Micro-hydropower impact on communities' livelihood analysed with the capability approach.

Arnaiz, M.[1], Cochrane, T.A.[1*], Hastie, R.[2] Bellen, C.[1]

[1] Department of Civil and Natural Resources Engineering, University of Canterbury, New Zealand.

[2]College of Arts, University of Canterbury, New Zealand.

[*]Corresponding Author: tom.cochrane@canterbury.ac.nz

Abstract

Isolated developing communities in mountain ranges can generate electricity with the help of micro-hydropower schemes. The arrival of electricity to communities can bring numerous socio-economic benefits as well as improved livelihood, but there is a lack of international studies on livelihood improvements brought by the implementation of micro-hydropower schemes. This study aims to identify the most significant livelihood improvements associated with the implementation of micro-hydropower schemes and highlighted the capacities communities have to make an effective use of such improvements. The analysis is based on the evaluation of 17 communities from Bolivia and the Philippines. Visits to communities, engagement with local developers and community interviews were used to evaluate 22 livelihood indicators from five broad categories: health, education, safety, community engagement and economy. The capability approach was used as a framework to identify the most common livelihood improvements. Results show significant improvements in all aspects, especially in education, community engagement and economy. Improved lighting is identified as the most influential factor across the five aspects, but developing organizations implementation techniques and electricity usage differ between countries. Women appear to benefit more from drudgery reduction and men from community engagement opportunities. In conclusion, livelihood improvements were clearly observed and these might have a positive impact in the future sustainability of schemes.

Keywords: micro-hydropower, livelihood, capability approach, community, developing countries

1. Introduction

Access to electricity is one of the cornerstones of human development (UNDP, 2001). The lack of access to electricity in remote areas in developing countries has been identified as a key factor that jeopardizes progress towards better livelihoods (Gurung et al., 2010). The electrification of households can produce improvements in health, safety and education. It can also promote the creation of small enterprises or boost the production and efficiency of existing ones, reduce drudgery, lower the cost of lighting and other energy services and provide higher levels of comfort to its beneficiaries (Bastakoti, 2006). Electricity is, thus, a means towards achieving economic growth, social progress and increased human well-being.

Micro-hydropower (MHP) schemes can produce electricity for isolated communities which are not connected to national electricity networks. The implementation of a MHP project is a cost-effective solution that has less environmental impact than traditional fossil fuel generators (Huang et al., 2014, Mainali et al., 2013). MHP brings improvements in livelihoods which are often more significant than community and household economic development (Murni et al., 2013). Measuring livelihood improvements, however, presents multiple challenges, particularly for remote communities of developing countries where material assets may be less important than cultural or social dynamics.

Two developing countries where remote communities can benefit from MHP are Bolivia and the Philippines. Both countries have good hydrologic resources and steep mountain ranges and this has allowed for the construction of over a hundred MHP schemes in each country since the mid 1990's. The socio-economic characteristics of remote communities in these countries, where basic food and education needs are generally covered, have made the arrival of electricity a necessary step towards development.

The objective of this study is to outline the most common livelihood improvements afforded by MHP schemes in Bolivia and the Philippines. The capability approach (Sen, 1993) is used in this study to quantify the livelihood improvements that schemes bring to communities.

2. Methods

To evaluate the social impact of MHP schemes on communities, 17 remote communities from Bolivia and the Philippines were studied during 2015 and 2016. Data was collected throughout a study of 35 schemes between Nepal, Bolivia, Cambodia and the Philippines (Arnaiz et al., 2018). These schemes represented a range of active and non-functioning schemes implemented by local developers in each country. Local developers were contacted to obtain key information on scheme and community characteristics. Schemes varied in years of operation, households serviced by MHP, regions, and power generation (Table 1). Subsistence agriculture was their main activity and all communities visited appeared to be around the poverty threshold (WorldBank, 2017).

Table 1. Synopsis of the micro-hydro schemes studied in Bolivia and the Philippines.

Scheme	Years Operating	Households	Region	Power (kW)
Bol.1	7	25	Andean	6
Bol.2	2	14	Andean	8
Bol.3(nf)	8	80	Sub-Andean	100
Bol.4(nf)	14	30	Sub-Andean	16
Bol.5(nf)	12	40	Sub-Andean	8
Bol.6(nf)	6	120	Sub-Andean	38
Bol.7(nf)	11	180	Llanos	40
Bol.8	1	60	Sub-Andean	35
Bol.9	7	313	Sub-Andean	100
Phi.1	7	58	Cordillera	15
Phi.2	9	14	Cordillera	5
Phi.3	14	43	Cordillera	6
Phi.4	16	52	Cordillera	7
Phi.5(nf)	6	100	Negros Island	32
Phi.6(nf)	5	30	Negros Island	5
Phi.7	8	200	Negros Island	32
Phi.8	8	150	Negros Island	32

(nf) – MHP scheme not functioning

Interviews on scheme implementation and community livelihood were carried out during the site visits (Table 2). Participants had to be adults, residents of the community, and users of the electricity generated by the scheme. Interviews were held casually and individually (avoiding social desirability biasing).

Table 2. Study interviews description.

Interview	Countries	Number of interviewees	Gender
Scheme implementation	Bolivia	64	33 F; 31 M
Community livelihood	Bolivia and Philippines	93 (64 Bol. 29 Phil.)	48 F; 45 M

Scheme implementation interviews were carried out in the nine communities in Bolivia. Individual interviews provided qualitative information on the community's response and engagement during the

phases prior, during, and post implementation of the scheme. Information was recorded on the social effects, barriers, issues and limitations of the implementation process of schemes.

Interviews on community livelihood, defined here as the combination of the individual well-being of the members of the community, were carried out in all 17 communities in Bolivia and the Philippines. The interviews allowed for additional qualitative comments that helped understand the rationale behind the answers. Interviewees were further asked to rate five basic aspects of their life: health and diet, safety, education, community engagement and leisure, and economy (named 'livelihood sub-set perceived importance' in this study). Measuring well-being is a complex task, thus, this study used the capability approach (Robeyns, 2005), as a method to measure well-being by evaluating the well-ness of the person's state of being, or, how much a person is succeeding in 'doing' or being' (Sen, 1993). The measure of what a person is capable of being (happy, healthy, educated) or doing (work, study, learn) are called 'functionings' and they "represents the diverse aspects of life that people value" (Alkire, 2005). The capability set of an individual are the functionings that the individual has actual access to. Achieved functionings are those functionings that individuals choose make use of. Individual semi-structured interviews on 22 livelihood indicators (i.e., functionings and achieved functionings) revealed which things the community could do or be as a direct result of MHP.

3. RESULTS AND DISCUSSION

The ‘Scheme implementation’ interviews in Bolivia revealed key information on engagement with MHP:

i. Developers initiate community-scheme engagement by giving a series of workshops to the community, explaining the benefits of the technology, familiarizing the community with the physical principles of MHP generation, and preparing them for the construction and maintenance of the scheme. During the preliminary workshops, 90% of the people said they had an active participation, and 93% said that they enjoyed such meetings. When asked if they enjoyed learning about the technology, 89% answered positively, and 85% said they’d like to learn more.
ii. When the construction process starts, the community is asked to participate with the acquisition of materials and construction of the civil works. 78% of the interviewed people in Bolivia participated in building the scheme, with 90% enjoying the process.
iii. After the construction of the scheme, operators are chosen to conduct regular maintenance and community members are asked to contribute to major repairs. 63% affirmed having participated with the repairs of the scheme during the life of the scheme.

The arrival of a MHP schemes generates in the community a sense of empowerment, offers an opportunity to work together, and fosters communal problem solving and decision making.

When questioned on ‘overall well-being contribution’, 68% of interviewees responded that electricity contributed to general comfort, a fact mainly explained by the improved lighting. However, electricity was seldom reported to extend free time (32%), as interviewees reported working longer hours at night and spending too much time watching TV. Only 30% responded that electricity helped towards doing their chores more effortlessly, with only a few reporting that cooking and house cleaning duties could be done easier.

The percentage of positive responses to semi-structured household interview done in Bolivia and the Philippines for the 22 indicators of the ‘Community livelihood’ were varied (Figure 2).

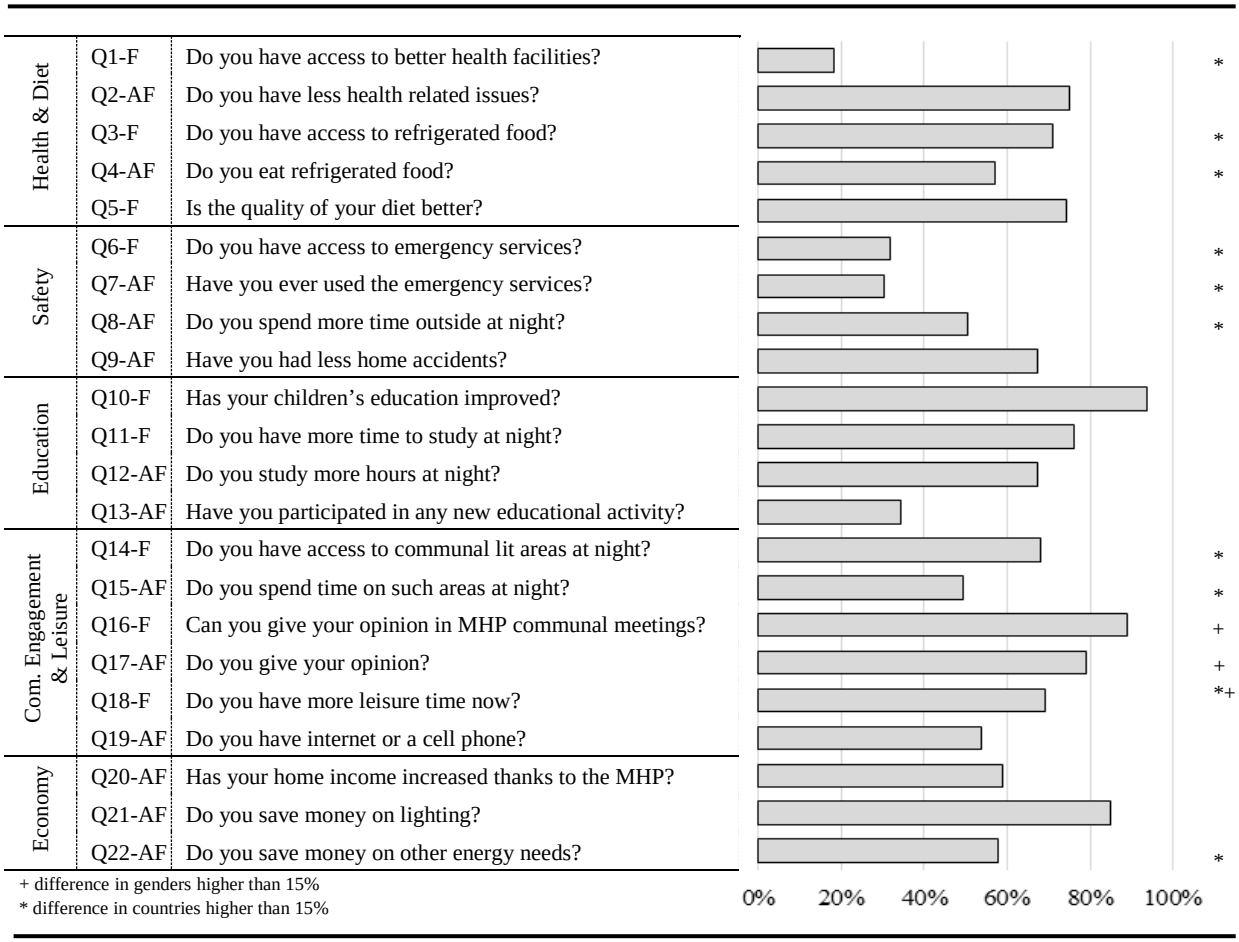

Figure 2. Percentage of positive responses for the semi-structured interview for 22 Community livelihood' indicators. An 'F' or 'AF' next to the question number indicates a functioning (F) or an achieved functioning (AF) type question.

Some of the benefits brought by the implementation of MHP schemes are directly related to the utilization of electricity, and thus, other energy sources could provide similar benefits. However, when and how this energy is generated has different impacts on the community.

The only two other common sources of energy that communities have access to are solar photovoltaic (with no large battery systems due to high cost) and diesel generators. Communities make most use of electricity early in the morning and late at night, when men and children wake up and come back from work or school. Multiple livelihood improvements are exclusive to the use of energy at night time, making MHP significantly more convenient that solar generation. Additionally, other livelihood improvements such as the creation of jobs for the operation and maintenance of the scheme or the creation of the MHP committee and the opportunities for socialization through the community meetings are unique to MHP schemes.

Health & diet

Only three communities, all in Bolivia (27%), reported having an improved health post facility as a direct consequence of the MHP scheme, which allowed refrigerated medicines and a place for outside doctors to come and do workshops on health practices, nursing, disease treatment and vaccinations.

The most significant reported impact was the reduction of health related issues (75%) (Q2). Traditional methods of generating light (i.e., candles and kerosene lamps) produce fumes that generate headaches, respiratory problems, eyesight loss and higher probability of fire accidents. Better lighting allows for better cleaning and preparation of food and extends meal time and makes it more pleasant (i.e., better visualization of food), resulting in higher food consumption. Lighting also allows for faster cleaning of houses, mending of wounds, and makes stumbling less likely, the most common source of injury reported, something recurrent for the elderly. Communities from both countries also reported that with extended hours of light, chores could be distributed more easily during the day, resulting in a less stressful life.

Most communities in Bolivia run refrigerators (84%), however, in the Philippines, communities showed less need for refrigerators (41%), as their diet seemed more vegetable based (lesser need for refrigerating meat or fish). Refrigerated food allows for better food quality and quantity due to less spoilage. Electricity, also, allows for ice making and for the use of blenders, especially convenient for two countries where fruit consumption is high. This resulted in improved diet variety and quality for both countries (74%) (Q5). However, elders in Bolivian communities pointed out that due to the cultural changes brought by television and the use of refrigerators, young people regularly consumed sugary fizzy drinks, resulting in apparent higher rates of overweight and diabetes.

Safety

Four Bolivian communities (44%), and one Philippine community (7%), saw the arrival of a phone or radio emergency service as a direct consequence of the MHP scheme (32%) (Q6). Remote communities usually do not have a resident doctor and in case of emergencies a doctor has to be called in or the patient needs to be transported to the nearest health post. Emergency services were regularly used in Bolivian communities (44%), while in the Philippines was never used (0%).

Lack of light during night-time was not a security issue for women in these communities, a fact also reported in a study in Pakistan, where women explained that prevailing restrictions in society are the source of insecurity, and not darkness (Mueller et al., 2012).

On average, interviewees in both countries expressed spending more time outside (51%) (Q8) simply due to the comfort brought by light. The cold climate of some of the communities in Bolivia resulted in fewer people spending time outside at night (44%) compared to communities in the Philippines (66%) where the climate is warmer.

Interviewees also reported a reduction in home accidents (67%) (Q9), a fact often explained by the safety brought by electric lighting, as opposed to conventional and dangerous flame sources of light.

Education

Communities' reported that improved lighting at schools and households had a significant positive impact on children's education (94%) (Q10). The impact on the community adult's education, however, is complex. Despite extended night study time (76%) (Q11), multiple interviewees affirmed they'd rather watch television, claiming education was no longer possible for them, and that farming duties occupied most of their time. However, extended light hours and better light quality helped people read magazines, books, and the bible (67%) (Q12). Occasionally, schools organize adult activities and workshops making use of projectors, speakers, computers, etc. (34%) (Q13).

Community engagement and leisure

Interviewees reported increased access to communal lit areas during night time (68%) (Q14). In Bolivia, a 63% of the interviewees reported using the communal lit areas to socialize during night time, while only a 21% of the interviewees in the Philippines reported spending time in such areas.

MHP schemes generate new sources of community interaction such as monthly open meetings around the operation and maintenance of the scheme where the majority of the members of the community can participate (89%) (Q16). Men actively gave their opinion (94%), while women often argued their husbands were in charge of such matter, or that they did not have enough knowledge on the scheme nor felt confident enough to express their ideas (64%). Such difference represents the most significant utilization function difference between genders observed in this study. The majority of the committees were solely formed by men, and no woman was found in charge of the operation of the schemes. Interestingly, while women are the primary users of the electricity and men the main decision-makers, the former often claimed having no interest in the functioning of the scheme, perhaps due to social conditioning.

Leisure time was increased significantly in both countries (69%) (Q18). People claimed chores could be done faster with better visibility, duties could be planned better through the day, and children required less attention. These factors were more important to women (78%), who spend more time at home with children, than to men (60%). Cell phones were now used by some members of the community (54%) (Q19), especially for those with relatives living outside of the community.

Both countries reflected that women gained higher benefit from the reduction of drudgery resulting in higher leisure time, but did not benefit as much from the opportunities brought by the organization behind the operation and maintenance of the MHP scheme or the communal meetings.

Economy

Households reported an increase in home income (59%) (Q20) because businesses could be enhanced with new machinery (fridges, welders, sawmills, grain mills), opening hours of retail shops were often extend until midnight thanks to improved lighting, and home manufacturing businesses, such as

knitting, could continue production during night-time. Moreover, several jobs were created for the operation and maintenance of the scheme. New businesses reliant on the energy generated, such as enhanced agricultural production, can create key revenue for the sustainability of the scheme.

Households highly benefited from the reduction of lighting cost (85%) (Q21), which varied from a half to a fifth of the original cost without MHP. Communities also expressed savings on other energy needs (58%) (Q22), such as diesel, gas, wood, or batteries. This was of special importance to the Philippines (79%), reporting greater savings due to less usage of batteries for torchlights, compared to Bolivia (48%).

Capability sets and achieved functionings

Interviewees from both countries saw a significant increase in their capability set (i.e. functionings that can be chosen), and achieved functionings. The overall average positive responses was 66% ("F" in Figure 2) for the examined functionings and 59% ("AF" in Figure 2) for the achieved functionings, which suggests that the new possibilities are positively valued by people and are utilized.

Overall averages do not show significant differences between genders on functionings or achieved functionings. A difference, however, exists in the overall capability set in the Philippines (54%) and in Bolivia (71%), a difference explained by the lack of access in the Philippines to communal lit areas, emergency services and health facilities.

Livelihood sub-sets

The grouping of all indicators into the 5 sub-sets reveals similarities across countries and genders. However, differences exist in the Health and Diet and Community Engagement and Leisure sub-sets between the two countries. (Figure 3).

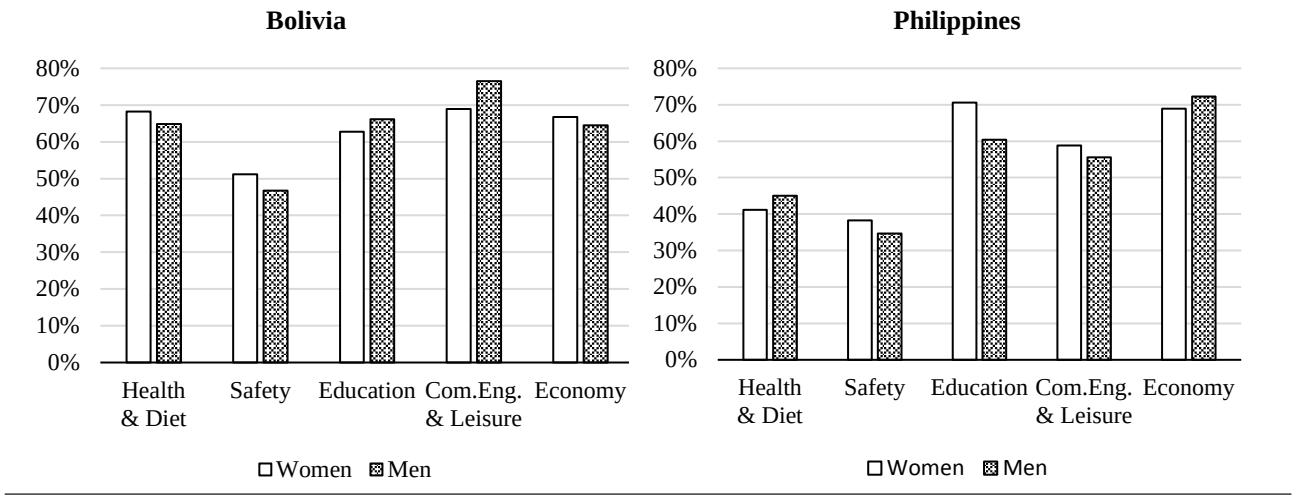

Figure 3. Percentage of positive answers grouped by sub-sets for Bolivia and the Philippines.

Bolivian communities had better health and diet due to increased access to health facilities and better access to refrigerated food as well as wider community engagement and leisure due to broader use of communal lit areas.

Interviewees were asked to rate the five basic aspects of their life (i.e., the five sub-sets) by level of importance (being 1 low importance, 2 moderate importance, and 3 high importance) (Table 3).

Table 3. Overall results for the 'Livelihood sub-set perceived importance' and 'Livelihood sub-set total average'

Livelihood sub-set perceived importance	Score Scale [1 - 3] (St.dev.)	Score Scale [0 - 1]	Livelihood sub-set total average (Total average of Figure 3)	Score Scale [0 - 1]
1st - Education	2.75 (0.49)	0.87	1st- Com. Eng. & Leisure	0.68
2nd- Health	2.73 (0.50)	0.86	2nd- Education	0.68
3rd- Economy	2.47 (0.66)	0.73	3rd- Economy	0.67
4th- Safety	2.46 (0.69)	0.73	4th- Health	0.59
5th- Com. Eng. & Leisure	2.16 (0.64)	0.58	5th- Safety	0.45

Education was rated first (Table 4, (0.87)), and was the second sub-set that received most benefits, thus, it is reasonable to conclude that communities highly value the contribution towards education. Safety, on the other hand, was rated 4th (0.73) and was the sub-set that received least benefits. Interestingly, both countries perceived community engagement and leisure as the least important sub-set (0.58), arguably the least basic sub-set. However, results reflect that community engagement and leisure received the most benefits, which suggests that some of the benefits brought by the MHP might not be as important for communities. The health sub-set was perceived as highly important (0.86), however, results reflect that schemes do not always provide health benefits (0.59). When analysing these results by gender and country, no significant differences were found.

4. CONCLUSIONS

The results of this study have shown that the electrification of communities through MHP produces improvements in a wide range of livelihood indicators.

Better lighting, arguably the most significant contribution, made daily duties easier and allowed communities to stay active after dusk, which resulted in a better distribution of chores and extended leisure times. High energy loads at dawn and dusk showed that MHP is a competitive energy source compared to small solar systems with no battery storage capabilities.

Bolivia and the Philippines showed similar results for most of the 22 livelihood indicators studied. Men benefited more from the community engagement opportunities brought by the organization, operation and maintenance of the scheme, and women experienced a higher reduction of drudgery brought by the electrification of households.

The most important livelihood impacts produced by the arrival of a MHP were:

- Health problems produced by traditional light sources were highly reduced. Diet was enhanced by the use of refrigerators and better cooking methods.
- Safety was increased by the reduction of accidents due to the lack of visibility and use of flame light sources.
- Children's education was highly improved thanks to enhanced schooling and extended light hours. Night time reading hours were also increased for adults.
- The management, operation and maintenance of schemes increased community engagement and generated a sense of empowerment.
- The local generation of electricity cut energy costs and allowed for the improvement of existing businesses and the creation of new ones.

Education was identified as the livelihood improvement that communities benefited most from, and safety the least. It is possible to assume that if livelihood improvements are brought by the installation of a MHP scheme, this can benefit positively the operation and maintenance of the scheme, thus increasing its sustainability.

However, the arrival of MHP schemes often represented an abrupt change for communities, resulting in negative diet alterations, TV misuse, cultural changes and community identity loss.

5. REFERENCES

ALKIRE, S. 2005. Why the Capability Approach? *Journal of Human Development,* 6**,** 115-135.

ARNAIZ, M., COCHRANE, T. A., CALIZAYA, A. & MAHABHARAT, S. 2018. A framework for evaluating the current level of success of micro-hydropower schemes in remote communities of developing countries. *Energy for Sustainable Development*.

BASTAKOTI, B. P. 2006. The electricity-livelihood nexus: some highlights from the Andhikhola Hydroelectric and Rural Electrification Centre (AHREC). *Energy for Sustainable Development,* 10**,** 26-35.

BLANCO, C. J. C., SECRETAN, Y. & MESQUITA, A. L. A. 2008. Decision support system for micro-hydro power plants in the Amazon region under a sustainable development perspective. *Energy for Sustainable Development,* 12**,** 25-33.

GURUNG, A., BRYCESON, I. & OH, S.-E. 2010. Micro-hydropower: A promising decentralized renewable technology and its impact on rural livelihoods. *Scientific Research and Essays,* 6**,** 1240-1248.

HUANG, S.-R., CHANG, P.-L., HWANG, Y.-W. & MA, Y.-H. 2014. Evaluating the productivity and financial feasibility of a vertical-axis micro-hydro energy generation project using operation simulations. *Renewable Energy,* 66**,** 241-250.

MAINALI, B. & SILVEIRA, S. 2013. Alternative pathways for providing access to electricity in developing countries. *Renewable Energy,* 57**,** 299-310.

MUELLER, A. M. & SCHWARZ, D. 2012. Making micro hydropower projects contribute to gender equality. *Appropriate Technology,* 39(3)**,** PP. 50-52.

MURNI, S., WHALE, J., URMEE, T., DAVIS, J. & HARRIES, D. 2013. Learning from experience: A survey of existing micro-hydropower projects in Ba'Kelalan, Malaysia. *Renewable energy,* 60**,** 88-97.

ROBEYNS, I. 2005. The Capability Approach: a theoretical survey. *Journal of Human Development,* 6**,** 93-117.

SEN, A. 1993. Capability and Well-Being73. *The quality of life,* 30.

UNDP 2001. Human Development report 2001. Making new tehcnologies work for human develpoment. *United Nations Development Program, New York.* Retrieved from http://hdr.undp.org/sites/default/files/reports/262/hdr_2001_en.pdf

WORLDBANK. 2017. *World Development Indicators* [Online]. World Bank. Available: http://data.worldbank.org/indicator/SI.POV.DDAY [Accessed 04-25 2017].