Biofuel: Potential Energy Source in Road Transportation Sector in Malaysia

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Abstract

In this present era transportation sector is consuming vast amount of energy which is mostly met by petroleum fuel and some part by biofuel. Global energy depletion and concern about increasing future energy demand forced researchers to find some renewable and sustainable alternatives. Since environment has been polluted at an alarming rate by gasoline and diesel fuelling thus the use of biofuel has crucial importance as it has no such problem. In this investigation we sought to extend our observation on present local energy scenario in transportation sector and prediction of future energy demand based on continuous trend.
Possible ways to meet the energy challenges especially in transportation sector has been focused locally. From the investigation, it is found that apart from petroleum fuel, natural gas and other sources, biofuel can be the key player to meet the increasing energy demand. As compared to petroleum and other fuel biofuel is the promising alternative which possesses many advantages such as renewability, environmentally friendly, higher lubricity, safer handling and so on. However, it should be noted that some application problems of biofuel are still exist which need to be resolved for its widespread applicability.

**Keywords:** Renewable energy, Biofuel, Road transportation, Emission, Energy demand

### 1. INTRODUCTION

Transportation system plays the crucial importance for the socio-economic development of a country. The predominant issue for this sector is the energy which is usually met by fossil fuel like diesel and gasoline. Because of rapid fossil fuel depletion, unknown petroleum reserve, increasing future energy demand the global warming and climate change due to the exhaust emission of the fossil fuel have been put forward to search the alternative solution regarding the energy. Even though various sources of alternative energy have been discovered, biofuel remain one of the most potential alternatives to cut down the dependency on fossil fuel by replacing it fully or partially. Transportation sector has dominated huge energy consumption and global warming as well. The consumption in transportation sector accounting for 40% of total energy regarded as a second largest consumption after the industrial sector in Malaysia. Presently, petroleum is met around 98% of the entire demand in transportation sector which is accountable for the harmful CO$_2$, NOx, HC and particular matters thus resulting the global warming at an alarming rate. Study report shows that the transportation sector is the responsible for the global warming of about 13.5% [1]. Global CO$_2$ emissions increased from 21 billion tons in 1990 to 29.4 billion tons of CO$_2$ in 2008. Within the total world emissions, 41% was originated from China and the United States, as these two countries alone produced 12.1 billion tons of CO$_2$ in 2008. On top of that, transportation sector contributed 6.6 billion tons of CO$_2$ which is 22.5% of total CO$_2$ emissions in 2008 [2]. Transportation sector emitted 1081 Mtoe (23.1%) in 1973 and climbed significantly to 2300 Mtoe which is 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 [3]. The share of road transport in the total energy consumption of the transport sector in 2008 was the highest at 80%, followed by air transport (11%), maritime transport (7%) and railways (3%) [4]. 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 [5]. A recent study regarding the influence of anthropogenic activities towards climate change had also proven that transportation sector would be the highest potential contributor to atmospheric warming in the near decades [6]. 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 living environment [7].

Over the years, several meeting and conference on global warming and climate changes have been conducted which have organized by the various organizations including United Nation and over 200 countries have participated around the world [8]. Nevertheless, the use of fossil fuel in transportation sector is growing faster and the trend appeared to be moving upward dramatically. Thereby, the development and implementation of sustainable energy in this sector have been given a priority in many countries including Malaysia [9]. Malaysia with a huge supply of palm oil for biofuels production is intended to implement mandatory biodiesel blends in its transportation sector in 2011 in order to achieve its carbon reduction commitment towards a more sustainable development [10]. Malaysia has the leading position in terms of the production and export. It has become one of the most crucial foreign exchange earners of this country. Rapidly increasing economic activities and rising incomes have led to an exponential
increase in the demand for both freight and passenger transport services in the country, especially in the rapidly growing urban areas. Malaysia has experienced high levels of motorization over the past two decades to meet the growing transportation demand. Road transport is the main energy consumption within the transportation sector. The Malaysian government has set on a strategy to utilize non-petroleum, domestic energy resources to increase self-reliance in energy. In order to meet the future energy demand especially in the transportation sector, this is the high time to make a constructive energy policy and emission standard. Policy makers should realize the future crisis and are required to make a long, medium, and long terms policy considering all the view, aspects, and alternatives. This paper presents the biofuel scenario in Malaysia, energy consumption in transportation sector, emission rate, and a trend of energy and emission pattern for transportation sector in Malaysia. In addition to that, a projection up to 2035 and 2050 for several parameters has been accumulated from the several studies. Apart from that, substantiality of biofuel in transportation sector as and some challenges are discussed in this study which may help the policy makers to step forward.

2. BIOFUEL

Biofuel is the environment friendly and renewable source of alternative fuel which is mainly produced from animal fats (tallow, lard, white or yellow grease, poultry fats, or fish oils); recycled greases (used cooking and frying oils); and most commonly, plant oils (from soybeans, corn, rapeseed, sunflowers, and cottonseeds, etc.). To use this biofuel in a diesel engine it requires no engine modification as well [11]. In general, the term biofuel is used to represent all the liquid and gaseous transportation fuels derived predominantly from biomass [12]. The biodiesel production process for diesel vehicle is shown in Fig.1. Currently, biodiesel and bioethanol are the two most promising biofuels being projected to replace conventional fossil fuels in transportation. Biodiesel or fatty acid methyl ester (FAME) is normally synthesised through transesterification of vegetable oils with methanol and the aid of appropriate catalysts. It can be used to replace mineral diesel in compression-ignition (CI) engine which has almost similar properties without requiring any major engines modifications. Commercial production of biodiesel has been well established and is available to be purchased as turn-key plants in many countries [13] On the other hand, bioethanol is suitable to replace the usage of gasoline in petrol engine. Conventional bioethanol is produced from the fermentation of simple sugar or starch crops. Its large-scale production has been well proven and demonstrated successfully in Brazil [14]. However, it competes with food sources for human consumption which renders it susceptible to criticisms. Another alternative raw material for bioethanol production is using inedible food sources mainly lignocellulosic material such as forest and agricultural biomass waste. However, additional pretreatment steps are normally required which will increase the overall production cost. Process optimisation is still being researched intensively at pilot plant scale in order to find a more cost-effective production method for mass commercialisation [15].
3. BIOFUEL SCENARIO IN MALAYSIA

In Malaysia, palm oil is the main sources of biofuel. It is produced domestically which helps to reduce the dependency of oil import of the country. In Malaysia biofuel also produces from non-edible oil source such as Jatropha and some other domestic crops which are highly potential and they do not contend with food crops [17, 18]. In 2009-2010, Malaysia produced about 40% (consumed 7.5%) of world palm oil, while Indonesia 46%, Thailand 3%, Nigeria 2%, Colombia 2% and others 7% [19]. Malaysia produces more than 17 million tonnes of crude palm oil (CPO) annually from a total of 4.69 million hectares of palm oil plantations [13]. More than 88% of the total palm oil production is exported to countries such as EU, China, India and US due to higher prices and demand. The rest of the palm oil is either being processed into food products for local usage or biodiesel for foreign exportation. Based on the current production volume and assuming that 80% of it was dedicated for food sources, Malaysia had sufficient supply of palm biodiesel to support up to B50 biodiesel blend for transportation [20]. At the same time, Malaysia have the potential to generate more than 104.55 million tonne of lignocellulosic biomass waste annually (including agricultural biomass and forest residues) [21]. Currently, most of the domestic biodiesel fuels are supplied by small and medium producers which can only cater for a restricted group of users. Procurement of biodiesel from Malaysia can secure a reliable biodiesel supply over a long term to prepare for the imminent mandatory biodiesel blending in transportation fuels. A stable supply of biodiesel can effectively quash public’s apprehension to embrace biodiesel as their choice of transportation fuel. Moreover, Malaysia has been able to produce high quality biodiesel consistently at optimised cost which meet the international standards for biodiesel (ASTM D 6571 and EN 14214). Recently Malaysian government has set the target to use B5 (5% methyl ester blend with 95% diesel) [22]. Malaysia imports about 10 million tonnes of petroleum diesel fuel annually and this import can be reduced by 500,000 tonnes by using “B5” saving an estimated amount of US $380 million per year [23]. In this respect every petrol stations are selling “B5” according to Malaysian government regulation since 1 January 2010 [24].

3.1 Global energy status and transportation perspective

The trend of world energy production from 1990 to present and the projection until 2030 has been shown in Fig. 2. It is depicted from the Figure that in the year of 2035 the production of total energy would be nearly 100Mb/d including development unused crude field, production from the new fields which would be found, natural gas and unconventional oil sources. However this is the big challenge to find new fields and implementation of energy form the projected natural gas and unconventional sources. Besides, present scenario and projection of consumption by transportation until 2050 is shown in Fig. 3. It is clear from the Figure that biofuel would be the one of the major contributor to meet future energy demand.
4. ENERGY CONSUMPTION BY TRANSPORTATION SECTOR IN MALAYSIA

Energy consumption 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 Fig. 4 [26] 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, transportation sector is highly dependent on petroleum products as the source of energy. In 2008, Malaysia has proven oil reserves of 5.46 billion barrels and 68% are located in East Malaysia Sabah and Sarawak [27]. Malaysia’s crude oil production has declined in recent years and the average oil production is around 690 thousand barrels per day in 2008. In terms of number of passenger and freight carried, road transport is still leading among the transportation modes in Malaysia. Fig. 5 shows the mode of transportation allocation for passenger [28]. There are more than 94% of passengers carried by road transport. The rail passenger is about 4.7% while air transport served 0.5% of total passengers. Table 1 presents the trend of energy consumption in transportation sector from different energy sources. It can be seen from the Table, that the leading source of energy in transportation is petrol followed by diesel and Aviation turbine fuel (ATF) and aviation gasoline (AV) gas. Recently a considerable change has been observed in the use of natural gas for the transportation sector. Furthermore, mostly the total energy consumption is increasing year by year and it has been more than doubled form the year of 1995 to 2008.
5. EMISSION

The vehicular exhaust emissions are one of the main sources of global warming and environmental pollution. The vehicular exhaust emission is increasing dramatically due to the increasing numbers of vehicle in the world, which have an adverse effect on environment as well as humans health [30, 31]. According to united state environmental protection agency (EPA), the legislated maximum amount of emissions from the heavy duty diesel engines are...
CO: 15.5 g/bhp-hr, PM: 0.01 g/bhp-hr, NO\textsubscript{x}: 0.20 g/bhp-hr and non-methane hydrocarbon (NMHC): 0.14 g/bhp-hr for the model year later 2007 [32]. Whereas, emissions standard of Euro V for the diesel engine vehicles are, carbon monoxide (CO): 500 mg/km, particulate matter (PM): 5 mg/km (80% lower than Euro IV standard), oxides of nitrogen (NO\textsubscript{x}): 180 mg/km (20% lower than Euro IV standard), combined emissions of hydrocarbons and nitrogen oxides: 230 mg/km [33]. The world petroleum reserve is diminishing swiftly but its demand is increasing day by day. Due to the depletion of fossil fuel along with environment concern, attention has been drawn to develop a clean alternative fuel which will reduce both of the exhaust emission and the petro fuel dependency [34]. Therefore, it became a global issue to develop such clean alternative fuel which is technically feasible, domestically available and environmentally acceptable. According to the Energy Policy Act of 1992 (EPACT, US), ethanol, natural gas, hydrogen, biodiesel, electricity, methanol are included as an alternative fuels. It is reported that these fuels can be used to reduce petroleum consumption, harmful pollutants and exhaust emissions. The use of biodiesel as internal combustion (IC) engine fuels can play a vital role to help the developing countries in terms of reducing the both of environmental impact and the adverse human health effect of fossil fuels. According to well to wheel base assessment, biodiesel from oil seed reduces about 40-60% GHG emission [35]. The biodiesel extends many environmental benefits over petro diesel. It is less toxic, huge biodegradable and emit lower CO, THC, and PM emission as compared to petro diesel [36]. Therefore, the production of biodiesel and its use is increasing steadily and hopefully retain in future. The transportation sector which fully utilizes petroleum products is no doubt the main contributor in CO\textsubscript{2} emission [37]. However, the projected CO\textsubscript{2} emission relief by sector and the key technology for reducing CO\textsubscript{2} emission has been shown in Fig.6 and 7 respectively. It can be seen form the Fig. 6 that transportation accounts the second largest sector to reduce the CO\textsubscript{2} emission of 23%. While from Fig.7 it is depicted that renewable energy is the third largest key factors to reduce (17%) projected CO\textsubscript{2} emission.

![Fig. 6 World energy-related CO2 emissions abatement by region [25]](image-url)
6. CURRENT BIOFUEL POLICY IN MALAYSIA

Since the introduction of Fifth Fuel Policy under the Eighth Malaysian Plan (2001–2005), Malaysia has been working to integrate renewable energy into its energy fuel mix. 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 up to 32.7% from 2000 within just an eight year span [39, 40] . Despite the fact that ample of efforts had been put forward to rein in the escalation of energy demand, the annual increment was still being forecasted at about 3.5% average. 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. Biofuel policy and development of biofuel are presented in Table 2.

Table 2 Chronology of biodiesel development in Malaysia [13, 41, 42]

<table>
<thead>
<tr>
<th>Year</th>
<th>Milestone</th>
</tr>
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<tbody>
<tr>
<td>1982-1985</td>
<td>Feasibility study of palm oil methyl ester in the laboratory, steering committee formation, construction of biodiesel plant having capacity 3000 tonnes in each year, and field trial in taxis conducted from the government of Malaysia and finally pilot plant launched at the end of this duration</td>
</tr>
<tr>
<td>1986-1994</td>
<td>Several Field trials conducted including 31 commercial vehicles and stationary engines in phase I, bench test by Mercedes Benz in Germany in phase II, and finally trail on commercial buses.</td>
</tr>
<tr>
<td>1995</td>
<td>Transfer of PME production technology to industry to produce oleochemicals, carotenes (pro-Vitamin A) and Vitamin E</td>
</tr>
<tr>
<td>2001</td>
<td>Use of a CPO and fuel oil blend for power generation initiated and Research on low-pour-point palm biodiesel initiated</td>
</tr>
<tr>
<td>2002-2005</td>
<td>Field trials using processed liquid palm oil and petroleum diesel blends (B2, B5, B10) in MPOB vehicles began (i.e. a straight vegetable oil SVO biofuel blend), Trials of refined, bleached and deodorised (RBD) palm oil and petroleum diesel blends (B5) using MPOB vehicles and shifting the technology from MPOB to Lipochem (M) SdnBhd and CarotinoSdnBhd</td>
</tr>
<tr>
<td>2006</td>
<td>National Biofuel Policy launched, First commercial-scale biodiesel plant began operations, Envo Diesel launched, 92 biodiesel licenses approved</td>
</tr>
<tr>
<td>2007</td>
<td>Increase in CPO price caused many biodiesel projects to be either suspended or cancelled</td>
</tr>
<tr>
<td>2008</td>
<td>Malaysian Biofuel Industry Act 2007 came into force</td>
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Usage of Envo Diesel was scrapped and replaced with B5

<table>
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<tr>
<th>Year</th>
<th>Description</th>
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<tbody>
<tr>
<td>2009-2010</td>
<td>Government vehicles from selected agencies began use of B5 blend and Government announcement that the B5 mandate for commercial use will be deferred to June 2011.</td>
</tr>
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</table>

7 CHALLENGES OF BIOFUEL

Recent study report [16] made concern on biofuel regarding its Supply cost, supply volume, dependence on a specific country, Influence on food prices, competition with farmland, Forest destruction etc. In addition, technological development, infrastructure, popularity, and policy can be the important factors for the wider application of biofuel. These influential factors are described in brief as follows.

7.1 Supply cost

One of the main barriers for the wider application of biofuel is its supply cost. Depending on the geographical situation and feedstock the price of the biofuel is several times higher than diesel and gasoline. Resulting people are discouraged to use biofuel. Moreover, there have various procedure including refining transesterification which are maintained to make adaptable with the internal combustion engine. Thereby the production cost becomes higher.

7.2 Supply volume

Adequate supply of biofuel is an important factor for the frequency of use in transportation sector. The cultivation of biofuels is not sufficient with compared to the amount required.

7.3 Dependency on specific country

Most of the countries in the world are not so much familiar on biofuel. Presently very few like, Malaysia, Indonesia, Brazil USA, and Nigeria are producing uttermost (more than 90%) amount of world total production. However, there have several countries consisting huge lands which are suitable for the biodiesel feedstock are not being utilized. In addition, some biodiesel feedstock’s like Jatropha can be grown in the marginal land and does not required much water. Therefore it is a vital issue to find the land availability worldwide and cultivate the biofuel feedstock. Otherwise, all other countries would be depended on the some specific country although they become interested to use it.

7.4 Contend of food

Most of biofuel like palm, soybean, sunflower, coconut etc. which are available in the market are used as a food thus there will be a great threat to the food price if the application of such feedstock is increased in the biodiesel production as well. Therefore, it is our recommendation to find new non-edible feedstock and use for biodiesel production. Meanwhile, some of non-edible feed-stocks such that Jatropha curcas, Madhuca indica, and Pongamia pinnata etc. are found to be very potential however, the cost of production is low as well as can be grown in the marginal land as well. So the emphasize should be given to the investigation of physicochemical properties of such feed-stocks and their standardization.

7.5 Technology

In order to replace the existing fossil fuel and make competitive with them, technological development is the pre request. Implementation of advanced technology in biofuel production can play their role for plantation, processing and final use. In order to enhance the production rate or oil yield, there have no alternative regardless of the advanced technology. Especially for the most populated country where the land for the cultivation is not enough is an important demand to increase the production rate with in land available. This can be achieved through intensive research in biotechnology, plant agronomy and precision agriculture techniques [9]. Technological advancement is required to for the oil extraction, transesterification and
fermentation processes of the biodiesel and bioethanol production respectively. The former had been well established but still requires some optimisation. The latter is still in research phase and technology breakthrough will be needed for full commercialisation.

7.6 Infrastructure
Another vital issue for the successful implementation of biofuels in transportation sector will be the establishment of both hard and soft infrastructure. The relevant biofuels supply chain infrastructure will need to be convenient and sufficient to reach to the end-users for their daily usage. In terms of hard infrastructure, biofuels blending and refuelling station facilities will need to be set up adequately together with complete transportation of biofuels supply network. This is best to prevent any conflict of interest since biofuels and fossil fuels are competing products of each other. Moreover, it can help to identify possible difficulties for better planning in the future [43]. Blending facilities will have to be in minimum distance from both conventional oil and gas refineries and biofuels processing facilities in order to minimize the transportation cost. Existing refuelling stations will need to be supplied with biofuels blends and equipped with necessary modifications. Some modification of existing diesel and gasoline engine will further lead to the increase in the performance and emission behavior as well.

7.7 Policy
For the long term social and economic development, well established policy from the government is pivotal. Government as the critical stakeholder in the implementation of biofuels blends for transportation sector will be responsible to stage a suitable platform or medium for other stakeholders such as industry players, non-governmental organisations (NGO), research institutes and private investors to contribute towards the development of the biofuels blends. Government policies will be critical in areas such as subsidisation scheme, tax relief, financial assistance, information dissemination, investment environment, authorisation and standards of biofuels blends. Previously, increasing environmental awareness had fuelled the demand for biofuels such as biodiesel and plenty of biodiesel plants were constructed. However, when the price of crude oil plummeted to about USD 30/bbl, expensive biodiesel was unable to compete with mineral diesel and thus rendered its demand to drop substantially. Consequently, most of the biodiesel plants were either being shut down or forced to cut down their production [13]. Future policy makers will need to address the above shortcomings and prevent the history from repeating itself.

7.8 Public acceptance
Public acceptance for biofuels will be the last challenge to be addressed once all the relevant infrastructures and supply system are in place. Since mass public is the major user of fossil fuels in transportation sector, their willingness to switch to biofuels blends is important to ensure the success of the implementation. Lack of public support for new transportation fuels can eventually lead to catastrophic failure as already seen in the case of natural gas in Canada and New Zealand. Whilst mandatory biofuels blends can force the public to make the switch, it was extremely important that they were being given sufficient information pertaining to the changes. Many of the citizens in developing countries such as Malaysia had low environmental awareness and are not familiar with the operation of biofuels.

8. CONCLUSION AND RECOMMENDATIONS

World is now confronted into two major crisis including energy crisis and global environmental pollution and resulting rapid climate change. If the crude petroleum production continues in the same manner as present then the production will be declined drastically from roughly 65Mb/d to 18Mb/d. Even though it is tried to keep the production rate likewise today, it is believed to fill up another 47 Mb/d by developing existing unproductive crude petroleum fields and by the discovering new field. However the increasing demand of projected up to 2035 of about 100 Mb/d would be managed by the alternative resources like natural gas and
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unconventional oil. Resulting dangerous adverse effect would be imposed on the developing
countries including Malaysia. If the projected crude fields are not found as predicted and
alternatives sources are not implemented as thought then the world would be confronted a
dangerous threat which may be more dangerous that second world war. Meanwhile, the
scenario war for oil has already been started. On the other hand, without new policy
intervention with regards to oil and emission, the CO2 emission would be doubled within
2050. Since the transportation sectors are accountable for more than 37% of total emission
thus without especial care and strong policy world has been faced drastic climate change.
Consequently, huge part of the world would be submerged into the see. Vital part of the some
south Asian countries like Bangladesh, Maldives will be lost by the ocean. In addition
Malaysia and some other developing country will face dangerous challenge as they are not
much concern about emission climate change etc. Meanwhile USA and Europe has set
emission standard for their own countries. However those standards have been set considering
their own geographical circumstances, socio-economic infrastructures, own political situation
and policy. Hence it is recommended that every country including Malaysia should be
established their own energy policy and emission standards taking in to consideration above
mentioned factors. Biodiesel is gradually gaining acceptance in the market as an
environmentally friendly alternative diesel fuel. Malaysia has huge potential for palm oil base
biodiesel production and plays a role to reduce the environmental impact of fossil fuel.
However, the use of inedible vegetable oils as an alternative fuel for diesel engine is
accelerated by the need of edible oil as food and the reduction of biodiesel production cost.
Therefore, jatropha and calophyllum inophyllum have great prospect as feedstock for biodiesel
in Malaysia. Apart from that, various aspects must be examined and overcome before
biodiesel can be established and continue to mature in the market. This study serves as a
guideline for further investigation and research in order to implement and improve the
transportation sector

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