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Trends in an increased dependence towards hydropower energy utilization—a short review

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Abstract: Over the past few decades, fossil fuels replacements have shown leaps and bounds of progressions. Hence, various nations have initiated the adoption of biomass energy, solar energy, wind energy and hydropower energy. Yet, these currently developing technologies have constantly faced dual pressure from both the economic growth and environmental protection. Hydropower has become a key candidate for considerable utilization in various countries due to its numerous social, economic and environmental benefits. In this paper, a short review was carried out to analyse the development of various hydropower plants and compare its utilization over the conventional fossil fuels. The main setback for the adoption of this technology is that large hydropower plant demands for huge deforestation. This would direly result in the destruction of critical ecosystems, migration of large population at downstream and other catastrophic outcomes such as flash floods and landslides. However, this singular setback could be alleviated with the utilization of small or micro hydropower plant. This technology, in particular, was found to

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PUBLIC INTEREST STATEMENT

Renewable energy sources have become the choices of future energy supply, chiefly due to energy security and the sustained emissions emanating from conventional energy sources leading to global warming. In this line, hydro energy has been utilized in many countries to contribute significantly in the process of substituting fossil fuels in the years ahead. In this paper, the trends of utilizing hydropower energy have been discussed to highlight its current status in regard to different aspects. Though hydropower has become a key candidate for considerable utilizations, the main hindrance for the expansion of large hydropower plant lies on the huge deforestation encountered during the development, which could result in the destruction of critical ecosystems, migration of large population at downstream, flash floods and landslides. This primary setback can be alleviated with the utilization of small or micro hydropower plants, which have been under increased utilization nowadays.

have minimal destruction effects to the environment and is able to produce affordable energy to the rural areas as it has proven in many countries.

Subjects: Environment & Agriculture; Environmental Studies & Management; Engineering & Technology

Keywords: renewable energy; sustainable energy sources; hydropower energy

1. Introduction

Fossil fuels such as coal, petroleum and natural gas have remained as the main sources of power generation worldwide (Chala, Aziz, & Hagos, 2018; Lazkano, Nøstbakken, & Pelli, 2017). Over decades of utilization, the impeding threat of global warming along with the continuous depletion of fossil fuels has called for the reduction in total dependency on these particular sources of energies (Chala, Guangul, & Sharma, 2019; Marques, Fuinhas, & Pereira, 2018). In USA and South Africa, for instance, the power generation requires about USD 600 billion and USD 150 billion, respectively to fulfil the power density based on USD 1/W capital cost in conventional gas power plant. Therefore, switching of fossil fuel technologies to renewable sources shows very obvious trend nowadays and hence came forth the initiation on the development of various alternatives and sustainable forms of energy sources (Guangul et al. 2019a, 2019b).

Switching towards green energy, such as geothermal, solar, water and wave energy has recently received high attention worldwide (Erinofiardi et al., 2017). Over the past decades, fossil fuels replacements have faced leaps and bounds of progressions. Various nations have put effort to adopt these alternatives energies. According to statistics provided by Indonesian National Energy Policy, there would be about 31% of total energy provided by renewable sources in 2050, from which biomass contributes about 23%, 21% from biodiesel, geothermal 20%, 10% of hydro power, 7% nuclear, 6% coal gas methane, 4% bio-ethanol and the rest are from biogas, solar, wind and sea amounting 8% in the country (Erinofiardi et al., 2017). These sources of energies have constantly faced challenges from economic growth and environmental protection (Ma'arof, Girma, & Ravichanthiran, 2018). The two main challenges in promoting the utilisation of renewable energy are that it is intermittent and encounters difficulties in control, and secondly, the generation mainly depends on the spatial distribution (Kocaman & Modi, 2017; Chala et al., 2018). This situation has led to the world's augmentation of the renewable power, especially in United States and Germany sharing 13% and 25% production facilities, respectively (Bildirici, 2016).

The main technologies used in a hydropower facility constitute dammed reservoir, running river, pumped storage, stream technology and new technology gravitational vortex [8]. In this regard, the research in Europe mainly focuses on the main elements of electromechanical equipments such as turbines, pumps and generators. Basically, there are two types of turbines: impulse and reaction turbines. There are three types of impulse turbines: Turgo, Pelton and cross flow turbines. However, most reaction turbines are of axial flow turbine (Kaplan turbine) type. Reaction turbines have better performance in low head and high flow sites compared to impulse turbines (Yaakob, Ahmed, Elbatran, & Shabara, 2014). The water flows via channel or penstock to a waterwheel or turbine where it strikes the bucket of the wheel, causing the shaft of the waterwheel or turbine to rotate. When generating electricity, the rotating shaft, which is connected to an alternator or generator, converts the motion of the shaft into electrical energy. World bank (WB: 2009) reported that hydropower would have important contribution to the efforts of the development and cooperation of region in scarce water resources (Vassoney, Mochet, & Comoglio, 2017). The inherent technical, economic, and environmental benefits of hydroelectric power make it an important contributor to the future world energy mix, particularly in the developing countries.

Hydropower plant becomes popular in some countries due to hilly areas and covered with numerous rivers, such as Malaysia, Nigeria, Ethiopia and Brazil, to mention few. Hydropower had generated 16.3% of world electricity and constituted about 75.1% of total renewable energy in 2013 (Briones Hidrovo et al. 2017). In the recent years, Nepal Electricity Authority (NEA) generates about 539 MW power, of which hydropower produced 485 MW while 54 MW was from liquid fuel. Similar study also noted that the Independent Power Producers (IPP) utilized hydro sources to generate 361 MW of power with total constituting 900 MW in Nepal (Alam et al., 2017).

Hydro energy in Europe has a potential of about 1,021 TWh/year, and the technical potential installed capacity in 2009 was 338 TWh/year (Manzano-Agugliaro, Taher, Zapata-Sierra, Juaidi, & Montoya, 2017). However, the construction of large hydropower station requires large capital cost and causes environmental problem leading to its less attraction in the present world economy (Kabo-bah, Diji, & Yeboah, 2018). This situation has led to the development of huge potential of small scale hydropower plant (SHP). According to European Commission, SHP production is listed for power lower than 10 MW; Mini-Hydropower produces less than 2 MW power; Micro-Hydro is for production below 500 kW and Pico-Hydro refers to production below 10 kW (Balkhair & Rahman, 2017). Therefore, energy from water in mini/micro hydropower plant has gained the highest attraction due to its environmental friendly operation and suitability for rural area electricity production. The technology is projected to be future sustainable as it produces clean, cheap and environmental friendly power sources. The power generation of small hydropower plant has been amplified to 25 MW in some countries like China or India (Balkhair & Rahman, 2017; Kong et al., 2015). In developing countries, renewable sources contribute to about 47GW and small hydropower plant shares about 1%–2% of the total capacity (Manzano-Agugliaro et al., 2017).

Electricity generation in Malaysia through hydropower was started in July 1900, during which a small hydro power plant was installed at Sempam River, Raub, Pahang (Haidar, Senan, Noman, & Radman, 2012). Now, there are 12 large hydropower stations with one in Sabah and Sarawak and the remaining are located at the Peninsula Malaysia. Besides, there are also about 36 mini-scale hydropower plant in Peninsula Malaysia and 9 in Sarawak and 5 in Sabah (Kadier et al., 2018). The power generated by these hydropower plants reaches to about 1911 MW, allowing successful commercial and domestic uses.

It is well reported that the utilization of renewable energy has increased in size and number in order to fulfil the ever-growing energy demand. Within the various options of renewable sources, the hydropower plants are found to be the most reliable and efficient in comparison to the other alternative energies (Tang, Zongmin, & Yan, 2018; Zhang, Linyu, & Cai, 2018). Subsequently, the hydropower plant is the renewable energy of interest nowadays. However, there are limited studies addressing the strength and weakness of hydropower generations. Therefore, in this paper a study in line to strength, weakness, benefits and disadvantages was carried out to further analyse the potential for the development of hydropower energy. Consequently, the benefits exploited would be filtered out for further development. Besides, it is necessary to highlight the threat of the power plant to minimise the consequences.

2. Hydropower energy generation

2.1. Strength of hydropower energy sources

Previous observation made upon countries utilizing sustainable energy highlighted that hydro-electric power has become an important contributor to the future world energy mix, particularly in the developing countries due to its inherent technical, economic, and environmental benefits (Manzano-Agugliaro et al., 2017). It also received attention due to its high density, high power, predictable and continuously available power. Besides, there are huge sources of hydropower generation such as wave energy, tidal energy and ocean energy (Behrouzi, Nakisa, Maimun, & Ahmed, 2016). In addition, hydropower energy can be decentralised as it can directly be used for grain milling, battery charging and so on in small industries, providing plenty benefits to the country (Haidar et al., 2012). Figure 1 depicts world renewable power productions and predictions.

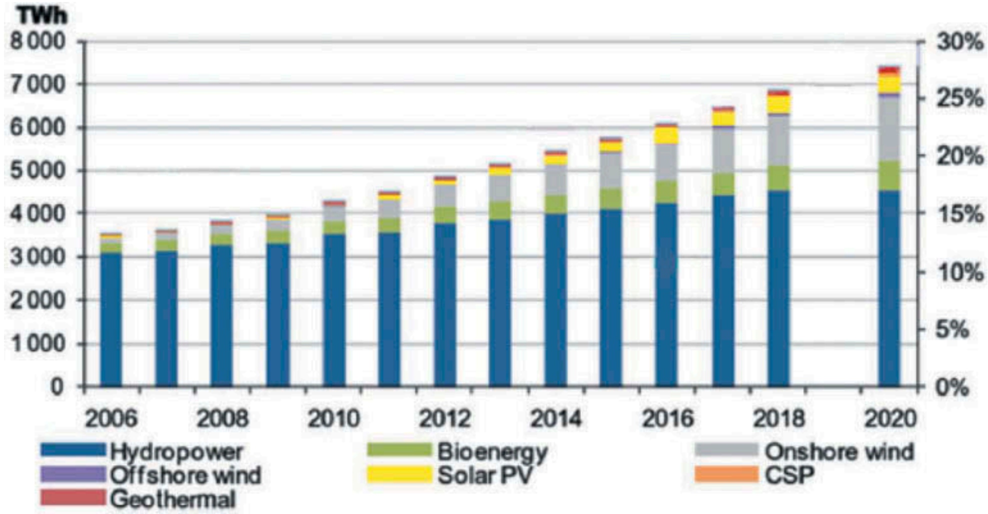

Figure 1. Global renewable electricity production and prediction (Behrouzi et al., 2016**).**

Green power became more essential in some developing countries, such as northern India, central southern China and Bangladesh. The huge potential of the hydropower in Nepal causes the country's prosperity to depend on the hydro resources utilisation. This situation allows Nepal to become one of the main exporters of green power and the country developed secured power purchase agreement with India and Bangladesh for sustained power trades. The revenue from power export is helping to achieve economic prosperity and generate funds for education, healthcare, housing, agriculture and infrastructures (Manzano-Agugliaro et al., 2017). The utilisation of the hydropower in these developing countries is mainly due to the fact that hydropower uses water to generate power with no consumption of water and the installation is beneficial in view of environment, social and economics (de Faria, Alex Davis, Severnini, & Jaramillo, 2017).

Regardless of its high construction costs, hydroelectric power plant has low breakeven point due to its low operating and maintenance costs with the favourable average annual rainfall making it more cost effective when compared to other green power sources. Hydropower can also help control flood, used as industrial and irrigation purpose and can be developed into recreational tourism (Bildirici & Gökmenoğlu, 2017). Micro-hydro is one of the most environmentally friendly energy technologies available nowadays. The technology is extremely robust, and systems can last for 50 years or more with little maintenance (Manzano-Agugliaro et al., 2017). The negation of fuel costs, technology efficiency, low operating and maintenance costs and reduced environmental impact made hydropower as an attractive alternative source of energy. Williams and Simpson studied the Pico-Hydro scheme, and discussed that Pico-Hydro was a cost-effective option for off-grid areas. Hydroelectricity can be an important contributor to meeting future energy needs, notably in developing countries where two billion people have no electricity supply. It was reported in 2009 that mini hydroelectric power is the cheapest option in terms of energy production for rural electrification.

Moreover, small hydropower plant becomes an ideal energy solution in many countries worldwide due to its cheaper price and it is adjustable following the geographical, economic and socio conditions (Ximei, Ming, Han, Lilin, & Deng, 2015; Yah, Oumer, & Idris, 2017). The utilisation of the small hydropower plant has also become more attractive in the developing countries due to its practical use and low cost. The reliable access of electricity through small hydropower plant can help solve the electricity supply and coverage problems in the remote area and hence increases the population life quality. It also creates job opportunities in operation, establishment and maintenance of the small hydropower plants (Xingang, Liu, Xiaomeng, Jieyu, & Pingkuo, 2012). The better social and economic impacts of the small hydropower over the large-scale power station has gained government supports. For example, China installed more than 45,000 small hydropower plants in the remote area that provide more than 65 GW power, which improved the livelihood of citizens (Aroonrat & Wongwises, 2015).

In Europe, small hydropower is the most feasible options with the installed capacity more than 10MW due to its low operational cost, well-developed technology and more reliable compared to solar and wind energies (Ioannidou & O'Hanley, 2018). According to Europe Small Hydropower Association, small hydropower has potential to supply 13 million household beside supporting water management policies and low greenhouse emissions (Ioannidou & O'Hanley, 2018). In addition to electricity production, it was highlighted that when water passes through turbine, enhanced water aeration and well additive mixing will be achieved that can help optimise water treatment processes. Low fish mortality and sediment clean up can be done as dive turbine and gate are installed in small water reservoir. The increased water temperature in hydropower reservoir during both late summer and early winter can affect aquatic organism metabolism and freshwater treatment (Manzano-Agugliaro et al., 2017). This proves that the coverage of benefit in the utilization of hydropower is beyond species.

Comparing to other energy sources, hydroelectric generation has low emissions of CO_2 and CH_4 and no SO_2, NOx and particulate matter emissions, leading to its better environmental performances. The many advantages of low head canal include no hydrological risk, close proximity to load centre, easily accessible, and assured water availability. Moreover, advantages of SSH, especially in Run-of-River (RoR), include the requirement for small construction facilities, hence, avoiding the migration of people out of the area, flooding small areas relative to their output, less ecological migration, less risk of sedimentation, and cost-effective technology (Balkhair & Rahman, 2017). SSH also causes reduction in greenhouse gasses. It has no significant environmental impacts and land acquisition or significant operating costs, providing quicker benefits and energy security to developing economies. Most of SSH are economically viable and their viability depends on many factors such as site, conditions and size of the project. The construction and operation of these proposed sites would have no negative impact on irrigation water delivery as well as water quality, and in some cases would be beneficial to irrigation as long as the flow rates are stable (Zeng, Cai, Ringler, & Zhu, 2017). Furthermore, sustainable usages of water resources for hydropower, water supply and irrigation have high return of investment.

It was reported that mini/micro hydropower plants are more efficient than other sources of renewable energy such as wind or solar. Micro hydro unit has an efficiency range of 60% to 90% as opposed to solar energy with much lower efficiency (Erinofiardi et al., 2017). According to the results of the short run causality, there is evidence to support the growth hypothesis in OECD countries with high income. There is also a support to the conservation hypothesis for Brazil, France, Mexico Turkey and countries with high growth. The conservation hypothesis suggests that the policy of conserving hydropower energy may be implemented with little or no adverse effects on economic growth, such as in a less energy-dependent economy. According to the long-run causality result, there is evidence to support bidirectional causality for all countries except Brazil and France. Hydropower energy consumption and economic growth are complementary and an increase in energy consumption stimulates economic growth, and vice-versa. Other authors have analysed and compared hydropower plants with the main electricity generation technologies, including those fuelled on fossil fuels, showing that hydropower has a good environmental performance, particularly with the emissions of GHG in its entire life cycle (Briones Hidrovo et al. 2017).

In the recent years, the development of Pico hydropower (PHP) becomes the main concern of power generation in Malaysia due to its efficient power generation in the remote areas (Kadier et al., 2018). Besides, the Pico hydropower does not require large water storage and migration of large population as opposed to large scale hydropower station. Due to its lower operational and simple construction, PHP can be constructed in rural or hilly area and the power generation is reported to be enough for the low energy requirement in the population. Moreover, this technology has become more competitive than wind and solar energies due to its flexibility, low capital cost, high efficiency, short payback period and less maintenances (Ximei et al., 2015). Consequently, PHP has constant output and less power fluctuations.

The advantages of hydropower can be categorized into three aspects: economic, social and environmental. Hydropower provides low operating and maintenance cost due to its proven technology and reliable services (Arias-Gaviria, van der Zwaan, Kober, & Santiago, 2017). Subsequently, the life span of the power plant can operate up to 50 to 100 years or more. The construction of the plant helps to instigate and foster regional development and create more chances for employment. The usage of hydropower energy shows a high rate of efficiency, and this could lower the use of fossil fuel to generate electricity. Furthermore, pollution and cost may be reduced. The construction of the hydropower plant can also enhance the recreation and sustain livelihoods. Another reason is that it helps to enhance accessibility of the territory and its resource by providing flood protection, enhancing navigation condition and providing water access to target area. It has wide application in agricultural, adaptation and mitigation. In the mitigation aspect, hydropower can help reduce emission of greenhouse gases (Song, Gardner, Klein, Souza, & Mo, 2018; Varun et al. 2012). It can also improve social resilience and increase agricultural yield, particularly within the aspects of utilization of small-hydropower plants.

2.2. Weaknesses of hydropower energy

Hydropower contributes to the effort of development and cooperation of region and scarce water resources and it is complex and brings a range of economic, social and environmental risks (Vassoney et al., 2017). Albeit the advantage of the utilization of hydropower plant as a form of sustainable and renewable energy, it is not without its own specific weakness. The generic weakness of a hydropower plant is similar to any other mega projects. Issues and limiting constraints such as huge investment cost, long construction duration and socio-cultural impacts are indeed the norm. But, it is emphasized that there is no other mega project that could bring the negative environmental impact as a hydropower plant. Regardless of the scale of the hydropower plant, the condemning weakness in the development of hydropower plant is flooding.

Since the construction of the hydropower plant is strongly geographical dependent and high level of water height is required to generate adequate amount of power, flooding is almost unavertable (Kocaman & Modi, 2017). The geomorphology processes and natural river habitat might be destroyed when building a dam as it acts as a physical barrier to disrupt natural connectivity of river and block the river and sediment flows (Ioannidou & O'Hanley, 2018). Besides, building large dam requires large areas of land causing deforestation and flood at low-level area. This situation directly causes agricultural damage and reduces safe access through the river and erosion of riverbank (Sivongxay, Greiner, & Garnett, 2017). Immense flooding of agricultural lands, submersion of cities under water, endemic water-borne diseases and serious alterations of ecosystem are typical factors of the colossal failures of large-scale hydropower plants. Associated to peaking conditions, water-level fluctuation can cause ecological damage and this form of catastrophic endeavour is almost irreversible at times.

A 2012 report suggested that the operation of hydropower dams in Nigeria was not based on any scientific analysis, hence, flooding due to the overfilling of the downstream reservoirs had occurred in the past, leading to the loss of lives and properties worth millions of dollars (Olukanni & Salami, 2012). In Naxeng, China, the hydropower project caused the loss of fertility of agricultural land due to the fine sediments caused by rock crushing for construction of dam (Sivongxay et al., 2017). Besides, the establishment of the Pico hydropower in the rural area can easily be destroyed by heavy rain and flood (Kadier et al., 2018). Furthermore, the recent operating reservoirs and announced reservoirs in the Amazon could flood 9,000 km^2 (out of an area of roughly 5 million km^2 in the Legal Amazon region in Brazil), which can adversely affect flora, fauna, and ecosystem services. The dam also blocks the natural river flow, affecting the migration of aquatic species and resulting in changes in the oxygen, thermal and sedimentary conditions in the reservoir area and at the downstream (de Faria & Jaramillo, 2017). In some cases, the flooding and decay of large stocks of biomass in the reservoir area lead to greenhouse gas emissions (GHG) that are comparable to those from fossil fuel power plants. Large hydropower projects also affect the local population through the resettlement of people living in the reservoir areas and the deterioration of social cohesion because of the high influx of workers, and loss of agricultural production.

The impact from flooding is nothing less than the region's climate and tectonic conditions as well as human activities are highly conducive for erosion and sedimentation (Lucena et al., 2018). Therefore, sediment management is paramount for the safety, reliability and longer life of infrastructures (hydropower dam, equipment, roads, bridges, irrigation systems and drinking water). Moreover, the generation of the hydropower electricity is influenced by the climate. For instance, rainy season during December to May lead to 40 GW power generation of hydropower plant in Amazon River in Brazil and this value is expected to decrease to 28 GW in dry period from May to November (Hunt, Guillot, de Freitas, & Solari, 2016). Hence, although it is theoretically sustainable, it is not without any means that the efficiency could not be reduced or affected by other external factors.

Another major concern in regard to hydropower plants is the greenhouse effects. It was reported that the reservoir of hydropower plants emits a considerable quantity of greenhouse gases, which could exceed the emissions of fossil fuel electric generation technologies (Briones Hidrovo et al. 2017). Results show that the cumulated hydropower reservoir emissions may exceed the ones from its thermal equivalent based on carbon, oil or natural gas over the time and after 25 years of operation, the emissions would start to equalize. The GHG emissions from hydropower are usually low; however, reservoirs located in tropical forested areas have the potential to emit large quantities of methane, a more powerful GHG gas compared to carbon dioxide (Botelho, Ferreira, Fátima Lima, Pinto, & Sousa, 2017). For long period of utilization, such emission may not be desired.

The limiting constraints in the investment towards the utilization of hydropower plant are the huge capital cost, long construction duration, extra high voltage tie-line requirement limits and the dire environmental impact mainly from flooding (Moog, 1993). As a result, nations had opted to the utilization of small-scale hydropower (SHP) scheme (less than 30 MW) as an attractive endeavour. Nevertheless, the power generation by the small hydropower plant is only limited for the rural usage (Yah et al., 2017). Besides, there are no batteries to store the energy produced by the micro hydropower plant and it cannot meet the customer demand during peak load (Murni, Whale, Urmee, Davis, & Harries, 2013). Although electricity generated by hydropower station can be in alternative current and direct current, the high voltage direct current is suitable for rural area due to its low losses and ease of control (Yah et al., 2017). However, this situation becomes a challenge as it is difficult to install transmission line in the rural and hilly areas. These setbacks and dire impacts in relation to the utilization of hydropower plant should be taken into serious concern. Table 1 summarizes the strength and weakness of hydropower energy sources.

2.3. Opportunities of hydropower energy sources

The geographical aspect is one of the major factors that influence the development of hydropower generation system in certain countries. The abundant hydro resources in Nepal is due to its steep gradient and mountainous topography (The Himalayan Times, 2018). The country's three major river systems such as Koshi River system, Gandaki (Narayani) River system, and Karnali (Goghra/Mahakali) River system and their smaller tributaries offer Nepal to produce economically and technically feasible power reaching 50,000 MW. Nepal can potentially generate over 90,000MW hydropower (Alam et al., 2017). In another case, due to high elevation of about 1,132 m of landscape in Turkey the formation of high gradient mountain streams appear to be suitable for SHP development (Manzano-Agugliaro et al., 2017). Turkey has an abundant hydropower potential to generate electricity and increase hydropower production in the near future. Moreover, perennial rainfall and the topology favours the required hydraulic heads.

Table 1. Summary of the strength and weaknesses of hydropower plant

Authors (Year)	Research title	Strength	Weaknesses
Manzano-Agugliaro et al., 2017	An overview of research and energy evolution for small hydropower in Europe	Technical, economic and environmental benefits to developing countries. For instance, Nepal became main hydropower exporter. Low operating and maintenance costs	Sediment management is paramount for hydropower plant construction.
Hunt et al., 2016	Energy crop storage: An alternative to resolve the problem of unpredictable hydropower generation in Brazil		Influenced by climate, reducing the power from 40GW to 28GW in dry period in Amazon river, Brazil.
Behrouzi et al., 2016	Global renewable energy and its potential in Malaysia: A review of Hydrokinetic turbine technology	High density, high power, predictable and continuously available sources.	
Haidar et al., 2012	Utilization of Pico hydro generation in domestic and commercial loads	Hydropower can be decentralised.	
Kocaman & Modi, 2017	Value of pumped hydro storage in a hybrid energy generation and allocation system		Hydropower plant is strongly geographical dependent and high water height is required to generate adequate amount of power.
Ioannidou & O'Hanley, 2018	Eco-friendly location of small hydropower		The geomorphology processes and natural river habitat may be destroyed by the building of dam.
Bildirici & Gökmenoğlu, 2017	Environmental pollution, hydropower energy consumption and economic growth: Evidence from G7 countries	No consumption of water in power generation and eco-friendly installation. Help in flood control, used as industrial and irrigation purposes beside recreational tourism.	
Aroonrat & Wongwises, 2015	Current status and potential of hydro energy in Thailand: a review.	Small hydropower plant solves unelectrified problems in the remote area, increases the population life quality	
Sivongxay et al., 2017	Livelihood impacts of hydropower projects on downstream communities in central Laos and mitigation measures.		Building of the large dam requires a lot of land that causes deforestation and flood to occur at low level area.

(*Continued*)

Table 1. (*Continued*)

Authors (Year)	Research title	Strength	Weaknesses
Yah et al., 2017	Small scale hydro-power as a source of renewable energy in Malaysia: A review	Small hydropower plant is cheaper and adjustable following geographical and economic conditions. More competitive due to its flexibility, low capital cost, high efficiency, short payback period and less maintenance is required	
Ioannidou & O'Hanley, 2018	Eco-friendly location of small hydropower	Small hydropower could power to supply 13 million households in Europe.	
Balkhair & Rahman, 2017	Sustainable and economical small-scale and low-head hydropower generation: A promising alternative potential solution for energy generation at local and regional scale.	Hydroelectric has low emissions of CO_2 and CH_4 and no SO_2, NOx and particulate matter emissions	
Balkhair & Rahman, 2017	Sustainable and economical small-scale and low-head hydropower generation: A promising alternative potential solution for energy generation at local and regional scale		Immense flooding of agricultural lands, submersion of cities under water. Endemic water-borne diseases, and serious alterations of ecosystem, typical of colossal failures of large-scale hydropower plants.
Erinofiardi et al., 2017	A review on micro hydropower in Indonesia.	Mini/micro hydro power is more efficient than other sources of renewable energy.	
Kadier et al., 2018	Pico hydropower (PHP) development in Malaysia: Potential, present status, barriers and future perspectives	Pico hydropower does not require large water storage and migration of large population. More competitive due to its flexibility, low capital cost, high efficiency, short payback period and low maintenances.	
de Faria & Jaramillo, 2017	The future of power generation in Brazil: An analysis of alternatives to Amazonian hydropower development.		The dam also blocks the natural river flow, affecting the migration of aquatic species and resulting in changes in the oxygen, thermal, and sedimentary conditions in the reservoir area and at the downstream. The flooding and decay of large stocks of biomass in the reservoir area led to greenhouse gas emissions.
Yah et al., 2017	Small scale hydro-power as a source of renewable energy in Malaysia: A review		Power generation by the small hydropower plant is only limited for the rural use.

Aside from high elevation grounds, the abundance in numbers of island and good geographical position, for example having high numbers of rivers, also creates a vast opportunity for the utilization of hydropower plants. Due to many islands and good geographical position with lots of rivers in Indonesia, hydro power plant in form of small hydropower until Pico hydro power plant would support the energy demand in the country. Moreover, the rivers can be used as source of mini/micro hydro power plant (Amri, Halim, & Faiz Barchia, 2014). Hydropower generation in Thailand is becoming one of the interests of development in the recent years. This is due to the fact that Thailand consists of 25 major rivers of about 800,000 million $m^3$of the river basin (Aroonrat & Wongwises, 2015). Aside from these, the construction of hydropower plant is able to provide both direct and indirect opportunity and benefits to the Laos community. The direct benefits are in term of social program, infrastructure development and employment, whereas indirect benefits are infrastructure development in term of road access, and improvement in tourism and hospitality facilities. The government of Laos had adopted a strategy named National Growth and Poverty Eradication System (NGPES) to improve the economic growth and reduce poverty by implementing the development of hydropower energy (Li, Yang, Zhang, & Zhou, 2017). The installation of this power plant helped improve the quality and quantity of the water release that affects the riverine and riparian ecosystem. While the blooming of the hydropower station provides substantial contribution to various new employments field such as fishing and aquaculture, forest product and craft, there still exist some minor negative impacts such as variation in river flow rates and water quality. The opportunity in this case is higher compared to the negative impacts.

Hydropower is the fourth energy sources in Malaysia after crude oil, natural and coal. The increased development of the hydropower station in Malaysia is mainly due to its geographical condition. There are about 50 rivers in East Malaysia and 150 in Peninsula Malaysia (Kadier et al., 2018). There is high average annual rainfall reaching 2,540 mm in Peninsula, 3,850 mm in Sarawak and 2,630 mm in Sabah, which is higher than average worldwide rainfall of only 750 mm (Yah et al., 2017). The advancement of hydropower in Malaysia is also caused by the long coastline, equatorial climate and irrigation channels (Sovacool & Bulan, 2012). The opportunity that can be taken from environment to build a hydropower station is mainly due to the mountainous landscape of the countries. Moreover, the river systems in the countries would also augment the development of the SHP.

2.4. Threats of hydropower energy sources

Although the utilization of hydropower plant brings various positive impacts to the nation, the threats tangling the good cause should be taken into critical consideration. Nepal unstable topology due to active seismic activities causes the hydropower plant to be well planned to mitigate environmental impact (Sharma & Awal, 2013). Most Himalayan Rivers contain huge quantities of sediment with hard abrasive particles. The region's climate and tectonic conditions as well as human activities are highly conducive for erosion and sedimentation. Brazil generates around 70% of its electricity from hydropower and still has an enormous hydroelectricity potential to be developed in the Amazon Watershed. However, its flat geology, large storage reservoirs make it impractical in the Amazon region (Hunt et al., 2016). After flooding in the hydro station, a considerable quantity of organic matter stays under water which, in the presence of oxygen, is decomposed and produces carbon dioxide. Conversely, in the absence of oxygen, the organic matter is decomposed and produces methane gas (through methanogenesis) with a global warming potential 21 times higher than carbon dioxide (Briones Hidrovo et al. 2017). Moreover, rivers commonly transport organic matter which contributes, with its concentration at the reservoir, to a continuous decomposition and production of the greenhouse gases (GHG). Thus, as the amount of flooded organic matter increases, GHG emissions also raise up.

Hydropower implementation causes several impacts on the affected watercourses, such as changes in river morphology and flow alterations (river impoundment, flow reduction, hydropeaking, etc.) with a consequent loss of habitats and biodiversity of aquatic biota (Finger, Schmid, & Alfred, 2006). Dam also influences the migration of the fish and quality of the flow of the natural water (Behrouzi et al., 2016). Negative impacts of hydropower generation are not only associated with large dams, reservoirs and related hydropower facilities, but also with small hydropower plants (SHP) originating cumulative effects impacting several rivers stretches (Morales et al., 2015). In Malaysia, some drawbacks exist with the establishment of the large-scale hydropower plant, such as ecosystem change, land losses, migration of humans and animals and safety concern (Yah et al., 2017).

Botelho et al. (2017) discussed that there are several reported environmental impacts relating to biodiversity limitation, flora and fauna impact, landscape view intrusion, impact on water resource, and the losses of historical relics and visual impact. Besides, fish breeding area would be blocked by the dam and hence reduces the productivity of the fish and disturbs the balance of the aquatic environment (Eloranta, Finstad, Helland, Ugedal, & Power, 2018). The element of flora is constantly brought up in several studies due to the impact of constructing dam. The consequences of the construction lead to the loss of agriculture, forestry, erosion and vegetation. Using the market value method by Gunawardena (2010), three types of environmental impact as a result of dam construction have been highlighted. The river flow will be diverted and altered affecting the historical monuments landscape and site, the loss of water sport and recreation activity, the destruction scenic view such as the forest land and home gardens. Loss of land and severe impact on forest and flora during Foz Tua hydropower plant was observed after carrying out life cycle assessment (LCA) perspective (Botelho et al., 2017).

The construction of the hydropower station tends to be strict as it requires high capital cost. Thorough study on the geological venue is needed prior to conducting the construction. For instance, Houziyan Hydropower Station faced a phenomena failure imposing safety threat to the construction structure and human life. The phenomena involved split, spalling, ballooning and cracking of the shotcrete layer while conducting the excavation process (Li et al., 2017). These phenomena caused difficulties in construction of the hydropower plant.

In the recent eras, the development of the large hydropower plant became less preferable due to its large capital cost, change in environment and ecological system and causing deforestations (Kadier et al., 2018). Large-scale hydropower station is always associated with the problems of landscape intrusion, biological limitation and impact on flora and fauna (Botelho et al., 2017). Therefore, many researches have been conducted to increase the efficiency and power performance of the small, micro-scale and Pico hydropower.

3. Conclusion

Global warming and the continuous depletion of fossil fuels have called for the development of various alternatives and sustainable energies sources. Fossil fuel takes the largest percentage in the power generation and it remains to be the bigger source of carbon dioxide emissions ahead. Consequently, steps are being taken to reduce the usage of fossil fuels. Hydropower, as a renewable energy resource, has brought many benefits to the human society as well as the environment. Hydropower can produce electricity without affecting the quantity of water. Hydroelectric power plants with the accumulation reservoirs offer incomparable operational flexibility. It can immediately respond to fluctuations in the demand for electricity and it is not intermittent. Hydropower provides the higher efficiency due to the flexibility and storage capacity of hydropower plants. Moreover, 22% of the power generation comes from hydropower, and this means that hydropower has a high potential to replace fossil fuel as it is also the main renewable energy sources in the G7 countries.

Hydroelectricity increases the stability and reliability of electricity systems. In order to meet peak demands, the operation of electricity system depends on the rapid and flexible generation sources to maintain the system voltage level. It also quickly re-establishes supply after a blackout. The power production from hydropower is considered quicker than other energy sources in terms of stability and reliability. The capacity could reach maximum in a rapid and foreseeable manner, making it appropriate for addressing alternations in the consumption and providing ancillary services to the electricity systems.

The installation of hydroelectric or hydropower brings a lot of benefit to communities such as electricity, highways and industry. This can enhance and develop the economy, improve the quality of life, provide good expansion to health and education. Hydropower is also a fundamental instrument for sustainable development. According to World Commission on the Environment and Development, the hydroelectric power plants are operated in a manner that is economically viable, environmentally sensible and socially responsible. The main setback for the adoption of this technology is that large hydropower plant demands for huge deforestation. This would direly result in the destruction of critical ecosystems, migration of large population at downstream and other catastrophic outcomes such as flash floods and landslides. However, this singular requirement/setback can be solved with the utilization of small or micro hydropower plant. The latter technology, in particular, is found to have minimal destruction effects to the environment and is able to produce affordable energy to the rural areas as it has proven in many European countries.

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