Impacts of Mini Hydropower Plants: A research design through preliminary studies

A Kariyawasam[1#] and B Thoradeniya[2]
[1]Northshore College of Business Studies, Colombo, Sri Lanka
[2]Institute of Technology, University of Moratuwa, Moratuwa, Sri Lanka
[#]amashanishashi@yahoo.com

Abstract— *Hydropower is the number one renewable clean source of energy used for power generation in Sri Lanka when compared with solar, wind and bio mass sources. Despite being identified as a clean source of power generation, the hydropower plants also create negative impacts on the environment and the society. The hydropower plants are categorised according to their generation capacities and the minimum impacts are expected from the smaller plants which are categorised as Mini Hydropower Plants (MHP). Many research studies have been conducted to establish the social and environmental impacts due to construction and operation of MHP and research literature discusses various positive and negative impacts. However the list of such impacts is non-exhaustive as the magnitude and the nature varies with location. This paper presents the outcomes of a preliminary study of an on-going research involving two case studies on MHPs in Sri Lanka. The descriptive analysis of the data collected at this stage reveals the localised impacts due to construction and operation of MHP compared to the impacts listed and discussed in the research literature. Thus, this paper endorses the importance of preliminary studies in eliciting the real life concerns that could contribute to future social and environment impact assessments prior to establishing MHPs.*

Keywords— *Mini hydropower, Social and environmental impacts, Preliminary studies*

I. INTRODUCTION

Hydropower plays a main role in Sri Lankan electricity generation since its commencement in 1950 supported by the Sri Lankan geo-climate setting which provides an excellent opportunity to produce hydropower (Deheragoda 2009). Though hydropower is often considered as the most environmentally friendly and economic source of power generation, there are social and environmental impacts which usually varies with the size of the power plant. When the smallest hydropower plants are considered these impacts are mostly localised and have not drawn wide public attention though some of the impacts could be seriously felt by the local populations. Further, such impacts could vary with the locations as described in the literature.

On the other hand research into establishing impacts of Mini Hydropower generation is often hampered by lack of quantitative data pertaining to different aspects of construction and operation phases of power generation. However, studying both negative and positive impacts of very small scale power generation could not be given a lesser importance given the fact that the directly impacted group is usually the under privileged communities of the society.

The hydropower generated through MHPs is used in two different ways in Sri Lanka. First is the currently more popular method of supplying generated power to the national grid. Second is the use of generated power in the local area. This type of hydropower generation was more prevalent in the up country tea estates over 100 years (Deheragoda, 2009). More recently, MHPs were established in villages to generate electricity requirements of villagers.

A research study is undertaken to compare the technical, social and environmental impacts of these two different types of Mini hydropower generation: a project connected to the national grid and a project directly supplying the village community. The minute and isolated nature of the construction and operation of MHPs compared to the larger scale power plants needs a research design which can specifically capture the localised impacts. This paper presents the research design developed using preliminary studies and its outcomes on which further research will be undertaken.

II. DEVELOPMENT AND IMPACTS OF HYDROPOWER

This section presents the historical development and the impacts of hydropower generation as identified by the earlier researchers.

A. Historical Development

The first detail on the use of hydropower was clocked around 250 BC (Gurbuz 2006). Foundation of hydropower is the wooden water wheel which had been used mainly for milling grain and lifting water for irrigation all around the world since 2000 years (Kumar and Schei 2008). During the 19th century water wheel was improved as a small and high speed device for electricity generation. After the invention of the first hydro turbine by Benoit Fourneyron in 1820 in France, hydro turbine was applied for their water wheels in milling to generate small scale electricity at the end of the century (Paish, 2002). In the early 20th century power generation was improved with the development of the electricity transmission and distribution methods (Gurbuz 2006). Hydropower was the main resource contributing to electricity generation all around the word before its replacement by fossil fuel. However since last few decades the world is focusing on green power generation without environmental pollution.

Hydropower generates 23% of total national electricity requirement of Sri Lanka and it is the second highest contributor to the total electricity generated, where thermal power consisting both oil and coal is the highest contributor at 70.9% (SLSA 2012).

Sri Lankan hydropower generation sector commenced with the large scale tea industry in 1897, as small scale hydropower generation. These MHPs produced electrical energy for conducting mechanical process of tea factories. The electricity thus generated mostly contained within the particular estate (Thoradeniya et al. 2007: Deheragoda 2009). MHPs were established in villages to generate electricity requirements of village community in 1990. Later the private sector was encouraged to establish MHPs to supply the national grid. The first MHP electricity was connected to the grid in 1994 (Thoradeniya et al. 2007). Table 1 compares large and small scale hydropower generation statistics in Sri Lanka for the years 2011 and 2012 (CEB 2012).

Table 1.Hydropower statistics of Sri Lanka (Source: CEB 2012)

	Hydro Large	Hydro small
No of power stations 2011	16	91
No of power stations 2012	17	109
% Change	6.3	19.8
Installed Capacity (MW) 2011	1207	194
Installed Capacity (MW) 2012	1357	227
% Change	12.4	17.3

As shown in Table 1, CEB had 16 large scale hydropower projects in 2011 which was increased up to 17 projects in 2012. In contrast the 91 small hydro power plants owned by the private sector in 2011 has risen up to 109 in 2012. It is evident that over the last decade small hydropower has enhanced as a replacement for large scale hydro projects and it has performed as sustainable, economic and environmental friendly source SLSA (2012). Table 2 shows situation of the small hydropower plants in 2010.

B. Reported Social and Environmental Impacts

Even with power generation by MHPs, there are different environmental and social impacts, both positive and negative, during the inception, construction and maintenance period of the plant. Sharma (2007) claims that impacts due to hydropower generation are depended on plant size, plant type, location of the plant, layout of the scheme, mode of operation and phases of MHP. Some of the many impacts found in the literature at different stages of MHPs are described below.

Table 2. Small Hydropower Status (Source: SLAS 2010)

Status	**No. of Projects**	**Capacity (MW)**
In operation	95	206
Under construction	118	209.8
Approval obtained	91	114.6

Impact on air at project zone - Heavy vehicles used for excavation and material transporting such as tractors and loaders emits polluted air due to fuel combustion during the construction phase of MHP (Cara et al. 2010). Dust is also emitted due to unloading sand and aggregate, cement silos and explosive material. Further, emissions from chemicals such as paints, fuel and lubricants available at the site affect negatively to the sensitive biodiversity around the project (Gvakharia 2010).

Impact due to noise - Project noise can affect during both construction and operation phases of a MHP. Concrete vibrators, diesel motors, heavy vehicles and explosions generate disturbing noise at the construction phase while turbines can generate continuous noise in the operation phase of hydropower plants (Cara et al 2010). Noise generated from construction work could temporary impact forest fauna; shall scare birds, reptiles and other animals. Yet the noise generated by turbines affects all fauna around the power plant throughout the operation stage.

Impact to the riverine environment - Chandra (2010) claims that if water is diverted or stored or restricted at up-stream of a river, it cause damages in the down-stream. In Sri Lanka the hydropower generation is always involved with the upstream areas of main rivers. Therefore if there are any impacts in upstream, they could affect the water body all over the country. Down stream flows are either completely eliminated or often considerably reduced during certain periods of the year due to water diversions for power generation. This variable water flow negatively impacts the aquatic ecosystem structure and fishing migration in between intake and outlet of the power plant (Kibler 2011; Cara et al. 2010). Furthermore Cara et al. (2010) and Sharma (2007) describe that water shortage of stream results in declined landscape values and tourism activities and cause disturbance to other leisure activities related to the stream. Water shortages are identified for irrigation, agriculture and other traditional usage of the stream due to disturbed natural flow of water in the project areas (Rupasinghe and De Silva 2007; Thoradeniya et al. 2007).

Oil spillage and mixing with stream could occur with chemicals which are used in construction and operation stages of MHP. This can affect water quality and whole biodiversity of the area (Gvakharia 2010).

Heavy sedimentation at the reservoir base due to constructing weirs and in forebay tanks are other main problems caused by Mini Hydropower generation (Sharma 2007).

Developers of MHPs have to fell trees damaging earth structure and remove vegetation in upper catchment area for providing easy access for construction of infrastructure for power generation (Sovacool et al. 2011; Thoradeniya et al. 2007; Rupasinghe and De Silva 2007). Such deforesting affects the sensitive aquatic structure of the area, displace habitats, destroy food for animals, disturb the food chain of the area and lead to soil erosion, damage top soil, result in slope instability in the project impact area (Gvakharia 2010). Further, water springs dry up due to deforesting and affect the domestic water supplies of the area. Felling economic crops and trees with timber value affects the economy of the society of the particular area (Thoradeniya et al. 2007). Building concrete structures and felling trees also change the topography of the area. Topographic changes reduce natural beauty and land value of the area.

During the construction of MHPs, developers have to use explosive material. Explosions impact health and safety of employees and neighbours at the construction phase of the MHPs (Cara et al 2010; Sharma 2007).

Positive impacts include improved roads which are built for transporting construction components of MHP, generation of new job opportunities for villagers and in certain instances particular project areas are attracted to tourists enlivening the revenues of tourism and hotel services of the area (Sharma 2007; Cara et al. 2010).

Transmission lines obstruct birds and other human activities due to their alignment through sensitive ecosystem. Hammond (2011) observe that it cause bird strikes and electrocutions. Further, high voltage transmission lines could cause health and safety issues like cancer and headache for human.

C. *Technical Aspects*

Amount of hydropower production depends upon both flow and head of water stream available for MHP. Head is the elevation difference between the forebay and the power house location. Flow is the volume of water passing per second. Mechanical power production of turbine shaft (P - in watts) is given by

$$P = \eta \times \rho\, g\, Q\, H$$

Where, η- Hydraulic efficiency of turbine (generally around 80%), ρ - Density of water (kg/m3), g - Acceleration due to gravity (9.81 m/s^2), Q - Water flow passes through the turbine (m^3/s) and H - Effective net water pressure of water across the turbine (m)

The best turbines have 80% to over 90% efficiency (η) and η depends upon the size and type of the turbine (Paish 2002). Though efficiency is reduced with time due to wearing of the turbine, it can be assumed to be a constant for a short period since it cannot be measured once in operation. In this research, gross head and efficiency of turbine are considered as constant. Hence it is considered that the mechanical power production of turbine shaft as only dependent upon the water flow which passes through the turbine.

III. RESEARCH DESIGN

This study aimed at comparing two Mini hydropower projects which have two different objectives, for their social and environmental impacts and the technical effectiveness. The objectives of the two projects differ due to the final receiver of the generated hydropower;

while one plant supplies the national grid the other directly supplies the community. In order to achieve this comparison a specific research framework is designed. The research design consisted of four distinctive stages;

- A literature review to identify the social and environmental impacts and the technical aspects of MHPs.
- Selection of two MHPs one supplying to the national grid and the other supplying generated electricity to the village.
- Preliminary study incorporating a SWOT analysis and a pilot survey
- Detailed study for final evaluation

The first stage is already presented under sections II B and II C. The following sections briefly describe the second and third stages of the Research design.

A. Selection of Mini Hydropower Projects

The judgement of social and environmental impacts of a project mainly depends on the attitudes of the local community. Further hydrology and the technical aspects could also have an impact in a comparative study. Therefore, in the selection of the two Mini Hydropower projects care was taken to have similar conditions as much as possible on the community, the hydrology, and technical details. Both MHPs are thus selected from the Kelani river basin within Kegalle district. They are the Amanawala MHP (Project A), and the Dedugalla – Gangaweraliya MHP (Project B). Both plants are run-of-the river projects with diversion weirs.

Of the two selected MHPs, Project A provides electricity only to the villagers. ‘Wee Oya’ stream, on which the hydro site is located, starts from the Western slopes of the Nagastenna and Windsor forest area. The topography of the area is gently sloping. The good water storage capacity of the catchment is supposed to ensure a gradual discharge throughout the year (CAPS 2006).

Project B situated on Ritigaha Oya stream at Lower1) Gangaweraliya in Bulathkohupitiya Division Secretary Division in Kegalle District provides electricity only to the national grid. The power generation is connected to the national grid at Dedugala tea factory with a transmission line of length 1000 m. The river basin is narrow and elongated. Length of the river reach up to the project area is approximately 5.5 km. Catchment is mainly covered with forest and tea plants. Due to the small size of the catchment and relatively steep valley slopes, the run off response of the catchment is rapid. Table 3 gives the technical details for the two selected MHPs.

Table 3. Technical details of the MHPs

Item	Project A (Amanawala)	Project B (Dedugala)
Catchment area (km^2)	32	
Average annual rainfall (mm)	4970	4550
Average daily flow of the stream (l/s)	3000	N/A
Design flow (l/s)	225	650
Gross head	3.5	62.0
Plant capacity (kW)	3.9	300

The data presented in Table 3 show the difference in the magnitude of the two projects where the capacity of Project B is about 77 times that of Project A. Such discrepancy in plant capacity is an unavoidable factor that exits between the two types of MHPs due to their supply targets.

B. Preliminary Study

Subsequent to the selection of MHPs, one option in the research methodology is to directly conduct a sample household survey to establish social and environmental impacts. This method has been practiced with earlier research (Thoradeniya et al. 2007). However, due to the complexities that could arise with the different size and supply of the two MHPs, the researchers decided to conduct a preliminary study prior to conducting a sample household survey involving field visits and interviews with stakeholder representatives. Data are collected at two stages within the preliminary study;

Stage 1: First stage field visits are used for collecting available secondary data and to perform a situational analysis. A SWOT analysis is proposed for this purpose. The outcomes of this stage are then used to develop the strategy for the second stage.

Stage 2: Interviews with community members are the mode of data collection. These interviews are based on two structured questionnaires; one for collecting social and environmental impacts while the second on collection of power utility data for project A.

IV. DATA ANALYSES AND DISCUSSION

The data collected at the two stages of the preliminary study are analyzed and discussed here.

A. Stage I analysis

The SWOT analysis provided the following results.

Strengths:

- Availability of power generation and sales data for project B
- Availability of project proposals for both projects

Weaknesses:

- The closest rain gauge recommended by the project documents for project B is not functioning.
- Stream gauging data are not available.
- Power generation data are not available in Project A

Opportunities:

- The expertise and the willingness of the project proponent –both projects A and B
- Availability of rainfall data in further but a representative gauge for project B
- Community satisfaction in project A

Threats:

- Community dislike towards project B due to some negative impacts experience.
- Time and resource requirement for an in depth study due to remoteness of the MHP locations.

This SWOT analysis showed that the power generation and rainfall data available at Project B is sufficient to perform a correlation analysis in order to establish any dependency of the generated power with the stream flow under the assumption that the stream flow is proportional to the rainfall received at the representative rain gauge. This analysis also shed light to the research design to develop an indirect method to estimate the generated power (approximately) for the project A, where such data was not available. The method proposed is based on a survey in all the households supplied with electricity generated by the MHP to estimate the daily consumption by the electrical appliances used.

The SWOT analysis revealed the acceptance level of the two projects by the local communities as high even with their deficiencies. Therefore strategy devised to develop the research methodology is to adopt a community household survey for collecting social and environmental data. The second stage of the preliminary study thus includes pilot surveys of household in the two communities nearby the MHPs. As mentioned above, one of the weaknesses realized in the SWOT analysis is the non-availability of power generation data for Project A. Thus the stage II of the preliminary study also included a pilot study of survey designed for collecting electricity usage data involving two households in Project A.

B. Stage II - Social and Environmental Data Analysis

The two pilot surveys were conducted with four villagers where two of them represented each MHP project A and B. Table 4 describes demographic factors of the respondents. All respondents are well educated and middle aged. Respondents A01, A02 and B02 are government employees. Further, all respondents have comparatively high monthly household incomes. This background allows considering that all respondents possess mature knowledge about the related social and environmental issues and also allows considering the responses with high reliability.

Table 4. Respondent's Profile

	Respondent			
	A 01	A 02	B01	B02
Gender	Male	Male	Male	Female
Age group	51- 65	36 - 50	36 - 50	36 - 50
Education*	T	S	S	V

*Education: T – tertiary, S – secondary, V - vocational

Table 5 and Table 6 indicate the responses received on a five-point Likert scale (1 - Fully agree, 2 - Partially agree, 3 – Neither agree nor disagree, 4 - Partially disagree, 5 – Disagree) for the inquired social and environmental impacts due to Mini Hydropower generation in construction and operation phases respectively.

Responses at both Mini Hydropower projects are almost same in the construction phase. However there were no new jobs generated for the villagers from construction activities of MHP in Project A. This is due to the fact that this MHP supply power to villagers and hence the villagers have rendered free service. In contrast, new jobs were generated for villagers at the construction stage of Mini Hydropower Project B. Similarly there was no profit earned by villager from selling land for MHP in Project A whereas people have sold their land for profit under Project B, as land had been acquired by the investors for construction of the MHP in project B. The differences that can be observed between the responses from the two projects (Table 5 and Table 6) are mainly due to the final objective of the power generation; whether it supplies to the villagers or to the national grid.

Table 5: Responses on social and environmental impacts - Construction Phase

Impact	Nature	Respondents			
		A 01	A 02	B 01	B 02
Disturbance to villagers with the noise of continuous operation of turbine.	(-)	4	4	2	2
Disturbed biological process between intake and outlet of MHP due to drying up of water stream.	(-)	1	1	5	5
Increased land sliding of the area due to felling trees and removing vegetation for maintenance process of the Mini Hydropower project.	(-)	5	4	4	4
Created environment problems from sedimentation by the diversion weir.	(-)	4	5	2	2
Generated new job opportunities to villagers in the operation and maintenance of MHP.	(+)	2	1	1	2
Created environmental problems due to felling trees for maintaining secure transmission lines.	(-)	2	1	1	2
Bird strikes and electrocutions with transmission lines.	(-)	5	5	5	5

At this pilot study, the four respondents provided the social and environmental impacts they had experienced which were extra to the list of impacts provided by the researchers. These additional responses are listed below.

1) *Respondent A01:* Suggested three positive social and environmental impacts at the operation stage of project A.
   - Improved life styles of villagers
   - Improved security for villagers and
   - Decreased number of accidence from kerosene oil lamps
2) *Respondent A 02*: Suggested three positive impacts at the operation stage of MHP. They are;
   - Saving money otherwise spent on kerosene
   - Better facilities for education of children with the electricity
   - Increased communication and information through TV, radio etc.
3) *Respondent B 01:* suggested one additional negative impact in construction stage and it is the disturbance occurred to villagers due to explosions of rock for weir construction.
4) *Respondent B 02:* suggested one additional negative impact at the construction phase and two additional positive impacts during the operation phase of MHP. They are;
   - High turbidity in the water stream due to excavation work for weir construction.
   - Development of community knowledge in a particular area about hydropower generation.
   - Lighting conductors of MHP help to provide safety environment

Table 6: Responses on social and environmental impacts - Operation Phase

Impact	**Nature**	**Respondents**			
		A 01	A 02	B 01	B 02
Felling trees for construction of MHP affected soil erosion.	(-)	2	2	4	4
Removing timber trees for construction process affected the economy of people in the particular area.	(-)	4	5	2	2
Construction of MHP affected natural beauty of the area.	(-)	2	2	2	4
Generated new job opportunities to villagers from construction activity.	(+)	5	5	1	1
Underground water sources dried up due to construction activities of Mini Hydropower project.	(-)	5	5	4	5
Road network of the area was damaged due to heavy vehicles used for construction process.	(-)	5	5	5	5
Villagers earn profit from selling land for Mini Hydropower project.	(+)	5	5	1	1

The impacts which were not found in the reviewed literature will be included in the survey tool (questionnaire) of the final survey. The final questionnaire is expected to be more user friendly with such amendments.

C. Stage II - Technical Data Analysis

The stage II of the preliminary study provided the opportunity to experiment with available data for developing the methodology for an analysis possible to discuss the technical effectiveness of the two projects.

1) *Project A (Amanawala MHP):* As stated earlier no records are kept of the generated power at this project. Therefore, a questionnaire drafted to capture the general household power usage was checked with the two respondents. It was possible to itemize all the electrical appliances and the average durations of usage in a household. Additionally, the arrangements made by the villagers were also studied not to exceed their usage over the maximum capacity generated by the power plant. It is expected that the data collected on power usage will facilitate to estimate the generated power and to study the effectiveness of the plant.

2) *Project B (Dedugoda MHP):* The design capacity of the project is 216 MWh. However, it was found that it has been achieved only in December 2010. The data collected and analyzed at this stage show that power generation is not technically efficient at this plant. An example is provided with the design capacity and the generated power for the year 2013 (Figure 1).

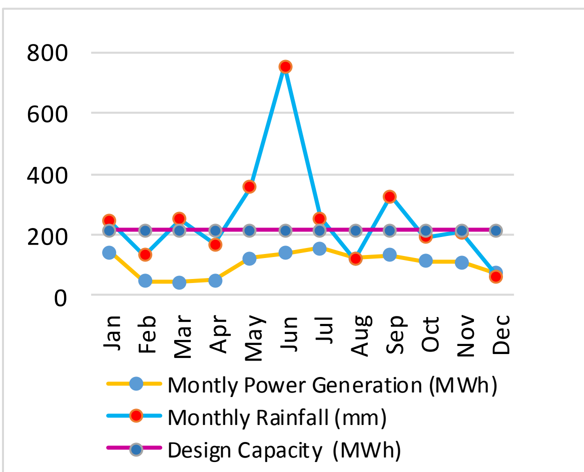

Figure 1 – Power generation and rainfall variations -2013

This situation created a further research questions; i.e. what is the reason for being unable to generate the expected quantity of power? The first suspected reason is the variation of rainfall. Therefore a correlation analysis was carried out between the monthly rainfall values for the period 2010-2014 and power generation for project B. The analysis returned a correlation coefficient of 0.55. This indicates a moderate positive correlation.

V. CONCLUSIONS

The studies of technical, social and environmental aspects MHP projects are important despite their minute and isolated nature compared to the larger scale power plants. A study undertaken to evaluate the above aspects in the two Mini Hydropower projects justified the development of research methodology to capture aspects that are important for the local population but may not have got the attention of previous studies. The two power plants differed on its supply targets, where one supplied the village community and the other supplied the national grid.

The major additional input in this work is the preliminary study proposed prior to the actual detailed household study which would have been usually conducted directly on pre-set questions developed under the guidance of the literature. A further improvement of the methodology is the SWOT analysis performed at the initial stage of the preliminary study which allowed a deeper knowledge about the ground situation.

This methodology allowed the inclusion of social and environmental aspects specific to local conditions while removing some aspects discussed in the literature from the questionnaires to be used in the detailed study.

A difference in the types of social and environmental impacts was found which can be attributed to the power supply target by the plant; whether it supplies the village or the national grid. Furthermore the levels of impacts too vary with the purpose of the MHP. Further, the data collected at this stage gives a good approximation about the impacts and power consumption of the two MHPs.

REFERENCES

Cara, A., Cara, M. and Shumka, S. 2010, Updating the social
And environmental impact assessment of Lengarica small hydro power plant (shpp) at prefecture gjirokastra, Albania,accessed 24 November 2014, <www.enso.customer.styriaware.com/UserFiles/file/Updated%20Report%20of%20ESIALangarica%20SHPP_Version%20Final%20English_June_28_2011_sm.pdf>

CAPS 2006, Consultancy and professional Services (Pvt) Ltd (2006) *Pre-Feasibility Study for Gangaweraliya Mini hydropower Project*. Colombo: Consultancy and professional Services (Pvt) Ltd.

CAPS, Consultancy and professional Services (Pvt) Ltd *Pre-Feasibility Study for Propose Sagara Weeoya Village Hydropower Project, Amanawala.* Colombo: Consultancy and professional Services (Pvt) Ltd.

CEB 2012, Statistical Digest report 2012, Ceylon Electricity Board,accessed 16 October 2014, <www.ceb.lk/sub/publications/statistical.aspx>

Chandra, R. 2010,*Bottlenecks in Hydropower Development, accessed 28 November 2014* ahec.org.in/wfw/.../power/BOTTLENECKS.doc

Gurbuz, A. 2006, 'The Role of Hydropower in Sustainable Development', *European Water* (on-line), pp. 63-70

Gvakharia, V. 2010, Construction and Operation of small HPP cascade in lukhuni river gorge (ambrolauri municipality)[online] accessed 24 November 2014 <www.rusmetali.com/pdf/1.%20EIA/EIA%20%20Lukhuni %20HPP%20-%20ENG.pdf>

Hammond, M. (ed.) 2011, 'Impact Assessment and Responsible Development for Infrastructure'*, Business and Industry,* Centro de Convenciones, Puebla – Mexic, 28 May- 4 June 2011

Kible, K. M. 2011, Development and Decommissioning of Small Dams*: Analysis of Impact and Context* [online], accessed 28 November 2014, <http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/22821/KiblerKellyM2011.pdf?se quence=1>

Kumar, A. and Schei, T. 2008, Hydropower. In: Morejon, C.D. & Krug, T., ed. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [Online], Cambridge University Press, pp. 437-496, accessed 7December 2014

Paish, O. 2002,'Small hydro power: technology and current status' *Renewable and Sustainable Energy Reviews*. 6, p. 537–556.

Rupasinghe, B.W.H.A and De Silva, S.N. 2007,'Environmental Impact of mini hydropower project in Sri Lanka' *International Conference on Small Hydropower – hydro Sri Lanka*, 22-24 October 2007, pp 373-382.

Sharma, M.P. 2007, Environmental Impact of mini hydropower project in Sri Lanka. *International Conference on Small Hydropower – hydro Sri Lanka*, 22-24 October 2007, pp 383-392.

Sovacool, B. K., Dhakal, S., Gippner, O. and Bambawale, M. J. 2011,' Halting hydro: a review of the socio-technical barriers to hydroelectric power plantsin Nepal'*Energy*36 (5), pp 3468-3476.

SLSA 2012, Sri Lanka Energy Balance 2012 [online]. Sri Lanka Sustainable Energy Authority, accessed 16 October 2014 <http://www.energy.gov.lk/pdf/EB_2012.pdf>

Thoradeniya, B., Ranasinghe, M. and Wijesekara, N.T.S. 2007'Social and Environmental Impacts of a Mini Hydropower Project on the Ma Oya Basin in Sri Lanka', *International Conference on Small Hydropower – hydro Sri Lanka.* 22-24 October 2007. pp 363-372.

BIOGRAPHY OF AUTHORS

Ms. Amashini Kariyawasam is a final year undergraduate student at the Northshore College of Business Studies pursuing for her M.Eng Degree in civil engineering. She worked as a Asst. Engineer in privet sector in 2013 and at the Institute of Technology, University of Moratuwa after obtaining National Diploma in Technology in Civil engineering with credit pass from the University of Moratuwa in 2013.

Dr. Bhadranie Thoradeniya is a Senior Lecturer at the Division of Civil Engineering Technology, Institute of Technology, University of Moratuwa. Her main research interest is in water resources development with emphasis on Economic, Social and environmental aspects and stakeholder engagement processes. She has over 20 articles presented at national and international conferences, published in journals and book chapters