The Challenges of a Biodiesel Implementation Program in Malaysia

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Date Submitted: 2021-04-27

Keywords: oleo chemical, palm oil, biodiesel implementation

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The palm biodiesel industry is facing many challenges implementing biodiesel program in Malaysia. This paper addresses the importance of the B10 blend (10% biodiesel, 90% petroleum diesel), global challenges of palm oil import and export, and protective measures for continuous positive growth of the palm oil sector. Palm oil is the backbone of Malaysia's economy, covering more than 5% of its gross domestic product (GDP). The key steps taken by the Malaysian government for the successful implementation of the B10 program are discussed in this review study. Till now, B5 and B7 biodiesel programs have been successfully implemented in Malaysia. The B10 biodiesel program is attractive because of the developed local palm oil sector. The B10 biodiesel program will increase the use of renewable energy sources, and is expected to increase the productivity of palm oil and biodiesel implementation in the country. Despite successful B5 and B7 programs, Malaysia is facing challenges for the implementation of biodiesel due to fluctuation in crude palm oil prices, low domestic usage of palm oil, and vehicle warranty. The improvement of palm oil and promotion of B10 through targeted agencies in the central region of Malaysia will help to implement the biodiesel program successfully.

Record Type: Published Article

Submitted To: LAPSE (Living Archive for Process Systems Engineering)

Citation (overall record, always the latest version):	LAPSE:2021.0236
Citation (this specific file, latest version):	LAPSE:2021.0236-1
Citation (this specific file, this version):	LAPSE:2021.0236-1v1

DOI of Published Version: https://doi.org/10.3390/pr8101244 processes

MDPI

Review

The Challenges of a Biodiesel Implementation Program in Malaysia

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Received: 8 August 2020; Accepted: 31 August 2020; Published: 2 October 2020

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Keywords: palm oil; biodiesel implementation; oleo chemical

1. Introduction

Nowadays, rapid growth in the world's population has led to an increase in the consumption of depleting fossil fuels. In a positive view, this scenario encourages the development and innovation of a new fuel that is renewable like biodiesel. As a fuel for the future, biodiesel has received great attention as an alternative fuel, considering its abundant resources and environmental benefits. Among the best renewable resources for the substitution of fossil fuels are biofuels [1]. Biodiesel is one of these biofuels that has numerous advantages over its counterpart, fossil fuel diesel. Biodiesel can be produced from edible and non-edible oils. Biodiesel, which can be produced via the transesterification of animal fats or plant oils (palm, corn, rapeseed, and soybean), has very similar properties compared to petroleum diesel [2]. Furthermore, it is also known for its biodegradability and non-toxicity, which could minimize its negative impacts on the environment, and is therefore suitable to be used as an alternative for petroleum-based diesel. In Malaysia, palm oil is the primary feedstock for biodiesel production, considering its role as the major agricultural export commodities in this country. Palm oil crops are considered as the highest oil-containing crops with the lowest cost of production. Indonesia and Malaysia are considered as the enormous palm oil producers in the world [3]. Palm oil production for Malaysia and Indonesia is presented in Figure 1. Based on the current global vegetable oil demand, the production of crude palm oil (CPO) is expected to reach 25.6 million tonnes by 2050 [4]. There are almost 800 palm oil mills operating in the world and producing crude palm oil, and 50% of them are in operation in Malaysia [5]. Up to today, Malaysia has implemented the B5 (blend of 5% palm oil and 95% petroleum diesel) and B7 (blend of 7% palm oil and 93% petroleum diesel) biodiesel programs in various sectors, including fisheries, government sectors, and industry.

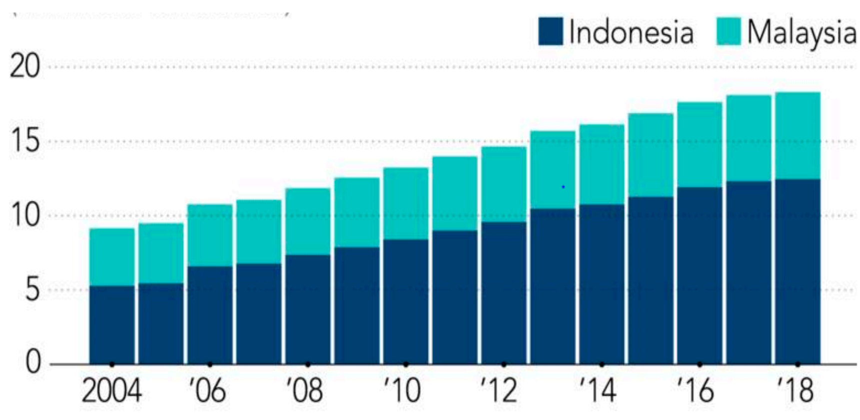

Figure 1. Palm oil production for Malaysia and Indonesia [6].

Figure 1 shows palm oil production in million metric tonnes. In this paper, the current status of Malaysia's palm oil industry has been elaborated. The challenges faced by Malaysia as one of the largest palm oil suppliers to the world has been elaborated as well. This paper discusses the progress on the biodiesel implementation in Malaysia, as well as the obstacles and initiatives taken by the government to implement the use of higher blended biodiesel in local transport [7].

2. State of the Palm Oil Industry in Malaysia

Oil palm is regarded as the most efficient and versatile cultivated crops in Malaysia. This is because of its continuous growing nature, high oil production rate, and shorter harvesting time, which can be considered as sustainable long-term feedstock for food and non-food industries [8]. Oil palm trees that originally belong in West Africa were first cultivated in Malaysia by the British in 1870 as a decorative plant. Since then, the palm oil industry grows as an important commodity crop for Malaysia socioeconomically, as it supports more than two million livelihoods and provides jobs opportunity [9]. Generally, oil palms produce two types of oils, such as palm oil and palm kernel oil, which are extensively utilized in food industries (frying, baking, non-dairy creamer, condensed milk, and ice cream) [10].

Meanwhile, the waste product of palm oil processing is often used in the chemical industry to manufacture chemicals for cosmetics, lubricants, paints, soap, and many more products. To date, oil palm plantation covers around 5.64 million hectares of land in Malaysia, with maximum crude palm oil (CPO) production capacity of over 19.5 million tonnes (as recorded in 2019) [11]. Hence, Malaysia is the second largest palm oil producer and supplier after Indonesia, contributing 31% of world palm oil production. Figure 2 illustrates the distribution of palm oil production by major players in 2016. The growth of the palm oil industry has led to an increase in the Malaysia's potential as a major player in oleo-chemical and biodiesel industries. Due to the dynamic growth of the palm oil industries, this sector has been described as the key contributor to the national economy, accounting for almost RM 67.6 billion of Malaysia's gross national income (GNI) [12].

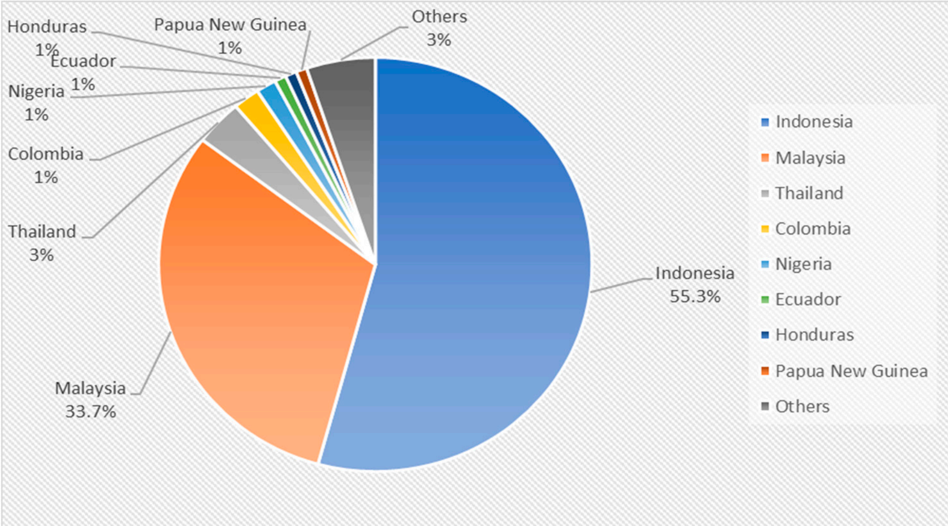

Figure 2. Overall palm oil production by country in 2019 [13].

2.1. Crude Palm Oil Production Versus Market Price

Currently, 89% of palm oil production is contributed by Indonesia and Malaysia. Therefore, the fluctuation of the CPO production from these major players would directly influence the global market price of CPO. Figure 3 shows the trend of CPO production in Malaysia and prices between 2009 and 2017. Overall, Malaysia shows positive growth of its palm oil supply to the world over the years, except for 2010 and 2016. The sudden decline in the CPO production in 2010 and 2016 could be related to the unusual weather conditions that affected Malaysia. In 2010, the CPO production dropped to 16.99 million tonnes, which was 3% lower than the previous year, which was recorded at 17.56 million tonnes. This was attributed to the combination of El Niño (first half of the year) and La Niña (second half of the year) phenomena that affected the oil palm's fresh fruit bunch yield, which consequently decreased the production of CPO [14]. However, the decline in the production actually resulted in a positive impact on the CPO price. The CPO prices experienced a sharp increase in 2011. exceeding RM 3000 per ton, which was the highest recorded in at least seven years. This was driven by high demand from China, India, Turkey, and South Africa as the result of limited global supplies of soybean oil and palm oil [15].

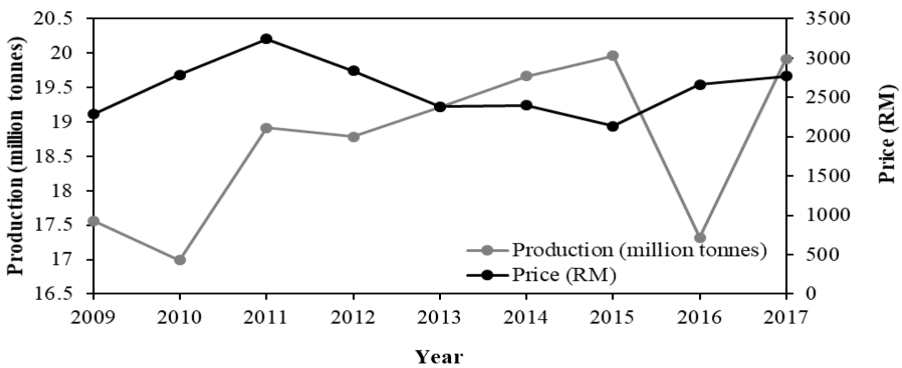

Figure 3. Annual production of crude palm oil (CPO) in Malaysia and prices [16].

Although production increased steadily in the following years, low demand from importers (Egypt, Pakistan, and Philippines) resulted in the build-up of the CPO inventory with declining the price from RM 3246 in 2011 to RM 2136 in 2015. This encouraged the Malaysian government to redesign the export duty structure in order to boost palm oil demand. Nevertheless, the average price fell to

RM 2136 in 2015. In 2016, Malaysia once again experienced severe El Niño phenomena, resulting in a sharp fall in CPO production. Although production dropped significantly to 17.32 million tonnes, which was 13.2% lower compared to 2015, it triggered a stronger rally to benchmark the Malaysian CPO prices. Despite low production during the year, the price had risen to RM 2664 and the increasing trend was expected to continue with a recovery in demand from top importers, especially China. With excellent weather and ample rains since October 2016, the productivity of Malaysia's palm oil significantly increased from 17.32 million tonnes in 2016 to 19.9 million tonnes in 2017. As for 2020, the CPO production is expected to climb further to 20.5 million tonnes [17].

2.2. Crude Palm Oil Export Versus Demand

The palm oil industry is a contributor to Malaysia's exports, accounting of greater than 5% of Malaysia's gross domestic product (GDP) [18]. Currently, there are seven major markets for Malaysia's palm oil, which contributed to 59.3% of total Malaysian palm oil supplies to the world in 2016. As shown in Table 1, India remained the top export country for Malaysia's palm oil which was then followed by China. Nevertheless, the export of palm oil to India and China dropped significantly by 23.3% and 20.9%, respectively, compared to the previous year [19].

The significant drop was attributed to the higher uptake of soybean oil and sunflower oil as a result of the weak price of these soft oils. China was the primary importer of Malaysia's palm oil for 12 consecutive years, from 2002 until 2014 [20]. During the first half of 2016, Malaysia's exports to China dropped by 50%, and as a consequence, Indonesia overtook the Chinese market for palm oil. This was probably due to the incorrect perception of the nutritive facts of palm oil and its effect on health and the environment. Thanks to a visit by the Prime Minister, Datuk Seri Najib Tun Razak, to Beijing in November 2016, the export to China market showed a positive development in the second half of 2016, during which it increased from 647.1 metric tonnes to 993.9 metric tonnes [21]. With the export growth of about 53.6%, Malaysia overtook Indonesia and reclaimed the position as the major palm oil exporter to China.

Table 1. Palm oil export market by country in 2016, 2017 and 2018 [22].

Country	Export (Million Ton) 2016	Export (Million Tonnes) 2017	Export (Million Tonnes) 2018
India	2.83	2.02	2.5
China	1.88	1.92	1.8
Pakistan	0.88	1.02	1.16
Netherlands	1.02	1.00	-
Turkey	0.66	0.68	6.31
Philippine	0.63	0.75	6.89
Vietnam	0.56	0.63	-
USA	0.59	0.55	5.4
Others	-	-	7.18
Total	9.04	8.58	16.48

Table 1 shows the total palm oil supply to different countries of the world. Total palm oil export for Malaysia is shown in Figure 4.

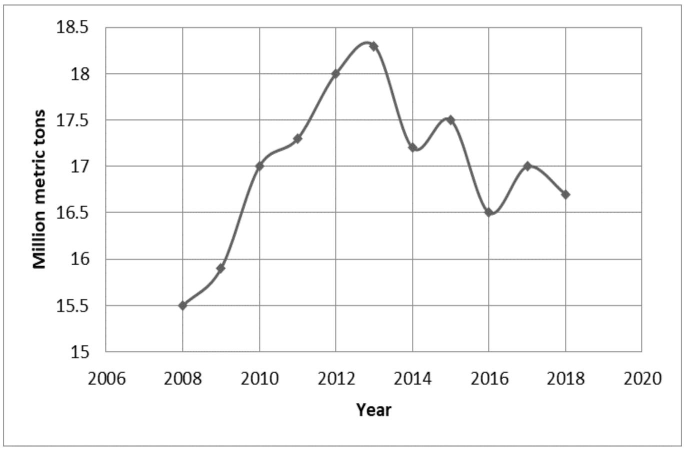

Figure 4. Malaysia palm oil overall exports [23].

2.3. Export Duty

Malaysia has a multi-tier tax rate for palm oil exports, ranging from 4.5% to 8.5%, that only applies when the CPO process exceeded RM 2250 (Table 2). Under the Customs Act 167 Customs (Values) (Palm Oil) Order 2013, which took effect on 1 January 2013, Malaysia can regularly revise the export duty structure based on the current reference CPO price calculated by the Southeast Asian nations like Indonesia, Malaysia, Singapore, and Thailand. Due to the increase in the CPO prices in March 2017, the Royal Malaysian Customs Department increased the export duty from 7.5% (as of February 2017) to 8.0% [21]. Although this slightly affected the export volume, the higher levy did not impact the planters. In fact, the planters can still enjoy good prices despite the weak demand. Furthermore, the palm oil duty can be avoided by selling palm oil to local downstream players or using in their own refinery units. Recently, India, the major consumer of Malaysian exports, doubled the import tax rate on CPO to 15% and refined palm oil to 25%, so that the local farmers can gain profit from exporting to major CPO suppliers like Malaysia and Indonesia [24]. Despite the tax hike in India, which could affect the industry's profitability, the price of CPO (as calculated by the Southeast Asian nation like Indonesia, Malaysia, and Thailand) has remained level at the benchmark of RM 2699 per ton, and thus, the Malaysian government has decided to lower the export duty to 5.5% for September 2020 [25,26]. In order to reduce the local CPO inventory, the Malaysian government had taken a preemptive measure by suspending the export tax on palm oil for 3 months, which was started in January 2018. This scheme was seen to be effective in improving the CPO export to major importers like China and India and may strengthen the palm oil prices.

Table 2. Export duty rate for palm oil in Malaysia (source: Malaysian Palm Oil Board (MPOB)).

CPO Market Price	Export Duty (%)
<RM 2250	Not Applicable
RM 2250–RM 2400	4.5
RM 2401–RM 2550	5.0
RM 2551–RM 2700	5.5
RM 2701–RM 2850	6.0
RM 2851–RM 3000	6.5
RM 3001–RM 3150	7.0
RM 3151–RM 3300	7.5
RM 3301–RM 3450	8.0
>RM 3450	8.5

3. Current Status of Palm Biodiesel in Malaysia

In 2006, the Malaysian government officially introduced the National Biofuel Policy, in order to support the use of environmentally feasible and sustainable energy sources. Besides minimizing dependency on depleted fossil fuels, this policy was developed to stabilize and further enhance palm oil prices. Under this policy, five strategic thrusts (Figure 5) were decided as the major components, which cover transport, industry, export, technologies, and biofuel for a cleaner habitat [27]. Malaysia is serious about the use of biodiesel for green technology and a cleaner environment, and as a result, the Malaysian Biofuel Industry Act was enacted by the Malaysian Parliament in 2007. The act was designed to enhance the mandatory use of palm oil-based biodiesel and establish a regulatory regime regarding the licensing of blending facilities, storage, transportation, and export of palm oil-based biodiesel.

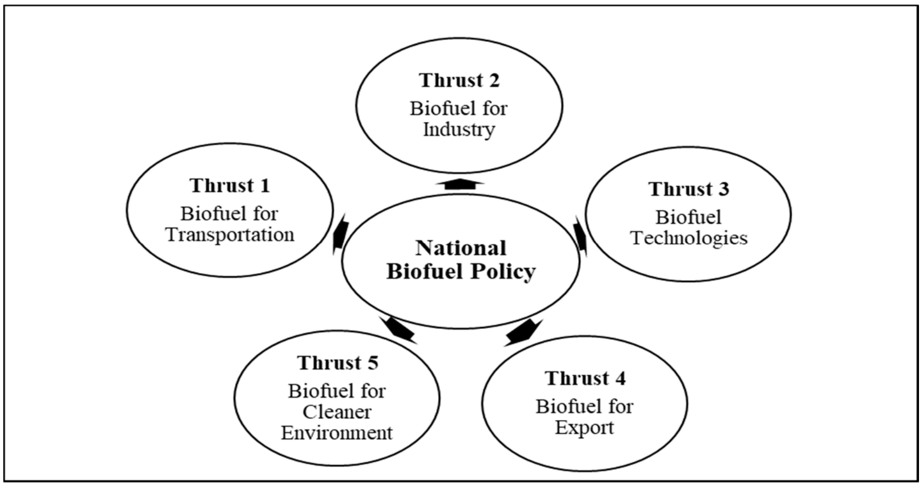

Figure 5. Five strategic thrusts under Malaysian National Biofuel Policy.

In line with the National Biofuel Policy, the Ministry of Plantation Industries and Commodities (MPIC) introduced a biodiesel program that covers the implementation and sale of biodiesel in the local transportation and industrial sectors [28]. In October 2011, Malaysia's Ministry of Plantation Industries and Commodities (MPIC) approved the licenses of 60 palm oil-based biodiesel production industries with a capacity of 6.79 million tonnes per annum. Before this approval, there were 18 biodiesel production industries working in the country, with a total manufacturing capacity of 2.3 million tonnes per annum [29]. The biodiesel production statistics for Malaysia from 2010 to 2019 are shown in Figure 6. It can be observed from the Figure 6 that the biodiesel synthesis decreased from 86,960 tonnes (2010) to 55,437 tonnes (2011). This happened because of the higher CPO prices that led to decrease in use of palm oil as a feedstock for biodiesel synthesis. However, the production of biodiesel started to increase again in the following years, due to the increased investment and global demand for biodiesel [30]. The continuously increasing trend of biodiesel production and implementation is expected, especially in fast-developing countries like Malaysia, where there is rapid economic growth and stability countrywide [31]. However, the production of biodiesel significantly dropped by 26% in 2016, and this was a consequence of the La Niña phenomena that affected the production of oil palm fruits. By the end of 2020, Malaysia is confident it will generate 1,000,000 tonnes of biodiesel, which is 80% higher than the previous year. However, the target may not be attained if the government has not taken action to implement a higher blended biodiesel policy like B10.

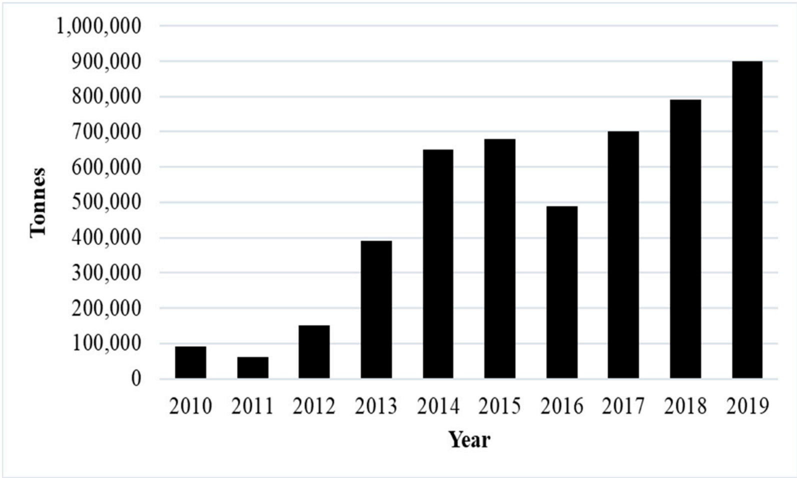

Figure 6. Production of biodiesel in Malaysia from 2010 to 2019 [32].

3.1. Challenges of Biodiesel Implementation in Malaysia

Malaysia started the application of B5 biodiesel (a mixture of 5% palm methyl ester (PME) and 95% regular petroleum diesel) in 2011 for subsidized sectors, including retail stations, fleet cards (a type of fuel cards), skid tanks, and fisheries. Although the B5 program was originally planned to be initiated in 2008, it was first introduced in the Malaysian market only in June 2011. Since then, it started to roll out in phases in the central area, southern area, northern area, and eastern region of the country. By the end of 2014, complete B5 blend use covering both western and eastern Malaysia was successfully achieved. As of 2014, more than 1500 retail stations were available with B5 biodiesel in the central and southern regions [33]. Table 3 sums up the status of the biodiesel implementation and its implementation date in Malaysia.

Table 3. Status on the biodiesel implementation in Malaysia.

Biodiesel Blend	Implementation Date	Current Status
B5	2011 (Central region: Putrajaya, Kuala Lumpur, Selangor, and Malacca) 2012 (Southern region: Johor) 2013 (Northern region: Perlis, Kedah, Penang, and Perak) 2014 (Eastern region: Kelantan, Pahang, and Terengganu) Eastern Malaysia (Labuan, Sabah, and Sarawak)	The implementation has expanded to transportation and other subsidized sectors.
B7	December 2014 (Whole peninsular Malaysia) January 2015 (Nationwide)	
B10 B7	To be confirmed To be confirmed	As of August 2017, no action has been taken.

While the B5 program is still on the move, Malaysia has upgraded its biodiesel mandate from a 5% to 7% biodiesel blend (B7), in order to further boost the consumption of CPO as the result of growing CPO stocks and declining prices. Table 4 shows the yearly price of CPO of Malaysia [34].

Table 4. Crude palm oil statistics [35].

Crude Palm Oil (Year)	Price (RM/Ton)
September 2001	900
November 2002	1400
January 2004	2000
March 2005	1500
May 2006	1510
July 2007	3700
September 2008	1500
November 2009	2800
January 2011	2500
March 2012	3500
May 2013	2400
July 2014	2200
September 2015	2000
July 2017	2400
November 2018	1831

This data indicates that the price of CPO was not static in past years, because of instability in overall palm oil production and export of country B7. B7 biodiesel is a mixture of 7% PME and 93% petroleum diesel, and has lower greenhouse emissions compared to the conventional diesel. The B7 biodiesel program was introduced by the Malaysian government in December 2014, with nationwide roll-out in December 2015, which covered road and sea transports. The introduction of the B7 program was expected to reduce the use of diesel by 667.6 million liters, while at the same time enhance the use of biodiesel from 300,000 to 575,000 tonnes annually [36]. Regardless of the higher percentage of PME in the biodiesel blend, the price of the B7 biodiesel was exactly in line with that of B5 biodiesel. To date, the Malaysian Palm Oil Board (MPOB) has set up a total of 35 petroleum depots, with in-line blending facilities located in Sarawak, Sabah, and Labuan worth RM 340 million with the participation of major petroleum industries like Petronas Dagangan Bhd, Shell Malaysia Trading, Petron, Boustead Petroleum Marketing, and Chevron Malaysia Limited [37].

To further boost the biodiesel demand, the use of B7 biodiesel has been expanded to industrial sectors—specifically, to heat boilers and generate electricity. Recently, Malaysia was planning to raise its current biodiesel mandate from B7 to B10 to support the palm oil industry. The new mandate would reduce the national palm oil inventory levels and further boost the local biodiesel demand. Furthermore, the use of 10% palm oil in diesel could reduce the effect of acid rain, from the reduction of approximately 350,000 kg of sulfur emissions in the atmosphere per year [38]. Meanwhile from the technical aspect, B10 biodiesel can burn effectively and decrease the fuel utilization on diesel engines. The B10 biodiesel that consists of 10% PME and 90% diesel was expected to be introduced at petrol stations nationwide beginning in June 2016, and it only affects Euro 2M diesel. The new biodiesel standard is expected to save 820 million liters of diesel with annual domestic usage of 709,000 tonnes of palm oil, compared to the current biodiesel mandate [39].

Unfortunately, full implementation of the B10 mandate has yet to be accomplished; it has been postponed several times while considering the difference between CPO and diesel prices at the current volatile market, and also because of the lower cost of crude oil. According to analysts, the implementation of B10 biodiesel is more impactful when the crude oil prices are above USD 50 per barrel [40]. This would consequently reduce the country's import of crude oil and remove the excess palm oil stock from the palm oil market, at the same time would increase the palm oil price. However, to date, the price of crude oil was traded below USD 50, which was around USD 48 per barrel. Therefore, it is not favorable to implement the mandate for the time being, as the demand for crude oil would be higher than that of local biodiesel [41]. Nevertheless, the decision has no dependency on the excess of CPO, since the current B7 grade of biodiesel only consumes about 350,000 tonnes, which is only 1.8% of the total CPO output (19 million tonnes). Furthermore, the delay of implementation occurred due to insufficient proof that B10 biodiesel was facing issues related to the specifications of all the carmakers who invested in Malaysia's Energy Efficient Vehicle program. As a result, most of the car companies in Malaysia are not confident to provide a warranty for their vehicles if the B10 mandate is implemented. This issue did not occur when the B5 and B7 policies were implemented, as the car manufacturers received assurance in which biodiesel up to 7% did not give any problem in the fuel delivery systems.

Presently, Malaysia has lagged behind many countries in terms of the implementation of higher blended biodiesel. This is attributed to the various factors, which vary from the fluctuation of CPO prices in the volatile markets to resistance by car manufacturers. Table 5 compares the current and future higher blended diesel mandate in various countries. As the biggest palm oil supplier to the world, Indonesia has also been regarded as the leader in biodiesel. The government has already implemented the B20 policy since early 2016 for the transportation and industry sectors. Meanwhile, Columbia and Argentina have also utilized B10 biodiesel, while Brazil is currently implementing B8 biodiesel [42]. On the other hand, Thailand implemented the B7 mandate in 2016; however, later that year, the government took an aggressive approach to decrease the utilization of palm oil in biodiesel from 7% to 5% as a result of lower palm oil production.

Table 5. Current biodiesel mandates in various countries [41].

Country	Current and Future Biodiesel Mandate
Argentina	B10
Brazil	B8 (2017), B9 (2018) and B10 (2019)
Colombia	B10
Indonesia	B20 (2016), B30 (2020)
Malaysia	B7 (2016) and B15 (2021)
Thailand	B5 (2016) and B10 (2018)

Despite all the issues, the Plantation Industries and Commodities Minister Datuk Seri Mah Siew Keong said that the government is determined and positive with regard to moving to the next phase of biodiesel mandate by upgrading the current B7 policy to B10 exclusively for local on-road and ocean transport [43]. Furthermore, they still have high hopes of achieving their goal to implement B15 biodiesel for the road sector by 2021, as included in the currently released Eleventh Malaysia Plan. If the higher blended biodiesel policy is not implemented as planned, the production of biodiesel would remain stagnant at the level of the previous year, which is around 700,000 tonnes. In addition, the delay of the mandate would consequently affect the local biodiesel players, as the demand for their product would be lower, and thus, would fail to generate profit from the millions of ringgit investments [44].

3.2. Biodiesel Blends Performance and Emissions

3.2.1. Combustion Characteristics of Biodiesel Blends

The use of biodiesel is advantageous over conventional petroleum diesel because it features better combustion characteristics and engine performance. Table 6 compares the combustion characteristics of various biodiesel blends with conventional biodiesel.

Table 6. Combustion characteristics of diesel blends [45].

	B0 (Pure Diesel)	B100 (Pure Biodiesel)	B20 (20% Biodiesel)	B50 (50% Biodiesel)
Density (kg/m^3)	837.90	860.00	842.32	848.95
Viscosity (cSt)	2.64	4.82	3.08	3.73
Higher heating value (MJ/kg)	44.79	39.9	43.81	42.35
Lower heating value (MJ/kg)	41.77	37.20	40.86	39.49
Cetane number	53.30	58.60	54.36	55.95
Air-to-fuel ratio	14.66	12.49	14.22	13.56
C (wt.%)	86.35	76.31	84.30	81.26
H (wt.%)	13.65	12.15	13.35	12.89
O (wt.%)	0.00	11.54	2.36	5.84

Table 6 compares the combustion characteristics of B0, B20, B50, and B100. It can be seen that pure diesel has the highest cetane number and density compared to other blends. However, the heating value of pure biodiesel is lower, which means that more biodiesel will be consumed in the engine to produce the same amount of heat energy compared to pure diesel blends. Therefore, it is much better to use biodiesel blends like B10, B15, B20 as a fuel. B0 has the highest heating value and carbon content. The highest carbon content causes the emissions of CO and CO_2. Therefore, it is necessary to discuss the comparison of NO_x, CO, CO_2, particulate matter, and hydrocarbon (HC) emissions for biodiesel blends. The comparison of gas emissions for various biodiesel blends is discussed below.

3.2.2. Greenhouse Gases Emission for Biodiesel Blends

There is a considerable interest in biodiesel because of its low greenhouse gas (GHG) emissions. There is a considerable positive effect on the reduction of hydrocarbons, carbon monoxide, carbon dioxide, particulate matter, and various oxides of nitrogen [46]. There is no significant effect of using biodiesel on NO_x. Figure 7 shows the emission of GHGs for various biodiesel blends when used in heavy-duty engines.

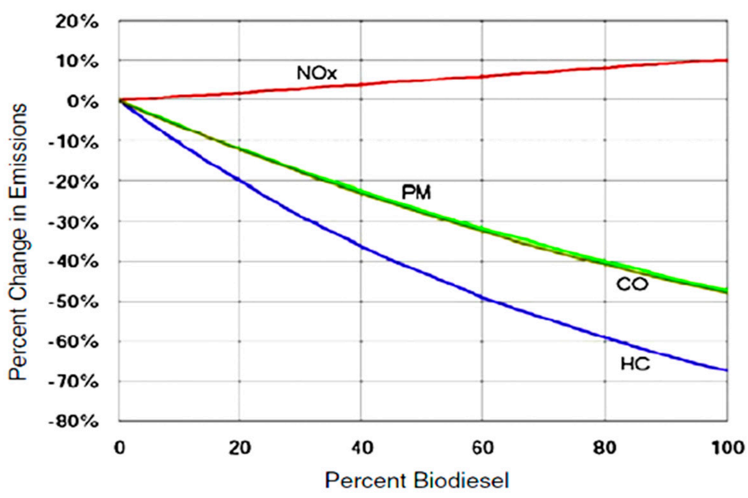

Figure 7. Biodiesel percentage effect on greenhouse gas emissions [47].

It can be observed from Figure 7, a high percentage of biodiesel present in a biodiesel–diesel blend decreases the emission of particulate matter, carbon monoxide, and hydrocarbons. An increase in NO_x emissions can be observed when a higher biodiesel blend is used [48]. Figure 8 below shows the emission of CO_2 for different biodiesel blends with different engine loads.

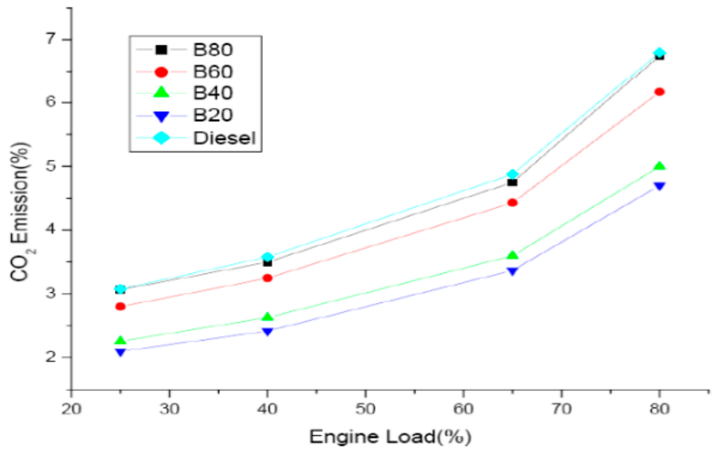

Figure 8. Effect of biodiesel and engine load on CO_2 emissions [49].

As can be observed from Figure 8, CO_2 emission does not linearly decrease with the increase of biodiesel percentage. The emission of CO_2 depends upon the carbon content present in the blend. Therefore, the emission of CO_2 is not linear.

3.2.3. Cold-Start Performance of Engines for Biodiesel Blends

This section of the manuscript describes the performance of engines running with various biodiesel blends. The aspects like engine starting time, stability after starting, and opacity peak for biodiesel blends are also discussed in this section.

Engine Starting Time

Generally, the engine starting time progressively increases towards higher biodiesel blends. The below Figure 9 shows the engine starting when operated between 0 °C to −10 °C.

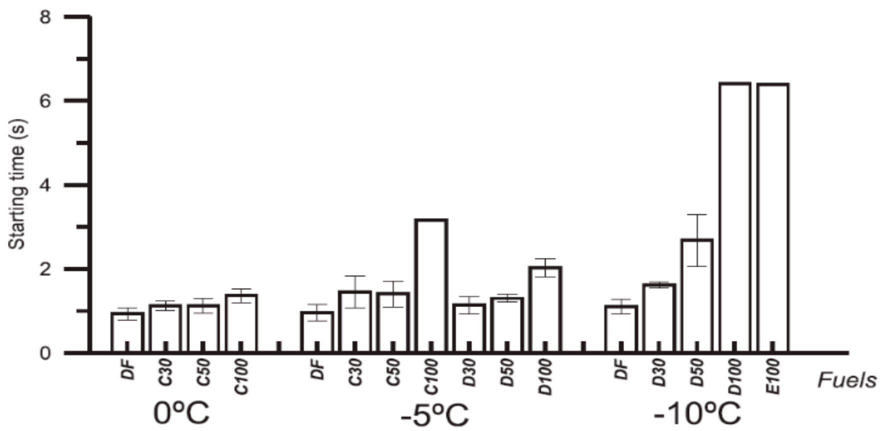

Figure 9. Starting time of engine for various biodiesel blends [50].

It can be seen that the engine operating with 100% biodiesel took the maximum starting time for every temperature. For other blends, engine start time increased with the increase of biodiesel blend. The engine working with pure diesel took the minimum time. This is considered to be a disadvantage, but it is necessary to see the effect of biodiesel usage on opacity peak and engine stability for better understanding of biodiesel performance of an engine.

Speed Stability

Figure 10 shows the speed stability for various biodiesel blends. The use of pure diesel causes a deterioration in speed at the colder temperature conditions. However, the use of biodiesel blends causes stability in the speed after the smooth starting of the engine.

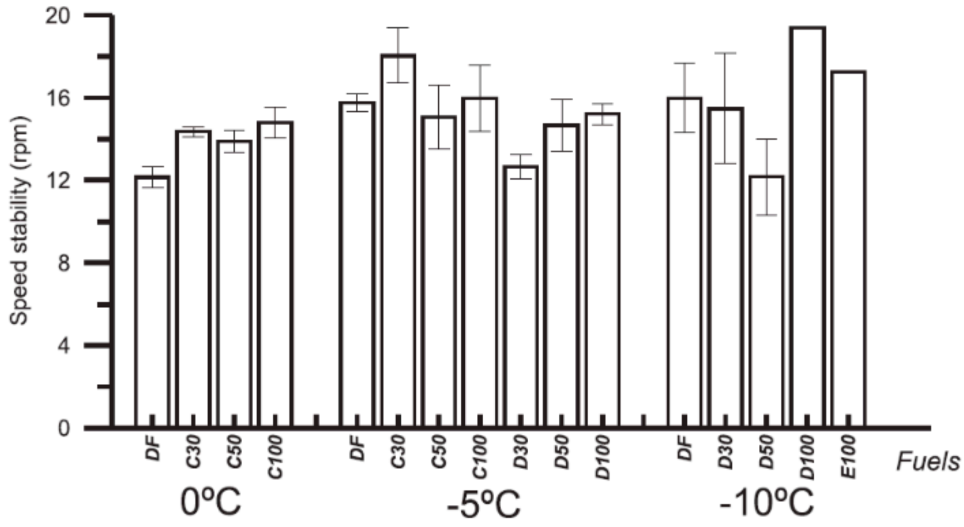

Figure 10. Biodiesel blends' effect on speed stability [50].

The behavior of speed stability is different for every biodiesel blend at a specific temperature. Colder conditions cause a delay in the engine starting, but stability in the speed. Therefore, speed stability and engine starting time are correlated generally.

Opacity Peaks for Biodiesel Blends

Figure 11 shows the opacity peaks for various biodiesel blends.

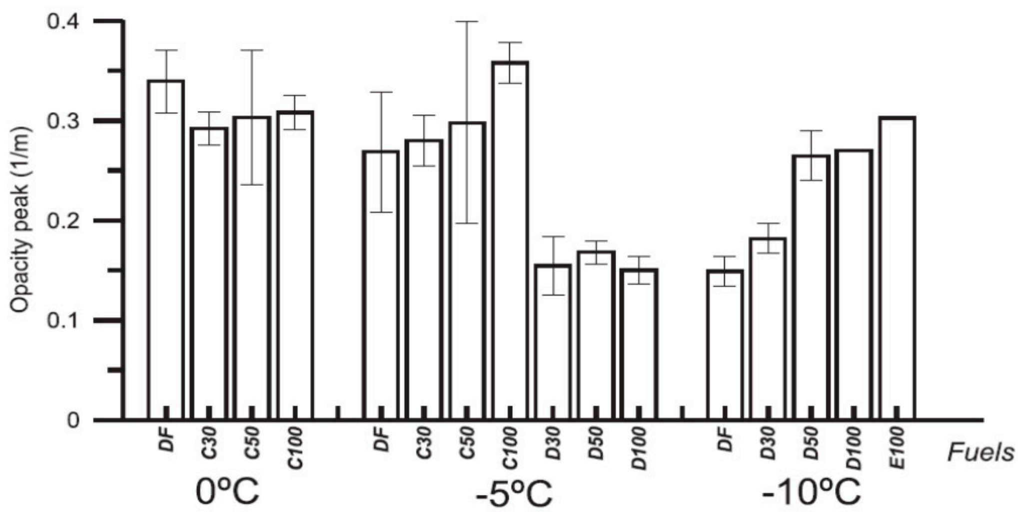

Figure 11. Opacity peak behavior for different biodiesel blends [50].

Opacity peaks of greenhouse gases are lower than the peaks measured with the pure diesel fuel. This is due to the higher oxygen content present in biodiesel, which promotes the soot oxidation during combustion in a better way. Moreover, increase of oxygen content is not linear with biodeisel blends. Therefore, the opacity peak shows different behavior for each biodiesel blend.

3.3. Government Initiatives

3.3.1. Negotiation on the Warranty Issues

Various approaches are being adopted by the government to raise public awareness of the benefits of B10 biodiesel, and most importantly, to convince the automotive companies on the compatibility of the fuel for commercial vehicles. Objection from the automotive companies is the main factor that has hindered the implementation of B10 biodiesel in Malaysia. Currently, vehicle manufacturers do not support the mandate, as the warranty has not been issued, and the present warranty from the European tests only supports up to B7 biodiesel. In order to convince the automotive manufacturers, the government, through MPOB with other agencies like the Malaysia Automotive Institute, has worked to solve the issues of manufacturers. The Ministry of International Trade and Industry (MITI), the Malaysian Automotive Association (MAA), and the Japanese Automotive Manufacturers Association (JAMA) has been in regular negotiations to increase the engine warranty up to B10 biodiesel for commercial vehicles [51]. When the fuel comes into the market, the commercial vehicles are expected to have warranties that cover the use of B10 biodiesel [52].

3.3.2. Field Tests

To date, many short-term and long-term tests have been carried out by the MPOB and local industries on the B10's compatibility in commercial vehicles, and the results show that higher blended diesel like B10 had no negative impact on the engine performance. MPOB with Dewan Bandaraya Kuala Lumpur (DBKL) has been conducting a long-term test program on the use of B10 biodiesel since 2013 [53]. The test that was actually commenced in January 2014 involved 50 vehicles of various sizes and engine capacity, which was comprised of tractors, excavators, backhoes, pick-ups, tipper trucks, vans, tow trucks, and water tankers. During the four-year period of the test, the vehicles have travelled and accumulated a total of 3 million kilometers without any engine failure issues or breakdown [53]. On March 2017, MPIC launched the B10 Trans Borneo Expedition at the MPOB Research Station in Belaga Sarawak. This program copes with the government's commitment to make the B10 program mandatory and increase awareness on the use of environmentally friendly fuel. This expedition covered the journey from Belaga to Miri, Brunei, Limbang, and Lawas to Kundasang, which covered about 1189 km using 14 4 × 4 vehicles and two 40-tonne fuel tankers filled with B10 biodiesel. Contrary to the myth that biodiesel would solidify at low temperatures, the five-day expedition successfully proved that the vehicles running on B10 biodiesel were as reliable as other vehicles powered by diesel and biodiesel [54].

3.3.3. Research and Development

Based on the current situation, automotive companies are not rejecting the implementation of B10 biodiesel. Instead, further research is required on biodiesel before its use in commercial vehicles becomes mandatory. To date, intensive research and development processes have been conducted by the MPOB to improve B10 biodiesel so that it complies with engine specifications [55]. According to research by the MPOB, the quality of B10 biodiesel meets the international qualification standards, namely EN14214 (Europe) and ASTM D6751 (United States), and hence, the fuel is safe to be used in all diesel vehicles without any modification to the engine. Furthermore, the MPOB with the Road Transport Department has run a test on a dynamometer, and the result showed that the power produced by B10 biodiesel is similar to that of fossil diesel fuel. The Department of Environment (DOE) conducted a diesel engine emission testing on the DBKL vehicles run with B10, and found that the smoke emission registered a Hartridge Smoke Unit (HSU) value of between 2.7 and 2.8, which was significantly lower than the smoke opacity limit (50 HSU). Nevertheless, more in-depth studies are actually needed to investigate the effect of B10 on the diesel engine, especially the older engines that are still in use. Notably, in a Department of Environment (DOE) test, which stipulates that vehicles used for free acceleration test with a smoke meter shall have an upper limit of 50 Hartridge Smoke Units (HSUs), the DBKL vehicles using B10 Biodiesel registered HSUs of between 2.7 and 2.8.

Due to the economic concern and objection from stakeholders that hindered the implementation of B10 biodiesel, Malaysia is planning to export the excess biodiesel products to various countries. Therefore, standalone biodiesel business is not profitable. This can be seen from the closure of some biodiesel companies in Selangor, Johor, and Sarawak due to unprofitability. The biodiesel implementation initiative is very important because of palm oil golden crops, and helps to generate the economy in Malaysia [56]. Due to this reason, B10 biodiesel had been mandatory from 1 February 2019.

3.3.4. Promotion and Public Awareness

Malaysian biodiesel industry needs more public support and awareness. The general public awareness related to palm biodiesel is still low. Most of the people who have information on biodiesel development belong to the government or are industry people, as well as some environmentalists. The majority of people are ignorant or have less knowledge related to palm biodiesel. This might be due to the fact that only 5% of motor vehicles in Malaysia are diesel-powered vehicles. Therefore, the public needs awareness, because these issues could be more relevant to them in the future [57]. This awareness can be done by educating people using appropriate platforms, and by creating no confusion between them. The public should be trained and made ready for sacrificing their wealth for a clean and sustainable environment. This is only possible when people are willing to use biodiesel, paying more than for petroleum diesel. The strength of the support given by the public has great importance to attract more investors and to further stabilize the palm biodiesel industry. Therefore, it is a big task for Malaysia to get public contribution in developing its biodiesel industry [58].

3.4. Palm Oil Market in Malaysia

Malaysia extracted around 19.5 million tonnes of crude palm oil from its palm oil cultivation area of 5.8 million hectares in 2018. The total export of the country was 16.7 million tonnes, contributing RM 67.5 Billion in the Malaysian economy [59]. The ministry said that two programs were expected to use 761,000 tonnes of palm oil yearly, decreasing the high feedstock levels. Palm oil was the largest contributor to the GDP of Malaysia, covering 3.8% of total GDP. The palm oil price will likely increase to RM 2200 per tonne in 2021 [60].

3.4.1. Improvement of Palm Oil Industry

For the improvement of palm oil sectors, it is necessary to find some innovative machines that have the capability to improve the harvesting of palm plantations. The higher research organizations and private enterprises are accumulating their assets and accelerate automation in oil palm territories, while the ministry is also arranging a competition to find a financially practical oil palm harvesting machines [61]. The winning inventions must have practical applications and be cost-effective, so that manpower can be minimized for harvesting, collecting, and managing oil palm fresh fruit bunches. The Ministry said that their target is one worker per 12 hectares, as opposed to one worker per eight hectares now. In February 2017, the MPOB initiated a worldwide competition, the International Competition on Oil Palm Mechanization, that offered a USD 1 million (RM 4.5 million) grand prize, in addition to cash prizes in the total amount of USD 130,000 (RM 585,000). Similarly, the Ministry has also implemented several initiatives in the country and approved RM 30 million for planting the new oil palm trees. Several research and development grants for promoting the palm oil sector and giving benefits to small stakeholders have also been introduced by the ministry. For smallholder growth, it is necessary to replant the trees that are older than 30 years. Mah said that the Ministry has approved an RM 30 million budget for smallholders for the cultivation of new palm trees, which comes out to be RM 7500 per hectare [62]. By replanting palm oil trees, the Ministry expects an increase of oil extraction rate of 23% by the end of 2020. This would ensure continued earning from selling oil palm fresh fruit bunches. To increase the source of income of local smallholders, local small investors are appreciated to invest in downstream sectors like oleo-derivatives and their chemical-related firms. The installation of more oleo-chemical plants in other countries of the world would help to add value to Malaysia's downstream palm industry, as stated by Mah. Investment of local palm oil players in palm oil sectors will help to increase the exports to China and India, which have decreased drastically over the last few years [63].

3.4.2. Main Issues with B10 Biodiesel Implementation

Biodiesel implementation has several main issues, including vehicle's warranty, the price gap between palm oil and local diesel, and safety tests. The use of biodiesel blends is at the discretion of the customer, and it does not automatically void an engine warranty. Paccar provides the warranty to medium-duty engines meeting ASTM D6751 specifications. The second major issue is the gap between palm oil and local biodiesel price in Malaysia. The higher demand for CPO has resulted in higher prices for biodiesel, resulting in the instability of biodiesel economics for the companies. Several tests have been conducted in order to fully implement this program in the country. All tests observed practically no fuel channel blockage. There was some degradation of motor oil when utilizing palm methyl esters. However, it was inside the allowable limits of the used oil execution test. The tests likewise indicated normal part mileage, just like no critical effect on motor execution. However, the MPOB discovered issues with material weakening—for example, the stripping of fuel tank coatings and paintwork, solidified fuel hoses, disintegration on copper and lead, and the dissolving of chloroprene material. The board suggested changing to Teflon coatings and stainless-steel braided hoses.

4. Conclusions

Biodiesel is a clean and green energy technology that could replace fossil fuels. In the context of the Malaysian economy, the use of palm biodiesel could increase the domestic use of palm oil and increase the commodity's price in the market. Malaysia successfully implemented the B7 policy for road sector. The government is determined to apply the B15 mandate by the end of 2020, but the goal seems to be hard to achieve the considering economic concerns and objection from stakeholders. Although the mandate could further reduce the CPO stock, the consumption rate of biodiesel still falls below 65%. Therefore, an alternative to convert the existing biodiesel plants to the production of other value-added products is greatly needed. Although showing a positive trend in palm oil exports, 2021 is expected to be a challenging year for the palm oil market in Malaysia because of the higher operating costs and increasing the anti-palm oil campaign. Overall, biodiesel production in Malaysia is far below capacity, and most industry players are operating at a utilization capacity of below 25% which is not enough to meet the biodiesel energy needs of the country. The government needs programs to familiarize the public with the benefits of biodiesel and to disseminate consumer concern about the potential mechanical damages to the engine. Distribution, quality assurance, safety, and user education problems need to be eliminated in order to successfully implement the biodiesel program in the country. Palm oil prices need to be more competitive to maintain a market share. As the Malaysian National Biofuel Policy was introduced in 2006, biodiesel implementation moved ahead from B5 to B7 in December 2014. The biodiesel B10 program was initiated so to reduce the dependency on petroleum diesel, but its implementation got delayed. According to the Malaysian Automotive Institute, the data was appropriate and compliant with the specifications required for Malaysia's Energy Efficient Vehicle program. Moreover, industry observers believe that the B10 program could prove to be efficient if completely applied in the country. It will have a positive impact on the prices of CPO, as palm oil usage is expected to increase in Malaysia. A high price of CPO has a significant impact on the economy as RM 1000 per tonne is added. Similarly, the higher price of CPO also supports thousands of smallholders who are totally dependent on the commodity for their livelihood. The Malaysian Palm Oil Board (MPOB) has additionally done all the testing engaged with palm biodiesel, drawing on the encounters of nations—for example, Colombia and Indonesia—that have effectively actualized B10 and beyond. In the past, the withdrawal of the B10 blend's implementation was due to the higher prices of crude palm oil. But the higher cost of CPO generates much better revenue for the local industries. Therefore, the price of crude oil should be lower for local smallholders.

Author Contributions: Conceptualization, Z. and M.H.M.Y.; writing—review, Z.; supervision, M.A. and M.H.M.Y.; data addition in review paper, N.J.; proofreading of review paper, A.Z.A. All authors have read and agreed to the published version of the manuscript.

Funding: The funding was provided by the Yayasan Universiti Teknologi Petronas (UTP) 015LC0-208 grant.

Acknowledgments: The authors acknowledged the financial support from Universiti Teknologi PETRONAS under a YUTP grant (015LC0-208) and STIRF grant (015LA0-016). Support from the Ministry of Education Malaysia through an HICoE award to CBBR is also duly acknowledged.

Conflicts of Interest: The authors declare no conflict of interest.

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