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Potential of Sugarcane Ethanol as Fuel for Vehicle in Malaysia

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Abstract

Climate change threat is rapidly increasing with the rise in global temperatures, largely due to emissions of harmful greenhouse gases. In Malaysia, the transportation sector is the main contributor of these emissions as most of the vehicles are still running on fossil fuels. Countries such as Brazil have already focused on their resources into cultivating biofuels, sugarcane ethanol. Sugarcane ethanol produced from sugarcane fermentation and can effectively be used as an ethanol-gasoline blend or as 100% pure ethanol fuel, in spark ignition engine vehicles. Malaysia's suitable weather and agricultural capabilities allow to produce high yield of sugarcane, that lead to the potential alternative source of fuel. This paper will discuss on the study of the impact of the economy and environment of sugarcane ethanol that lead to its potential as a fuel for vehicles in Malaysia. Previous studies show the use and the production sugarcane ethanol give impacts to the economy, with the unit cost price of sugarcane ethanol being RM 0.22 per litre. The results also proved that the production and use of bioethanol positively impacted the environment, with total carbon savings increase with the increase in bioethanol concentration. Better economy and environmental results subsequently proved the positive impact towards society.

Keywords: biofuel, renewable energy, bioethanol, sugarcane, vehicle

INTRODUCTION

The beginning of the 18th century European Industrial Revolution had introduced large emissions of carbon dioxide (CO_2) and other greenhouse gases (GHG) to the atmosphere, which may lead to irreversible major climate change when rapidly accumulated [1-3]. Burning of fossil fuels and natural gases are major contributors to the large quantities of these harmful gas emissions to the atmosphere. Based on a study done by the Intergovernmental Panel on Climate Change (IPCC), fossil fuel burning in 2010 contributed to 14% of the global GHG emissions, with estimations of doubling of CO_2 emissions by the year 2050 [4] and the transportation as the main contributor to GHG emissions [5]. Due to this issue, many researchers, scientists, and engineers have invested their time and effort to find the solution in preventing further irreversible damage to the environment. One of the solutions is by using biofuels, made from palm oil, sugarcane, corn and other biomass as an alternative resource of fuel [6].

In this paper, a feasibility study was carried out via numerical analysis on the potential of the biofuel sugarcane ethanol as a fuel for vehicles in Malaysia. Sugarcane grows in large quantities, as Malaysia has a strong agricultural capability caused by yearlong sunshine and rainfall [7]. This study was focusing on the impact of this potential sugarcane ethanol as an alternative vehicles fuel based on the economy and environmental impact in Malaysia.

Economically, the fuel performance of sugarcane ethanol in countries such as Brazil and Mexico were proven to cost less, and the final waste produced was significantly reduced. In addition, the production can also be made from different forms of sugarcane such as the molasses or sugarcane juice itself [8-9]. Similar studies were carried out by Wang et al. [8], and Garcia et al. [9], but all of this are not directly applicable to Malaysia due to factors such as politics, economy, and environment. [9]

Studies on the general impact and potential of biofuels globally were done by Oumer et al. [10]. Sugarcane was stated as a good source of ethanol, being the second largest source of production of first-generation ethanol, and Brazil being the main producer [10]. Due to its high starch content, sugarcane can yield large quantities of ethanol through the process of fermentation. The policy in Brazil is such that a minimum of 22% of ethanol is required in their gasoline, and users are also able to purchase 100% ethanol as well [10]. The research by Oumer et al. was focusing more on the costs of production and the effect on the environment, rather than effect of emissions due to production. The sugarcane ethanol is proven to be a good alternative as vehicle fuel source that shows 90% lower carbon emission as compared to gasoline fuel [8]. In addition, Brazil's agriculture yields large quantities of sugarcane due to their weather and location [10].

Lim et al. [1], and Sadhukhan et al. [11] both discussed Malaysia's pledge during the 2009 Copenhagen United Nations Climate Change Conference to reduce CO_2 emissions by 40% in 2020 compared to emissions in 2005. In the conference, the main contributor is believed to be the transport sector, and as such the implementation if biofuels are a progressive step towards keeping the pledge. However, both researches focused

mainly on palm oil biodiesel as the choice biofuel, studying in detail it's potential as an alternative fuel source in Malaysia.

Another study by Derman et al. [12] in 2018, focusing on the necessity of Malaysia relying on alternative fuel sources not only due to environmental motivations, but also the continuous decline of non-renewable fuel sources and drastic increase in economy and population. This need to meet energy demands as the energy crisis of fossil fuels are currently the major energy source throughout the world and are steadily depleting. This study covers various biomass utilisations, such as biofuels, bio-power, and biogas, their respective conversion processes, energy generated, and biomass source. However, sugarcane was not even considered as a main biomass source in Malaysia in their research [12].

Aditiya et al. conducted research highlighted on the urgency of developing the biofuels due to the steady decline of fossil fuels [13]. The increase in fuel demand in the transport and industry sector, increase in global GHG emissions, and Malaysia's relatively low fuel reserves which are approximated to be 5.5 billion barrels [13]. This is very low as compared to reserves in Iraq with 115 billion barrels, Iran with 138 billion barrels, and Saudi Arabia with 260 billion barrels [13]. In their research, an estimation was made on the growth and projected growth of vehicles in Malaysia over a 15-year time span from 2005 to 2020, which raises concerns on whether the country can sustain on the current main fuel source alone.

Further investigation of the current fuel source and sugarcane ethanol as fuel in vehicles are required to prove that which resources will give more benefits to the country in terms of economy and environment aspects. Based in the economy aspect, if the production is profitable, then the Malaysian economy stands to improve as a new resource is available for domestic use, as well as for exportation to other countries. As for the environmental impact, the use of sugarcane ethanol, which is a biofuel, can reduce the carbon footprint caused by cars and greener as the leftover wastes from production may be used for other purposes such as compost material.

METHODOLOGY

A numerical analysis study on the impact of sugarcane ethanol as a fuel for vehicles in Malaysia was conducted based on the data collected from an economic and environmental aspect on the impact of sugarcane ethanol. This was done by comparing the current main vehicle fuel source in Malaysia, and the potential sugarcane ethanol. The potential of the sugarcane ethanol was determined based on the triple bottom line (TBL) approach, a framework normally used for accounting. This approach however can be applied to various fields due to its three strategic viewpoints which are economy, environment, and society [14]. The results from these studies on the potential of sugarcane ethanol as fuel in vehicle can be proven. This then led to an additional information on its social impact includes the societal standards and acceptance of it as a fuel source may be useful to determine the external factors that affect the sugarcane ethanol's potential.

Economic Analysis of Sugarcane Ethanol

For the economic analysis, it is crucial to find worth of using sugarcane ethanol as a fuel source for vehicles in Malaysia, which has a strong existing petroleum economy largely contributed by the transportation sector [15]. The selling price of sugarcane ethanol should either match or be less than that of the current fuel prices for it to be able to compete with petrol as a vehicle fuel source. The cost of sugarcane ethanol was calculated using the following formulae, and the selling price inclusive of a standard profit margin can be determined.

The sugarcane ethanol's production plant life cycle cost (LCC) will be modelled based on the following Eq. (1) [14];

$$LCC = CC + OC + MC + FC - SV - BPC \quad (1)$$

Where, CC is the capital cost average presented by Eq. (2), OC is the operating cost Eq. (3), MC is the maintenance cost Eq. (4), FC is the feedstock cost Eq. (5), SV is the salvage value Eq. (6), and BPC is the by-product credit Eq. (7) [16].

The capital cost is based on a research done by Howell [16], which factors in production capabilities (PC) of a biofuel plant and calculates the maximum, average, and minimum initial capital costs of a biofuel plant. This research utilises the average capital cost equation is as shown in Eq. (2) to determine the initial capital cost of a sugarcane ethanol plant.

$$CC = -430.13 \times PC^2 + 205\,235 \times PC + 2\,696\,000 \quad (2)$$

The operating cost over the production period, shown in Eq. (3), is an estimation that relies on the production capacity and an estimated fixed rate of cost per tonne (OR) of sugarcane ethanol produced [16]. MC is the sum of maintenance cost, and FC is the sum of feedstock cost over the total production period and is presented by Eq. (4) and Eq. (5) respectively [16]. SV is the salvage value, Eq. (6), is an estimation that accounts for annual depreciation rate and is modelled based on a substitution cost instead of the early capital cost [16]. Eq. (7), which is the by-product credit, is an estimation based on the production volume and price of the bioethanol production by-product carbon dioxide, which can be compressed and sold to carbonated drink manufacturers [16].

$$OC = \sum_{i=1}^{n} \frac{OR \times PC}{(1+r)^i} \quad (3)$$

$$MC = \sum_{i=1}^{n} \frac{MR \times CC}{(1+r)^i} \quad (4)$$

$$FC = \sum_{i=1}^{n} \frac{FP \times FU}{(1+r)^i} \quad (5)$$

$$SV = RC \times (1-d)^{n-1} \quad (6)$$

$$BPC = \sum_{i=1}^{n} \frac{CDP \times CDG}{(1+r)^i} \quad (7)$$

The total produced sugarcane ethanol cost (TPC) can then be calculated using the life cycle cost from Eq. (1), as shown in Eq. (8), and the final sugarcane ethanol unit cost (FBC), Eq. (9), can also be derived [16].

$$TPC = 1.1 \times \frac{LCC}{n} \quad (8)$$

$$FBC = \frac{TPC \times \rho}{PC} \quad (9)$$

Environmental Analysis of Sugarcane Ethanol

The total carbon savings (TCS) was determined by the product of the net avoided emission and the amount of sugarcane ethanol needed and is shown the following Eq. (10) [16]. Carbon savings are positive markers for environmental sustainability, and a higher carbon savings signifies greater potential of being environmentally friendly.

$$TCS = NAE \times GC \times \eta \times \frac{HVG}{HVB} \quad (10)$$

Where NAE is the net avoided emission, GC is gasoline consumption, η is the fossil gasoline replacement rate, HVG is the heating value of gasoline fuel, and HVB is the heating value of bioethanol fuel.

Since the research focuses mainly on sugarcane ethanol as a fuel for vehicles in Malaysia, a direct comparison of the effect of raw material harvesting (sugarcane and crude oil) between sugarcane ethanol and petroleum cannot be accurately made. This is due to the nature of both materials being cultivated and/or extracted by drastically different means.

Potential of Sugarcane Ethanol as a Fuel for Vehicles in Malaysia

The impact on society caused by sugarcane ethanol as a fuel for vehicles in Malaysia can be concluded based on the first two impacts, as they are related. A positive impact on the economy and the environment will almost surely lead to a positive impact on society. However, the existence of external factors such as 'food or fuel' anxiety, scepticism, and slow integration of biofuels into daily lives may affect how society perceives the use of sugarcane ethanol as a fuel source. Comparisons of each factor should be made between sugarcane ethanol and the current fuel source to determine the potential of sugarcane ethanol.

RESULTS AND DISCUSSION

Using the framework and equations stated in the methodology, the analytical studies was carried out and a set of results were obtained and discussed. A table of the economic data used in this study is shown below and was based on research of bioethanol in Malaysia carried out by Hanif et al. [16]. The global sugarcane feedstock prices for the year 2019 were used and obtained through price index websites.

Economy

The values from Table 1 was used in equation (10). Note that the calculations were done in USD in consistence with the data available and the final bioethanol unit cost was converted to MYR. The conversion rate used was based on the exchange rate on the 25th of June 2019.

Table 1. Relevant data applied to the study.

Item	Data
Production capability	54 ktons
Depreciation model	10% annually
Capital Cost	USD 12.5 million
Feedstock price	USD 270/ton
Operating rate	USD 80/ton
Maintenance cost	2% of annual capital cost
Replacement cost	USD 10 million
CO_2 price	USD 40/ton
Discount rate	8%

The results from the calculation shown that the life cycle cost, LCC is USD 1.0374 billion, the total annual production cost, TPC is USD 57.056 million and final bioethanol unit cost, FBC is USD 0.05 / Litre or equivalent to RM 0.22 / Litre. Assuming a 30% profit margin, and taking RON95 as the base gasoline, the estimated selling prices for the bioethanol-fuel mixture for different concentrations of sugarcane ethanol is calculated and tabulated in the table below.

Table 2. Estimated prices for different concentrations of Sugarcane Ethanol.

Concentration of Sugarcane Ethanol (%)	Estimated Selling Price per Litre (RM)
10	1.90
20	1.72
30	1.54
40	1.36
50	1.18
60	1.00
70	0.82
80	0.64
90	0.47
100	0.29

The current market fuel price for RON95 in Malaysia (as at 24th May 2019) is RM 2.08 / Litre. Comparing the prices in Table 2., with the current price of RON95, it is clearly seen that the

use of sugarcane ethanol would be economically beneficial. This is made even clearer as the increase in concentration of the biofuel results in a significant decrease in estimated selling price, which is a result of the low unit cost of sugarcane ethanol.

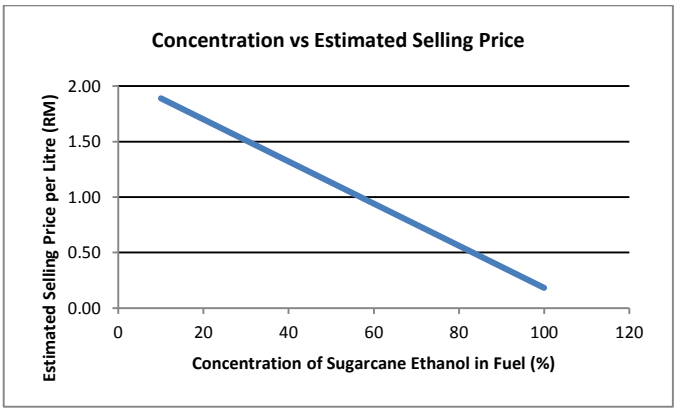

Figure 1. Graph of Concentration of Sugarcane Ethanol in Fuel vs Estimated Selling Price per Litre (RM).

This finding is consistent with the research done by Wang et al. [8], Garcia et al. [9], and Hanif et al. [16]. Wang et al. and Garcia et al. found that sugarcane ethanol was favoured in Brazil and Mexico due to its low cost and significantly reduced final waste product. Hanif et al. found that bioethanol in Malaysia had positive economic impact due to decrease in cost, proven by their study of Sri Kanji 1 cassava bioethanol in Malaysia. As such, the analysis of sugarcane ethanol's impact on Malaysian economy is in line with the aforementioned researches.

Environment

Applying a net avoided emission (NAE) constant of 2.014 [14], to Eq. (10) and using a set series of bioethanol needed, the following results are observed in **Figure 2**.

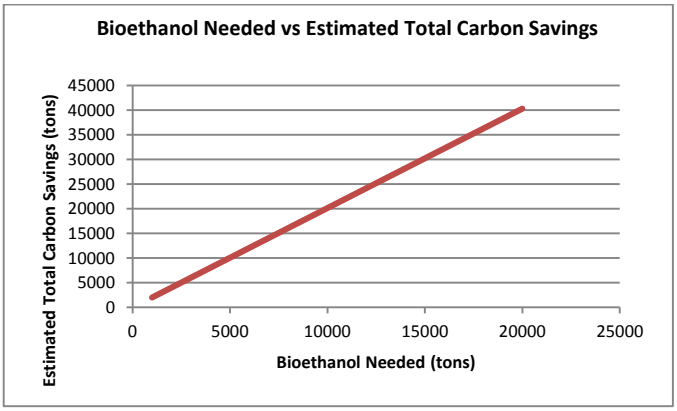

Figure 2. Graph of Bioethanol Needed vs Estimated Total Carbon Savings.

The graph shows clearly that an increased use of bioethanol results in an increase of carbon savings. This supports the theory that greater use of bioethanol, including sugarcane ethanol, causes lower carbon emissions. Thus, it can be said that the use of sugarcane ethanol would have a positive impact on the environment by having less carbon emissions compared to the current main fuel source.

Society

The third and final factor of the framework, addressing the effects of sugarcane ethanol used as a fuel for vehicles in Malaysia has towards society relates to the impact the bioethanol has on both economy and environment. The biofuel can provide a more affordable alternative to current vehicle fuels, which may indirectly link to better productivity and lifestyles. Bioethanol's more positive impact towards the environment would also improve society as progress heads toward a more sustainable and eco-friendly future. As such, it can be said to also have a positive impact on society.

CONCLUSION

Based on the findings, it is clearly shown that the use of sugarcane ethanol is not only economically feasible, it may also be profitable. Replacing fractions of gasoline with sugarcane ethanol to make a biofuel mixture would significantly reduce the price of fuel for vehicles in Malaysia, with higher concentrations of sugarcane ethanol resulting in corresponding lower selling prices.

The environmental analysis also showed that an increase in the use of biofuel would result in significant increases in carbon savings. Carbon savings are a good method of studying the impact something has on the environment, and the results of the total carbon savings proves the positive impact sugarcane ethanol would have on the environment in Malaysia.

Finally, it can be concluded that the use of sugarcane ethanol as a fuel for vehicles in Malaysia has good potential. It can positively impact both the economy and the environment of Malaysia. As such, further study and investment can be made in this field for future use.

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