

Evaluation of Potential Sites for Harnessing Tidal Energy around Coastal Area of Malaysia

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Abstract. This paper present the potential sites around coastal area of Malaysia for electricity generation by harnessing tidal energy. As the electricity demand increase over the year and generating electricity by using fossil fuel caused the increase number in CO₂ emission, thus renewable energy become one of the solution for alternating energy for electricity. There are a few of identified locations along Malaysia's coastal area that have potential for tidal energy implementation. The approaching for harnessing tidal energy are by using tidal barrage approach which are consist three types of mode generation ebb-mode, flood-mode and double-mode. The output generations are calculated by identify the size of basin at identified locations. For suitable location identification is by using geographical map and bathymetry map. At the end, the identified location that suitable for harnessing tidal energy are Pulau Langkawi, Pulau Pinang, Lumut, Miri, Kota Kinabalu, Kudat, Lahad Datu, Tawau and Labuan.

1 Introduction

Renewable energy become one of the energy source that many countries looking for nowadays for electricity generation [1]. This is because, many countries still depend on the fossil fuel for electricity generation to fulfil the demands however, by using this energy source it will increase the number of CO₂ emission as the demands increased that caused the global warming [2]. As a developing country, Malaysia population of 27.4 million in 2007 with an average annual growth rate of 1.8% will reach to 33.4 million by the year 2020 and approximately 37.4 million in 2030. In 2009, the total electrical energy generated was 103.2 TWh and the demand is expected to increase by 4.7% per annum to 274 TWh by the year 2030. It will heavily influenced by strong demands from the industrial and residential sectors as Malaysia enters into an industrialized nation, whereby per capita electricity demand is expected to reach 7571 kWh/person in the year 2030, more than double from 2002 [3].

As earth 70% covered by the ocean, it's become one of the renewable energy sources that available on the earth. The potential and commercial viability of harnessing tidal energy in Malaysia is not studied thoroughly. Until recently, a preliminary study was carried out to explore the potential of harnessing tidal energy in Malaysia for electricity generation [4]. Tidal energy is harnessed by using tidal barrage either by (a) Single-basin or (b) Double-

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basin. For the single-basin tidal barrage there are three types which are (a) Ebb-mode generation (b) Flood-mode generation and (c) Double-mode generation [5].

Tidal barrage is a physical barrier namely the barrage, is created within the sea with Sluice Gates to control the flow of seawater [7, 8]. The Sluice Gates are to be closed at high tide so that the water level inside the barrage is held at its highest level. As the tide recedes, a difference in water level in between the barrage and the sea is created. The potential energy from the water level difference can then drive turbines to generate electricity [6].

Table 1. Fuel mix in electricity generation, 2000-2010 [3].

Year	% of total					Total (GWh)
	Oil	Coal	Gas	Hydro	Others	
2000	4.2	8.8	77.0	10.0	0.0	69,280
2005	2.2	21.8	70.2	5.5	0.3	94,299
2010	0.2	36.5	55.9	5.6	1.8	137,909

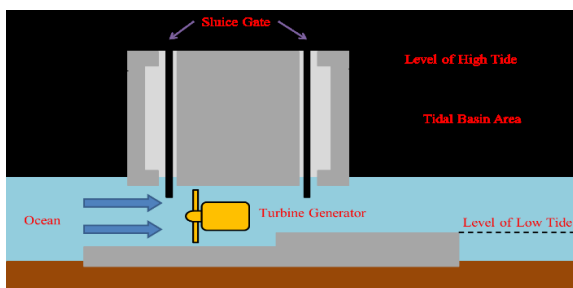


Fig. 1. Tidal barrage [6].

There are 16 tides station around coastal area of Malaysia not included with the east-coast region, which provided the tides range data which are Pulau Langkawi, Pulau Pinang, Lumut, Pelabuhan Kelang, Tanjung Keling, Kukup, Johor Bahru, Sejingkat, Bintulu, Miri, Kota Kinabalu, Kudat, Sandakan, Lahad Datu, Tawau and Labuan. These data is an annual data publication by Department of Survey and Mapping, Malaysia. From these data, an annual estimation output can be calculated.

The objective of this paper is to present the results of the assessment which are critical to policy makers and the potential investors on tidal energy in Malaysia for decision making. The results may help the neighboring countries to realize the possible potential of their ocean energy. This paper will begin with a brief introduction to the means of generating tidal data, followed by the characteristics of tides around Malaysia and the potential amount of electricity generation by tidal energy.

2 Data collection

First of all, before proceeding with the identification or selecting of potential site it will go through with data collection. There is a certain data that must be considered for calculating the output power generation because the purpose of the harnessing tidal barrage is to generate the electricity that can meet the local demand. The data are (a) tides range, (b) number of household and (c) electricity demand.

2.1 Tides range

The data collected from the Department of Survey and Mapping Malaysia, shows that the highest tidal range of almost three meters is located at Sabah and Sarawak. Malaysia has 21

stations of tide gauge installation installed near to village or town. The purpose of tide gauge installation near village or town is to avoid and give warning if there is a change in increasing water level as usual that may cause flood to the nearest region. Since the tide gauge located near and at the coastal area, there will be advantage to make analysis of tidal range at nearest location of tide gauge station [9, 10, 11, 12, 13].



Fig. 2. Tidal stations location.

Tidal range can be defined from the tide different during the phase of flood and ebb tides. This different in height of tide can be further calculate for the tidal power generation. Figure 4 shows the average of tidal range difference of year 2011.

$$Flood\ Generation = |high\ tides - low\ tides| \tag{1}$$

$$Ebb\ Generation = |low\ tides - high\ tides| \tag{2}$$

Tidal range in Malaysia’s coastal area not as high as the others countries that implement tidal barrage, however it is still reasonable to study and propose that this tidal energy in Malaysia because there are some places that identified as potential sites for harnessing tidal energy. As show in Table 2 the tides range for all locations in Malaysia.

Table 2. Tidal range in Malaysia [9, 10, 11, 12, 13].

Tide Stations	Mean Sea Level, (m)	Tidal range (m)	
		Ebb	Flood
Pulau Langkawi	2.17	1.80	1.79
Pulau Pinang	2.65	1.38	1.38
Lumut	2.16	1.63	1.63
Pelabuhan Kelang	3.61	3.06	3.07
Tanjung Keling	2.83	1.31	1.32
Kukup	4.01	1.98	1.98
Johor Bahru	2.87	1.92	1.91
Sejingkat	2.41	2.98	2.98
Bintulu	2.84	0.90	0.88
Miri	2.82	0.89	0.84
Kota Kinabalu	2.23	0.95	0.90
Kudat	2.31	1.04	0.97
Sandakan	5.68	1.04	0.99
Lahad Datu	1.90	1.14	1.14
Tawau	2.18	1.72	1.73
Labuan	2.53	1.01	0.95

2.2 Number of household and electricity demand

The average electricity consumption in Malaysia is assumed 3966kWh per household annually [14, 15]. By using assumed electricity consumption, then amount of electricity demands by local population is calculated and shown in the Table 2.

Table 3. Local electricity demand [14, 15].

Location	Mukim	No. of household	Demand (GWh)
P.Langkawi	P.Langkawi	26,000	103.12
P.Pinang	Georgetown	64,653	256.41
Lumut	Lumut	16,591	65.80
P.Kelang	Kelang	3,447	13.67
Tg. Keling	Tg. Keling	2,991	11.86
Kukup	Serkat	1,976	7.84
J.Bahru	Sg. Tiram	3,703	14.69
Sejingkat	Padawan	6,636	26.32
Bintulu	Sebauh	35,274	139.90
Miri	Sibuti	11,958	47.43
K.Kinabalu	Tambunan	81,747	324.21
Kudat	Pitas	16,745	66.41
Sandakan	Tongod	64,194	254.60
Lahad Datu	Kunak	34,179	135.55
Tawau	Nabawan	69,656	276.26
Labuan	W.P.Labuan	19,719	78.21

From Table 2, the highest electricity demand is Kota Kinabalu follow by Tawau, Pulau Pinang, Sandakan, Bintulu, Lahad Datu and Pulau Langkawi which is the demands exceed more than 100 GWh annually. While, the rest locations are below 100 GWh.

3 Sites selection

For the site selection, there are two types of maps that will be used which are (a) geographical map and (b) bathymetry map.

3.1 Geographical map

Geographical map normally used to see the type of earth structure on that particular selection area and observe the population pattern, population activities and development. This important before make a site selection for tidal barrage implementation.

Geographical map that has been used are from Google Earth and Google Map. Figure followed shows the selection area for Pulau Langkawi, Pulau Pinang, Lumut, Pelabuhan Kelang, Tanjung Keling, Kukup, Johor Bahru, Sejingkat, Bintulu, Miri, Kota Kinabalu, Kudat, Sandakan, Lahad Datu, Tawau and Labuan.

From these map, the type of earth structure and population activities are examining in order to see either that location are suitable for harnessing tidal energy for electricity or not.



Fig. 3. Pulau Langkawi [16].



Fig. 4. Pulau Pinang [17].



Fig. 5. Lumut [18].

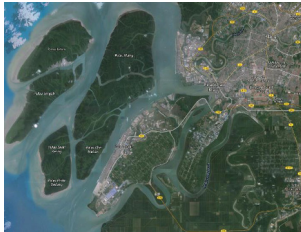


Fig. 6. Pelabuhan Kelang [19].



Fig. 7. Tanjung Keling [20].



Fig. 8. Kukup [21].



Fig. 9. Johor Bahru [22].



Fig. 10. Sejingkat [23].



Fig. 11. Bintulu [24].

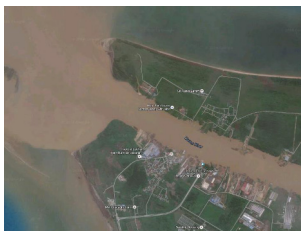


Fig. 12. Miri [25].



Fig. 13. Kota Kinabalu [26].

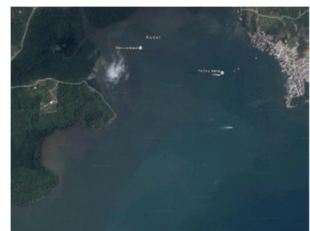


Fig. 14. Kudat [27].



Fig. 15. Lahad Datu [29].

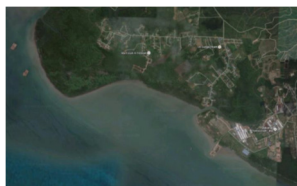


Fig. 16. Tawau [30].



Fig. 17. Labuan [31].

From 16 suggested locations, only 9 places that identified as suitable for harnessing tidal barrage which are Pulau Langkaw, Pulau Pinang, Lumut, Miri, Kota Kinabalu, Kudat, Lahad Datu, Tawau and Labuan.

The suggested tidal basin area, Ab are Pulau Langkawi (1.55 km²), Pulau Pinang (0.50 km²), Lumut (0.77 km²), Miri (0.66 km²), Kota Kinabalu (2.40 km²), Kudat (0.22 km²), Lahad Datu (1.50 km²), Tawau (0.80 km²) and Labuan (0.07 km²) respectively.

3.2 Bathymetry Map

When the potential locations is identified in the Google Map, the next step is to study and examine the characteristic of the coastal area on that location. The important data that very needed the most is bathymetry. Bathymetry data give the information of the sea level on that area which is very important in order to decide either that place suitable for tidal barrage implementation or not.

This is because, the minimum bathymetry requirement for the tidal barrage implementation is about 3 metres. When the bathymetry is higher is will give in result for higher tides range, which is result for the higher potential energy. When the potential energy created from tides is higher it will generate higher installed capacity and output power generation for electricity.

Even Malaysia's coastal area only have a few locations that achieved the minimum requirement, but it still consider as the potential area because Malaysia consists a few number of natural lagoon.



Fig. 18. Bathymetry of Pulau Langkawi [33].

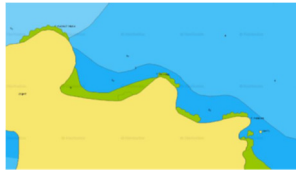


Fig. 19. Bathymetry of Pulau Pinang [33].



Fig. 20. Bathymetry of Lumut [33].



Fig. 21. Bathymetry of Miri [33].



Fig. 22. Bathymetry of Kota Kinabalu [33].



Fig. 23. Bathymetry of Kudat [33].

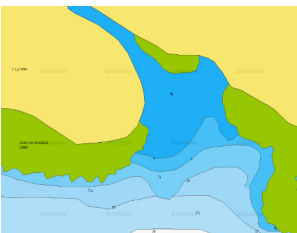


Fig. 24. Bathymetry of Lahad Datu [33].



Fig. 25. Bathymetry of Tawau [33].

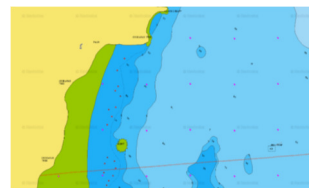


Fig. 26. Bathymetry of Labuan [33].

4 Output power generation estimation

The tide contains both potential and kinetic energy. The potential energy is the work done in lifting the mass of water above the ocean surface. The energy available from a barrage

depends on the area of the water surface impounded by the barrage and the corresponding magnitude of the tidal range. The potential energy contained in the water volume impounded in a basin, can be expressed as:

$$E_p = 0.5 \rho g A_b \Delta h_b^2 \tag{3}$$

Where E_p = potential energy over a tide cycle (GJ); ρ = density of sea water (t/m^3); g = acceleration due to the Earth’s gravity (9.807 m/s^2); A_b = horizontal area of the enclosed basin (km^2); and Δh_b = mean tidal range in the basin (m). The density of sea water varies from 1.021 to 1.030 t/m^3 , and is typically assumed to be 1.025 t/m^3 . The coefficient of 0.5 in Eq. (1) is due to the fact that as the water in the basin is released through the turbines, the water head across the dam will be reduced accordingly. The maximum available head only occurs at the moment of low water, assuming that a high water level is still present in the basin. It can be seen from Eq. (1) that different tidal ranges influence greatly the value of the potential energy, and the magnitude of the mean tidal range and the value of the impounded area are the most important factors that determine the feasibility of a tidal barrage in terms of the annual energy output.

For coastal regions where tidal power generation is economically attractive, the tidal regime generally consists of two flood and two ebb tides, with a semi-diurnal period of 12.42 hours. At low tide the potential energy is zero. Therefore, the total potential energy per day from the barrage approximates to:

$$E_{total} = \frac{24}{12.42} \times E_p \tag{4}$$

and the corresponding mean potential power can be written as:

$$P = \frac{24}{12.42} E_p / 86,400 \tag{5}$$

$$P = 1.1244 \times 10^{-4} (A_b \cdot \Delta h_b^2)$$

in which P is in GW. Tidal energy projects are characterized by low values of power conversion efficiency of η , usually ranging from 20% to 40%, with an average of 33% often being used. Therefore, the potential annual tidal energy output from a barrage can be approximately calculated as:

$$E_{year} = 0.987 A_b \Delta h_b^2 \eta \tag{6}$$

Where E_{year} in GWh.

5 Result and discussion

5.1 Tidal basin area power generation

Figure 6 shows the local demand for electricity and power generation from tidal barrage by using double-mode of generation. From the figure, it is shown that by using double-mode generation it can at least satisfy the electricity demand from the local usage compare to by using ebb-mode generation and flood-mode generation.

Double-mode generation can produce the higher output power generation because of the way it operates. The operation is combinational of the ebb-mode generation and flood-mode generation, from this the operations it is almost a continuous proses if compare to the ebb-

mode generation and flood-mode generation that are only operate at one time of tides process which are during ebbs and floods.

Table 4. Output power generation.

Location	Basin Area, A_b (km ²)	Output power generation, $P_{electricity}$ (GWh)		
		Ebb	Flood	Double
P.Langkawi	1.55	1.94	1.92	2.99
P.Pinang	0.50	0.40	0.39	0.61
Lumut	0.70	0.77	0.77	1.19
P.Kelang	N/A	-	-	-
Tg. Keling	N/A	-	-	-
Kukup	N/A	-	-	-
J.Bahru	N/A	-	-	-
Sejingkat	N/A	-	-	-
Bintulu	N/A	-	-	-
Miri	0.66	0.17	0.15	0.25
K.Kinabalu	2.40	0.73	0.68	1.09
Kudat	0.22	0.08	0.08	0.12
Sandakan	N/A	-	-	-
Lahad Datu	1.50	0.83	0.83	1.28
Tawau	0.80	1.01	1.01	1.56
Labuan	0.07	0.03	0.02	0.04

Once the output power generation is calculated with suggested tidal basin area, the result is compare to the local demand and number of household on that locations. This is for comparison to see how much the contribution of harnessing tidal energy for electricity could supply for local population. Table 4 shows the comparison and contribution of the output power generation from tidal energy by using double-mode generation.

From Table 4, the highest power generation and percentage of contribution are Pulau Langkawi with output power generation 2.99 GWh and could supplied to 753 houses with 2.90% of contribution from the whole number of household on that area. Then followed by Lahad Datu with 1.28 GWh, 322 household supplied and 0.94% of contribution. The lowest output power generation are in Labuan with 0.04 GWh of power generation, only 10 houses supplied from output power generated and percentage of contribution 0.05%.

Table 5. Number of house supplied by tidal energy and percentage of contribution.

Location	Power generation, GWh	House supplied	% of contribution
P.Langkawi	2.99	753	2.90
P.Pinang	0.61	153	0.23
Lumut	1.19	300	1.81
P.Kelang	-	-	-
Tg. Keling	-	-	-
Kukup	-	-	-
J.Bahru	-	-	-
Sejingkat	-	-	-
Bintulu	-	-	-
Miri	0.25	63	0.53
K.Kinabalu	1.09	274	0.34
Kudat	0.12	30	0.18
Sandakan	-	-	-
Lahad Datu	1.28	322	0.94
Tawau	1.56	393	0.56
Labuan	0.04	10	0.05

6 Conclusions

In this paper, it was attempted to study the potential of harnessing tidal energy for electricity generation in order to satisfy the local demand. Three modes of generations which are ebb-mode generation, flood-mode generation and double-mode generation is studied and the result showed that double-mode generation can produce the power generation that can meet the local demand. Besides, the potential sites for tidal barrage implementation also are identified which are Pulau Langkawi, Pulau Pinang, Lumut, Miri, Kota Kinabalu, Kudat, Lahad Datu, Tawau and Labuan. However, the tidal range become one the challenges since tides Malaysia doesn't meet the minimum tides requirement for tidal barrage and other solution or method for increasing the water level need to be studied.

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