Social Impacts of Large-scale Hydropower Project in Myanmar: A Social LifeCycle Assessment of Shweli Hydropower Dam 1

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Abstract

Purpose: Hydropower is currently the primary renewable energy source for Myanmar. However, hydropower projects can cause direct and indirect detrimental impacts on the livelihoods of populations. Social impacts of planned hydropower projects should therefore be assessed. In this paper, we report on the application of a Social Life Cycle (impact) assessment (S-LCA) for evaluating social and human rights impacts of hydropower construction, operation and maintenance, and transportation of materials.

Material and Method: S-LCA is capable of assessing multiple social stressors and tracking different impact categories within potentially affected communities. Both, direct and indirect interaction between stakeholders and social impacts at every stage of a project can be evaluated. An existing large-scale hydropower dam in the Ayeyarwady River, Shweli hydropower dam 1, is used as an example.

Results: Results indicate the magnitude and intensity of social and human right impacts caused by the Shweli hydropower Dam 1 in Myanmar. The dam gives rise to a series of negative impacts while offering little to no tangible benefits to local people and society. Overall, the most commonly held view expressed by stakeholders was that the dam did not offer the promised social and economic benefits. The weakest social performance was observed in the governance and socio-economic repercussion categories.

Conclusion: A number of important socio-economic impacts are identified, offering useful insights to energy, ecosystem services and land use policy makers. The results offer opportunities to examine potential impacts of forthcoming hydropower projects in the region and create long-term socio-economic benefits.

Keywords: Hydropower, Myanmar, S-LCA, MCDA, Shweli, Ayeyarwady.

Introduction

For many countries around the world, hydropower is or promises to be a strategic renewable source of energy that can contribute to economic, social and environmental development objectives. There is now more than 1,300 GW of installed hydropower capacity globally (IRENA, 2020). Despite slowing capacity growth, hydropower generation increased by 2.5 per cent in 2019, and it continues to be the world's largest source of renewable electricity (International Hydropower Association, 2020). However, hydropower, as with any major infrastructure development, inevitably brings changes to the environment and communities. It can affect people's lands, rights and culture. Furthermore, greenhouse gas emissions are emitted from reservoirs (Aung et al., 2020). Hydropower projects in developing countries often fail to achieve long-term goals and result in adverse environmental and social consequences (Urban et al., 2013). Myanmar, like many lower to middle-income countries, suffers from significant energy poverty (Dapice, 2016) and only 30% of Myanmar's population has access to electricity. The considerable deficit in power supply currently constraints the government's poverty alleviation efforts (Sovacool, 2013).

Myanmar has a development potential of hydropower up to an estimated total production capacity of 100 gigawatts (The Nature Conservancy, 2016). However, to date this substantial potential has remained underused. China is currently becoming a major player in dam construction in Myanmar, primarily in Shan, Kachin and Karen states. The electricity produced from hydropower could help meet Myanmar's energy demands as well as to generate revenue from energy exports (Kattelus et al., 2015). While economic benefits of hydropower projects are apparent, associated potential environmental, social and human rights impacts are also well documented (Institute for Human Rights and Business, 2012). Hydropower development in conflict zones and disputed areas has long been associated with an increased risk of ethnic armed conflict, displacement, landmine contamination and human rights abuses (International Finance Corporation, 2018a). Moreover, evidence from past similar developments suggests that China's hydropower projects can incur significant social and environmental costs (Brown et al., 2008).

As of 2018, Myanmar had 29 hydropower plants in operation, six under construction and 51 in the pre-construction stages. The Ayeyarwady river has the highest installed capacity with 17 existing and 31 planned projects in the basin. If all proposed projects were realised, the Ayeyarwady would produce around 28,000 MW of electricity (WWF, 2018). Whilst the steep elevation and the fast-flowing Ayeyarwady river provides a high potential for hydroelectricity, it is also one of the most important rivers for the livelihood of Myanmar's people, with its water basin covering 61% of the country's total area and serving as the most important commercial waterway (Simmance, 2013). The river basin also provides for substantial provisioning, regulating and supporting ecosystem services (Kattelus et al., 2015). However, the river is experiencing degradation of ecosystem goods and services from the establishment of hydropower projects and smaller-scale irrigation dams (International Finance Corporation, 2018b). There are associated economic and livelihood crises due to e.g. disruption of fisheries and agriculture. Furthermore, the risk of armed conflict and forced resettlements has increased (Karen Human Rights Group, 2018). As a consequence, some fierce opposition has emerged against hydropower dams on the Ayeyarwady river, led by local communities and civil societies. For instance, many villagers in Kachin State protested against the controversial Myitsone dam, financed by a Chinese state-owned company, leading to the suspension of the project (Kachin Environmental Organization, 2004).

Due to these challenges, it is necessary to effectively manage the environmental and social consequences of dams in Myanmar (Manik et al., 2013) and in this context, Aung et

al. (2020) investigated the life cycle environmental impacts of hydropower plants in the country. Given the intense interrelatedness of the environment and Myanmar society (Middleton & Lamb, 2019), considering social impacts in LCA of hydropower dams is of key importance. In addition to social impacts, S (social) -LCA (a social impact assessment technique which assesses the social, economic and human rights aspects of products, processes and projects) can be useful in determining energy injustice throughout the life cycle of an energy system (Fortier et al., 2019). Conducting a comprehensive S-LCA of energy systems remains challenging, though (Macombe et al., 2013), in particular as social impacts are difficult to standardize and quantify (Siebert et al., 2018). Although there are some studies examining potential socio-economic impacts, to date there has been no study focusing on the Life Cycle social impacts of hydropower developments in Myanmar (Han, 2018; International Finance Corporation, 2018b; Karen Human Rights Group, 2018; Simpson, 2013; Tsai, 2015). This paper reports on the social implications of an existing hydropower generation system in the Ayeyarwady river in Myanmar, namely the Shweli hydropower dam 1, using the S-LCA methodology.

What is Social Life Cycle Assessment (S-LCA)?

S-LCA uses parts of the modelling technique and systematic assessment process from E (environmental)-LCA and social-science methodologies (Arcese et al., 2020). S-LCA measures impact categories and sub-categories that positively and / or negatively affect stakeholders during the life cycle. S-LCA assesses products and services based on pre-defined life cycle stages. The entire life cycle or parts of the life cycle can be covered, depending on available data. The main differences between S-LCA and other social impact assessment (SIA) techniques are underlying objective, scope and systematic approach (Arcese et al., 2020). S-LCA assesses products and services based on the pre-defined life cycle stage. SIA is the process of analysing, monitoring and managing social consequences of planned projects, policies or programs before a project starts to assist the development of legislation at the national level (Vanclay, 2003). S-LCA also differs from the recently developed method, Social Organization Life Cycle Assessment (SO-LCA) in that the latter focuses on organizations, whereas S-LCA focusses on products or services. There is no standardized S-LCA practice with regards to characterization and indicator selection (Arcese et al., 2018). Since it was first developed, UNEP-SETAC's S-LCA Guidelines and methodological sheets have been widely applied. A weakness of S-LCA can be lack of robustness, with judgments of those applying it playing a key role in evaluation. Whilst Zimdars (2017) suggested to include two activity variables; biophysical pressure and added value (e.g. working hours of involved labour forces) in S-LCA, using data from MRIO and a Social Hotspot Database, currently there are no data for Myanmar.

The study applied Multi-Criteria Decision Analysis (MCDA) to integrate participatory and modelling methods in assessing complex social issues. MCDA permits to directly incorporate the perceptions of different experts and stakeholder groups (Hisschemöller & Cuppen, 2015). Over the past few years, some authors have utilized MCDA and participatory methods in environmental LCA (E-LCA) studies (Angelo et al., 2017; De Felice et al., 2013a; Recchia et al., 2011; Zanghelini et al., 2018). The use of MCDA in the S-LCA of hydropower projects and the energy sector in general has remained limited (Geller & Meneses, 2016; Günkaya et al., 2016; Liu et al., 2015; Pacca, 2007; Wang, Changbo & Liu, 2015; Pant et al., 2016; Pascale et al., 2011). Takeda et al., (2019) is one of the few studies available, assessing the S-LCA of renewable energy technologies, including hydroelectricity in Malaysia. They used a Social Hotspots Database (SHDB) to calculate a social hotspots index. Their study concluded that renewable energy has greater adverse

impacts on supply chain workers than conventional electricity production. They also found that renewable energy production requires longer hours per unit electricity produced. The S-LCA study by Corona et al. (2017), on the other hand, showed that solar power plants increased social welfare in Spain.

Materials and Methods

The methodological approach of the research underlying this paper was developed through the framework defined by the ISO 14044 and the "Guidelines for Social Life Cycle Assessment of Products", introduced by the Society of Environmental Toxicology and Chemistry (SETAC)/United Nations Environment Programme (2009; revised in 2019; UNEP, 2019). This was modified in order to address the Myanmar context. The Guidelines provide an overview of how to assess social life cycle impacts of products and systems and a method for adapting E-LCA to assess social and socio-economic impacts. The revised Guidelines aim at offering more practical reference for the average users (Arcese et al., 2020). Within the two broadly defined types of S-LCA methods, i.e. performance reference point and impact pathway (Chhipi-Shrestha et al., 2015; Sureau et al., 2020), here the former was used due to data availability and accessibility of required information. The assessment is based on both, desk and field research. Desk research included an analysis of recent official documents, scientific publications and the relevant grey literature. This allowed for a compilation of indicators and the establishment of stakeholders. Field research included structured questionnaires and face-to-face interviews with selected stakeholders.

The methodology consisted of the following steps:

- Goal and Scope definition (system boundaries and functional unit)
- Identification of stakeholder categories
- Identification of impact categories and subcategories
- Selection of a panel of experts for weighting of indicators
- Social Life cycle Inventory (LCI) data collection; questionnaire survey and interviews
- Social Life Cycle Impact Assessment (S-LCIA)
- Interpretation of results and conclusions

This is subsequently explained in further detail.

Aim and Scope definition

The overall aim of this paper is the investigation of the adverse social Life Cycle impacts of hydropower generation in Myanmar, focusing on one of the largest hydropower dams in the country, Shweli 1. The system considered in the analysis is gate-to-gate product Life Cycle, including all aspects of the hydropower plant Life Cycle from raw material and energy resource consumption, and transportation to the deterioration of electric equipment. As the power plant is still operating, we eliminated waste disposal from the demolition phase of the plant. While the emphasis of the study is on Shweli 1 hydropower dam, the S-LCA results can be considered representative for how hydropower development potentially affects societies in Myanmar, as most of the hydropower projects are located in contested areas with similar investment patterns and livelihood conditions (Middleton & Lamb, 2019).

System Boundary

Following UNEP-SETAC Guidelines (2009), we built a system boundary based on the framework of a standardized E-LCA system boundary (United Nations Environment

Programme, 2009). UNEP-SETAC identified three categories in S-LCA; 1. cradle-to-grave (entire life cycle of products and services), 2. cradle-to-gate (value chain) and 3. gate-to-gate or gate-to-grave (parts of the life cycle). Due to limited data availability in Myanmar, the scope of our assessment is defined as gate-to-gate, covering parts of the life cycle of the hydropower dam under study. Myanmar currently lacks national data for S-LCA and there is no global reference data for characterisation. The study therefore used site-specific data and collected indicator values along the production system and characterized them, using primarily quantitative regional sector-specific references. In that way, the authors were able to define the most appropriate set of social indicators and indices relevant to the study context.

The S-LCA analysis focuses on electricity production, transmission and distribution of the hydropower plant (from generating station to switchyard) before electricity is consumed. The life span of the power plant (temporal boundary) is 50 years (Ribeiro & da Silva, 2010). The system consists of three main Life Cycle stages: construction (main dam, two saddle dams, powerhouse, spillway, equipment installation); transportation; and operation and maintenance for electricity generation and overall maintenance. Generally speaking, hydro-electricity generating stations take advantage of the kinetic energy produced by falling water. The flowing water drives a turbine, which then converts the motion of water into mechanical and electrical power. To generate electricity, a generator's electromagnet or rotor, located inside a cylinder which contains windings of electricity wires, is rotated by the spinning turbine (IEA, 2000). Main activities of hydropower development are: site preparation, blasting and drilling, constructing offshore/onshore installations, dewatering and draining, dredging, effluent treatment and discharge, equipment and road maintenance, excavating land, grouting, concreating and asphalting, reservoir filling and soil stripping (International Energy Agency, 2000).

Functional Unit

As the analysis relies mainly on qualitative data (unlike in E-LCA), impacts cannot be expressed by a functional unit or per unit of process output. S-LCA determines information about the attributes and criteria of processes (UNEP, 2009). Hence, results are aggregated across the Life Cycle and expressed quantitatively, using the widely accepted weighting methodology MCDA (Almeida, 2019; De Felice et al., 2013; Luca et al., 2015).

Hydropower Project Background

Shweli Hydropower Dam 1 is located in Man Tat Village, Namkham Township in the Northern Shan State of Myanmar. It is the most upstream hydropower plant of a three-dam cascade (Shweli 1, 2 and 3) on the Shweli River. The river is a principal tributary of the Ayeyarwady River, and the source lies in China's Yunnan province at about 11000 ft above sea level. Based on the results of an extensive desktop screening and based on the geographic location of the dam, Man Tat Village is considered a social hotspot. Man Tat village is located on a hill on the bank of Shweli River. The 1000 ft waterfall near the village presents a technically favourable location for hydroelectricity generation.

The total expected production capacity of the dams is about 1420 MW of electricity, most of which will be exported to China (International Rivers, 2008). The Shweli Hydropower Dam 1 began generating power in late 2008 (The World Bank, 2009). The main dam is constructed across the Shweli River, diverting the water along a conduit tunnel through the hill. The electricity is generated by a power station and transmitted through high

voltage cable lines (230 kV and 220 kV) and substations. The project aims to supply electricity to Namtu mine, the Monywa copper mine, and the Thabeik Kyinn nickel mine. The project owner of the project is the Shweli River 1 Power Station Company Limited, a joint venture between the Burmese Ministry of Electric Power and a Chinese consortium that includes the Yunnan Joint Power Development Company and China Southern Power Grid Corporation. The powerplant was constructed by China's Sinohydro Corporation. The installed capacity of the project is 600 MW, and the actual power supply is 174.8 MW with an annual power output of 4033 GWh. Most of the reservoir of the plant is forested land with an approximately 80-day turnover time at 235m (The World Bank, 2009). The technical parameters of the hydropower plant are summarized in Table 1.

Project Description	
Dam type	Concrete Gravity Dam
Dam structure length	161.8 m
Dam structure height	46.93 m
Diversion tunnel	10.05 m diameter, Length, 256.41 m
Conveying tunnel	7.01 m diameter, Length, 5,014 m
Installed capacity	600 MW
Initial construction costs	million USD 23.698, 97.506
LAT N/LON E	Ayeyarwady
Basin	Shweli
Sub-basin	Built
Status	People Republic of China
Owner country	Foreign Joint Venture
Investment Type	2009
Commission Year	400 MW
Domestic Use (MW)	200 MW
Export	4022 GWh
Annual Generation (GWh)	Run-of-River
System Design	12,597 km^2
Catchment Area (km^2)	1,418 mm
Catchment Annual Rainfall (mm)	400 mm
Mean Annual Inflow into Reservoir (mm)	1.1 km^2
Reservoir Area (km^2)	Above Ground
PowerHouse Type	

Table 1: Shweli Hydropower Dam 1 project description

Stakeholder Categories

A territorial analysis and a literature review provided the basic information for the stakeholder analysis. The study area of the S-LCA covered the directly impacted area of the project in Man Tat Village, including the reservoir, potential resettlement host areas, construction areas, upstream and downstream areas of the dam, and indirect influenced areas within the Namkham Township. The main objective is to obtain a precise view of the most sensitive zones. The area is surrounded by mountains and hardwood forests endowed with great biodiversity, valuable forest products and medicinal plants used by local people. The area has also seen armed conflict (Environmental and Social Working Group, 2019).

Determining the stakeholder groups for each stage of the project system is a key task in S-LCA. The selection of stakeholders was determined, based on their relevance in a specific Life Cycle stage. The selection process followed the recommendations of the UNEP-SETAC S-LCA methodology (United Nations Environment Programme, 2013).

Four stakeholder were classified categories (value chain actors, workers, local community and wider society) for three Life Cycle phases; construction, operation, and maintenance/transportation (see Table 2). The composition of each category has been identified on the basis of terrestrial analyses done through expert consultation and an extensive review of current official statistics and documents:

- Value chain actors: These are mostly related to suppliers of raw materials (steel, stainless steel, iron and aluminium), fuel, water and energy required for the

construction phase of the hydropower plant. According to the context of the hydropower project system, a value chain actor category is included only for the construction phase of the plant for the purpose of this study. Although there are other actors involved in the operation and maintenance/transportation phases of the plant, it is impossible to trace all information related to suppliers. The stakeholders included in this category are project management, government agencies and local NGOs. It was not possible to include suppliers as a data source because most of the raw materials for the construction of a hydropower plant are imported from overseas and we were unable to obtain supplier information from project management.

- Workers: Those employed in the entire Life Cycle of the hydropower project. Due to the nature of hydropower development in Myanmar, there are several types of workers involved at each step of the project, including full-time workers, fixed-term workers and irregular workers. Main data sources are workers themselves, government agencies, non-government agencies and management.
- Local community: This is the directly affected community. Stakeholders related to this group are those living within 10 km of the project site (Manik et al. 2013). The area is mostly populated by the Palaung (Ta'ang) people, one of the indigenous nationalities in the northern Shan state of Myanmar. In addition, Shan, Kachin and other ethnic minorities also reside in the Man Tat area. As in other parts of Myanmar, the livelihood of the local community heavily relies on natural resources and ecosystem services. They are mostly rice farmers, fishermen and hunters. Site specific data sources include community members, employees, government agencies, NGOs and management.
- Society: Including the general public and the affected communities within the region where the hydropower plant is located. The stakeholder group in this category is basically composed of all those individuals not included in the 'workers' and 'local communities' groups. Data are obtained from NGOs and government agencies. They cover both, micro-level (local authorities) and macro-level (national officials) organizations.

The characterization of impact categories

Impact categories and sub-categories are the basis of a S-LCA and are assessed by use of inventory indicators, measured by attributes. With reference to the UNEP-SETAC Guidelines and a comprehensive literature review, this study included 24 impact sub-categories and four impact categories that are associated with four stakeholder groups, including; governance, human rights, community rights and socio-economic repercussion. *Respect for indigenous rights* has been adapted to *respect to ethnic minority rights* to highlight the existence of other minority ethnic groups in the region. Table 2 details the indicators for each Life Cycle phase. S-LCA encounters both, positive and negative impacts of the process Life Cycle. Here, we used qualitative measurements designed to consistently generate information, reflecting positive changes.

Inventory Analysis

At this stage

, data are collected, the system is modelled and LCI results are obtained. Given the uniqueness of the hydropower projects and the Myanmar context, the inventory data for this study are based on the sector level and country-specific primary data, rather than generic data. By using site-specific data, the challenges associated with generic data, such as the

differences in geographical and temporal scope set by goal and scope, and technological challenges can be avoided. To the authors' knowledge, there is no previous LCA studies conducted in the same region that can be used as a reference framework. Data for specific social, socio-economic and human rights impacts are difficult to obtain. Currently, the Social Hotspots Database (SHDB) does not cover the hydropower sector for Myanmar. SHDB is the first commercially available database for S-LCA, composed of 57 sectors in 133 countries (Takeda et al. 2019). Some LCA studies have used the SHDB database for collecting background data for the customers and suppliers within the supply chain (Lenzo et al. 2017). Some researchers have incorporated generic data from SHDB when primary data are not available (Martínez-Blanco et al., 2014; Rivera-Huerta et al., 2019)

There is a need for prioritization in site-specific data collection in S-LCA, as it is costly and time consuming. The end-user or customer category has been excluded, as the hydroelectricity is very different from other production systems and it is hard to identify social impacts of this category (Faria et al. 2017). For the same reason, the study also does not include suppliers as a source of data. With regards to background information, the study relied on project specific-data, provided by the Myanmar Ministry of Electricity and Energy (MOEE). Site-specific data are highly desirable in S-LCA studies (United Nations Environment Programme, 2009).

The primary data collection consists of auditing enterprise documentation and reports from government and NGOs, conducting a survey with experts to assign weights, designing the questionnaire and interview questions for stakeholders, and collecting responses. The first step of the inventory analysis for S-LCA is weighting of criteria, as well as of impact categories and sub-categories. The use of MCDA allows for the transformation of qualitative judgements into quantitative measurements (Luca et al. 2015). The weighting process was accomplished by involving a panel of 10 experts and decision-makers from the electricity sector and NGOs in Myanmar. The panel consists of four members of non-governmental social/environmental organizations, five government representatives from the Ministry of Electricity and Energy (MOEE) and Ministry of Labour, Employment and Social Security (MOLESS), as well as one member of a civil society organization (CSO). Members were selected based on their knowledge of the hydroelectricity sector in Myanmar, as well as on their familiarity with the project site and experience working with social issues in the region. All experts were participating in the "Seminar on Energy Poverty Reduction for Myanmar", jointly held by the International Poverty Reduction Centre, China (IPRCC) and United Nations Development Program (UNDP) in Beijing, China during October 2019. The focus group discussion was conducted to perform the weighting process, using a questionnaire, allowing experts to assign scores to every category (Fig 1). This approach ensures assessment of local level issues of concern and their relative importance, in line with a particular stakeholder's understanding. Experts provided the individual relative importance scores to the categories and sub-categories during the meeting, using a five-point Likert scale, ranging from "extremely important = 5" to "not important = 1". The weights of each impact category and sub-category were calculated and aggregated, using the following mathematical operation. It is important to note that the weights of each sub-category were aggregated based on each impact category and not on the sum of all the categories to obtain results at category level. Experts' rating questionnaire is provided in supplementary material.

$$W_{xi} = \left(\sum_{n=1}^{n} Sx_{mn}\right) / \left(\sum_{i=1}^{n} \sum_{n=1}^{i} Sx_{in}\right) \quad \text{.....(1)}$$

Wx_i is the weight of each category and sub-categories

Figure 1: Focus-group discussion with experts during IPRCC, Beijing, China.

Primary data were gathered through face-to-face interviews and a questionnaire survey designed for each stakeholder category. A number of field visits were also conducted during November 2019. These data were supplemented by previously published reports on human rights and socio-economic impacts of mega hydropower projects in Myanmar (Environmental and Social Working Group, 2019; Han, 2018; Institute for Human Rights and Business, 2012; Kachin Environmental Organization, 2004; Karen Human Rights Group, 2018; Simpson, 2013; Ta'ang Student and Youth Organization, 2007; Tsai, 2015; H. Yee, 2016; H. W. Yee, 2017). Three sets of questions were prepared for the different stakeholder groups, including (a) government, non-government and project management, (b) workers and (c) local community (see Supplementary). The questions were principally intended to obtain inventory data for each sub-category presented in Table 2. The total population of Man Tat Village is 700 (all ethnic minorities). Given the small population, 60 villagers comprising Palaung (Ta'ang), Shan, Kachin and other minorities, participated in the study. 22 of the villagers represented the workers' stakeholder category and the remaining were considered to be 'local community'. For these groups, local native research assistants were employed to interview in local dialect which is different from the Burmese language. A total of 30 questionnaires were completed by representatives of government, non-government and project management categories. Some of the questionnaires were distributed in person, and some were sent by email.

Initially, all the questions were answered with "YES" or "NO" which was later converted to "YES=1" and "NO=0" for aggregation and weighting calculation purposes. The score of each impact category or indicator results was characterized and calculated, using the following formula:

$$Sx_i = \frac{B_i(x)+C_i(1-x)}{Bi+C_i} \quad \text{.....(2)}$$

$$x = \begin{cases} 0, (1-x) = 1 \\ 1, (1-x) = 0 \end{cases}$$

Sx_i is the score of each category and sub-categories

Scores were then aggregated by means of a weighted sum, and the final score was obtained. This process allowed to convert the heterogeneous data in a-dimensional indices between 0 and 1. A score of 1 is high, i.e. unlike E-LCA, a higher score represents a more socially sound performance of the project. Accordingly, a final score <0.33 would indicate a high social Life Cycle impact, between ≥ 0.33 and <0.66 would suggest a medium social Life

390 Cycle impact, and between ≥ 0.66 and <1 or =1 would indicate low social Life Cycle impact
391 associated with the project.

Life Cycle phase	Stakeholder Categories	Impact categories	Impact Sub-categories	Attributes
Construction	Value Chain Actors	Governance	Fair competition (G1)	Compliance with legislation preventing anti-competitive behaviour, anti-trust, or monopoly practices.
			Promoting CSR (G2)	Promoting the use of social responsibility certifications and/or product labels.
Construction, Transportation, Operation and Maintenance	Workers	Human rights	The employment of Child/juvenile labour (H1)	The conditions are favourable for the occurrence of child labour, and the existence and quality of the prevention and mitigating measures taken by the organization.
			The employment of forced labour (H2)	The use of forced or compulsory labour in the organization.
			Fair Salary (H3)	Compliance with established standards and if the wage provided is meeting legal requirements, within industry standard, whether it can be considered as a living wage.
			Freedom of association and collective bargaining (H4)	1) whether the workers are free to form and join associations even when this could damage the economic interest of an organization, 2) whether the workers have the right to organize unions, to engage in collective bargaining and to strike.
			Decent hours of work (H5)	The number of hours worked is in accordance with the ILO standards, and when overtime occurs, compensation is provided to workers.
			Health and Safety (H6)	The rate of incidents and the status of prevention measure and management practices.
			Social benefit and security (H7)	Provides for social benefits and social security (non-monetary employment compensation) of workers and to what extent.
			Equal opportunity and free from discrimination (H8)	Any distinction, exclusion or preference made on the basis of race, colour, sex, religion, political opinion, national extraction or social origin
Construction, Operation and Maintenance	Local Community	Community rights	Decolonization and migration/Land confiscation (C1)	Contribute to delocalization, migration or involuntary resettlement within communities.
			Community engagement (C2)	Includes community stakeholders in relevant decision-making processes.
			Respect to cultural heritage (C3)	Respects local cultural heritages.
			Respect to ethnic minority rights (C4)	Respect for the rights of ethnic minorities as a group or as individuals.
			Local employment (C5)	The role is directly or indirectly affecting local employment.
			Access to immaterial resources and material resources (C6)	Improve community access to immaterial resources, material resources and infrastructure.
			Access to electricity (C7)	How organizations impact community safety and health
			Safe and healthy living conditions (C8)	How organizations impact community access to electricity
			Secure living conditions (C9)	How organizations impact the security of local communities with respect to the conduct of private security personnel and how the organization interacts with state-led forces.
Construction, Operation and Maintenance	Society	Socio-economic repercussion	Public commitments to sustainability (S1)	Engagement in reducing its sustainability impacts according to the agreement made.

			Prevention and mitigation of conflicts (S2)	The role (positive and negative) in conflicts or situations that might, in the future, develop into conflicts.
			Contribution to economic development (S3)	The extent of contribution to the economic development of the country.
			Corruption (S4)	Evidence that it has engaged or has been engaged in corruption.
			Technology development (S5)	Transfer of technology and knowledge. Participates in joint research and development for efficient and environmental sound technologies.

Table 2: Stakeholder categories, Impact categories, sub-categories and indicator attributes for each Life Cycle phase

Results and Discussion

Social Life Cycle Impact Assessment (S-LCIA)

Based on the characterization framework, the reference scale social life cycle impacts of electricity generation from the Shewli 1 hydropower dam were calculated. The scores obtained were then weighted and converted into four impact categories and 24 impact sub-categories to get a final weighted performance score. Table 3 summarizes the normalized measurements obtained.

Impact Categories	Impact Sub-categories	Inventory Indicators	Score
Governance	Fair competition (G1)	G 1.1. Presence of legal actions pending or completed regarding anti-competitive behaviour and violation of anti-trust.	0.000
		G 1.2. Presence of policy to prevent anti-competitive behaviour.	0.000
		G 1.3. Employee positive perception about fair competition.	0.000
	Promoting CSR (G2)	G 2.1. Possession of environmental and social certificates	0.000
		G 2.2. Publication of CSR report.	0.000
		G 2.3. The enterprise has audited the suppliers with regard to CSR.	0.000
Human rights	The employment of Child/juvenile labour (H1)	H 1.1. Absence of working children under the legal age of 15 years old.	0.000
		H 1.2. Children do not perform work during the night.	0.000
		H 1.3. Presence of records of all workers stating ages.	0.467
	The employment of forced labour (H2)	H 2.1. Workers agreed upon employment terms based on the contracts.	0.400
		H 2.2. Worker identification documents are not retained.	0.533
		H 2.3. Workers are free to terminate employment.	0.533
	Fair Salary (H3)	H 3.1. Absence of lowest paid workers compared to the minimum wage.	0.000
		H 3.2. Absence of wage deduction.	0.000
		H 3.3. Regular payments.	0.000
	Freedom of association and collective bargaining (H4)	H 4.1. Workers are free to join unions.	0.600
		H 4.2. Presence of notice period regarding operational changes.	0.000
		H 4.3. Workers have access to dispute resolution procedure.	0.000
	Decent hours of work (H5)	H 5.1. Average hours work is in accordance with the ILO standard.	0.267
		H 5.2. Number of holidays are in accordance with the ILO standard.	0.333
		H 5.3. Presence of agreement concerning overtime.	0.400
	Health and Safety (H6)	H 6.1. Absence of frequent injuries or fatal accident during the work hours.	0.000

		H 6.2. Presence of formal policy for health and safety.	1.000
		H 6.3. Presence of occupational safety measures and emergency protocols.	0.333
	Social benefit and security (H7)	H 7.1. Provides health insurance, pension fund, childcare etc.	0.200
		H 7.2. No evidence of the violation of social security law.	1.000
		H 7.3. Presence of paid time off.	0.133
	Equal opportunity and free from discrimination (H8)	H 8.1. Project proponent complies with formal policies on equal opportunities.	0.000
		H 8.2. Men and women receive an equal salary.	1.000
		H 8.3. Absence of discrimination based on gender, race, religion and age.	0.267
Community rights	Decolonization and migration/Land confiscation (C1)	C 1.1. Absence of resettlement due to the project.	0.000
		C 1.2. Project proponent complies with resettlement policies (due diligence/safeguard).	0.000
		C 1.3. Presence of procedure for migrant worker's integration.	0.000
	Community engagement (C2)	C 2.1. Project proponent complies with policies on community engagement.	0.600
		C 2.2. Presence of frequent meetings with community stakeholders.	0.400
		C 2.3. Stakeholder engaged are diverse.	0.533
	Respect to cultural heritage (C3)	C 3.1. Project proponent protect cultural heritage.	0.333
		C 3.2. Information about the project is published in the local language.	0.733
	Respect to ethnic minorities (C4)	C 4.1. Project proponent protects the right of ethnic minorities.	0.267
		C 4.2. Annual meeting held with ethnic minorities.	0.200
	Local employment (C5)	C 5.1. Percentage of the local workforce hired is high.	0.467
		C 5.2. Project proponent complies with a policy on local hiring.	0.467
		C 5.3. Project proponent complies with the policy on locally based suppliers.	0.133
	Access to immaterial resources and material resources (C6)	C 6.1. Developed project-related infrastructure with community access and benefit.	1.000
		C 6.2. Presence of risk assessment for resource conflict.	0.000
		C 6.3. Presence of certified environmental management system.	0.200
	Access to electricity (C7)	C 7.1. Access to electricity increases due to the project.	0.533
		C 7.2. The number of hours with electricity increases due to the project.	0.000
	Safe and healthy living conditions (C8)	C 8.1. Presence of management oversight of structural integrity.	0.667
		C 8.2. Project proponent put efforts to strengthen community health.	0.000
		C 8.3. Management put efforts to minimize the use of hazardous substances.	0.000
	Secure living conditions (C9)	C 9.1. Absence of legal complaints against the organization with regard to security concerns.	0.200
		C 9.2. Absence of casualties and injuries ascribed to the organization	0.733
Socio-economic repercussion	Public commitments to sustainability (S1)	S 1.1. Presence of publicly available documents (EIA/SIA reports)	0.267
		S 1.2. Absence of protests/complaints issued related to the non-fulfilment of agreements by the organization by the local community or other stakeholders.	0.267

	Prevention and mitigation of conflicts (S2)	S 2.1. There is no evidence of the project's role in the development of conflicts.	0.467
		S 2.2. The project is not located in the disputed region.	0.000
		S 2.3. There are no ethnic armed groups in the region.	0.000
	Contribution to economic development (S3)	S 3.1. Contribution of the project to economic progress (revenue gain, paid wages etc.)	0.333
	Corruption (S4)	S 4.1. The commitment of the project proponent to prevent corruption.	0.000
		S 4.2. Absence of active involvement of the project proponent in corruption and bribery.	0.000
	Technology development (S5)	S 5.1. Involvement in technology transfer program or projects.	0.333
		S 5.2. Partnerships in research and development.	0.200
		S 5.3. Investments in technology development/ technology transfer.	0.133

Table 3: Impact categories, sub-categories, indicators and normalized measurements

The results of the social Life Cycle impact assessment are shown in Table 4. This table summarizes the weights of the impact categories and sub-categories obtained from the experts' judgements and the weighted scores. The interpretation of results consists of the identification of significant issues for each stakeholder group. Figure 2 illustrates the results in a radar chart by impact sub-category, and figure 3 presents the results by impact category. The results of the analysis show that the overall social performance of the Shweli Hydropower dam 1 is low, as the final score obtained was 0.245 (> 0.33). Figure 2 illustrates the social Life Cycle impacts by categories and sub-categories.

Governance

The Governance impact category corresponds to the value-chain actors' stakeholder category and consists of two sub-categories: fair competition and promotion of corporate social responsibility (CSR). This impact category is used only for the construction phase of the hydropower project. The fair competition category is about measuring whether the project proponent's competitive activities are conducted in a fair manner (United Nations Environment Programme, 2013). This sub-category is measured by three inventory indicators shown in Table 3. The second sub-category seeks to assess if the project developer promotes corporate social responsibility through three different indicators. The inventory data for this category are mainly achieved through interviews with Government, NGOs and project management. Due to the complicated nature of the hydropower project's supply chain, we were not able to include the suppliers in our stakeholder group. Based on the results of the analysis, both sub-categories in the governance category performed poorly with a score of 0.00 and 0.21, respectively. Myanmar currently has no planning and licensing mechanisms guiding investment projects, nor is there legislation preventing anti-competitive behaviour, anti-trust or monopoly practices. The lack of such guiding principles can lead to a developer's negligence to consider the interests of stakeholders.

Human rights

The Human rights category in this study measures the rights of the workers employed in the construction, transportation, operation and maintenance phases of the hydropower project. Data were collected from workers, government, NGOs and project management. The category consists of eight impact sub-categories, measured by three inventory indicators. Based on the results, the human rights impact of the powerplant on the workers is considered to be low as the overall result was 0.091 with all scores >0.33. Notably, the rating for the

employment of child/juvenile labour (H1), fair Salary (H3) and freedom of association and collective bargaining (H4) indicates deficiencies. Issues with regards to forced labour, child labour and low wage payments were also evidenced by the Ta'ang Student and Youth Organization (2007). It was reported that the inhabitants from Man Tat village were forced to work in road construction for the dam and paid half the standard wage. The use of forced labour was also reported for the installation of transmission lines for the project. Specifically, one person from each household in Man Tat village was forced to work at the planned transmission line route without the help of any machinery. Each village was responsible for a 5-mile stretch of the road connecting Mantong to Namkhan (Ta'ang Student and Youth Organization 2007). Some truck owners also claimed that they were forced to travel to Lashio without any payment to carry electric wire and materials for the construction of transmission lines. Our analysis shows that other aspects, such as decent hours of work (H5), health and safety (H6), social benefit and security (H7) and equal opportunity free from discrimination (H8) were also below the acceptable standards. Our findings can explain the opposition to the dams by many activists and local communities in Myanmar. In particular, there are indicatios of systematic human rights abuses, amongst other concerns (Simpson, 2013). For Malaysia, Takeda et al. (2019) found that hydroelectricity caused the lowest negative impacts on workers, among other renewable energy production. However, this can be attributed to the relatively stable labour and employment law in Malaysia. In other renewable energy projects, such as solar power plants, health and safety and labour rights appear to be the highest social risks (Corona et al., 2017).

Regarding equal opportunity for employment and the conditions of employment, Myanmar currently does not have any law to protect women and children (Tsai, 2015). Existing studies have revealed that women and children in ethnic areas are considered disadvantaged groups and are usually affected most by large-scale hydropower dams (H. Yee, 2016).

Community rights

This impact category seeks to measure the impacts of the hydropower dam on local communities in Man Tat village with regards to their environmental and social safeguards. The data for this category were collected from the members of the local community, government, NGOs and project management. The Life Cycle phases targeted are construction, operation and maintenance phases. This impact category involves nine impact sub-categories with two to three inventory indicators. We conducted a community-based assessment and collected data through site visits and individual interviews with impacted ethnic community members. The results of the analysis indicate that the assessment criterion 'decolonization and migration/land confiscation' (C1), scores 0.00. All villagers reported cases of land confiscation and property damage due to the dam. The Shweli 1 hydropower dam development led to large-scale involuntary resettlements and direct displacement of local people from their lands. In all cases, it was reported that forced relocation and unfair compensation resulted in several displacements in the region. Land confiscation is particularly evidenced in the construction phase of the dam and local land and homes along the route were seized during construction. The majority of the villagers usually earn a living through agriculture and rely on their property and related ecosystem services for their food and income. Most of the confiscated lands are paddy and hillside fields, tea plantations and community forests, which means they are faced with a substantial degree of livelihood destruction. The loss of community forests can have adverse impacts on ecosystem services supply to local land users (Zaehringer et al., 2020). When lands along the riverbed were confiscated, farmers were forced to move to mountain lands where productivity is very low.

It is also anticipated that approximately 2,000 acres of community forests and cultivated farms will be flooded due to the low-lying geographic location of the project site (Karen Human Rights Group, 2018).

Community engagement (C2) is a poorly performing impact category with a score of only 0.014. Despite social and environmental concerns, there is still no formalized public consultation process related to mega hydropower projects in Myanmar. The consideration of public interests remains an ad hoc affair, and associated decisions are made arbitrarily. Some villagers claimed that they had a chance to participate in project planning meetings and expressed their preference for resettlement. However, there were limited opportunities to voice any grievances and negotiate adequate compensation. Respect for cultural heritage (C3) and respect to ethnic minorities (C4) also received low scores. The effects on vulnerable ethnic groups, indigenous peoples and minorities are of particular concern in hydropower projects (IEA, 2000). In Man Tat village, an increase in military presence, migration of Chinese workers, the establishment of work camps and resettlement led to changes in the community and social structure, and also to an increase in safety risks and to restrictions of freedom of movement. Villagers also reported impacts on aesthetic, cultural, archaeological sites and places of religious or historical value in the region. Ta'ang Student and Youth Organization (2007) said that only Chinese workers were employed at the project's construction site, although there is evidence of local forced labour at the road construction with unfair pay. Hence, local employment (C5) opportunities were unsatisfactory.

Regarding access to immaterial resources and material resources (C6), and access to electricity (C7), the final scores from our analysis are 0.010 and 0.011, respectively, and are therefore very low. The initial claims made by China and the military to build hospitals and post-primary schools are yet to be fulfilled. Local villagers are not allowed to use the facilities at the clinic established for Chinese workers and soldiers. The road projects for the dam contribute little to transportation for local people. Instead, they facilitate the movement of soldiers and construction materials and have increased access to drugs in the village. The project also did not improve access to electricity, and the majority of the produced power is transmitted to military factories and mining operations and exported to China. Safe and healthy living conditions (C8) and secure living conditions (C9) were also considered weak, in particular as safety issues are a significant concern in the region once the project is implemented. Public health, shelter and food security are threatened due to modifications of water quality and quantity, loss of terrestrial and aquatic food resources, and replacement of farmlands. This is in line with e.g. Fortier et al. (2019) who found that renewable energy projects negatively affect local communities' lands, culture, and traditions.

Socio-economic repercussion

This indicator refers to the impacts on members of society in general. Like the workers' stakeholder category, this category includes the entire process chain, including construction, operation and maintenance phases. It consists of five sub-impact categories; public commitment to sustainability (S1), prevention and mitigation of conflicts (S2), contribution to economic development (S3), free from corruption (S4) and technology development (S5). Each sub-category comprises two to three indicators, except for contribution to economic growth (S3) which has only one, namely the contribution of the project to economic progress, measured by revenue gain and paid wages. The questionnaires were answered by members of the local community, government, NGOs and project management. In the Life Cycle assessment, the weighted score of the first sub-category; public commitments to sustainability (S1), is 0.015. This indicator measures the commitment of the project proponent to society, which includes employees, shareholders, local community and the public, regarding social,

environmental and ecological impacts. This is assessed through available documents (EIA/SIA reports) and through protest and complaint issues related to the non-fulfilment of agreements. Most existing hydropower plants in Myanmar were officially permitted by the military regime with no input from society and there has been little transparency. Therefore, when local populations face significant environmental and social damage, widespread protests and anti-dam sentiments often escalate in Myanmar. Environmental and social impact assessment (EIA/SIA) frameworks have only been promulgated recently in Myanmar. By the time Shweli hydropower dam 1 was in operation, there were no formal requirements for environmental and social monitoring (Aung, 2019). Hence, EIA and SIA for the dam have never been disclosed. There is also no evidence of public consultation before or after the project. However, there are mandatory EIA, SIA and human rights (and conflict) impact assessment requirements for the two planned dams on the Shweli River, Shweli 2 and 3 (Environmental and Social Working Group, 2019).

The second sub-impact category; prevention and mitigation of conflicts (S2) scored 0.009. This is measured by the evidence of the project's role in arising conflicts, the project's location in the disputed region and the existence of ethnic armed groups in the area. All participants responded that the project is located in a disputed region, and that there are ethnic armed groups in the region. Almost half of the respondents believe that projects are connected with conflicts. The overall low score in this category is not surprising because most of the built and planned hydropower projects in Myanmar are located in conflict-affected areas. The construction of large-scale dams in these areas has shown to intensify the risk of conflicts between ethnic armed groups and the government (IEA, 2000). In many cases, the development of dams fuelled existing armed conflicts (Hedström, 2019). The lack of public consultation and opaque decision making, as well as increased militarization exacerbated ethnic tension and armed conflict in the areas surrounding the Shweli dam 1 (Ta'ang Student and Youth Organization, 2011). With regards to the contribution to economic development (S3), although some respondents agreed that there is some economic improvement due to the dam, the overall score is only 0.013. This can be due to little positive impacts on local employment and income. There is also no evidence of supply chain opportunities, infrastructure development and public services offered to societies.

All survey participants said that the project was not free from corruption. Stakeholders do not believe that the project proponent made any effort to prevent corruption. Generally speaking, the allegations of corruption, opacity and rent-seeking[1] behaviours are prevalent in the Myanmar hydropower sector (Chen, 2014). For the sub-category technology development (S5), the overall score was 0.007. This category was expressed though three indicators: the involvement of the project in technology transfer program or schemes, the establishment of partnerships in research and development and the investments in technology development/ technology transfer. Similar to material resources, there was little to no contribution made by the dam project in offering immaterial resources, such as knowledge and technology transfer, as well as skills and capacity development.

Category	Weight	Impact Sub-categories	Weight	Overall weight	Score	Weighted Score
Governance	0.186	Fair competition (G1)	0.354	0.066	0.000	0.000
		Promoting CSR (G2)	0.646	0.120	0.178	0.021

[1] "Rent-seeking is a concept in economics that states that an individual or an entity seeks to increase their own wealth without creating any benefits or wealth to the society." (Corporate Finance Institute, 2017).

Human rights	0.293	The employment of Child/juvenile labour (H1)	0.151	0.044	0.156	0.007
		The employment of forced labour (H2)	0.151	0.044	0.489	0.022
		Fair Salary (H3)	0.136	0.040	0.000	0.000
		Freedom of association and collective bargaining (H4)	0.088	0.026	0.200	0.005
		Decent hours of work (H5)	0.139	0.041	0.333	0.014
		Health and Safety (H6)	0.130	0.038	0.444	0.017
		Social benefit and security (H7)	0.103	0.030	0.444	0.013
		Equal opportunity and free from discrimination (H8)	0.103	0.030	0.422	0.013
Community rights	0.287	Decolonization and migration/Land confiscation (C1)	0.162	0.047	0.000	0.000
		Community engagement (C2)	0.097	0.028	0.511	0.014
		Respect to cultural heritage (C3)	0.081	0.023	0.533	0.012
		Respect to ethnic minorities (C4)	0.114	0.033	0.233	0.008
		Local employment (C5)	0.091	0.026	0.356	0.009
		Access to immaterial resources and material resources (C6)	0.084	0.024	0.400	0.010
		Access to electricity (C7)	0.140	0.0400.025	0.267	0.011
		Safe and healthy living conditions (C8)	0.088	0.041	0.222	0.006
		Secure living conditions (C9)	0.143		0.467	0.019
Socio-economic repercussion	0.234	Public commitments to sustainability (S1)	0.243	0.057	0.267	0.015
		Prevention and mitigation of conflicts (S2)	0.243	0.057	0.156	0.009
		Contribution to economic development (S3)	0.171	0.040	0.333	0.013
		Free from corruption (S4)	0.204	0.048	0.000	0.000
		Technology development (S5)	0.138	0.032	0.222	0.007
Final Score						0.245

Table 4: Social Life Cycle Score

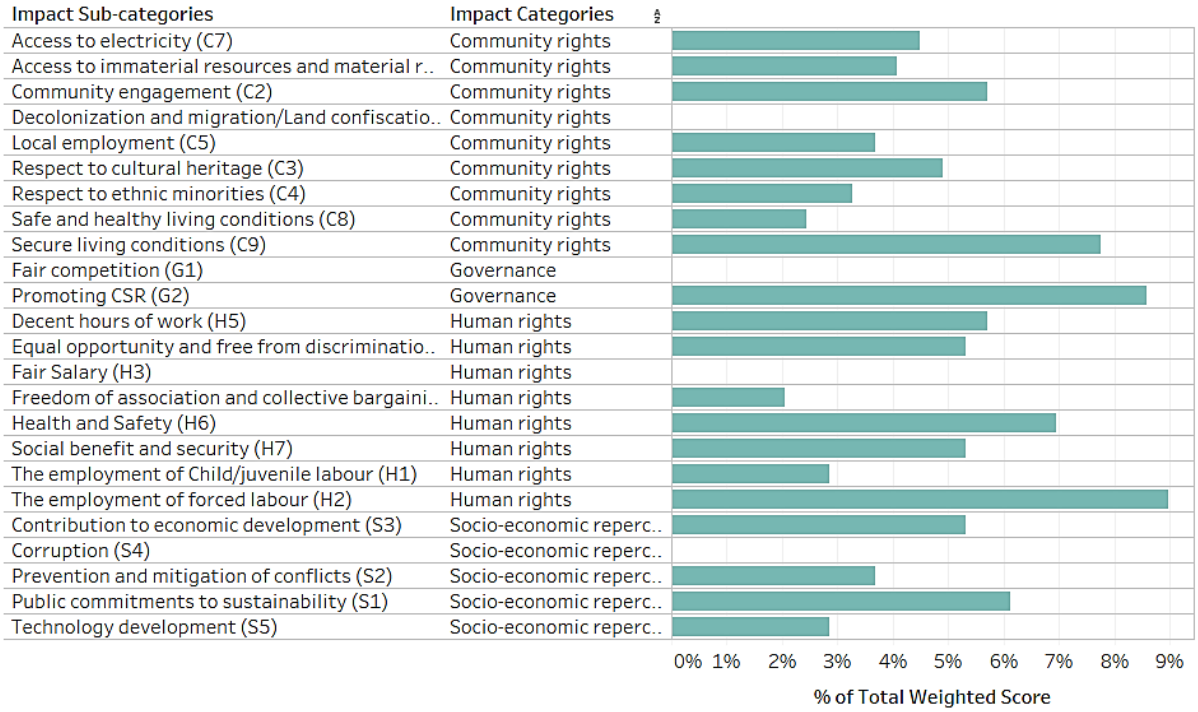

Figure 2: Social life cycle impacts by category and sub-categories

Conclusions

Results from Social Life Cycle Assessment indicate the magnitude and intensity of social and human right impacts caused by the Shweli hydropower Dam 1 in Myanmar. The low final score suggest that the dam is giving rise to a series of negative impacts while offering little to no tangible benefits to local people and society in general. All stakeholders' experiences and perceptions of effects are consistent across different impact categories. Overall, the most commonly held view expressed by stakeholders was that the dam did not offer the promised social and economic benefits. The weakest social performance was observed in the governance and socio-economic repercussion categories. These weaknesses can be very harmful because sub-categories, such as the promotion of CSR, mitigation of conflicts and prevention of corruption are crucial for the sustainable development of Myanmar. Given the past and on-going armed conflicts in the project area, failing to prevent conflict situations will aggravate challenges and risks for the up-coming two new large-scale dams, Shweli 2 and 3. More importantly, as locals perceived the project as being linked to armed conflicts in the region, the tension between local actors and project proponents will continue to be high. For these reasons, the Myanmar government should suspend the implementation of large-scale hydropower projects in conflict-affected areas until a nation-wide peace agreement is reached.

In the human rights category, all respondents identified unfair payment practices. The majority of them also suggested the project used forced labour and child labour during the construction of the dam. Although slightly better than other sub-categories, some indicators for human rights abuses are lower than the acceptable scores (i.e. close to 1). This is an expected outcome, though, since human rights and labour rights violations have long been associated with hydropower projects in the region (Opperman et al., 2017). Likewise, the overall results for the community rights category suggest that the local population is highly dissatisfied with the contribution of the project to the community. As expected, all participants claimed that there were incidents of land-confiscation and forced relocation. It is

crucial to make sustainable provisions to compensate local people who have lost their lands and properties (see e.g. Xu et al, 2021). Local communities should be consulted and be given the opportunity to negotiate for compensation before the start of the project. This issue is linked to a complete lack of formal opportunity to participate in the planning and decision making of the project. If the government wants to continue hydropower development in Myanmar, there should be stakeholder involvement as early as possible. Another pressing issue is access to electricity in the region. The power generated from large hydropower dams should provide dependable and affordable electricity for the local population. Instead, the local community reported that they did not benefit from the electricity produced by the dam. A similar perspective was heard from many of the stakeholder representatives about the economic benefit of the dam.

These results are significant because they explain the expectation of the local population and society as a whole for equitable benefit sharing, meaningful participation and impact mitigation concerning hydropower projects. Understanding and fulfilling local expectations can prevent opposition and public protests. The Life Cycle social and human rights implications of the plants offer opportunities to examine potential impacts of forthcoming hydropower projects in the region and create long-term socio-economic benefits.

Ethical Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee or comparable ethical standards. This research does not contain any studies with animals performed by any of the authors. Informed consent was obtained from all individual participants included in the study.

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