The Role of Hydropower in Mitigation and Adaptation of Climate Change: A Developing Country's Perspective

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Introduction

As climate change impact and risk predominate, the need for clean, affordable, renewable and sustainable energy sources is inevitable. Hydropower is one of the reliable and efficient technologies in power generation. In addition, hydropower can also play a vital role in delivering the mitigation and adaptation measures to climate change. Based on Malaysia Third National Communication and Second Biennial Update Report to UNFCCC, hydropower generation and its reservoir has been identified as one of the mitigation and adaptation plans for climate change to reduce Malaysia's greenhouse gasses (GHG) emission projection through renewable energy generation, and to ensure water security and measure for flood risk management due to its ability to build up water reserve and control its downstream water flow. The water inflow to the water reserve originates from nearby water catchment areas. The protection of water catchment areas is essential to ensure water quality and adequate water supply to the water reservoir.

The state of Sarawak is the largest renewable energy generator in Malaysia and its annual energy generated in 2018 from hydropower is 20,888 GWh which accounts for 78% of the state's energy generation. Per annum, 51,794 million m^3 of water flow into the reservoir and 92% of this total inflow water is regulated by Sarawak Energy, the largest hydropower developer and operator, for energy generation. This volume of water is predicted to increase further as the large hydro installed capacity in Malaysia is anticipated to increase from 4,773 MW to 8,129 MW by 2030 (planned scenario). To ensure that there will be sufficient water resource for the growing energy demand, a healthy catchment area needs to be established. In doing so, a holistic approach through integrated catchment management plan must be taken to achieve a resilient hydropower resource to mitigate and adapt to climate change.

This paper discusses the role of hydropower in mitigation and adaptation of climate change which is dependent on how the hydropower catchment areas are managed.

1. Background

Climate change is a global phenomenon which effects will vary by region depending on scenarios of future anthropogenic and natural forcing with CO_2 being the main GHG involved. Even though anthropogenic emissions of CO_2 associated with the use of fossil fuels are mainly from the rich post-industrial countries, the impacts are more severe in poor developing countries. This is because of many developing countries are lacking with economic and technological capacity to address climate change impact (Mertz, Halsnæs, & Olesen, 2009).

One example of such developing country is Malaysia. Malaysia is a Southeast Asian country that is rapidly growing with 4.72% annual GDP growth (The World Bank, 2018) where agriculture comprised of 6.9% of the GDP (Department of Statistics Malaysia, 2019). Malaysia has a tropical climate and its weather variability is dictated by Southwest and Northeast Monsoons. Drier weather with less rainfall is experienced during Southwest Monsoon which typically occur in the months of April to September. Whereas, more precipitation is experienced during the Northeast Monsoon which typically occur in the months of October to March.

Climate change has affected the country's rainfall distribution, sea water level as well as average annual temperature where the average annual rainfall for Malaysia is projected to increase as high as 6%, sea level is projected to rise as high as 0.15m, and the average annual temperature is projected to increase by 1^0C at maximum from year 2000 (Ministry of Energy, Science, Technology, Environment and Climate Change, 2018). Increasing occurrence of extreme events have been observed in Malaysia for the past decades with the most recent major flood happening across few peninsular states in January 2018. The annual northeast monsoon brought unusual heavy rain which had caused floods that displaced 12,000 people with 2 fatalities (Tang, 2019).

Malaysia has identified agriculture, forestry, biodiversity, water resources, coastal and marine resources, public health and energy as sectors that will be significantly affected by the impacts of climate change (Tang, 2019). Malaysia has identified energy sector as one of the major contributors to climate change. Aligned to the outcome of Paris Agreement which highlights the importance of renewable energy development, Malaysia has come up with the National Renewable Energy Policy which aims to reduce dependency on non-renewable fuel by targeting to achieve 20% renewable energy capacity mix by 2025 (Malaysia Sustainable Energy Development Authority, 2019).

Approximately 13.7% of Malaysia's energy generation mix is from renewable energy which is predominantly contributed by hydropower (13.3%) (Figure 1). The total hydropower installed capacity in Malaysia is 6,094 MW and 3,452 MW (57%) of the installed capacity is from the state of Sarawak (International Hydropower Association, 2018). Under planned scenario, large hydro installed capacity in Malaysia is anticipated to increase from 4,773 MW to 8,129 MW by 2030 (Ministry of Energy, Science, Technology, Environment and Climate Change, 2018). By 2026, the hydropower installed capacity in Sarawak is projected to increase to 7,100 MW. Malaysia has included hydropower and its reservoir as one of the mitigation and adaptation plans for climate change (Ministry of Energy, Science, Technology, Environment and Climate Change, 2018).

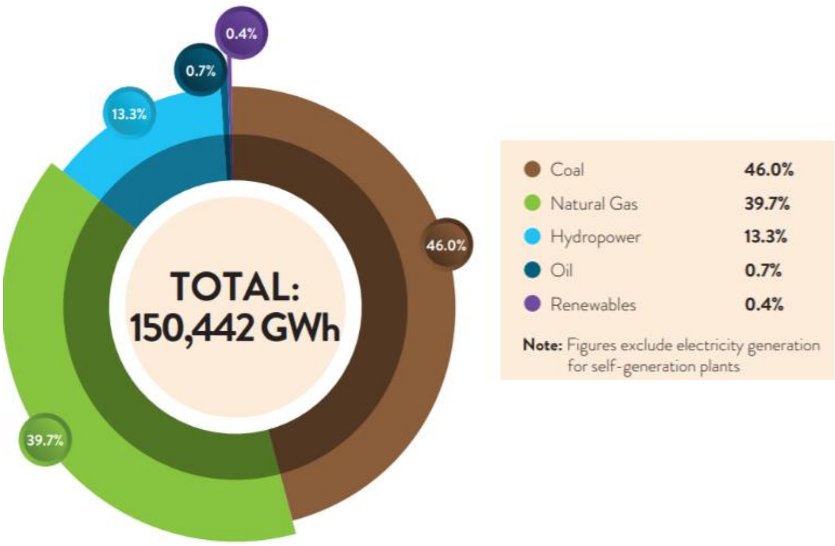

Figure 1. Malaysia's generation mix by fuel types, 2016 (Energy Commission of Malaysia, 2018).

2. Resilient Hydropower Resource: Healthy Water Catchment

Sarawak, the largest state of Malaysia by land area, is the richest in terms of natural resources including hydrocarbon and timber. With a total GDP of RM108.78 billion, Sarawak has among the highest GDP per capita among the Malaysian states with manufacturing, mining, quarrying and agriculture being the main contributors to the its total GDP (The Edge Malaysia, 2018).

Sarawak Energy, fully owned by the state of Sarawak is the largest hydropower developer and operator in Malaysia and its electricity sales alone accounts for 4% of the state's GDP. With hydropower predominating its generation mix (78%), Sarawak Energy is powering one of the five national's economic corridors, the Sarawak Corridor of Renewable Energy (SCORE), which has attracted RM 79.3 billion worth of investments and created more than 61,000 jobs (The Star, 2018).

In 2018, Sarawak Energy generated 20,888 GWh energy by regulating 47,817 million m^3 of water that is drawn from a 21,584 km^2-sized water catchment area for its hydropower energy generation. The viability and long-term sustainability of hydropower operation is heavily dependent on land use within the catchment areas. One of the important challenges that may be faced by hydropower operation is to cope with reservoir sedimentation which is mainly contributed by uncontrolled activities within the catchment areas. Not only sedimentation reduces the total storage capacity of reservoir, it also impacts the turbine and other mechanical equipment through abrasion.

To manage these risks, a proper catchment management policy, framework, procedures and guidelines need to be in place. Currently, Sarawak is in the process of developing the policy, procedures and guidelines on integrated watershed management for Sarawak. In line with its long-term key strategies to secure upstream resource supply, Sarawak Energy continuously plays a proactive role in advocating good practices in managing catchment and is in a strategic position to provide assistance to the state government in the development of the integrated watershed management plan from hydropower perspective (Figure 2).

Sarawak Energy's Objectives on Integrated Watershed Management:

- Advocate good practices in managing catchment by providing assistance to the state government in the development of the integrated watershed management plan from hydropower perspective.
- To support the establishment and implementation of the catchment management policy.
- Identify, develop and implement focus areas for catchment management initiatives through partnerships.
- Creating awareness on the importance of catchment management.

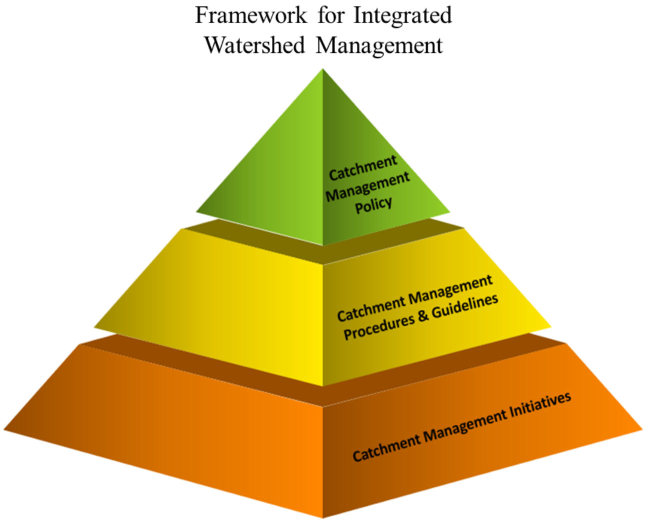

Figure 2. Sarawak Energy's strategic position on integrated watershed management.

This integrated watershed management plan will benefit hydropower by ensuring healthy catchment that contributes to good water quality and adequate water supply to the water reservoir for the growing energy demand while subsequently continue to deliver environmental social services for downstream needs which results in a resilient hydropower resource. This in turn increases the coping capacity of hydropower to mitigate and adapt to climate change.

In line to the integrated catchment management plan and to ensure resilient hydropower resource, Sarawak Energy has embarked on a few ongoing strategic initiatives in collaboration with relevant government agencies and NGOs, such as the Heart of Borneo (HoB) declaration, Forest Landscape Restoration (FLR) programme and the Wildlife Connectivity project in Baleh Watershed to support the implementation of the catchment management policy, procedures and guidelines. The benefits of these initiatives are manifold including conservation of biodiversity, expand forest connectivity and ensure sustainable land use practices (Figure 3).

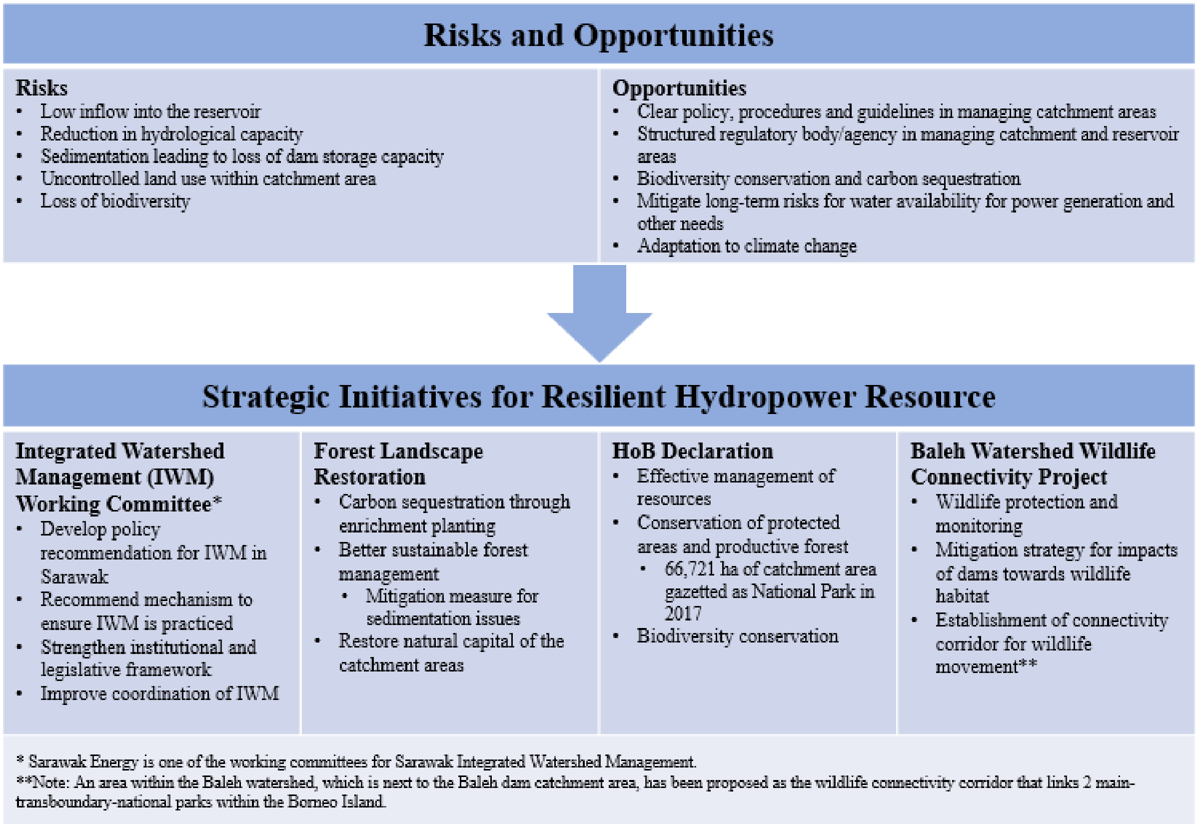

Figure 3. Integrated catchment management initiatives for a resilient hydropower resource.

2.1 Climate Change Mitigation

Climate change mitigation refers to human intervention to reduce or limit the extent of climate change by abating or ameliorating the direct or indirect anthropogenic factors of climate change, for instance enhancing the sinks of GHG (United Nations Environment Programme, 2019; Martínez, Alfonso Piña, & Fletscher Moreno, 2018; International Hydropower Association, 2018).

Hydropower is the most mature, reliable and cost-effective renewable power generation technology available (Brown, Müller, & Dobrotková, 2011) and its viability is heavily dependent on the health of its catchment area. Under optimal condition, hydropower has about 90% water-to-wire efficiency (U.S. Department of the Interior Bureau of Reclamation Power Resources Office, 2005). Conservation of the land within the catchment areas minimises the risk of sedimentation; thus, optimising the hydropower performance (Figure 7).

In addition, land conservation within the catchment area also enhances the carbon sink because plants and soils are natural carbon sequesters (Figure 7). Carbon sequestration is estimated to be 350 tonnes of carbon per hectare in relatively undisturbed mature tropical forest (Flint & Richards, 1994). A study shows that the Baleh watershed in Sarawak, that covers an area of 1.24 million hectares, provides a total of USD 180 million of annual value of ecosystem services (provisioning services, regulating services and cultural services) of which USD 86.95 million is contributed by the value of carbon sequestered by the forest (WWF-Malaysia, 2018).Through Sarawak Energy’s partnership with Forest Department of Sarawak in the FLR programme, which is one of the long term initiatives under the strategic integrated catchment management, 5,614 ha of degraded forest within one of the hydropower catchments is set to undergo a restoration process and will result in 1.9 million tonnes of carbon being sequestered annually upon completion.

As the state of Sarawak is transitioning to a sustainable economic growth, it relies more on renewable energy, namely hydropower. Hydropower is second only to wind among renewables in terms of having the lowest carbon emission intensity at 24 gCO_2eq/kWh (Figure 4). With 78% of its energy generation mix from hydropower, Sarawak's main grid hits the lowest emission intensity at 0.193 tCO2eq/MWh for the year 2018 (Figure 5). From 2016 to 2018, Sarawak exported over 3,286 GWh to Kalimantan, it's transboundary neighbour, which has resulted in the displacement of 1.87 million tCO_2eq, comparable to a sequestration capacity of 5,342 ha tropical forest.

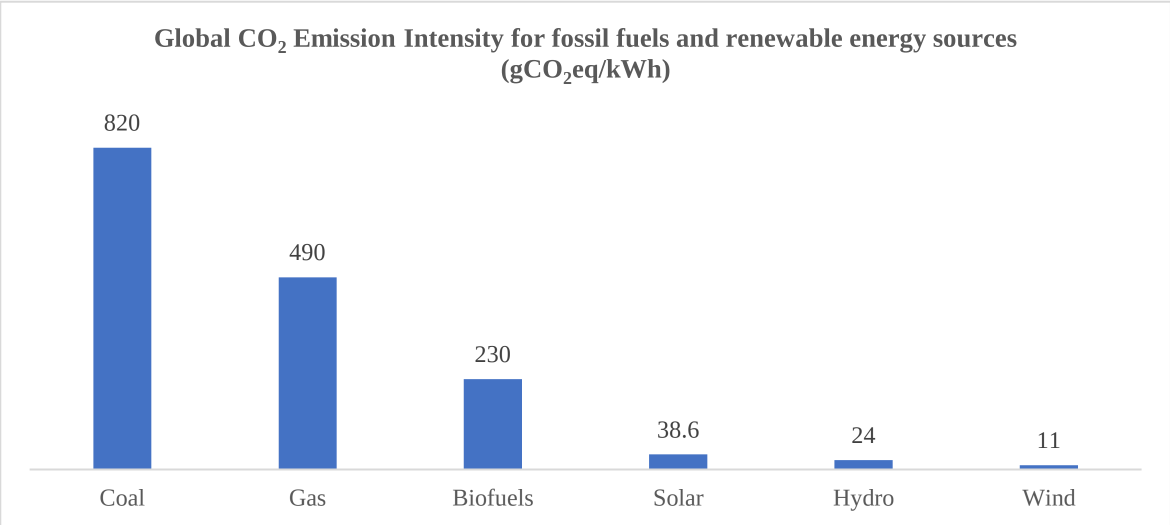

Figure 4. Global carbon dioxide emission intensity for fossil fuels and renewable energy sources (Kiesecker & Naugle, 2017).

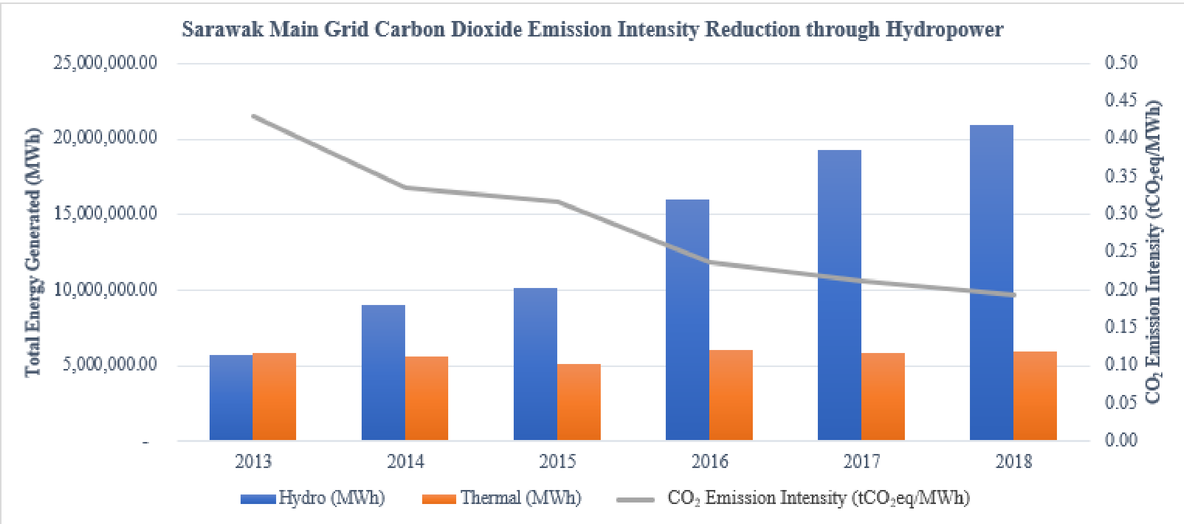

Figure 5. Sarawak's main grid carbon dioxide emission intensity reduction through hydropower.

2.2 Climate Change Adaptation

On the other hand, climate change adaptation is defined as an effort that seeks to lower the risks posed by the consequences of climatic change or tapping into the beneficial opportunities associated with climate change via prediction of its trends and impacts (Grantham Research Institute & Clark, 2012; Martínez, Alfonso Piña, & Fletscher Moreno, 2018; International Hydropower Association, 2018). Due to its ability to build up water reserve and control its downstream waterflow, hydropower and its reservoir also serves as adaptation plans for climate change by ensuring water security and enhancing flood risk management (Figure 7).

By 2030, Malaysia is projected to have 2.5% increment of average annual rainfall as compared to year 2000 due to impacts of climate change. However, the same analysis shows that dry spells with 5-10 years return periods (up to 36.3% of rainfall reduction) will occur frequently in the country (Ministry of Energy, Science, Technology, Environment and Climate Change, 2018). This means that even though the average annual rainfall is predicted to increase, it will be accompanied by longer periods of dry weather throughout the year as well.

Therefore, systematic water resource management needs to be in place to ensure that there is enough water stored during the Northeast Monsoon season that could last through the dry spell periods. Annually, Sarawak produces 280 million m^3 of water that is for domestic, commercial and industrial usages. This accounts for only 0.59% of the total water regulated for energy generation (47,817 million m^3) in Sarawak. Thus, much of this water reserve can be utilised not only to provide reliable renewable energy, but also to sustain socio-economic wellbeing of the state.

Water-intensive sector, such as agriculture makes up a substantial portion of Malaysia's economic activities and is identified as the most vulnerable sector impacted by climate change. Malaysian agricultural water withdrawal is equal to 23% of the total water withdrawal (Food and Agriculture Organization of the United Nations, 2016). Through controlled irrigation and by leveraging on the hydropower reservoir storage, it reduces the dependency of crop yield on rainfall patterns.

Aligned with the global best practices set out by International Hydropower Association (IHA), hydropower infrastructure should be planned and delivered with an awareness and measures to address environmental disturbances like flood occurrence. This is demonstrated through the retention capacity of a reservoir being a significant flood-risk reducing factor for downstream areas. In the occurrence of high rainfall within the catchment areas, hydropower dams are built to hold the fast-flowing water and thus mitigating the risk of flood occurrence downstream.

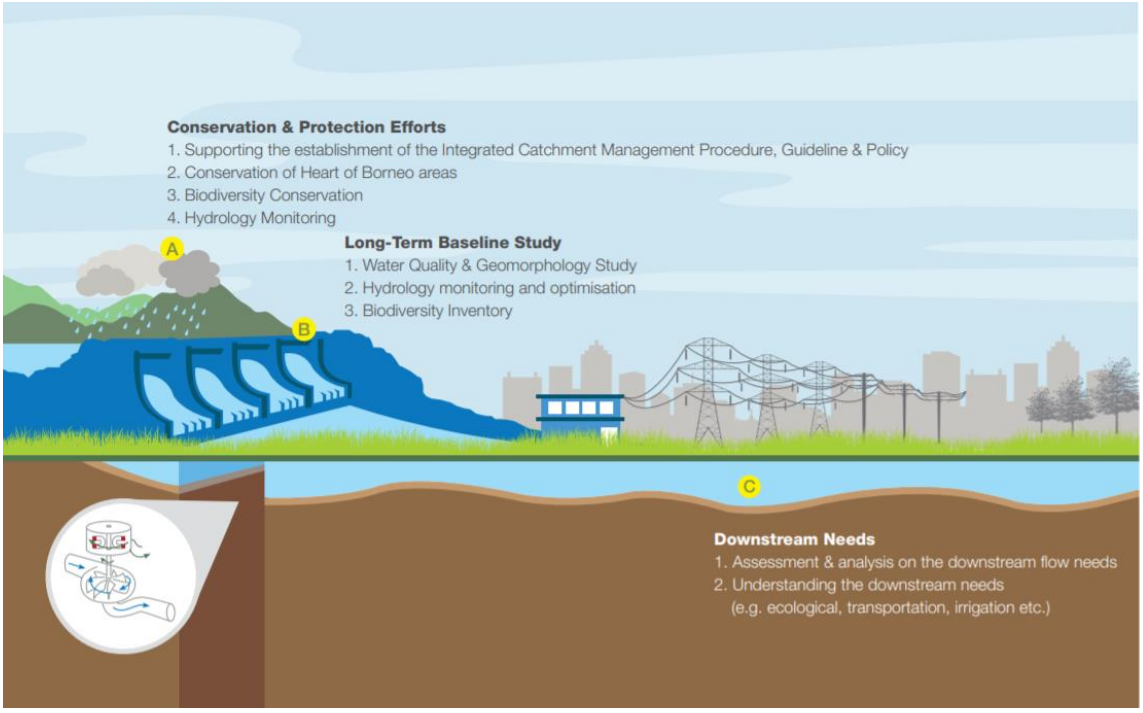

Figure 6. Safeguarding upstream hydropower resources to meet downstream needs through integrated catchment management.

In addition, a hydropower project should be able to contribute to multiple demonstrated needs that include the provision of energy and fresh water services (Figure 6). To help drive the economic growth, Sarawak is set to fill the gaps in its water supply infrastructure through building a water grid that would supply treated water to interior residents across Sarawak. It was estimated that 39% of the rural populace (114,00 households) still did not have access to clean water (The Edge Malaysia, 2018). In view of this, Sarawak has come up with a plan on a water grid project which utilises clean water supply from hydropower reservoirs to local communities scattered in rural area and for agricultural irrigation across the state (The Star, 2018).

Resilient Hydropower Resource	
• Safeguard upstream water catchment • Deliver growing energy demand • Deliver environmental and social services for downstream needs	
Mitigation	**Adaptation**
• 90% water-to-wire efficiency • Renewable energy • Greenhouse gases reduction • Carbon sink	• Retention capacity and downstream flow control • Secured water supply for socio-economic sustenance • Climate change risk management (e.g. flood, downstream needs, etc.)

Figure 7. Roles and functions of a resilient hydropower resource in mitigation and adaptation to climate change.

3. Conclusion

Climate change impacts are more severe in developing countries like Malaysia where it significantly affects sectors like agriculture, forestry and water resources. As energy sector is identified as one of the major contributors to climate change, Malaysia has included hydropower and its reservoir as one of the mitigation and adaptation plans for climate change. This is only possible through a resilient hydropower resource which can be achieved through leveraging on the real risks and opportunities from hydropower development and operation. To mobilize this, interdependent solution and collaboration between various stakeholders must be approached holistically through a catchment management plan.

Resilient hydropower resource is achieved through safeguarding the upstream water catchment; thus, capable to provide good water quality and adequate water supply for the growing energy demand while subsequently continue to deliver environmental services for downstream needs. This, in turn increases the coping capacity of hydropower to mitigate and adapt to climate change.

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