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Importance of palm biodiesel as a transportation fuel in Malaysia

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Abstract: The world today is faced with serious environmental pollution and global warming. Besides, fossil fuel will become rare and faces a serious shortage in the near future. This has triggered the awareness to find sustainable energy sources as alternative energy. Transportation has dominated global fuel consumption and greenhouse gas effects have risen at an alarming rate. In Malaysia, the transportation sector is the second largest energy consuming sector after the industrial sector, Gasoline and diesel consumption for road transport have a faster growing rate than other sector and the trend appeared to be moving rapidly upwards in the near future. This has caused much concern to improve the sustainable energy of this sector. Even though different alternative energy solutions have been put forward to reduce the dependency on fossil fuels, biofuels remain one of the few options which are capable of replacing the fossil fuels roles in the transportation sector without suffering from major economic losses. Palm oil is one of the most efficient oil bearing crops in terms of oil yield, efficiency, land utilization and productivity. As a leading producer of palm oil, Malaysia is intended to implement mandatory biodiesel blends in its transportation sector in order to balance the energy demand and achieve its carbon reduction commitment towards a more sustainable development. This article discusses the potential of palm oil-based biodiesel fuel and the current scenario of transportation sector development in Malaysia. The study found that there is an urgent need to adopt suitable energy policy to balance the energy demand and reduce emission in the transportation sector. It is hoped that this case study will enable the Malaysian government to achieve their renewable energy target in the transportation sector..
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1. Introduction

The increasing industrialization, modernization and development have led to high demand of petroleum worldwide. Global energy consumption in 2008 was growing from 6630 million tonnes of oil equivalent (Mtoe) in 1980 to almost double of the energy consumption which had reached 11,295 Mtoe in 2008 (1). However, the world reserve for fossil fuel such as petroleum has been depleted and causing the price to hit new highest record of US$ 136 per barrel in July 2008 (2). In Malaysia, the final energy consumption has risen at an annual growth rate of 7.2% from 1990 to 2008 and reached 44.9 Mtoe in 2008 (3).

The transportation sector is one of the major components of globalization and makes a vital contribution to the economy. Besides, it plays a curial role in daily activities around the world. Unfortunately, this activity is major energy consumption and use most of the limited non-renewable energy that creates a negative impact to the living environment. On top of that, the transportation sector is responsible for a large and growing share of emissions that affects global climate change (4). One of the primary concerns will be the green-house gas (GHG) emission of CO2 and air pollutants like NOx and particulates. CO2 emissions generated by the transportation sector have been causing much concern among the scientific community worldwide due to its rapid growth rates. At the moment, the transportation sector accounts for 13.5% of global warming (5). Indeed, transportation has the fastest growing carbon emissions of any other economic sector. Proliferating numbers of automobiles are the key reasons as more than 600 million passenger cars are now on roads around the world.

The global final energy consumption was growing from 4676 million tons of oil equivalent (Mtoe) since 1973 to 8429 Mtoe in 2008 (6). Transportation sector occupied 23.1% in 1973 and risen significantly to 27.3% of the total global energy consumption in 2008. The main reason for the increase in transport sector is the continuing growth in household incomes and number of vehicles (7).

Global CO2 emissions increased from 21 billion tons in 1990 to 29.4 billion tons of CO2 in 2008. On top of that, transportation sector contributed 6.6 billion tons of CO2 which is 22.5% of total CO2 emissions in 2008 (8). It remains the second biggest emitting sector over the period. Global demand for transport appears unlikely to decrease in the foreseeable future as the World Energy Outlook projects that it will grow 45% by 2030 (9).

In Malaysia the crucial challenge faced by power sector currently is the issue of sustainability. Besides, the world today is faced with a serious global warming and environmental pollution. The major sources of greenhouse gas (GHG) emissions are gasoline and diesel fuel from the transportation sector. The world is confronted with the twin crises of fossil fuel depletion and environmental degradation (10). Thus, there is an urgent need to find an alternative renewable energy resource that is renewable, clean, reliable and yet economically feasible. Biodiesel, a cleaner renewable fuel has been considered as the best candidate for diesel fuel substitution due to it can be used in any compression ignition engine without any modification on the engine. Biodiesel is gradually gaining acceptance in the market as an environmentally friendly fuel and the demand is expected to increase sharply as an alternative renewable energy source in the near future.

Biodiesel fuel is mono alkyl ester derived from vegetable or animal fats which has characteristics similar to diesel fuel and has lower exhaust emissions and it can be blended with diesel fuel (11–13). On the other hand, the main vegetable oil drawbacks have to overcome due to the high viscosity and low volatility which will cause a poor combustion in diesel engines(14). Transesterification is the process successfully employed to reduce the viscosity of biodiesel and improve the other characteristics (15). Biodiesel seems to be a realistic alternative renewable fuel in the near future and this review is focused on the possibilities of using palm oil biodiesel as an alternative fuel for transportation sector in Malaysia.

2. Transportation energy consumption

The transportation sector has experienced growth steady in the last 3 decades. It is believed that currently this sector is responsible for about 60% of total world oil demand and will be the strongest growing energy demand sector in the future. Between 2006 and 2030, around three quarters of the projected increase in oil demand is expected to come from transportation (16,17). Transportation sector is estimated to increase annually by an average of 1.8% over the entire period between 2010 to 2035. Figure 1 shows total world liquids consumption, transportation liquids consumption and other sector's liquids consumption between 2007 and 2035 (16,18).

Transportation sector energy used includes the energy consumed in moving people and goods by road, rail, marine, air, water and pipeline. The road transport includes small trucks, light duty vehicles such as automobiles, minivans, sport utility vehicles and motorbikes as well as medium and heavy-duty vehicles, such as buses used for passenger travel and large trucks used for freight moving. Road vehicles are one of the fastest growing energy and dominate global oil consumption. It represents nearly 81% of transportation energy demand. Globally, the second largest energy consuming sector after the industrial sector is the transportation sector which accounts for 30% of the total world's delivered energy. The share of the transportation sector of total world liquids consumption increased from 50% in 2002 to 53% in 2007 and projected to reach about 61% in 2035 accounting for 87% of the total world liquids consumption increase.

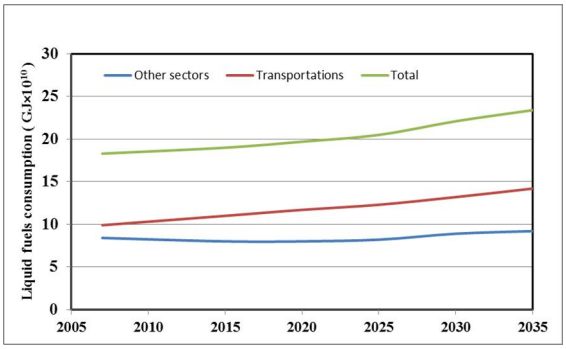

Figure 1. World liquid fuel consumption

3. Transportation sector development in Malaysia

Malaysia's population is about 27.73 million and the gross domestic product grew over the last 2 decades at an average 6% (19). As such, being a fast industrializing and boosting of economy country, transportation makes a vital contribution to the economy and plays a curial role in daily activities. This is one of the factors that increase motor vehicle ownership. The motor vehicle ownership has increased significantly every year and reached double of the number for every 10 years. Figure 2 shows the total road transport vehicles in Malaysia (20).

The road transport vehicles have increased dramatically from 4.5 million vehicles in 1990 to 18 million vehicles in 2008 which grow almost 4 times with the annual growth rate of 8%. The highest growth rate is in year 1996 and 1997 at 11.43% and 11.25% respectively. Apart from that, Figure 3 illustrates the total share of motorization in Malaysia in 2008. It is obvious that the average usage of public

transport in the city is merely 16% in Malaysia and is the lowest figure among the countries in Asia. Figure 4 shows the split mode between private cars and public transport mode for year 1990 to 2008. There is a big gap between the proportion of private car and public transport with public transport share appears diminishing trend over the year. The proportion of public transport is only 1.9% in 2008 and private passenger car occupies 98.1%.

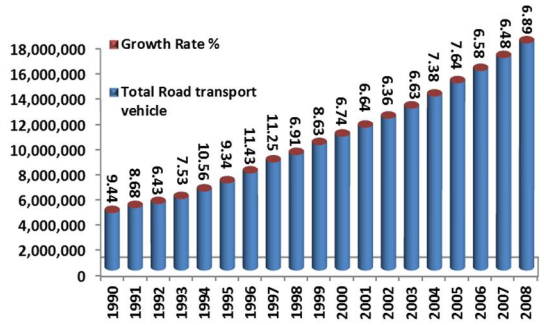

Figure 2. Total Road transport vehicles growth in Malaysia (20)

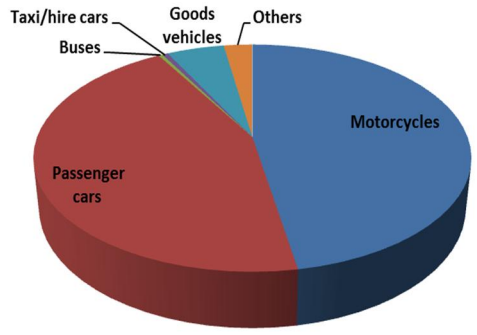

Figure 3. Total Road transport vehicles in Malaysia in 2008 (20)

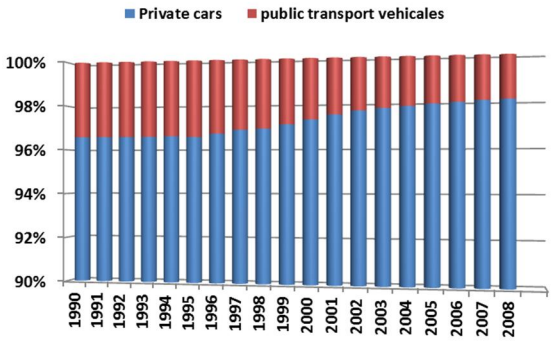

Figure 4. The proportion of private cars and public transport in Malaysia (20)

4. Transportation sector energy consumption in Malaysia

In Malaysia, the final energy use has risen at an annual growth rate of 6% from year 2000 to 2008 and reached 45 Mtoe in 2008. A huge portion of total energy is consumed in industrial and transportation sector. The transportation sector alone accounted for 36% of total energy use in 2008 as shown in Figure 5 (21). The increased use of energy raised serious concerns in the Malaysian government about the need to overcome heightened energy expenditure by promoting the end-use energy efficiency. On top of that, the transportation sector is highly dependent on petroleum products as the source of energy.

According to BP statistical data (22), in the year 2011 Malaysia produced 26.6 million tonnes of oil from reserves however in the same year 26.9 million tonnes were consumed, Figure 6 shows oil production and consumption in Malaysia for year 1990 to 2008. Analysts predict that escalating global oil prices will force Malaysia to become a net oil importer in the years to come. Malaysia uses oil mainly in the transportation sector. The depleting reserves and high price of oil had significant effect the role of oil in the energy mix. In 2008, Malaysia has proven oil reserves of 5.46 billion barrels and 68% are located in East Malaysia Sabah and Sarawak .Crude oil production in Malaysia has declined in the last years and the average oil production in 2008 is about 690 thousand barrels per day. When the production rate is consistent nearly 700 thousand barrels per day, the ratio between reserve and production indicated that oil reserves in Malaysia will be exhausted in the next 21 years (23).

In order to reduce huge demand of fossil fuel in transportation sector the Malaysian government introduced National Biofuel Policy in 2006. Hence, the government's focus is on providing a sustainable energy supply by increasing energy sufficiency and enhancing energy efficiency through increasing the usage of biofuel and biodiesel which will decrease dependence on petroleum products (24). The pattern of energy consumption by transportation sector based on fuel types in Malaysia is shown in Figure 7 (21,25). Total energy use by transportation sector increased from 7.83 Mtoe in 1995 to 16.4 Mtoe in 2008. This high growth rate is more than double with an annual growth rate of 6.6% over the year. The main energy consumption by transportation sector is from fossil fuel with the primary use is petrol, followed by diesel. There are some changes in the pattern of energy use after year 2000 in which the amount of natural gas use increased to 194 Ktoe in 2008. This is due to the policy of the government in promoting natural gas as an alternative fuel for road transport.

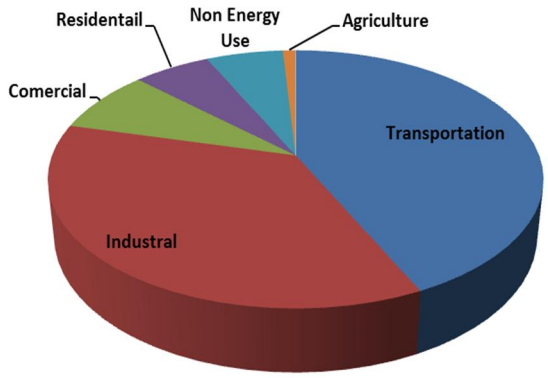

Figure 5. Final energy consumption by sector in 2008

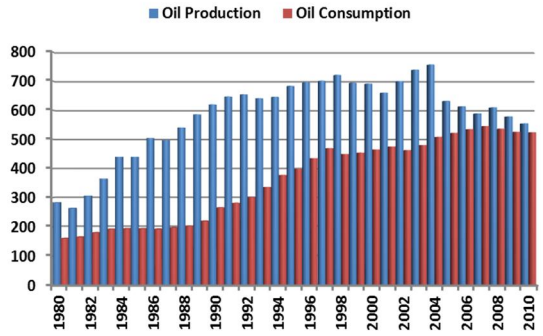

Figure 6. Oil production and consumption in Malaysia

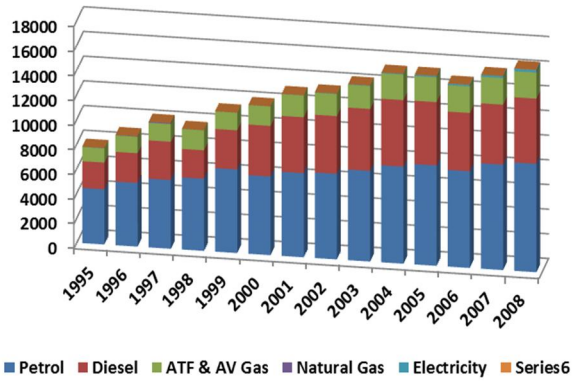

Figure 7. Transportation sector energy use by fuel types

5. Transportation sector emissions

The major GHG emission in the transportation sector is carbon dioxide (CO2) and accounts for 95%. An additional one percent of GHG emissions come from nitrous oxides (N2O) and methane (CH4). The leakage of hydro fluorocarbons (HFCs) from air conditioning systems is responsible for the remaining three GHG emissions percent. Transportation sector also emits carbon monoxide (CO), ozone, and aerosols. These substances are not counted as greenhouse gases but are believed to have an indirect effect on global warming, although their impact has not been quantified with certainty (26). Figure 8 shows the total world emission trends until 2035 (27). Transportation sector accounted for about 23% and 22% of total world CO2 emissions in 2007 and 2008, respectively (8,28). Within this sector, road transport, accounting for 10% of global GHG emissions (29).

According to the United Nations' Intergovernmental Panel on Climate Change, in 2004 the transportation sector was responsible for nearly 23% of total greenhouse gas emissions. Within this sector, passenger vehicles account for about 45% of this total (30). Due to the excessive energy demand coupled with a large portion of its energy sources were still derived from fossil fuels, transportation remained as one of the largest GHG emitters in Malaysia. The emission was worsen due to the lack of proper public transportation infrastructure in Malaysia which has resulted in heavy reliance on passenger vehicles. Approximately 49% of the total GHG emissions can be attributed to transportation related activities (31).

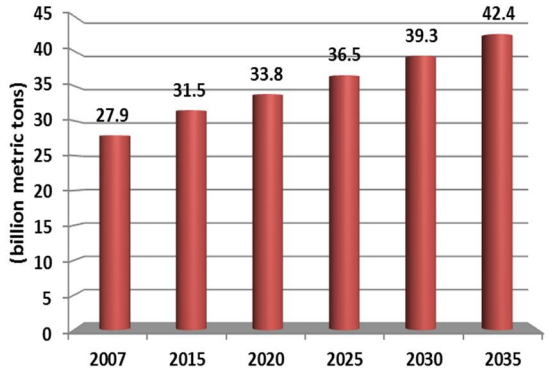

Figure 8. Total world carbon dioxide emissions from 2007 to 2035 (32)

Emissions of fossil fuel:

The transportation sector which fully utilizes petroleum products is no doubt the main contributor in CO2 emission (33). In order to calculate the potential environmental impact, the emission factor for carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxide (NOx) and carbon monoxide (CO) with different fuel types are shown in Figure 9 (34). The annual emission is the summation of emission for all fuel types consumed by the transportation sector. The CO2, SO2, NOx and CO emissions had increased steadily over the past 13 years and still moving upwards. It is estimated about 50 million tons of CO2 emissions in 2008 which is more than double from 1995 with annual growth rate 8.4%. This

emission rate is considered relatively high among the developing countries. It is inevitable that pollutant emissions will continue to climb as long as fossil fuels remain as the main contributor in this sector. Therefore, it is important that accurate emission inventories are prepared for the transport sector in order to design and implement suitable technological and policy options for appropriate mitigation measures (35).

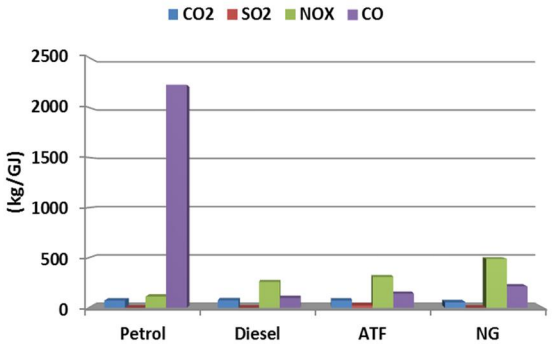

Figure 9. Emission factor for different fuel types

Emissions of biodiesel:

Biodiesel is the renewable energy derived from the reaction of vegetable oils or lipids as well as alcohol and has great potential to serve as an alternative to petro-diesel fuel in compression ignition (CI) engine. Currently, many countries around the world have explored and commercially used biodiesel blends for their vehicles such as US, Germany, Japan, Brazil, India and so on. Due to the increasing interest in the use of biodiesel, the Environmental Protection Agency has conducted a comprehensive analysis of the emission impacts of biodiesel using publicly available data. Biodiesel mainly emits carbon monoxide, carbon dioxide, nitrogen oxides, sulphur oxides and smoke. The average effects are shown in Figure 10 (36). The ignition timing, fuel contents and fuel viscosity will affect emission exhaust from the engine. Apart from using additives fuel properties by preheating or oxidizing, many aftertreatment devices such as particulate matter filter, exhaust gas recirculation (EGR) are used.

Biodiesel which has combustion characteristics similar to diesel and biodiesel blends has a shorter ignition delay, higher ignition temperature and pressure as well as peak heat release compares to diesel fuel (11). Moreover, the engine power output and brake power efficiency were found to be equivalent to diesel fuel. Biodiesel and diesel blends can reduce the smoke opacity, particulate matters, unburned HC, CO2 and CO emissions but NOx emission have slightly increased as obvious from Figure 10 (37). The typical greenhouse gas emission saving for main feedstock of biodiesel is shown in Figure 11 (38). It is clear that Palm oil biodiesel have the maximum greenhouse gas emission saving between the other main feedstock of biodiesel. Life cycle analysis (LCA) conducted on various biodiesels revealed that palm oil-based biodiesel can reduce greenhouse gases (GHG) emission by 62% as compared to soybean oil (40%), rapeseed oil (45%) and sunflower oil (58%).

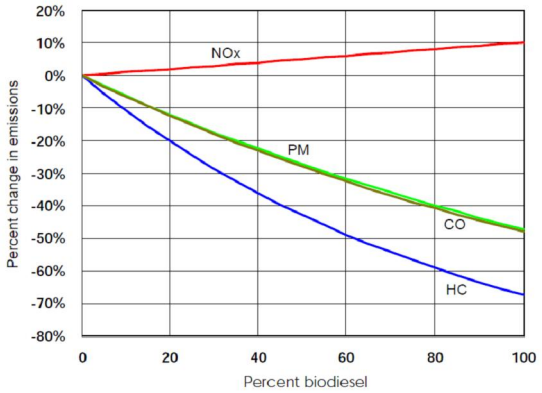

Figure 10. Average emission impacts of biodiesel for heavy-duty highway engines

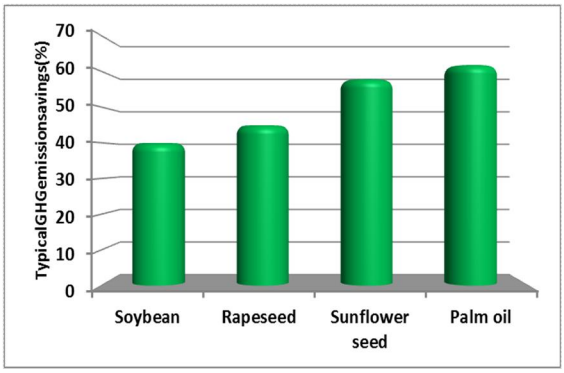

Figure 11. Typical GHG emission saving for main biodiesel feedstock

6. Biodiesel as a transportation fuel

The concept of using biofuel in diesel engines is not a radically new idea, an inventor named Rudolph Diesel demonstrated his first developed compression ignition (CI) diesel engine using peanut oil as a fuel at the World Exhibition in Paris in 1900 (39,40). However due to abundant supply of diesel and vegetable oil fuel were more expensive than diesel, research and development activities on vegetable oil were not seriously pursued (41). There is a renewed interest in vegetable oil in the last decades when it was conclusively realized that petroleum fuel are dwindling fast and environmentally friendly renewable substitutes must

be identified (42). Biodiesel is gaining more and more interest as an attractive fuel due to the depleting nature of fossil fuel resources and environmental protection reason.

Vegetable oil which also known as triglycerides have the chemical structure comprise of 98% triglycerides and small amounts of mono and diglycerides (43). Transesterification is the process of reacting triglyceride with an alcohol in the presence of a catalyst to produce glycerol and fatty acid esters (42). Biodiesel is defined as the mono alkyl esters of vegetable oil or animal fats. Vegetable oil can be used as liquid engine fuel in various ways such as straight vegetable oil, oil blends, pyrolysis, micro-emulsification and transesterification in diesel engine (44). Biodiesel which has combustion characteristics similar to diesel and biodiesel blends has a shorter ignition delay, higher ignition temperature and pressure as well as peak heat release compares to diesel fuel (11). Moreover, the engine power output and brake power efficiency were found to be equivalent to diesel fuel.

Biodiesel and diesel blends can reduce the smoke opacity, particulate matters, unburnt hydrocarbons, carbon dioxide and carbon monoxide emissions but nitrous monoxide emissions have slightly increased (37). However, the main drawback of biodiesel fuel is their high viscosity and low volatility, which causes poor combustion in diesel engines including formation of deposits and injector cocking due to poorer atomization upon injection into the combustion chamber. Transesterification of the oil reduces the oil viscosity to a range of 4–5mm^2/s closer to that of diesel and hence improves combustion (45,46). Biodiesels or fatty acid esters are efficient, clean and natural energy alternative to petroleum fuel. The use of biodiesel grew dramatically during the last few years. Feedstock costs account for a large portion of the direct biodiesel production costs, about 75-80% of the total production cost (45). Any type of feedstock that contains free fatty acids or triglycerides such as vegetable oils, waste oils, animal fats and waste greases can be converted into biodiesel (13). However, the final products must meet stringent quality specifications of ASTM D 6751 (American standard) or EN 14214 (European standard) before it can be accepted as biodiesel fuel. Biodiesel is a clear amber yellow liquid with a viscosity similar to diesel fuel. Biodiesel is non-flammable with a flash point of 423 K as compared to 337 K for diesel.

The source for biodiesel production is usually chosen according to the availability in each region or country. Palm oil and coconut oil are surplus in coastal area countries like Malaysia, Indonesia and Thailand have become the primary source for biodiesel. Figure 12 shows the average oil yield of major oil sources for biodiesel feedstock (47,48). As noted in the figure, the highest oil productivity is palm oil which is about 13 times better than soybean oil and follows by coconut oil. The global potential volume of biodiesel production is 51 billion liters annually and top five biodiesel production countries are Malaysia, Indonesia, Argentina, United States and Brazil account for over 80% of the total production. Figure 13 shows the top 10 countries ranked by overall biodiesel potential production volume with Malaysia far ahead among the rest. The feedstock for biodiesel for those nations are 28% for soybean oil, 22% for palm oil, 20% for animal fats, 11% for coconut oil and 5% for rapeseed, sunflower and olive oils each (49). The potential market for biodiesel in road transport is projected to climb from 24 Mtoe in 2006 to 118 Mtoe in 2030 (9). The rapid increase of biofuel in transportation is due to new national biofuel policy in several countries and high fossil oil price.

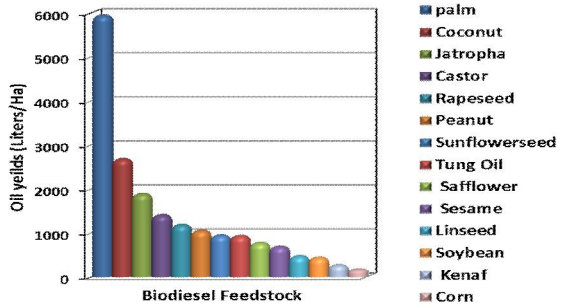

Figure 12. Average oil yields for major oil sources

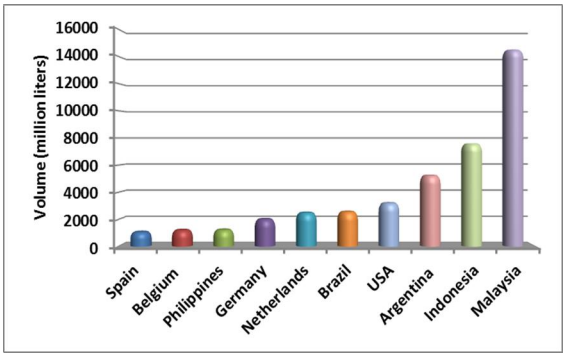

Figure 13. Top 10 countries by absolute biodiesel production

Biodiesel fuel in Malaysia:

Malaysia is currently the world's second top producer of palm oil (after Indonesia) and largest exporter, Malaysia continues to revise the policies to better intensify this huge industry. By increasing the demand for energy and the intensified production and usage of this renewable energy source, Malaysia

could find itself as a potent country in this area. Malaysia has embarked on a comprehensive palm biodiesel program since 1982. Biodiesel's status in Malaysia as a renewable energy source was further solidified when the National Biofuel Policy was introduced Envo Diesel in 2006. Envo Diesel (B5) was a mixture of 5% blend of processed palm oil with 95% petroleum derived diesel (50). However, the Malaysian government has stopped the Envo Diesel project as it failed to market in 2008 as planned. On top of that, the government of Malaysia will implement the mandatory use of biofuel for vehicles in mid of 2011.

The mandatory biodiesel implementation in the transport and industrial sectors involves blending of 5% biodiesel (palm methyl ester) with 95% ordinary diesel and is part of the country's biofuel initiative under the B5 program. Apart from that, the biofuel implementation plan includes the RM43.1 million instigation of depot with inline blending facilities to be placed in Port Klang, the Klang Valley Distribution Terminal (KVDT) in Selangor, Negeri Sembilan and Tangga Batu, Malacca. Besides, increasing the planted area to more than 5 million hectares in 2011 (51), is widely seen as a way to achieve high productivity, furthermore to enhance Malaysia's long term target at an average of 35 tons of fresh fruit bunches and oil extraction rate of 25% by 2020 (52).

Palm oil abundance in Malaysia is the main driving force for its biodiesel industry development. Malaysia is one of the larger world's producers of palm oil and produced 18.7 million tons of oil palm in 2011(53). Therefore, Malaysia does not need to depend on foreign import for raw materials to develop its own biodiesel industry. Furthermore, using raw materials from own plantations will enable biodiesel developers to control the cost and quality of the biodiesel production more efficiently (54). Hence, development of biodiesel in Malaysia had been growing by leaps and bounds.

As the biggest producer and exporter of palm oil and palm oil products, Malaysia plays an important role in fulfilling the growing global need for oils and fats in general. Malaysia has positioned himself on the right path to utilize biofuel as a source of renewable energy and this can act as an example to other countries in the world that has huge biomass feedstock. The current installed biodiesel production capacity in the country is about 10.2 million tons (55). There are many active biodiesel plants installed in the year 2008 with a total annual biodiesel installed capacity of 1.2 million tons (50). An additional four biodiesel plants with combined annual capacity of 190 ktons are expected to commence commercial production by the end of year 2009 (56).

7. Future demand of biodiesel and other alternative fuels

The use of biodiesel as internal combustion engine fuels can play a vital role in helping the developed and developing countries to reduce the environmental impact of fossil fuels. Based on five strategic in which, the energy mix in Malaysia is contributed by five main sources, namely natural gas, coal, oil, hydro and renewable energy. Malaysia has been working to integrate renewable energy into its energy fuel mix. The national biofuel policy will help the country to spell out a comprehensive framework and concrete initiatives for the use of biodiesel in Malaysia (54). This policy is expected to reduce the dependency on petroleum and diesel. At the same time, it is also in line with the global efforts to reduce the greenhouse gasses. All these factors will contribute to biodiesel development especially palm oil based biodiesel. Transportation sector had the largest energy demand in the year 2000 with roughly 41% out of the total energy demand at 29.70 Mtoe (million tonne of oil equivalent). Even though energy demand for industry had surpassed transportation in 2008 as the largest energy demand sector, transportation still recorded a considerable increase in energy demand.

The Malaysian government is seeking to intensify the development of renewable energy, to attempt to motivate the nation to place a greater emphasis on developing and implementing renewable sources of energy to combat climate change and reduce GHG emission, particularly biomass, as the 'fifth fuel' resource under the country's Fuel Diversification Policy. The introductory phase of implementation of mandatory use of palm biodiesel started with B5 by Government Departments on 3rd February 2009. Government Departments involved in the B5 implementation were, Armed Forces (ATM) and Kuala Lumpur City Hall (DBKL). On April 2009, Malaysia formulated the National Green Technology Policy to reflect that Malaysia's seriousness in driving the message that 'clean and green' is the way forward towards creating an economy that is based on sustainable solutions (57).

8. Conclusions

Rapidly growing energy demand and emissions from Malaysia's road transportation vehicles in the last decades have raised concerns over oil security, urban air pollution and global warming. This rapid growth will be likely to continue in the next years. Malaysia currently has a depleting petroleum fuel sources for its increasing vehicle fleet. However, the Malaysian transportation sector is still heavily dependent on non-renewable fuel such as

fossil fuels and natural gas as a source of energy. There are many policies implemented for road transport to reduce fuel consumption such as fuel economy standard, fuel economy label and fuel switching. It is found that fuel switching to alternative renewable fuel can solve the scarcity of fossil fuel consumption. Biodiesel is gradually gaining acceptance in the market as an environmentally friendly alternative diesel fuel, it has similar combustion characteristics as diesel and plays a role to reduce the environmental impact of fossil fuel. In Malaysia, it is economically feasible to use palm oil as a feedstock for producing biodiesel as Malaysia has huge potential for palm oil base biodiesel production. This study serves as a guideline for further investigation and research in order to implement and improve the transportation sector fuel demand in Malaysia.

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