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Energy, Economic and Environmental Impact of Hydropower in Malaysia

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Abstract

Malaysia is rich with natural resources, a true gem with plenty of water and receives high rain volume per year which is used to generate power. Hence, the use of hydropower becomes relevant in this country. Hydropower is a renewable source of energy which produces very little greenhouse gasses. Besides that, it is the least costly way of storing large amounts of electricity. Utilization of electrical energy is an important aspect to the economic growth for a country and improvement in people's living standards, especially in developing countries. The growing demand for electrical energy, the environmental effects of fossil fuel usage as well as fear of losing fossil fuels, are the main topics driving us towards the direction of focusing on hydropower as a source of renewable technology. Therefore, this paper discusses the impact of hydropower in Malaysia for the energy produced, economic aspect and also environmental impact.

Keywords: *Hydropower; Energy; Economic; Environment; Renewable energy*

1. Introduction

Energy is fundamental to how we live daily. It is necessary for countries to utilize it if they were to engage in important activities: industrial, domestic, and agricultural activities. Due to its importance for sustainability, the demand for energy has increased significantly. A 1.6% rise in the annual rate of global primary energy consumption between 2009 and 2030 is expected [1]. However, most the energy resources used are non-renewables, mainly fossil fuel followed by nuclear. Fossil fuel has occupied 78.4% of the total worldwide energy consumption whereas 19% comes from renewables, which are broken down into different renewables used (See Figure 1) [2]. The use of non-renewable resources has been inducing negative impact to the environment such as acid rain, air pollution, global warming, ozone layer depletion, and emission of radioactive substances [3]. Other than that, it contributes to an increase in the rate of diminishing fossil fuel resources and detrimental to public health [4].

To tackle the numerous adversities faced by non-renewables, we should focus on a renewable energy resource which is one of the cleanest source of energy and curbs the following negative impacts above – hydropower. It is the best alternative to non-renewables due to the fact that our community is more aware of the importance of saving our environment thus many countries are shifting their focus towards cleaner sources [5]. Hydropower electricity generation comes from different forms such as waves, tides, ocean currents, natural flow of water in rivers, or marine thermal gradients and be can further classified as large, small, mini, micro and pico (see Table 1) [6].

In Malaysia, The Energy Commission, a government monitoring agency of national renewable energy development had set a goal to increase the electricity output from renewables by 5.5% by 2012, which was a success due to the establishment of Sustainable Energy Development Authority. Additionally, Malaysia was in the top 9 countries for hydropower capacity added which implemented 700 MW in 2015 (See Figure 2)[2]; The reason for great extension of hydropower was due to its sustainable geographical location which has an equatorial climate, high

rainfall, high access to sea, many rivers, and irrigation channels [7].

In order to develop Malaysia's energy industry, we should focus on all factors instead of energy output solely. We must select the best available energy source by evaluating each factor thoroughly. Judging from Malaysia's many water resources, it should avail its resources to its advantage by building hydropower energy generation to fulfil its potential. Therefore, this review paper provides an overview of utilizing the hydropower energy source by focusing on 3 main areas: energy impact, economic impact, and environmental impact.

2. Energy Impact

Malaysia is blessed with a profusion of water resources thanks to 150 river systems situated in West Malaysia and another 50 rivers in East Malaysia. Moreover, having its geographical position on the equator, it receives an estimated average annual rainfall of 2000 mm, which is 1250 mm higher than the world's average annual rainfall, 750 mm [8]. From 1990 to 2013, Malaysia has been growing exponentially which paved way for great development in electricity generation for its fast-growing population in the country. In 2013, electricity generation is produced mostly using gas (46.29%), followed by coal (41.04%), hydropower (10.74%), Diesel (1.05%), Oil (0.03%) and others (0.85%) (See Figure 3) [9]. Hydropower ranks at third place among other electricity generation methods, but the first renewable energy source compared to other renewable energy sources in Malaysia. Due to its geographical location which delivers an estimate 29,000 MW of potential hydropower, it ensures a clear mind to Malaysians that hydropower development is most welcomed here thus possessing a great impact in Malaysia's energy development.

2.1 Hydropower in Peninsular Malaysia and East Malaysia

As for the fulfilment of its high potential in hydropower, the total of installed capacity of hydropower stations is 5434.5 MW in Malaysia (See Table 3) [10]. The installed capacity can be separated into two areas due to separation of lands by the South China Sea: Peninsular Malaysia and East Malaysia. Peninsular Malaysia has a total installed capacity of 1930.5 MW with most of its capacity coming from hydropower stations from North Malaysia (Kelantan and Terengganu). As for East Malaysia, it has 3,504 MW of electricity generated, mainly from Bakun Dam, which is situated in Sarawak. As for the estimated 29,000 MW of hydropower potential, it is mainly from East Malaysia because Peninsular Malaysia has nearly unlocked all of its potential whereas East Malaysia still has so much hydropower potential, yet to be exploited [11]. The total power generated solely by hydropower recently is 15,524 GWh, which is 10.89% of Malaysia electricity generation mix (see Table 2 and Figure 3) [9].

2.2 Future of hydropower in Malaysia

In Peninsular Malaysia, there is a hydropower station named Ulu Jelai, which is still under construction. This Ulu Jelai Hydroelectric Project (HEP), which is located on the Bertam River in the Cameron Highlands, has an installed capacity of 372 MW which can contribute 326 GWh of peak energy annually to Peninsular Malaysia [12]. Another project that is still under construction is the Hulu Terengganu Hydroelectric Project, which is located upstream of Kenyir lake. It has an installed capacity of 265 MW and it can produce 467 GWh per year [13]. As for East Malaysia, the proposed Baleh Hydroelectric Project, which is located on the Baleh River and has a total installed capacity of 1,295 MW, was approved by Sarawak state cabinet on 30th June 2016 and to be expected to produce 8,076 GWh of energy per year [14]. The total additional GWh in the future that is secured for the future is 8869 GWh which shows that the Energy Commission Act in 2001, which promotes renewable sources and conservation of non-renewable sources, has a great impact on Malaysia's electricity generation mix [15].

2.2.1 Connecting the East to the West

With so much installed capacity of renewable electricity, a plan was proposed to transmit 70% of the generated capacity by Bakun Dam to Peninsular Malaysia via 730 km of overhead HVDC transmission lines in East Malaysia, 670 km of

undersea HVDC cable and 300 km of HVDC transmission line in Peninsular Malaysia [16]. There was also a plan envisioning Trans-Borneo Power Grid Interconnection which links the whole of Borneo which will connect three countries (Brunei, Indonesia, and Malaysia), solely the island. With the possible access to this single largest renewable source of energy throughout the whole country, Malaysia will have the option to minimize the use of fossil fuel for electricity generation by focusing on hydropower by conducting feasibility studies on high hydropower potential areas, which has an estimated hydropower potential of 29,000 MW in Malaysia, and build new hydropower stations [14].

2.3 Overall impact of hydropower in Malaysia

Hydropower is vital in Malaysia's energy development. It constitutes more than 10% of Malaysia's total electricity generation, which stands at 29,974 MW, and it will increase in the future due to the later completion of hydropower stations [9]. According to Malaysia Energy Statistics Handbook 2016, natural gas generated the highest amount of energy as of 2015 but it faced a slight decline from recent years (See Table 2). However, coal, second to gas, has increased exponentially since 2001 due to the Fuel Diversification Policy that was introduced to decrease oil consumption [17]. As for hydropower, from 2010, it is obvious that it started growing from a decade of dormancy and has increased year by year. Compared to biomass, biogas and solar, which are categorized under Others in Table 2 and accounts for less than 0.85% of Malaysia's electricity generation mix and fossil fuels (Natural gas, Coal, Oil and Diesel) which accounts for majority of the electricity generation mix, hydropower is getting priority and gaining momentum. Hydropower is an alternative to depleting nonrenewable sources which are expected to play a vital role in electricity generation.

3. Economic Impact

Hydropower is the only renewable energy technology that is commercially available on a large scale. The reason being is hydropower plants have no such byproducts like high content of sulphur because the whole process of electricity generation from water input through the turbines and water output do not change the nature of the water, hence, saving expenses on sustaining a clean environment. Also, the electricity generation efficiency (the ratio between the useful output of an energy conversion machine and the input, in energy terms) of hydropower is the highest, which led to being one of the lowest cost of electricity (total cost of installing and operating a project expressed in $/kWh by the system over its life), bringing great positive impact on the economy due to less expenses on electricity generation [18].

3.1 Current economic contributions of hydropower in East Malaysia

Sarawak is one of the two states that make up East Malaysia, it is separated by the South China Sea from Singapore and West Malaysia, and Sarawak is by far the largest state in the country with more than 120,000 square kilometers. Other than the high rainfall, the availability of suitable hydroelectric power (HEP) dam sites also contributes to the implementation of hydropower as a long-term sustainable energy source for current and upcoming electricity consumption in Sarawak. Currently, there are three functioning hydropower dams in Sarawak, namely Batang Ai Dam, Bakun Dam and Murum Dam [19].

In some cases, the implementation of a hydropower scheme must take into consideration not only the need for energy, but the potential source for both water supply and irrigation. Currently, there is no implementation of a specifically-designed multi-purpose dam, except for existing Batang Ai Dam in Sarawak and Kenyir Dam in Terengganu, the water released from the dam has been abstracted for water supply usage from a raw water intake downstream. In addition to providing regulated baseflow for water supply, irrigation and navigation, these dams can also function to prevent floods mitigations during the monsoon season. This multipurpose dams would hope to reduce the million ringgit of losses during the annual end year monsoon floods [19].

3.2 Plans to use hydropower to boost Malaysia's economy

Sarawak Corridor of Renewable Energy (SCORE) is a major project that plans to build 12 new dams in Sarawak [20]. The SCORE Master Plan has planned to make an investment of RM$334 billion (US$105 billion) by 2030 and is currently managed by the

Regional Corridor Development Authority, RECODA. The development's aim is to grow Sarawak's economy by a factor of five, increase the number of jobs in the state by a factor of 2.5, and double the population of Sarawak by 2030 [21]. The SCORE master plan articulates a five-pronged, sequential strategy of energy development. First, it aims to attract investments from ten key industries to take advantage of surplus hydroelectric capacity.

Oil and Petrochemicals such as refineries, chemical manufacturing, oil tank farms and marine bunkers can earn and boost the country's economy. Likewise, aluminum is also needed in constructing a solid and stable hydropower dam, there are planners targeting for 25 million tons of production capacity for aluminum by 2030 [22]. This plan is oriented towards exports for Asian markets. Palm Oil can help in processing by-products such as compost and fiber for dam construction purposes [23]. Timber, livestock, aquaculture, Marine Engineering as well as steel and glass will benefit greatly from the constructions of the dams. The industries will then attribute to improving the country's economic status.

3.2.1 Inevitable expansion of hydropower

Scores development plan wants to establish a network of transportation and communication nodes between industries, via roads and the establishment of telecommunication infrastructure. Third, planners want to expand those industries as online businesses, offering a relatively cheaper source of electricity. Some of this power can be exported to Peninsular Malaysia via undersea cable, plugged into the Trans-ASEAN grid, or interconnected to Brunei and Kalimantan (located in Indonesia) through an exchange of electricity between regions [24]. It well aims to develop tourism too, especially within the lakes of the dams and along the beaches. The plans to build these dams have encouraged the needs of better roads and infrastructure, the development of new attractions and service providers to promote eco-tourism.

SCORE plan is to build 9379 MW of hydroelectric by the year 2030, which needs approximately RM$44.4 billion of direct investment. Electricity from Bakun dam and Murum dam can feed at least two aluminum smelters, one a US$1 billion, 330,000 ton/year facility owned by the State Grid Corporation of China (GiiG Holdings). Another aluminum smelt would be under Aluminum Corporation of China that will require 600 MW; another a US$2 billion, 550,000 ton/year facility operated by Rio Tinto and Cahaya Mata Sarawak Berhad that will need 1200 MW of power [20].

3.3 Conclusion for Malaysia's future economy

Economic perspective of how hydropower improves the income of the country is mainly focused in the state of Sarawak. Little is known of the economic status of hydropower in West Malaysia as not much research has been done on the hydropower. Peninsular Malaysia's main source of energy is from oil and gas, and no massive projects such as SCORE has been planned to improve or use hydropower a main source of income [25].

4. Environmental impact

The environment provides us with the essentials to live. In the recent years, an increase in population has caused a rise in demand that cannot be supplied. Non-renewable energy such as fossil fuel is the most commonly used source of energy in Malaysia, and energy sources as such will eventually be used up. Hence, hydropower is a great alternative as it does not pollute the water, it makes it usable for other purposes such as to supply drinking water to households, irrigation for agriculture usage, used for recreational activities like swimming and promote eco-tourism. Known to be one of the oldest sources of alternative energy, it is very well established.

There are a total of 21 dams in Malaysia to date, mainly found in Sungai Perak and Sungai Pahang as both rivers are long. Hydropower is found to emit the least carbon into the air, it reduces air pollution from happening and even slows down the greenhouse effect [26]. Hydropower contributes to storing water because it can collect rain water and can protect aquifers from depletion and reduce our vulnerability to floods and droughts [3].

4.1 Advantages of hydropower towards the environment

Hydropower is one of the biggest renewable sources to generate electricity because there is a continuous supply of water from rivers. It does not depend on weather changes unlike tidal, solar and wind energy. Adding on to that, it does not produce any waste, unlike fossil fuels. The production of electricity using fossil fuels is one of the major contributors to GHG emissions; accountable for 41% of total GHG emissions globally [27]. Hydropower can prevent excess GHG emissions and therefore ensure that we have a cleaner environment to live in. It also emits plenty of energy quota, being the third most energy quota in Malaysia, compared to biomass which is unrenewable (See Table 4). The emission of CO2 from hydropower is the lowest compared to other renewable sources of energy such as solar, wind and biomass energy. Hence, it will reduce the rise of the greenhouse effect as well as global warming (See Table 5) [28]. More importantly, the total unit exergy cost (cT), which includes the renewable (cR) and non-renewable (cNR) unit exergy costs, for hydropower is the lowest [29, 30]. Because of that, there are more exergy left (useful work possible) in the energy source for us to utilize even after it was used for generating electricity.

4.2 Disadvantages of hydropower

Every energy source has its flaws. Hydropower dams can destroy habitats of aquatic life as well as inhibit the migration of fish [3]. Bakun dam, consisting of a catchment area of 1.5 million hectares logged and a reservoir area of about 70,000 hectares, will destroy 6 rare and endangered species of fish as well as mammals respectively, 32 protected bird species, and more than 1600 protected plants (including the Silvered Leaf Monkeys, Bornean Gibbons, Langurs, and Flying Squirrels endemic to Borneo). Meanwhile, Murum dam, taking up a reservoir area of 24,500 hectares and with a massive catchment area of 275,000 hectares, will displace 755 people, and threaten 300 rare and engendered species. Other proposed dams could cause the water quality to deteriorate in Mulu National Park, home to one of the world's largest cave and a UNESCO World Heritage Site [13]. This will affect the food chain and breeding grounds of aquatic animals. Other than that, a study from the United Nations Development Program warned that the dams in Sarawak, if fully developed, could damage water quality and water levels, produce industrialization and growth of the population that will contaminate water. Several studies have shown that the operation to maintain the hydro station of the Cameron Highlands scheme are affected by land development, which leads to sedimentation [31]. Sedimentation can lead to unnecessary floods commonly suffered by those living in Cameron Highlands.

4.2.1 Ways to overcome the disadvantages.

Small-scale hydropower can be used instead of large hydropower dams, which required way more space for construction. Humans can still obtain electricity through hydropower while habitats will not be brutally damaged. Despite the fact that it only produces as little as 30MW of power, it does not harm the environment drastically by preventing huge deforestations, leading to less CO_2 in the atmosphere thus mitigating global warming thanks to the photosynthesis by trees and the disruption of the natural processes of all living organisms, by allowing the habitat of animals to continue living and avoid any destruction of breeding grounds [25]. Moreover, small-scale hydropower can be built at rivers near remote rural areas as decentralized electricity generation, avoiding deforestation to occur for the need of extension of power grid from urban to these areas [32].

4.3 Final thoughts on Malaysia's environment

To create a secure environment, Malaysia must strive to increase its efforts in attaining greater efficiency in energy conversion, transmission and utilization to prevent drastic destructions to the environment [7]. If the country only aims at increasing energy output – to meet the energy demands of the people – without considering the aforementioned factors, it may be able to solve the energy demand problems but it will aggravate the welfare of the people in overall.

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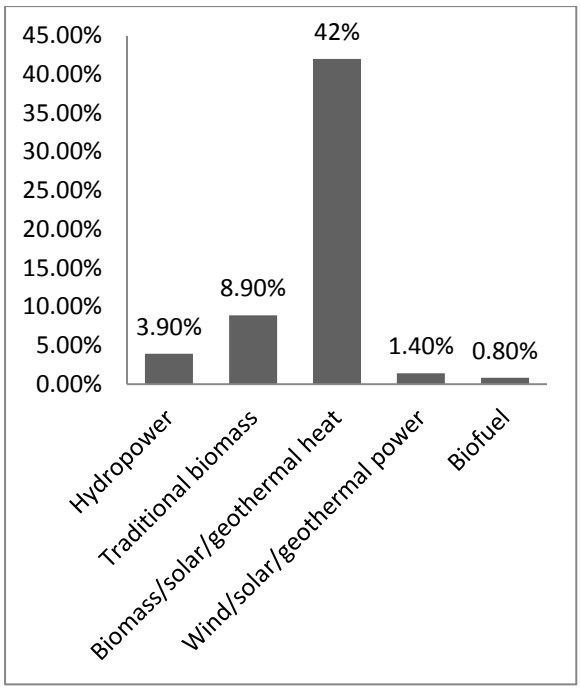

Fig. 1 Estimated percentage of world's energy consumption and breakdown of the renewable energy share in 2014 [2]

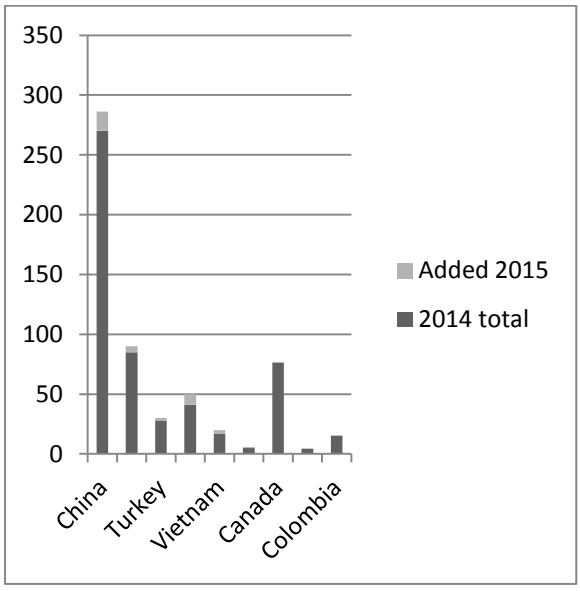

Fig. 2 Hydropower Capacity and Additions, Top Nine Countries for Capacity Added, 2015 [2]

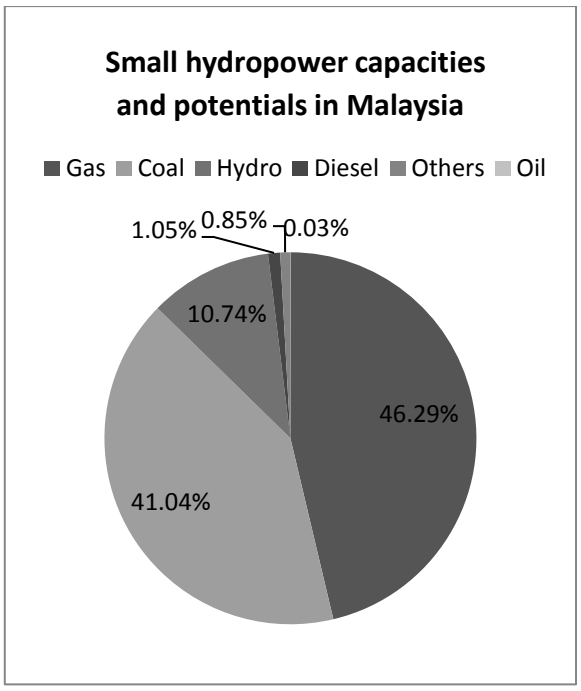

Fig. 3 Small hydropower capacities and potentials in Malaysia [9]

Table 1: Classification of hydropower plants [6]

Hydropower plant	Capacity	Feeding
Large	>100 MW	National power grid
Small	Up to 25 MW	National power grid
Mini	<1 MW	Micro power grid
Micro	Between 6 kW and 100 kW	Small community or remote industrial areas
Pico	Up to 5 kW	Domestic and small commercial loads

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Table 2: Mix of electricity generation in Malaysia from 1990 to 2015 [9]

Year	Electricity Generation Mix in GWh						
	Hydro	Gas	Coal	Oil	Diesel	Others	Total
1990	518	623	–	367	585	–	2093
1991	762	525	–	379	612	–	2278
1992	4286	11398	3837	9724	862	–	30107
1993	4853	13905	3880	9820	865	–	33323
1994	6483	17491	4081	8756	988	–	37799
1995	6184	17726	3974	9687	1249	–	38820
1996	5184	29641	4177	9510	1584	189	50285
1997	4134	18387	2460	10784	1300	–	37065
1998	4457	40223	3655	10339	971	–	59645
1999	7552	45988	4522	4220	747	–	63029
2000	6994	50314	4038	2383	552	–	64281
2001	6066	54066	6238	2531	831	–	69732
2002	5415	53979	9559	4465	746	–	74164
2003	5090	56478	13435	1221	976	–	77200
2004	5573	61363	22627	1130	729	–	91422
2005	6007	61396	25231	1048	348	–	94030
2006	6323	64768	26626	1265	643	50	99675
2007	5957	65568	30856	1091	677	63	104212
2008	7807	67779	31029	1048	601	66	108330
2009	6890	63370	37644	1041	685	132	109762
2010	6361	61342	49401	933	726	170	118933
2011	8056	55732	52302	4295	5108	1576	127069
2012	9251	60992	55615	2279	4344	1596	134077
2013	11799	71174	53663	1571	1741	1318	141266
2014	13540	74466	53693	376	756	995	143827
2015	15524	66919	59335	45	1516	1226	144565

Table 3: The installed capacity of hydropower stations in Malaysia [10]

Station	Installed capacity (MW)	Total (MW)
1. Terengganu		
Stesen Janakuasa Sultan Mahmud Kenyir	4 × 100	400
2. Perak		
Stesen Janakuasa Temenggor	4 × 87	348
Stesen Janakuasa Bersia	3 × 24	72
Stesen Janakuasa Kenering	3 × 40	120
Chenderoh	3 × 10.7 + 1 × 8.4	40
Sungai Piah Upper Power Station		14.6
Sungai Piah Lower Power Station		54
3. Pahang		
Stesen Janakuasa Sultan Yussuf, Jor	4 × 25	100
Stesen Janakuasa Sultan Idris II, Woh	3 × 50	150
Cameron Highland Scheme		11.9
4. Kelantan		
Pergau	4 × 50	600
Kenerong Upper	2 × 6	12
Kenerong Lower	2 × 4	8
5. Sabah		
Tenom Pangi	3 × 22	66
6. Sarawak		
Batang Ai	4 × 23.5	94
Murum HEP	4 x 236	944
Bakun HEP	8 x 300	2400
Total		5434.5

Table 4: Renewable energy quota in Malaysia [33]

Year	Biogas	Biogas−sewage	Biomass	Solid waste	Small hydro	Solar PV <1 MW	Solar PV >1 MW	Total (MW)
2011/2012	20	10	60	20	30	10	40	190
2013	20	10	50	30	30	10	40	190
2014	20	10	50	30	30	10	40	250

Table 5: Life cycle CO2 emission by renewable energy technologies [34]

Type of renewable source	Emission, g-CO2/kWh
Hydropower	3.7–237
Solar	53.4–250
Wind	9.7–123.7
Biomass	35–178

5. Conclusions

Malaysia is a blessed country because of its already existing exposure to mass amounts of water in its geographical location which allows hydropower to flourish. The process for developing a hydropower plant is feasible due to Malaysia's long-life experience in handling hydroelectric projects in its domain, which is to say that Malaysia has a complete advantage in developing hydropower: ranging from natural resources (abundance of water) to human resources (technical expertise). The procedures for building the hydropower infrastructure include determining hydropower potential by using hydrological analysis method and hydrological model. Next, a detailed study should be conducted to evaluate the existing river flow characteristics, which plays a vital role in determining the hydropower potential. Lastly, the estimated power output from the river by using a variety of turbines can be obtained by the speed and flow of the water. Speaking from an environmental perspective, the damage inflicted onto the environment by the construction and operation of the hydropower plants can be avoided by building non-large hydropower plants which do not damage the environment. Such development will grow the country's economy abundantly as hydropower reminds us of the interconnected nature of the challenges facing big infrastructure and development projects. The price of hydropower that has been developed is significant with critiqued environmental impact assessments. The demand for space to build the hydropower has also affected those within the region in terms of dislocation, relocation, and resettlement which involved high social and compensation costs to Sarawak. Furthermore, the priority for Malaysia so far has been to refocus into securing for more raw materials like natural gas and coal to match with the future power generation and domestic demand since hydropower is not a major source of power for Malaysia. Despite all that, hydropower remains an important source of clean energy. Hydropower may cause harm but it is minimal on a macro scale as it does not contribute to the rise in global temperature, contrary to natural gas and coal. There is a constant supply for hydropower plants to generate energy which can help reduce the wipe out of non-renewable energy such as fossils fuels too quickly. The most important step now for Malaysia to partake is to consider the consequences from utilizing every single energy source for electricity generation, which is a must to secure the welfare of the people, rather than having solely the intention of meeting the growing energy needs of the country.

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