Social, Economic and Environmental Sustainability of Hydroelectric Power Plant: A Literature Review

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ABSTRACT

Hydroelectric power plants are increasingly regarded as a viable source of sustainable renewable energy in various countries, including the Philippines, given its extensive archipelagic landscape. Despite their pivotal role, there is a notable scarcity of research on the sustainability aspects of hydroelectric power plants. This study aimed to assess the impact of hydroelectric power plants on the lives of residents in the Philippines by examining their social, economic, and environmental dimensions. The research employed a literature review that scrutinized existing scientific literature about the social, economic, and environmental sustainability of hydroelectric power plants. Content analysis was utilized to categorize articles based on content grouping, encompassing topics such as the water quality of Lake Lanao, sustainability variables, and the overarching policies of the Philippine government concerning the sustainability of hydropower dams. The literature review revealed adverse effects of hydroelectric power plants, particularly on the social, economic, and environmental aspects associated with these projects. Concerns were identified, ranging from issues related to the water quality of Lake Lanao and the river to the lack of adequate waste management systems among residents. Compounding these challenges were forced evictions and a reduction in job opportunities, resulting in a diminished contribution to industrial processes. These findings underscore the urgent need for a comprehensive examination of the Agus Phase 1 Hydroelectric Power Plant, considering all three major variables—social, economic, and environmental—in the context of policy modification.

Keywords: *Sustainability, Hydroelectric, Power Plant, Literature Review*

Introduction

Sustainable development is crucial as hydroelectric power plants play an increasingly prominent role in meeting global communities' power needs. According to the World Commission on Environment and Development's (1987) report, sustainable development involves meeting current needs without compromising the ability of future generations to meet their own needs. This encompasses the integration of social development, economic growth, and environmental protection as mutually reinforcing pillars.

Hydroelectric power plants are considered a solution for sustainable renewable energy in various countries, including the Philippines, given its expansive archipelago. The Philippine government has demonstrated support through the establishment of numerous hydroelectric power plants. However, in the late 1960s, large dams globally faced removal due to unacceptable social, economic, and environmental costs. Unfortunately, the sustainability of hydropower dams is often inadequately scrutinized, with construction priorities emphasizing energy generation for industries and

urban areas, neglecting social, economic, and environmental considerations. Local communities bear the brunt, grappling with socio-economic and environmental damages, along with a loss of livelihoods.

Hydropower development causes significant ecological disruptions in river systems, leading to declines in freshwater availability, seasonal changes in river discharge, loss of downstream freshwater habitat, floodplains, coastal erosion, and salinity changes. Additionally, hydropower dams negatively impact ecosystem structure, composition, and function. Therefore, there is an urgent need for sustainable measures that integrate hydropower development with other energy sources, mitigating adverse environmental, behavioral, cultural, and socioeconomic effects (Moran et al., 2018).

The Agus-1 Hydroelectric plant, located in Marawi City, Philippines, is a crucial power source catering to various needs, such as potable water, agricultural support, environmental flow, water availability, and electricity for industrial, recreational, and commercial development (Hansel and Metillo, 2016; NPC, 2021). Despite these vital roles, research on the sustainability of hydroelectric power plants is limited. This literature review aims to present and discuss relevant literature and studies, focusing on evaluating the Agus Phase 1 Power Plant's impact on residents' lives in Marawi City across social, economic, and environmental dimensions.

The objective is to formulate a policy that improves the power plant's operations based on existing literature, catalyzing tangible changes in policy and society. This policy development, with exclusive specifications, will directly benefit residents near the power plant in terms of social, economic, and environmental aspects.

Methodology

The research methodology employed a comprehensive literature review to explore existing scientific literature on the social, economic, and environmental sustainability of hydroelectric power plants. This analysis utilized content analysis, drawing on sources from reputable research databases including Google Scholar, a directory of open-access journals, ScienceDirect, and other pertinent websites. The content analysis process, a well-established method in social sciences research, followed a five-step procedure outlined by Shropshire and Kadlec (2012).

The content analysis procedure consisted of the following steps: selecting content for analysis, defining units and categories of analysis, establishing coding rules, coding the text based on these rules, analyzing the results, and drawing conclusions (Luo, 2020). In this specific case, the researcher conducted searches using keywords such as "social, economic, and environmental sustainability of hydroelectric power plants," yielding an initial pool of 136,000 results. Following the initial review, 70 articles were identified as containing relevant information and were selected as the sample for the study. The selection of websites was guided by criteria including reputation, accessibility, content availability, and bibliometrics.

To categorize the articles, a coding process was employed based on content grouping. This involved addressing specific aspects such as the water quality of Lake Lanao, sustainability variables, and the general policies of the Philippine government related to the sustainability of hydropower dams. This systematic approach ensured a thorough examination of the literature and provided a foundation for the subsequent analysis of the social, economic, and environmental dimensions of hydroelectric power plants in the Philippines.

Findings and Discussion

Water Quality of Lake Lanao

In the study conducted by Angagao et al. (2017), observations of Lake Lanao indicated that the water exhibited a colorless and odorless appearance, with predominantly pleasant and sunny weather during the sampling period. The pH levels of the water ranged from 7.5 to 7.6, indicating a slightly basic nature. Specifically, both stations 1 and 2 had pH readings of 7.6, resulting in an average pH level of 7.6. This falls within the recommended pH range of 6.5-8.5 as set by the Philippine Department of Environment and Natural Resources (DENR). The pH of an ecosystem is known to play a crucial role in influencing its production, with indirect consequences being more significant than direct ones, affecting various metabolic parameters in aquatic bodies.

The recorded water temperatures at the three sampling stations ranged from 23 to 24 degrees Celsius, staying within the permissible limit set by the DENR, as there was no increase of more than 3 degrees Celsius compared to the ambient temperature. Factors such as water depth, air temperature, shade, and thermal pollution from human activities contribute to temperature changes. The average depth in the southern half of Lake Lanao was measured at 12.3 meters, with Station 1 being the deepest at 14.4 meters and Station 2 being the shallowest at 10.8 meters. Although Lake Lanao has a maximum depth of 112.00 meters and a mean depth of 60.00 meters, it's important to note that the recorded depth in this study was at the coastline and not at the center of the lake.

The clarity of the lake water is influenced by the presence of suspended silt, marl ($CaCO_3$), organic matter particles, free-floating algae, and zooplankton. Algae, in particular, has a significant impact on water transparency. The average transparency value at the three sampling stations was measured at 7.4 meters, with Station 1 exhibiting the highest transparency at 7.9 meters and Station 3 showing the lowest at 6.7 meters. Notably, during the dry season when

the study was conducted, no obvious algal development or runoffs were observed. The Secchi-disc transparency mean value was higher during the dry season compared to the rainy season, likely attributed to the absence of floodwaters, surface runoffs, and the settling of suspended materials after rain.

Variables of Sustainability

Social Sustainability

In Cernea's study (2004), it was disclosed that the construction of hydropower dams has a profound impact on the social life of communities, leading to forced population displacement, land takings, and alterations in land use, forests, or waters for economic stability. The repercussions are far-reaching, affecting over a thousand people and the entire community. Hydropower dam construction is identified as a major factor causing forced evacuations, resulting in the permanent loss of land rights for landowners and leading to displaced decapitalizations—both natural and artificial loss of capital. The World Commission on Dams (WCD) reported that 40-80 million people are affected by dam development, excluding those losing lands and facing eviction. Displacement also results in a loss of income sources, creating difficulties in establishing new work due to the need for new investments, approaches, and adjustments. Affected individuals face temporary loss of shelter, and chronic conditions persist, impacting their social lives. Notably, the study found that women experience more depression than men after relocation.

Contrastingly, the study by Huang, Lin, Li, & Ning (2018) focuses on the social impacts of dam-induced resettlement and displacement both before and after construction. While residents receive social benefits such as medical insurance during displacement, the project harms the community economically. Changes in farm-based work and unemployment rates significantly impact the employment structure, with wooded areas and residents' forests submerged in the reservoir. The dam project fails to provide financial or job prospects, prompting residents to seek alternative employment. However, a lack of professional qualifications and skills leads to increased unemployment rates.

Ndirangu's study (2014) investigated the impact of dam construction projects on household livelihoods. Land acquisition emerged as a major impact, causing residents near the dam to lose livestock and agricultural land. Social disruption caused by dam construction significantly influences household income, while religion and culture remain unaffected.

On a broader scale, Kumar's study (2019) explored the social, economic, and environmental impacts of renewable energy resources. The research revealed that renewable energy improved health, provided work opportunities, and benefited local economies by utilizing local labor, materials, businesses, shareholders, and services of local banks. Additionally, renewable energy projects facilitated communities by establishing trust funds to invest earnings in the local economy. The environmental aspect, including the reduction of carbon dioxide emissions, raised awareness about climate change in the community. While some impacts on specific areas, tourism, energy supply costs, and education were minimal, significant impacts were observed in improving living standards, creating social bonds, and fostering community development. The study acknowledged the complexity and local environmental sensitivity of renewable energy projects.

Economic Sustainability

Nguyen et al.'s study (2017) delved into the repercussions of hydroelectric development and resettlement on the social and natural capital of rural livelihoods. The research revealed that residents experienced recovery from resettlement, witnessing improved income situations after the construction of hydroelectric dams. Most households became less vulnerable to food insecurity due to enhanced income. However, the study identified that the village's improved quality of life was primarily attributed to the new location, providing easier access to education, water, electricity, infrastructure, healthcare, agricultural markets, and labor. Paradoxically, the relocated residents also faced challenges, including a significant loss of income from bamboo plantations and diminished social connections and activities within the village.

In contrast, Diao & Ghorbani's study (2018) focused on the production risk caused by human factors in thermal power plants. The findings suggested that the use of thermal power plants can have a positive impact on production sources and output variability risk through human factors such as environmental awareness and creativity. Workers' creativity can contribute to technical or procedural improvements in production, while their commitment to environmental conservation aids in resource and energy conservation during production procedures.

The International Atomic Energy Agency (2015) emphasized the imperative for more sustainable approaches to produce and use energy, aligning with the post-2015 United Nations development strategy. This strategy aims to achieve human well-being while preserving resources and capital, both human-made and natural. Addressing urgent challenges in existing energy systems, including extending access to clean energy for the 41% of the global population relying on solid fuels, is crucial. The strategy also seeks to meet the growing global demand for energy services while preventing adverse health effects, climate change, and impacts on land, water, and biodiversity. Ensuring energy security for all nations and regions and adopting long-term perspectives in investments and financing policies are essential. The transformation of the energy system is a key focus in the United Nations' Sustainable Development Goal (SDG) on energy. The study emphasizes that a diversified mix of energy sources is necessary to tackle global energy challenges. The role and compatibility of nuclear power with sustainable development objectives must be evaluated in comparison

with existing alternatives on a level playing field, with the ultimate choice of the energy mix being a sovereign decision based on each country's situation and needs.

Environmental Sustainability

The Wisconsin Public Service Commission noted that the construction and operation of a power plant can have both temporary and permanent environmental impacts. The plant and its auxiliary components, such as pipelines, water intakes, and disposal sites, occupy physical space and utilize resources like water. The plant's activities may result in the emission of pollutants into the air. The construction footprint eliminates land-use opportunities and may affect adjacent and nearby land parcels. The height of structures in coal-fired plants can raise safety concerns for aircraft and visual impacts for local landowners. The study highlighted the potential impacts on land use, soils, and wildlife, particularly in "greenfield" areas.

Operating power plants burning coal, oil, or natural gas emit air pollutants, necessitating pollution control equipment. Many pollutants are regulated by environmental agencies. Power plants often draw water from various sources, affecting local stream flow and groundwater aquifers. Decreased stream flow can harm stream morphology, habitats, and aquatic life. The study emphasized the need for the Department of Natural Resources to regulate water use in power plants, particularly those using groundwater.

The construction of power plants can displace wildlife, leading to the loss of habitats for certain species and the attraction of others. It may also result in the creation of new habitats for "edge species" and "generalists," impacting the survival of species specific to the original habitat. The study also raised concerns about the potential harm to birds, fish, mussels, and other aquatic life during the construction and operation of power plants. It emphasized the importance of addressing environmental impacts in power plant discussions and cited Hansel and Metillo (2016) as a source detailing management efforts for Lake Lanao and its watershed.

The historical efforts to improve the Agus 1 Hydroelectric power plant have led to changes in its physical features. However, the study noted that these improvements have been hindered by budget constraints and political circumstances, leading to incomplete or unimplemented management plans. Various projects and initiatives aimed at preserving Lake Lanao have faced challenges. A bill for the Lake Lanao Development Authority is awaiting congressional action. The study stressed the importance of participatory management to address critical environmental issues and concerns.

Guiamel & Lee (2020) focused on potential hydropower sites in the Mindanao River basin, assessing the hydropower capacity based on watershed modeling. They identified 114 small-scale, 16 mini-scale, and 24 medium-scale hydropower sites with an estimated total monthly power capacity of 5,551.35 Megawatt. The study proposed hydropower development as an alternative for sustainable energy resources in Mindanao, addressing energy capabilities and flood mitigation.

Humagain & Shrestha (2020) studied the effects of generation dispatch orders on the Integrated Nepal Power System, emphasizing the impact on system parameters. The existing hydropower plants in Nepal were found to affect the social sustainability of local communities, leading to forced eviction and income challenges. The study recommended government focus on providing new income sources to address sustainability.

Naga (2020) explored the impact of a dam in Lake Lanao, highlighting the immediate effects on the shoreline and flooding after the construction of a hydropower plant. The researcher suggested the government in Nepal should focus on providing new income sources for locals to make the impact of hydropower plants sustainable.

The Department of Environmental and Natural Resources (2014) identified challenges in water quality and allocation in the Agus River basin. Water competition among different sectors was observed, and the need for a sustained supply of clean water became a concern due to the growing population and industrial activities. Development objectives were crafted to address these challenges, including increasing water supply for various uses and improving water access.

Government General Policies Related to the Sustainability of Hydropower Industries

PD 1586 – Environmental Impact Statement System – Environmental Compliance Certificate

Presidential Decree No. 1586, issued in 2015, establishes an Environmental Impact Statement System, incorporating various environmental management-related measures for multiple purposes. The objective of this decree is to achieve and sustain a rational and orderly balance between socio-economic growth and environmental protection.

RA 8749 – Philippine Clean Air Act - Air Pollution, 2017

Republic Act No. 8749, known as the Philippine Clean Air Act of 2017, mandates companies to safeguard and promote people's rights to a balanced and healthful ecology in harmony with nature. The state aims to foster and protect the global environment for sustainable development, acknowledging the primary responsibility of local government units in addressing environmental issues.

Department Administrative Order (DAO) – 2000-81 – IRR of RA 8749

DENR Administrative Order No. 2000-81, the Implementing Rules and Regulations (IRR) of RA 8749, should be interpreted liberally to execute the national policy of balancing development and environmental protection within the

framework of sustainable development. Sustainable development, as defined, entails meeting present needs without compromising future generations' ability to meet their own needs.

RA 9275 – Water Quality Management - Discharge Permit
Republic Act No. 9275, the Philippine Clean Water Act of 2004, focuses on safeguarding the country's water bodies from pollution originating from various land-based sources. It advocates a comprehensive and integrated strategy involving all stakeholders to prevent and minimize pollution.

DAO – 2016-008 Water Quality Guidelines and General Effluent Standards
Environmental Management Bureau's Administrative Order No. 2016-008 serves as a guide for classifying water bodies, assessing trends in water quality, determining stages of deterioration and improvement, and identifying water quality management areas.

RA 6969 - Control Toxic Substances and Hazardous and Nuclear Wastes – Hazardous Waste Management
Republic Act No. 6969 addresses the control of toxic substances and hazardous and nuclear wastes. Chemical Control Orders and Hazardous Wastes Generator ID numbers are integral components of its implementation, regulating the use, manufacturing, import, export, transit, processing, and wholesale of chemicals.

Department Administrative Order (DAO) – 2013-22 Revised Procedures and Standards for the Management of Hazardous Wastes
DENR Administrative Order No. 2013-22 updates hazardous waste classification and enforces stringent rules and standards for waste generators, transporters, and TSD (Treatment, Storage, and Disposal) facilities.

RA 9003 – Solid Waste Management
Republic Act No. 9003 serves as the legislative basis for the systematic, comprehensive, and ecological solid waste management program in the Philippines, ensuring public health and environmental protection.

Corporate Social Responsibility and Environmental Stewardship CSRESP – NBP Res. No. 9717
National Power Corporation Resolution No. 9717 emphasizes the implementation of a proactive social and community development program by NPC. This program aims to provide fair and adequate compensation for the disruption caused by the operations, including power plants, watershed reservations, and right of way.

Conclusion

This review underscored the adverse effects of hydroelectric power plants, particularly in the realms of social, economic, and environmental aspects associated with such endeavours. Notably, ongoing concerns encompass problems related to the water quality of Lake Lanao and the river, as well as the lack of proper waste management systems among local residents. The issues are exacerbated by forced evictions and a decrease in employment opportunities, further hindering contributions to industrial processes. These challenges emphasize the urgent necessity for a thorough assessment of the Agus Phase 1 Hydroelectric Power Plant, considering all three major variables—social, economic, and environmental—in the context of potential policy modifications.

Contributions of Authors

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Conflict of Interests

The author declares no conflicts of interest

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