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Empowering rural electrification in the Philippines: a case study

Isidro Antonio V. Marfori III, Alvin B. Culaba and Aristotle T. Ubando

Abstract: The paper describes the application of micro hydro power to improve the quality of life of people in rural areas. In this paper, two case studies in the Philippines are presented. One case study is a micro hydro power plant located in Parina in the north of the Philippines developed by an academic institution, De La Salle University; it utilises simple technology. In contrast to Parina, another micro hydro case study developed by a non-governmental organisation (NGO), YAMOG, is located in Timodos in the southern region of the Philippines; it implements more sophisticated technology. Even with differences in technology, similarities in terms of community dynamics, preparation, development, and impact on the community are evident in both case studies. The implementation phases for the two case studies were analysed to determine the characteristics for a successful micro hydro project in conjunction with its social impact. It is shown that micro hydro is a potential solution for clean and sustainable energy access for rural areas.

Keywords: Micro hydro, rural electrification, social impact

Note on the authors: The authors are all in the Department of Mechanical Engineering of De La Salle University, Manila, the Philippines.
isidro.marfori@dlsu.edu.ph

1. Background

Micro hydro power or MHP is a clean source of renewable energy that has been utilised for remote communities for electricity generation. The technology of MHP is mature and proven and operates on the same principle as a large hydroelectric power plant but with much lower power capacity. Depending on the country standard, micro hydro plants are mostly hydroelectric power plants with a capacity between 1 kW and 100 kW (Philippine Department of Energy 2011). Most micro hydro systems are run-of-river type systems in which a specific volume of water available all year round is diverted from the river to the MHP system using diversion weirs. Large dams are usually avoided for MHP systems due to their environmental impact. Instead, a natural head brought about by the topographic terrain is used for MHP. MHP requires a continuous supply of water for at least the majority of the months of the year and a significant head; otherwise it is not feasible. Because of the requirements for water and head coupled with grid-unreachable communities, MHP is mostly used in mountainous tropical rural areas. Micro hydropower had already proven itself to be a practical and potentially low-cost option for generating electricity at remote sites. In Indonesia, MHP accounts for 0.1 per cent of the consumed renewable energy power, accounting for 2,600 kW of installed capacity out of a potential 143,845.3 kW (Erinofiardi *et al.* 2017). In west Malaysia, a total of 109 MHP sites have been identified through a reconnaissance study totalling 20,400 kW of potential power (Raman *et al.* 2009). In the Philippines, MHP is tapped to support the government's rural electrification programme targeting 100 per cent *Barangay* (or village) electrification with a potential of 27,000 kW (Philippine Department of Energy 2013). As of 2013, there were a total of 105 operational MHP sites in the Philippines with capacities ranging from 0.03 kW up to 75 kW. Table 1 shows the number of MHP sites as well as the total installed capacity per region in the Philippines. The total MHP installed capacity as seen in Table 1 indicates 1,065 kW while the potential for the Philippines is 27,000 kW. This indicates that there is still a large potential for MHP in the Philippines. Although it is unknown whether the potential is intended for community electrification or commercial use, either way good practices must be observed to achieve the full benefits of MHP. In most cases in the Philippines, the utilisation of MHP is for lighting and for powering small appliances. In some cases, battery charging is chosen, especially for communities with a greater distance between households and the MHP powerplant. Another use of MHP is to power machinery, such as small post-harvest agricultural machinery. In this paper, a Philippine case study on MHP is presented, showing the entire process from planning, to development and then to Utilization. The basic components of the MHP are also discussed with examples from several selected MHP sites.

Table 1. MHP installed capacity in the Philippines.

Region	*Count of MHP plants*	*Total capacity, kW*
CAR	42	370
II	4	3
III	2	2
IV	6	223
V	2	4
VI	23	100
VII	9	110
VIII	2	75
IX	4	1
X	4	11
XI	4	75
XII	3	91
TOTAL	**105**	**1065**

Sources: The majority of the data were provided by the Philippine Department of Energy while some data were taken through a survey of the developer or contractor of the MHP plant.

2. The social dimension of micro hydro power

When dealing with the social impact of an MHP system to a benefiting community, it is first essential to understand the basic principles of MHP. A typical MHP plant is shown in Figure 1. The first step in the operation of an MHP plant happens in the intake weir located at the highest elevation relative to other components of the MHP plant. The function of the intake weir is to divert water from the river unto the canal. The canal is a long channel used to convey water safely from the diversion weir into a silt basin and then to a forebay. In many cases with a relatively short canal, the silt basin is omitted and a combination of silt basin and forebay is used. The forebay is a water settling tank used to filter debris and sand from flowing water before it enters the penstock. Depending on the length of the canal, the forebay is typically just a few metres lower in elevation than the diversion weir. The diversion weir, canal, silt basin, and forebay are all designed based on the water flow rate and topographical features of the MHP system. The penstock is a long, large pipe often made of steel. The penstock is used to maintain a vertical head, H, as seen in Figure 1, which is necessary for the proper operation of the turbine located in the power-house. The power-house also contains the electric generator for the conversion of mechanical to electrical energy and controls to ensure the safe operation of the MHP turbines and generators. The final component of the MHP system is the transmission, which distributes the energy among the households within the community. It is important to understand the basic operation of the MHP plant because it has a significant impact on the community from the

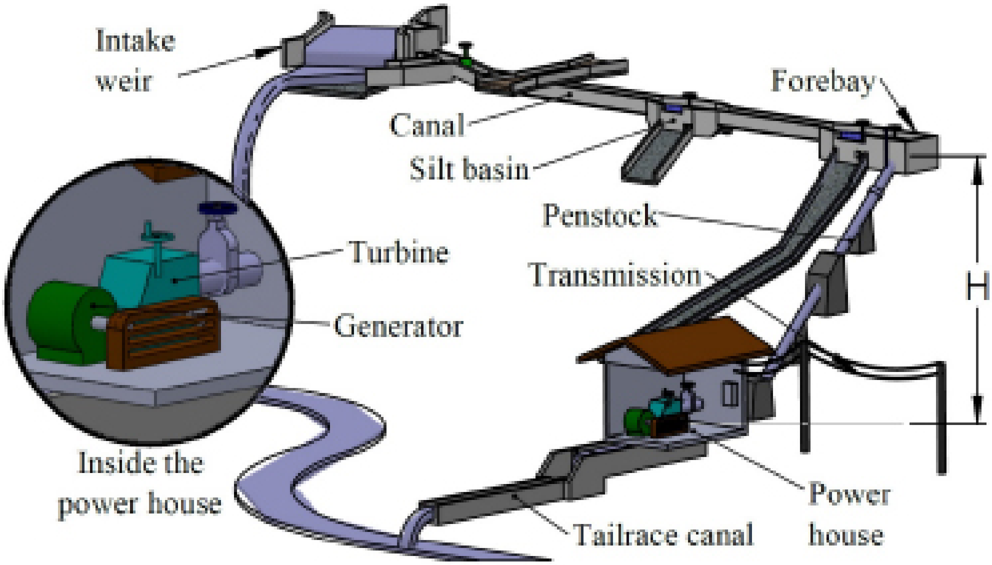

Figure 1. Components of an MHP plant (Culaba & Marfori 2020).

development stage, to the use phase and finally the end-of-life phase of the MHP plant. The complexity of the components plays a significant role as it affects the adaption, acceptance and success of MHP by the community. In the succeeding sections, details on the components of the MHP plant will be discussed and how these affect the social dimension of the MHP system.

One of the greatest features of MHP is its ability to provide access to affordable and clean energy, which is a requirement for achieving sustainable development. The goal of an MHP project is to improve basic quality of life, which could include the areas of health, education, income, and the environment (Culaba & Marfori 2020). It has been demonstrated in the literature that having electricity significantly improves the life of people compared to situations where there is no access to power (Murni *et al.* 2012). However, the success of MHP lies in the dynamics of the community. The typical model for an MHP project as off-grid community electrification is through government or private subsidy. In such cases, the community is often expected to provide free labour as its contribution. In other cases, labour maybe sourced by other financial means. In either case, the operation of MHP in the use phase will still be in the hands of the community. The operation will include technical and managerial activities which all require training or skills development. It is therefore crucial that the community has a good understanding of the technical, financial, economic, and social aspects of the MHP system. It is only then that the community will have a complete appreciation of the benefits of MHP and how it can affect people's lives.

3. Philippine MHP case studies

Two MHP sites are included in this case study: Parina and Timodos MHP sites. Parina MHP is located in the northern part of the Philippines while Timodos is located in the southern part. The two MHP sites were chosen based on the available data and on the difference in geographic location. Figure 2 shows the location of the two MHP sites. Parina MHP was established by De La Salle University (DLSU) in Manila with a partnership between the local government of Calanasan and SN-Aboitiz Power. Timodos MHP was established by a non-governmental organisation, Yamog Renewable Energy Development Group (YAMOG), with funding from Misereor Germany and the Government of the Federal Republic of Germany.

3.1 Parina MHP

Parina MHP is specifically located north of Luzon in the province of Apayao and in the municipality of Calanasan in the Cordillera administrative region (CAR). Parina is a small village, which had 65 households at the time of the development of the MHP system. The main economic activities of the residents are farming and

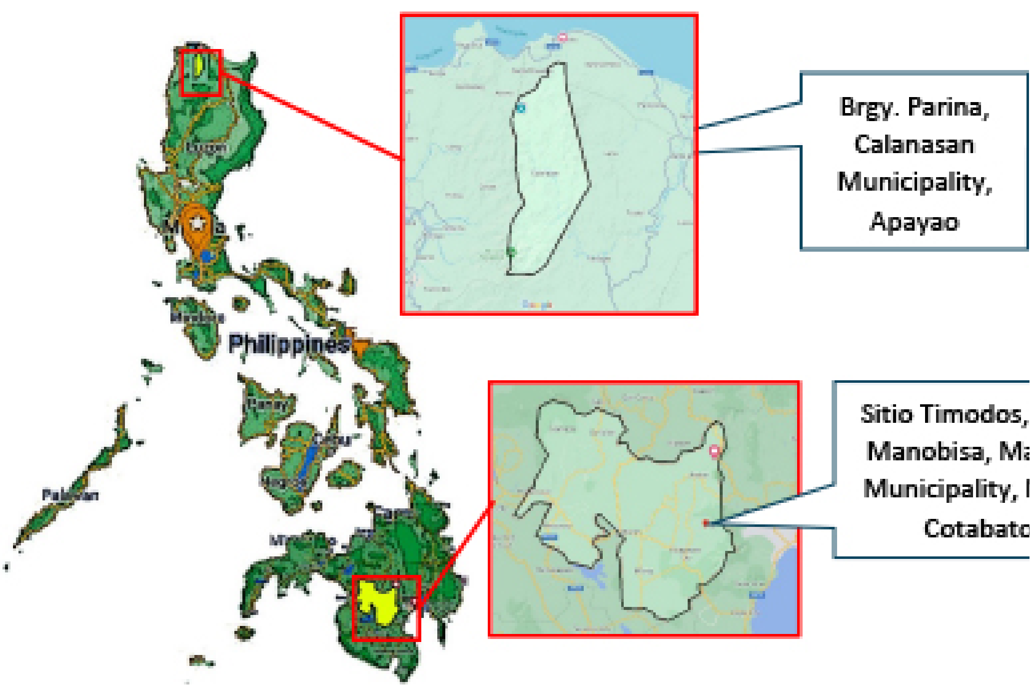

Figure 2. Location of Parina and Timodos MHP plants.

seasonal construction work. The area is characterised by mostly rolling and sloping terrains and is about 30 km from the nearest power grid. A roadway was established from the town of Claveria up to the town of Tanglagan that passes through Parina. At the time of the development of the MHP the road was mostly rough earth. Public access to Parina is through a heavy-duty jeepney with a pick-up point at Claveria with only one trip leaving in the afternoon and returning on the morning of the day after. The jeepney ride typically takes between 2 and 3 hours depending on the road conditions. The fare for each passenger was 100 Philippine Pesos (₱) for a one-way trip.

Environmental conditions in Parina are characterised by dense forestry, hilly terrain, and several creeks that lead to the Calanasan river. The people of Parina had already been practising good watershed practices. Historically, the people of Calanasan including those in Parina had experienced degradation of the forest due to excessive logging. Local regulation was implemented, and this led to good environmental practices, such as fines on illegal logging and dumping of waste in the river, etc. Pre-school and primary school education is offered in Parina up to grade 6, while secondary schooling is offered in the town of Tanglagan 7 km away. Most children are able to finish primary school while others who have relatives in the nearby town are able to finish secondary school as well. Electricity use in Parina is very rare. One household is equipped with a diesel generator and can have lighting and power small appliances. It is interesting to note that this single household usually hosts regular television viewing among the young in Parina through DVDs and sometimes regular shows through satellite pre-paid subscription. This indicates the technical ability of some of the people in Parina.

Prior to MHP implementation, Parina engaged in pico-hydro power through the local government, but this was unsuccessful as it only lasted several months because the turbine broke down. During the pre-implementation phase of the MHP system, it was found that the previous failure of pico-hydro was due to limited technical capacity in hydro systems. It was found that the pico-hydro system was under-capacity and poor turbine selection had been implemented. On the other hand, the previous implementation of pico-hydro had had a positive impact on the community of Parina. During the limited time the pico-hydro was operational, the people of Parina had experienced the benefits of electricity and how it can have the potential to improve their lives. Furthermore, the previous pico-hydro project gave the leaders and key people of Parina insights into the working principle of a hydro-power system. In comparison, in communities that have no prior knowledge of the principles of hydro-power, extensive community preparation is needed to acquaint the people with the concepts, benefits and all things needed for MHP.

3.2 Timodos MHP

Timodos is located in Barangay Manobisa which is one of the 36 Barangays of Magpet Municipality in North Cotabato. Out of a total land area of 1,824 hectares, about 4.35 per cent is forested while the rest is classified as agricultural land. Similar to Parina, the main economic activity of the inhabitants is farming. Timodos is about 6 km from the nearest power grid and it can be reached on foot from the centre of the Barangay or Municipality, or by means of a passenger motorbike locally called a '*habal-habal*'. The access road from the centre of Magpet Municipality to Timodos is in very poor condition and access is usually made possible only through an old, rugged road that is almost impassable during the rainy season.

Timodos can be characterised by an abundance of springs, waterfalls, and river systems. The Timodos MHP system is situated near a 700-hectare watershed. The people of Timodos assign crucial importance to the watershed as it is not only home to diverse flora and fauna, but it is also the major source of drinking water for local inhabitants. The watershed is characterised by biodiversity, with sightings of the endangered Philippine Eagle in the densely forested areas. Historically, the forest cover of Timodos had steadily decreased due to both legal and illegal logging and slash-and-burn farming. As a result, soil erosion, river siltation, flash floods, and landslides emanating from heavy rains became a common occurrence.

Prior to the establishment of the MHP system, there were a total of 119 households in Timodos, but this decreased to 87 households due to armed conflict in the area. Inhabitants of Timodos mostly belong to the Manobo tribe with just a handful of lowland, Christian settler-families. The average family size was five members with incomes ranging from ₱4,000 to ₱5,000 per month, which was below the poverty line. Malnutrition among the children of Timodos was prevalent due to low income. Low income was attributed to a lack of post-harvest facilities for corn, a staple crop of the people of Timodos. Poor road conditions that resulted in high transportation costs also contributed to the low income. Primary school from grade 1 to 4 is available in Timodos, but very few children are able to finish school. Secondary school is said to be almost impossible as the nearest secondary schools are kilometres away. Prior to the MHP system, Timodos residents utilised firewood, and later on kerosene for cooking and household lighting, respectively. At the time of project conceptualisation, the residents were spending ₱150 to ₱200 per month per household on kerosene. Other sources of energy were vehicle batteries and dry-cell batteries.

It is interesting to note the differences between Parina and Timodos. Parina seems to have established good governance as evidenced by their ability to

Table 2. Conditions in Parina and Timodos before the MHP establishment.

	Parina	*Timodos*
Socio-economic	• Mostly from agricultural industry such as farming and post-harvest processing of rice. • Some provide labour work in the construction industry of mostly roads. • Lighting is mostly from kerosene lamps.	• Mostly from agricultural industry such as farming and post-harvest processing of corn. • Broom making for some women. • Lighting is mostly from kerosene lamps.
Education	• Primary education up to grade 6. • Most students can finish with some students continuing secondary education in the nearby town.	• Primary education up to grade 4. • Few students are able to finish. • There is no secondary education available nearby.
Health	• There were no clinics or health centres in the area. • Barangay health workers provide basic health care. • Incidence of respiratory illness was evident.	• There were no clinics or health centres in the area. • Barangay health workers provide basic health care. • Incidence of respiratory illness was evident. • Incidence of gastrointestinal illnesses.
Environment	• Laws and regulation had already been imposed and implemented for watershed protection.	• Activities regarding watershed protection was not evident.

implement and enforce local environmental laws and regulations. In comparison in Timodos, the local government has difficulty providing basic social needs to the community, mainly due to the lack of financial allocation from central government. However, in terms of income and quality of life, Parina and Timodos share the same conditions. Both Parina and Timodos have household incomes lower than the Philippine poverty threshold. Table 2 provides a summary of the conditions of Parina and Timodos in the categories of income, education, health, and the environment prior to the establishment of an MHP system.

4. Community involvement

One of the essential requirements of a successful MHP project is in the interaction and participation of the stakeholders. A study conducted by Sovacool with ten community-based energy project case studies indicated that one key factor for a successful energy system is the active participation of the community (Sovacool

2013). Sovacool stated that, for a successful energy system, community awareness and information on renewable energy are essential. Developers of successful energy systems have strong marketing, promotional, and demonstration activities for the community, not only for the project, but also for renewable energy technologies (Sovacool 2013). In the two case studies of the Parina and Timodos MHP, the developers DLSU and YAMOG both provide marketing activities to promote renewable energy. At that time, DLSU had been engaged in several activities within the Philippines, such as MHP training, seminars, and symposia. DLSU also provided brochures, free plans and drawings, and manuals for other MHP developers. YAMOG on the other hand provides promotional and marketing through their official website and social media platforms.

The Parina MHP first began as a failed pico-hydro project. Initial assessment for rebuilding of the pico-hydro system was conducted by representatives from SN-Aboitiz Power (SNAP). At that time, it was said that SNAP and the local government of Calanasan had a partnership for the development of small hydro in the area as a corporate social responsibility or CRS project by SNAP (Aboitiz 2021). The involvement of DLSU as the developer of the Parina MHP came about through academe–industry linkage, as one of the representatives of SNAP knew that DLSU was engaged in MHP development. The first activity involving DLSU, SNAP, and the community was a stakeholder meeting (Culaba & Marfori 2020). The meeting was only with key people from the community, such as the Municipal Mayor, the Barangay chairman and officers, teachers, and tribal elders. Typically, a kind of townhall meeting is often conducted, but for the case of Parina it was not necessary as the community already had prior knowledge of MHP. Other activities that involved all community members were also conducted, such as basic electricity, use and care of the MHP plant, and watershed protection.

Timodos MHP began as a community effort. The Timodos community with the help of the office of the Barangay made a request to YAMOG for a site assessment. The community of Timodos knew about the benefits of energy from a nearby village in which YAMOG had also developed a scheme. YAMOG first conducted a rapid site survey to determine whether a MHP system was suitable for the community. A meeting with the stakeholders was also conducted. Planning, funding, community contribution, development, and management were discussed at the meeting. Because the project was funded by a German NGO Misereor and KZE-Germany, a project proposal was first created with the assistance of YAMOG. The involvement of the community began at the very start of the project in planning, construction, and management. As a counterpart, the community provided the majority of unskilled labour during the construction phase. Skilled labour also came from the community, while other specialised skilled labour was sourced outside the community. The community was also involved in survey and other activities that served as a training component of the project. Basic electricity training was also conducted, participated in by volunteers from the community, which was the foundation for the community-based technicians who would serve the community for operation and maintenance. Finally, operation and maintenance training were conducted three months prior to the completion of the project. It is also vital to note that, aside from providing access to clean energy, the Timodos MHP also aimed to provide other objectives. One of these was the provision of safe drinking water.

4.1 Rapid site survey

With the approval of key stakeholders, a rapid site survey is often the first activity of the developer with the community. One objective of a rapid site survey is to identify the volumetric flow rate of water Q, the elevation head h, and community energy demand. This activity is crucial to the community, as the information will determine whether an MHP is suitable for the site. The MHP developer usually divides the activity into a technical survey to identify Q and h, while another activity is dedicated to identifying the energy demand of the community. The technical survey is often assisted by several members of the community. Typically, the technical survey is assisted by no more than ten able-bodied men composed of Barangay officials and individuals who are familiar with the terrain. The technical survey requires the identification of a suitable location where physical measurement of the condition of the river is possible and safe. The role of the community at this stage is to guide the developers through the mountainous terrain and bring to them to a suitable spot within the river or water source. Community members with the technical site survey team may be required to clear the area or path of vegetation, branches, and bushes to make the location conducive for site measurement. The technical survey utilises simple measuring techniques such as the area–velocity method for Q and an open-piezometer for h. These two techniques are often chosen because of their simplicity, making it easy for community members with the site survey team to understand the concept. At this stage, it is still not known whether there is enough flowing water or enough elevation head for MHP potential and therefore it is important to provide this information right away so as not to arouse false expectations. In many successful MHP projects, the initial rapid site survey is welcomed by several community volunteers and leaders. The community will often undertake prior preparation, such as coffee, snacks, and some meals, which are good indicators of community acceptance of the MHP technology.

In the other part of the rapid site survey, a team from the developer is deployed to assess the community energy demand (Table 3). For both Parina and Timodos,

Table 3. Rapid demand estimation detail for Parina and Timodos.

		Parina Item Detail	*Timodos Demand Detail*	*Item*	*Demand*
Lighting load	Number of households	65		87	
	Number of light bulbs per household	2		2	
	Wattage of light bulbs, W	5	650	5	870
Outlet provision per household	Small appliance wattage, W	100	6,500	100	8,700
Refrigeration load	Number of refrigerators	1		2	
	Wattage of refrigerator, W	1,000	1,000	1,000	2,000
Education	School power needs		1,000		1,000
Other			2,000		2,000
	Total Demand, W		**11,150**		**14,570**

the energy demand survey was conducted by a team composed of social scientists and research assistants. The energy demand survey is composed of interviews with the heads of several household, teachers, health-care workers, and Barangay officials. In both Parina and Timodos, the community had little knowledge of electricity. There were several accounts of the elders saying that they had not seen a lightbulb before. The objective of the energy demand survey is therefore to identify the basic needs of the community and to identify appropriate technology to meet these needs. Other information, such as technical capacity, income, health, and education, is gathered during the rapid site survey. For both Parina and Timodos, energy needs tend towards better lighting and food preservation. There were accounts of electricity usage to provide income, such as welding applications in Parina and post-processing of agricultural products in Timodos.

4.2 Community preparation

Although the Parina and Timodos projects show differences in the implementation for community preparation, they share the same objective. For both Parina and Timodos, the objective of community preparation was to provide information to the community about the development of the MHP system. The Parina MHP project had already established good community organisation through the leadership of the Barangay chairman. In the past, most men in Parina had engaged in construction work, with the Barangay chairman acting as the foreman. The Parina community seemed to have good trust in the Barangay chairman in many aspects of living, such as in farming, health, income, and laws. The Parina Barangay chairman was the only college graduate among the members of the community. He has good knowledge of physics and natural sciences, and this made MHP easily implementable in Parina. Community preparation in Parina was therefore mostly dissemination of information about the concepts of MHP and electricity, as the organisational structure had already been established. The roles and responsibility for the development of the MHP project in all its phases were absorbed by the existing Barangay organisation. A separate organisation intended for management, operation, and maintenance was established later on.

Timodos, on the other hand, was different, as organisational activities along with information dissemination were necessary. At the pre-implementation stages, organisational activities were conducted. Initially, committees were formed with members from the community, YAMOG, representatives from the local government units, and key stakeholders for water use and energy use. Timodos needed to identify how the water would be divided for potable drinking, agricultural needs, and for energy use. Community organisation activities, including the formation of sub-groups, the preparation of a constitution and by-laws, the election of a board of directors and officers, and identification and agreement of tariff rates, were conducted. Timodos also conducted activities to strengthen the commitment from all members of the community, key stakeholders, and local government units. A community group called the Rural Infrastructure Working Committees or RIWC was formed, as well as other committees for watershed protection.

For both Parina and Timodos, the social preparation resulted in stronger organisation and better appreciation of the benefits of MHP. Aside from the basic requirements for the MHP project, the organisations and groups developed from community preparation also provided the people with an avenue to express their needs, sentiments, and ideas. Members of the community are involved in analytical decision-making, taking into consideration the real needs and aspirations of the community. This ensures that all succeeding stages will have sustained community support. Beneficiaries have a clear grasp of the MHP system and how it affects their lives, thereby enhancing social acceptability and a sense of community ownership.

4.3 Development phase

An MHP system could be built as simply as possible using resources readily available in the area or could be built using state-of-the art technology, requiring materials and expertise from outside to be brought to the area. Table 4 shows a

Table 4. MHP development key differences for Parina and Timodos.

Components	*Parina*	*Timodos*	*Community Involvement*
Intake	• Combination of natural weir and man-made weir. • Build with concrete and stone masonry. • Stones and gravel were sourced at the site. • Cement was brought to the site by foot.	• Steel-reinforced concrete cement. • Sand and gravel were sourced at the site.	• Location identified by community members. • Provided both skilled and non-skilled labour. • Elderly men helped in the hauling of stones. • Some women and children also helped in hauling of sand and gravel.
Headrace canal	• 300-m-long open canal. • Stone masonry for the first 50 m from the intake. • The rest were made from steel-reinforced hollow concrete blocks.	• 306-m long made from steel-reinforced hollow concrete blocks. • Closed with concrete slab throughout the length with several cleaning access points.	• In Parina, it was said to be the most difficult component to build according to locals. • Timodos closed canal was preferred to minimise periodic cleaning as the slab cover prevents falling leaves and branches entering the canal.
Forebay and penstock	• Steel-reinforced concrete. • Located at the previous pico-hydro project. • Size increased significantly. • Constructed near a sloping terrain. • With retaining wall. • 0.3-m-diameter steel penstock. • 36-m-long penstock.	• Steel-reinforced concrete. • Constructed away from sloping terrain. • More excavation requirements due • to the depth and penstock access. • 0.4-m-diameter steel penstock. • 56-m-long penstock.	• For both MHP sites, community provided labour. • Welding needs provided by manpower outside the community. • For Parina, 'bayanihan method' for the hauling of the steel penstock proved to be effective.
Powerhouse and electromechanical equipment	• Philippine-made cross-flow turbine. • Manual controller. • Single-phase generator.	• Indonesian-made cross flow turbine. • Load controller. • Three-phase generator	• For Parina, community members participated in hands-on fabrication of the turbine. • Both MHP sites had the community participate in management, financial, operation, and maintenance capacity building, and training.

comparison of the components of the MHP systems for Parina and Timodos. The majority of the components are made mostly of concrete, stone masonry, and steel reinforcements. So typical construction techniques were utilised in which the community could fully participate. For both case studies, the majority of the men had adequate experience in construction and so the manpower requirements for the entire development phase were provided by the community. Although the involvement of the community is mostly in the provision of labour by able-bodied men, other members of the community, such as the elderly, women, and children, also contributed to the development of the MHP plant. Older men along with male teenagers participated though hauling sand, gravel, or stone. Women and female teenagers participated in the preparation of meals, although there were some instances of women who also hauled materials.

For both case studies, the locations of the forebay and penstock are accessible only on foot and a typical penstock in the case of Parina was 6 m long with a weight of about 800 kg. For a well-organised community, the hauling of heavy materials is accomplished through a traditional activity called in the Filipino language ‘*bayanihan*’. In the context of MHP, several volunteers from the community carried the penstock on foot from the drop-off point of the jeepney all the way to the forebay area. This was accomplished by wooden poles attached along the length of the penstock while a person on both ends of the wooden pole would carry it, as shown in Figure 3.

Several key members of the community spent days at the DLSU workshop for a hands-on experience in the manufacturing of the MHP turbine. Aside from basic metal working processes and welding, members from Parina also gained knowledge of the working principle of the turbine. Aside from benefits for the operation and maintenance of the MHP system, the training also gave a good sense of ownership. Other capacity building and training were conducted for both case studies. Capacity building training in organisational strengthening, financial management, watershed conservation, basic electricity, leadership and conflict management, operation and maintenance were implemented.

5. Impact of MHP

The impact evaluation is based on interviews between the authors and the developers of the two case studies. Reports and documents from the case studies were also provided to the authors. Parina MHP was inaugurated and began operation in May 2013. A monitoring visit was conducted by the DLSU developer at Parina six years after the inauguration. The monitoring visit consisted of interviews with key

Figure 3. Community volunteers from Parina MHP hauling a steel penstock in '*bayanihan*' fashion. (Photograph courtesy of DLSU.)

community members, including local government officials, schoolteachers, health-care workers, and members of the Parina micro hydro association. Table 5 shows the impact of MHP for the two case studies. In education, children had a reduction in time spent on many manual activities, such as fetching water and fuelwood; instead students now spend more time in school. Interviews with parents claim that children can study better at night with the provision of better lighting. The use of computers, radios, mobile phones, and televisions was now made possible in the school. Interviews with local government officials indicate improvements in livelihoods and savings from reduced kerosine use. An appliance repair service also became common in the community, as well as a welding service and other services that utilise electricity. On health, there was evidence of decreased respiratory illness due to the decreased use of kerosine lamps. A community refrigerator to be shared among the residents of Parina was purchased and it was claimed that it gave better access to food.

The Parina community formed the Parina micro hydro association which is tasked with managing all aspects of the MHP plant in terms of operation, maintenance, collection, and reporting. The association was able to collect tariffs so diligently among the community that it was able to raise funds to purchase a secondary generator to be used as back-up during maintenance. The Parina MHP

Table 5. Impact comparison of before and after Timodos MHP.

	Before MHP	*After MHP*
Socio-economic	• Mostly from agricultural industry, such as farming and post-harvest processing of corn. • Broom making for some women. • Lighting was mostly from kerosene lamps.	• Women and household members can conveniently do household chores at night. • Capacity building formation has increased through project managers, organisational development workers,financial management personnel, operation and maintenance personnel, community electricians, women leaders, youth leaders, and community leaders. • Household savings as much as ₱600 per month as a result of a significant decrease in kerosine use. • The presence of electricity has prompted the Barangay Local Government Unit (BLGU) and Municipal Local Government Unit to improve the access road going to the community which has had a positive impact on farming. • Production of brooms has increased due to longer hours at night. • Women's role has increased to higher management level.
Education	• Primary education up to grade 4. • Few students were able to finish. • There was no secondary education available nearby.	• Improved study environment for children. • Improved access to information from radios and TV.
Health	• There were no clinics or health centres in the area. • Barangay health workers provided basic health care. • Incidence of respiratory illness was evident. • Incidence of gastrointestinal illnesses.	• Records from the Barangay Health Workers of the BLGU reveal a reduction in the incidence of respiratory diseases, and gastrointestinal-related illnesses.
Environment	• Activities regarding watershed protection were not evident.	• TTriMPA with BLGU developed policy watershed protection. • Cutting of hardwood within the watershed has been significantly reduced.

was also able to source additional funds from government subsidies for the replacement of all the wooden transmission poles by more durable steel poles.

The evaluation of the impact of the Timodos MHP system on the community was a combination of quantitative and qualitative approaches, and a simple before-and-after study that was caried out by YAMOG. The methods employed include a review of key project documents, report preparation, and primary data gathering. The sample size of the household surveys consisted of 40 per cent of the 87 households as well as focus group discussions and key informant interviews with project stakeholders. A summary of the results is given in Table 5 with a comparison with the situation before the installation of the MHP system. Significant improvement was evident in the socio-economic aspects. Aside from household savings due to the dramatic decrease in kerosine use, other income-generating activities were improved, with an increase in production in broom making and electricity service-related livelihoods.

6. Key points for a successful MHP system

The following discussion lists the essential elements for a successful MHP project, based on findings from the two case studies.

- *Marketing and awareness*
  As in the study by Sovacool, it was identified that communication is a necessary ingredient for a successful MHP project. For both case studies, community consultation, dialogue, and consensus-building were utilised to enable community participation in all stages of the project.
- *Ownership*
  Community participation is essential to achieve a sense of community ownership for the MHP project. The residents participated in the identification of the sources of micro hydro power, identification of the riparian zones and critical areas in the watershed, conduct of site surveys, finalisation of design, construction of hydropower, preparation and implementation of watershed protection, operation, and maintenance.
- *Capacity building*
  Training in different forms and fields related to MHP itself or more managerial or financial in nature are all necessary. In both case studies, capacity-building strategies were attuned to the uniqueness of the community.
- *Utilisation of appropriate technology*
  In terms of the overall impact, the two case studies share almost the same

characteristics, even though Parina has inferior technology compared to that of Timodos. This can be related to the study by Sovacool, indicating that successful MHP programmes tend to be oriented towards energy service matched with the needs of the end-user, which indicates that even simple technology can have a similar impact to complex technologies (Sovacool 2013).

- *Leadership*
  Successful MHP programmes often receive consistent support from government, an experienced implementing agency, and a clear project champion (Sovacool 2013). Similar findings were made in a case study by Culaba *et al.* (Culaba & Marfori 2020). In Parina, the Barangay leader led the community to accomplish the development of the MHP system with support and financial assistance from the local government, while Timodos had consistent support from the developer YAMOG.

7. Conclusions

MHP has been proven to be an effective approach for providing clean electricity to rural areas, but it is not always successful. In many studies, it has been established that the success of MHP rural electrification depends not only on the technical aspects but more on the social, governmental and community aspects. The Parina and Timodos MHP case studies show a similar trend. Although the Parina MHP system has inferior technological features to those of the Timodos MHP system, the two MHP projects have had similar impacts on the community and similar indicators that led to their success. Unity and a positive outlook among the members of the community have been evident since the start of the MHP projects. This can be seen in the formation of the Timodos Tribal Micro Hydro Power Association (TTriMPA) and the Parina Micro Hydro Association. Through these endeavours, the recognition and acceptance of women in varying roles became possible as women are managerial members of these groups. The participation of stakeholders, such as local government, developers, and the community, has provided a voice for the community.

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