

Review Article

An Overview of Energy Sector and Wind Power Potential in Malaysia

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ABSTRACT

With the new era of industrialization and urbanization, the use of renewable energy is a solution to resolve the impacts of the current dependency on fossil based fuels and hike in fuel prices in the world. The rapid economic development in recent years has led to the energy increase demand in Malaysia and the situation is expected to grow in the near future. The country energy sector is heavily dependent on fossil based fuels for electrical energy generation. Currently wind energy systems are swiftly gaining recognition as one of the best sources of renewable energy because of its emission free characteristics. This paper reviews the recent scenario and the future expected energy situation in Malaysia. Wind energy resources assessment and potential in Malaysia is also discussed.

Key words: Malaysia, Energy, Wind, Wind Speed, Energy Density, Wind Potential

1. INTRODUCTION

Malaysia is a two separate boundary country located in Southeast Asia which comprises of Peninsular, Sabah and Sarawak. The country is located in the equatorial zone in between 3° 10' in the north of latitude and 101° 42' in the east of longitude. Because of this, the country is generally hot and humid with the average mean daily temperature ranges from 20°C-27°C. The country has tropical weather which is influenced by monsoonal climate namely northeast monsoon which start from September to March, southwest monsoon blows between May to mid September and shorter monsoon in April and October [1, 2].

Malaysia has a land area of 329,847 km² with thirteen states, and its mean elevations of about 300m. The country has a population concentration with a density of 86 people per square kilometer. It has a population of 29,695,233 as at 2010 house population census [3]. The country is known to be a newly industrial developed nation and it has maintained a GDP

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growth over 5% for the past few decades and a significant percentage of GDP , about 40% is the output of higher value added manufacturing sector. Nevertheless, the service sector's contribution to GDP is about 50% which are creating a solid foundation for the future development of the country in the near future [4].

The country's energy demand is predicted to grow annually at the rate of 3.5% to reach 146.7Mtoe in 2030, which is a 2.6 % increase from 2002. Among the fossil fuels, coal is projected to grow at the fastest rate of 9.7 percent annually, followed by natural gas at 2.9 percent and oil at 2.7 percent. Coal demand will increase substantially to meet the rising electricity demand, accounting for 93 percent of the total incremental coal demand of 31.2 Mtoe [5].

The energy consumption in Malaysia is becoming a topic of interest nowadays given the fact that the Malaysia's electricity consumption per capita is the second highest among the five ASEAN founding nations as shown in table 1. With the rapid industrial development in Malaysia the primary energy consumption was 38.9 Mtoe in 2005, the projected ultimate consumption is expected to reach 98.7 Mtoe in 2030 [6,7]. However, the transport sector will grow faster during the next 25 years with the annual growth projected at 5.3%. The industrial sector and other sectors like residential, commercial and agricultural sectors will grow at an annual rate of 4.8% and 4.2% respectively, and this indicates that to achieve the country's energy need oil will still remain the most used fuel and may probably grow at 4.7% per annum and renewable energy sources will be the least used resources for energy need and will have a growth rate of 1.5% [8].

Table 1: Electricity per capita Consumption in ASEAN (kWh per capita) [6]

Country	1980	1990	2000	2006
Malaysia	670.25	1,178.07	2,742.82	3,387.60
Singapore	2,781.31	4,859.86	7,575.41	8,520.02
Indonesia	44.37	161.37	400.36	529.72
Thailand	291.26	708.13	1,462.14	1,984.33
Philippines	367.90	352.73	501.29	572.28

Due to rapid growth in population, urbanization, industrialization and extensive uses of fossil based fuel, Malaysia can expect a very large growth in energy demand. Malaysia is endowed with renewable energy sources such as hydro, tidal, solar and wind. These potentials are promising in the short term in the country; they can also serve as a solution to the future energy problems. Among the source of renewable energy in Malaysia, wind energy has the most prospects in the near future. The main reason that smoothen the progress of wind energy is climatic changes that severely jeopardize the universe, which will lead to the world temperature increase to 58⁰C during the next ten decades [9]. This paper

assesses the energy production-consumption, demand and wind energy potential in the area and presented the results in figures and tables form.

2. RECENT ENERGY SITUATION IN MALAYSIA

Malaysia primary energy sources include natural gas, coal, oil, biomass although renewable energy sources such as solar, wind, geothermal, tidal and hydro are currently being exploited. According to Malaysia Economic Planning Unit (EPU), there is an estimated 2.5 trillion gas and 5.9 billion barrels of oil reserves that will last 39 and 25 years respectively [10]. The value of energy produced in Malaysia was 89,693 as of 2009. However for the past 38 years this indicator reached a maximum value of 93,118 in 2008 and a minimum value of 4,770 in between 1971 to 1974 as shown in figure 1 [12].

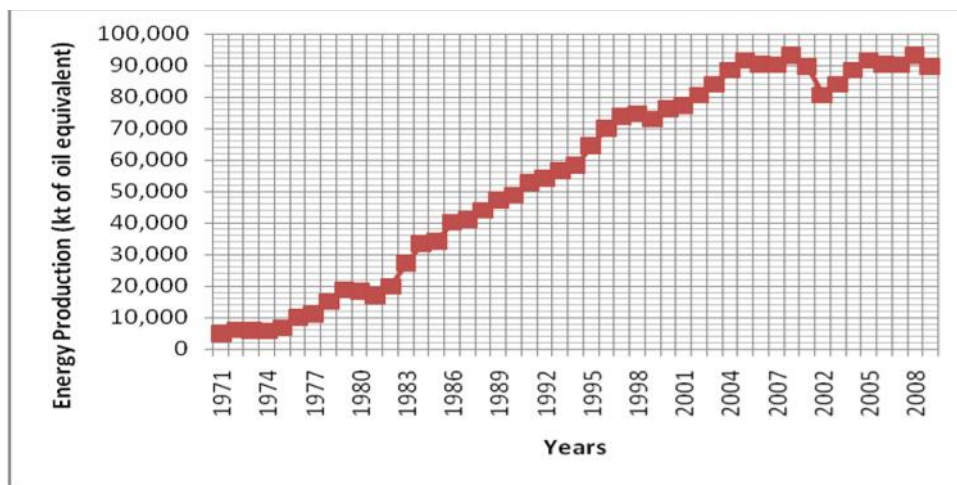


Figure 1: Energy Production in Malaysia from 1971-2008

Electricity production increased from 23,061 in 1990 to 87,306 GWh in 2005. This is equivalent to an average annual growth rate of 9.3% over this period. Over the period from 2005-2030, and the rate is expected to hit 314,984 GWh in the reference scenario with an annual growth rate of 5.3% and 389,734 GWh in the high scenario posting an annual growth rate of 6.2% [12].

Table 2: Electricity Production from 1990 to 2030, in GWh

By Type	1990	2005	2030 (Reference)	2030 (High)
Coal	2,825	23,134	154,684	194,913
Thermal (oil)	11,138	2,489	3107	3,068
Natural Gas	5,064	55,899	139,025	173,587
Hydro	3,989	5,784	18,166	18,166
Total	2,016	87,306	314,984	389,734

91 The Demand for commercial energy in Malaysia is projected to continue its upward trend
 92 from 1244 Petajoule (PJ) in 2000 to an estimated 2218 PJ in 2010 and is expected to
 93 continue increasing in future years [13]. The movement of energy mix in Malaysia indicated
 94 a continuous decrease in the percentage of oil and petroleum product share and steady
 95 growth in coal demand; figure 2 shows the percentage of primary commercial energy supply
 96 sources [14].

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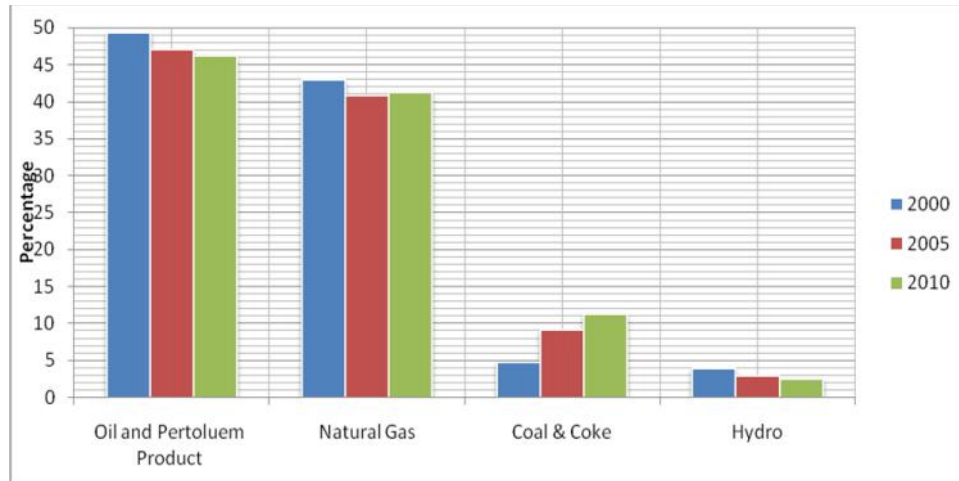


Figure 2: Share of Primary Energy Supply Source

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101 Malaysia primary energy consumption is shown in Figure 3. The total consumption increased
 102 from 6,940 Ktoe in 2005 to 9,240 Ktoe in 2011 [15].

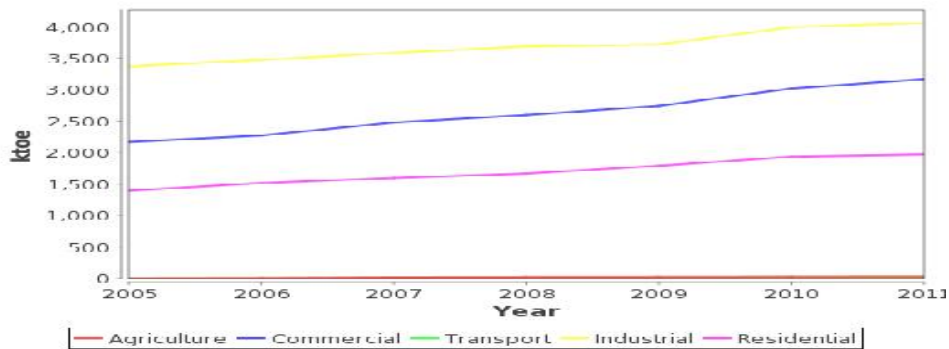


Figure 3: Primary Energy Consumption in Different Sectors of Malaysia

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106 From figure 3, it can be noted that the energy utilization had **increased** from 2005 to 2011.
 107 The industrial and transport sectors are the two major consumer of energy in the stipulated
 108 years. However, commercial and residential sectors were the third biggest consumers, while
 109 the agricultural sector was the smallest consumer of energy in the country.
 110 Malaysia estimated total oil production is 630,000 barrels per day (bbl/d) in 2011. More than
 111 half of the total oil production comes from Tappis field in the offshore. The country consumes

majority of its oil production. Gross natural gas production has been rising steadily reaching 2.7Tcf in 2010. While the domestic natural consumption has also reached 1.1Tcf in 2010, this shows 42% of the total production [16].

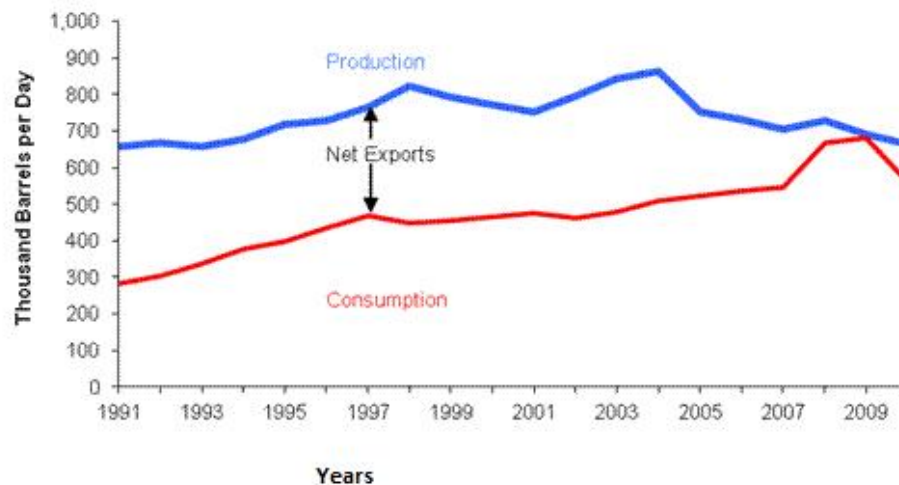


Figure 4: Malaysia's Oil Production and Consumption

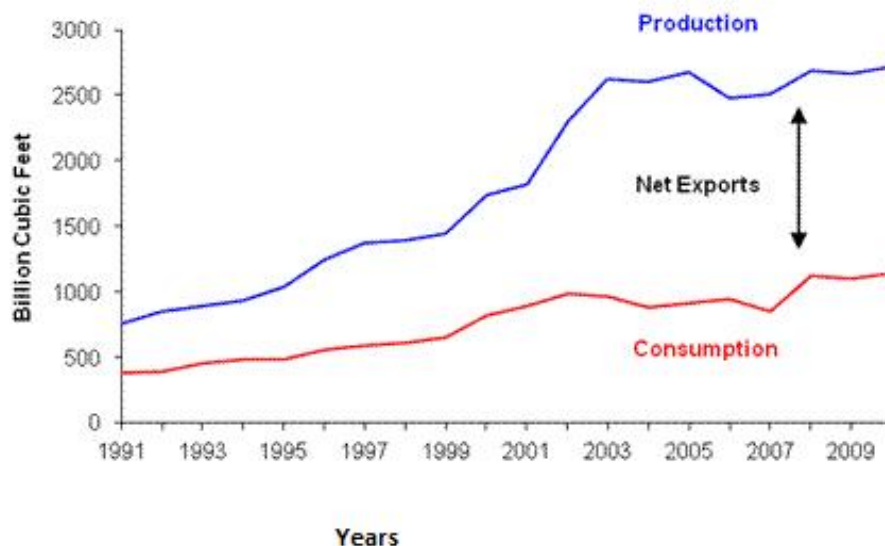


Figure 5: Malaysia Natural Gas Production and Consumption

As seen from figure 4 Malaysia is a large oil producer. On the other hand, there is significant variation in the rate of oil production/consumption from 1991 to 2006. However, from 2007 onward involves a mark reduction in production and an increase in the consumption. Therefore to balance up the high demand in the near future there is the need for alternative energy sources.

125 Burning of coal is associated with many challenges like emission of greenhouse gasses;
 126 coal is still projected to play an important role in Malaysia energy supply. Coal has been
 127 identified as part of fuel mix strategy and form part of the long term plan development of a
 128 sustainable energy supply in Malaysia. The country is blessed with large reserves of coal
 129 deposit. Most of the coal reserves are found in less developed areas where there is an
 130 inadequate infrastructure. As of 2004, the production of coal in Malaysia stands at about
 131 383,000 tons, a significant increase from 65,000 tons in 1991 [17]. Similarly the reserves
 132 and production of coal as at December, 2005 are 1,483.06 and 782,107 metric tons
 133 respectively [14]. According to the 2010 BP Statistical Energy Survey, Malaysia had
 134 consumed about 4 million tonnes oil equivalent in 2009\$, this figure stand as 0.12% of the
 135 total coal produce in the world. Coal production has been decreasing slowly, due to mine
 136 closure as well as lower demand. Malaysia's coal reserves are located primarily in Sarawak
 137 and Sabah, with smaller deposits in Selangor, Perlis and Perak. Total estimated coal
 138 resources stand at just more than 1000 Mt. These coal resources are considered as
 139 strategic in terms of Malaysia's power requirements. Malaysia actively promotes coal as a
 140 fuel of choice for power generation in order to free up more of its natural gas for export [18].
 141 Malaysia coal importation, production and consumption are shown in figure 5 [19].

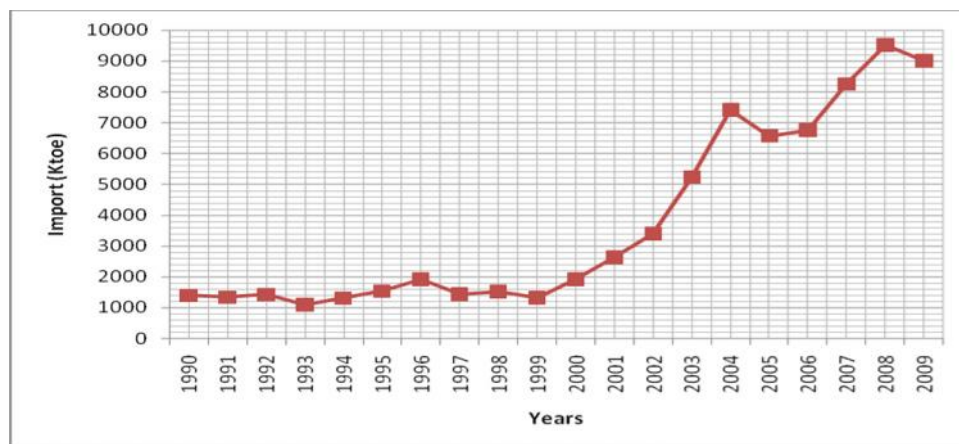


Figure 6: Malaysia Coal Import

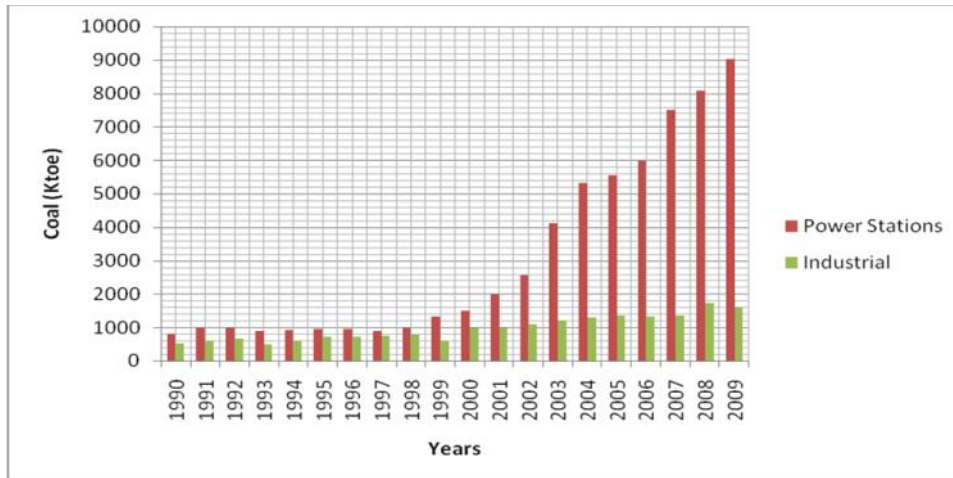


Figure 7: Coal Consumption by Sectors

Hydropower is cost effective and environmentally friendly use of water resources toward energy development [20]. Hydropower energy is widely used throughout the world, varying in size from Pico to large scales serving several countries. Hydropower provides a significant percentage in many developed and developing nations. Malaysia uses hydro power for 11% of its electricity. Due to high rainfall receives in the country; the average rainfall is slightly above 2,600mm per year. The total gross estimated hydropower potential is 414,000 GWh/year of which about 85kWh/year is available in Peninsular [21].

At the moment, Malaysia had utilized this potential mainly in the range of large and mini hydropower but very few in the micro hydro range, the country have a total of 149 sites with estimated micro hydro potential of 28.9MW identified. Currently, there are twelve large scale hydropower stations and eight mini scale hydropower stations in Malaysia, wholly owned by Tenaga Nasional Berhad (TNB) and has been trusted to operate and maintain 30 numbers of mini hydro stations throughout the Peninsular of Malaysia with total installed capacity of approximately 16 MW [22].

Malaysia is a tropical country that has significant solar radiation but a very limited radiation network. The mean annual average of total solar radiation varies (table 3). The country receives solar radiation at the level of about 15MJ/day; average sunshine hours are estimated more than 4000 hours per annum [23, 24].

172 **Table 3: Average Yearly Solar Irradiance in Various Towns of Malaysia KWh/m² per**
 173 **day [25]**

Town	Annual Average Solar Irradiance (KWh/m ²)
Alor Setar	4.96
Georgetown	5.15
Kota Bharu	5.28
Kuala Lumpur	4.90
Johor Bharu	4.55
Kota Kinabalu	5.41
Kuching	4.61

174

175 Malaysia is the fourth largest PV module producers in the world, but the utilization of solar
 176 technologies is still limited due to the high cost of installing PV systems. Currently solar
 177 energy is used for thermal applications and PV technologies are used for electricity
 178 generation [26].

179

180 Geothermal power generation is another potential in Malaysia. There are 79 confirmed
 181 geothermal manifestation areas, 61 of which are in Peninsular Malaysia, 8 are in Sarawak
 182 and 10 in Sabah. The total number excludes other geothermal areas reported to exist in the
 183 remote vicinities of Sabah and Sarawak, the veracity of which is yet to be determined due to
 184 the areas' inaccessibility [27]. Malaysia's first geothermal plant, to be built at Apas Kiri in
 185 Sabah's Tawau district is expected to have the capability of generating more than 100MW of
 186 electricity [28].

187

188 Malaysia possesses the potential of generating electricity from an indigenous biomass
 189 source, however the estimated capacity based on current biomass yields is about 400MW.
 190 Palm oil is the single source which could contribute to generate about 375MW (figure 8). On
 191 the other hand paddy residue is another emerging source that could contribute substantial
 192 amounts of electricity; other sources such as pineapple fruit and vegetable plant are
 193 currently under investigations for consideration as future energy potentials [29]. Figure 9 and
 194 10 show potential of biomass energy and resources from palm oil mills in Malaysia [30].

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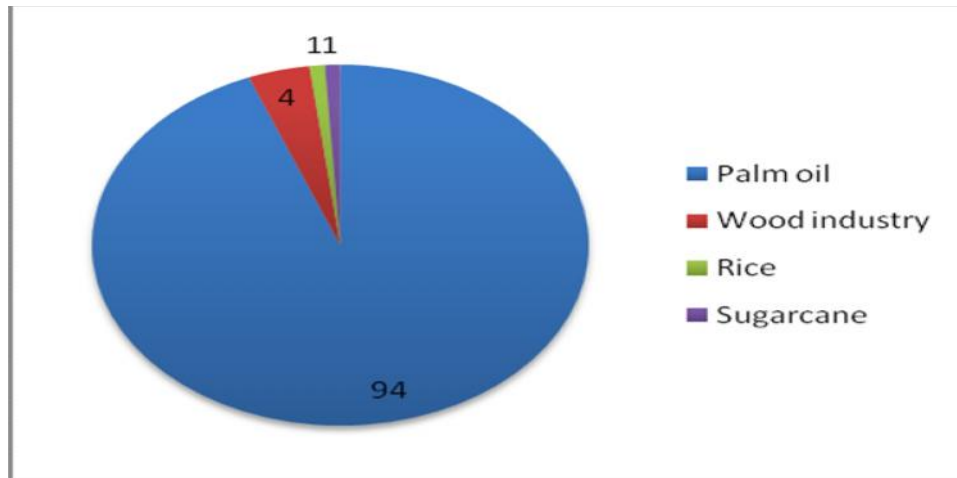


Figure 8: Biomass Resource from Agricultural Residue

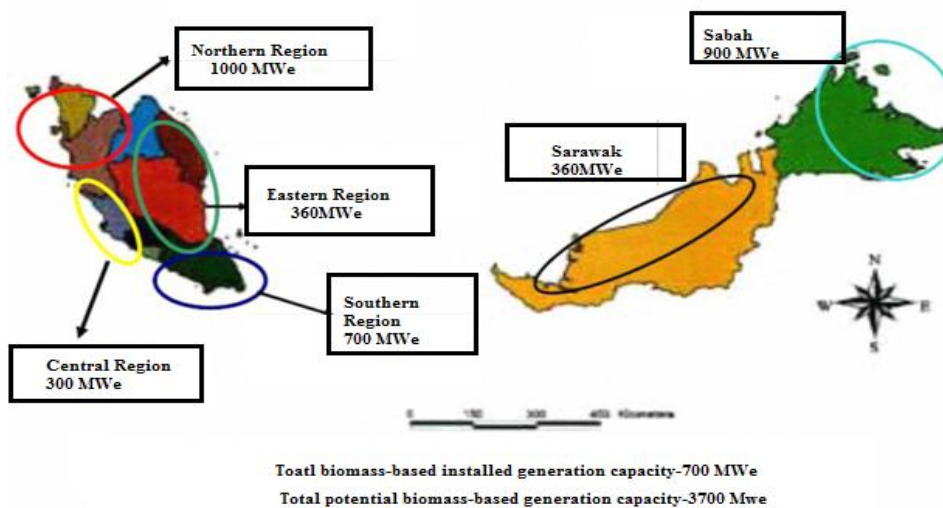


Figure 9: Biomass Energy Potential in Malaysia

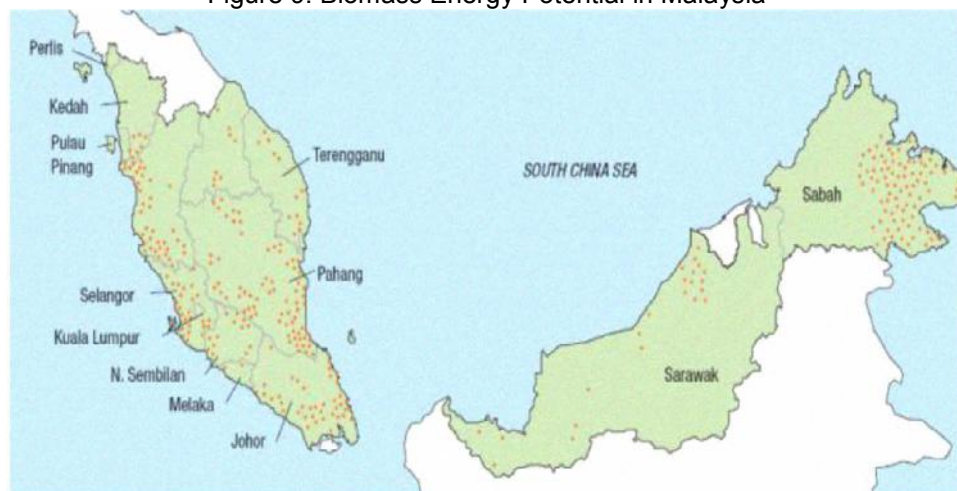


Figure 10: Biomass Energy Resources from Palm Oil Mills in Malaysia

3. WIND ENERGY POTENTIAL

Wind energy is considered as a clean source of renewable energy and is almost the fastest growing energy source in the world. At the end of the year 2012, the total annual installed wind capacity attains 44,711MW. However, the cumulative installed wind capacity from 1996 to 2012 is 282, 430MW and is expected to reach 265 GW by 2020 [31]. The change in global wind power from 1996 to 2012 is shown in figures 11 and 12 respectively. The installed capacity in Asia has increased by 16% between 2011 and 2012 as shown in table 4. Wind energy stills provide a fraction of the global electricity demand and currently very little electricity is produced from wind in the Asian region to reach more than five million people.

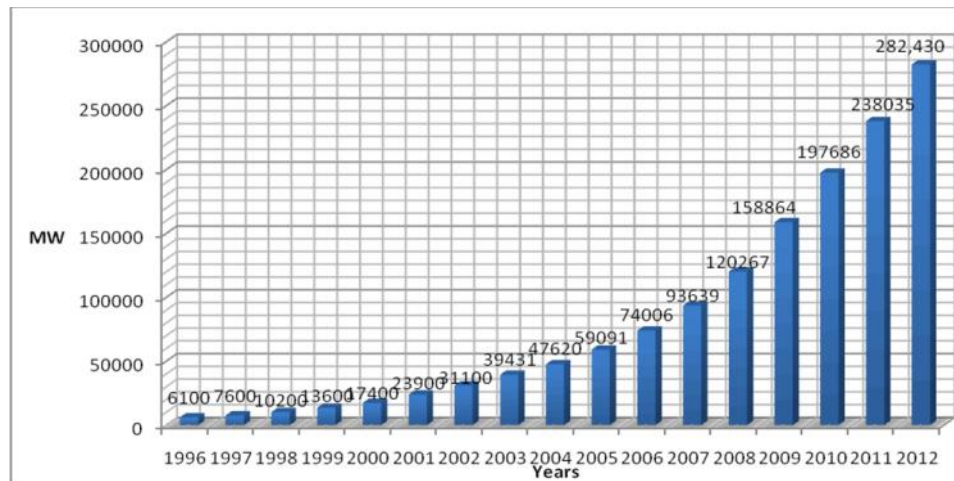


Figure 11: Cumulative Installed Global Wind Capacity

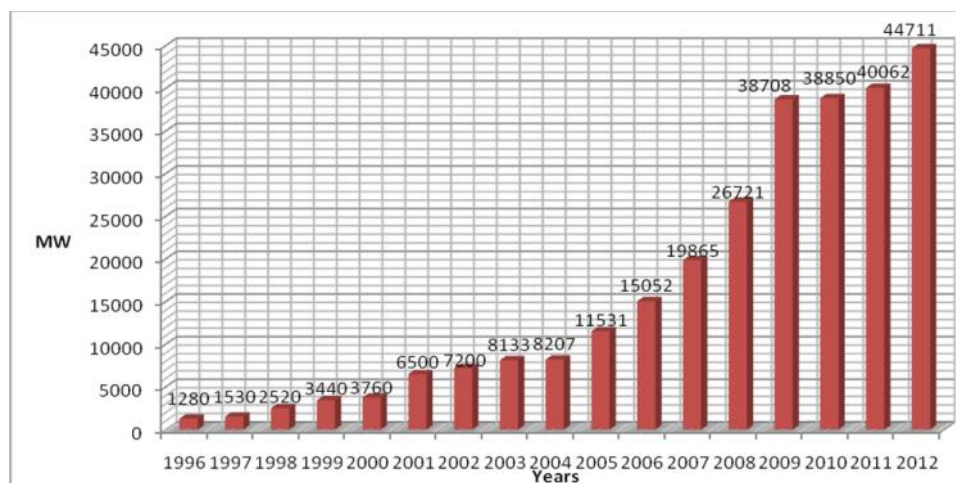


Figure 12: Annual Installed Global Wind Capacity

237 **Table 4: Change of Wind Power in Asia [31]**

Installed Wind Capacity (MW)			
Country	End of 2011	New 2011	End of 2012
PR China	62,364	13,200	75,564
India	16,084	2,366	18,421
Japan	2,536	88	2,614
Taiwan	564	-	564
South Korea	407	76	483
Pakistan	6	50	56
Others	106	-	108
	82,070	15,750	97,810

238

239 Wind energy potential varies depending on the location. Various studies conducted within
 240 Malaysia have shown that the country does not possess large scale wind generation
 241 potential. However wind turbine, speed limit 3-4m/s, is found to be economically feasible in
 242 many regions in the country.

243

244 As mentioned earlier Malaysia has a land surface area of 329,847 km². The country is vastly
 245 surrounded by the ocean where wind power potential has been recognized by many
 246 researchers as a better site to harness clean wind energy source. The total electricity
 247 consumption of Malaysia as 2012 is 93.8 billion kWh (93.8TWh). The theoretical wind power
 248 of Malaysia is estimated about 25 TWh/year (figure 13) which is about 26.7% of the
 249 electricity consumption of Malaysia [32].

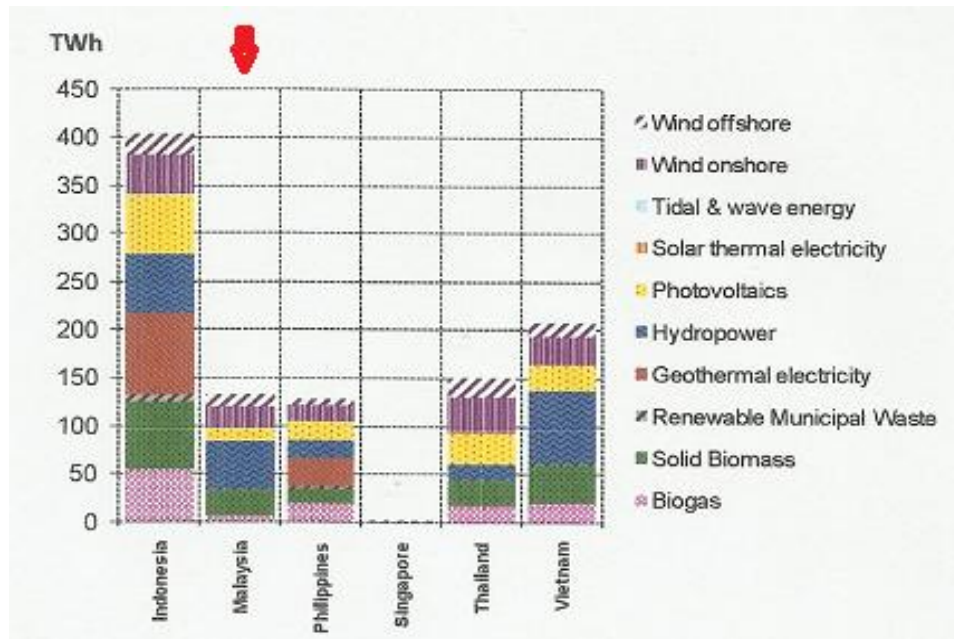


Figure 13: Total Realizable Potential for Renewable Energy in ASEAN Countries

Considering Malaysia has great potential to harness the energy content in a wind, in recent time several research works has been carried out in order to investigate the potential of having wind energy in the country. Records from Malaysia Meteorological Department (MMD) shows that the highest maximum wind speed of 41.7m/s was recorded in Kuching, Sarawak on 15th September, 1992, while maximum mean daily wind speed of 3.8m/s recorded at Mersing, in Johor. Due to availability of wind data, on daily, monthly, seasonal and annual basis wind potential have been investigated and reported by many researchers. Based on wind data collected from 2004 -2007. Nik et al. [33] analyzed the potential of having wind energy in Kuala Terengganu. The monthly average wind speed of the potential site is shown in table 5. The maximum annual monthly wind speed is 5.20m/s, it could be concluded that a small wind turbine could be used to provide power in this area.

Table 5: Monthly Average Wind Speed for East Coast of Malaysia from 2004-2007

Study Area	Latitude (°N)	Longitude (°E)	Monthly Average Wind (m/s)							
			2004		2005		2006		2007	
Kuala Terengganu	4°13.6'	130°26.1'	Min	Max	Min	Max	Min	Max	Min	Max
			2.10	4.82	2.01	3.78	2.12	4.72	2.15	5.20

266 Young et al. [34] have analyzed the wind speed for nine locations in Malaysia by using
 267 statistical approach, the average annual wind speed for the year 2009 at 10m and 100m
 268 heights are summarized in table 6. The results of the study show that the large scale wind
 269 turbine generator is not economically feasible; however, a small wind system can run
 270 throughout the year at Mersing.

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Table 6: Wind Energy Potential of Some Locations in Malaysia

Study Area	Latitude (°N)	Longitude (°E)	Annual Wind Speed (m/s)			
			At 10m		At 100m	
			Min-	Max	Min-	Max
Mersing	2.4	103.8	2.40	4.76	3.47	6.89
Bintulu	3.2	113.03	1.66	1.99	2.25	2.69
Kuala Terengganu	5.3	103.15	1.57	2.65	2.83	4.79
Pulau Langkawi	6.35	99.80	1.44	3.10	1.95	4.19
Sandakan	5.97	118.17	2.02	2.97	2.73	4.01
Kudat	6.88	116.83	2.05	3.19	3.16	4.92
Kota Kinabalu	5.97	116.12	1.81	2.60	2.26	3.25
Kuching	1.55	110.33	1.61	2.14	2.91	3.87
Tawau	4.28	117.91	1.51	1.92	2.46	3.14

274

275 The monthly and seasonal variation of wind characteristics was investigated in [35], in terms
 276 of wind energy potential using available wind speed data from 1991-2008 at 10m altitude on
 277 Pemanggil Island. The result of the study strongly indicates that a small scale wind power
 278 can be generated in the area. The values are summarized in Table 7.

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287 **Table 7 Wind Energy Potential in Pemanggil Island**

Study Area	Latitude °N	Longitude °E	Average Annual wind Speed (m/s)	
			Min –Max	
Pemanggil Island	2.58	104.33	1.71	6.70

288

289 The work on wind resource assessment at five locations in west Malaysia was conducted in
 290 [36]. Based on average hourly wind speed data available from (2005-2009).The authors
 291 used maximum likelihood method, the study revealed that Mersing possessed high wind
 292 energy potential to implement low wind speed driving systems. Table 8 summarized the
 293 results.

294 **Table 8: Wind Energy at Various Locations in Malaysia**

Study Location	Latitude (°N)	Longitude (°E)	Annual wind Speed (m/s)
Langkawi	06° 25'	99° 45'	1.76
Penang	05° 24'	100° 23'	1.15
Kuala Terengganu	05° 20'	103° 08'	1.69
Kota Bharu	06° 70'	102° 14'	1.58
Mersing	02° 25'	103° 50'	2.65

295

296 The assessment of wind energy potential has been evaluated based on the experimental set
 297 up using Davis Pro weather station in Perlis by [37]. The recorded wind speed data from
 298 January to December 2008 is shown in Table 9. The results showed that, Perlis is the best
 299 area with maximum annual wind speed of 2.60m/s.

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308 **Table 9: Wind Energy Potential at Perlis at 21.7M**

Study Area	Latitude (°N)	Longitude (°E)	Average Annual wind Speed (m/s)	
			Min –Max	
Perlis	2.58	104.33	1.60	2.60

309
 310 An extensive study conducted in Kudat and Labuan presented in [38], by using a 2-
 311 parameter Weibull function. Findings from the study concluded that both sites are unsuitable
 312 for large wind energy production; however small-scale wind energy with high efficiency can
 313 be generated at 100m. Table 10 shows a summary of this research works.

314 **Table 10: Wind Potential at Kudat and Labuan**

Location	Latitude (°N)	Longitude (°E)	Annual Average Wind Speed (m/s)		
			2006	2007	2008
Kudat	6.88	116.83	3.37	3.36	3.00
Labuan	5.00	115.00	3.50	3.81	2.67

315
 316 A recent studies was carried out by [39] on the analysis of wind speed in some selected wind
 317 stations across Malaysia. There are fourteen stations selected for the research. The stations
 318 are located in Alor Setar, Bayan Lepas, Ipoh, Kota Bharu, Kota Kinabalu, Kuala Terengganu,
 319 Kuching, Labuan, Malacca, Mersing, Miri, Senai and Subang. All the data used in the study
 320 comes from MMD. The study used Firstlook software provided by 3TIER to examine the
 321 wind speed variation. The results obtained from the software showed that Kota Belud, Kudat
 322 and Langkawi are the most promising location to install wind turbines. But according to the
 323 mean value Mersing is the most potential. However, based on instantaneous maximum wind
 324 speed Kota Kinabalu is the most suitable site for the installation of wind energy system. The
 325 monthly mean wind speed for the 14 selected stations is shown in figure 14.

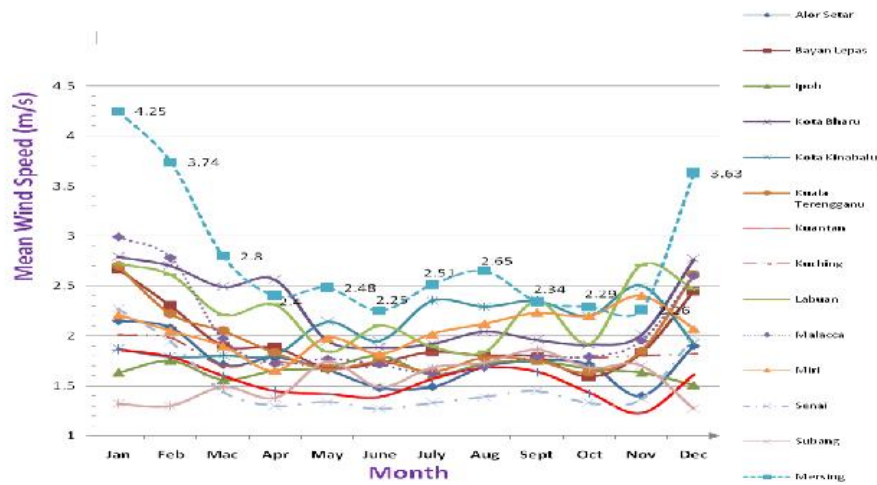


Figure 14: Monthly Mean Wind Speed at 14 Stations in Malaysia [39].

A recently recent published study in [40] proposed the use of Wind Atlas Analysis and Application Software (WAsP) based on spatial analysis to investigate the potential of wind energy at Kudat. The results of the study prove strongly the potential for developing a small scale wind farm in the northern part of Kudat. The interpolated wind speed in the area varies from 4.3-5.4m/s.

Wind power density indicates the potential of wind energy per unit area. From various studies conducted in Malaysia, average wind power density is summarized in table 11. As seen from table 11, the wind energy potential varies depending on the location. However, the most attractive region to harness the wind energy potential is Mersing, Labuan and Perlis.

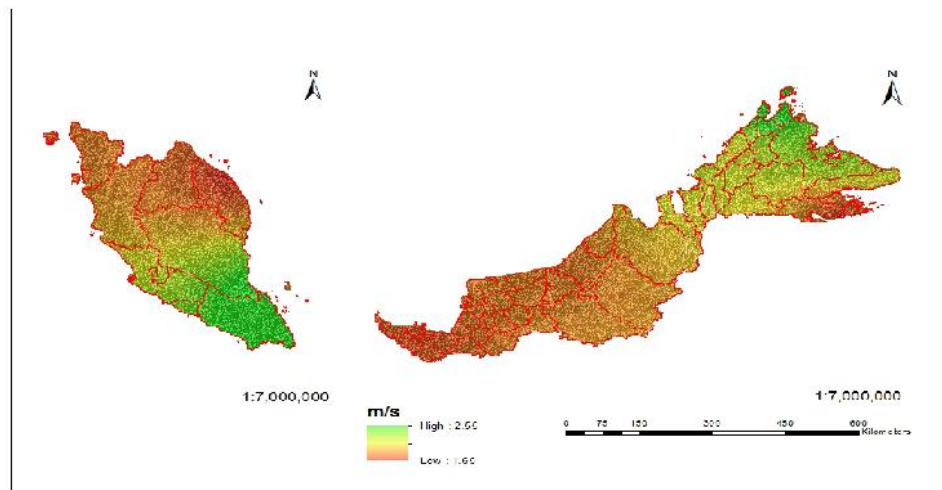
Table 11: Wind Potential of Various Locations in Malaysia [36, 38, 41].

Location	Average Annual Wind Power Density (W/m^2)
Kudat	67.40
Labuan	50.81
Mersing	26.70 62.00
Melaka	11.98

Kuantan	8.40
Langkawi	≈10
Penang	≈10
Kota Bharu	≈10
Kota Kinabalu	≈10
Perlis	64.27

341

342 The spatial prediction of wind speed at different heights investigated in [34]. Their research
 343 work indicates the low and high windy area of Malaysia. Figure 14 and 15 shows the wind
 344 speed and the energy potential distribution for 10m and 100m in Malaysia.



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Figure 15: Wind Speed Distribution Map of Malaysia in 2009 at the 10m Height [34]

348 As shown in figure 12 most of the high windy regions were found in the southern part of
 349 peninsular and Sabah, while part of Sarawak and north peninsular are the low windy region
 350 at 10m height. Figure 15 shows wind energy potential at 100m,

351 The highest wind speed was in the south of Peninsular, the state of Johor showed the
 352 highest wind speed in the range of 2.36-6.88m/s. The highest wind speed found at the tip of
 353 Borneo is in the range of 2.33-4.92m/s.

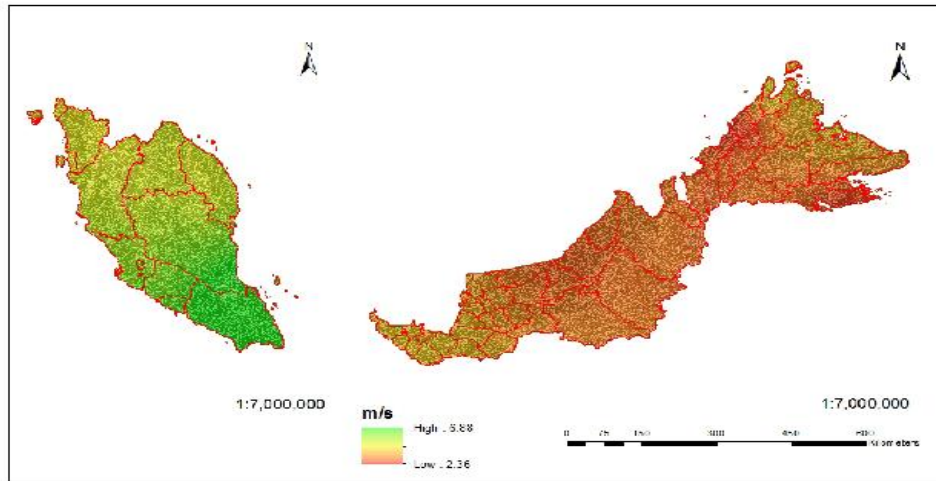


Figure 16: Wind Speed Distribution Map of Malaysia in 2009 at the 100m Height [34]

4. CONCLUSION

Malaysia is endowed with both renewable and nonrenewable energy sources. From the review here of the country is heavily depends on fossil based fuel as a source of energy, hence there is a need for the country to enhance national competitiveness to face the challenges in domestic and global scenario in terms of prime environmental consideration of global warming.

More than 90% of the electricity generated in Malaysia is based on fossil fuels and the energy consumption is rapidly increasing. The share of renewable energy at present is negligible. Also, the country has substantial hydroelectric and geothermal potential at economic capacity. Currently there is no nuclear wind power plant in the country, hence nuclear power should be considered for future development of energy in the country.

Despite the above, the country is endowed with an abundance of natural resources for renewable energy such as solar, wind and biomass. Considering the current utilization of wind and solar power systems in the world, the resources are still at limited utilization in Malaysia.

Wind energy is one of the most significant and rapidly developing renewable energy sources in the world and it provides clean emission free energy resource. Wind energy has great potential in Malaysia. Theoretically the estimated feasible wind power of Malaysia is 25TWh/year.

This figure stands at 26.7% of the total electricity consumption of the country per annum. The wind speed values are higher in northeast monsoon season in the country, most if not all research works conducted in the country shown the possibility of implementing small scale wind power plant.

Currently wind energy in various parts of Malaysia is becoming economical due reduction in wind turbine costs. Because of this, it is necessary to make use of this abundant natural resource as additional source of energy, especially for standalone applications in rural and remote areas.

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