Chapter

A Comprehensive Review on Available/Existing Renewable Energy Systems in Malaysia and Comparison of Their Capability of Electricity Generation in Malaysia

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Abstract

Malaysia is one of the fastest emerging and developing countries in the world. To drive the economical workhorse, large amounts of power is required. The power demand has risen to 156,003 GWh per year in the year 2016, almost 30,000 GWh more than 5 years prior. Fossil fuels such as natural gas, coal, oil, and diesel have been the driving force powering Malaysia's grids. However, these resources will not last forever, and they do harm to our environment. To counter this, renewable energy (RE) projects have been constructed all around Malaysia. This paper discusses on available and existing renewable energy systems (single/hybrid) in Malaysia and provides a comparison of their electricity generation capabilities. The renewable energy sources that are covered in this paper include Solar, Hydropower, Biomass, Tidal and Geothermal. At the moment, hydropower is the largest renewable energy producer, contributing to almost 15% of the country's total energy generation. A lot of resources have been channeled towards the initiative of hydropower and it has definitely borne much fruit. This is followed by Solar Energy. Even though it is not as successful as hydropower, there is still a lot of avenues for it to grow in a tropical country like this. Malaysia is still relatively new in terms of power generation using biomass sources. There has been a gradual increase in the power generation using biofuels through the years and its future does look bright. Energy generation from wind, tidal, and geothermal sources has been rather challenging. Because of Malaysia's geographical location, it experiences slow winds on average throughout the year. This has led to insufficient output for its financial input. Besides that, Malaysia also has relatively low tide, if compared to other Asian countries such as Indonesia and the Philippines. This contributed to the failure of tidal energy in Malaysia, but there have been signs of locations that can be suitable for this energy generation. Besides that, the country's first geothermal power plant project failed due to a lack of preparation and discipline during the project's execution. There is a high initial cost for geothermal projects, and the chances of failure are high if the necessary precautions are not followed. This could

be one of the reasons why this branch of renewable energy has not been explored deeply.

Keywords: Malaysia, renewable energy, solar energy, hydropower, biomass, geothermal

1. Introduction to renewable energies

The demand for electricity increases new ways of electrical generation are required that is both cleaner and safer. In Malaysia, research has shown that about 3.8% of the population reside below the poverty line. Most of these people are located in rural areas in Malaysia. The electricity coverage in Peninsular Malaysia is at 99.62%, while Sabah and Sarawak's electrical coverage is around 79%. The challenge is to build a grid system through jungles and mountain. To add to that, building a grid system through these types of the area will also not be economic. A way to solve the problem would be through the implementation of Renewable Energy (RE) in these villages. The main source of Malaysia's energy supplies is from Natural Gas, Hydro, Oil, RE and Coal. Among these five Energy Sources (ES), coal supplies the most energy in terms of electricity production at 26,177 GWh. The types of RE which were researched are Solar, Wind and Hydropower. Not all of these energies are widely used in Malaysia. Some Renewable Energy Sources (RES) are ideal because of the terrain or weather in Malaysia, while others are under the research phase to determine the possibility of implementation in Malaysia. Malaysia has been amply endowed RESs such as Solar and Biomass Energy. However, these ESs have been greatly underutilized. A comparison of each REs was done to understanding the applicability of each of these resources in the Malaysian context. Being able to implement these ESs especially in areas not connected to the national grid would be beneficial to Malaysia to improve the living quality of Malaysians in rural areas.

2. Malaysia solar energy information

2.1 Introduction to solar energy

Sun is the ultimate resource on earth as it is responsible for all the weather conditions and ESs on earth. Sun emits Solar Energy due to the nuclear fusion reactions in the sun's core and subsequently produces a tremendous amount of energy. However, small portion of it is directed towards earth in the form of light and heat. Solar energy, which correlates to the sunlight's photons has an abundant potential that can fill our global needs if it is harnessed in the right way.

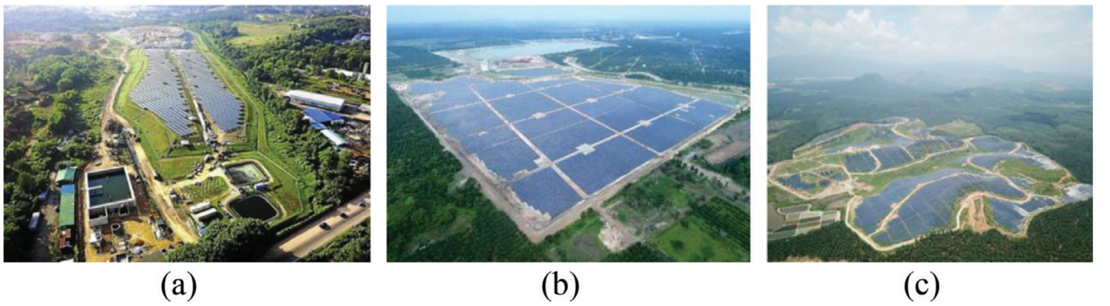
Generally, there are two main ways to harness Solar Energy, which is using either photovoltaics or solar thermal collectors. Photovoltaic (PV) or commonly known as solar cells, comes in various shapes and are made from electricity producing materials such monocrystalline silicon, polycrystalline silicon and thin film solar cells. When sunlight gets in contact with the solar cells' semiconductor material, they get absorbed and consequently, generate electricity [1]. This conversion is mainly due to the photovoltaic effect. When this effect occurs, the photons from the sun's radiation knocks electrons loose, causing them to flow and thus generate electricity. The initial generated current is the direct current (DC). In order for, this can be stored in the battery and used for DC appliances. To make it useable for regular households, it is first converted to alternating current (AC) using an inverter. If the system is connected to the grid, then additional electricity is fed to the main supply. The other way of tapping the sun's energy is by capturing the heat produced by the solar radiation. This form of harnessing is usually done in a large scale in such a fashion that power stations are built. These power stations are called Concentrated Solar Power (CSP) plants. The term concentrated comes from a large number of mirrors in the plant which are used to focus the sun's rays on tubes containing molten fluid that can store heat well. The molten fluid then is used to convert water into steam. Subsequently, the steam produced rotates a turbine and thus, generate electricity [2].

In Malaysia, solar cells are commonly used to generate electricity. In 2018 alone, 467344.2 MWh of power was generated based on Malaysia's Feed-in Tariff (FiT) system. Comparing this figure to the other RE, harnessing solar energy comes up on top. Although the nation is exposed to long hours of sunlight daily, the average maximum amount of energy produced per solar cell has an efficiency of 15–20 percent. This efficiency poses an issue whereby not many investors would invest in the technology. A way to overcome this situation in Malaysia is by constructing Large Scale Solar (LSS) power plants. This way, the amount of electricity generated can be maximized. The LSS power plants are not to be mistaken with CSP plants. The main difference between the two is that LSS captures light via solar cells and converting them into electricity whereas CSP captures heat which is transformed into mechanical energy that rotates a turbine and subsequently produces electricity. In Malaysia, CSPs are not developed yet. Having the minimal Direct Normal Irradiance (DNI) within the range of 1900 to 2000 kWh/m2/year, is the main requirement to start a CSP project. However, the DNI for Malaysia is below this threshold and it is due to the geographical position of the country which is not situated in high solar insolation zones [2].

2.2 Solar energy in Malaysia

2.2.1 Pajam, Negeri Sembilan

On 20th March 2012, an 8 MW large scale solar PV plant, developed by Cypark Resources Berhad, was officially launched and operational. **Figure 1** shows the aerial view of the solar power plant. This project is the first-ever completed LSS above 1 MW and operational under the Sustainable Energy Development Authority's (SEDA) Feed-In-Tariff Mechanism (FiT) in Malaysia. The LSS has received two accolades by the Malaysia Book of Records as it is recognized as one of the largest grids connected solar parks in the nation. The land coverage by the LSS is approximately 41.73 acres and it is equipped with 31, 824 solar panels [3]. Being the first of its kind in the country, the RM150 million project has the ability to power



(a) (b) (c)

Figure 1.
Aerial view of three major Solar Energy Projects in Malaysia. (a) An aerial view of the 8 MW large scale solar photovoltaic plant [8], (b) An aerial view of Mukim Tanjung 12 Solar Photovoltaic Plant [9] and (c) An aerial view of Sungai Siput solar photovoltaic power plant [13].

over 17,000 households annually. In 21 years from its initiation, it is expected to generate up to RM500 million worth of electricity. This is equivalent to the power generated by 9, 300 tons of coal each year. For the environment, it is capable of reducing 14, 335 tons of carbon emissions and 664 tons of methane gas annually [3, 4].

2.2.2 Mukim Tanjung 12, Kuala Selangat, Selangor

As of November 2018, the nation's largest LSS has started its operation. The project won in competitive bidding by Tenaga Nasional Berhard (TNB) and subsequently, the project started its development in July 2017. The 10 km of 132 kV power and fiber optic underground cables were connected to 230, 000 solar panels in this plant. This LSS is capable of producing 50 MW of electricity to the national grid. The total cost of this project is approximately RM339 million. The total land size used is up to 242.16 acres. Due to the success of TNB, this project serves as a booster and aspiration in further developing more RE projects in Malaysia. Consequently, by 2030, Energy, Science, Technology, Environment and Climate Change Ministry has set a goal to increase the country's electricity usage powered by 20% based on Res [5] Also, TNB's success in this project has led the company to secure RM144 million in developing a second large scale solar project for the country [5, 6] **Figure 1** shows the aerial view of the LSS.

2.2.3 Sungai Siput, Perak

On 27 November 2018, one of Malaysia's advance solar PV power plant has started its operation. This project began on 16 March 2017 when Sinar Kamiri Sdn Bhd signed a power purchase agreement with Tenaga Nasional Berhad to develop and operate a 49 MW large scale solar photovoltaic power plant which cost around RM270 million [6]. This LSS is situated in Sungai Siput Perak over a land size of 150 acres and is equipped with 170, 961 panels. In this land, the complex mountain topography has posed many challenges for the developers as this would often cause shadows, string mismatches as well as high temperature and humidity. However, the land offers a long duration of sunshine and high solar irradiance throughout the year. To overcome this topographical situation, the developers have integrated Huawei Fusion Solar Smart PV Solution into the grid [7]. This includes the smart PV string inverter SUN2000-42KTL to troubleshoot the string mismatch issues faced in Sungai Siput as well as a PLC technology which helps to deliver a simpler system with safer and more reliable data transmission. As a consequence of using these PV systems, this LSS has obtained 2% higher energy yields and a 50% increase in efficiency compared to other LSS of the same scale. **Figure 1** illustrates the aerial view of the LSS.

2.2.4 Kudat, Sabah

In July 2017, RM250 million green socially responsible investment (SRI) sukuk has been issued to Tadau Energy Berhad to further develop the current state of RE usage in Malaysia. Also, this green SRI sukuk receives funds for the projects due to its international endorsement and potential tax benefits via deduction of issuing expenses against the taxable income of the issuer [8]. In other words, it helps companies to achieve their corporate social responsibilities. With this cash in hand, the company started to develop a 50 MW solar power plant in Kudat, Sabah which covers up to 189 acres. This LSS is equipped with 188, 512 solar panels. 2 MW out of 50 MW of the available power channels the local Kudat electricity grid while the remaining 48 MW is channeled into 132 kV transmission line which is distributed through Sabah [9].

2.3 Comparing the projects

Based on the information in **Table 1**, the selected 4 LSS projects can be arranged and compared between one another in terms of generation capacity, number of solar panels, generation capacity per solar panel, land area and project cost.

First, among the projects, the LSS which has the highest generation capacities are Mukim Tanjung 12, Sungai Siput and Kudat. Each of these LSS has a generation capacity of around 50 MW. Subsequently, this is followed by Pajam at 8 MW. The difference in the capacities is based on the purpose of the project. For example, the reason why Kudat's generation capacity is high is that the power generated is used to supply the local villages as the remaining is supplied to the power grid, which is then distributed throughout Sabah [9]. A smaller LSS may not have the same purpose and the demand for electricity in the area may not be as high as areas with more population or activities. Alongside this reasoning, it corresponds as well with the total number of panels. Although Mukim Tanjung 12, Sungai Siput and Kudat have similar generation capacity and project motives, the number of panels used at each plant is different. As seen in the table, Mukim Tanjung 12 uses 230, 000 panels, Sungai Siput uses 170, 961 panels and Kudat uses 188, 512 panels. Coinciding with this information, it can be inferred that the panels which are used in each power plant have different efficiencies. For instance, although Sungai Siput uses fewer solar panels compared to Mukim Tanjung 12 nad Kudat, it is still having a similar power output as the other two. This is because the panels which the LSS has, uses Huawei's Fusion Solar Smart PV Solution panels. These panels have the potential to increase energy yields, maximize the return of investments (ROI) and helps customers optimize initial investments. Also, DC combiners are not needed in these plants [7, 8]. The reasoning in the paragraph is also backed up by the amount of each that each panel can generate. From the table based on the third row, the highest yielding panel to lowest is Sungai Siput at 286.61 W/panel, Kudat at 265.23 W/panel, Pajam at 251.31 W/panel then Mukim Tanjung 12 at 217.39 W/panel. From here, the quality of the panels used in both Sungai Siput and Kudat are of higher efficiency. Next, the amount of land size used from highest to lowest is in an order of Mukim Tanjung 12 at242.16 acres, Kudat at189 acres, Sungai Siput at 150 acres and lastly Pajam at 41.73 acres. The land coverage is closely dependent on the required generation capacity as well as the yield per panel. If the required generation capacity is low, the land size will not cover over a large area as seen in Pajam.

Location	Pajam, Negeri Sembilan	Mukim Tanjung 12, Selangor	Sungai Siput, Perak	Kudat, Sabah
Generation Capacity (MW)	8	50	49	50
Number of Solar Panels	31, 824	230, 000	170, 961	188, 512
Yield per Solar Panel (W/panel)	251.38	217.39	286.61	265.23
Land Area (acres)	41.73	242.16	150	189
Project Cost (RM in millions)	150	339	270	250

Table 1.
Summary of information of the four selected LSS.

Also, if the yield per panel is high, the land size needed is small. The last aspect that can be compared is the project cost. This correlates with the land size, efficiency of the panels and ease of installation. Generally, it would cost more for a land of a bigger size. This goes the same for a higher quality panel. In terms of ease of installation, it depends on the safety factors that are given to each component in the power plant based on the land's topography and weather. Some areas could be flat land while some are covered by hills. In Mukim Tanjung 12, since its land size is large, it accounts for the high cost of the project. Subsequently, Sungai Siput's project cost is relatively high as well and this is due to the hilly area which the LSS is built on as well as the quality of the solar panels.

2.4 Comparing solar energy in Malaysia to the World

In Malaysia, the country's first LSS was developed in 2012. However, it does a gradual impact on the awareness of people on using RESs. Ever since then, more and more LSS projects have been developed and the country has started to see this RE's advantages. Consequently, in the current years, the country has new policies such as the Renewable Energy Transition Roadmap (RETR) 2035 which aims to further explore the possible strategies and action plans to reach the country's renewable target of 20% in the national power mic by 2025. In **Table 2**, the new addition in the panels is around the same value for each year. This is due to the country's reliance on coal and fuel which has also been one of the main sources of the country's economy. As a result, transitioning to another form of ES requires confidence built up by the country. Nonetheless, this issue is slowly alleviated as the awareness of using more RESs has increased every year.

Among these four countries, in terms of annual production in 2018 (**Figure 2**), China has produced the most energy of a figure close to 80 GW. This is followed by Malaysia with an annual production of approximately 15 GW. Subsequently, Japan produced around 5 GW in that year and lastly, the USA has produced half of Japan's [12].

2.5 Section conclusion

Based on the trends, the number of solar PV additions by each of the countries has plateaued in recent years due to hurdles faced within the country. Considering this, some other countries have been growing in this field including Malaysia. Ever since the first LSS was developed, the country has been developing more projects that is able to harness the sun's energy. Due to the country's accumulative efforts, Malaysia has the potential to become one of the leading countries in solar PV generation given that further research and development is given into this field.

3. Malaysia hydropower information

3.1 Introduction to hydropower

Hydropower is the conversion of Kinetic Energy (KE) of water into electricity and is considered a RES due to the water cycle being constantly renewed by the sun. According to an article on the US Geological Survey website, a hydropower dam works by having the water in the reservoir flow into a pathway called the penstock when the sluice gate is opened. This penstock is directly connected to the turbine, which is spun by the force of the water moving from a location of higher pressure to one of lower pressure. The water itself then flows out to a river below, whereas the turning of the turbine causes the conversion of KE from the water force into

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	2015		2016		2017		2018	
Country	**Total solar PV Addition (MW)**	**Net Solar PV Capacity (MW)**	**Total solar PV Addition (MW)**	**Net Solar PV Capacity (MW)**	**Total solar PV Addition (MW)**	**Net Solar PV Capacity (MW)**	**Total solar PV Addition (MW)**	**Net Solar PV Capacity (MW)**
China	15,150	43,530	34,540	78,070	53,000	131,000	44,018	175,018
US	7,300	25,620	14,730	33,100	8,173	41,273	8,419	49,692
Japan	11,000	34,410	8,600	42,750	7,000	49,000	6,500	55,500
Malaysia	63	231	54	286	50	386	52	438

Table 2.
Net solar PV capacity and total addition by country from 2015 to 2018 [10, 11].

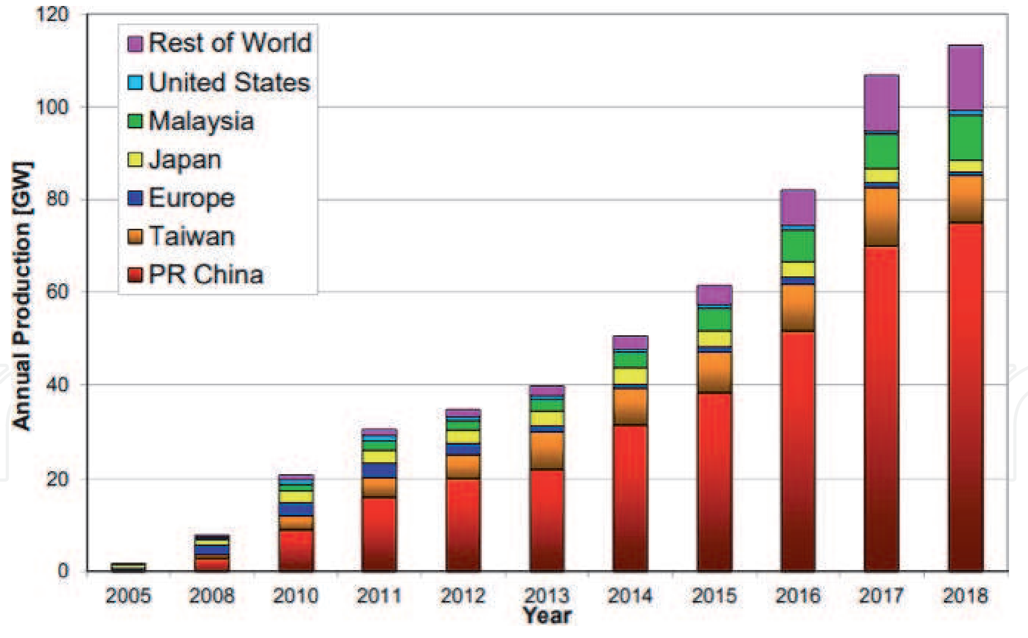

Figure 2.
Global PV cell production from 2015 to 2018 [12].

mechanical energy for use by the generator, which is connected to it by way of shafts or gears. This turning of the turbine also causes the rotor within the generator to turn and consequently causes the electromagnets on its edge to move past the stators placed in a static position outside the rotor, allowing for the conversion of the mechanical energy from the turbine into Electrical Energy (EE). The electricity produced from this conversion process is then carried out to other locations and facilities by way of power to transmission lines connected directly to the generator.

3.2 Hydropower in Malaysia

International Hydropower Association states that the installed hydropower capacity is 6094 MW in 2016, with hydropower generating roughly 11% of the country's electricity and less than 20% of the technically feasible generation potential utilized to date in their article from May 2017 [14]. The following comparison has been done by choosing the most five powerful Hydropower plants in Malaysia.

3.2.1 Bakun Hydroelectric Plant, Sarawak

The Bakun Hydroelectric Plant is located on Batang Lui in the upper parts of the Rajang River, roughly 37 km upstream of the town of Belaga in Sarawak. The plant is powered by eight 300 MW turbines, allowing for an installed generation capacity of 2400 MW and has a power transmission system that directly connects to the existing power transmission network in Sarawak. The plant has been operational since 2011 and produces an average electricity generation of 1700 MW to 2110 MW depending on demands. The dam is considered to be the largest and tallest Concrete-Faced Rock-fill dam in South East Asia with a 205 m height and 750 m length, with the capability to contain 16.93 million m^3 of water, allowing the reservoir a surface area of around 695km^2 with a catchment area of 14750 km^2 [13].

3.2.2 Murum Hydroelectric Plant, Sarawak

The Murum Hydroelectric Plant was completed back in 2016 and is located on the Murum River in the upper region of the Rajang River Basin, roughly 200 km from Bintulu. The plant is powered by four 236 MW turbines, which totals to an installed generation capacity of 944 MW [13, 14], with its average production being around 635 MW and would be delivered through the state power grid. The dam is 141 m high and 473 m long, with a reservoir area of 270km^2 and a catchment area of 2750km^2. The cost of the project totaled about RM 4.8 billion [15]. Besides that, Murum also has the world's tallest stepped chute spillway that helps to reduce KE by aerating the water overflow, which also helps to preserve the riverine ecosystem and the Batu Tungun rock formation, which is considered sacred to the local Penan community [14].

3.2.3 Pergau Hydroelectric Station, Kelantan

The Pergau Hydroelectric Station is located on the Pergau Lake, around 100 km away from Kota Bharu, Kelantan. The plant is powered by four 150 MW turbines totaling 600 MW of installed generation capacity and was designed to operate at a daily load factor of 25%. The Kuala Yong dam, which the power station receives its water from, is 75 m high [15, 16], with a 54km^2 upper catchment and lower plain area. Besides that, the station also has a $1.5 \times 10^6 m^3$ reregulating pond designed to accept peak generation flows and to release them into the river in a controlled manner, which also had a generating cycle of 5.5 hours when at full station output. The cost of the project is totaling to RM 2.23 billion [17].

3.2.4 Sultan Mahmud Power Station, Terengganu

The Sultan Mahmud Power Station was completed in 1985 and located 55 km southwest of Kuala Terengganu on the Kenyir Lake. The plant is powered by four 100 MW turbines, totaling 400 MW of installed generation capacity, with continuous generation being 165 MW. The dam is 155 m high and 800 m long in crest, with a reservoir area of 369km^2 and a catchment area of 1260km^2. The water height is around 120 m at minimum capacity and can go up to 153 m when it's at maximum, with a full supply level of 145 m [16, 17]. The lake itself can store 13.6 billion m^2 of water, with its deepest point being 145 m. Besides that, it can also release any excess water flow in the reservoir directly downstream into the Terengganu River.

3.2.5 Ulu Jelai Hydroelectric Power Plant, Pahang

The Ulu Jelai Hydroelectric Power Plant was completed in 2016 and is located in the Cameron Highlands, Pahang on the Bertam River. The plant is powered by two 186 MW turbines which are placed in an underground plant [18], totaling to 372 MW of installed generation capacity for electricity. The Susu Dam, which is the dam that forms the Susu Reservoir of this hydropower plant, was built using almost 750,000m^2 of concrete through the Roller-Compacted Concrete (RCC) method, a very modern way to build such a dam. Said dam is measured to be 88 m high and 460 m long in the crest, with a 0.1km^2 catchment area. The total cost of the project was RM 4.2 billion and is expected to reduce 250,000 tons of carbon dioxide equivalent per year by substituting coal or fossil fuel-based generator stations during peak hours, according to a United Nations report [17, 18].

3.3 Comparing the projects

Based on the information gathered here, the five selected hydropower projects can be arranged and compared between each other within the categories of installed generation capacity, dam size, catchment area, reservoir area, and project cost (**Table 3**) [15, 18].

When it comes to total installed generation capacity, the Bakun has the highest of the five at 2400 MW, followed by Murum at 944 MW, Pergau/Sultan Ismail Petra at 600 MW, Sultan Mahmud at 400 MW and lastly Ulu Jelai at 372 MW. The reason behind the high output behind Bakun is not only it's high number of turbines, but the capacity of 300 MW that each turbine is capable of, which in and off itself is close to rivaling the entire output of the Ulu Jelai station at 372 MW. This makes it the most powerful hydroelectric power plant in Malaysia and the largest power generation facility in Sarawak, as it also supports the Sarawak Corridor of Renewable Energy (SCORE) initiative required for the energy-intensive heavy industries such as the Samajaya Industry Park. In terms of the dam sizes, Bakun has the largest at 205 m high and 800 m long, followed by Sultan Mahmud at 155 m high and 800 m long, Murum at 141 m high and 473 m long, and lastly Ulu Jerai at 88 m high and 460 m long. The length of the Pergau/Sultan Ismail Petra was not given but can be assumed to be the smallest of the five as the height is only 75 m. As for catchment area, which is a land area where water can flow into the plant reservoir [15, 18], the largest is Bakun at 14750km^2, followed by Murum at 2750km^2, Sultan Mahmud at 1260km^2, Pergau at 54km^2 and lastly Ulu Jerai at 0.1km^2. Ulu Jerai is the smallest of the bunch as it uses the Bertam River, whereas the rest have a larger area to work with as they are built on lakes and other large bodies of water. Out of the five stations, only Bakun, Murum and Sultan Mahmud have a listed reservoir size at 695km^2, 270km^2 and 369km^2 respectively. Having a reservoir allows for the storage of water as conversion fuel for a later date [17], meaning that Bakun has the largest water reserve of them all and thus can use more water to generate more electricity in comparison. When it comes to cost, the most expensive project was Bakun at RM 7.3 billion, Murum at RM 4.8 billion, Ulu Jelai at RM 4.2 billion, and lastly Pergau at RM 2.23 billion, whereas the cost for production of the Sultan Mahmud plant was nowhere to be found but could be assumed to be between Pergau and Murum due to the size being between those two and that it was completed in 1985. The cost of Bakun being the highest is because it uses more turbines that are very powerful in order to produce more power than the rest of the ones on the list combined at peak usage, not to mention the size of the construction project itself.

To wrap this part up, the Bakun Hydroelectric Plant is the best hydroelectric plant available in Malaysia due to the amount of installed generation capacity for electricity that it can provide due to the massive size of the project itself, but such power comes at a great price tag. In comparison, a project such as the Sultan Ismail Power Station or Pergau Hydroelectric Station would be a more feasible one to create in a higher quantity for a developing country such as this due to the lower

Hydropower Station	Max Power (MW)	Turbine Amount	Dam Dimensions (h x l)	Surface Area (km^2)	Catchment Area (km^2)	Project Cost ($ Billion)
Bakun	2400	8 x 300	205 x 750	695	14750	7.3
Murum	944	4 x 236	141 x 473	270	2750	4.8
Pergau	600	4 x 150	75 x —	54	—	2.23
Sultan Mahmud	400	4 x 100	155 x 800	369	1260	—
Ulu Jelai	372	2 x 186	88 x 460	—	0.1	4.2

Table 3.
The data for each of the five selected hydroelectric power plants.

costs and less space requirement, while still capable of pumping out a respectable amount of electricity for the towns, villages and cities found in this country.

3.4 Comparing hydropower in Malaysia to the World

Malaysia's annual hydropower energy production is rated at 4.5 Mtoe/year (Megaton of energy per year) [16] with an installed hydropower capacity of 6094 MW and a hydropower usage percentage of 11%. The largest dam or hydropower facility in Malaysia is the Bakun Dam at 2400 MW of installed generating capacity.

From the information gathered here, the leading hydropower nations were China, Brazil, and Canada, with 96.9 Mtoe/year, 32.9 Mtoe/year and 32.3 Mtoe/year (megaton of energy per year) respectively, whereas overall energy input from hydropower in Malaysia is totalled to be 4.5 Mtoe/year (kiloton of energy per year). In comparison to the 3 countries stated previously, Malaysia's hydropower energy input is extremely tiny in comparison (**Table 4**). When it comes to the respective strongest dams in terms of output, China's Three Gorges Dam is the highest at 22.5GW of installed generating capacity, followed by the joint Brazil/Paraguay Itaipu Dam at 14GW and lastly Canada's Robert-Bourassa Dam at 5616 MW. Malaysia's largest one, Bakun at 2400 MW, is respectable and considered the largest in South-East Asia [13, 17], but the output is nothing compared to these giants. It is generally more than enough for providing electricity to Sarawak itself and can support the local heavy industries found in the state. When it comes to percentages of hydropower usage for electricity in a country, Brazil has the largest at 64%, followed by Canada at 62%, China at 20%, and lastly Malaysia at 11%. Malaysia's percentage of hydropower usage is lower compared to these other countries as Malaysia still relies heavily on coal for most of their power stations [15], which should be changed as soon as possible as it's a non-RES and could dry up in the future. In terms of installed hydropower capacity, China is the largest at 341,190 MW, followed by Brazil at 100,273 MW, Canada at 79,323 MW and lastly Malaysia at 6094 MW. Considering how small Malaysia is compared to all the three countries above, it's understandable that the installed hydropower capacity is far lower than them as Malaysia has much less space and water bodies to work with in comparison, while not to mention Malaysia's economy not being as strong as them (**Figure 3**).

3.5 Section conclusion

Taking an example out of Canada or Brazil here would be a good idea as there are many rivers and water bodies that could be exploited for hydroelectricity generation, however building more mega-dams like Bakun could harm the rainforests

Country	Annual Energy (Mtoe/year)	Strongest dam & output (MW)	Installed hydropower capacity (MW)	Usage Percentage (%)
China	96.9	Three Gorges' Dam (22,500)	341,190	20
Brazil	32.9	Itaipu Dam (14,000)	100,273	64
Canada	32.3	Robert-Bourassa Dam (5,616)	79,323	62
Malaysia	4.5	Bakun Dam (2,400)	6,094	11

Table 4.
Data for three of the world's leading hydropower countries in comparison to Malaysia's.

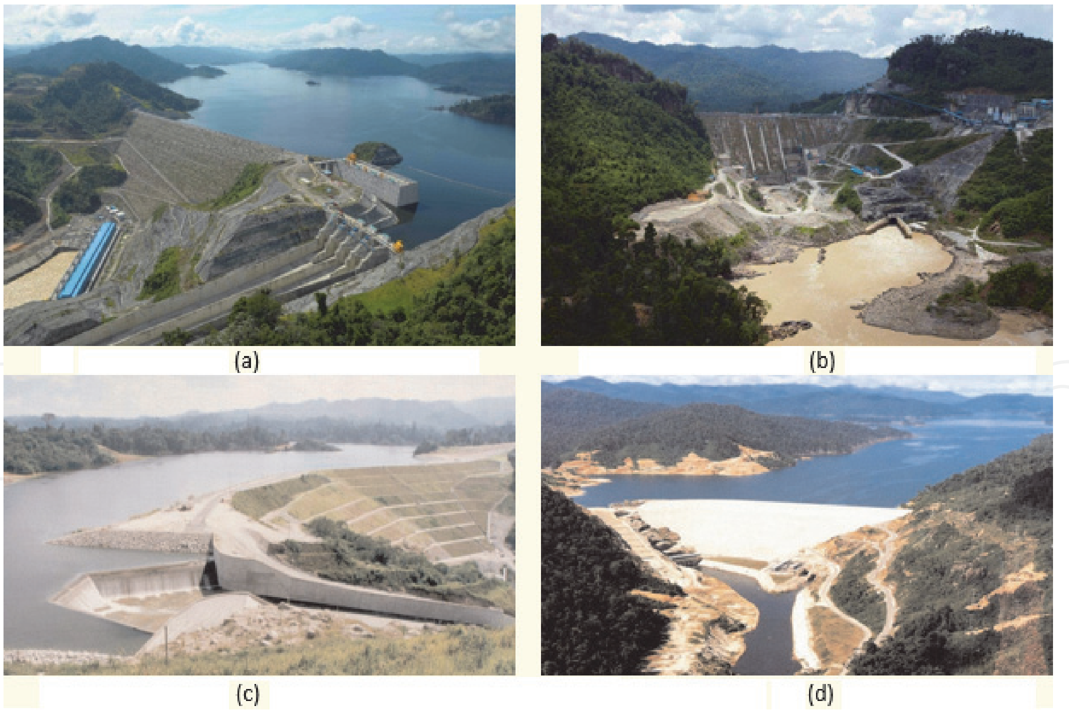

Figure 3.
Hydropower Major projects in Malaysia. Aerial view of the (a) Bakun Hydropower, (b) Murum Hydropower, (c) Yong Hydropower and (d) Kenyir Hydropower.

and animal species that makeup country's ecosystem, not to mention potentially displacing the natives and eating large sums of money that could be used for other equally beneficial projects. Therefore, a balanced method of implementing hydropower while maintaining the ecosystem should be explored, so that Malaysia could progress to the future with hydropower while still maintaining the well-being of Malaysia's unique ecosystem.

4. Malaysia biomass energy information

4.1 Introduction to biomass energy

Biomass is a type of fuel developed from organic materials. It is both sustainable and renewable in terms of generating EE. The organic materials are obtained from living and recently living things. These materials can include scraps of lumber, manure and forest debris. Biomass power is able to generate electricity which is carbon neutral through renewable organic waste [19]. This energy releases heat when burnt. These energies are utilized through burning them to produce steam to run turbines which in turn generates electricity.

4.2 Biomass in Malaysia

4.2.1 Biomass resources in Malaysia

Malaysia is a country filled with many conventional energy resources. These energy sources include oil and gas which are non-renewable and RESs like solar, hydro and biomass energy. For biomass, Malaysia has plenty of opportunities as far as exploiting biomass energy in Malaysia. Malaysia is filled with agricultural biomass and wood waste which can be exploited and used to replace non –RESs in use [19].

4.2.2 Palm oil biomass

Malaysia's exporting of 19.9 million tons of palm oil in 2017 makes this country a world leader as an exporter of palm oil. In 2011, the country was able to generate more than 80 million tons of oil palm biomass. 30% of the 379 palm oil mills here in Malaysia utilize palm oil mill effluent (POME) by turning it to biogas [19].

4.2.3 Rice husk

Another important agricultural biomass is rice husk. This resource has a very good potential for biomass cogeneration. Biomass cogeneration refers to "generating together", this is a process where heat and EE is obtained at the same time from fuel. This type of biomass is implemented in technologies such as steam turbines, gas turbines and reciprocating engines. Currently, Malaysia has constructed its first rice husk power plant in the state of Kedah in Padang [19, 20].

4.2.4 Municipal solid wastes

For the generation of solid waste in Malaysia, the amount of mass-produced in a day range from 0.45–1.44 kg/day. This result is dependent on the economic status of the area within Malaysia. The organic waste in Malaysia contains a high amount of moisture with a bulk density of above 200 kg/m^3. The bulk density is with respect to the population growth in Malaysia, the higher the number of populations in the area the larger the bulk density of the waste. These waste are generally disposed of as landfilling which makes them ideal for being used for biomass [20] (**Figure 4**).

4.3 Biomass projects in Malaysia

4.3.1 TSH resources Berhad

The plant has huge commercial potential from its biowaste in the palm oil industry. It does this through an integrated complex system in Kunak, Tawau situated in east Malaysia, Sabah. This plant has both biomass and biogas power plants as well as being equipped with a pulp and paper plant. The plant is considered friendly to the environment as it takes into consideration the protection and preservation of the environment. This plant is responsible for the generation of electricity through the disposal of waste from oil palms. This plant is under the

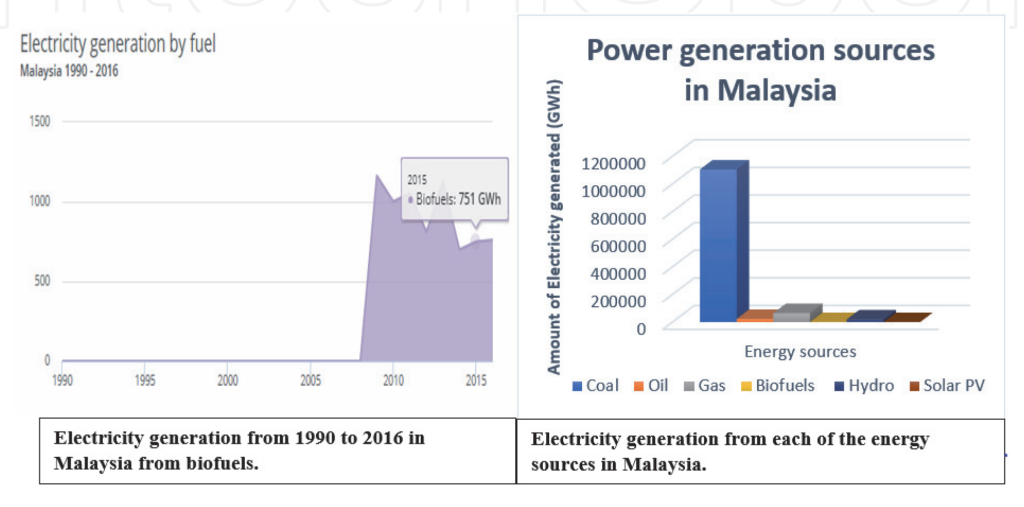

Figure 4.
Electricity generation by fuel and Power generation sources in Malaysia.

ownership of the Kumpulan Sawit Kinabalu and has taken considerable precautions in order to create a sustainable wealth while ensuring the protection and preservation of the environment. The amount of energy production has dropped by nearly 85% since the opening of the power plant, and as a result, increasing the profit of the mills by RM1.14 million [21]**.** The power generation of the plant is 14 MW of completely RE from biomass cogeneration plant [21]. The plant is also the first biomass power plant connected to the main grid in Malaysia. The RE from the biomass power plant has formed an agreement with the Sabah Electricity Sdn Bhd to provide green electricity of up to 10 MW [20, 22]. TSH built up approximately 50,000 ha in a planted area across Sabah which are strategically located with associated companies. The company also has 65,000 ha worth of unplanted land bank for future development, this is to keep the company busy for many years to come. In addition to that, the company also has 3 mills in Sabah which has a 1.0 million tons of Fresh Fruit Bunches processing capacity per annum. The refining crude palm oil and kernel located at Kunak Jaya, Sabah has capacities of 2600 tons and 600 tons per day respectively [21, 22].

4.3.2 Seguntor bioenergy and Kina biopower biomass power plant

Both these power plants are in Sandakan, Sabah. Seguntor Bioenergy and Kina Biopower Power Plant are owned by HRE Seguntor Bioenergy Sdn. Bhd and HRE Kina Biopower Sdn. Bhd respectively [23]. These two power plants are implemented with a similar design. The power plants have a fuel consumption of 23.123 kg/h and a boiler capacity of 56 tons per hour at 420 degrees Celsius. Adding to that, a mechanical draught cooling tower, counterflow, water flow of around 2491 t/h. The coldwater temperature is measured at 32 degree Celsius and 42 degree Celsius for the hot water temperature. The generators are enclosed and has an in –built water – air-cooled system. A synchronous generator is also used in the system. Each power plant can provide a total of 11.5 MW of green energy from biomass energy [23, 24]. These efforts are made to ensure the provision of a stable power supply to consumers in the East Coast of Malaysia. The power plants are located strategically about 20–90 km to 15 palms oi mills. Furthermore, the power plants are located 10 km radii of SESB's substation making it ideal for grid interconnection [20, 23]. About 654,000 tonnes per year of biomass will be generated from the Nilai Tani Resources Sdn. Bhd., Monsok Palm Oil Mill Sdn. Bhd, Prolific Yield Sdn. Bhd. and Tanjung Panjang Sdn. Bhd palm oil mills. The power plants are expected to cost around RM120 million each.

4.3.3 Jana Landfill

The Jana Landfill is owned by the Jana Landfill Sdn Bhd which runs a power plant and municipal storage waste sites. It is a subsidiary of TNB Energy Services. The power plant is located in Ayer Hitam Forest Reserve in Puchong, Selangor. The Jana Landfill obtains its fuel via the decomposition of natural municipal waste from the landfill site. The power plant generates a total of 2 MW of green energy using landfill gas as a fuel source [21, 24]. The power plant has two separate sections, Jana 1 and Jana 2. Each power plant can generate up to 1 MW of energy. To date with the arrival of Jana 3, the power plants is expected to generate a combined total of 6 MW which is beneficial to about 6000 homes in Malaysia.

4.3.4 Recycle energy Sdn. Bhd

The Recycle Energy power plant is the first power in the whole of Southeast Asia to initiate Refuse Derived Fuel (RDF). RDF is the product of separating noncombustible and combustible portion from municipal solid waste. This method can help increase the recycling levels in Malaysia as well as decrease the overall waste. To add to this, this method does not require additional cost from processing, baling, wrapping and transportation logistics making it less expensive than that of the landfilling [25]. RDF can be used as a renewable fuel for any coal – fired power plant. Recycle Energy power plant is located at Kampung Pasir in Semenyih, Selangor. The plant is located about 13 miles from the main capital. This facility is able to process a total of 1100 tons of solid waste a day. These wastes are then converted into RDF which is in fluff form. The RDF in fluff form is used as biofuel to enable the production of 8 MW of electrical energy a day [24, 25]. This electricity is used to power up the RDF plant and any remaining electricity is sold for usage in the national power grid. The RDF power plant is 28 – acre wide and is handled by the Malaysian government (**Figure 5**).

4.4 Comparison between the biomass energy usages in different plants in Malaysia

When compared, the TSH Resources Berhad power plant located in Kunak, Tawau in Sabah has the highest power generation at 14 MW. The main reason for the success of the TSH Resources Berhad power plant is its immense area of coverage. Palm oil is able to be attained from the within the power plants location. Continues supplies of palm waste can be obtained and processed rapidly in the power plant. The Kumpulan Sawit Kinabalu also ensures the protection and preservation of the palm oil farms. The Seguntor and Kina power plants needs to transport its oil palm waste 20–90 km from the mills to the power plants thus having a lower efficiency rate compared to the TSH Resources power plant. Furthermore, the TSH Resources Berhad power plant uses a biomass cogeneration system enabling it to attain both electrical and heat energy from the biomass fuels (**Table 5**).

In terms of the turbines used, steam engine has a better power-to-weight ratio making them ideal for reciprocating engines. For a small size is able to generate a high amounts of power output and does not produce a lot of vibration compared to other reciprocating counterparts. The steam turbine has a higher operating efficiency and reliability compared to that of the gas turbines. Jana Landfill is the only

Figure 5.
Major biomass projects in Malaysia.

Power Plants	Power generation	Type of Turbine	Fuel	Cost	Area coverage
TSH Resources Berhad	14 MW	Steam turbines	Empty fruit bunch		5e+8 square meter (used land) and 6.5e +8 (unused land)
Seguntor Bioenergy Power Plant	11.5 MW	Steam turbines	Empty fruit bunch	RM120 million	400000 square meters
Kina Biopower Power Plant	11.5 MW	Steam turbines	Empty fruit bunch	RM120 million	400000 square meters
Jana Landfill	2 MW (From Jana 1 & 2), 6 MW (with the future addition of Jana 3)	Gas turbines	Biogas		
Recycle Energy power plant	8 MW	Steam turbines	Refuse-derived fuel		113312 square meters

Table 5.
Comparison between the biomass energy of different power plants in Malaysia.

power plant in Malaysia using gas turbines and from power generation it is the lowest compared to all the other power plants which are using steam turbines. A main issue is that, having variation in its fuel specs can lead to an enormous drop in the efficiency of the turbine. In addition to that, external power is required to ensure turbine can carry out a self-sustained operation [23, 26]. In terms of the most eco-friendly fuel source would be the source used by the Recycle Energy power plant. This power plant uses a refuse-derived fuel source making it ideal to not only for making biofuels to power up turbines inside the power plant, but also recycling resources which are not combustibles.

From the comparison table, it can be seen that in terms of practicality and usage in the whole Malaysia the TSH Resources Berhad power plant is the most ideal. It is able to generate the highest amounts of the greenest EE at 14 MW which is why it is connected to the main grid in East Malaysia.

4.5 Comparison between the usages of biomass energy in Malaysia against the World

Unlike the other countries, Malaysia is highly reliant on the usage of palm oil and coconut husk as biomass sources. Malaysia is still unable to completely utilize all resources which can lead to the production of biomass. If Malaysia can utilize converting municipal waste as a source for biomass, there is no reason to why Malaysia cannot increase their power generation from biomass. In addition to that, if Malaysia is able to produce more biomass power plants situated around palm oil fields like the TSH Resources Berhad power plant, the amount of power generated from biomass is bound to increase within the country (**Table 6**).

4.6 Section conclusion

Malaysia is still relatively new in terms of the power generation using biomass sources. From the year 2014–2016 there is a gradual increase in the power generation using biofuels in Malaysia. Thus. the potential is bright for the usage of biomass as a RESs in Malaysia.

Country	Power generation from biofuels (GWh)			Source of waste
	2014	2015	2016	
America	62357	61640	60493	Wood waste, agricultural crop, animal manure, plants and recycled waste
China	44400	52700	64700	Agricultural, forestry waste and domestic livestock (manure).
India	293926	24997	41972	Agricultural wastes.
Malaysia	701	751	760	Palm oil biomass, rice husk and municipal solid waste.

Table 6.
Comparison between the amounts of electricity generation from biomass between countries.

5. Malaysia tidal energy information

5.1 Introduction to tidal energy

Tides are created from the gravitational pull from the Earth and the moon, creating coastal tidal waters at a different time at the day. This movement of water has an enormous amount of potential energy. This energy is predictable and renewable with low operating cost. Although tidal energy is recognized as one of the promising technologies, the technology currently doesn't exist in Malaysia. There are three main types of tides phenomenon which are diurnal, semidiurnal and mixed tides [27]. Diurnal tides have one high tide every day. Semidiurnal tides have two high tides every day. Mixed tides are the combination of the characteristics of diurnal and semidiurnal tides. Tidal energy can be harnessed through different methods. A tidal barrage makes use of the tides. A barrage looks like a dam, but it's lesser height and very much bigger [28]. The other method would be the tidal stream. It works just like wind turbines, but it's placed underwater using the movement of water created by tides [27, 28]. A tidal lagoon is another method similar to the tidal barrage, but the dam is replaced by a 360-degree enclosure, creating a pool. Water will enter and exit the lagoon due to different water tides.

5.2 Feasibility of tidal energy in Malaysia

To determine the feasibility of tidal energy in Malaysia, it is required to understand the available tides in Malaysia. In Malaysia, there is no diurnal tides. The North and West of Peninsula have majority of semidiurnal tides while the area of South and East have majority of mixed tides with dominant semidiurnal. The rest of the area of Malaysia has mixed tides with dominant diurnal (**Figure 6**).

The tides differ at a different location and different times of the year. The height of water level between tides also influences the potential energy that could be harnessed. As shown in the below figure, the most potential location to harness tidal energy would be Selangor with height range between 0.4 meters to 5.3 meters when compared to other locations [28, 29].

5.3 Section conclusion

The tidal energy will always be influenced by the gravity of the moon and the sun. However, it has more advantages than wind and solar energy as it has a more predictable nature with high environmental benefits. Different locations in Malaysia have different tides and it must be considered before installing a tidal power

Figure 6.
Types of tides available in Malaysia [29].

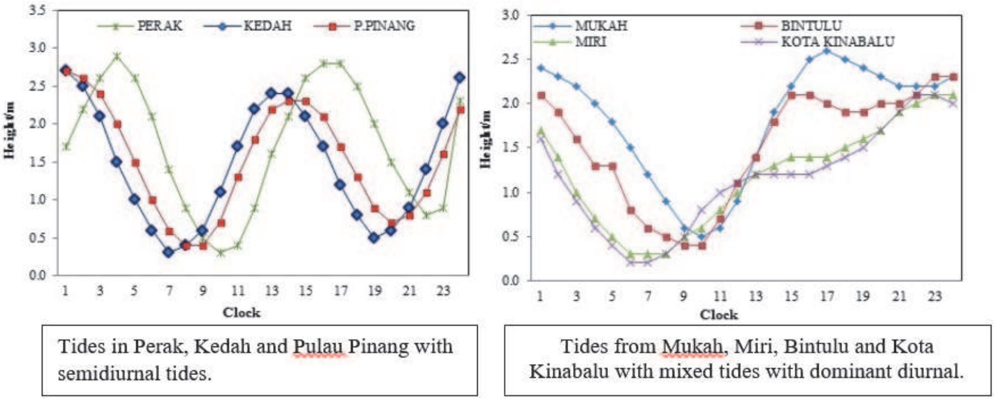

Figure 7.
Semidiurnal and Dominant semidiurnal Tides.

plant. Based on the analysis being done, Selangor has the highest potential to harness tidal energy compared to other locations in Malaysia (**Figure 7**).

6. Malaysia geothermal energy information

6.1 Introduction to geothermal energy

Geothermal energy is created by the gravitational energy of the Earth and the unstable radioactive decay of atoms [29]. Geothermal energy is mainly used to generate electricity and to provide heating. Although geothermal energy technologies have been around for over 40 years, they are still undergoing research and development. This is due to the complexity and high investments before executing geothermal projects as it includes underground exploration and requires multidisciplinary expertise [30] (**Figure 8**).

6.2 Feasibility of geothermal energy in Malaysia

Malaysia does not have technology that harnesses geothermal energy. However, there are several potential locations in Malaysia.

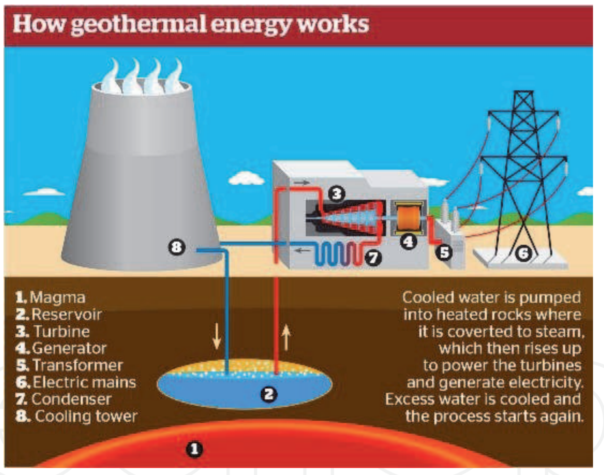

Figure 8.
How geothermal energy works.

Figure 9.
Tawau geothermal project being abandoned.

According to a study by the Deputy Natural Resources and Environment of Malaysia back in 2010, Tawau has the potential to generate up to 67 MW of electricity per day, meeting the demands of Tawau [1, 31]. The water temperatures below the selected area are near to 235 degrees which is more than enough to heat and at the same time generate electricity. This geothermal project was initiated in Tawau, Sabah, Malaysia back in 2015. However, the project site has not shown any progress and had seemed to stop operations in the third quarter of 2016. Therefore, the project's approval is being cancelled and is now currently abandoned [29, 31] (**Figure 9**).

6.3 Section conclusion

The feasibility of geothermal energy in Malaysia is inclusive of geothermal exploration and resource assessment, which requires a very high cost. The country's first geothermal power plant project failed due to the lack of preparation and great deal of discipline in executing the project. Based on the history of geothermal development, the geothermal project can easily go wrong if not all aspects are addressed adequately.

7. Conclusion

Malaysia is a developing country and being able to harness RE would be a great attribute to improve the country. The existing RE in Malaysia includes Solar energy, Hydropower energy, and Biomass energy. Other potential REs in Malaysia could be harvested such as Tidal energy. Solar cells are commonly used to harness solar energy. The technology can be further investigated and improved to increase the efficiency of electricity generation. Hydropower in Malaysia is generating 11% of the country's electricity as Malaysia has many rivers and water bodies that could be exploited. A balanced method of implementing hydropower can be done to always ensure the ecosystem of Malaysia is not disturbed. Malaysia is still relatively new in using Biomass energy. However, the gradual increase of power generation using biofuels has increased the potential of biomass energy in Malaysia as a renewable energy source. Tidal energy has the potential to be harnessed in Malaysia as there are locations such as Selangor and Johor having tides that could generate a decent amount of electricity. Geothermal energy also has the potential in Malaysia as there are multiple hot springs. Sabah has the potential to harness geothermal energy as it originates within young volcanic area. However, more research and investment would be needed to harness geothermal energy in Malaysia. It is quite convincing that Malaysia could harness more RE as the sustainability of energy consumption is crucial in this era.

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