An Assessment of the Implications of Biodiesel Consumption Promotion in the Transportation Sector for Thailand

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Abstract. This paper assesses the implications of the promotion of biodiesel consumption in the Thai transportation sector in terms of energy, environment and agriculture. In order to analyse the implications, scenarios are modelled quantitatively to assess their impacts for the period 2019–2037. Scenarios developed in this paper represent various percentages of biodiesel blending mandates including REF (7% biodiesel blend), B10 (10% biodiesel blend) and B20 (20% biodiesel blend). The analytical tool employed to assess the scenario impacts is the Low Emissions Analysis Platform (LEAP) model. The analyses suggest that an increase in percentage share of biodiesel blend would contribute to a reduction in diesel consumption and hence crude oil requirement. Consequently, it would generate less CO₂ emissions and especially less Fine Particulate Matter (PM2.5) – an issue of contemporary environmental health concerns. It is further revealed that higher shares of biodiesel in diesel would result in an increased demand for oil palm production in order to meet a rising growth in biodiesel production. Such an increase in demand for oil palm feedstock would result in higher commodity prices and therefore higher income for farmers. However, a high oil palm production demand would require a substantial crop cultivation area. The effort to increase palm planting and productivity to meet the growing demand is a challenging task. In order to overcome this challenge, this paper suggests the implementation of agricultural zoning and the advancement of crop species and biodiesel conversion technology.

1. Introduction

For Thailand, oil has played an important role in the country’s economic and social development. In 2019, petroleum products consumption in Thailand accounted for 49% of final energy consumption [1]. Of the total petroleum products, diesel consumption accounted for 47%. Moreover, Thailand has heavily relied on imported oil to meet the rising demand because of its limited indigenous energy resources. Given concerns about the energy security and environmental health, the Thai government has implemented policies on the promotion of biodiesel consumption in the transportation sector over the last twenty years. In 2005, the government began a campaign to promote the production and consumption of biodiesel. B5 (a blend of 5% biodiesel and 95% fossil diesel) has been on sale since 2005. In 2014, the...
The government has increased the proportion of biodiesel blending to 7% (B7). In 2020, the government has made further efforts to push to increase the proportion of biodiesel blending to B10 and B20 with a view to balance the entire palm oil system in the country, stabilize palm oil prices and help reduce pollutions including carbon dioxide emissions and Fine Particulate Matters (PM 2.5). An increase proportion of biodiesel in diesel would certainly result in an increase of biodiesel production. A rising demand for biodiesel would further require a substantial amount of energy crops especially palm oil and hence have an impact on land for growing crops. With this background, this paper aims to assess the implications of the promotion of biodiesel consumption in the Thai transportation sector in terms of energy, environment and agriculture.

2. Research Methodology

The methodology employed in this paper is the Low Emissions Analysis Platform (LEAP). LEAP is a widely-used software tool for energy policy analysis and climate change mitigation assessment, developed by the Stockholm Environment Institute (SEI). It is an integrated, scenario-based modelling tool originally developed to track energy consumption, production and resource extraction in all sectors of an economy. It can account for both energy sector and non-energy sector greenhouse gas (GHG) emission sources and sinks \[2\]. LEAP has been employed by several studies to assess the energy and environmental impacts of bioenergy including biofuels \[3-7\].

In this paper, the impacts of an increase share of biodiesel in diesel are assessed in terms of energy, environment and agriculture. The impacts on energy are assessed in terms of diesel consumption and crude oil requirements. The impacts on environment are assessed in terms of CO\(_2\) emissions and Fine Particulate Matter (PM2.5). And, the impacts on agriculture are assessed in terms of production demand for oil palm and future land requirements.

In order to analyze the implications, scenarios are developed to assess their implications for the period 2019-2037. In this paper, three scenarios (namely REF, B10 and B20) represent various percentages of biodiesel blending mandates. The REF scenario reflects a situation in which the proportion of the biodiesel blending for standard diesel is B7 and B10 is optional. The B10 scenario is developed to represent the case that biodiesel blending for standard diesel is B10. In the B20 scenario, 20% biodiesel blending (B20) is set to be standard diesel. For more details of each scenario, Table 1 provides an overview of the key scenario descriptions. In addition, the refinery capacity throughout the entire studied period is assumed to be the same as the capacity in 2019. The capacity for crude oil refinement in 2019 was 1.2 million barrel per day \[1\].

| Scenario theme | Key scenario descriptions |
|----------------|--------------------------|
| REF scenario   | • The demand growth for diesel consumption in the transportation sector is assumed to be 3.3% annually \[8\].  
|                | • The proportion of the biodiesel blending for standard diesel is 7% (B7) and B10 is optional.  
|                | • The consumption shares of B7 and B10 are 95% and 5% respectively. |
| B10 scenario   | • The demand growth for diesel consumption in the transportation sector is assumed to be 3.3% annually \[8\]. |
3. Scenario theme

| Scenario theme | Key scenario descriptions |
|----------------|---------------------------|
| B20 scenario   | - The demand growth for diesel consumption in the transportation sector is assumed to be 3.3% annually [8].
|                | - 20% biodiesel blending (B20) is set to be standard diesel which is 100% consumption share. |
| B10 scenario   | - Percentage share of biodiesel blending for standard diesel is 10% (B10) and B20 is optional. |
|                | - The consumption shares of B10 and B20 are 70% and 30% respectively. |

3. Data Consideration

In accordance with the multidisciplinary nature of the research, this paper requires extensive data including energy, environment and agriculture. The data is in the form of biofuel policies, the Alternative Energy Development Plan (AEDP), statistical data of energy supply and consumption. The information on energy (for example, consumption of crude oil, diesel and biodiesel) is available from various Thailand Energy Balance reports and Thailand Alternative Energy Situation reports, annually published by the Department of Alternative Energy Development and Efficiency (DEDE) [1, 9]. The growth for final energy demand can be obtained from the Ministry of Energy (MOE) and the DEDE [10]. Oil palm yield and productivity of oil palm can be taken from the Office of Agricultural Economics (OAE) and the DEDE [11-12].

4. Empirical Results

This paper provides an assessment of the scenario impacts on agriculture, energy and environment. The assessment is accordingly divided into three sub-sections, namely, energy, environment and agriculture.

4.1. Energy

In this paper, the scenario impacts on agriculture are assessed in terms of a decrease in projected diesel consumption and crude oil requirements.

4.1.1. Projected diesel demand

Figure 1 reveals that projected diesel demand in the transportation sector under the REF scenario would increase continuously, from 20,960 Million litres in 2019, to 39,058 Million litres in 2037. In 2037, the B10 scenario would contribute to a reduction of 4,673 Million litres in comparison with the REF scenario. The demand for diesel in the case of the B20 scenario in 2037 would be 10,064 Million litres less than diesel demand under the REF scenario. Therefore, the demand for diesel in the case of B10 and B20 scenarios would be 12% and 26%, respectively, lower than in the REF scenario. This is a result of an increasing share of biodiesel in diesel. It is evident that higher shares of biodiesel in diesel would undoubtedly cause less demand for diesel.
4.1.2. Crude oil requirements
In order to meet an increasing demand for diesel, crude oil requirements in the REF scenario is expected to grow considerably. Table 2 shows crude oil requirement for the period 2019-2037. The results from Table 2 reveals that crude oil requirements would increase from 19,383 KTOE in 2019 to 36,119 KTOE in 2037—a double increase over the period 2019-2037. In 2037, crude oil requirements in the case of B10 and B20 scenarios would be 10% and 22%, respectively, lower than in the case of the REF scenario. Table 2 further shows that crude oil requirements in the B10 and B20 scenarios is expected to decrease continuously as compared with the REF scenario. For example, a decrease in crude oil requirements, under the B10 scenario, in 2027 would be 1,775 KTOE, in 2037 would be higher – 3,747 KTOE in comparison with the REF scenario. And, in the B20 scenario, a reduction in crude oil requirements in 2027 would reach 3,728 KTOE, in 2037 would be higher – 7,870 KTOE, as compared with the REF scenario. This signifies that increased share of biodiesel in diesel would contribute to higher crude oil savings.

| Year | REF scenario | B10 scenario | B20 scenario |
|------|--------------|--------------|--------------|
|      | Crude oil requirement | Crude oil requirement | Changes from REF scenario | Crude oil requirement | Changes from REF scenario |
|      | (KTOE) | (KTOE) | (KTOE) | (KTOE) | (KTOE) |
| 2019 | 19,383 | - | - | - | - |
| 2027 | 27,310 | 25,535 | -1,775 (-6%) | 23,582 | -3,728 (-14%) |
| 2037 | 36,119 | 32,372 | -3,747 (-10%) | 28,249 | -7,870 (-22%) |

Notes: Number in brackets show percentage change from the REF scenario.

4.2. Environment
In this section, the implications of biodiesel consumption promotion on the Thai transportation sector are analyzed. This analysis incorporates three main attributes, namely, CO₂ emissions and emissions of Fine Particulate Matters (PM2.5)
4.2.1. CO₂ emissions
The results from Table 3 reveal that CO₂ emissions under the REF scenario is estimated to reach from 56 million tonnes in 2019, to 105 million tonnes in 2037, an increase of 49 million tonnes over the 2019 emission level. CO₂ emissions in the B10 scenario is expected to grow to 92 million tonnes in 2037 - a decrease of 13% in CO₂ emissions as compared with the REF scenario. In the case of B20 scenario, CO₂ emissions in 2037 would be 27 million tonnes (29%) lower as compared to the CO₂ emissions in the REF scenario. Furthermore, Table 3 shows that the B10 and B20 scenarios would contribute to a slowdown in a rise of CO₂ emissions in comparison with the REF scenario. In the B10 scenario, a reduction of CO₂ emissions in 2027 would reach 6 million tonnes, in 2037 would be higher - 13 million tonnes, as compared with the REF scenario (as shown in Table 3). It is further noticed that the B20 scenario would result in highest CO₂ savings - 27 million tonnes in 2037, as compared with the REF scenarios. Such a reduction in CO₂ emissions accords with the decrease in diesel consumption. It is evident that an increase in percentage share of biodiesel blend would contribute to a reduction in diesel consumption and hence lower CO₂ emissions.

| Year | REF scenario | B10 scenario | B20 scenario |
|------|--------------|--------------|--------------|
|      | CO₂ emission | CO₂ emission | Changes from | CO₂ emission | Changes from |
|      | (million     | (million     | REF scenario | (million     | REF scenario |
|      | tonnes)      | tonnes)      |             | tonnes)      |             |
| 2019 | 56           | -            | -            | 92           | -            |
| 2027 | 79           | 92           | (-6, -8%)    | 78           | (-27, -29%)  |
| 2037 | 105          | 92           | (-13, -14%)  | 78           | (-27, -29%)  |

Notes: Number in brackets show percentage change from the REF scenario.

4.2.2. Fine Particulate Matters (PM2.5)
Figure 2 reveals that annual emissions of PM2.5 under the REF scenario would increase from 18 thousand tonnes in 2019, to 34 thousand tonnes in 2037, an increase of 16 thousand tonnes over the 2019 emission level. In 2037, annual emissions of PM2.5 in the case of B10 scenario would be 12% lower than the emissions under the REF scenario. Moreover, the B20 scenario would contribute to a decrease of 24% in comparison with the REF scenario. Figure 3 further show that annual emissions of PM2.5 in the B10 and B20 scenarios would decrease continuously in comparison with the REF scenario. For example, a decline in emissions of PM2.5, in the case of B10 scenario, in 2027 would be 2 thousand tonnes, in 2037 would be higher -4 thousand tonnes in comparison with the REF scenario. And, in the B20 scenario, a decrease in emissions of PM2.5 in 2027 would reach 4 thousand tonnes, in 2037 would be higher -8 thousand tonnes, as compared with the REF scenario. Such a reduction could be a result of a decrease consumption of diesel which is one major source of PM2.5 emissions. It is widely known that most PM2.5 derives from inefficient combustion in diesel engines, wood burning and dust from combining of pollutant gases and the industrial activities. The issue of PM 2.5 has currently been moved to the forefront of global health concern discussion. This is because PM2.5 could cause several health problems including respiratory and cardiovascular morbidity and lung cancer. The promotion of diesel substitution
by biodiesel would contribute to a slowdown an increase of PM2.5 emissions and therefore provide benefit to the public health (as shown in figure 2).

![Figure 2](image)

**Figure 2** Fine Particular Matters (PM2.5) emissions over the period 2019-2037

![Figure 3](image)

**Figure 3** Changes in Fine Particular Matters (PM2.5) emissions in the case of various scenarios

4.3. Agriculture

In this paper, the scenario impacts on agriculture are assessed in terms of production demand for oil palm and future land requirements for growing oil palm.

4.3.1. Production demand for oil palm

The policy to promote biodiesel consumption in the Thai transportation sector would result in a rising demand for oil palm. Figure 4 shows the projected oil palm production demand for the period 2019-2037. It should be noted that crop production for oil palm in this paper requires 4 kg of fresh fruit bunches (FFBs) for 1 litre of biodiesel [13]. The results from Figure 4 reveals that the demand for oil palm production in the case of REF scenario would increase by about 0.4 million tonnes, from 0.5 million tonnes in 2019 to 0.9 million tonnes in 2037. The demand for oil palm in the B10 scenario is expected to grow to 3.5 million tonnes in 2037 - more than four-fold increase in oil palm production demand in
comparison with the REF scenario. Especially, the demand for oil palm, in the case of B20 scenarios, in 2037 would increase by about 8 times as compared with the demand under the REF scenario.

Figure 4. Projected production demand for oil palm over the period 2019-2037

Figure 5. Projected future land extension for growing oil palm

4.3.2. future land requirements
To supply the increasing demand for oil palm production, the projected future land requirement is expected to rise considerably. The results from Figure 5 reveals that the projected future land extension for growing oil palm in the REF scenario is expected to rise by about 936 Thousand hectares. The requirement for land extension in the B10 scenario would be about 6,364 Thousand hectares – approximately seven-fold increase in comparison to the land extension in the case of REF scenario. In the case of B20 scenarios, the demand for future land extension would increase by 14,595 Thousand hectares – about 15 times higher than in the REF scenario. A substantial increase in crop production demand would directly result in a rise of future land requirements for growing oil palm.
The inference drawn from the above analyses is that an increase in percentage share of biodiesel blend would provide beneficial impacts on various aspects. In terms of energy, increased share of biodiesel in diesel would contribute to a reduction in diesel consumption and hence crude oil requirement. For example, in the case of B20 scenario, crude oil requirements in 2037 would be lower by 15% and 28%, respectively, as compared with the B10 and REF scenarios. For the environmental impacts, increased share of biodiesel in diesel would help slowdown an increase of CO_2 and PM2.5 emissions - an issue of contemporary environmental health concerns. For instance, CO_2 emissions in the case of B20 scenario would be 19% and 35%, respectively, lower than the emissions in B10 and REF scenarios. And, PM2.5 emissions in the case of B20 scenario would be 15% and 31%, respectively, lower than the emissions in B10 and REF scenarios. Even though the B20 scenario would provide a positive impact on several perspectives, it would require more energy crops for biodiesel production and future land requirements in comparison with other scenarios. For example, in the case of B20 scenario, demand for oil palm in 2037 would be higher by 52% and 87%, respectively, as compared with the B10 and REF scenarios. Additionally, future land requirements in the case of REF, B10 and B20 scenarios in 2037 would be 2 time, 7 times and 14 time, respectively, as compare with land requirement for growing oil palm in 2019. In order to reduce the demand for oil palm production, the efficiency improvement of the biodiesel conversion technology is essentially important. In fact, a rise in oil palm demand would help farmers generate extra income. This should be cautiously considered in the context of Thailand - the country that always face crop price volatility. In addition to the increased demand, a substantial increase in future land requirements would be one major challenge. This paper, therefore, recommends that the advancement of crop species and the agricultural zoning could be effective strategies in order to overcome this challenge. The advancement of crop species would help improve crop yield and hence help reduce crop cultivation area. In addition, the implementation of agricultural zoning is one of the key strategies to help balancing between food crops and energy crops production and increasing productivity of crops.

5. Conclusion
This paper assesses the implications of the promotion of biodiesel consumption in the Thai transportation sector in terms of energy, environment and agriculture. The assessment reveals that an increase in percentage share of biodiesel blend would provide beneficial impacts on several perspectives. For example, increased share of biodiesel in diesel would contribute to a reduction in diesel consumption and hence crude oil requirement. Increased biodiesel share would contribute to about 28% reduction in crude oil requirement. It would also help mitigating CO_2 and PM2.5 emissions. CO_2 emissions could be reduced by about 35% as a result of increased share of biodiesel. Also, PM 2.5 emissions could be reduced by 31% due to increased share of biodiesel. It would, however, require high crop production demand and a substantial increase in future land requirements. Increase in biodiesel share would require 87% more oil palm. This would result in a 14 times future land required for growing oil palm. The effort to increase palm planting and productivity to meet the growing demand is a challenging task. In order to overcome this challenge, this paper suggests the advancement of crop species and biodiesel conversion technology as well as the implementation of agricultural zoning would be effective strategies.

6. References
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[2] Stockholm Environment Institute 2020 Low Emissions Analysis Platform (LEAP): training
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