CHEMICAL ENGINEERING TRANSACTIONS

VOL. 89, 2021

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Jeng Shiun Lim, Nor Alafiza Yunus, Jiří Jaromír Klemeš

ISBN978-88-95608-87-7; **ISSN** 2283-9216

DOI: 10.3303/CET2189033

Flood Impact on Renewable Energy System in Malaysia

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Renewable energy, often referred to as clean energy is derived from natural resources and does not deplete when used. Malaysia targets to achieve 31 % renewable energy generation by 2025. The availability and reliability of renewable energy resources are highly vulnerable to climate conditions. Floods, which account for almost 40 % of natural disaster can adversely affect energy resources generation, transmission and infrastructure. Malaysia as a tropical country is especially prone to floods due to the high average rainfall it receives annually. Malaysia energy policy planning has placed more emphasis on efficiency of generation and emissions reductions. The need to adapt to flood disasters and other climatic change challenges has not been adequately addressed. Due to the flood risk in Malaysia, adaptation to climate change and disasters such as flood needs to be considered in Malaysia's energy policy planning. This paper reviews scholarly papers and news articles related to the flood phenomenon in Malaysia, and analyses the impact of flood disasters on renewable energy generation and energy policy planning in this country. The findings indicate that flood has an insignificant effect on Malaysia's renewable energy power generators as they are not located in flood-prone areas. The east coast of Peninsular Malaysia, which is exposed to flooding during the monsoon season, is the most vulnerable to flood disasters. Most renewable energy generation facilities including biomass power stations, hydropower, and solar panels are located on the west coast of Peninsular Malaysia, and in Sabah and Sarawak. The potentially high risk of flash floods and unpredictable climate conditions in Malaysia should not be underestimated and must be duly considered.

1. Introduction

Flood is an overflow of a large amount of water beyond its normal limits, resulting from excessive rain on the land or overflow from the river or streams (Ching et al., 2015). Southeast Asia region such as Malaysia is especially prone to floods. In the rural area, flood is usually caused by river overflow, while in urban lands, it may be due to stormwater drainage, which causes flash floods (Samsuri et al., 2018). Floods can happen due to many reasons, either because of natural factors or human factors. Overflow of rising rivers or known as river flood is known to be the common cause of flood. Sea-level rise due to storms, hurricanes or tsunami waves, heavy monsoon rainfall and the inability to drain water precipitated on certain areas can also be the factors causing floods (Garcia and Ollero, 2016). Man-made factors such as dam failure, changes in the drainage patterns due to urbanization, agricultural practices, and deforestation can also cause floods (Ching et al., 2015).
Renewable energy plays an essential role in reducing climate change by partially replacing fossil fuel-based energy sources. Their capacity is highly vulnerable to climate conditions such as flood. It is challenging to keep their share in the existing energy system when it comes to reliability and stability (Perera et al., 2020). In energy system design, reliability and availability are critical aspects that should be tackled simultaneously (Orosz et al., 2018). Lee and his team found that natural disasters have a significant and negative impact on oil, renewable, and nuclear energy consumptions (Lee et al., 2021). Although population and infrastructure are most vulnerable to disaster, the impact on the energy sector cannot be neglected. To date, there is limited study about the impact of natural disaster or extreme weather, especially floods on the energy system. To the best of the authors'

Paper Received: 11 May 2021; Revised: 19 October 2021; Accepted: 1 November 2021
Please cite this article as: Ibrahim N.A., Wan Alwi S.R., Abdul Manan Z., Mustaffa A.A., Kidam K., 2021, Flood Impact on Renewable Energy System in Malaysia, Chemical Engineering Transactions, 89, 193-198 DOI:10.3303/CET2189033

knowledge, none of the studies explicitly examined flood impact on the renewable energy system in Malaysia, although flood is the most common disaster in this country.

This paper summarizes the contribution of their authors to a few strategic studies, research workshops, and international conferences related to flood and renewable energy in Malaysia. It provides an interpretation on the energy scenario in Malaysia, impact of flood on renewable energy systems and Malaysia's energy policy to address the research gaps. The overall objective of this study is to give insight into the phenomena of major flood in Malaysia and its effect on renewable energy systems in the country.

2. Flood in Malaysia

Flood is a natural disaster that often occurs in Malaysia because of high average rainfall it receives annually. The climate in this country is humid, with an average annual rainfall of 2,500 mm in Peninsular Malaysia, 3,000 mm in Sabah, and 3,500 mm in Sarawak. Table 1 shows the summary of major flood phenomena which occurred in Malaysia from 1990 to 2020.

Table 1: Major flood events in Malaysia from 1990 to 2021

Date	Location	Flood incident description	Reference
15 January 2021	Sabah and Sarawak	Almost 2,000 people have evacuated their home in Sabah, and about 4,000 affected in Sarawak.	(Davies, 2021)
8 January 2021	Johor, Pahang, Terengganu, Kelantan, Sabah, Sarawak	More than 48,000 people in six Malaysian states have been evacuated. The worst affected state is Pahang, where about 27,000 residents have been evacuated.	(Hassan and Ng, 2021)
28 December 2014	Kelantan	The worst flood in Kelantan, in which 202,000 victims were displaced.	(Baharuddin et al., 2015)
December 2011	Kuala Lumpur and Selangor	La Nina phenomenon and monsoon seasons (which brought floods- "terrible twins").	(Diya et al., 2014)
December 2010	Kedah and Perlis	An estimated 45,000 hectares of rice fields had been destroyed. More than 50,000 evacuated and four people were killed. Over two-third of Perlis land was submerged.	(Buslima et al., 2018)
December 2006-January 2007	Johor	Eighteen deaths and USD 489 million in damage.	(Chan, 2012)
November - December 2000	Kelantan, Terengganu, Kedah	15 people were killed in Kelantan and Terengganu. More than 10,000 people lost their homes in Kedah.	(Chan, 2012)
December 1996	Sabah	241 people were killed and more than USD 97.8 million in damage due to floods brought by Tropical Storm Greg in Keningau, Sabah.	(Chan, 2012)

There are many types of floods namely river floods, flash floods, urban floods, surface water floods, monsoon floods and coastal floods. Flash floods and monsoon floods are the most common in Malaysia, according to the Malaysian Drainage and Irrigation Department (DID, 2009). Flash floods normally occur in the city for a short period, and it takes only few hours to return to the normal water level. This phenomenon is due to man-made factors such as infrastructure development near the river areas and disposal of solid wastes into the river (Mohd Taib et al., 2016). A month-long monsoon flood occurs from May to August for the Southwest Monsoon and November to February for the Northeast Monsoon (Othman et al., 2014). This phenomenon is summarised in Table 1, where most of the flood events occurred from November until January. The east coast (Pahang, Kelantan and Terengganu), the southern part of Peninsular Malaysia (Johor), east coast Sabah and Sarawak are susceptible to the Northeast monsoon flood.

A flood could affect the country's quality of life and economic growth. This phenomenon can result in severe damage of property, and on rare occasions, loss of human lives. From Table 1, it can be seen that Kelantan was hit by the worst flood so far, in which 202,000 victims were affected, and the damage amounted approximately MYR 200 million.

3. Energy scenario in Malaysia and flood impact

Figure 1 illustrates the primary energy share in Malaysia for the year 2019. Malaysia is one of the top oil and natural gas producers in the Southeast Asia region after Indonesia (Energy Information Administration, 2021). As a country that is rich in these resources, Malaysia has been relying on fossil fuels for a long time. To date, by referring to Figure 1, energy mix in Malaysia has been monopolized by coal, natural gas and oil for electricity generation (Energy Commission Malaysia, 2019). Malaysia's energy mix is becoming more carbon-heavy as coal had increased from 5 % in 1996 to more than 20 % in 2018. This situation is different from other countries which aim to reduce coal usage in their energy mix.

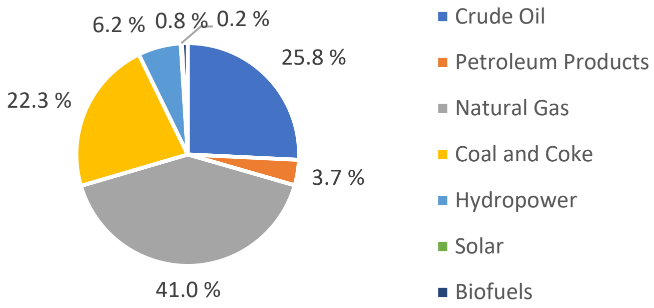

Figure 1: Energy mix Malaysia (Energy Commission Malaysia, 2019)

Renewable energies such as hydropower, wind, solar and biomass cover a variety of energy sources that are renewable and often referred to as clean energy. It comes from natural sources or processes that are constantly replenished (Shinn, 2018). Renewable energy in Malaysia consists of three types; hydropower, bioenergy (biomass, biogas, and biodiesel) and solar. Malaysia government has set a 31 % of renewable energy by 2025. As shown in Figure 1, renewable energy types (excluding hydropower) is below 2 % in the total energy mix. This situation might be because of the difficulty in balancing the three elements of energy trilemma for renewable energy use in Malaysia; affordability and access, energy security and environmental sustainability. There is variability or uncertainty in the supply of solar energy because solar farms only produce power when the sun is shining. It might be harmful for the industrial and commercial sectors to highly depend on solar energy since these sectors consume more than 80 % of the country’s electricity supply (The Star, 2021). Solar energy shows the lowest share of energy mix in Malaysia, although this country has high average of solar radiation annually. This is because of the uneconomical of photovoltaic cells and solar electricity tariff rate (Mekhilef et al., 2012).Due to that reason, mass research and development on solar energy need to be done in order to enhance the photovoltaic market in Malaysia.

Malaysia has become one of the largest hydropower potential areas among ASEAN countries since this country has many water source from 189 rivers with high temperature (28 – 33 °C) and high rainfall volume and humidity out of season (Abdullah et al., 2019). In Malaysia, hydroelectric power plant that is generally used is an impoundment facility. It is a large hydropower system that operates by using a dam to store river water in a reservoir. There are about 149 mini-hydropowers in this country since Malaysia has abundant streams flowing to foothills (Hussein and Raman, 2010). Small hydropower had already been proven to be a practical and potential low-cost option for generating electricity in sub-urban or small village areas compared to the non-economical extension of a grid system. Bioenergy is a renewable energy source derived from biological sources, including biogas, which can then be used to produce energy. Malaysia produces approximately 168 Mt of biomass, including resources from palm oil waste, rice husks, coconut waste, sugar cane waste, municipal waste and forestry waste. As one of the largest palm oil producers in the world, Malaysia has abundant potential resources from biomass. In terms of potential, biomass potential in Malaysia can generate up to 2,400 MW (Ozturk et al., 2017). Malaysia has the highest potential for solar uptake as it is strategically located near the equator, and the weather is hot and sunny throughout the year. The average solar irradiation for Malaysia is estimated at 400–600 MJ/m^2 per month. The estimated potential for solar generation can reach up to 6,500 MW. There are two main categories of solar energy applications in Malaysia namely solar thermal application and photovoltaic (PV) technologies (Mekhilef et al., 2012).

Based on the previous section, it is proven that flood regularly happens in Malaysia. A natural disaster such as flood will certainly affect the energy sector. Although impacts on energy supply and demand are the most intuitive, flood can also directly affect energy resources, infrastructure, and transportation, and indirectly affect other economic sectors (Ebinger and Vergara, 2011).

4. Impact on renewable energy systems

Renewable energy is highly vulnerable because of its dependency on weather and climate. Energy systems consist of energy resources, supply, demand, transmission and infrastructure. Table 2 summarises the flood impact on renewable energy systems in Malaysia. As shown in Table 2, renewable energy resources are highly affected by floods, especially bioenergy production. Crops productivity will be reduced, and the areas suitable for growing bioenergy crops are affected if a flood happened (Cronin et al., 2018). From Table 2, hydropower generation might be boosted because of flood due to higher rainfall. Some hydropower units have been temporarily closed to minimize any discharge of water that could worsen the flooding, hence, limiting hydropower output (Quaranta et al., 2020). In October 2013, four people died and 100 houses were destroyed because of flash flood in the catchment area of the Ringlet reservoir behind the Sultan Abu Bakar dam. The water level increased rapidly due to sedimentation in the reservoir. The amount released was unable to be controlled sufficiently because of inefficient control system from the dam (Hill, 2013). Flood could potentially increase the risk of physical damage for all renewable energy transmission and infrastructure. Floodwater that brings together the large sediment and debris loads can block dam spillways, and powerful masses of water can damage important structural components (Blackshear et al., 2011).

Table 2: Summary of impact of flood on renewable energy system

	Hydropower	Bioenergy	Solar	References
Resource	Increased river run-off and higher water levels. Flood gates are opened.	Reduced net primary production of feedstocks	Loss of effective generating capacity because of physical damage	Ebinger and Vergara (2011)
Supply	Increased electricity generation.	Decreased electricity generation	Decreased electricity generation	Quaranta et al. (2020)
Demand		-	-	
Transmission	Increased risk of physical damage	Increased risk of physical damage	Increased risk of physical damage	Allen-Dumas et al. (2019)
Infrastructure	Physical damage-destructive to dams, increased turbidity of the water heading to the hydraulic generator	Potentially damage computerized control units installed on biomass plants, anaerobic digesters and other waste-to-energy plants.	Reduced output, material damage, and need for cleaning	Blackshear et al. (2011)

Based on the summary in Table 2, there is insufficient data to draw any conclusions about the impact of flooding on energy demand. If the ambient temperature rises, such as during a drought, energy demand will increase, but floods will have less of an impact (Ebinger and Vergara, 2011). In this section, the data on primary energy supply for renewable energy sources in Malaysia and energy demand in terms of electricity in Figure 2 are analysed.

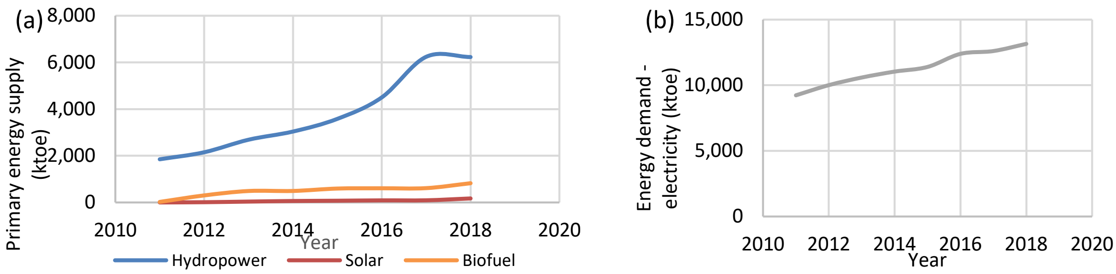

Figure 2: a) Primary energy supply in Malaysia for renewable energy source and b) Total energy demand in Malaysia based on electricity from renewable energy sources (Energy Commission Malaysia, 2019)

A general conclusion that can be made from the graph trend in Figure 2a and 2b is that currently, the flood has not significantly affected the amount of energy supply and demand in Malaysia. This situation could be due to the fact that renewable energy power generators are typically not located in flood-prone areas. The east coast of Peninsular Malaysia is prone to flooding due to monsoon flood (Ismail and Tahereh, 2018). Meanwhile, most of the biomass power stations, hydropower and solar panels are built on the west coast of Peninsular Malaysia, Sabah and Sarawak. This condition should not be underestimated since this country still has a high risk of flash floods and unavoidable climate consequences in the future.

5. Impact on energy policy and planning

In 2011, Malaysia had executed the Renewable Energy Act 2011 and implemented the Feed-in Tariff (FiT) scheme to deploy renewable energy as part of its national energy mix (Abdullah et al., 2019). By 2025, Malaysia has targeted 20 % of renewable energy generation sources from the total generation mix. It is quite challenging since this country is very dependent on fossil fuels resources. The inefficiency in the enforcement and implementation has resulted in renewable energy to have less than 2 % of the energy mix even after more than a decade since its introduction and numerous relevant programmes had been done (Oh et al., 2018). Despite more than five decades of flood disaster management, Malaysia is still subjected to severe floods, and it will never be flood-free. Even though disaster management has received considerable attention due to its impact on one's country, Malaysia is not prepared for it (Mohd Taib et al., 2016).

Floods will continue to impact the people and have destructive effects on life, properties and infrastructure, including energy systems. Energy policy formulation of a country and technological alternatives evaluation could also be affected by extreme weather and natural disaster including floods. Some climate risks had been included in their operation and planning. Energy systems' vulnerability to climate can be reduced by taking appropriate adaptation measures such as building capacity, improving information for decision-making, and integrating climate risks into management and operational decisions. The country's energy policy and planning should be tailored based on the diversity of energy needs and supply options and varying degrees of exposure to extreme weather (Ebinger and Vergara, 2011). To the best of the authors' knowledge, energy policy and planning in Malaysia has neglected the impact and future risk of extreme weather on the energy system due to the stable climate of the country. As flooding will continue and might become worst in the future due to climate change, it may be advisable to include contingencies for increased intensities and frequencies in risk management.

6. Conclusions

In Malaysia, flash and monsoon floods are the most common. The flood events often occur from November until January caused by the Northeast monsoon flood affecting the east coast (Pahang, Kelantan and Terengganu), the southern part of Peninsular Malaysia (Johor), and the east coast of Sabah and Sarawak. Renewable energy resources are highly affected by flood, especially bioenergy production. Hydropower resource generation might be boosted because of flood due to higher rainfall. As flood becomes worst, hydropower units might temporarily be closed to minimise any discharge of water, hence, limiting hydropower output. Renewable energy demand and supply in Malaysia may not be affected by the flood. Climate risk and consequences in the future should not be underestimated. Current Malaysia energy policy and planning has neglected the impact and future risk of extreme weather on the energy system because of the stable climate of the country. As flooding will continue and might become worst in the future due to climate change, the contingencies for increased intensities and frequencies in risk management, especially for the sustainability of renewable energy systems in Malaysia is of utmost importance. The vulnerability of renewable energy to the consequences of flood can be reduced by considering adaptation responses such as increasing the height of hydropower dam, improving design of solar panels to withstand floods, introducing the new crops for bioenergy production with higher water stress tolerance, relocating into areas with lower risk of flooding, or developing early warning system.

Acknowledgements

The authors would like to gratefully acknowledge the financial support from the Malaysia Ministry of Higher Education, Fundamental Research Grant Scheme with Vote Number: FRGS/1/2020/TK0/UTM/01/3 for this research project.

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