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The Assessment of Biofuel Utilization Policy on the Total Output and CO_2 Emissions in Thailand

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Abstract: The transport sector is the largest energy-consuming sector in Thailand. Its primary energy supply is heavily depended on imported oil. Since 2005, world crude oil price has been rising and had reached a record of 147 $/barrel. Therefore the policy on promotion of biofuel utilization was initiated in 2005 by the Ministry of Energy; however, the economy-wide impacts have been rarely assessed. This paper presents the energy Input-Output Analysis (IO) of the economy-wide impacts on the promotion policy, in particular, the change in Greenhouse Gas (GHG) emissions. In order to measure the total GHG emission from different economic sectors, the contribution of emissions has to be considered. In this paper, the focus is placed on CO_2 emissions. To calculate the amount of CO_2 emissions, the emission amount of various final consumptions in the economy evaluated by the IO must be applied. The direct CO_2 emissions in final energy consumptions in Thailand are evaluated by using conversion factors from Guidelines to Defra's GHG conversion factors, Annexes updated in June 2007. The CO_2 emissions in various economic sectors will be calculated and compared with the figures in 2015 when the policy is fully implemented.

Keywords: Biofuel utilization, GHG emissions, energy input-output analysis, energy assessment.

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1. Introduction

The transport sector is the largest energy-consuming sector in Thailand, and the primary energy supply in this sector is heavily depended on imported oil. According to Alternative Energy Development Plan: AEDP 2012-2021, 80% of oil consumed in Thailand are imported from aboard. The rising of world crude oil price has greatly impact on the transport sector and Thai economy as a whole. Since 2005, the Ministry of Energy has set a target to promote the use of alternative energy in the transport sector to reduce the oil consumption and increase energy independency. The policy on promotion of biofuel was first initiated in 2005. As Thailand has been one of the fastest growing economies in South East Asia for the past twenty years and experienced a parallel increase in demand for energy to fuel its impressive industrial expansion, the Thai Government had set forth a sustainable energy plan that would address the country's short-term and long-term supply and demand issues, and which secures Thailand's future energy sufficiency.

Thai government has designated a 15-year plan from 2008 to 2022, and aimed at covering 20% of total national energy demand by reproducible energy. To begin with, the government has set a policy in 2008 to reduce oil consumption in the transport sector by 15 % (Bhandhubanyong, 2006). Moreover, there is a two-phase strategy developed by Ministry of Energy (Gonsalves, 2006). The first phase concerns with replacement of MTBE (Methyl Tertiary Butyl Ether) and ETBE (Ethyl Tertiary Butyl Ether) in gasoline with ethanol. With this phase, the production of ethanol should be amplified to 1.155 million liter per day. In the second phase, gasohol mandate will stimulate ethanol production to satisfy the increasing gasohol users. In addition, the Energy Policy and Planning Office (EPPO) has launched a strategy aiming at reducing energy consumption in all sectors. Recently, from year 2008 to 2009, there was a 13% increase in gasohol use (Energy Policy and Planning, 2009). In addition, the government has promoted the production and the use of biodiesel in order to reduce the country's imported fuel oil, reduce air pollution, and enhance the quality of life. It is estimated that the policy on promotion of biofuel will be fully implemented in 2015. All diesel sold in Thailand will be 5% blended biodiesel, called B5, and gasoline will be blended with 20% ethanol, called E20. Consequently, the energy structure of Thailand; particularly in transport sectors, is changed due to the implementation of the promotion on biofuel utilization, and the study of its macroeconomics impacts has already been assessed by using the IO model (Suanmali et al, 2010). However, the economy-wide impacts on CO_2 emission factors have been rarely assessed. In this paper, the focus is placed on CO_2 emissions. To calculate the amount of CO_2 emitted, the emission factors of various final consumptions in the economy, evaluated by the Input-Output Analysis (IOA), must be applied.

The Input-Output model was developed using the 2005 Input-Output table provided by the Office of the National Economic and Social Development Board (NESDB) (NESDB, 2009). For the analysis, all 180 sectors from the Input-Output table were carefully reorganized and reduced to 18 sectors (see Table 1). The direct CO_2 emissions in the final energy consumption in Thailand are evaluated by using conversion factors from Guidelines to Defra's GHG conversion factors, Annexes updated in June 2007 as shown in Table 2. This paper is aimed at measuring CO_2 emission factors in various economic sectors and comparison of factors in 2015 when the policy of promotion of biofuel utilization is fully implemented.

Table 1. Recognized sector

Sector	Name
1	Agriculture
2	Mining Cons
3	Construction
4	Commercial
5	Road transportation
6	Other transportation
7	Food & Beverages
8	Textiles
9	Wood and Furniture
10	Paper
11	Chemical
12	Non-Metallic
13	Basic Metallic
14	Fabricated Metal
15	Coal and its products
16	Petroleum products and natural gases
17	Electricity
18	Others

Table 2. Conversion factor

Standard Road Transport Fuel Conversion Factor					
Fuel used	Total units used	Units	x	kg CO_2 per unit	Total kg CO_2
Petrol	units used	liters	x	2.3154	kg of CO_2
Diesel	units used	liters	x	2.6304	kg of CO_2

2. Policies and Situation in Thailand

Thailand has a population of 63 million; it draws 49% of national annual consumption of energy from overseas countries. It imports 85% of crude oil annually. To decrease import dependency of energy, Thai government has designated a 15-years plan from fiscal year 2008 to fiscal year 2022 to cover 20% of total national energy demand by renewable energy.

The Government has also formulated a strategy to ensure that by 2012 all the diesel sold in Thailand will be 10% biodiesel (B10). In addition, Thailand's Energy Policy was delivered to the cabinet on December 30, 2008 by Mr. Abhisit Vejjajiva, former Prime Minister of Thailand to emphasis the promotion the production and utilization of biofuels. It has become a national agenda by encouraging the production and the use of alternative energy, particularly biodiesel (B5, B10).

Biodiesel is the name given to these esters when they are intended for use as transportation fuel. Biodiesel is blended with petroleum diesel. There are three main type of biodiesel: B2, B5 and B10. The number listed after a letter 'B' indicates the percentage of biodiesel blended in the combination with petrol. B2 was introduced in the market in 2008. Afterwards, B5 was first sold in the market in 2007 and extended nationwide in 2011. Also, B10 was set to be used with any diesel engines in 2012.

Global warming is currently an important agenda worldwide. A higher in the average temperature leads to many problems including a rise in sea level and an increase in the frequency of some extreme weather events. A long-term renewable energy policy on lower CO_2 emission should be considered. The policy on promotion of biofuel utilization in transport sector is a way that will certainly reduce the amount of CO_2 emissions. The plan is clearly presented to the Parliament that Thailand will be aiming at Green house emission reduction (Nunt-Jaruwong, 2011). In 2012 -2016, the focus will be placed on development of alternative energy technology industry, encourage new alternative energy R&D to achieve economic viability including new technologies for biofuels production and introduce a model development of Green City to communities for sufficient economy and sustainability development. The long term from 2017 to 2022, Thailand will enhance utilization of new available alternative energy technologies such as hydrogen, bio hydrogenated (BHD), extend green city models throughout Thai communities and encourage to be hub of biofuel and alternative energy technology exports in ASEAN regions. These midterm and long term plans require the cooperation from experts in inter-disciplinary areas such as engineering, environmental, economic business, and agricultural researchers. Engineering and production management is an important key in this situation as it will gathers researchers and industry experts to come up with an efficient solution or plan to increase the proportion of renewable energy production and utilization in Thailand (Ko, 2011).

3. Research Methodology

In this paper the IO model (Wassily, 1986) is applied. When the government initiates the policies, they will have both direct and indirect effects on many industries of the entire economy because the total consumption of a particular product at the final and intermediate levels will represent final demand in the economy. This is applicable to the final energy demand.

One important step in developing the model is to determine the total requirement from the economy. It can be obtained from the sum of the final consumption and the intermediate requirements for intermediate sectors (Miller and Blair, 1985). Thus, if the economic structure consists of n sectors, we define the following variables as

X_i = The total output or production of sector *i*.

Y_i = The total final demand for sector *i*'s product.

z_{ij} = The inter-industry sales by sector i to sector *j*,

Where

$1 \le i, j \le n$. The equation that describes the relationship among X_i, Y_i and z_{ij} in each sector *i* can be expressed in Eq. (1) as

$$X_i = z_{i1} + z_{i2} + \cdots + z_{in} + Y_i. \qquad (1)$$

The technical coefficient or input coefficient is the ratio between input and output of each sector and is denoted as a_{ij}, where

$$a_{ij} = \frac{z_{ij}}{X_j}. \qquad (2)$$

Then, we define

$$X_j = \min\left(\frac{z_{1j}}{a_{1j}} = \frac{z_{2j}}{a_{2j}} = \cdots = \frac{z_{nj}}{a_{nj}}\right) \qquad (3)$$

Hence, the relationship among X_i, Y_i and z_{ij} in all n sectors can be described as

$$\begin{aligned} X_1 &= a_{11}X_1 + a_{12}X_2 + \cdots + a_{1i}X_i + \cdots + a_{1n}X_n + Y_1 \\ &\vdots \\ X_i &= a_{i1}X_1 + a_{i2}X_2 + \cdots + a_{ii}X_i + \cdots + a_{in}X_n + Y_i \\ &\vdots \\ X_n &= a_{n1}X_1 + a_{n2}X_2 + \cdots + a_{ni}X_i + \cdots + a_{nn}X_n + Y_n. \end{aligned} \qquad (4)$$

Then, we rearrange Eq. (4) and each place the variable Y_i on the right-hand side; the equation becomes

$$(I - A)X = Y, \qquad (5)$$

Where

I is an identity matrix of order n, $A = (a_{ij})$ is an $n \times n$ matrix, and both X and Y are $n \times 1$ vectors. Thereby,

$$X = (I - A)^{-1} Y, \qquad (6)$$

and the matrix $(I - A)^{-1}$ is referred as Leontief inverse.

When the energy substitution policy is implemented, the final demand will change. Subsequently, the change in final demand will alter the total output of production, which is the focus of this paper. Therefore, the Eq. (6) is developed into $\Delta X = (I - A)^{-1} \Delta Y$

In addition, certain assumptions are required. First, there is no great variation in economic change from the year 2005 till present. That is, the economic structure and the flows between sectors remain just about the same. Second, most biofuel are used in road transportation (sector 5). Trucks, trailers, railways and water transports use diesel as the main fuel. Third, biofuel is produced from agricultural crops; consequently, an increase in biofuel demand would increase the final energy demand in sector 1. Fourth, the demands of other unrelated/irrelevant sectors remained unchanged. Hence, the impact of this energy substitution policy will be placed only upon agriculture and transportation sectors. Hence, the change in final energy demand in these sectors is nonzero, and all other entries equal zero. Fifth, the engine or technology efficiency is constant.

The final energy demand vector, Y_i, is derived from the 2007 Energy Report in the same way as the study done on ethanol utilization (Suanmali et al., 2010). The business as usual (BAU) case or base case of fuel consumption in Thailand's transport sector is calculated. It is obtained that in the BAU case the final energy demand in agricultural and transportation sectors are 31,374,306 thousand Baht and 571,740,092 thousand Baht respectively. In order to evaluate the impacts of the biodiesel utilization policy on the change in the total output of the agricultural and transport sectors, three structural changes are considered in this paper. They are 100% utilization of B5, 100% utilization of B10, and 50% utilization of both B5 and B10.

In addition to assessment of the economy-wide impacts of biodiesel utilization policy, the total CO_2 emitted in each sector can be obtained through the Leontief inverse or $(I - A)^{-1}$ (Limmeechokchai and Suksuntornsiri, 2007). A matrix of energy consumption of each in the 18 sectors is defined and is denoted as a matrix *F*. Its dimension is *k* x *n*, where n is the number of sectors and *k* is the number of fuel types. Thus, each entry of matrix *F*, F_{ki}, is the direct consumption of fuel *k* in a physical unit by the monetary output of economic sector *I* (Limmeechokchai and Suksuntornsiri, 2007). The focus of this study was placed on two types of fuel – gasoline and diesel. Therefore, *F* is a 2 x 18 matrix in this study as shown in Table 3. Then, each element, F_{ki},, where $1 \le i \le 18$ and $1 \le k \le 2$, is multiplied by its corresponding conversion factor demonstrated in Table 2 as shown in Eq. (7)

$$B_{ki} = F_{ki} \times \text{conversion factor}_{ki} \qquad (7)$$

The matrix $B = (B_{ki})$ is a matrix of sectoral CO_2 emission. The study of Limmeechokchai and Suksuntornsiri (2007) supported that the emission of CO_2 relies on the fuel type *k*, and the total CO_2 emission or bCO_2 is obtained through a calculation in Eq. (8)

$$bCO_2 = B(I - A)^{-1} \qquad (8)$$

Because the implementation of the promotion of biofuel utilization is mainly focused on the transport sector, the measure of CO_2 emissions in this study is emphasized on agricultural and transport sectors. In addition, year 2005 is defined as the base year in order to compare CO_2

emissions with those in 2015 when the policy of promotion of biofuel utilization is fully implemented.

A simple linear regression is employed to predict the sectoral energy consumption matrix of each fuel type (gasoline and diesel) in year 2015 denoted as F^{2015}. The elements of matrix F^{2015} are the predicted gasoline and diesel consumptions in each sector assuming that the policy is not implemented. Then from matrix F^{2015}, the sectoral energy consumption matrix of each fuel type (gasoline and diesel) in 2015 is predicted under the assumption that the biofuel utilization policy is fully implemented. It is observed that the implementation of utilizing E20 instead of gasoline and B5 instead of diesel is applied to the transport sector only (sectors 5 and 6). Hence, the elements of matrix F^{2015} in sectors 5 and 6 are adjusted by multiplying them by a gasoline mixture ratio – 0.80 for E20 and 0.95 for B5. The deleted 20% of gasoline and 5% of diesel are, thereby, added to agricultural sector as ethanol and biodiesel are by-products of that sector. The overview of each entry in the adjusted F^{2015} matrix is described in Table 4.

Table 3. Matrix F of Energy Consumption in each sector

	Sector 1	Sector 2	…	Sector 18
Gasoline (Liters)	F_{11}	F_{12}	F_{1i}	$F_{1,18}$
Diesel (Liters)	F_{21}	F_{22}	F_{2i}	$F_{2,18}$

4. Results

4.1. Part I: Assessment of Biodiesel Utilization Policy

After the change in final energy demand vector or ΔY in each of the three structural changes is obtained, the change in total output of production vector or ΔX is found. The results from the IO model for case 1, case 2 and case 3 are summarized in tables 5 - 7 respectively, where case 1 is for 100% utilization of B5 in the transport sector. Case 2 and case 3 are for 100% utilization of B10, and 50% utilization of both B5 and B10 in the transport sector respectively.

When 100% of B5 is utilized, the final energy demand in the agricultural sector rises by 26,067 million Baht (ΔY) or increases by 52.21%. So the output of production in this sector increases by 26,224 million Baht (ΔX). On the other hand, the final energy demands in the transport sector decreases by 48,244 million Baht or decreases by 17.02% with the total output production decreases by 48,246 million Baht or decreases by 17.02%.

In the situation where 100% of B10 is utilized, it requires more biodiesel in the energy mix. It is estimated that doubling biodiesel is required. As a result, this policy helps to promote agricultural sector by 112.72% or, numerically, 57,788 million Baht. This is because more crops; especially palm oil, jatropha oil, soy bean oil, physic nut (black soap) and vegetable oils, are required for biodiesel production. If 100% of B10 is implemented, the final energy demand in the transport sector decreases by 5.53% and the total output of production decreases by 19.52%.

If 50% of B5 and B10 is implemented, the final energy demand in the agricultural sector increases by 41,754 million Baht or increases by 83.63%, while the total output of production in this sector increases by 42,006 million Baht or 81.94%. On the other hand, the result show that this policy will reduce the final energy demand and the total output production in the transport sector; the final energy demand decreases by 18.30% and the total output of production decreases by 18.29%.

4.2. Part II: Assessment of CO_2 Emissions

The CO_2 emissions from final consumptions in the base year 2005 are presented in Table 8. CO_2 emissions in each sector in 2015 are also summarized in Table 8. The fourth column presents CO_2 emissions in 2015 when the biofuel utilization policy is fully implemented. The results in each sector are obtained from the adjusted matrix F^{2015} as explained in Table 4. The focus is kept on for the agricultural and transport sectors. The percentage changes of CO_2 emissions in 2015 when the policy is implemented in these mentioned sectors are demonstrated in Table 9.

The amount of CO_2 emissions in each economic sector depends on the amount of fuel and fuel types (gasoline and diesel). In 2005, road transportation (sector 5) has the highest CO_2 emissions, followed by agricultural sector (sector 1) and other transportation sector (sectors 6 - trucks, trailers, railways, air, and water transportations). Similar results are obtained in 2015 as CO_2 is emitted mostly in the sector 5.

Table 4. The Adjusted F2015 Matrix that Reflect the Implementation of the Biofuel Utilization Policy in Transport Sector

	Sec. 1	…	Sec.5	Sec.6	…	Sec. 18
Gasoline (Liters)	$F^{2015}{}_{11} + (0.2)F^{2015}{}_{15} + (0.2)F^{2015}{}_{16}$		$(0.80)F^{2015}{}_{15}$	$(0.80)F^{2015}{}_{16}$		$F^{2015}{}_{1,18}$ (unadjusted)
Diesel (Liters)	$F^{2015}{}_{21} + (0.05)F^{2015}{}_{15} + (0.05)F^{2015}{}_{16}$		$(0.95)F^{2015}{}_{25}$	$(0.95)F^{2015}{}_{26}$		$F^{2015}{}_{2,18}$ (unadjusted)

Table 5. Summary of ΔY and ΔX when 100% of B5 is Utilized.

	B5	Final Energy Demand (Y) (1010 Baht)	Change in Final Energy Demand (ΔY)(1010 Baht)	Percentage Change	Total Output of Production (X)(1010 Baht)	Change in Total Output of Production (delta X) (1010 Baht)	Percentage Change
Agricultural Sector	Business as usual	4.9925			5.1265		
	Policy implemented	7.5992	2.6067	52.21%	7.7489	2.6224	51.15%
Transport Sector	Business as usual	28.3471			28.3501		
	Policy implemented	23.5227	-4.8244	-17.02%	23.5255	-4.8246	-17.02%

Table 6. Summary of ΔY and ΔX when 100% of B10 is Utilized.

	B10	Final Energy Demand (Y) (1010 Baht)	Change in Final Energy Demand (ΔY)(1010 Baht)	Percentage Change	Total Output of Production (X)(1010 Baht)	Change in Total Output of Production (delta X) (1010 Baht)	Percentage Change
Agricultural Sector	Business as usual	4.9925			5.1265		
	Policy implemented	10.7366	5.7441	115.05%	10.9053	5.7788	112.72%
Road transport Sector	Business as usual	28.3471			28.3501		
	Policy implemented	22.8144	-5.5327	-19.52%	22.8172	-5.5329	-19.52%

Table 7. Summary of ΔY and ΔX when 50% of B5 and 50% of B10 are Utilized.

	50% of B5 and B10	Final Energy Demand (Y) (1010 Baht)	Change in Final Energy Demand (ΔY)(1010 Baht)	Percentage Change	Total Output of Production (X)(1010 Baht)	Change in Total Output of Production (delta X) (1010 Baht)	Percentage Change
Agricultural Sector	Business as usual	4.9925			5.1265		
	Policy implemented	9.1679	4.1754	83.63%	9.3271	4.2006	81.94%
Road transport Sector	Business as usual	28.3471			28.3501		
	Policy implemented	23.1608	-5.1863	-18.30%	23.1636	-5.1865	-18.29%

5. Conclusion

From the analysis, The Input-Output model indicates the macroeconomic impacts. The results from tables 5 - 7 indicate that once there is a change in the energy sectors, the impact will be on several industrial sectors; in particular, in the agricultural sector and transport sectors.

The results of 100% utilization of B5 pointed out that for a one Baht increased in final energy demand then, the agricultural sector will increase the total output in the same sector by 1.00602 Baht. In addition, if the 100% utilization of B10 is implemented, a one Baht increased in final energy demand in the agricultural sector will increase the total output by 1.00605 Baht, which is higher than the case of B5. Lastly, for the 50% of B5 and 50% of B10 is implemented, a one baht increase in final energy demand in agricultural sector will increase the total output of production by 1.00604 Baht. Proportionally, a decline of one Baht in final energy demand of the transport sector will decrease the total output by 1.00004 Baht if 100% of B5 is implemented. On the other hand, if 100% of B10 is implemented, the proportion of a decrease in final energy demand to the total output in the transport sector is 1:1.00009. Also, if the third case is implemented, the ratio will be 1: 1.00003. For comparative efficiency, the increase of output in the agricultural sector must be compared with the decrease of output in the road transport sector. The utilization of 100% utilization of B10 is the most promising policy that should be implemented because it gives the highest value of output in the agricultural sector.

In addition to the assessment of biodiesel utilization policy, the assessment of CO_2 emissions reveals that requirement of fossil-fuel directly affects the amount of CO_2 emissions. The transport sector (both sectors 5 and 6) are the highest fossil-fuel consuming sector and have the high CO_2 emissions. The trend of CO_2 emissions would be lower in the case of a successful utilization of renewable energy; particularly, the transport sector could be lower by almost 10%.

Finally, Thailand will be able to produce biofuel domestically, so promoting the utilization of this alternative energy will also increase the output in agricultural sector due to the higher demand in biofuel production. Most of all, the implementation of the biofuel utilization would certainly reduce the amount of imported fuels, increase Thailand's energy independency, and decrease CO_2 emissions

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Table 8. Summary of CO_2 Emissions in the Sectors

Sectors	CO_2 Emissions in 2005 (ton CO_2/million Baht)	CO_2 Emissions in 2015 (ton CO_2/million Baht)	
	Based Year	No Policy is Implemented	Policy of Utilizing Biofuel is Implemented
1	10.35	10.53	14.95
2	0.06	0.06	0.05
3	0.35	0.35	0.35
4	0.03	0.03	0.04
5	47.47	49.18	44.52
6	4.99	5.67	5.39
7	0.84	0.84	0.88
8	0.04	0.04	0.05
9	0.09	0.09	0.09
10	0.08	0.08	0.08
11	0.60	0.60	0.61
12	0.22	0.22	0.22
13	0.09	0.09	0.09
14	0.13	0.13	0.13
15	0.00	0.00	0.00
16	0.00	0.00	0.00
17	0.22	0.22	0.22
18	0.72	0.72	0.72

Table 9. Percentage of Changes in CO_2 Emissions when the Policy is Implemented

Sector	CO_2 Emissions in 2015 (ton CO_2/million Baht)		% Changes
	No Policy is Implemented	Policy of Utilizing Biofuel is Implemented	
1	10.53	14.95	+41.970%
2	0.06	0.05	-5.000%
3	0.35	0.35	-0.090%
4	0.03	0.04	+30.050%
5	49.18	44.52	-9.470%
6	5.67	5.39	-4.500%
7	0.84	0.88	+3.820%
8	0.04	0.05	+6.460%
9	0.09	0.09	+2.650%
10	0.08	0.08	+0.350%
11	0.60	0.61	+1.590%
12	0.22	0.22	-0.010%
13	0.09	0.09	-0.040%
14	0.13	0.13	-0.060%
15	0.00	0.00	+40.030%
16	0.00	0.00	+10.440%
17	0.22	0.22	-0.006%
18	0.72	0.72	+0.162%

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