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AN OUTLOOK ON HYDROPOWER IN MALAYSIA: POLICIES, CONDITIONS, AND THE POTENTIAL OF SMALL HYDROPOWER IN MALAYSIAN RIVERS AS A NEW NORM IN RENEWABLE ENERGY

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ABSTRACT

The demand for electricity in Malaysia is increasing rapidly due to network expansion and economic growth. Renewable energy (RE) presents an excellent alternative to solve the energy crisis in countries that largely rely on depleting fossil fuels to generate power. Acknowledging the need for an energy transition, the Malaysian government implemented many policies and regulations to facilitate the adoption of RE. Hydropower is one of Malaysia's primary RE resources, used in almost every state to supplement the national power grid via large power stations and mini-stations. It is green and produces minimal CO2 emissions. However, large hydropower projects in Malaysia have negatively impacted cultivation lands, the ecosystem, and the displacement of indigenous communities. Therefore, this paper aims to discuss Malaysia's existing policies regarding RE development projects, the benefits and potential sites of small-scale hydropower projects, as well as the way forward for their implementation.

Keywords: *Green energy, Small hydropower, Renewable energy, Malaysian river*

INTRODUCTION

Malaysia is expected to see an increase in energy demand in the coming years. In the last 10 years, the electricity demand in Malaysia has increased by roughly 4.8% due to lifestyle modernization and is projected to exceed 150,000 GVh by 2030 (Ahmad et al., 2020). Fossil fuels are projected to make up a substantial portion of the energy mix, ranging from 33 to 50 % (International Energy Agency, 2019; Shi, 2016; Trueman, 2018). With most electricity generation in Malaysia still dependent on natural gas and coal, there is a growing concern to explore alternative power generation sources (Behrouzi et al., 2016).

Renewable energy (RE) has emerged as one of the fastest-growing alternatives worldwide for sustainable and low-carbon energy generation (BP p.l.c, 2020). RE has become crucial in finding solutions to depleting fossil fuel resources and mitigating the harmful effects of CO2 emissions. Researchers are investigating various sources of RE, such as wind, water movements (including river flows and waves), geothermal heat, sunlight, and vibrations, to substitute fossil fuels for power generation. According to the International Renewable Energy Agency (IRENA), in 2020, RE sources contributed to 36.6% of the world's total installed capacity (International Renewable Energy Agency, 2020). Therefore, Malaysia has set a target to increase RE share to 31% or 12.9 GW by 2025 and 40% or 18.0 GW by 2035 (Sustainable Energy Development Authority Malaysia, 2021). The Malaysian government has also introduced many policies and regulations to support RE implementation as a move towards a more sustainable and green energy approach (International Renewable Energy Agency, 2020).

Hydropower is a clean and cheap RE source, generating almost zero CO2 emissions with no dangerous production of byproducts. Several countries have made investments in hydropower, resulting in significant installed capacities, as shown in Figure 1 (Hossain et al., 2018; International Energy Agency, 2021). This rapid implementation of clean hydropower-producing sources has caught the attention of ASEAN countries, which have taken an interest in developing clean RE sources (Economic Research Institute for

ASEAN and East Asia, 2020). This shows that hydropower as an RE source has a high economic and sustainability value compared to other sources. The government policies on RE are discussed in detail in Chu & Majumdar (2012), and the authors have mentioned the key advantages of RE development in the energy sector. Furthermore, many ASEAN national energy councils are standardizing the mechanism and guidelines for RE standards and net metering policies (Asian Development Bank, 2016; Chaianong et al., 2019; Erdiwansyah et al., 2019).

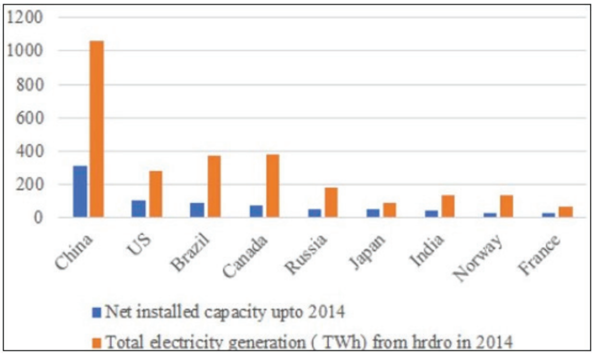

Figure 1. Top Hydropower-producing Countries Worldwide

Source: International Energy Agency, (2021)

In Malaysia, hydropower currently comprises roughly 11% of the country's total electricity generation, higher than any other RE sources. The percentage of hydropower is expected to increase to 35% by 2030 (S. Tang et al., 2019). Most of the hydropower in Malaysia comes from large-scale hydropower stations (Abdullah et al., 2019). However, due to the high cost, long construction duration, and severe negative impacts of large-scale hydropower stations, it is becoming less desirable to build (Yusop et al., 2017).

Malaysia has extensive hilly areas and a vast network of rivers, providing abundant opportunities for hydropower generation. Moreover, the country's annual rainfall of 2,500 mm results in sufficient water storage for large-scale hydropower production across all its states (Hossain et al., 2018).The central highlands, which form the watershed between Malaysia and Indonesia, set the drainage pattern of East Malaysia. The streams, which are perennial due to year-round rainfall from the cycle of monsoon seasons, create a dense network covering the entire region (Tun Jamil et al., 2018). Geographically, Malaysia is rife with abundant intricate rivers and streams flowing throughout the country. Rivers in Malaysia flow all year long with little natural interruption, but due to the constant rainfall (Lockard et al., 2019; World Atlas, 2021), the volume of transported water fluctuates with the localized and torrential nature of the rainfall. These geographical characteristics provide river streams for hydropower generation in Malaysia, offering numerous suitable sites for small hydropower projects (Yah et al., 2017). This paper aims to discuss Malaysia's existing policies regarding RE development projects, the benefits and potential sites of small-scale hydropower projects, as well as the way forward for their implementation.

EXISTING RENEWABLE ENERGY (RE) POLICIES IN MALAYSIA

Malaysia is committed to stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system as a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) Kyoto Protocol. To achieve this goal, Malaysia needs to develop and utilize RE as an alternative to fossil fuel-derived energy while preserving fossil fuels through more effective energy utilization (Abdullah et al., 2019). RE was established and promoted in Malaysia decades ago, with many policies, programs, incentives, and funding to encourage RE development (Hamdan et al., 2014). These policies are listed as (Shamsuddin, 2012):

1.Four Fuel Diversification Policy, 1981
2.Fifth Fuel Diversification Policy, 2000
3.National Bio-fuel Policy, 2006
4.National Green Technology Policy, 2009
5.National Renewable Energy Policy, 2010

Together with oil, gas, and coal, the Malaysian government identified hydropower as one of the four fuels in the Four-Fuel Diversification Policy. Other RE sources were added as the fifth fuel, leading to the introduction of the Fifth-Fuel Diversification Policy. In keeping with the Fifth-Fuel Diversification Policy, the National Biofuel Policy was developed to encourage the use of biofuels, which aimed to reduce reliance on fossil fuels that cause significant greenhouse gas emissions. Subsequently, the New Energy Policy was introduced to consider the economic, environmental, and social aspects of ensuring energy security (K. H. D. Tang, 2020). Malaysia has also developed the National Green Technology Policy to demonstrate the country's commitment to promoting a sustainable economy based on clean and green technologies (Shafie et al., 2011).

By 2020, several objectives were listed to be achieved in Malaysia under the National and International Renewable Energy Policy 2010 and action plan, including increasing RE contribution in the national power generation mix, facilitating the growth of the RE industry, ensuring reasonable RE generation costs, conserving the environment for the future generation, and enhancing awareness of the role and importance of RE (Ahiataku-Togobo, 2014; International Renewable Energy Agency, 2020; Song, 2015). The expected impact of these objectives includes a minimum of MYR 2.1 billion in savings in external costs to mitigate CO2 emissions, with a total of 42 million tonnes avoided from 2011 to 2020 based on MYR 50 per tonne of external cost. Additionally, a minimum of MYR 19 billion of loan values for RE projects will provide local banks with new sources of revenue, and a minimum of MYR 70 billion of RE business revenues will be generated from RE plants operation, which can generate taxable income of a minimum of MYR 1.75 billion for the government. Furthermore, the construction, operation, and maintenance of RE power plants will require 50,000 jobs, based on 15-30 jobs per MW.

These policies and impact expectations demonstrate Malaysia's commitment to implementing RE. The government aims to save nearly MYR 5 billion by utilizing at least 5% of RE in the energy mix operation within five years (Khor & Lalchand, 2014). The government took another step forward in the Eleventh Malaysia Plan (2016–2020) by focusing on reducing the national dependence on fossil fuels while continuing to develop reliable and affordable energy resources. In 2018, Malaysia created an objective to achieve a 20% RE mix by 2025, supporting the Incentive-Based Regulation (IBR) launched in 2014 to reduce fuel subsidies and promote RE implementation (Abdullah et al., 2019).

To streamline emerging RE projects, the Malaysian Ministry of Energy, Green Technology, and Water (KeTTHA) established the Special Committee on Renewable Energy (SCORE) to review small-scale RE projects before their approval (Yah et al., 2017). The ministry has also proposed a new RE policy to boost the usage of suitable hydropower sites and subsidize the national electricity supply and sustainable economic development projects. As a show of appreciation, the government recognized small-scale hydropower contributors to inspire Malaysia's many institutions and industry leaders to be involved in small hydropower projects (Kadier et al., 2018).

HYDROPOWER GENERATING RESOURCES IN MALAYSIA

Malaysia has over 20 large operational hydropower plants with a total generation capacity of over 2,100 MW. Hydropower makes up 92.55% of the total RE used in Malaysia, contributing 8.7% of the country's whole energy generation. This includes power generation by fossil fuel, gas, and coal (Aslam & Zulkifli, 2013; Izadyar et al., 2016). Globally, hydropower generation in Malaysia only accounts for 0.22%. The national electricity supplier, Tenaga Nasional Berhad (TNB), manages and maintains over 50 mini hydropower stations distributed between seven states, including Perak, Terengganu, Kedah, Kelantan, Pahang, Sarawak, and Sabah. These TNB-operated mini hydropower stations have a total power capacity of approximately 16,643 kW (Pratap Nair & Nithiyananthan, 2016). In West Malaysia, there are 36 mini- scale hydropower stations, while in East Malaysia, there are nine in Sarawak and five in Sabah (Kadier et al., 2018). On average, these power stations yield 15 GWh annually. Figure 2 and Figure 3 show the distribution of identified mini hydropower power stations in East and West Malaysia.

Several public-licensed mini hydropower stations are operated by private sectors, such as AMDB Perting Hydro Sdn. Bhd. in Sg. Perting, Pahang (4.2 MW) and Esajadi Power Sdn. Bhd. in Sg. Kaingaran (2.5 MW), Sg. Kadamaian (2 MW), and Sg. Pangpuyan (4.5 MW), all located in Sabah, as shown in Figure 3 (Badrin, 2012). The privately owned mini hydropower stations, including those not listed, have a combined installed power capacity of 28.993 MW, as shown in Table 1. Other hydropower plants and dams in Malaysia are currently in the feasibility and planning stages in Lawas, Limbang, Mejawa, Baram, Belaga, and Puna Bah (Durin et al., 2022). However, the development of large hydropower projects will not proceed until feasibility studies and social and environmental impact assessments have been completed. This is due to the numerous environmental concerns that arise, including the impact of flooding.

Table 1. Installed Capacity of Private Sector-owned Mini Hydropower Stations in Malaysia

Location	State	Capacity (MW)
Peninsular Malaysia	Kedah	1.556
	Perak	3.207
	Terengganu	1.936
	Kelantan	3.158
	Pahang	3.504
East Malaysia	Sabah	8.335
	Sarawak	7.297
Total		28.993

Source: Author

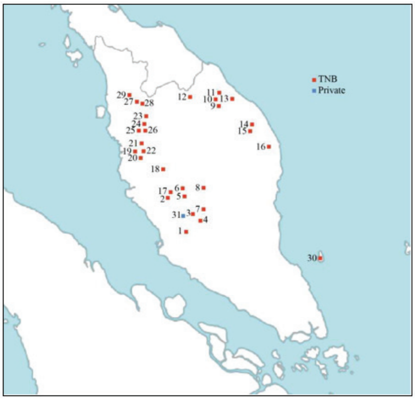

Figure 2. Distribution of Mini Hydropower Stations Operated by TNB and Private Sector in Peninsular Malaysia

Source: Author

Figure 3. Locations of Public-licensed Mini Hydropower Stations Operated by the Private Sector in East Malaysia

Source: Author

IMPACTS OF LARGE HYDROPOWER PROJECTS IN MALAYSIA

The construction of large dams has submerged about 400,000 km2 of land across the globe. The construction of the Baram Dam on the Sg. Asap that was shelved in 2015 would have flooded more than 2,000 km2 of the rainforest, causing irreparable damage to the surrounding ecological state. The Bakun Dam alone had submerged 700 km2 of land, equivalent to the size of Singapore. The flooding decimated plant and animal endemism, especially unique species exclusive only to the location. There are 32 protected bird species, more than 1,600 protected plants, as well as several rare or endangered fish and mammals affected by the Bakun Dam (Faizal et al., 2017).

Similarly, the Batang Ai Dam in Lubok Antu, Sarawak, relocated the communities and a portion of the rainforest due to the construction and flooding caused by the dam. Thousands of indigenous people who lived in that area were also forced to relocate due to the construction of the Bakun Dam. Furthermore, the construction of Murum Dam took up 24,500 hectares of the reservoir area and 275,000 hectares of the catchment area. The displacement of over 700 people has forever impacted the natural way of life of those who lived there (Aeria, 2016).

A study has also shown that bats residing near hydropower stations have significantly higher mercury concentrations in their bodies (Syaripuddin et al., 2014). Bats consume insects emerging from aquatic systems, where bacteria transform inorganic mercury, naturally present in soil and plants, into toxic methylmercury, which enters the food webs of the aquatic insects. The proposed and canceled construction of dams around the Mulu National Park, which houses the world's largest cave, would have deteriorated the water quality in that area, affecting aquatic animals' food chains and breeding grounds (Faizal et al., 2017). The negative impacts of large-scale hydropower projects are hard to mitigate, even if proper environmental assessments are conducted.

SMALL-SCALE HYDROPOWER PROJECTS IN MALAYSIA

A small-scale hydropower system, in essence, is just the shrinking of a large- scale hydropower system. They share the same working technology, albeit with inconsistent power production rates. The same size of small hydropower systems can produce different power output rates at different locations due to their non-dependency on man-made reservoirs. While small hydropower systems possess this disadvantage, it is also due to this characteristic that they can accomplish much lesser negative impacts on their surroundings. To combat the inconsistencies, a more accurate site survey can be done to predict whether the site is suitable for a particular size hydropower project. The small size also simplifies the system's construction, reduces the cost, and opens up many more locations for implementation while having a significantly lesser impact on its surroundings. These traits made small-scale projects more flexible and achievable for smaller organizations.

Small hydropower projects are not a new concept in Malaysia. Nearly 70% of published hydropower studies conducted in Malaysia until 2021 have been done on small projects (Yap & Yap, 2021). These studies have mainly focused on the social, environmental, and economic aspects of small hydropower projects. Additionally, there have been a few successful implementations of small hydropower projects and research on potential sites for future small hydropower projects. For instance, a study conducted in Royal Belum State Park, Perak, found that the locals preferred hydropower as an energy source, and plans to install a micro hydropower plant are underway (Sarip et al., 2016). Still, as of 2023, no relevant news regarding the hydropower project has come out. Another similar project was done in Endau Rompin National Park, Johor, where the ECO-Hydro team from Malaysia Tun Hussein Onn University (UTHM) developed a hybrid micro hydropower project to support a small settlement (Yusop et al., 2017). The project successfully reduced the negative impact of the existing diesel generator financially and environmentally by sharing the power production load.

Some studies have also explored the potential for Malaysia to develop more small-scale hydropower projects to support the national grid and reduce dependence on fossil fuel generators. These studies found that Malaysia has many beneficial characteristics in terms of geography, socioeconomic conditions, and experience that support the development of future small hydropower projects (Abdullah et al., 2019; Hossain et al., 2018; Kadier et al., 2018; S. Tang et al., 2019; Yah et al., 2017).

THE POTENTIAL AND BENEFITS OF SMALL-SCALE HYDROPOWER PROJECTS IN MALAYSIA

Malaysia has a favorable geographical advantage with abundant high-elevated terrains and a vast network of river systems branching throughout the country, providing numerous promising sites for small hydropower systems. These systems can be installed as an alternative to fossil fuel generators or large hydropower stations, which can hugely contribute to overcoming energy problems in remote and hilly areas. As mentioned before, small-scale hydropower projects are considered more environmentally favorable due to their smaller footprint both in carbon and space, and impact lesser damage to their surroundings compared to large-scale hydropower projects and fossil fuel-powered facilities. It can also bring significant socioeconomic development and the possibility for off-grid connections to serve as a decentralized power generation network from small hydropower to the surrounding areas. Currently, there are over 109 identified potential sites for small-scale hydropower systems throughout the peninsular, with a combined estimated power of 20,407.3 kW, mostly in Pahang (26 sites) and Perak (34 sites) for a total estimated power of 14,781 kW (Raman et al., 2009). In context, a 1 kW hydropower system can satisfy the annual electricity usage of 1 average home.

The conventional method of harnessing hydropower, which involves dams, has been proven to create significant undesirable environmental effects (Botelho et al., 2017). In contrast, smaller hydropower projects can minimize the damage caused by large projects. Small hydropower projects are ideal for streams or rivers with a minimum dry weather flow or those regulated by a larger reservoir upstream. Due to its low start-up cost, flexibility on location, less complex maintenance, and fewer operation workforce needed, developing countries can adopt this system to supply power to small communities in isolated areas where the national power grid system extension is uneconomical. Apart from fossil fuel-based generators, many individuals living in remote areas rely on small hydropower systems as the primary source of energy generation, mainly when utilized on a stable river stream, and are often used to charge home batteries. Therefore, this energy source is considered economical since it can generate energy without purchasing fuel or other consumables (Yah et al., 2017).

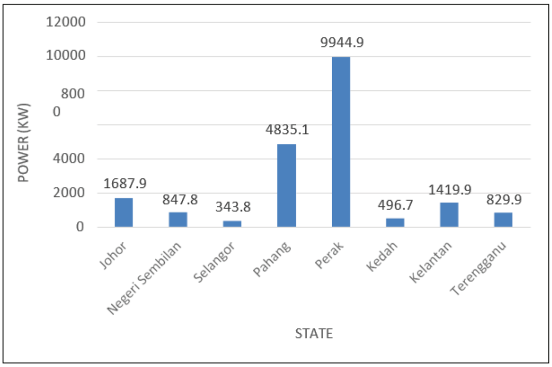

Figure 4. Potential Hydropower Production in Malaysia

Source: Author

The potential power production for hydropower systems in Malaysia is summarized in Figure 4, while Tables A1 to A8 in the appendix present detailed data on the potential sites across different states in Malaysia. Although some states are not included due to the unavailability of verifiable data, it is evident that Malaysia could greatly benefit from a more progressive move towards small-scale hydropower programs. This move can utilize its many potential hydropower sites and further reduce the dependence on coal, fossil fuels, and large hydropower facilities, especially in isolated areas near moving water. Micro or Pico hydropower systems, which are environmentally friendly and relatively cheap in start-up and maintenance costs, can also be encouraged for further development. Local researchers have shown interest in developing small hydropower projects, as documented by Yap & Yap (2021), who reported ongoing small hydropower projects all over Malaysia.

OBSERVATION AND RECOMMENDATIONS

Hydropower has become the most reliable RE source in Malaysia. The government has established five RE initiatives and a committee to evaluate new proposals for RE projects. However, the implementation of RE in Malaysia is progressing too slowly. Although there is interest in developing small-scale hydropower projects in Malaysia, most are constructed for academic purposes. There is practically no movement to push for the government to encourage or incentivize the development of small-scale hydropower projects.

To reiterate, constructing large-scale hydropower stations will negatively impact the environment and nearby ecosystems. Small-scale hydropower projects, on the other hand, have minimal impact and should be developed to address the concerns that come with large-scale hydropower projects. With abundant rivers and decent rainfall, Malaysia's geographic advantage provides numerous suitable sites for these projects. This country can significantly reduce its dependence on coal, fossil fuels, and large hydropower projects by encouraging more small hydropower projects to be constructed.

The following are recommendations for the development of small hydropower in Malaysia:

1. The Malaysian government should promote more private- sector investment in hydropower generation under the Small-Scale Renewable Energy Program (SREP). Under this program, there are several incentives for constructing hydropower plants and selling electricity under a green

technology financing scheme with fiscal advantages (Hossain et al., 2018). Hence, the development of small hydropower plants with high head streams can be identified and prioritized, which have the potential to generate more electricity and provide greater benefits.

2. More efforts must be undertaken to raise awareness among policymakers about the contribution of hydropower to reducing greenhouse gas emissions and the reliability of the energy supply. Presently, only large- scale hydropower facilities are regarded as RE. Policymakers need to consider the benefits of small-scale hydropower facilities, including their reasonable initial investment, long lifespan, as well as low operation and maintenance costs. Additionally, it should be noted that hydropower has one of the highest conversion efficiencies of all known energy sources, making it a desirable option for RE.

3. Small-scale hydropower development in Malaysia faces challenges that need attention from experts in the field. There is a lack of technical expertise to assess risk and identify solutions, especially for water shortages, variable river flows, and sedimentation issues. It is necessary to conduct more comprehensive research on sedimentation to effectively address the issues and facilitate their management in small-scale hydropower systems. Policymakers should consider providing incentives and support for research to enable the successful implementation of small-scale hydropower projects.

4. Hydropeaking is the fluctuation in river flow caused by a sudden release of stored water (Vaidya et al., 2021). While not common in Malaysia, it is wise to also address how hydropeaking may alter the facilities of downstream regimes during peak hours of demand if the hydropower system usage warrants it. Operational schemes should be explored to modify sub-daily variability hydropeaking to prevent the downstream flow according to the season. This can be achieved by adjusting the flow rate during peak hours or creating additional reservoirs to store water during off-peak hours for use during peak hours.

CONCLUSION

Malaysia has a high potential for RE, including hydropower, due to its location in the equatorial region with high rainfall and abundant water resources. This paper also found that Malaysia holds many potential hydropower sites that can be tapped for small-scale hydropower projects. Although many policies and programs have been implemented to support RE, including integrating hydropower into the grid, there is still much room for improvement in mitigating the environmental impacts associated with large hydropower facilities. The effects on the local ecosystem and environment due to the use of dams for hydropower generators cannot be ignored, as the situation is getting worse daily. Exploring alternative and cleaner hydropower methods is crucial to minimize environmental damage. Small-scale hydropower systems show promise for Malaysia, providing potential for sustainable energy generation with minimal ecological impact. It is hoped that this paper can be a catalyst towards the shift for more small-scale hydropower projects to be built, especially to supplement areas that need power but are disconnected from the grid.

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AUTHOR CONTRIBUTIONS

All authors contributed to the research and have read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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APPENDIX A

A.1.Identified micro hydropower potential sites in Johor (Raman et al., 2009)

No.	Stream Name	Site Location	Available Head (m)	Catchment Area (km2)	Annual Flowrate (m3/s)	Available Power (kW)	Possible Energy Demand
1	Sg. Senderet	Orang asli village of Sg. Selai, Bekok	100	6	0.20	117.7	Alternative off-grid generation
2	Sg. Lamyang	Orang asli village of Sg. Kemidak, Bekok	120	8	0.27	190.7	Alternative off-grid generation
3	Sg. Genal	Orang asli village of Sg. Kemidak, Bekok	120	2	0.07	49.4	Alternative off-grid generation
4	Sg. Kemarat	Orang asli village of Sg. Kemidak, Bekok	140	9	0.30	247.2	Alternative off-grid generation
5	Sg. Sechawai	Orang asli village of Kg. Tamok, Bekok	80	6	0.20	94.2	Alternative off-grid generation
6	Sg. Pencharang	Orang asli village of Kg. Tembayan, Bekok	100	15	0.50	294.2	Alternative off-grid generation
7	Sg. Anak Ayer Puteh	Ladang Tangkak, Sagil, Tangkak	200	3	0.07	82.4	Alternative off-grid generation
8	Sg. Ayer Panas	Mt. Ledang recreation park, Tangkak	100	6	0.14	82.4	Alternative off-grid generation
9	Sg. Sagil	Sagil, Tangkak	100	3	0.07	41.2	Alternative off-grid generation

10	Sg. Legeh	Ladang Kebun Bahru, Kebun Bahru, Tangkak	200	2	0.05	58.9	Alternative off-grid generation
11	Sg. Ulu Jementah	Kg. Peng Jongkang, Jementah, Tangkak	100	9	0.21	123.6	Alternative off-grid generation
12	Sg. Ayer Hitam Besar	Mt. Pulai waterfall, Pekan Nenas, Skudai	130	10	0.40	306	Alternative off-grid generation

A.2.Identified micro hydropower potential sites in Negeri Sembilan (Raman et al., 2009)

No.	Stream Name	Site Location	Available Head (m)	Catchment Area (km2)	Annual Flowrate (m3/s)	Available Power (kW)	Possible Energy Demand
1	Sg. Temalai	Orang asli village of Kg. Gelang, Jelebu	100	5	0.07	41.2	Alternative off-grid generation
2	Sg. Kering	Orang asli village of Kg. London, Jelebu	200	7	0.10	117.7	Off-grid Generation
3	Sg. Gemansir	Jeram Toi Waterfall, Jelebu	100	5	0.07	41.2	Alternative off-grid generation
4	Sg. Papan	Felcra Ulu Jelebu, K. Klawang	100	4	0.06	35.3	Alternative off-grid generation
5	Sg. Jelebu	Felcra Ulu Jelebu, K. Klawang	140	8	0.11	90.7	Alternative off-grid generation
6	Sg. Jenam	Felcra Ulu Jelebu, K. Klawang	100	2	0.03	17.7	Alternative off-grid generation
7	Sg. Luat	Orang asli village of Kg. Langkap, Tg. Ipoh	100	4	0.07	41.2	Alternative off-grid generation
8	Sg. Bendol	Kg. Ulu Bendul, Terachi	80	3	0.05	23.5	Alternative off-grid generation
9	Sg. Berlubang	Kg. Bendul, Terachi	120	4	0.07	49.4	Alternative off-grid generation
10	Sg. Ayer Sejok	Kg. Solok Paku, Terachi	160	3	0.05	47.3	Alternative off-grid generation
11	Sg. Sikai	Kg. Bukit, Seri Menanti	180	3	0.05	53.0	Alternative off-grid generation
12	Sg. Jumbang	Kg. Jumbang, Seri Menanti	100	4	0.07	41.2	Alternative off-grid generation

13	Sg. Mungkal	Kg. Mungkal, Gadong, Kota	100	4	0.09	53.0	Alternative off-grid generation
14	Sg. Kendong	Kg. Ulu Kendong, Kendong, Gadong, Kota	130	2	0.04	30.6	Alternative off-grid generation
15	Sg. Batu Hampar	Kg. Empat Batu, Chembong	80	8	0.18	84.8	Alternative off-grid generation
16	Sg. Pedas	Kg. Ulu Pedas, Pedas	80	3	0.07	32.9	Alternative off-grid generation
17	Sg. Ulu Nuri	Kg. Betong, Tampin	200	2	0.04	47.1	Alternative off-grid generation

A.3.Identified micro hydropower potential sites in Negeri Sembilan (Raman et al., 2009)

No.	Stream Name	Site Location	Available Head (m)	Catchment Area (km2)	Annual Flowrate (m3/s)	Available Power (kW)	Possible Energy Demand
				Ulu Langat			
1	Sg. Gabai	Gabai Waterfall	80	9	0.28	131.9	Alternative off-grid connection
				Gombak			
2	Sg. Chul Tinggi	Taman Rimba Templer	200	6	0.18	211.9	Alternative off-grid connection

A.4.Identified micro hydropower potential sites in Pahang (Raman et al., 2009)

No.	Stream Name	Site Location	Available Head (m)	Catchment Area (km2)	Annual Flowrate (m3/s)	Available Power (kW)	Possible Energy Demand
				Bentong			
1	Sg. Tampik	Kg. Ceringing Hulu, Janda Baik	110	2	0.110	71.2	Alternative off-grid connection
2	Sg. Sum Sum	Kg. Sum Sum, Janda Baik	160	1	0.050	47.1	Alternative off-grid connection
3	Sg. Leba	Orang asli village of Kg. Sg. Leba	180	5	0.140	137.7	Off-grid generation
				Temerloh			
4	Sg. Galung	Orang asli village of Kg. Mentuh, Jenderak	80	4	0.100	47.1	Off-grid generation

5	Sg. Rangit	Pusat Latihan Gajah Kuala Gandah	120	5	0.130	91.8	Alternative off-grid connection
Kuantan							
6	Sg. Jerangka ng	Jerangkang Waterfall	240	8	0.250	353.2	Alternative off-grid connection
Kuala Lipis							
7	Sg. Sempar	Orang asli village of Kg. Titum, Hulu Jelai	100	6	0.280	164.8	Off-grid generation
8	Sg. Senuh	Orang asli village of Kg. Kuala Besuk, Hulu Jelai	80	3	0.140	65.9	Off-grid generation
9	Sg. Betau	Orang asli village of Kg. Cerung, Hulu Jelai	120	6	0.280	197.8	Off-grid generation
10	Sg. Sinderut	Orang asli village of Kg. Sinderut, Hulu Jelai	240	8	0.320	452.1	Off-grid generation
11	Sg. Rungak	Orang asli village of Kg. Shean, Hulu Jelai	140	6	0.280	230.7	Off-grid generation
Rompin							
12	Sg. Air Besar	Kg. Tekek, Tioman Island	260	3	0.126	192.8	Off-grid generation
13	Sg. Lalang	Kg. Lalang, Tioman Island	160	4	0.170	160.1	Off-grid generation
14	Sg. Paya	Kg. Paya, Tioman Island	160	3	0.080	75.3	Off-grid generation
15	Sg. Nipah and Sg. Seriah	Tg. Nipah, Tioman Island	120	7	0.290	204.8	Off-grid generation
16	Sg. Keliling	Kg. Juara, Tioman Island	120	4	0.170	120.1	Off-grid generation
17	Sg. Mentawa k	Kg. Juara, Tioman Island	220	5	0.210	272.0	Off-grid generation
18	Sg. Asah	Kg. Asah, Tioman Island	120	3	0.130	91.8	Off-grid generation
19	Sg. Raya	Kg. Mukut, Tioman Island	160	6	0.250	235.4	Off-grid generation
Cameron Highland							
20	Sg. Terisu	Pos Terisu, Orang Asli Settlement	80	10	0.430	202.5	Alternative off-grid connection
21	Sg. Menlock	Kg. Teji, Pos Telanuk, Ringlet	200	11	0.640	753.4	Off-grid generation

22	Sg. Bertik	Kg. Rening, Ringlet	80	5	0.290	136.6	Off-grid generation
23	Sg. Cai	Kg. Renglas, Pos Telanuk, Ringlet	100	7	0.410	241.-	Off-grid generation
24	Sg. Kelow	Pos Mensun, Ringlet	120	7	0.410	289.6	Off-grid generation

A.5.Identified micro hydropower potential sites in Perak (Raman et al., 2009)

No.	Stream Name	Site Location	Available Head (m)	Catchment Area (km2)	Annual Flowrate (m3/s)	Available Power (kW)	Possible Energy Demand
Chenderiang							
1	Sg. Bekut	Kg. Baharu Kinjang	220	5	0.23	297.8	Alternative off-grid connection
2	Sg. Kinchan	Kg. Baharu Kinjang	120	8	0.38	265.1	Alternative off-grid connection
3	Sg. Kinjang	Kg. Kinjang	240	12	0.56	791.0	Alternative off-grid connection
4	Sg. Ijok	Kg. Kinjang	100	7	0.33	194.2	Alternative off-grid connection
Tanjung Malim							
5	Sg. Mut	Kg. Keding	80	18	0.60	282.5	Alternative off-grid connection
6	Sg. Bersih	Pos Bersih Orang Asli Settlement	80	18	0.60	282.5	Off-grid connection
7	Sg. Kerok	Pos Jerenang Orang Asli Settlement	200	6	0.20	235.4	Off-grid connection
8	Sg. Behrang	Kg. Tengah	200	5	0.17	200.1	Off-grid connection
9	Sg. Perah	Kg. Tengah	120	7	0.23	162.5	Off-grid connection
Tapah							
10	Sg. Palapalam	Kg. Semai Orang Asli Settlement	130	5	0.24	183.6	Alternative off-grid connection
11	Sg. Lengkok	Kg. Semai Orang Asli Settlement	80	15	0.70	329.6	Alternative off-grid connection
12	Sg. Batu Sepuloh	Kg. Batu Sepuloh Orang Asli Settlement	100	9	0.42	247.2	Alternative off-grid connection
13	Sg. Ayer Busok	Ladang Orang Asli	160	15	0.70	659.2	Off-grid connection

14	Sg. Bot	Kg. Bot Edit, Tapah	80	11	0.52	244.9	Alternative off-grid connection
15	Sg. Gedong	Pos Bekau, Gedong, Bidor	100	10	0.46	270.8	Off-grid connection
Gopeng							
16	Sg. Chalir	Kg. Sedor, Pos Selim, Simpang Pulai	100	4	0.12	70.6	Alternative off-grid connection
17	Sg. Selim	Pos Selim, Simpang Pulai	120	6	0.18	127.1	Alternative off-grid connection
Kampar							
18	Sg. Kampar	Kg. Jantong, Pos Atap, Kampar	100	10	0.65	382.6	Off-grid connection
19	Sg. Ulu Kampar	Pos Atap, Kampar	80	9	0.58	273.1	Off-grid connection
Larut							
20	Sg. Ayer Itam	Kg. Ayer Itam, Batu Kurau	120	17	1.20	847.6	Alternative off-grid connection
21	Sg. Teras	Kg. Ulu Teras, Selama	140	12	0.85	700.4	Alternative off-grid connection
22	Sg. Tebing Tinggi	Kg. Kelian Gunong, Selama	100	8	0.56	329.6	Alternative off-grid connection
23	Sg. Lata Puteh	Kg. Kelian Gunong, Selama	200	8	0.56	659.2	Alternative off-grid connection
Kuala Kangsar							
24	Sg. Perwor	Pos Perwor	60	33	0.58	204.8	Off-grid connection
25	Sg. Penduk	Kg. Pendeg, S. Siput Orang Asli Settlement	140	12	0.21	173.1	Off-grid connection
26	Sg. Kernam	Kg. Kernam Orang Asli Settlement	120	3	0.05	35.3	Off-grid connection
27	Sg. Hidup	Kg. Dawai Orang Asli Settlement	100	7	0.12	70.6	Off-grid connection
28	Sg. Mu	Orang Asli Settlement along Sg. Mu	60	59	1.00	353.2	Off-grid connection
29	Sg. Gebul	Pusat Latihan Pertanian, Manong	200	8	0.16	188.4	Alternative off-grid connection
30	Sg. Jeliung	Kg. Jeliung Baharu, Manong	120	12	0.24	169.5	Alternative off-grid connection

31	Sg. Serai	Kg. Kelik, Sg. Siput	100	30	0.53	312.0	Alternative off-grid connection
Lenggong							
32	Sg. Dindap	Pos Piah	120	9	0.26	183.6	Off grid connection
33	Sg. Luat	Kg. Talong	100	20	0.27	158.9	Alternative off-grid connection
34	Sg. Dang Lang	Kg. Dang Lang Ulu	100	8	0.10	58.9	Alternative off-grid connection

A.6.Identified micro hydropower potential sites in Kedah (Raman et al., 2009)

No.	Stream Name	Site Location	Available Head (m)	Catchment Area (km2)	Annual Flowrate (m3/s)	Available Power (kW)	Possible Energy Demand
Baling							
1	Sg. Tawar Besar	Kg. Tawar Besar	100	10	0.202	118.9	Alternative off-grid connection
Sik							
2	Sg. Pegong	Kg. S. Limau	100	9	0.250	147.2	Alternative off-grid connection
Langkawi							
3	Sg. Ayer Langkat	Durian Perangin	100	3	0.120	70.6	Alternative off-grid connection
4	Sg. Perangin	Teluk Burau	140	4	0.160	131.8	Alternative off-grid connection
5	Sg. Temurun	Teluk Tok Manap	60	2	0.080	28.2	Alternative off-grid connection

A.7.Identified micro hydropower potential sites in Kelantan (Raman et al., 2009)

No.	Stream Name	Site Location	Available Head (m)	Catchment Area (km2)	Annual Flowrate (m3/s)	Available Power (kW)	Possible Energy Demand
1	Sg. Bertak	Pos Gob, Bertam Orang Asli Settlement	100	4	0.28	164.8	Off-grid connection
2	Sg. Chegeruk	Pos Belaltim, Bertam Orang Asli Settlement	200	5	0.30	353.2	Off-grid connection
3	Sg. Toy	Kg. K. Layang, Bertam Orang Asli Settlement	100	6	0.37	217.8	Off-grid connection

4	Sg. Balar	Kg. K. Balar, Bertam Orang Asli Settlement	60	1	0.05	17.7	Off-grid connection
5	Sg. Nya	Katok Batu Mines	80	3	0.19	89.5	Alternative off-grid connection
6	Sg. Serawok	Pos Brook, Nenggiri Orang Asli Settlement	100	3	0.16	94.2	Off-grid connection
7	Sg. Setog	Fort Ber Orang Asli Settlement	60	7	0.27	95.4	Off-grid connection
8	Sg. Arik	Kg. K. Telur Orang Asli Settlement	80	2	0.11	51.8	Off-grid connection
9	Sg. Perges	Kg. Perges, Bertam Orang Asli Settlement	100	7	0.44	259.0	Off-grid connection
10	Sg. Talong	Fort Hau, Bertam Orang Asli Settlement	100	2	0.13	76.5	Off-grid connection

A.8.Identified micro hydropower potential sites in Terengganu (Raman et al., 2009)

No.	Stream Name	Site Location	Available Head (m)	Catchment Area (km2)	Annual Flowrate (m3/s)	Available Power (kW)	Possible Energy Demand
Besut							
1	Sg. Peng	Kg. Bogil	100	5	0.26	153.0	Alternative off-grid connection
2	Sg. Tadau	Kg. Bogil	100	2	0.11	64.8	Alternative off-grid connection
Dungun							
3	Sg. Bangan	Kg. Pasir Raja	100	19	1.04	612.1	Off-grid connection