The Implementation of Micro Hydro Projects in Remote Villages on the Border of Indonesia and Malaysia: Lessons Learnt

Sari Murni[1], Tania Urmee[1], Jonathan Whale[1], John Davis[1] and David Harries[2]

[1]Murdoch University, WA 6150, Australia

[2]University of Western Australia, WA 6010, Australia

Abstract:

Implementing micro-hydro system (MHS) in a remote or rural location in an off-gridarea is a complicated process. Technical, social, economic andorganisationalissues need to be considered as well as the policy environment in which they are implemented. An understanding of the demand for electricity, of the benefits and impactsthat they can potentially have, as well as the roles of all stakeholders in the different stages of the MHS project, are also required. This paper presents the findings of a survey of stakeholders involved with two MHS projects in the highlands of Borneo. The survey results confirm that in order to ensure project success, particular attention needs to be paid to key critical factors. The performance and reliability of the MHSs were found to be strongly influenced by the role of the local micro-hydro management committee, and the relationship between the committee and the other members of the local community. The more successful schemes tended to be associated to more proactive committees that clearly informed the villagers about the issues of MHS and its sustainability. Other factors that were found to have an influence on project success were village cultural (which was related to the size villages) and the national energy policy framework in which the programs are planned and implemented.

Index Terms—Micro-hydro, Social factors, Organizational and cultural factors, Load factor, Successful project

I. Introduction

THE benefits of access to electricity for rural households and communities in remote areas in developing countries in terms of alleviating poverty, and improving health, education and quality of life are now well recognised and accepted. These benefits are so important that rural electrification programs have become a major plank of development strategies in such areas.

The large island of Borneo consists of the nation of Brunei Darussalam, five Indonesian provinces (West Kalimantan, East Kalimantan, North Kalimantan, South Kalimantan and Central Kalimantan), and two states of Malaysia (Sabah and Sarawak). This large island is best known for its tropical forests and its biodiversity. The current research focuses on Ba'Kelalan (the Kelalan Valley) in the highlands of Sarawak and the adjacent Krayan sub-district in North Kalimantan. Both are located in the northern part of the Heart of Borneo and both are close to the national border. Those that live in these two communities on either side of the border share a common ethnic background. Improvements in their standards of living have been hindered in both cases by their remoteness, but this same remoteness has also protected the unique features of the local environments and the culture of the communities in this area.

Although located in the tropics, solar insolation levels are relatively low due to the high number of cloudysky days per year in these highland valleys. Having topographical relief and high rainfall, they do, however, possess hydro resources and these are a logical choice for renewable energy technology in these areas [1]. The ‘run-of-river’ micro hydropower systems (MHSs) that have been built in the areas have enabled a number of the villages to be supplied with electricity without the social and environmental impacts of larger hydro schemes [2]. Providing electricity by MHS in such remote locations, however, is a complicated process. The number of issues that need to be considered is large. They include technical, social, economic, organisational, policy and environmental factors.

The villages located in these areas are similar in geography, ethnicity and religion, but differ in their economic and political situations as they lie on either side of, and close to, a national border. Using data collected from field work, four case studies were used to examine the technical, organisational,

economic, social, and cultural and policy aspects of the projects. The aim was to identify the key factors that influence the success of implementing MHS projects in remote settlements such as these villages.

II. Heart of Borneo and Micro-Hydro Systems

Industrial logging and extensive conversion of land to oil palm plantation has changed the tropical forests of Borneo [2-4] and river pollution and loss of natural ecosystems have now emerged as serious problems as a consequence of this. In order to preserve pristine forest and the richness of the biodiversity, governments of the countries constituting Borneo, Malaysia, Indonesia and Brunei, with support from WWF, agreed to preserve the 220, 000 square km area called the ‘Heart of Borneo’, in its central highlands. [5].

Ba'Kelalan (the Kelalan Valley), and Krayan, in the Bawan Valley, are located in the northern part of the Heart of Borneo (Figure 1). The climate is relatively cool (the mean daily temperature is 30°C) because although these areas lie close to the equator the elevations of both valleys are approximately 1000 m above mean sea level [8].

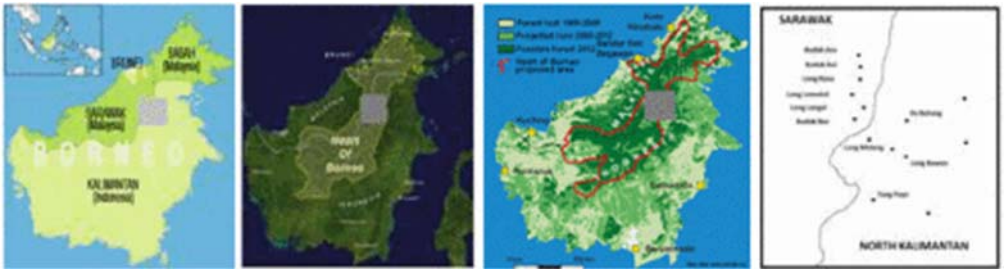

Figure 1a. Map of Borneo. 1b. Heart of Borneo region. 1c. Estimated remaining forest in Borneo in 2012. 1d. Sketch map of the research villages. Sources: [6,7]

A. Geography and Demography

Ba'Kelalan is located in the southern part of the Lawas District, between latitudes 3° 57’ and 4° 04’ latitude N and longitudes 115° 36’ and 115° 38’ E. The average elevation of the area is approximately 970 m ASL [9] and the region is characterised by hilly topography and a monsoonal tropical climate. Monsoonal rains come from southwest between April to October, and from the northeast between October and February.

Across the border in Indonesia, the Bawan Valley comprises two sub-districts of Nunukan Regency: Krayan and Krayan Selatan. This study focuses on the Krayan sub-district, which consists of 65 villages with a total population of 8438 [10]. It is located in the northern part of North Kalimantan and has borders with Sabah and Sarawak. There are roads connecting to Sarawak, but none to Sabah. As a consequence the interactions between the people in Ba'Kelalan and those in the Krayan Valley are more intensive than they are between villages in other areas on their own sides of the national border.

B. Energy Situation

Due to its remoteness, Ba'Kelalan is not connected to the regional electricity grid of Sarawak. Kerosene and candles are used for lighting, while firewood and LPG are used for cooking. Small petrol generators are used to provide the electricity required to operate power tools and appliances. Larger diesel generators are used to supply the electricity used to operate larger equipment such as rice mills.

Krayan is a remote land-locked area in mountains surrounded by the Krayan MentarangNational Park, and this has hindered the Government's ability to provide public facilities and infrastructure such as electrification. The people in Krayan also use candles, kerosene lamp or a generator for lighting. Petrol and diesel are used to run generators to operate power tools, rice mills and home appliances. Fuels (petrol, diesel, kerosene and LPG) are brought from Ba'Kelalan and due to the price paid in Ba'Kelalan and the transportation costs, the prices of these fuels are high. Only the wealthiest are therefore able to run their generator on a daily basis.

C. MHS in Ba'kelalan and Krayan

Six micro-hydro systems have been built in Ba'Kelalan to date. These projects have been funded through a range of funding mechanisms, including government, NGO, community-based and private funding. They also serve a range of purposes vary in terms of their output capacities and also in terms of the processes that have been put into place for maintaining and managing the micro-hydro plants.

In Krayan sub-district (N. Kalimantan), ten MHS have been installed to date in a number of villages. However, only four of these were operating at the time that the survey was undertaken. The funding sources for these projects were also varied (government agencies, community-based organisations and private organisations). Each of the funding sources involves different procedures in terms of project planning, implementation and management. This survey investigated the roles that the various stakeholders played in each stage of micro-hydro projects and considered how those roles influenced the problems and barriers encountered and the benefits and impacts that the MHS had, especially on the expenditure on energy and social benefit.

III. Methodology

The aim of the study was to obtain a better understanding of the MHS programs in terms of designs, implementation and benefits of the programs for different types of funding sources. The study also looked at the approaches used in delivering the program and the political and institutional frameworks within which the programs are being implemented. By selecting projects in a border area between two countries (Malaysia and Indonesia), it was reasoned that the impacts of the differences in policy frameworks could be highlighted. An overview of the methodology used for the research is shown in the block diagram in Figure 2.

A literature review was used to understand the current status of the programs and how the programs are being implemented, who the main actors are and how they are linked with each other. A field

survey was undertaken over the period September 2009 to March 2012 that included a preliminary survey, questionnaire survey, stakeholders' interviews and follow-up survey of the MHS programs. The focus of the survey was on the institutional and other mechanisms used, the policy environment and framework in which the programs are being implemented. Open-ended questions were used to collect data from interviews with representatives from implementing agencies, funding bodies, policy makers, and government organisations.

Most of the primary data was collected through interviews of village stakeholders, representatives from policy making and implementing organizations to obtain the views of implementers and policy makers on their programs. One focus group discussion was organized in Buduk Bui to obtain the views of implementers and policy makers on their programs. SPSS software was used to analyse the responses to the questionnaires and the interviews were transcribed and then analysed.

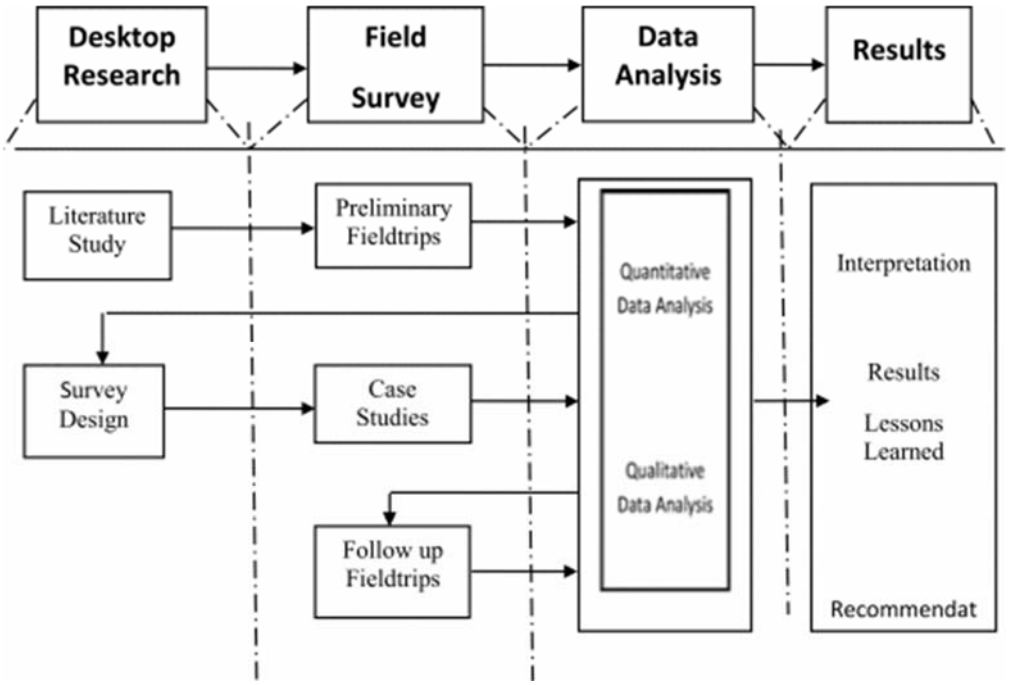

Figure 2: Methodology flow chart

IV. Demographic and Energy Characteristics of the Case Study Villages

The information presented here was obtained from questionnaires and semi-structured interviews with village headmen and the heads of households connected to a MRS. In Ba'Kelalan, twenty-one and forty-nine households were surveyed by means of a questionnaire in the villages of Buduk Bui and Buduk Nur, respectively, while in Krayan fifty and thirty two households were surveyed in Liang Butan and Tang Paye, respectively. The questionnaires sought information regarding the household occupant's demographic profile, income, expenditure and current energy usage.

A. Demographic Profiles

Most of the houses surveyed in Buduk Bui, Buduk Nur, Liang Butan and Tang Paye are grouped in clusters and are typically made from wood with roofs made of corrugated iron sheets. From field observations, the houses seem well equipped and maintained and there are no signs of poverty. The number of people living in anyone house ranges from 1–10. Figure 3 shows the number of occupants in the households in the case study areas.

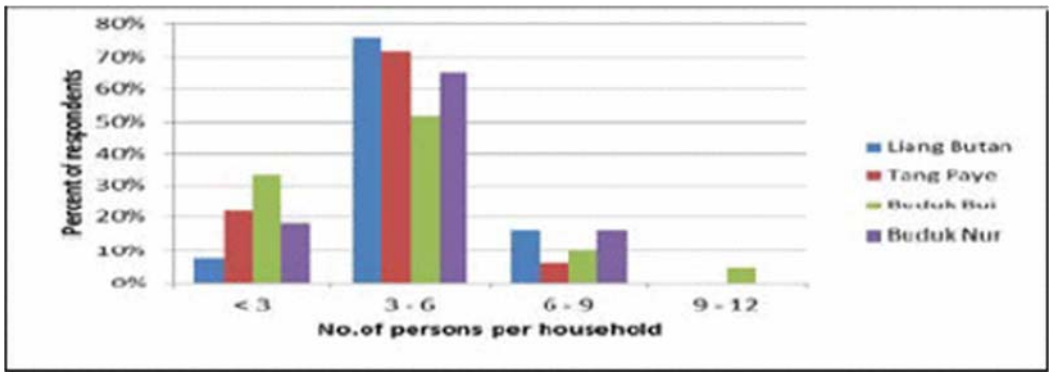

Figure 3: Average household size of the participants.

The average household size is 3–6 in all four areas. The lower number of occupants in Buduk Bui households is due to the geographical distance of the village to the Ba'Kelalan Primary School in Long Langai, which means that the school aged children either board or stay with their relatives during the school week.

Most of the respondents could read and write and had completed primary education. In Buduk Bui the highest education level of the respondents was high school graduate while in other cases, around 5–15% respondents had completed either a diploma or a bachelor degree (Figure 4). Almost a quarter (24%) of the respondents in Buduk Bui had no formal education, while in Buduk Nur only 4% of the respondents are illiterate. In Liang Butan and Tang Paye all respondents had formal education.

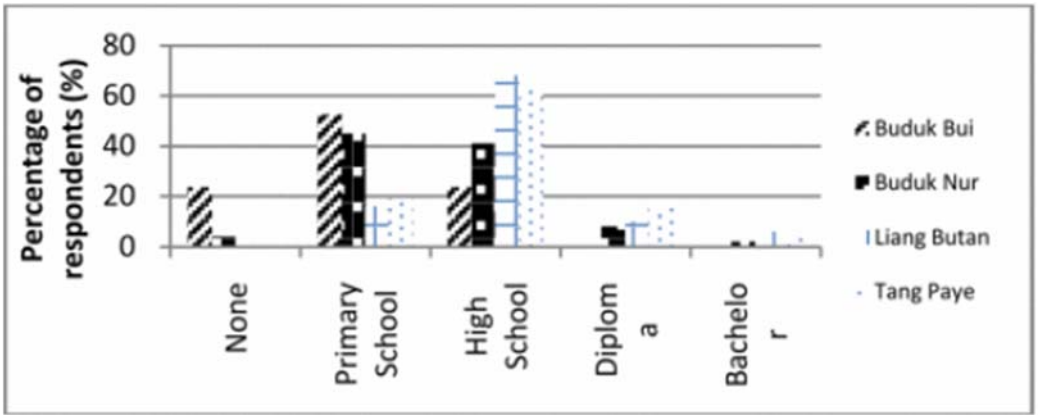

Figure 4: Level of education of the respondents in the case study areas in Ba'kelalan and Kray

Most of the people in Ba'Kelalan source their food from farming, forest hunting or fishing. Respondents' incomewasmainly derivedfrom farming, supplemented by small business and services. The income structure in Krayan is similar to Ba'Kelalan in which the villagers have a viable lifestyle without a regular salary by exchanging goods. Figure 5 shows the annualincome of the respondents in the case study area.

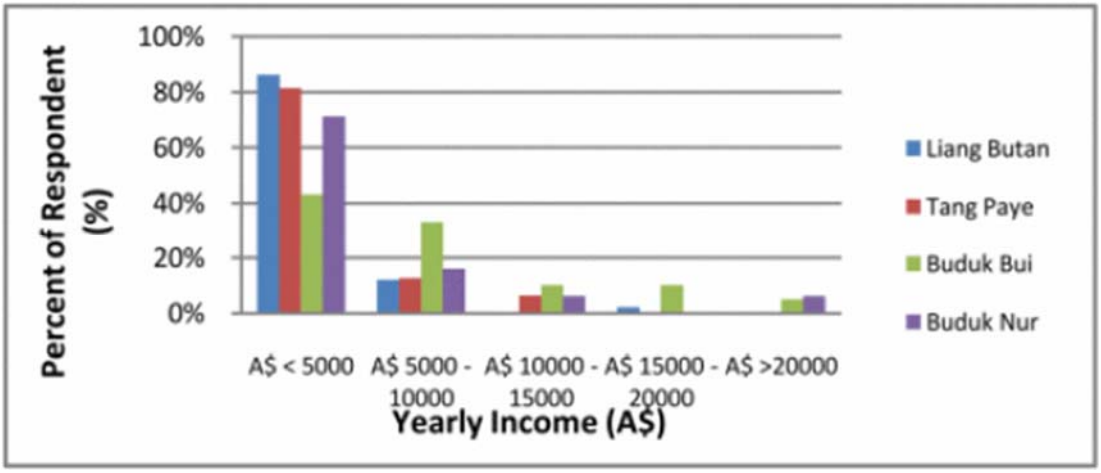

Figure 5: Yearly income of the respondents

B. Current Pattern of Energy use

Energy audits, which assist in determining the match between demand and supply, were conducted in Ba'Kelalan and Krayan to evaluate the current energy usage patterns in those areas. A wide range of energy sources are used by the participants to meet their daily energy needs. Wood, kerosene and LPG are used for cooking, while diesel and petrol are used for transportation and electricity production. During the field trips, the MHSs in both villages in Ba'Kelalan were working, although on some nights, black-outs occurred in Buduk Nur due to overloading. The MHS in Liang Butan, Krayan, was not working during the field trips and for lighting, people operated petrol or diesel generators and kerosene lamps. In all four cases the micro-hydro committee (MHC) in the village suggested limiting electricity use (In Buduk Bui and Tang Paye a limit of 240W per household had been set, while in Buduk Nur and Liang Butan a 100W per household had been set. No current limiting devices to enforce the limit were observed during the energy audit of households.

Figure 6 shows the variation in average daily electricity consumption among the surveyed households in both case study areas. It can be seen that in Indonesia, 90% or more of the respondents consumed less than 2kWh/day, while, on the Malaysian side around 50–65% of participants consume the same. In part, higher loads are associated with the load limits suggested by the MHC of each village and thus higher loads in Buduk Bui are expected. However, although the load limits that have been set in Tang Paye are similar to those in Buduk Bui and Buduk Nur, the respondents in Tang Paye did not have high loads.

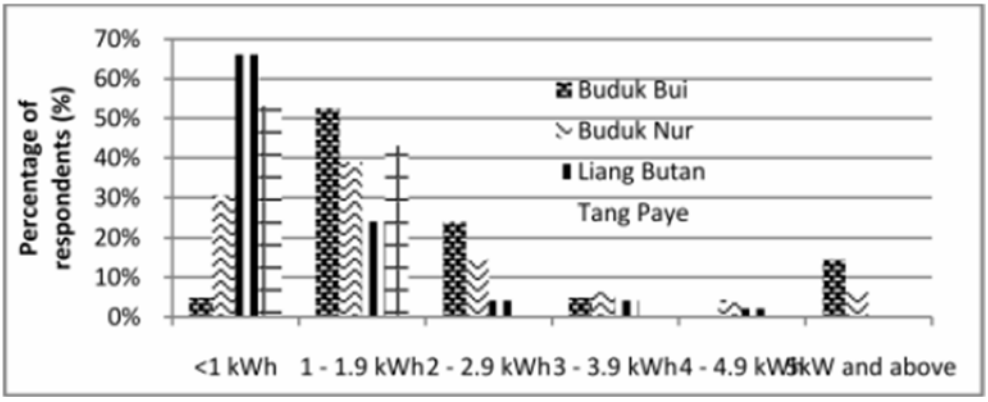

Figure 6: Distribution of daily consumptionin case study areas

V. Evaluation of Microhydro Projects in Ba'Kelalan and Krayan

The evaluation of the MHSs was focused on technical, organisational, economic, policy, social and cultural aspects of the program. These are discussed below.

A. Technical Evaluation

Site selection is one of the most important steps in MHS development, as that will largely determine the amount of energy that can be harnessed and whether it can meet the load demand of the community [2], [11], [12]. All of the MHSs investigated this study were designed as run-of-river schemes As a result, the output of each of the systems is determined by the available river-flow rates and the power produced fluctuates with the seasonal changes in flow throughout the year. In all cases, a hydro-resource assessment was undertaken with spot-readings of flow rates taken using the ‘float’ method in the dry season [13]. The determination of average annual flow rates was based on using qualitative data provided by the community to make adjustments to the spot readings to take into account the seasonal variations. Long term flow rate data collected over a year or a longer-term period, such as a decade that could be used to support the estimations of seasonal flow rate variability existed. All four schemes were designed as instantaneous induction turbine MHSs with no storage incorporated in the systems. With this configuration, all of the power produced by the MHS is used by the load and any excess power is dumped. On the other hand, if the load is greater than the power available, blackouts or brownouts occur

Managing the load is another important requirement for a MHS to run consistently. In Buduk Bui, each household was provided with electricity access of up to 250 W, which effectively meant that they could run lights and a TV only. When it was realised that there was excess power from the MHS, a few of the households started to operate additional appliances. The MHS in Buduk Nur was initially installed to run a health clinic, but the community subsequently gained approval from the Ministry of Health to supply electricity up to 100 W(capacity for 5 lights)to every household of the village.

Some households ignored the agreement and operated additional appliances, which often caused blackouts due to over-loading. There are no current limiters used in this system, which makes it

difficult to control the household loads. Unstable voltages have caused the vaccine freezer of the clinic to remain broken since September 2010, and thus the inclusion of the households has jeopardised the main aim of MHS project, which was to keep the vaccine freezer in the clinic operating 24 hours a day.

In Liang Butan, a current limiting device was used for each cluster of 4 to 6 households in order to avoid overloading, where by each household was limited to 0. 5 A. The drawback of this scheme was that overloading often still occurred and people who complied with the current limit complained as they had to reconnect their households several times a night. In addition, it was hard to manage the load between the clusters as nobody knew who was overloading. In Tang Paye, every household has access to 1Aelectricity, except 3 households, two headmen of different hamlets and one secretary, who had access to 2 A. All households are advised to operate a maximum of 5 lights and a television set and not to operate other appliances. To distribute the load, they split the power into 3 lines. Two lines serve 20 households, five 20Wstreet lights and a church. The other lines serve 19households, five 20Wstreet lights and a government office. The problem of bypassing the current limit was not reported except once when a household tried to turn on other appliances and ended up with a blackout. The committee identified the house and advised them to not do it again.

Out of four case studies, Buduk Bui MHS is the only project where supply from the MHS exceeded demand. In this case, all potential resources were utilized, but there was no clear planning on what the excess power was to be used for. In the other three systems (BudukNur, Liang Butan and Tang Paye)

MRS supply did not meet demand. In Buduk Nur and Liang Butan the power was planned to be distributed equally, while the distribution in Tang Paye relied more on personal demand with a certain maximum demand per household, which was set by the MRC.

In some cases, the MRS capacity was not determined solely on technical grounds (e.g. available resources), but also on the basis of social factors. In Buduk Nur, the MRS capacity was first designed as 7. 5 kW to satisfy the health clinic's needs and to match the available resource, but was later the system capacity was upgraded to 20 kW to fulfill the community's request to access electricity for

households. In upgrading the system design, the increased load was taken into account, but not the available resource. Adjustments to system design were also found in Liang Butan, which firstly aimed to electrify around 333 households in the Long Bawan location, yet increased this to 430 households as other villagers became engaged in the implementation. The adjustment in planning led to dissatisfaction in both case studies since the larger number of end-users increased the required complexity in load management due to the limited power produced by the MRS. This finding is in line with the result of Asim (2004) who found that community involvement in technical decisions can lead to worse outcomes for the project [14].

B. Organisational Evaluation

An organisational evaluation was performed to see how the management of the projects was carried out, and to ascertain the roles of the stakeholders in the projects. The survey found that the number of stakeholders and their roles in the MRS projects varied from one project to another and depended on the funding scheme. In general, the main stakeholders for an MRS project are project initiator, government, funding body, contractor or implementing organization, community, NGO, electricity authorities, manufacturers/suppliers, etc.

It was found that in the case of the government funded schemes(Buduk Nur and Liang Butan), that the stakeholders that have the most influential roles are the government and the manufacturer/supplier. On the other hand, in the community-based scheme (Buduk Bui and Tang Paye) the community could have influence in a range of areas besides project funding, including planning (e.g. deciding which river to use and the power house location), implementation, operation and maintenance.

Overall, the number, type and role of stakeholders of MRS varied, depending on the funding scheme. There was dissimilarity in planning, implementation, and operation and maintenance (O&M) processes for each project. The involvement of the community was through the MRCs and their role differs depending on the funding scheme. From Table I we can see the O&M of the MRS in all case studies was run by the MRC itself once the MRS project was handed over to the community after commissioning. In all case studies examined the O&M of the MRS did not involve any preventive

maintenance leading to a “fix only when fail” approach, where “fix” was often a case of “trial and error”.

This suggested that the O&M training, provided by the supplier to increase capacity building, was not enough for the MRC to address the problems. In Liang Butan, the technician needed to stay near the power house, which is far from the village.

Table I: Stakeholders and their role in MHS Projects in Ba'kelalan and Krayan

	Community based - MY Buduk Bui	Government MY Buduk	Governmen scheme- Liang Butan	Community scheme - Tang
Stakeholde	Funding body – Rotary Club, community, distributor, Sawarak Energy	Government community, distributor, Energy Berhard	Government manufacturer, community	Funding body - PNPM, community, Government community
Dominated stakeholde	Funding body, community, distributor	Government distributo	Government contractor	Funding body, community
Community involvement	Funding, planning, civil work and O&M,	Civil work and O&M, MHC	Civil work (paid worker) and O&M, MHC	Proposing, funding, planning, civil work and O&M, MHC

The dam is located just 30 m above the power house, but due to an extremely steep slope and slippery trail, it is difficult to reach the dam and made the job risky. According to one respondent, low wages compared with the safety hazards in the job caused a high turnover of operators. The responsibility of O&M lies with the community, but in the case studies villages, as with most rural communities there is a lack of sufficient expertise in terms of both project management and technical skills. This emphasises the importance that capacity development plays in O&M of the MRS, and that it needs to be embedded in the planning of the project. Various studies conducted have revealed that untrained operators [15] and poor maintenance [16] were key factors in the failure of MRS.

The absence of any maintenance handbook in both Buduk Nur and Liang Butan is also a causal factor for poor maintenance practice. A lack of technical skills and knowledge, and managerial skills (both financial or leadership), resulted in poor performance, and this again highlights the importance of capacity building. Appropriate training in terms of materials and time needs to be provided to ensure

the community is capable of running the O&M smoothly so that repairs are not carried out on a trial and error basis.

C. Economic Evaluation

The funding of the MHS in this study came from different sources. The MHS in Buduk Bui and Tang Paye were jointly funded by the community and an NGO, while funding of the MHS in Buduk Nur and Liang Butan came only from the government. In Buduk Nur, the funding covered the costs of the equipment, materials and set-up only, thus the community needed to be voluntarily involved in civil work, whereas in Liang Butan, the funding covered all project expenses and the community was involved as paid workers for the civil works. None of the funding, either from the government, community or NGO, was set aside for O&M costs. Thus, after hand-over, the community was responsible for O&M, including budgeting funds. A lack of O&M funds were reported in three out of the four case studies and as a consequence, O&M activities could not be undertaken as scheduled; longer times were needed to collect enough money to fix problems and often components were replaced with low-quality materials in order to meet the budget.

A monthly electricity bill is used to cover the O&M cost including technicians' and operators' salaries, and component replacement. The monthly electricity bill used a fixed rate tariff on the Malaysian side and was variable on the Indonesian side. The monthly bill set up by the MHCs was not sufficient to fully cover the O&M costs. The cost of electricity from the MHS proved to be cheaper than from diesel/petrol generators. For example, in Liang Butan, to access electricity 6 hours per day people had to spend $6 per month on average, compared with Tang Paye villagers who had to pay only $3.75 per month to access electricity for 12 hours per day.

Both in Buduk Bui and Buduk Nur about a quarter of the respondents agreed that their income had been impacted by the construction of the MRS, since it allows them to use lighting and tools at night to make handicrafts and, in the case of Buduk Bui, to have a longer time for sewing. Additional income generation was also mentioned by one respondent, a committee member, who obtained a salary as a MHS technician. In Buduk Nur, besides the micro-hydro allowing handicraft and sewing,

it also gives the opportunity to use refrigerators to keep meat, cold drinks and snacks for sale. In Liang Butan 38% and in Tang Paye 59% of respondents agreed attribute increased income to the MHS. The opportunities for handicraft businesses in Indonesian are greater than they are on the Malaysian side of the border due to the greater availability of labour in Indonesia than Malaysia. This is reflected in figure 7, which shows that in Indonesia more people agreed that the impact of the micro-hydro on income is positive.

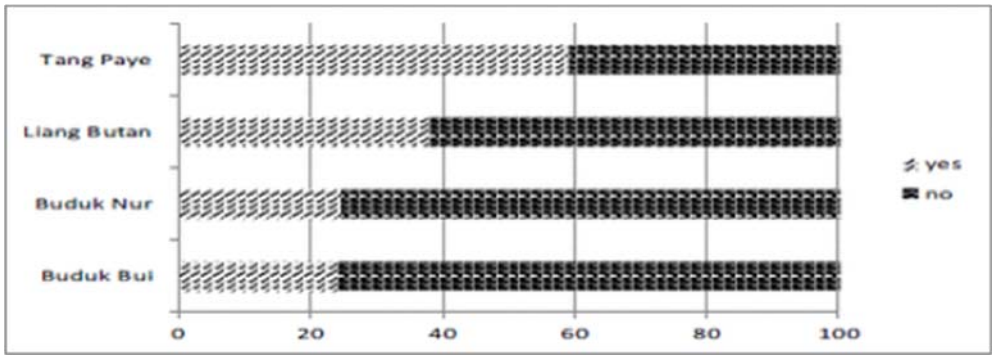

Figure 7: Impact of MHS on Income

D. Policy Context

Government coordination for renewable energy technology programs in Indonesia is generally poor. For example, a river in Lembudud village, with a potential hydro-electricity capacity of 15 kW, could not be harnessed because the project budget exceeded the limit of the relevant funding program (the National Program for Community Empowerment, *PNPM*). Despite one government respondent mentioning that there has been shared funding from the national Ministry for Disadvantaged Areas and local government for some projects, negotiations to share the cost of the Lembudud MHS project between PNPM and the local government were unsuccessful. Another difficulty for the implementation of national programs or strategies arises from the way decentralisation and local autonomy reforms in Indonesia have made it difficult for government agencies to coordinate national policies and programs down through provincial and local levels of government.

In Malaysia, implementation of renewable energy projects lag far behind their targets. To increase the share of renewable energy in the Eighth Malaysia Plan and the Ninth Malaysia Plan, a Small

Renewable Energy Power (SREP) Program was introduced [1]. Due to lack of capacity, a lengthy approval process, lack of monitoring, exclusion of important stakeholders and few (if any) pre-feasibility studies, this national policy to promote small-scale renewable electricity achieved only 12 MW of its 500 MW target in 2005 and 61. 7 MW of the 350 MW target for 2010 [17].

The case studies indicate that the presence of a local (sub-district) government office in an area increases the role that government has in MHS implementation. There is no local government representative in Ba'Kelalan and any matters involving government need to be processed 100km away in Lawas. Issues related to village remoteness, such as lack of communication due to no mobile phone network, also constrain community-government relations. Consequently, any problem with the clinic MHS could not be promptly reported to the local government.

In Indonesia, the local government offices are located in Long Bawan village, and the presence of government officers facilitated the communication between the community and the government. Government staff members were also involved in the MHS operation and maintenance. Some respondents mentioned, however, that Long Bawan is ignored by national government, especially in the important stage of developing a project budget, due to its geographic isolation.

E. Social and Cultural Evaluation

In two of the four case studies, the MHSs failed to meet the electricity demands of the end users. In Buduk Nur, 55% of respondents were dissatisfied with the current MHS due to its poor quality and limited power supply. Dissatisfaction caused by limited access and poor quality was also reported by 60%of respondents in Liang Butan. Despite facing similar supply limitations, 90%of respondents in Buduk Bui and Tang Paye were satisfied with the MHS supply. This shows that the level of satisfaction depends to a large degree on the users' perception, and highlights why community consultation before the project implementation is so important.

The dissatisfaction in both Buduk Nur and Liang Butan is linked to their possession of a range of electrical appliances and householders' desire to buy new appliances, such as blenders and freezers, but which they are unable to reliably operate due to the limited capacity of the MHSs. The MHSs in

Buduk Nur and Liang Butan were not able to meet this “hidden” and growing demand of communities, which has emerged since they got access to electricity [18]. The initial strategy of harnessing whatever hydro power was available and sharing it equally among the end users ended up causing dissatisfaction with the MHS and some conflict between the opportunists who exceeded their allocated power and those who did not but had to suffer blackouts.

Inability to maintain stable voltages in the Buduk Nur MHS has meant that this project has not been able to meet even its primary objective, the refrigeration of vaccines and other sensitive supplies in the health clinic. This objective was compromised by the final design of the distribution system in which household needs were met before those of the Clinic. In contrast, most people in Buduk Bui and Tang Paye did not have any electrical appliances before the MHSs were installed. The villagers used the clear reliable light (which the MHS enabled) at night to do handicraft work, although their experience with electricity on line from the MHS encouraged some to purchase television sets. Nevertheless, this growing demand from Buduk Bui and Tang Paye households was under control since, when the MHS was set up, the power demand was low and the MHCs commenced with regulations to limit the power that a household could draw and, on the whole, the villagers complied with the agreed limits.

The survey found mixed results in terms of the impact of the MHS on social cohesion within the communities. The MHS lighting provides the community with comfort and safety to go out at night to visit people get more information on health etc., but on the other hand also reduced social interaction since some prefer to stay at home and watch TV. There was no evidence that the MHS helped to stem outmigration from the villages, rather the. The main economic benefit of the MHSs was to reduce the expenditure on energy as MHS electricity was cheaper than that from a portable generator. Having a MHS has also strengthened the bargaining power of these border communities.

VI. Discussion and Lessons Learnt

The degree of success or failure of MHS programs depends on multiple factors and the importance of these factors varies from program to program, depending on the type of funding, policy, etc. From the above evaluation of the MHS projects, we can find the following critical factors that play a major role in successful micro-hydro implementation. Each of the MHS implementation stages needs to be addressed, focusing on the following issues to deliver a successful MHS project in remote rural border areas.

Technical

- Selection of the sites should be based on the available resources
- Micro-hydro resources need to be determined carefully using long-term flow-rate data and seasonal variation
- Demand and supply need to be matched
- Excess power needs to be used to maximise the overall benefit of MHS
- Before planning the design, it is very useful to get an overview from the different manuals and guidelines that already exist for the sector.

Organisational

- Identify the stakeholders and their roles
- Identify community's strength and include the community in decision-making
- Provide on-site training and use training materials that have been specifically adapted to the local situation.
- Appropriate training with training materials and maintenance handbook is mandatory for members of the MHC
- O&M details should be embedded in the planning process of MHS implementation

- Provide proper training for operation and maintenance
- Similar programs being implemented in other areas in the country may have lessons that have been learnt, and it is recommended that other ongoing programmes be analysed to look for synergies.

Economic

- MHC members needs training on how to set the tariff and what cost it needs to include
- The tariff, as a minimum, must reflect the true costs of operating and maintaining the MHS scheme, with the inclusion of savings set aside for periodic major overhauls.
- While designing the funding, O&M costs need to be included
- Funding need to incorporate the operational and maintenance costs
- Productive end-use, under the right circumstances, can significantly increase revenue generated, thereby improving the economic sustainability of an MHS scheme.

Policy Context

- Checking on the local rural development plans before the implementation of an MHS program increases the likelihood of project success.
- Government coordination with the stakeholders is very important while designing the projects.
- Coordination is needed between national and local government.
- The presence of a local (e.g. sub-district) government office in an area increases the extent of government's involvement in the program and builds the trust of the community in regard to the program.
- A lack of communication strains community-government relations and needs to be avoided.

- The regulatory framework (including local government decrees and regulations) must be studied carefully before an MHS program is implemented.

Social and Cultural

- The level of satisfaction depends to a large degree on the perception of the users, and thus community consultation before the project implementation is essential.
- It is important to understand the village's current energy situation as well as future demands, to develop proper strategies on load management in order to meet customer satisfaction.
- MHSs do create some opportunities for some people to earn extra income.
- Integrating productive end-use equipment in the initial design is worthwhile because it is much easier than attempting to add it on later.

VII. Conclusion

MHS technology has been applied in the Heart of Borneo for many years now, but only a small proportion of the two countries' huge mini and micro-hydro power (MHP) potential has been exploited to date, and there has been a high rate of failure of MHS projects. Challenging framework conditions for stand-alone systems and on-grid schemes, lack of specialist know-how in rural areas and a lack of awareness of public administration have been the main reasons for the modest progress in the past. The lessons learnt from the combined experience of four MHS in these two countries presented in this paper represent the first attempt to extract and condense the range of practical experiences and approaches that exist in the Bawan Valley and Krayan and are presented to aid future projects.

VIII. References

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