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The role of micro hydro power systems in remote rural electrification: a case study in the Bawan Valley, Borneo

Sari Murni[a], Jonathan Whale[a], Tania Urmee[a], John Davis[a], David Harries[b]

[a] *Murdoch University, 90 South Street, Murdoch, Perth 6150, Australia*
[b] *The University of Western Australia, 35 Stirling Highway, Crawley, Perth 6009, Australia*

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Abstract

Like communities all over the world, the people of the Bawan Valley in the East Kalimantan Province of Indonesian Borneo want the benefits of electricity. The Bawan Valley, however, is geographically isolated from the rest of East Kalimantan, making access to electricity via the national electricity grid impossible. Hydro resources are abundant in the Bawan Valley and hydroelectricity is a promising option for electrification of remote villages in this area. The existing micro hydro systems in the area have been built as government, community-based or private agency projects. Some of these micro hydro systems have been more successful than others. This paper presents the results of a study of two micro hydro systems in the Bawan Valley villages of Liang Butan and Tang Paye. The study aimed to provide insight into critical issues in the stages of development and the impacts of a micro hydro system on rural communities in the Bawan Valley. Surveys of the villages included field observations, written questionnaires, energy audits and semi-structured interviews with community leaders and householders. Various key informants, such as village headmen, *Kepala Adat* (grass roots community leader), and micro hydro equipment manufacturers were also interviewed. The key findings of the study were that the success of micro hydro systems depends not only on technical aspects, such as design and operation and maintenance, but also on social factors such as community capacity building, and that the successful implementation of micro hydro systems in remote areas requires careful planning and the involvement of all stakeholders in the planning process.

Keywords : micro hydro; rural communities; technical aspects; social impact; stakeholders

Introduction

The people of the Bawan Valley in the East Kalimantan Province of Indonesian Borneo were willing to get electricity access in order to improving quality of life. Bawan Valley is located in the Nunukan Regency of East Kalimantan, within the region known as the 'Heart of Borneo' that extends across the borders into Malaysia (Sarawak and Sabah) and Brunei (Fig. 1). Bawan Valley is administratively divided into two sub-districts, Krayan and Krayan Selatan. Long Bawan is the administrative headquarters of the Krayan sub-district and has a total population of approximately 10,000. Beside its role as an

administrative centre, Long Bawan is also a trade centre for the entire Bawan Valley and a local hub for cross-border trading with Ba Kelalan in Sarawak [1].

Fig. 1.a: Location of Long Bawan 1.b Location of Long Bawan within the 'Heart of Borneo' 1.c Sketch map of Long Bawan

Sources : http://pam.wikipedia.org/wiki/Kalimantan
http://brunei.cfbt.org/bn/heartofborneo/hobmenu.html

The surrounding Kayan Mentarang National Park has isolated the Bawan Valley from other parts of East Kalimantan. It is therefore easier to bring most goods, including fuel, overland from Ba Kelalan (Malaysia) to Bawan Valley rather than to air-freight them from elsewhere within Indonesia. Although fuel is supplied overland, the high cost and concerns over continuity of supply are the main barriers to fulfilling villagers' needs. Accessing electricity from the national grid is impossible due to the valley's isolation [2]. The only viable alternative is to use off-grid generation and it seems reasonable to utilise renewable energy rather than using fossil fuels as the latter are not available in this region.

Solar energy resources, although abundant in this area, are less attractive than hydro power due to the limited number of cloudless days per year, the high unit capital cost ($/kW) and high unit energy price ($/kWh) of solar power systems [3][4]. Wind resources in this area are quite poor (less than 4m/s) and are inconsistent over the year [5]. Wind energy is therefore not a feasible energy supply option. Hydro power, which is plentiful in this area, is the most viable option for electrifying this remote area.

Ten micro hydro systems (MHS) have been installed and serve 24 villages within the Krayan sub-district [6]. These projects were funded by various agencies: Government, community-based and private. Some of these MHSs have been more successful than others. This study focuses on two micro hydro systems in the villages of Liang Butan and Tang Paye. These two MHS were funded in different ways. The MHS in Liang Butan was funded by the national government through the National budget, while the MHS in Tang Paye was funded by the National Program for Community Empowerment (PNPM-*Program Nasional Pemberdayaan Masyarakat*). This study used surveys to find out whether these different sources of funding were associated with different procedures in terms of project planning, implementation and management of an MHS, and to understand the linkage between these factors and the success of the MHS. In line with this aim, some objectives such as identifying critical stages and issues that arise during planning and implementation, as well as understanding the impacts on the community, especially on the expenditure on energy and social benefits, will be discussed to find the lessons learned for implementing a MHS in rural communities such as these.

Methodology

Various techniques, including field observation, written questionnaire, energy audits and interviews were used in the survey for this study (see Fig. 2).

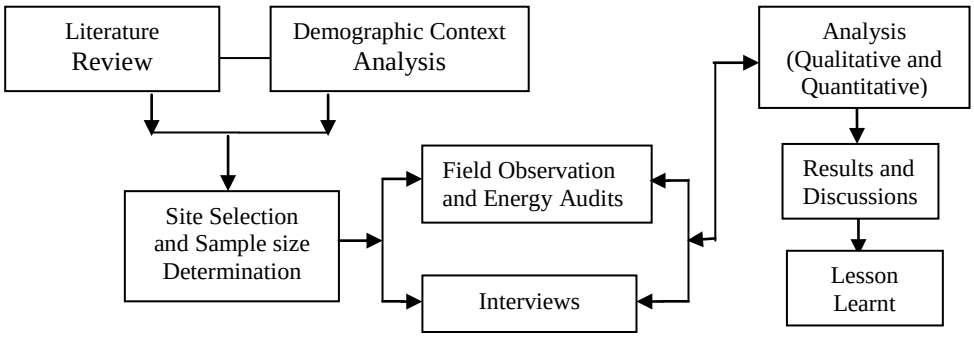

Figure 2: Research Methodology

The two villages, Liang Butan and Tang Paye were selected for the case study based on the fact that these two villages have a common source of income and demography but the MHS were funded by different sources. Due to resource and administrative constraints, a 90% confidence level and a 10% margin of error were used to determine the sample size. In Liang Butan out of a total of 144 households, a sample of 47 was used, while in Tang Paye 32 out of 59 households were chosen as a sample [7].

Site surveys along with energy audits were conducted in the two selected villages. The study involved two field trips, one in September 2009 and the second in November – December 2010. During the first field trip both MHSs were working but during the second fieldtrip the MHS in Liang Butan was not in operation. The survey was nonetheless carried out using a modified questionnaire.

Interviews were held with key informants from different agencies, such as village headmen, *Kepala Adat* (grass-roots community leader) and also micro hydro equipment manufacturers. Data was then analysed and is summarised in the results and discussion sections of this paper. The findings from this study are summarised in terms of their implications for the implementation of future micro hydro systems.

Survey Results

The survey results are presented in term of findings relating to the aspects of planning, design, installation, operation and maintenance, and impacts of the micro hydro system. A description on each aspect is reported based on the data gathered using the various techniques.

3.1 Planning

The numbers and roles of stakeholders involved in the planning stage differed in the two case studies. In Tang Paye, beside the government, the equipment manufacturer, the headman, members of the community and the PNPM as the funding body were also involved. As a community-based scheme, the community, including the headman and the funding body played more significant roles. The members of the community, including the headman, were involved in proposing the project and along with the PNPM, planned the budget and the location of MHS.

In Liang Butan the government's role was more intense in the scheme funded through the national budget. Almost all activities in the planning stage were handled exclusively by the Government.

3.2 *Design*

In both Liang Butan and Tang Paye, the MHS was designed as a run of river scheme as the construction of storage dams was not feasible in the steep terrain. As a result, the capacity of the MHS is determined by the available river flow rates. The seasonal fluctuation of flow throughout the year has an impact on the amount of power produced. In both cases a hydro resource assessment was undertaken using the spot reading method [8]. The determination of average annual flow rates was based on qualitative data provided by the community and adjustments were made to the spot readings to account for seasonal variations. No long-term flow rate data existed to support the community estimates of seasonal flow rate variability over a year or over a longer term e.g. a decade.

The systems are designed as instantaneous induction turbine MHS with no storage incorporated in the systems. With this configuration, all of the power produced by the MHS should be used by the load and excess power is dumped. On the other hand, if the load is greater than the power available, blackouts or brownouts occur. This non-robust scheme does not have flexibility to cope with the typical loads of end users, which often peak during the evenings and are at a minimum during the daytime.

In Liang Butan, the powerhouse is located on the side of the river opposite to the village and the operator needs to cross the river by climbing over rocks to reach it. This hazardous situation hinders the operation of turning the turbine on and off during rainy days, especially when the water levels are high. In addition, the intake is located three (3) metres below the water level, which makes the task of cleaning the intake extremely difficult during the wet season.

3.3 *Installation*

Community involvement in the two case studies differed slightly based on project funding conditions. In Liang Butan, as the project was handled by a contractor, there was no community involvement during the construction stage other than a small number from the Pa Betung village who were paid workers. In Tang Paye, the community was involved during the installation stage as volunteers due to the fact that the limited funding that was made available covered only the equipment and construction materials.

Due to the geographical isolation and the condition of the airstrip, the logistics of delivery became a constraint as the equipment needed to be freighted in by a 12-passenger small aircraft. A knock-down modification was developed to fit the equipment to the plane door size and to adhere to the maximum weight allowed on the plane. One strategy for reducing the supply cost and delivery time was to bring materials, such as cement and steel overland from Ba Kelalan (in Malaysia).

Due to demand exceeding the MHS supply capacity, the 430 households of Liang Butan are divided into 2 clusters, with each cluster being supplied with electricity on alternate days. A circuit breaker has also been applied to limit consumption to avoid overloading. Initially the circuit breaker was installed for a sub-cluster of several households. The drawback of this scheme was the need to reset the device on overloading and the difficulty in identifying which households were causing the overloading. Single limits on each individual household were subsequently applied, using 1, 2 or 3Amp limits according to the villager’s request. This system worked well for a few years but some villagers began to ignore the regulation and bypassed their circuit breaker. This has led to difficulties for load distribution management.

In Tang Paye the MHS committee regulated that each household could operate lights and a television set only. A current limit of 1 Amp limit per household was applied. This regulation has been complied with and the MHS has operated without overloading.

3.4 *Operation and Maintenance*

The operation and maintenance of the MHS in Liang Butan is undertaken by a technician and two operators. The trained technician is responsible for all O&M, including mechanical and electrical matters. The two operators are responsible for the daily O&M in the powerhouse, including turning the turbine on and off, greasing the turbine and clearing the intake. The operators were not provided with any formal training and were trained only by the trained technician. Operators did not stay long in this position because of the low pay.

In Tang Paye, a MHS committee is responsible for O&M. The committee members come from two villages in Tang Paye and include a chairman, a secretary, a treasurer and technicians. One of the committee members attended a 3-day MHS training course that was held in Long Bawan. Three days of basic training were provided by the PNPM program prior to the project commissioning to support the person selected to run the Operation and Maintenance (O&M) of the Tang Paye MHS. In Liang Butan, the current MHS O&M person was hired after the MHS was commissioned so he joined the training to increase his skill and knowledge.

For both villages the operating hours were overnight between 5.00 pm and 6.00 am. The reason for this was that the main purpose of the power from the MHSs was for lighting at night. The decision to not operate the MHS during day time was different in the two villages. In Liang Butan the villagers believed that the flow rates are insufficient for 24 hour operation. In Tang Paye, the decision was also based on safety issues. As the adults worked during the day and children were attending school, the villagers agreed to turn off the MHS to prevent the risks of young children at home being electrocuted as a result of any electricity faults.

The O&M of the MHS in both Liang Butan and Tang Paye has required a dedicated O&M budget, as the initial funding covered only the installation. MHS end users are levied a monthly charge to cover the cost of O&M. In Liang Butan, the monthly electricity supply charge varies according to the limit of the installed circuit breaker. Households are charged IDR 15000 (AUD 1.8) per month for a 1 Amp limit; IDR 30000 (AUD 3.5) for a 2 Amp limit are charged and IDR 60000 (AUD 7) per month for a 3 Amp limit. The money is collected and managed by the technician. The tariff scheme in Tang Paye is slightly different. The monthly electricity charge is determined by what appliances are used. The villagers are allowed to operate a maximum of 5 lights and a television. The levy for operating three lights is IDR 10000 (AUD 1.2) per month. The additional levy for operating one additional light is IDR 5000 (AUD 0.6). The levy for operating a television is an additional IDR 20000 (AUD 2.4) per month. The money is collected and managed by the MHS committee.

3.5 *Impacts of MHS on the Community*

The survey results contribute to our understanding on the impact of MHS on communities, especially on their energy expenditure and changes in social activities.

3.5.1 *Expenditure on Energy*

An estimate of household expenditure on major items - food, medicine, education and energy (fuel, electricity from micro hydro, wood, battery, candle, LPG, kerosene) was obtained through the survey. The approximate monthly expenditure of major items is shown in Figure 3 below.

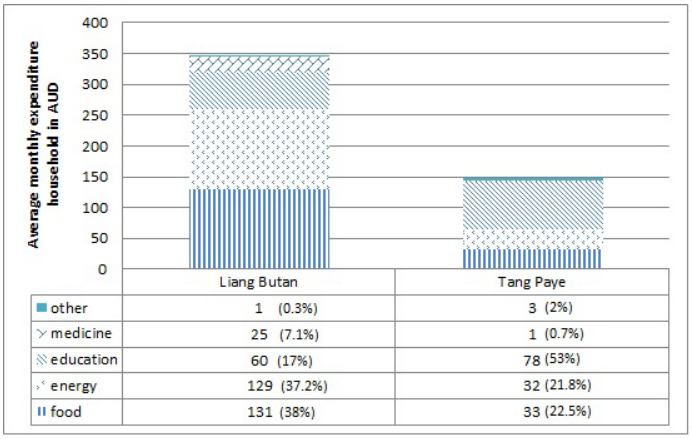

Figure 3. Average monthly expenditure per household in AUD
Source: author's survey in 2010

At the time of the survey, average monthly expenditure per household in Liang Butan was more than double that in Tang Paye. In Liang Butan, total household expenditure was dominated by expenditure on energy and food, while in Tang Paye education was the largest household expenditure item.

The reason for the high energy expenditure in Liang Butan was the MHS in Liang Butan was not working during the data collection period. Households had to run their generators for electricity, while in Tang Paye electricity was supplied from the micro hydro at low cost. Only the wealthiest villagers in Liang Butan could afford to run their generators regularly. Tables 1 and 2 present the energy resources unit price and the cost of main energy resources in Liang Butan respectively.

Table 1. Unit prices of energy resources in Liang Butan (November 2010)
Source : author's survey in 2010

Energy Resource	**unit**	**price/unit (AUD)**
Petrol	litre	2
Diesel	litre	2
Kerosene	litre	1.8
LPG	kg	2.5
wood	kg	1.2

Table 2. Costs of main energy resources (excluding micro hydroelectricity) in Liang Butan (November 2010)
Source: author's survey in 2010

Technology used	Period of use of energy technology (hour)	Frequency of use of energy technology	Average fuel consumption per week (litre)	Total cost of energy per week (AUD)
Generator	3 hour	Daily	10	20
	3 hour	Second day	5	10
	6 hour	Daily	20	40
Kerosene lamp	6 hour	Daily	0.25	0.45

3.5.2 *Impact of micro hydro system on social life*

The availability of the relatively low cost electricity from the MHS has led to some social interaction changes at both the community and the household levels. Not all impacts were regarded by the villagers as being positive as some respondents claimed that the installation of the MHS had resulted in some social drawbacks.

Respondents were asked about the impacts of MHS on social cohesion. Fifty percent of respondents in Tang Paye stated that the MHS had resulted in reduced intra-community interaction. One respondent said that previously only around 10% of inhabitants had televisions, so people watched television with their neighbours. Now, with affordable electricity from the MHS, almost every household owns a television and this has reduced social interaction.

In Liang Butan, around 40% of respondents stated that they had less interaction with people when the MHS was working as they preferred to watch television at home. They reported that since the MHS had ceased operating, those who did not own their own generator had to go to their neighbours if they wanted to watch television or to recharge their mobile phones, or they went to the café. Other negative social impacts of the MHS were reported as reduced attendance at regular church services, especially at evening prayer meetings. On the hand, a positive impact of the MHS was increased levels of lighting around the village, to which reduced incidence of drunkenness and juvenile delinquency is attributed.

In regard to the social impacts of MHS on household life, about 45% of respondents in both Liang Butan and Tang Paye stated that the MHS had increased their entertainment. With affordable electricity, respondents felt free to watch television until late. Some respondents indicated that they leave the television on all night long.

The highest level education available in Bawan Valley is senior high school. Young people wanting further education have to migrate to another city. Some of them study in big cities in Kalimantan, while others send their children to Java for secondary studies. In both Liang Butan and Tang Paye, most respondents stated that MHS has had no impact in terms of reducing outmigration.

Respondents were asked whether the electricity provided by the MHS had any impact on their household incomes. The majority of respondents in Liang Butan indicated that their income was not affected by the MHS although 38% of respondents attributed increased income to the MHS. When the MHS was working, some respondents were able to operate a blender to make some snacks or sell ice or sell meat and fish, etc. On the other hand, some respondents who were selling fuel gained more income when the MHS was not working.

In contrast, 59% of respondents in Tang Paye stated that their disposable income had increased as a result of the MHS having been installed. Prior to the MHS being commissioned, they made handicrafts only during the day until dinner time. Now with the MHS providing light they have the opportunity to make crafts until late. No respondents reported selling ice or meat because in this village they were not allowed to operate appliances such as a fridge or freezer. The reported impact of micro hydro on income is presented in Figure 4 below.

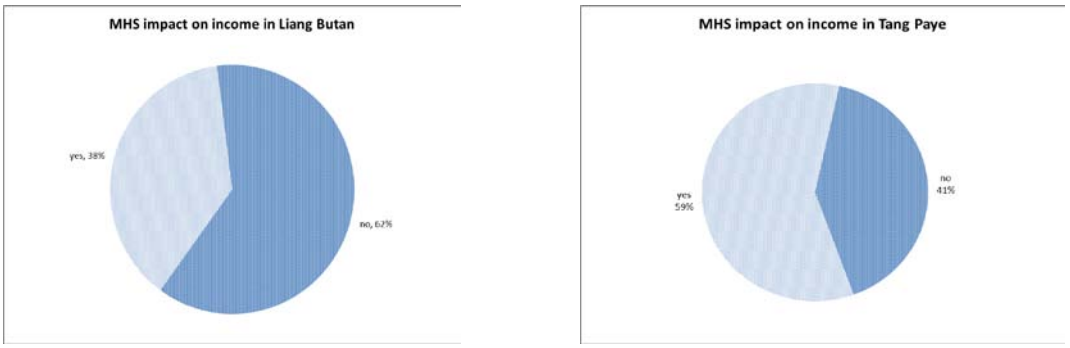

Figure 4. The proportion of respondents whose reported that their income had increased since micro hydro electricity has been available in Liang Butan (left) and Tang Paye (right)

Discussion

From the survey results we can see that stakeholders' roles varied depending on the funding source of the micro hydro scheme. Even though many stakeholders were involved in the micro hydro systems, some of the key stakeholders, especially government staff and the headman, can play an important role in line with the principle of serving people's wellbeing and bringing more benefits to the rural community [9].

Design of the MHS is very important. Design should be based on long term river flow data which was missing in both systems. The capacity of the MHS was calculated based on spot readings which meant that estimates of the MHS output over the year were highly unpredictable. The impact of global and regional climate changes on river flows is also uncertain, although research in India, Sri Lanka and Vietnam has found that hydrological discharges, especially rainfall, in each of these three case studies have a tendency to increase [10]. In contrast, however, a United Nation report shows that temperatures in the tropical regions of Asia are expected to rise by between 2 and 8 degrees Celsius over the next 40 years and those further climatic variations will include decreased rainfall [11]. Therefore accurate determination of micro hydro capacity requires long-term measured hydrological data and a better understanding of the impacts of climate change.

The design of the MHS in the two case studies was not based on a robust assessment of current or projected electricity demand or fluctuations in demand as they were designed as instantaneous systems. Consequently power shortages occurred during the peak periods in the evening, but the generator was shut down during the day and the river flows unused.

Overloading is the most critical issue for the system in Liang Butan, but this is not a technical problem as current limit devices have been installed. Increased household expectations for use of electricity have led to non-conforming behaviour such as bypassing the limit devices. When households use more electricity than the set limit, electricity distribution management is difficult. Thus most electricity supply companies are wary to implement this current-limit approach [12].

Operation and maintenance is an important factor to be considered in designing an MHS where operational safety also needs to be taken into account. The survey showed that providing O &M training to increase capacity building in the community helps in reducing the cost and maintenance time. This finding is in line with result by the International Energy Agency that most renewable energy projects in developing countries that have not been sustainable in the long term have failed due to poor maintenance and monitoring [13]. This may be partly caused by high rates of turnover of maintenance staff who are

poorly paid and see better opportunities to earn money elsewhere. This has been documented in Bhutan, where the reimbursement to the operator is less than that which could be earned as an agricultural labourer [14]. The management of tariffs in Liang Butan also needs to be improved. The electricity tariff needs to cover at least the O&M costs, so as to ensure components are replaced as scheduled, and ideally the reimbursement for the O&M staff.

The cost of electricity from the micro hydro system has proved to be cheaper than diesel/petrol generators and kerosene lamps. Tang Paye villagers only pay IDR 30000 (AUD 3.75) per month to get electricity for half a day. Even though the power supply depends on the water availability and reduced water levels cause disruptions to supply, the villagers have found that electricity from MHS is preferable.

The micro hydro systems have had an impact on social cohesion at both the community and household levels. The project also created some opportunities for some people to earn extra income. Clear reliable light at night enabled people in Tang Paye to do handicraft work, while in Liang Butan people benefit from using appliances such as blenders and freezers powered by micro hydro. This is in line with what was achieved from a micro hydro system in Nagrak, Tasikmalaya, Indonesia that enabled villagers to get extra income by small scale enterprises such as embroidery home industries [15]. However, according to Koojiman-van Dijk and Clancy [16], electricity is more likely to benefit households on good incomes rather than drive rural economic development, although the scale of analysis influences what is considered to be an impact.

1. Conclusion and Lesson Learnt

A survey of two micro hydro systems in the Bawan Valley villages of Liang Butan and Tang Paye has provided insight into critical issues in the stages of development and the impacts of a micro hydro system on rural communities. The key lessons learnt are:

- Success of an MHS depends on stakeholders' involvement to ensure that the project is carefully designed and provides the maximum benefit to the community in the long-term.
- Stakeholders need to be identified and engaged at the beginning (planning stage) of the process so that they are able to play their part in every stage of the MHS project.
- When designing a MHS, knowledge of seasonal variations in flow rate is critical to prevent the problem of intermittent power supply disruptions.
- Occupational health and safety need to be considered in the design stage to minimise the chance of workplace accidents in the construction phase and during operation of the system.
- Impact of geography on logistics needs to be considered to avoid project delays and cost over-runs.
- Planning for a MHS needs to consider a range of social impacts, some of which can be unexpected.
- Capacity building to assist the community members operate their own MHS and keep it running is often overlooked but is essential.
- Non-technical expertise such as managerial skills needs to be developed to manage cash flow and reliable financial reporting, building community trust and cooperation.
- The factors relating to the effectiveness of O&M are social rather than technical especially the role of the MHS committee in management of the tariff.
- The MHS have provided limited job opportunities and had no impact on the youth out-migration.
- There are limited income generation opportunities with MHSs providing such restricted supply.

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