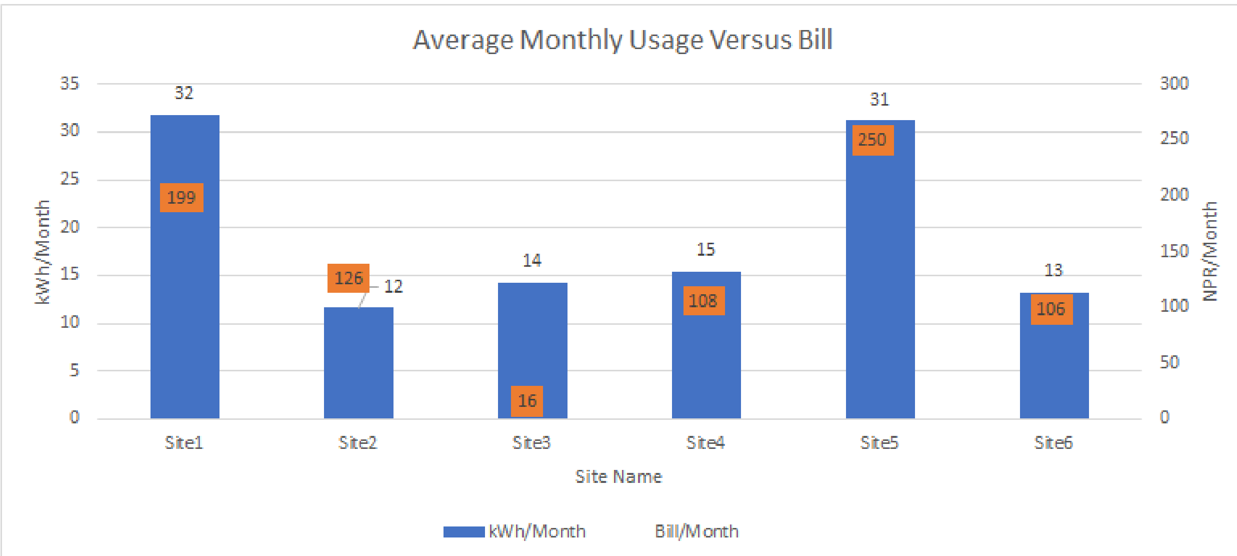


Figure 14: A comparison of approximate electricity usage per household per month profile against average monthly bills. Data is sourced from community member interviews. Bars indicate the electricity usage profile per site. This can act as a rough indicator of income. Positioning of the bill amount indicates comparative cost/month. The usage profile was obtained from details provided by respondents regarding appliance ownership and appliance usage duration per month. Tariff structures unique to the site were then applied to obtain the monthly bill profile.

It is recommended to scale the tariff rates based on the community's electricity usage profile instead of offering an uninformed price. In Figure 14, the blue bars indicate total monthly production, which in this case is assumed to be a proxy for relative wealth. Current tariff rates were then cross-graphed with the monthly production, with the best-case rates assumed to be those that matched production linearly. In other words, best-case rates would visually line up with the top of their respective blue bar. Calculations were then completed as shown in Table 16 to determine relative distance from the perceived "ideal rate," where a positive percentage indicates the percentage below ideal rate by which the bill could theoretically be increased. A negative percentage indicates the quantity by which the bill should be decreased to reach the ideal. To clarify, Table 16 highlights that Site 3 fails to earn 89% of its revenue because of its liberal tariff rates. On the other hand, Site 2 over-charges by a third more than their ideal rate.

Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Unearned Revenue	22%	-33%	89%	28%	3%	18%

Table 16: Approximation lost revenue/ overcharging. Derived from Figure 1

6.3.5 Identifying In-Community Anchor Customers

Identifying potential in-community anchor customers is challenging due to the variation in potential opportunities across rural locations. For example, the surveys conducted in Achham district show that Site 1, with its co-operative management structure, attracted anchor customers whose businesses contributed to improvements in community well-being. Therefore, there are clinics, soap industries, computer labs, mills, and hotels (Figure 15). Community leaders reported plans of investing in electronics shops and remittance shops in the future. Interestingly, as outline in Table 18, there is also a consistent increase in earning potential once electricity is accessible for businesses. Despite the individuality of each site in relation to potential in-community opportunities, locals almost always understand the desires of fellow citizens. Communication with locals can often act as a useful, easy route to understanding the most effective businesses to anchor a micro-hydro plant.

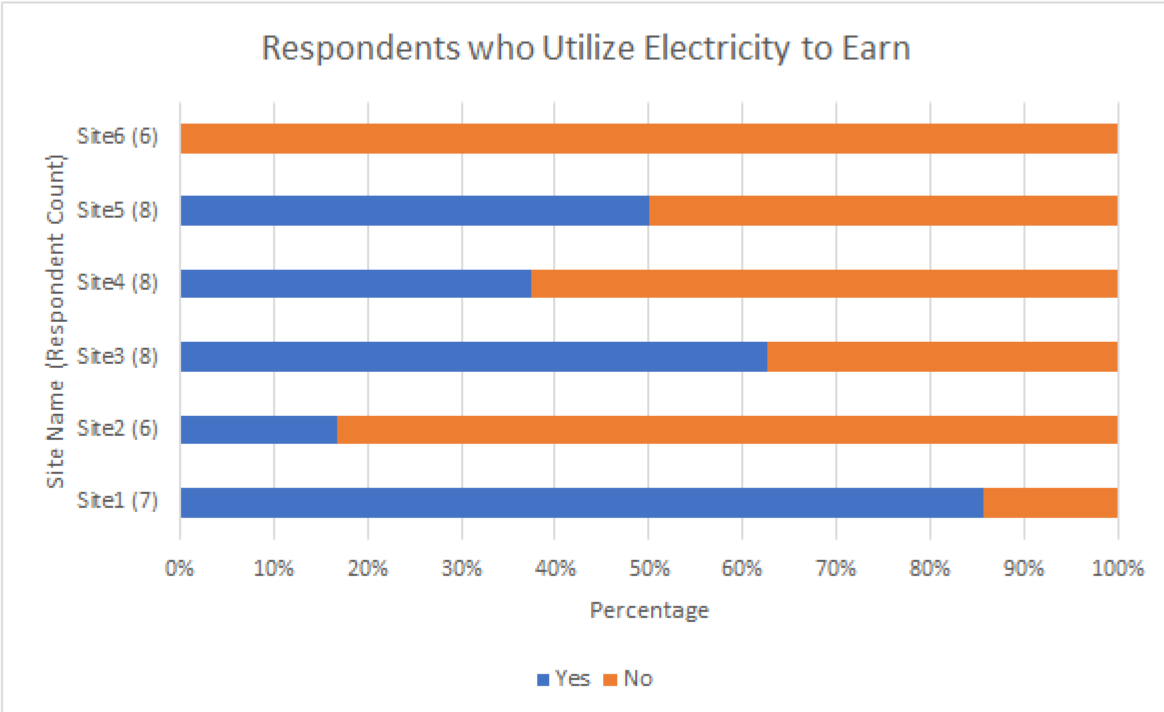


Figure 15: Percentage of respondents who use utility to earn based on site.

As a further emphasis on the variability of best-case in-anchor businesses, Site 3 acts as a passage to other villages in the vicinity because it is connected to them by a well-traveled road. As such, it has a larger count of grocery shops and hotels that cater to passing commuters. Again, community enablers or others with knowledge of village characteristics can assist in identifying potential anchor clients for a given location.

Business Types	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Soap industry	1	0	0	0	0	0
Hotel	1	0	2	1	1	0
Clinic	1	0	0	0	0	0
Wood mill	1	0	0	0	0	0
Grain mill	1	0	0	0	0	0
Grocery	3	1	4	3	3	0

Tailor	0	0	1	0	1	0
Computer Lab	1	0	0	0	0	0
Communication Shop	1	0	0	0	0	0

Table 17: Table indicating profession distribution among interviewed respondents.

Change in Income	**Count**
Reported earning more after Project	10
Reported earning less after Project	0
Earned the same income before and after the Project	5

Table 18: Respondents who reported to a change in income since installation of MHPs.

Each of the surveyed sites were deemed whether or not to have factors that encourage and enable in-community anchor tenants, as illustrated in Table 17.

Factor/Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Capacity	YES	YES	NO	YES	YES	YES
Reliability	YES	YES	PARTIAL	NO	YES	NO
Availability	YES	YES	PARTIAL	YES	YES	NO
Low cost	YES	NO	YES	YES	PARTIAL	NO
Social Influences	YES	NO	NO	YES+NO	NO	NO
Opportunity	YES	YES	YES	YES	YES	YES

Table 17: Table of generic factors that encourage anchor customers. Availability is how many hours of day the MHP is running. Reliability indicates how consistently the MHP can operate during expected operation hours. Affordability indicates whether the community is affluent enough to keep up with electricity rates. Social influences indicate situations that might impact the decision to become an anchor customer, which is elaborated in the next table. Opportunity indicates factors that anchor customers can potentially take advantage of in the future.

When looking at the sites from a social perspective, we find that every site has two aspects, the first of which being the generic aspects common to every site. Issues pertaining to the generic aspects may be addressed with a generic solution applicable throughout all MHPs in the country. On the other hand, there are the aspects unique to the sites that require a personalized approach. Both of these aspects are explored further in Table 18 (below). The case studies described in section 4.0 provide detailed insights into situations unique to the sites that were visited.

Factor/Site	Positive Social Influences	Negative Social Influences	Opportunities
Site 1	1.Community takes pride in successful MHP as well as Co-Op	NONE	1. 22kW capacity unused, awaiting new anchor clients.
Site 2		1. Respondents claim prices too high as the community is excessively poor 2. Claims of manipulation or MHP operation times to suit community leaders	1. Eight Schools in the vicinity that may act as anchor clients
Site 3		1. Electricity beyond 7 hours deemed unnecessary 2. 85% revenue not realized	1. Many local businesses waiting on greater electricity hours
Site 4	1. Presence of pre -established agricultural co-op encourages business	1. Taken advantage of by local telecommunications company. 2. Villagers made false promises of payment for MHP labor. 3. Voltage Spike incident that resulted in mass appliance damage	1. Schools with computer courses can be anchor customers if operation improves.
Site 5		1. Electrocution of a Buffalo left local community terrified to touch any switches or outlets	1. Presence of a market in the vicinity allows for a large potential base of anchor clients
Site 6		1. Takes three weeks to perform repair-work, during which site is blacked out 2. 20% of the community perpetually out of power because of a broken transformer 3. Some respondents claim community leader set bad example by refusing to pay personal debts	1. Excellent Infrastructure, Multiple mills waiting for proper connectivity

Table 18: Table of unique site-specific opportunities and challenges present at our survey sites.

First, quality of electricity services, such as availability and reliability, are required to support additional anchor customers. That said, an MHP requires steady anchor customers to provide the revenue stream required to generate consistent electricity. While this may appear to be a circular cause and effect dilemma, if the social negative influences described in Table 18 are addressed, more anchor customers can be encouraged to subscribe to electricity. Further, it is highly advised that operators be educated regarding the capabilities of the generators, especially the fact that they are designed to run 24×7. In most cases, the employment of 4 operators to a site can allow for round-the clock generation, causing a potentially large increase in revenue.

This leads us to the second social aspect that is unique to each site - none of their negative influences are insurmountable. The following are ways that some of these issues unique to these sites can be addressed:

Site 2 suffers from rates beyond the average community members affordability, and Site 3 loses most of its revenue to an extravagantly cheap monthly bill. Other sections of the report have highlighted how standardization of revenue rates commensurate to community earning is necessary. It has been previously noted that allowing a community enabler respected by the community to broach the topic of tariff standardization might be advisable. This is especially true in case of these two sites.

Site 5 displays an acute fear of electrocution. This is also the site that boasts an actual market, which could be a very large potential revenue source. Fear of electrocution keeps a significant portion of entrepreneurs from subscribing to a connection. Education drives about safe practices, and benefits regarding electricity can change the village's overall outlook.

Site 6, unfortunately, faces technical issues that are not as easily addressed. However, as discussed above, visits to communities where leaders lead by example might encourage leaders there to be more effective.

6.5.0 Out-of-Community Anchor Customer

6.5.1 Introduction

Another possible solution to problems posed by the unfeasible financial situation is a partnership with an out-of-community entity with high electricity demand. Large consumers offer consistent demand for electricity, acting as a stabilizing force for the micro-hydro plant by providing consistent dividends in exchange for electrical generation. Though anchor companies are usually businesses, non-governmental organization interaction, inter-governmental organization funding, and government support can also provide unorthodox platforms for anchor tenants. For example, it is possible to partner with non-governmental organizations to bring equipment to villages that could transform non-anchor entities into anchor consumers. This idea is discussed more in the "Small Infrastructure" section below. It is also important to note that, as with every recommendation in this report, an out-of-community partner will not represent a feasible solution to financing problems for all micro-hydro plants. However, they are potentially useful for some locations providing consistent and profitable electrical consumption.

External anchor customers align with the first step of the ABC development financing process. While it is most convenient to confirm the participation of such a large electricity consumer in the early stages of construction, it is also possible to attract a major consumer of electricity after a plant is operational. For many communities in Nepal, this could address multiple community problems simultaneously. For example, anchor customers could address needs like healthcare, education, and cell phone service while providing a consistent demand for electricity that would bolster micro-hydro plants.

6.5.2 Small Infrastructure

Importantly, an out-of-community anchor customer is one that does not have a presence in a community prior to its association with a micro-hydro plant. This offers a stark contrast to existing potential anchor tenants in a community, who can range from small business owners and potential entrepreneurs to existing schools or health clinics. If a village is lacking any of the potential anchor facilities listed above, those facilities could instead act as out-of-community anchor tenants. This could require further government investment (for example, building a school), but it could also be spurred by partnerships with NGOs or businesses. Examples includes NGOs that supply computer equipment to schools and organizations that focus on creating rural health clinics.

Any partnership acting as an external anchor tenant would demand high quantities and quality of electricity in relation to households in the rural Himalayas, in addition to offering a vital service that benefits the entire community. Education could be an especially compelling tool for electrification. The project team discovered that households desired electricity for education more than any other reason besides lighting in general, as shown in Figure 19. With the addition of computers, which admittedly would likely require further government investment if a partner NGO could not be identified, schools could act as stabilizing forces for micro-hydro plants while providing the community with its most-desired service - an opportunity for children to pursue endeavors outside of subsistence agriculture.

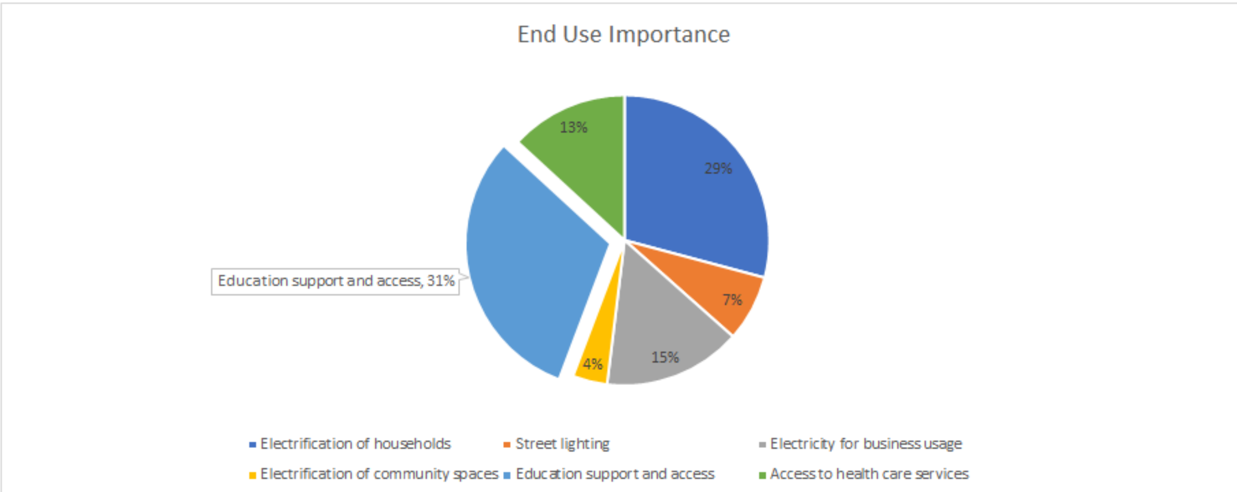


Figure 19: Desired End Use of Electricity.

Unfortunately, where partnerships fall through government investment can be a difficult proposition. That said, a subsidy housed at the Ministry of Energy or Ministry of Education could offer the opportunity for the spread of computers in rural areas. Equally, energy-oriented international private donors like Engie or the Shell corporation could offer grants that could help provide large consumers of electricity to villages in a less traditional manner.

6.5.3 Large Infrastructure

Another type of anchor tenet is a large organization like a telecom company, which would demand substantial and consistent electricity with the added benefit of infrastructure build-out. For example, a large communication company like NCell can construct regional cell towers near micro-hydro plants with the capacity to support them. Though this model may not be applicable in every scenario, in the locales where major infrastructure would make sense it could be a highly useful catalyst. For example, locations with high population densities and minimal existing cellular coverage could offer high-benefit locations for cell towers. Those towers would then serve as a customer willing to purchase substantial, consistent quantities of electricity from micro-hydro plants.

This strategy is not without risk, as we saw in Site 4. Through surveys of community members, leaders, and plant operators, the project team was able to identify a critical potential issue with high-demand industrial electricity consumers. In that community, a telecom company promised to purchase electricity from the micro-hydro plant in a deal that required the community to offer labor to build the cell tower. Members of the village worked without pay to erect the cell tower, but once constructed the company refused to purchase electricity from the local microgrid, opting instead to input their own solar on-site unless the village covered the cost of connectivity. The situation came to pass because of a change in leadership on the side of the telecommunication company, but with little leverage, members of the community were left without recourse. While they do benefit from the improved cell coverage, their micro-hydro plant remains in a state of flux without the promised consistent electricity demand and necessary financial support to operate stably.

It is important that there is some guidance to bind both sides of an agreement with an external tenant to their respective commitments. That guidance could be provided by AEPC's central office in Kathmandu. However, it would likely best be completed by utilizing a predetermined clearing house that would match potential out-of-community entities to appropriate villages. Once those two groups were matched, responsibility could be turned over to the individuals living within each respective community to complete the project. Importantly, AEPC would likely provide high-level guidance to that clearing house so that fairness would be ensured throughout the entirety of the process.

6.6.0 Role of Microfinance in Micro-Hydro Plant Sustainability

Microfinancing can help solve both the supply and demand problems associated with minigrids' continued operations. There is low demand for electricity because there is no supply of capital for people to buy equipment that uses electricity. As background, microfinancing is the act of loaning small amounts of money to individuals that are not traditionally served by larger banks or have access to traditional loans. It fits well into the framework of having in-community anchors, as described above. Microfinance provides a relatively small quantity and low-cost initial capital strategy, which provides the money needed for community members to utilize electricity for productive uses (Bhattacharyya, 2013). This in turn generates revenue that people can use to pay for electricity, which provides the micro-hydro plant with dependable cash flow, potentially starting a positive feedback loop.

The supply issue can be defined as a lack of accessible capital in the form of loans. Larger financial institutions do not have access to the communities and the government is not in the business of loaning money. Therefore, smaller inputs of money are needed. Additionally, patient capital is needed because the payback periods tend to be longer due to the low interest rates. Village Development Funds (VDFs) are one available scheme to foster microfinancing.

Pact, a non-governmental organization (NGO), has had tremendous success in establishing Village Development Funds to serve people that receive electricity from minigrids (Harrison & Matthew, 2018). Pact is an non-profit international development organization that seeks to improve lives through systematic changes across a variety of impact areas including health, governance, and capacity development. In their methodology, VDFs are run by the Village Development Committees (VDC). The VDFs is essentially a grant matching program. Specifically, the money-making process begins when the VDC internally generates $50-200, which Pact then matches. The VDC lends that money to community members at an interest rate that is catered specifically to each affected community. The interest gains are reinvested in other projects, thereby increasing the fund (Reilly, 2018).

AEPC should consider a similar scheme in which the existing VDCs that oversee the micro-hydro plants act a microfinancing institution through the use of a VDF. The community members can pool their resources or use revenue from the existing micro-hydro plant to create a fund.

Bilateral donor funds channeled through AEPC or a third party could be used to match the VDC investment. This should ideally be included in the Concept Note that AEPC distributes to NGO's across the globe when seeking funding. It is important to understand that microfinancing mechanisms such as this are a combination of public and private input. The government has to establish policies and regulations that enable the private funding. Further, although the fund ought to be used to encourage consumption of electricity, it also could act as a contingency fund for community members in the case of emergency. This has been utilized well at the Site 1 Micro-Hydro Plant, as outlined in the Site 1 case study included in this report. It is something to consider as possibilities with funding by microfinance - a diverse portfolio attracts more customers, and therefore increases the accessible pool of money.

As illustrated in Figure 20 below, almost half of the community members surveyed in Nepal self-identified as entrepreneurs (though it is important to note that the respondents were not randomly sampled). Even further, as the graph in Figure 21 shows, the income of the villagers varies, and in many cases does not generate sufficient cash to purchase appliances. These two charts demonstrate that there is potential demand for loans from entrepreneurs that do not have very high income. The loans can be used to expand a variety of businesses by people that already have their own small business, or to inspire people that are interested in starting a business to generate income and provide a good or service to their community. For example, many surveyed community members indicated that education was important to them. In light of that insight, an entrepreneur could take out a loan to buy a computer and software and then charge people in the village to use the computer. This provides both a benefit to the community members and a source of revenue for the computer owner, who then can pay the electricity bill that will be used to keep the micro-hydro plant operational.

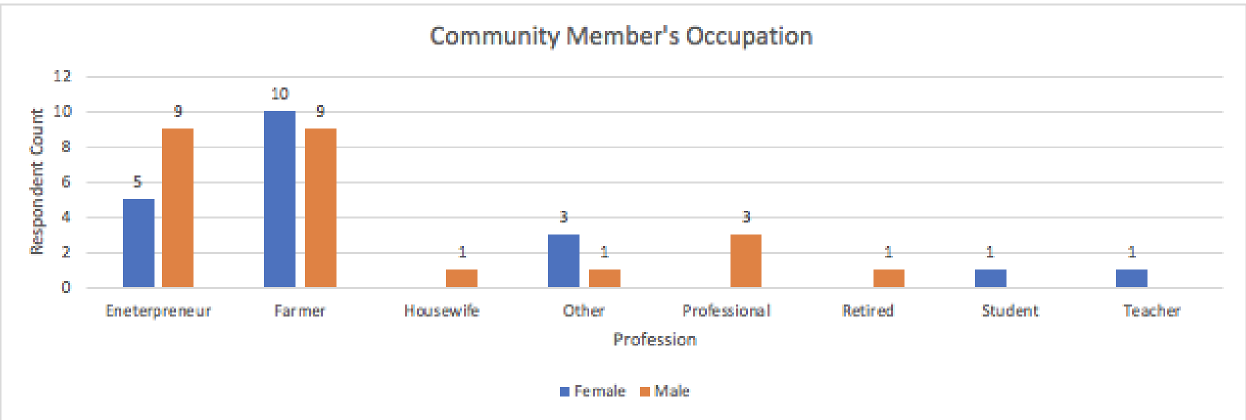


Figure 20: Community members are mainly entrepreneurs and farmers.

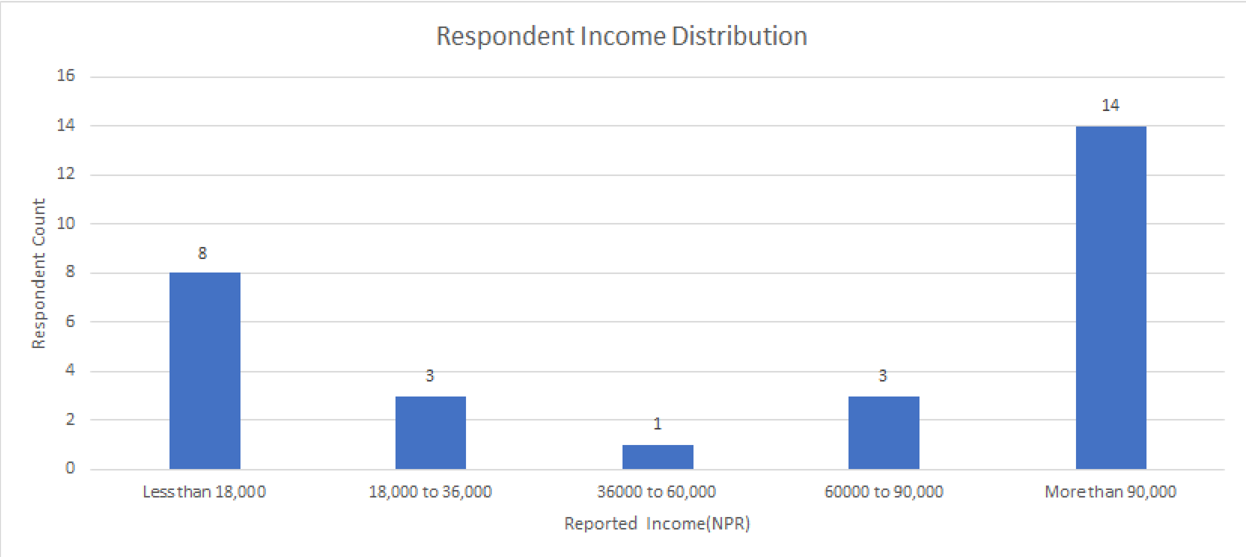


Figure 21: Income levels vary across community members surveyed.

The demand issue can be defined as a lack of productive uses for electricity due to a dearth of household appliances and larger-scale tools. In other words, there is little demand for electricity because they don't have a need for it. This result is that people are not using and/or paying for electricity, which inhibits the sustainability of the micro-hydro plant.

Microfinancing can be used to increase the demand and consumer base of electricity by providing capital for people to purchase appliances and equipment (Bhattacharyya, 2013). It is not enough just to install the generating asset, there must be mechanisms in which community members can invest in electrical equipment that will enable them to initiate a revenue producing endeavor. As can be seen in Figure 22, villagers have mobile phones and light bulbs, but not equipment that is helpful to running a business and making money. People are innovative, they just need a framework that enables them to have access to capital so they can get the tools that will enable them to create businesses.

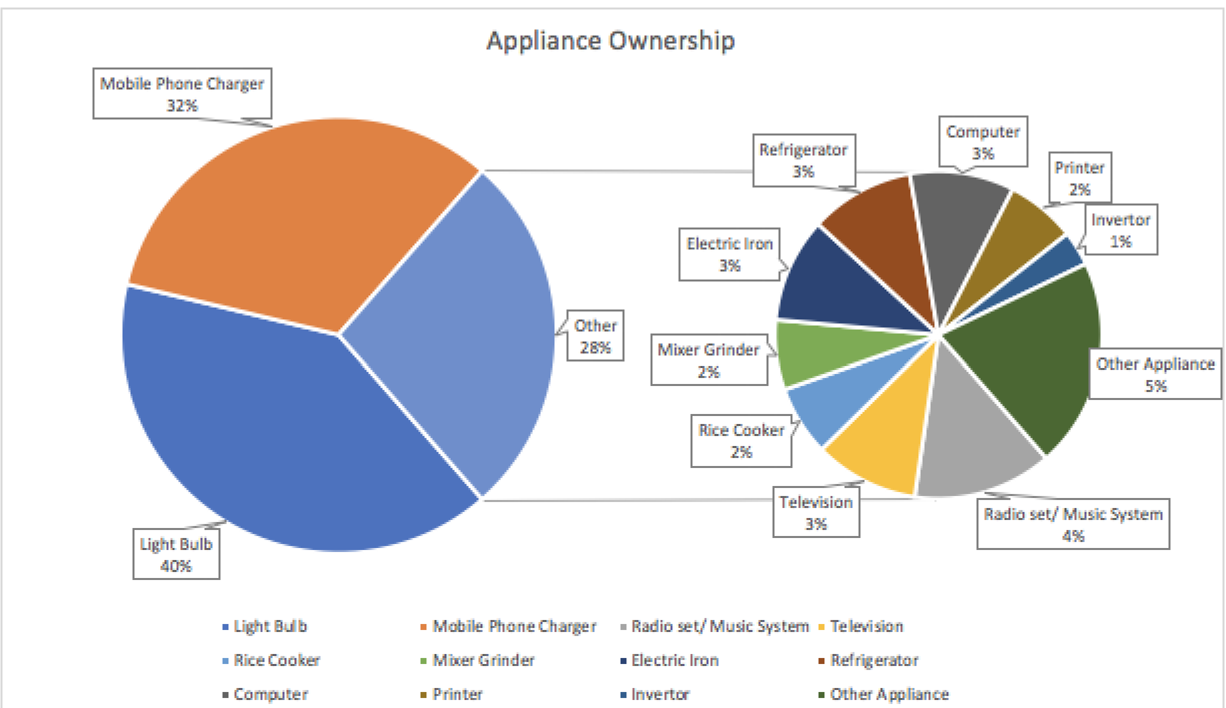


Figure 22: Community members tend to have light bulbs and/or mobile phone chargers, only a few have other appliances.

6.7.0 Suggestions for the Future

6.7.1 Leveraging Grants and Low-Interest Funds

Some financing options exist from the international community to support micro-hydro plants and similar energy access projects, but successful funding proposals in Nepal has been limited in the past. As part of their updated priorities, the United Nations Sustainable Development Goals (SDGs) now include universal energy access for all. Its mission is ambitious, and it is unanimously agreed from the global community that "it's going to take more than business as usual" (The World Bank, 2015). That said, the decision to pursue the goal opens up many avenues through collaboration amongst governments, the private sector, civil society, multilateral development institutions, and international financing institutions. Even with mixed results from proposals in the past, the new additions to the SDGs should further improve the odds of receiving grants for MHP development and operation. Nepal has a strong partnership with the United Nations, especially through the REDP, and continue collaboration is crucial to the success of micro-hydro plants in the country.

Development funds have been used to implement a wide array of activities, including initial installation of micro-hydro plants, developmental and environmental activities, capacity development, enterprise development, local participation and social inclusion, and standardization and quality management (United Nations Development Programme, 2012). While all these factors are paramount during the initial phases of the program, when the priority is to foster adoption and momentum, a focused approach is required to sustain long-term operation of micro-hydro plants. As these micro-hydro plants mature, location specific issues arise. Therefore, it is advisable to have site and activity specific focus when allocating funds rather than allocating funds broadly.

According to findings outlined in section 5.6.4, the inability to carry out routine maintenance appear to be a main cause in plant failures. Especially evident during and shortly after monsoon season, the lack of an adequate funding reserve to supply crucial repairs contributes to prolonged plant downtime. This in turn exacerbates the distrust of the quality and reliability of the electricity supply and hinders the community's trust in the plant's reputation, an aspect that is crucial in developing partnerships with in- and out-of-community anchor customers.

As such, international funds and grants should be used to complement revenue collection from customers. It is not advisable for micro-hydro plants to solely rely on grants and debt instruments to sustain long-term operation. Defining an affordable yet adequate electricity tariff is fundamental as micro-hydro plants serve the "bottom-of-the-pyramid" customers. In cases where the community may not be able to afford to pay the amount required to offset operational costs, grants and low-interest funds help fill that gap to sustain long-term optimum plant performance.

6.7.2 Rate Structure Recommendation

Determining a rate structure that is both affordable and adequate is a special challenge in the energy access sector. A careful balance is required that considers the community's ability to pay while keeping in mind the financial costs of continued operations and maintenance, which continues to be a challenge for many micro-hydro plants.

A common way to structure electricity rates is to set the price at a rate that at least offsets the cost of producing electricity, otherwise known as the levelized cost of electricity. This metric considers capital costs, fuel costs, fixed and variable operations and maintenance costs, and financing costs (U.S. Energy Information Administration, 2018). Revenue should cover operation costs while still generating sufficient surplus for major repair events to avoid unsatisfactory plant performance that would otherwise stagger public trust and productive uses. The micro-hydro plants do not require fuel to be purchased, which is one of the reasons they are attractive.

In order to set rates, micro-hydro plant operators must do two things: adopt standard accounting practices and establish a consistent way to measure electricity usage. Standardized accounting will enable operators to understand the plant's expenses and revenues, capturing vital financial information at any given time. This can be done on paper or electronically via a computer. It should be kept up-to-date and shared with the community enabler for each site. In order to be transparent and determine reasonable rates, the electrical demand must also be measured. This is typically done through metering at the household level. When metering is not a viable option, the load and quantity of appliances can be used in conjunction with an estimate of the number of operating hours to determine a general calculation of peak loads and rate.

Without complete information about electricity supply and demand, it is difficult to determine the tariff rate for each residential and commercial consumer structure. According to the surveys, the current tariffs for electricity varies widely across villages, from 0.05 NPR/kWh to 10 NPR/kWh. Not surprisingly, the village that is charging 0.05 NPR/kWh is unable to sustain micro-hydro plant operations. Conversely, some villages are charging rates that the local community members cannot afford for a prolonged period. In many cases, these rates are set almost on a whim, without proper accounting and data to support the rates.

The rate structure should exist in tiers that best serves the micro-hydro plant's customers. When possible, power purchase agreements (PPAs) should be set-up with out-of- and in-community anchor customers to guarantee a consistent revenue stream that directly offsets costs associated with operating and maintenance. Different tariff schemes should be set-up for small businesses and residential based electricity load and ability to pay. However, rate structure can only be set-up given sufficient available data. In many cases, this remains a notable hurdle. Though we recognize the oversimplification, it is recommended to start off with a basic single rate structure at a fair cost for the village it serves. During this time, data -- generation, demand, and load curves -- should be collected and calculated before refining into a more complex, tiered structure. Generally, tariffs for residential consumers should be prioritized based on a fair cost, while electricity prices businesses should prioritize with recovering the costs necessary to continue plant operations and future upgrades and expansions.

6.7.3 International Renewable Energy Credits

An institutionalized system of renewable energy credits (RECs) in the United States, and similar mechanisms in the European Union and other industrialized nations, establish market-based tracking and trading systems for energy generation from renewable resources. In general, RECs represent 1 megawatt-hour of electricity produced from a renewable resource. Tightly regulated tracking systems ensures that each megawatt-hour is not double counted before it is traded or sold. In the United States, RECs are used to track renewable energy from the point of generation (National Renewable Energy Laboratory, 2015). Consumers, like large corporations, can then purchase RECs to meet their sustainability goals and substantiate claims about their commitment to the environmental movement. In the context of micro-hydro plants, RECs can offer an additional important revenue stream.

The creation of RECs splits electricity produced from a renewable source such as micro-hydro facilities into two separate revenue streams: environmental and electricity (Roberts, 2015). It's important to clarify that RECs are different from the actual sale of electricity produced. RECs represent a different commodity -- the social and environmental benefits of traditionally one MWH of clean electricity. Therefore, regardless of where the RECs are produced, consumers who purchased the REC can make claims of the environmental and social additionality. RECs are essentially the proof of carbon neutral energy generation.

International renewable energy credits (I-RECs) is a standardized system of tracking and trading across multi-national borders that is in place in many countries where a nationally formalized system does not exist. Overseen by the International REC Standard organization, an impressive and growing number of countries have joined the list. As of January 2019, 24 countries, including some of Nepal's neighbors - China, India, and Vietnam – are participating in the I-REC tracking system (The International REC Standard, 2019). Approval to the I-REC is subject to strict standard control. Although a handful of MHP meet that accounting and tracking standards recommended by I-REC, a majority does not.

The I-REC system creates an incentive for villages in Nepal with micro-hydro plants to set up and monitor the renewable energy production to conform to the standards of I-RECs. Understandably, this can be difficult, especially because most of the plants are located in remote and isolated regions. The tracking of electricity production that is in the I-REC scheme is audited by a third party, further reinforcing the need for clear guidelines to manage electricity data from individual micro-hydro plants. That said, consensus is that, "in emerging markets with no active or credible ability to track and trade ownership of renewable claims -- such as those in developing countries -- RECs provide an enormous value" (Powers & Haddon, 2017).

Commercial interest for procurement of clean energy is at an all-time high. This can be seen in the rapid growth of the I-REC market, where the total units of registered devices has grown by 720% from 20 in 2015 to 164 in 2018. Together, they make up 11,698 MW of capacity (The International REC Standard, 2018). For context, as of 2016, Nepal has a installed micro-hydro capacity of 23 MW (Acharya & Bajracharya, 2013). Nepal's installed capacity is comparable to other similarly size countries like Taiwan (which is taking advantage of the opportunities provided by the global green movement). With new additions coming online, registration to I-REC is an attractive method of supporting the success of these plants.

With an abundance of hydropower, Nepal holds tremendous potential to thrive in the I-REC market. However, the country's absence from the registry list can be explained by the lack of accurate accounting and record keeping of electricity generation. The I-REC Standard Organization upholds a strict protocol in its accounting to ensure that each megawatt-hour of clean energy is accurately entered to prevent double-counting when traded. To qualify for I-RECs, national micro-hydro plant and off-grid electricity standards and subsequent enforcement to uphold them is encouraged. Enforcing standards has multiple benefits, including not just meeting the requirements of I-REC but also providing insights to the supply and demand of electricity. It also facilitates the ability to identify priorities that will make the largest impact in MHP operations. The importance of accurate accounting and record keeping cannot be stressed enough.

	Devices					MW Capacity				
	2015	2016	2017	2018	Total	Wind	Hydro	Solar	Biomass	Other
Brazil		2	14	32	48	993	2173	5	110	
Chile			1	1	2		450		26	
China	5	20	13	1	39	1648	145	323	60	
Colombia		4	3	0	7	20	2010			
Guatemala			4	0	4		28	6		
Honduras		1	0	0	1			60		
India		2	1	0	3		230			
Israel			5	4	9			186		
Mexico		1	0	0	1			39		
Malaysia		3	1	0	4		5		23	
Philippines			2	3	5		42	72		692
Singapore		1	1	0	2				14	
Spain	12	X	X	X	12		1760			
South Africa		1	1	0	2		2	50		
Thailand		1	3	2	6			32	9	8
Turkey	1	0	2	0	3	56	48			
Taiwan	1	2	1	0	4		39			
Uganda		1	0	0	1		6			
UAE			1	1	2			213		
Vietnam	1	4	1	3	9		114			
Total	20	43	54	47		2717	7052	986	242	700
Cumulative	20	63	117	164						

Figure 23: Growth of power production devices and capacity registered to the International Renewable Energy Credit Standard Organization (The International REC Standard, 2018).

RECs are the only globalized way that an electricity consumer, residential or commercial, can claim and prove that it is using clean power. Nepal's potential future participation in the I-REC market not only would create an additional much-needed revenue stream to sustain micro-hydro plants, but also would attract an international focus to its humanitarian and environmental efforts. Buyers who want to make environmental claims and meet their sustainability and carbon emissions reduction goals must rely on RECs worldwide. Promisingly, the continued momentum of desiring renewable energy tends to increase the value of RECs as the market matures. An additional source of revenue also creates a buffer for unforeseeable operations costs and will incentivize underpaid workers with adequate compensation. Surplus profits can also theoretically further enable micro-hydro plants to act as a microfinance institution that directly benefits the surrounding community. With its ambitious green program and abundant natural resources, Nepal is in a unique position to harness the explosive demand of the I-REC market to repair and expand existing micro-hydro plants and to finance new installations if they are able to improve record keeping practices.

6.8.0 MHP as an Enterprise Asset Report Conclusion

The lack of record keeping remains a fundamental challenge in micro-hydro plant operation. It is the bedrock for the long-term success of plant operations. Recommendations needs to be based on factual evidence, and without essential and accurate information regarding each plant's specifications, productions, and other operation metric, this is all but impossible. Accurate bookkeeping and accounting cannot be stressed enough, as they open up channels to explore financial options from both the central government of Nepal and the international community.

Although there are a few avenues from which micro-hydro plant and their overseeing committees can choose, it is important to note that the key issues are site specific and require a tailored list recommendation in making large-scale decisions. However, internal and external anchor customers should remain a priority on the list. In the realm of energy access, they are considered a vital part of the privatization of energy projects – a direction that AEPC is interested in heading for its micro-hydro plant fleet across rural Nepal. Anchor customers provide a consistent demand for electricity supply in which the micro-hydro plant can capitalize on. The revenue from anchor customers cannot be understated as it is easy to estimate, hedges against supply and demand risks, and provides a guaranteed source of money for operations.

Microfinancing as a method to stimulate the local community's economy can also be explored. In Site 1, this proved to be a successful endeavor as the committee that oversees the micro-hydro plant operations has set-up a microfinance initiative that allows villagers to borrow money to purchase business equipment and electronics. The benefit of setting up a microfinancing institution through micro-hydro plant operation is two-fold. It allows drives the surrounding community's entrepreneur spirit, and as more businesses and villagers purchase electronic equipment, more demand for electricity is created. The increasing demand for electricity and the expansion of local business can motivate maximum operation of the micro-hydro plant, minimizing plant downtime.

Of the avenues that micro-hydro plants can choose from to support operations, it is worth noting that each situation is unique due to geographical, cultural, and economic sensitivities. Though broader, scalable solution can be extrapolated, they must be tailored specifically to overcome individual challenges and exploit novel opportunities each site possesses. For example, the success of Site 1 is in part due to its relatively convenient location, which allows maintenance supply to arrive quickly in the case of malfunction. It also boasts a relatively high number of trained staffs, and a host of other advantages not exhibited in other sites that we surveyed. These recommendations are meant to be considered as broad guiding principles in which tailor-made, specific solutions can be later derived after more extensive village-level investigation.

7.0 Recommendations

In light of the findings from field surveys, anecdotes during site visits, literature reviews, and technical analysis, we have identified three high-level reasons why some micro-hydro plants are failing or on the brink of failing and propose here six broad recommendations that can be implemented in the future to ensure long term viability of the assets. The three main reasons for micro-hydro plant failure are:

1. Lack of revenue
2. Inconsistent electricity production
3. Poor communication

In order to remedy these issues, we recommend the following improvements:

1. Clear and consistent tariff structures
2. Standardized and accessible bookkeeping
3. A heightened role for Community Enablers
4. Increased training for plant operators

5. Substantial effort to support adoption of internal and external anchor customers
6. Microfinancing options available for community members.

Clear and consistent tariffs for electricity usage and microgrid connection address the issue of the lack of revenue, which in turn supports electricity production. Currently, the rate structures vary greatly across communities, are seemingly set at random, and are not enforced to any degree of consistency. It is interesting to note that sometimes people do not want to pay for electricity because the availability is intermittent. This seemingly circular problem can be resolved by implementing rates that are affordable, clearly communicated, and enforced. If consumers pay consistently for electricity, the plant operators can pay for maintenance and spare parts as well as receive a salary.

Accurate data is vital to understanding the current situation, and consequently to develop effective solutions. Without accurate bookkeeping, it is very hard to know how much electricity the plants are producing, if the assets are profitable, and if community members are paying for electricity. Record keeping addresses in part the issue of poor communication as well. It is recommended that AEPC develop a standardized system of recording keeping for all sites that they can then follow within their community management structures. Standardization will enable efficient data analysis and faster response times as issues arise. Community enablers can bring this organized information to AEPC in Kathmandu, where it will then be easier to process.

Community enablers from AEPC should act as liaisons to communities as the governmental organization standardizes solutions and works on managing plant improvements. As the enablers travel amongst micro-hydro sites, they can help solve the problems relating to poor communication, inconsistent electricity production, and even lack of revenue. The enablers are the key to implementing recommendations, as they can develop personal relationships with people living in rural villages and therefore are well-respected. We cannot emphasize enough how important their role can be in shaping a more successful future for micro-hydro in Nepal. The community enablers can increase electricity production from the plants by both educating the operators on best practices for operations and maintenance as well as by bringing needed spare parts and supplies. Many of the run-of-the-river turbines are in very remote areas of Nepal, and therefore hard to access. This makes it challenging to get spare parts quickly, but if the community enabler frequently visits the sites, he or she can bring the needed equipment. Community enablers foster communication both between villages and AEPC and within a given village. Some of the new ideas that the community enablers can share from one village to another include successful structures of micro-hydro plant committees, appropriate tariff rates, and varied microfinancing strategies.

Training micro-hydro plant operators is essential in order to maintain asset longevity. If the operators understand neither how the system is meant to function nor how to properly maintain and fix it, the plant will operate at a much lower capacity factor. Ensuring the plant is run properly will address the issues of lack of production and low revenue. At most sites, people pay for electricity based on consumption, and so when production is low, people do not have the ability to use a lot of electricity and plant income is smaller than it could be. Due to the fact that the fuel for generation, in this case running water, is free, there is essentially no marginal cost to running the plant for more hours. It is worth noting too that at the six sites the Project Team visited, each of the generators was rated for 24/7 operation. Ensuring the plant operators are well trained and aware of these basic facts has the potential to reduce plant downtime, thereby increasing electricity production and revenue.

Encouraging internal or external anchor consumers will improve the viability of the plants in both the short and long-term. The main benefits these anchor customers provide to the micro-grid is they demand consistent electricity and therefore guarantee consistent revenue streams for the plant. The main benefit for the community at large is that the anchor customers provide a service or good that otherwise is unattainable. An internal anchor consumer that starts a business that utilizes electricity provides a source of income that was not possible without the micro-hydro plant. This business can benefit the well-being of the community and improve the standards of living.

Microfinancing can address both the supply and demand issues currently hindering the sustainability of rural micro-hydro plants. At some sites, there is not enough demand for electricity simply because people do not have appliances or electronics that use electricity. Due to low or non-existent incomes, community members need assistance purchasing appliances. Microfinancing can provide the necessary capital needed to purchase equipment. The new assets will increase demand of electricity, which will in turn cause the operators to run the plants more and supply their communities with power.

The current situation in the villages in relation to micro-hydro plants is varied and complex, which means the solutions should be adopted to varying degrees at each site. Addressing the issues of revenue generation, unreliable electricity production, and lack of communication will ensure long-term sustainability of the micro-hydro plants in Nepal which will enable rural communities to reap the many benefits that come with having access to electricity.

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Appendix

A.1.0 Micro-Hydro Plant Operator/Engineer Survey Questionnaire

Identification

Household Number	
District	
VDC/Ward	
Village	
Name of Enumerator	
Name of Supervisor	
Date	
Site Number	
Questionnaire Number	

1.0 Personal Data

1.1 Profile

Name/Title	
Age	
Sex	
Main Occupation	
Education	
Mother Tongue	

2.0 Pre-Existing Survey Results:

(If AEPC has these surveys at HQ, this section may be removed)

2.1. Are Results of a 'Demand Survey' available for this plant? A. Yes B. No	**2.2. Are Results of a 'Hydrology Survey' available for this plant?** A. Yes B. No
2.3. Are Results of a 'Pre-Feasibility Survey' available for this plant? A. Yes B. No	**2.4 Are Results of a 'Operation and Maintenance Study' available for this plant?** A. Yes B. No
2.5. Are Results of a 'Electricity Cost Study' available for this plant? A. Yes B. No	**2.6 Does this plaint maintain a 'Cost Sheet'?** A. Yes B. No
2.7 Does this plaint maintain a 'Revenue Sheet'? A. Yes B. No	

3.0 MHP status and Generic Specifications

3.1 Is this MHP considered successful? If so, what aspects would you contribute the success to: Social [ ] Technical [ ] Economic [ ] Environmental [ ] Policy [ ]	
3.2 Is this MHP considered a failure? If so, what aspects would you contribute the success to: Social [ ] Technical [ ] Economic [ ] Environmental [ ] Policy [ ]	
3.3 What is the MHP Generation Capacity(kWh) on paper? A. Value:____________________ B. Do not know C. Professional Observation: ____________________	**3.4 What is the Predicted Capacity factor(Unitless) of the MHP?** A. Value: ____________________ B. Do not know C. Professional Observation: ____________________
3.5 What is the Present-day Capacity Factor(Unitless) of the MHP? A. Value:____________________ B. Do not know C. Professional Observation: ____________________	**3.6 What is the head (height that the water drops) of water in meters?** A. Value:____________________ B. Do not know C. Professional Observation: ____________________
3.7 What is the Flow Rate (m^3/sec) of harnessed water for the MHP? A. Value:____________________ B. Do not know C. Professional Observation: ____________________	**3.8 What is the current-day estimated efficiency (unitless) of the MHP?** A. Value:____________________ B. Do not know C. Professional Observation: ____________________
3.9 What was the gross predicted load(kWh) for the MHP at completion? A. Value:____________________	**3.10 What is the present-day load(kWh) for the MHP?** A. Value:____________________

B. Do not know C. Professional Observation: ______________________________	B. Do not know C. Professional Observation: ______________________________

4.0 Operations and Management

4.1 What were the predicted O&M costs(NPR) on completion of the MHP? A. Value: ______________________________ B. Do not know C. Professional Observation: ______________________________
4.2 What are the present-day O&M costs(NPR) of the MHP? A. Value: ______________________________ B. Do not know C. Professional Observation: ______________________________
4.3 Is there any contingency fund(NPR) available for O&M? A. Yes, Value: ______________________________ B. No C. Professional Observation: ______________________________

5.0 Management Structure

5.1 In case of needs of water other than the MHP, Is there integrated management structure? A. Yes [ ] B. No [ ]
5.2 How is conflict resolution done in drought periods in case of multiple water resource requirement? A. Observation: ______________________________

6.0 Governor Specifications

6.1 What are the frequency sensitive loads on the system? A. Load 1: ______________________________ B. Load 2: ______________________________ C. Load 3: ______________________________ D. Load 4: ______________________________ E. Load 5: ______________________________	**6.2 Among the loads mentioned above, can you identify the load with the least tolerance? What % change might it allow?** A. Value: ______________________________ B. Do not Know C. Professional Observation: ______________________________
6.3 What are the voltage sensitive loads? A. Load 1: ______________________________	**6.4 Among the loads mentioned above, can you identify the load with the least tolerance? What % change might it allow?**

B. Load 2: ______ C. Load 3: ______ D. Load 4: ______ E. Load 5: ______	A. Value: ______ B. Do not Know C. Professional Observation: ______
6.5 What kind of governor is used to ensure tolerance is achieved? A. Value: ______ B. Do not Know C. Professional Observation: ______	**6.6 How much tolerance does the Governor Allow(%)?** A. Value: ______ B. Do not Know C. Professional Observation: ______
6.7 What are the repair costs for the governor device? A. Value: ______ B. Do not Know C. Professional Observation: ______	

7.0 Supply System

7.1 Is the Supply System: AC or DC?	A. Yes [ ] B. No [ ]
7.2 If the Supply System System is less than <10kW and AC, what are the justifications for such a system? A. Professional Observation: ______	**7.3 If the Supply System System is less than >10kW and DC, what are the justifications for such a system?** A. Professional Observation: ______
7.4 What kind of generator does the Supply System Use? A. Synchronous B. Asynchronous C. Professional Observation: ______	**7.5 In case of AC: Single Phase or 3 Phase?** A. Single B. Three C. Professional Observation: ______
7.6 What Kind of Voltage Regulation does the supply system Make use of? A. Professional Observation: ______	**7.7 What Kind of Switching gear does the supply system Make use of?** A. Professional Observation: ______
7.8 What Kind of Electronic Load Controller does the supply system Make use of? A. Professional Observation: ______	**7.9 Are you aware of the load(kWh) per branch of the 3-phase system?** A. Phase 1: ______

	B. Phase 2: ____ 3. Phase 3: ____
7.10 What are the inductive (VAR) loads on the system? A. Load 1:_________Value(VAR)_____________ B. Load 2:_________Value(VAR)_____________ C. Load 3:_________Value(VAR)_____________ D. Load 4:_________Value(VAR)_____________ E. Load 5:_________Value(VAR)_____________	**7.11 What are the Resistive (W) loads on the system?** A. Load 1:_________Value(W)_____________ B. Load 2:_________Value(W)_____________ C. Load 3:_________Value(W)_____________ D. Load 4:_________Value(W)_____________ E. Load 5:_________Value(W)_____________
7.12 Is there any technical load efficiency curve available for generators? A. Yes [ ] B. No [ ]	

8.0 Transmission System

8.1 Is the transmission-system HV or LV? A. HV [ ] B. LV [ ]	**8.2 If the Transmission System is LV, what are the justifications for such a system?** A. Professional Observation: ____
8.3 What is the overall length of the transmission system? A. Value: ____ B. Do not Know C. Professional Observation: ____	**8.3 How much are transmission losses?** A. Value: ____ B. Do not Know C. Professional Observation: ____
8.3 How much variation of voltage from no load to full load does the transmission system allow? A. Value: ____ B. Do not Know C. Professional Observation: ____	

9.0 Overall System Maintenance Details

	How often Does routine maintenance Occur?	How often Does any malfunction occur?	What would be the period be in case of natural wear and tear?	In case of malfunction, what's the most common cause?	What is the usual repair cost in case of malfunction?
Penstock					
Weir & Intake					

Flood Control Gates					
Valves					
Joints					
Turbines					
Governor					
Drive System					
Generator					
Switchgear					
Transmission Lines					

A.2.0 Micro-Hydro Plant Community Leader Survey Questionnaire

Informed Consent

Thank you for your willingness to talk with me about electricity access in your community. My name is "Insert Name" and I am working as a member of a team based at Duke University in the United States studying the sustainability and effective use of electricity-generating micro-grids here in Nepal. We are interested in learning how people experience access to electricity here in "Insert Village Name." In particular, we are hoping to draw conclusions that could improve efficient use of electricity here. If you agree to take part in our study, I will ask you to talk with me about your experiences in the community with respect to electricity use and in particular the micro-hydro plant that provides electricity to your village. I will ask you different kinds of questions about what it is like to live in this community and how electricity affects the day-to-day life of community members. I will also ask you questions about the regulation and maintenance of the micro-hydro plant that powers the village. We can talk for as long as you like, but I expect our conversation will take about 30 minutes. If you find any question too personal or private, please let me know and we will skip that question. We hope our findings will help improve our knowledge and understanding of effective use of the micro-grids that provide electricity to your community and others like it. Please note that the data we derive from this research may be used by other researchers to inform their studies. We will not record your name anywhere in our reports. You can skip any question that you do not want to answer. You can also stop our interview at any time, for any reason. Your decision will in no way affect any of the services you and your family receive now or in the future. Please let me know if you have any questions for me at this time. For questions about this study, please contact our team through our advisor, Dr. Robyn Meeks, at robyn.meeks@duke.edu. For questions about your rights, please contact the Duke University research ethics committee at 919-684-3030 or campusirb@duke.edu. Please sign, initial, or note otherwise here to indicate that you understand the above explanation of consent and are willing to answer the questions we will ask in this survey:

____.

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Identification

Household Number	
District	
VDC/Ward	
Village	
Name of Enumerator	
Name of Supervisor	
Title/Role	
Date	
Site Number	
Questionnaire Number	

1.0 Personal Data

1.1. Profile

Person	
Age	
Sex	
Main Occupation	
Education	
Mother Tongue	

2.0 Household Data

2.1. What is your primary electricity source? A. NEA Grid B. Micro Hydro (10 to 100kW) C. Mini Hydro (> 100kW) D. Diesel generator E. Solar Home System F. Soar tuki/lantern G. Rechargeable batteries H. No electricity	**2.2. What is your primary cooking fuel source?** A. Gas B. Kerosene C. Firewood Chulha D. Charcoal E. Other: ____________________
2.3 What is your space heating primary fuel source? A. No space heating B. Gas C. Kerosene D. Firewood Chulha E. Charcoal F. Other: ____________________	**2.4 What is your yearly household income in NPR?** A. Less than 18,000 B. 18,000 to 36,000 C. 36000 to 60,000 D. 60000 to 90,000 E. More than 90,000

3.0 Project Design and Implementation

3.1 Were you involved in the design and implementation of the project? Yes [ ] No [ ]	
3.2 Did you personally provide any of the following for the Project? (Circle all that apply) A. Money B. Labor C. Supplies D. Other: ____________________ E. None of the above	**3.3 What was the primary goal of providing electricity of the Project?** A. Power homes B. Power for new businesses C. Power for existing businesses D. Health care services E. Education support and access F. Other: ____________________ G. Do not know
3.4 Were you involved in setting the goal of the Project? Yes [ ] No [ ]	
3.5 Who were the main stakeholders in the design and implementation of the Project? A. Community leaders B. Political leaders C. NGO D. Government agencies and representatives E. Other: ____________________ F. Do not know	**3.6 Who chose the location of the Project within your Village Development Committee (VDC)?** A. Community leaders B. Political leaders C. NGO D. Government agencies and representatives E. Do not know

3.7 Are rules in place that establish functions, power and responsibilities in the project? Yes [ ] No [ ]
3.8 If answered no to 3.7, skip to 3.9. If yes to 3.7, ask: Have community members asked to discuss and approve the rules that establish functions, power and responsibilities in the project? Yes [ ] No [ ]
3.9 Are you satisfied with the construction process, the location, and the maintenance procedures of the project? Yes [ ] No [ ]

3.10 What factors in the design and implementation of the project brought about the successes in the project? A. Peoples participation B. Sufficient funding C. Bottom approach of the project D. Wide consultation E. Other: _______________________________	**3.11 In your opinion, what is the most important use of electricity?** A. To power homes B. To power businesses C. To power new businesses D. To provide health care services E. To provide education support and access F. Other: _______________________________

3.12 Have you attended a workshop or meeting about using the electricity to power your home? Yes [ ] No [ ]
3.13 Have you attended a workshop or meeting about using the electricity to use for a business? Yes [ ] No [ ]

4.0 Access to Electricity Services for Lighting

4.1 Does everyone that gets electricity from the Project get electricity at the same time? Yes [ ] No [ ] Do not know [ ]
4.2 Is the distribution of electricity equal? Yes [ ] No [ ] Do not know [ ]

4.3 What determines how many hours per day you receive electricity? A. The amount of people using electricity B. The amount of water flowing in the river C. If the Project is operating correctly D. If the transmission lines are operating correctly E. Do not know F. Other: _______________________________	**4.4 In the past seven days how many hours on an average did you receive electricity supply?** A. Between 4 and 8 hours per day B. Between 4 and 8 hours per day C. Between 8 and 16 hours per day D. Between 16 and 23 hours per day E. Minimum of 23 hours F. Do not know
4.5 During what time of day do you expect to have access to electricity? (Mark all that apply) A. Early morning (4:00-7:00) B. Morning (7:00-11:00) C. Mid-day (11:00-13:00) D. Afternoon (13:00-16:00) E. Evening (16:00-19:00)	**4.6 How does your electricity supply and availability change during rainy and dry season?** A. More electricity is expected in the rainy season than the dry season B. More electricity is expected in dry season than the rainy season

F. Night (19:00-23:00) G. Middle of night (23:00-3:00) I. Never J. Do not know	C. The amount of electricity expected is the same in seasons D. Do not know

5.0 Reliability

5.1 On average, how often does load shedding occur? A. No load shedding B. Between 0 and 3 times per week C. Between 4 and 14 times per week D. More than 14 times per week E. Do not know	**5.2 On an average, how long was the duration of load shedding?** A. No load shedding B. Less than 2 hours in a week C. More than 2 hours per week D. Do not know
5.3 How often do you experience unplanned outages or breakdowns? A. Never B. Between 0 and 3 times per week C. Between 4 and 14 times per week D. More than 14 times per week E. Do not know	**5.4 On an average, how long is the duration of unplanned outages or breakdowns?** A. No unplanned outages or breakdowns B. Less than 2 hours in a week C. More than 2 hours per week D. Do not know
5.5 If the electricity supply is of bad quality, do you experience any of the following? (Circle all that apply) A. Economic losses from electricity blackout B. Appliance damage from unstable voltage C. Insecurity D. None of the above E. Other: ________________________________	**5.6 How long did it take to restore the service last time?** A. 1 day or less B. Between 1-7 days C. More than 7 days E. Do not know
5.7 Have you not been able to use any electrical equipment due to low voltage of supply? Yes [ ] No [ ]	
5.8 Has a low voltage resulted in damage of electrical appliances? Yes [ ] No [ ]	

6.0 Safety

6.1 Has there been any incidence of electrocution involving members of your community? Yes [ ] No [ ]
6.2 How risky do you feel it is using electricity in your home or business? A. I do not feel any risk B. I feel some risk C. I feel there is high risk
6.3 Has there been any fires started by the Project (at the plant and in the wires)?

Yes [ ]   No [ ]

7.0 Appliances

I will ask you six questions about each of the following appliances:

Item #	Item Description	7.1 Do you or any member of your household have... [item description]? [If no, skip to next item]	7.2 Approximately how old is it?	7.3 Does your household use it every month? [If no, SKIP to 7.6]	7.4 On average, how many days per month do you use it?	7.5 On average, how many hours per day does your household use it?	7.6 For what purpose do you it? [Choose one or both]
1	Light bulb	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
2	Mobile Phone Charger	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
3	Radio set/Music System	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
4	Television (TV)	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
5	Electric Fan	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
6	Rice Cooker	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
7	Mixer grinder	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
8	Electric Iron	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
9	Hair Drier	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]

10	Heater/hot plate for cooking	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
11	Toaster	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
12	Water Pump	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
13	Water Heater	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
14	Refrigerator	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
15	Computer	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
16	Printer	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
17	Air Conditioner	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
18	Microwave Over	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
19	Invertor	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
20	Washing Machine	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
21	Other: ______ ___________	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]

8.0 Access to Energy for Cooking

8.1 What cooking stove do you mainly use? A. Traditional 3-stone fire stove B. Traditional tripod stove C. Improved cooking stove with chimney D. Kerosene pressure stove E. LPG stove F. Electric stove G. None (no food cooked) H. Other: ________________________________	**8.2 What is the primary fuel you use in the cooking stove?** A. Firewood B. Biogas C. Dung D. Kerosene E. LPG F. Electricity G. Other: ________________________________
8.3 How do you obtain your main cooking fuel? A. Gather B. Purchase C. Produce at home	**8.4 How much time in a day does your household spend collecting (time it takes to acquire) cooking fuel?** A. Less than 15 minutes B. Less than 30 minutes C. Less than 1 hour D. Less than 3 hours E. More than 3 hours F. Do not know
8.5 If biofuel (circle one or both: firewood, dung) How much time in a day does your household spend collecting cooking fuel? A. Less than 15 minutes B. Less than 30 minutes C. Less than 1 hour D. Less than 3 hours E. More than 3 hours F. Do not know	

9.0 Satisfaction from Energy Use

9.1 Overall how satisfied are you with the electricity you receive from the Project? A. Satisfied B. Neutral C. Not satisfied D. Do not get electricity from the MHP	**9.2 Rank the following in order of importance to you (rank 1 to 6. 1 is most important).** A. [ ] Electrification of households (including household lighting) B. [ ] Street lighting C. [ ] Electricity for business usage

	D. [ ] Electrification of community spaces E. [ ] Education support and access F. [ ] Access to health care services
9.3 How much are you willing to pay for electricity per month if it were available 24 hours with sufficient voltage level? A. Less than RN ____________ per month B. Between RN ________ and_______ per month C. Greater than _________ per month	

10.0 Committee

10.1 Is there a committee or group formed to manage the Project (different than the plant manager)? Yes [ ] No [ ] Do not know [ ]	**10.2 How many members are in this committee?** A. Male: _________ B. Female: __________ C. Prefer not to identify
10.3 How often do the members in the committee meet? A. Once a week B. Once a month C. Once every six months D. Once a year E. Other: _________________________________	**10.4 Are notes (minutes) recorded during each meeting?** Yes [ ] No [ ] Do not know [ ]
10.5 How are the committee members chosen? A. Decided by village leader B. People volunteer C. Democratic process D. Random assignment E. Other: _________________________________	**10.6 How does the committee make decisions?** A. Vote B. Discussion C. One person decides. What is that person's title [not name]? _________________________________ D. Other: ________________________________

10.7 On average how long is a person in the committee? A. Less than one year B. One year C. 2 to 4 years D. More than 4 years	**10.8 Do you always have an opportunity to be involved in making decisions which affect you?** Yes [ ] No [ ]
10.9 How often does any of the committee members communicate with: (Circle all that apply) the Alternative Energy Promotion Centre, Renewable Energy for Rural Livelihood, or Nepal Electric Authority? A. Weekly B. Monthly C. Once every six months D. Once a year E. Never F. Other: ___________________________	

11.0 Payment for Electricity

11.1 Do people in your VDC pay for electricity? Yes [ ] No [ ] Do not know [ ]
11.2 If No or Do not Know to 11.1 skip to 12.1. If Yes to 11.1, is everyone in the VDC charged the same way for electricity? Yes [ ] No [ ] Do not know [ ]
11.3 Are there different rates for electricity for residential consumers and businesses? Yes [ ] No [ ] Do not know [ ]

11.4 In what ways are consumers in the VDC charged for electricity? A. Pay a flat charge per month for electricity of NPR payment amount: ____________ B. Pay for what is used based on the energy meter C. Pay for the number of appliances used in home or buisness D. Other: ___________________________	**11.5 Who decides how people are charged for electricity usage in your VDC?** A. Service provider B. Project Committee C. Village Leader D. Other: ___________________________ E. Do not know

11.6 Does your Service Provider provide incentive to the members who pay electricity bills within a stipulated time? Yes [ ] No [ ]	**11.7 If Yes to 11.6, what incentive is offered to members who pay electricity bills within a stipulated time?** ____
11.8 What does the Service Provider do if someone defaults on their electricity bill? A. Stops service B. Charges a penalty C. Nothing D. Other: ____	

12.0 Miscellaneous questions

1. How was land ownership of the MHP determined?
2. Do businesses provide adequate/ expected load?
3. In your opinion, why is there not enough business?
4. What is your opinion on the metering policy?
5. What is the most common complaint brought to your office?
6. Which, among these problems would be easiest to solve?
7. Which would be the hardest to solve?
8. Is there any difference in experience as leaders and electricity consumers?
9. Do operators experience a perspective different from the leaders?
10. Does everyone take advantage of the payment incentives?
11. Are delayed payment penalties strictly enforced?
12. Are any rules presently being amended?
13. Are there any wooden poles?
14. If so, How soon does the committee plan on replacing the old wooden poles?
15. What's the most common reason for non payment of bills?
16. Has shifting to co-operative model changed how you operate the office?

a. **OR** Do you think the MHP would benefit from shifting to a co-op model?

17. Pros/Cons of the change?
18. Would it be possible to establish microfinancing here?
19. Would increasing staff improve the availability of electricity?
20. Is there any way to increase electricity duration while staying economically feasible?

21. What are the community's short and long term goals?
22. Do you believe the plant is sufficiently maintained?
23. Does the committee promote any woman empowerment agenda?

13.0 Additional Comments

13.1 Do you have any other comments regarding electricity generation from the Project, electricity usage in your community, and maintenance of the Project? If so, please indicate below.

Thank you for completing the survey.

A.3.0 Micro-Hydro Plant Community Members Survey Questionnaire

Informed Consent

Thank you for your willingness to talk with me about electricity access in your community. My name is "Insert Name" and I am working as a member of a team based at Duke University in the United States studying the sustainability and effective use of electricity-generating minigrids here in Nepal. We are interested in learning how people experience access to electricity here in "Insert Village Name." In particular, we are hoping to draw conclusions that could improve efficient use of electricity here. If you agree to take part in our study, I will ask you to talk with me about your experiences in the community and in your home with respect to electricity use. I will ask you different kinds of questions about what it is like to live in this community and how electricity affects your day-to-day life and earning potential. I will also ask you specifically about the micro-hydro plant project that provides electricity to your village. We can talk for as long as you like, but I expect our conversation will take about 30 minutes. If you find that any question is too private or personal, please let me know that you would like to skip that question and we will do so. We hope our findings will help improve our knowledge and understanding of effective use of the microgrids that provide electricity to your community and others like it. Please note that the data we derive from this research may be used by other researchers to inform their studies. We will not record your name anywhere in our reports. You can skip any question that you do not want to answer. You can also stop our interview at any time, for any reason. Your decision will in no way affect any of the services you and your family receive now or in the future.

Please let me know if you have any questions for me at this time. For questions about this study, please contact our team through our advisor, Dr. Robyn Meeks, at robyn.meeks@duke.edu. For questions about your rights, please contact the Duke University research ethics committee at 919-684-3030 or campusirb@duke.edu. Please sign, initial, or note otherwise here to indicate that you understand the above explanation of consent and are willing to answer the questions we will ask in this survey:

______________________________________.

Identification

Household Number	
District	
VDC/Ward	
Village	
Name of Enumerator	
Name of Supervisor	
Date	
Site Number	
Questionnaire Number	

1.0 Personal Data

1.1 Profile

Name/Title	
Age	
Sex	
Main Occupation	
Education	
Mother Tongue	

2.0 Household Data

2.1. What is your prmary electricity source? A. NEA Grid B. Micro Hydro (10 to 100kW) C. Mini Hydro D. Diesel generator (> 100kW) E. Solar home system F. Soar tuki/lantern G. Rechargeable batteries H. No electricity	**2.2. What is your primary cooking fuel source?** A. Gas B. Kerosene C. Firewood Chulha D. Charcoal E. Other: ____
2.3 What is your primary space heating fuel source? A. No space heating B. Gas C. Kerosene D. Firewood Chulha	**2.4 What is your yearly household income (NPR)?** A. Less than 18,000 B. 18,000 to 36,000 C. 36000 to 60,000 D. 60000 to 90,000

E. Charcoal F. Other: ______________________________	E. More than 90,000

3.0 Project Design and Implementation

3.1 Were you involved in the design and implementation of the project? Yes [ ] No [ ]	
3.2 Did you provide any of the following for the Project? (Circle all that apply) A. Money B. Labor C. Supplies D. Other: ______________________________ E. None of the above	**3.3 What was the primary goal of providing electricity of the Project?** A. Power homes B. Power for new businesses C. Power for existing businesses D. Health care services E. Education support and access F. Other: ______________________________ G. Do not know
3.4 Were you involved in setting the goal of the Project? Yes [ ] No [ ]	
3.5 Who were the main stakeholders in the design and implementation of the Project? A. Community leaders B. Political leaders C. NGO D. Government agencies and representatives E. Do not know	**3.6 Who chose the location of the Project within your Village Development Committee (VDC)?** A. Community leaders B. Political leaders C. NGO D. Government agencies and representatives E. Do not know

3.7 Have you been asked to discuss and approve the rules that establish functions, power and responsibilities in the project? Yes [ ] No [ ]

3.8 Are you satisfied with the design and implementation procedures of the project? Yes [ ] No [ ]
3.9 In your opinion, what is the best use of electricity? A. To power homes B. To power businesses C. To power new businesses D. To provide health care services E. To provide education support and access F. Other: ____
3.10 Are you a participant of the Project? Yes [ ] No [ ]
3.11 Have you attended a workshop or meeting about using the electricity to power your home? Yes [ ] No [ ]
3.12 Have you attended a workshop or meeting about using the electricity to use for a business? Yes [ ] No [ ]

4.0 Access to Electricity Services for Lighting

4.1 What determines how many hours per day you receive electricity? A. The amount of people using electricity B. The amount of water flowing in the river C. If the Project is operating correctly D. If the transmission lines are operating correctly E. Do not know F. Other: ____
4.2 Does everyone that gets electricity from the Project get electricity at the same time? Yes [ ] No [ ] Do not know [ ]
4.3 Is the distribution of electricity equal? Yes [ ] No [ ] Do not know [ ]

4.4 In the past seven days how many hours on an average did you receive electricity supply? A. Between 4 and 8 hours per day B. Between 4 and 8 hours per day C. Between 8 and 16 hours per day D. Between 16 and 23 hours per day E. Minimum of 23 hours F. Do not know
4.5 During what time of day do you expect to have access to electricity? (Mark all that apply) A. Early morning (4:00-7:00) B. Morning (7:00-11:00) C. Mid-day (11:00-13:00) D. Afternoon (13:00-16:00) E. Evening (16:00-19:00) F. Night (19:00-23:00) G. Middle of night (23:00-3:00) H. Never I. Do not know
4.6 How does your electricity supply and availability changed during rainy and dry season? A. More electricity is expected in the rainy season than the dry season B. More electricity is expected in dry season than the rainy season C. The amount of electricity expected is the same in seasons D. Do not know

5.0 Reliability

5.1 On average, how often does load shedding occur? A. No load shedding B. Between 0 and 3 times per week C. Between 4 and 14 times per week D. More than 14 times per week E. Do not know

5.2 On an average, how long was the duration of load shedding? A. No load shedding B. Less than 2 hours in a week C. More than 2 hours per week D. Do not know
5.3 How often do you experience unplanned outages or breakdowns? A. Never B. Between 0 and 3 times per week C. Between 4 and 14 times per week D. More than 14 times per week E. Do not know
5.4 On an average, how long is the duration of unplanned outages or breakdowns? A. No unplanned outages or breakdowns B. Less than 2 hours in a week C. More than 2 hours per week D. Do not know
5.5 If the electricity supply is of bad quality, do you experience any of the following? (Circle all that apply) A. Economic losses from electricity blackout B. Appliance damage from unstable voltage C. Insecurity D. None of the above E. Other: ____
5.6 How long did it take to restore the service last time there was an issue with electricity? A. 1 day or less B. Between 1-7 days C. More than 7 days E. Do not know
5.7 Have you not been able to use any electrical equipment due to low voltage of supply? Yes [ ] No [ ]
5.8 Has a low voltage resulted in damage of electrical appliances? Yes [ ] No [ ]

6.0 Safety

6.1 Has there been any incidence of electrocution involving members of your community? Yes [ ] No [ ]
6.2 How risky do you feel it is using electricity in your home or business? A. I do not feel any risk B. I feel some risk C. I feel there is high risk
6.3 Has there been any fires started by the Project (at the plant and in the wires)? Yes [ ] No [ ]

7.0 Appliances

I will ask you six questions about each of the following appliances:

Item #	Item Description	7.1 Do you or any member of your household have… [item description]? [If no, skip to next item]	7.2 Approximately how old is it?	7.3 Does your household use it every month? [If no, SKIP to 7.6]	7.4 On average, how many days per month do you use it?	7.5 On average, how many hours per day does your household use it?	7.6 For what purpose do you it? [Choose one or both]
1	Light bulb	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
2	Mobile Phone Charger	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
3	Radio set/Music System	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
4	Television (TV)	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
5	Electric Fan	Yes [ ]	______Months	Yes [ ]			For household [ ]

		No [ ]	______ Years	No [ ]	_______Days	_______Hours	For Business [ ]
6	Rice Cooker	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
7	Mixer grinder	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
8	Electric Iron	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
9	Hair Drier	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
10	Heater/hot plate for cooking	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
11	Toaster	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
12	Water Pump	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
13	Water Heater	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
14	Refrigerator	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
15	Computer	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
16	Printer	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
17	Air Conditioner	Yes [ ]	______Months	Yes [ ]	_______Days	_______Hours	For household [ ]

		No [ ]	______ Years	No [ ]			For Business [ ]
18	Microwave Over	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
19	Invertor	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
20	Washing Machine	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]
21	Other: ______ ___________	Yes [ ] No [ ]	______Months ______ Years	Yes [ ] No [ ]	_______Days	_______Hours	For household [ ] For Business [ ]

8.0 Access to Energy for Cooking

8.1 What cooking stove do you mainly use?
A. Traditional 3-stone fire stove
B. Traditional tripod stove
C. Improved cooking stove with chimney
D. Kerosene pressure stove
E. LPG stove
F. Electric stove
G. None (no food cooked)
H. Other: ____

8.2 What is the primary fuel you use in the cooking stove?
A. Firewood
B. Biogas
C. Dung
D. Kerosene
E. LPG
F. Electricity
G. Other: ____

8.3 How do you obtain your main cooking fuel?
A. Gather
B. Purchase
C. Produce at home
D. Other: ____

8.4 How much time in a day does your household spend collecting (time it takes to acquire) cooking fuel?
A. Less than 15 minutes
B. Less than 30 minutes
C. Less than 1 hour
D. Less than 3 hours
E. More than 3 hours
F. Do not know

8.5 If biofuel (circle one or both: firewood, dung) How much time in a day does your household spend collecting cooking fuel?
A. Less than 15 minutes
B. Less than 30 minutes
C. Less than 1 hour
D. Less than 3 hours
E. More than 3 hours
F. Do not know

9.0 Satisfaction from Energy Use

9.1 Overall how satisfied are you with the electricity you receive from the Project?
A. Satisfied
B. Neutral
C. Not satisfied
D. Do not get electricity from the MHP

9.2 Rank the following in order of importance to you (rank 1 to 6. 1 is most important). A. [ ] Electrification of households (including household lighting) B. [ ] Street lighting C. [ ] Electricity for business usage D. [ ] Electrification of community spaces E. [ ] Education support and access F. [ ] Access to health care services

10.0 Payment for Electricity

10.1 Do you pay for electricity? A. I do not have access to electricity B. I do not pay for electricity C. I pay for electricity
10.2 How often do you pay for electricity? A. Weekly B. Monthly C. Twice a year D. Once a year E. Not applicable F. Other: ____________________________________
10.3 How are you charged for electricity usage? A. I pay a flat charge per month for electricity of NPR payment amount: ________________ B. I pay for what I used based on the energy meter C. I pay for the number of appliance I have D. Other: ____________________________________ E. Not applicable
10.4 Who decides how people are charged for electricity usage? A. Service provider B. Project Committee C. Village Leader D. Other: ____________________________________ E. Do not know

10.5 Does your Service Provider provide incentive to the members who pay electricity bills within a stipulated time? Yes [ ] No [ ]
10.6 What does the Service Provider do if you default on your electricity bill? A. Stops service B. Charges a penalty C. Nothing D. Other: ___________________________________

11.0 Income-generating activity

11.1 Do you use electricity to generate income? Yes [ ] No [ ]
11.2 What types of business do you do to generate income using electricity? (Circle all that apply) **A. Grinder/huller mills** B. Carpentry C. Computer Lab D. Library E. Poultry Farm F. Cable for television G. Cheese factory H. Bread factory I. Communication J. Other: ___________________________________
11.3 Was this activity/business possible before the Project was introduced? Yes [ ] No [ ]
11.4 If Yes to 11.3, how was the business powered before the Project? A. The activity was not possible B. The activity was possible and was powered by biofuels C. The activity was possible and was powered by: ______________________________
11.5 How many people are employed (paid) by the business? Number of people: _________________

11.6 How much income per month on average does the activity/business generate? A. NPR: ____________________ B. Not applicable
11.7 Is the amount of income from the activity/business the different than before the Project? A. I generate more income after the Project B. I generated more income before the Project C. I generate the same income before and after the Project D. Not applicable
11.8 If the amount of income has changed, why has it changed? A. I was not able to provide this service before having electricity B. I can make and sell more goods now C. Other: _______________________________________

12.0 Miscellaneous questions

1. Do you know of any other way to power your home?
2. Would you be able to provide space if solar was offered?
3. Are you satisfied with the cooperative efforts?
4. Would you avail a loan if microfinance was available?
5. Do you have any idea how you might be able to increase your income potential using electricity?
6. Any point where you feel the MHP is underperforming?
7. Do you agree that the functional group is transparent?
8. How do you think local businesses can be encouraged to consume more electricity?

13.0 Additional Comments

13.1 Do you have any other comments regarding electricity generation from the Project, electricity usage in your community, and maintenance of the Project? If so, please indicate below.

Thank you for completing the survey