Climate Resilience for Hydro Power Projects at Project Development Stage

Michael Kalumbu Nsefu[1], Erastus Mishengu Mwanaumo[2] and Stephen Gumboh[3]

[1]Zambia Metrology Agency, Lusaka, Zambia, *PhD Candidate.* Email: kalumbunsefu@gmail.com.

[2]Department of Civil and Environmental Engineering, School of Engineering, University of Zambia, Great East Road, Lusaka, Zambia. Email: erastus.mwanaumo@unza.zm

[3]GumStep Analytical Solutions (PPP and Public Sector Development Consultancy), Lusaka, Zambia Email: stephen.gumboh@gmail.com

Abstract

One predominant sector which has been cited in the Seventh National Development Plan launched in 2017 by the Zambian government, is the energy sector. This is also in line with the Sustainable Development Goal No.7 regarding infrastructure expansion and the provision of clean energy. Hydropower projects despite being a renewable energy source, it is site-specific which require huge investment and have long gestation periods. These characteristics expose hydropower projects to various uncertainties and risks such as economic, environmental, social, geological, regulatory, political, technological, financial, natural, and safety. The environmental risk is so predominant in this energy sector if not appropriately managed, there is the potential of project failures. One of the risk factors of the environment is climate change. Sustainability has also become a critical and unavoidable issue in hydropower development due to climate change risks. Sustainable development is related to techno-economic development along with preserving the environment. To mitigate this climate change risk, there is a need for a comprehensive and well-designed Risk Management Framework/Model (RMF/RMM) to effectively manage the climate change risks and many others at the project development stage. This is a critical stage as when risk mitigation measures are well managed during feasibility, planning, and procurement, it enables minimization or elimination of these risks impacts on hydropower projects on other project life cycle. Hydropower projects risk planning with the integration of climate-resilient perspective it enhances the designing of infrastructure that has capabilities to resist climate change.

Keywords: Climate Change, Framework, Hydropower, Impact, Model, Risks

1.0 Introduction

Hydropower is the only renewable energy technology which is presently commercially viable on a large scale(Sameer sadoon al-juboori, 2003; The Economist Intelligence Unit, 2016). The advantages for hydropower are that it is renewable, produces negligible amounts of greenhouse gases, least costly way of storing large amounts of electricity, and it can easily adjust the amount of electricity produced to the amount demanded by consumers. It makes great significant contribution to achieving the targets of the Paris

Climate Agreement and the Sustainable Development Goals. The availability of quality renewable energy infrastructure which is accessible and efficient contributes greatly to the social-economic growth of any nation(Shediac, Hammami, Abouchakra, & Najjar, 2008; O. Kodongo & Ojah, 2016). As of the year 2010, Hydropower was cited as the most widely used form of renewable energy commanding about 16 per cent of the world's electricity consumption due to its low cost, environment-friendly, and dependence on well-proven technology (Jamal Aslam & Syed M. Saad, 2014; Singh & Nachtnebel, 2015).

2.0 Background of the Study

Hydropower projects despite facing a lot of disapproval from environmental activists and local communities(Jamal Aslam & Syed M. Saad, 2014), also projects are characterized by hydrology risks. This is among the highest risk for HPP development as it determines plant power generation and revenues. Thus, reliable data must be obtained during the feasibility stage for subsequent incorporation during the design and planning stage. There is a high emphasis on planning hydropower systems from a long-term and climate-resilient perspective so that energy infrastructure is not compromised by climate change. Sameer sadoon al-juboori (2003) explains that hydropower has an impact on climate change and also it is impacted by climate change risk.

Thus, there is a need to devise a strategic technique in achieving hydropower project purposes within the principles of time, cost, quality, safety, and environmental sustainability. This is the reason international financing institutions and governmental agencies are engaged in resilient investment for adaptation to climate change on the various energy projects. And this is complemented with the integration of risk management models/ in the hydropower project appraisal, design, construction and operation. Risk management in construction projects is a prime process (Braeckman, 2008; Mccann & Busadm, 2014; Devan, n.d.)and the process only realizes value for money and sustainability once implemented systematically (Nelms, 2012). This paper explores climate resilience for hydropower projects at the project development stage

3.0 Statement of the Problem

Hydropower projects are highly sensitive to climate change impacts(Berga, 2016). Water which is the main input into the power generation may be affected not only by changes in the hydrologic cycle but also by climate-related changes in the upstream water use. These may include increased use of water for human consumption, agriculture, industry, or biodiversity maintenance (IUCN et al., 2004). Increase in temperature may trigger the change in the electricity demand. These factors can affect the HPP performance, thus the need for assessing a broader range of climate-related economic, social and environmental factors in the analyses. Also, the increase of the extreme climate events and enlarged erosion additionally pressures the hydropower generation.

Despite HPP being renewable energy, Studies have demonstrated that HPP power potential tends to the gradual reduction in its potential due to climate change and increasing water demand (Yamba et al., 2011). Therefore, this paper strives to mitigate the climate change risk on HPP, by developing a risk management framework with the integration of Climate Change Resilience Measures (CCRM) necessary in the identification of the project needs, analysis of identified risks then incorporates the technical inputs for the successful implementation of HPP.

3.0 Research Methodology

The research methodology used in the study was a qualitative approach. The research design involved an extensive literature survey on various materials on Climate Change, Risk Management and hydropower projects.

4.0 Discussion

4.1 Hydro Power Project (HPP) Impact on Climate Change

United Nations (2019), state that to avoid substantial changes to current human and natural systems, global Carbon dioxide emissions should reduce. As much as efforts are being made to reduce the greenhouse gas intensity of production, this is not happening fast to attain environmentally sustainable production. And this is accelerating climate change. United Nations recommends policies on many projects, innovative technology and significant behavioural changes. However, HPP offers significant potential for carbon emissions reductions(International Finance Corporation (IFC) of the World Bank, 2011) and it mitigates global warming. It generates more than 4,000 terawatt-hours of electricity globally every year, which caters for over 1 billion people with clean energy. It also has one of the best conversion efficiencies of all known energy sources (about 90% efficiency, water to wire).HPP displays high reliability, flexibility, and variety in project scales and sizes, which gives it the ability to meet large centralized urban and industrial needs as well as decentralized rural needs(Berga, 2016).

Kumar & Freitas (2012), explains that hydropower projects are presumed to steadily grow even in the absence of greenhouse gas (GHG) mitigation policies due to demand. It provides energy and water management services including boosting food security with a reliable source of water for irrigation. However, there is a need to manage environmental and social impacts. Berga(2016), illustrates that HPP possesses an empowering role beyond the power generation as it aids as a financing instrument for multipurpose reservoirs. It further acts as an adaptive measure regarding the impacts of climate change on water resources. This works so because regulated basins with large reservoir capacities are more resilient to water resource changes, less vulnerable, and act as a storage buffer against climate change.

4.2 Impacts from Climate Change on Hydro Power Projects –HPP

Despite hydropower having some beneficial impact on the climate change, however, there is high probability of climate change altering river discharge, resulting in impacts on water availability, water regularity, and hydropower generation(Berga, 2016; Neupane, 2018). Climate change affects the hydrologic cycle which disturbs the water flows also other climate-related changes in the upstream water use, such as increased use of water for human consumption, agriculture, industry, or biodiversity maintenance. The potential for precipitation patterns susceptible to change should be considered in project planning. Hamududu & Killingtveit(2012), illustrates that the change of precipitation and temperature are the most driving factors. Increase of the extreme climate events and enlarged erosion furthermore pressures the hydropower production. Jing-Li Fan et al. (2020) confirms that hydropower is sensitive and vulnerable to climate fluctuation, leading to many uncertainties for its development in the future. Lumbroso et al. (2014), revealed that Ethiopia, Malawi, Zimbabwe, Zambia which is largely based on hydropower of late have encountered a reduction in power generation due to climate change.

4.3 Climate Resilience on HPP

The African continent is one of the most susceptible regions to climate change (WMO, 2020). High temperatures above the global average are likely to be experienced by most of the African countries including variations in precipitation patterns. Southern African countries have already experienced a notable level of warmth (more than 1°C above the average temperature of 1981-2010) and abnormally low precipitation in 2019 (WMO, 2020).

IHA (2017), elucidates climate resilience on HPP as the capacity of *"a project or system to absorb the stresses imposed by climate change and in the process to evolve into greater robustness. Projects planned with resilience as a goal are designed, built and operated to better handle not only the range of potential climate change and climate-induced natural disasters but also with contingencies that promote constructive, minimally-destructive failure and efficient, rapid adaptation to a less vulnerable future state".*

There is technical guidance that has been developed by The International Hydropower Association (IHA) in helping the hydropower industry becoming more resilient to the impacts of climate change. These guidelines offer support to financing agencies, clients and project developers to make informed decisions about how to plan, build, upgrade and operate hydropower systems in the face of increasingly variable climatic and hydrological conditions.

The guidelines are summarized in the following five phases (IHA, 2017):

a.) Project climate risks screening - *To understand the vulnerability of a hydropower project to climate change, considering its geographic, regulatory, technical and socioenvironmental characteristics;*
b.) Initial analysis - *Based on the analysis of climatic data and the definition of the baseline scenario, determine the proper approach for Phase 3. Climate stress test;*
c.) Climate stress test - *To assess project performance under different possible future climate scenarios to support decision making on resilient design and operation, and to quantify climate risks;*
d.) Climate risk management - *To adapt the project design – and/or make the project design adaptive – to ensure it is resilient to climate changes while remaining cost-effective and economically sensible and sound;*
e.) Monitoring, evaluation and reporting- To track how resilient the project is in operation and to allow the climate resilience management plan to be monitored, reported on, evaluated and updated.

Resilient hydropower can play a key role in the achievement of Sustainable Development Goals(Byiers et al., 2016), clean energy transitions and climate change adaptation.

4.4 Barriers to implementing climate resilience measures in African HPP

Some few barriers affect the implementation of climate resilience that include the following:

a) **Reliable and Accessible Information on Climate Change:** Several countries have insufficient climate and hydrology data. Despite, some countries having meteorological and hydrological data, there is limited access by the project investors, sponsors and consultants. This enables poor modelling as it is based on misleading data. EEA(2019) advises that it is difficult to choose the most effective set of resilience measures without accurate data and information about potential climate impacts on hydropower plants;
b) **Inadequate Incentives for Decision-Makers:** The benefits of investment in climate resilience measures on hydropower plants are likely to be seen only after several years or even decades, while the capital cost of implementing the measures is incurred immediately (OECD, 2018). Furthermore, the benefits of resilience tend to be spread across the value chain, while the immediate cost is likely to be imposed on service providers. These can make decision-makers hesitant to initiate or implement resilience measures on hydropower plants, despite their longer-term benefits;
c) **Unfavorable Legal and Regulatory Frameworks:** There is a need for the favourable legal and regulatory framework to mitigate misleading signal to developers and service providers, leading them to overlook climate resilience in the design, operation and maintenance process;
d) **Lack of Capacity Forestalls and Cope with climate impacts:** Ogallo and Oludhe (2009) illustrate that climate prediction and early warning systems are often constrained in Africa due to the lack of capacity. There is a need for an in-depth comprehension of the devastating impacts of climate variability and extreme weather events. This can be useful for timely decision-making for the adoption and implementation of resilience measures.

5.0 Conclusion

There is no construction project which is risk-free and the identified risks cannot be eliminated but can be prevented from occurring or effectively allocated should they occur. Hydropower projects are complex, long term and highly technical, not all projects have been successful even in situations which have well established legal frameworks and steady economies(Chou and Pramudawardhani 2015; Zhang,2005; World Bank, 2014; Kabanda, 2014; Muzenda, 2009; Tah and Carr, 2000; World Bank,2018; Thomas et al., 2006 and Voelker et al., 2008; Beckers et al., 2013; Hlaing et al., 2008; Alsulaiman, 2015). The study has revealed that climate change risks can affect the HPP through projected droughts. The dry periods reduces run-off including reservoir storage volume resulting in reduced power generating capacity. Also, projected wet years may cause floods that can pose as a threat to damage to HPP infrastructure. This is the reason this author recommends for the development of a well-designed Risk Management Model (RMM) with the integration of Climate Change Resilience Measures (CCRM) necessary in the identification of the project needs, analysis of identified risks then incorporates the technical inputs for the successful implementation of HPP(Travis & Bates, 2014). Berger (2006), confirms that several risks can be minimized or eliminated if adequate identification is conducted thoroughly during feasibility studies and planning stage.

References

A Case Study of Bujagali Hydropower Public-Private Partnership Project Between Uganda Government and Bujagali Energy Ltd in Electricity Generation in Africa. (2014). *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, *8*(1), 1–13.

Berga, L. (2016). The Role of Hydropower in Climate Change Mitigation and Adaptation: A Review. *Engineering*, *2*(3), 313–318. https://doi.org/10.1016/J.ENG.2016.03.004

Braeckman, J. P. (2008). *Finance*. *July 2016*.

Byiers, B., Große-Puppendahl, S., Huyse, H., Rosengren, A., & Vaes, S. (2016). *European Centre for Development Policy Management Principles for public-private partnerships – towards sustainability? Lessons from SAGCOT, healthcare in Lesotho, and Better Factories Cambodia*. www.ecdpm.org/dp194

Chou, J. S., & Pramudawardhani, D. (2015). Cross-country comparisons of key drivers, critical success factors and risk allocation for public-private partnership projects. *International Journal of Project Management*, *33*(5), 1136–1150. https://doi.org/10.1016/j.ijproman.2014.12.003

Dambudzo Muzenda. (2009). Increasing Private Investment in African Energy Infrastructure. *Nepad_Oecd Africa Investment Initiative*, 19. http://www.oecd.org/investment/investmentfordevelopment/43966848.pdf

Devan, D. V. G. (n.d.). *Public-private partnerships - risk management in engineering infrastructure projects*.

Hamududu, B., & Killingtveit, A. (2012). Assessing climate change impacts on global hydropower. *Energies*, *5*(2), 305–322. https://doi.org/10.3390/en5020305

IHA. (2017). Hydropower Sector Climate Resilience Guide. *Encyclopedia of GIS*, 216–216.

International Finance Corporation (IFC) of the World Bank. (2011). *Climate Risk and Business: Hydropower*.

IUCN et al. (2004). *Sustainable livelihoods and climate change adaptation. A Review of Phase One Activities for the Project on, "Climate Change, Vulnerable Communities and Adaptation."* 28.

Jamal Aslam & Syed M. Saad. (2014). Hydropower: Best Option for India. *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)*, *4*(6), 1–8. http://www.tjprc.org/view-archives.php?year=2014_48_2&id=67&jtype=2&page=4

Kodongo, O., & Ojah, K. (2016). Does infrastructure explain economic growth in Sub-Saharan Africa? *Review of Development Finance*, *6*(2), 105–125. https://doi.org/10.1016/j.rdf.2016.12.001

Kumar, A., & Freitas, M. (2012). *Hydropower*. *December 2014*.

Lumbroso, D., Hurford, A., Winpenny, J., & Wade, S. (2014). Harnessing hydropower: A literature review. *Evidence on Demand: Climate, Environment, Infrastructure and*

Livelihoods, Commissioned by DFID (HR Wallingford), August, 1–76. https://doi.org/10.12774/eod

Mccann, S., & Busadm, B. (. (2014). *A Public Sector Governance Model for Public-Private Partnership: Integrating Partnership, Risk and Performance Management in the Operating Phase*.

Nelms, C. (2012). *A Risk Identification Framework and Tool for Large Infrastructure Public Private Partnership Delivery*. *December*, 430.

Neupane, A. (2018). Contractual Issues for Hydropower Construction in Nepal. *Hydro Nepal: Journal of Water, Energy and Environment*, *23*(23), 56–57. https://doi.org/10.3126/hn.v23i0.20826

Sameer sadoon al-juboori. (2003). Hydro-electric power. *Journal of the Franklin Institute*, *192*(4), 551–552. https://doi.org/10.1016/s0016-0032(21)91525-4

Shediac, R., Hammami, M., Abouchakra, R., & Najjar, M. R. (2008). *Public - – Private Partnerships A New Catalyst for Economic Growth*. 1–20.

Singh, R. P., & Nachtnebel, H. P. (2015). Prioritizing Hydropower Development Using Analytical Hierarchy Process (Ahp) – a Case Study of Nepal. *International Journal of the Analytic Hierarchy Process*, *7*(2). https://doi.org/10.13033/ijahp.v7i2.253

The Economist Intelligence Unit. (2016). *Power Up: Delivering Renewable Energy in Africa*. 33.

Travis, W. R., & Bates, B. (2014). What is climate risk management? *Climate Risk Management*, *1*, 1–4. https://doi.org/10.1016/j.crm.2014.02.003

United Nations. (2019). *2019 World Economic Situation and Prospects Report*. https://www.un.org/development/desa/dpad/

World Bank. (2014). *Overcoming constraints to the financing of infrastructure*. *February*.

Yamba, F. D., Walimwipi, H., Jain, S., Zhou, P., Cuamba, B., & Mzezewa, C. (2011). Climate change/variability implications on hydroelectricity generation in the Zambezi River Basin. *Mitigation and Adaptation Strategies for Global Change*, *16*(6), 617–628. https://doi.org/10.1007/s11027-011-9283-0