The Assessment of the Policy on Promotion of Biofuel Utilization on the Greenhouse Gas Emissions (CO_2) in Thailand

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Abstract

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. Since 2005 world crude oil price has been rising and had reached a record of a triple-digit price per barrel at 147 $/barrel. Since 2005, the Ministry of Energy has set a target to promote the use biofuel in the transportation sector to reduce the oil consumption and increase energy independency. Therefore the policy on promotion of biofuel was initiated in 2005; however, the economy-wide impacts on CO_2 emission factors have been rarely assessed.

In order to measure the total Greenhouse Gas (GHG) emission factors from different economic sectors, the contribution of emission has to be considered. 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 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 June 2007. This paper is aimed to measure the CO_2 emission factors in various economic sectors and to compare its factors in 2015 when the policy of promotion of biofuel utilization is fully implemented.

Keywords: biofuel substitution management, GHG emission factors, energy input-output analysis, renewable energy assessment

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. 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 years plan from 2008 to 2022 aiming to cover 20% of total national energy demand by reproducible energy. To begin with, the

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government has set a policy in 2008 to reduce the oil consumption in the transport sector by 15 percent (Bhandhubanyong, 2006). Moreover, there is a two-phase strategy developed by Ministry of Energy (Gonsalves, 2006). The first phase concerns with replacing MTBE (Methyl Tertiary Butyl Ether) and ETBE (Ethyl Tertiary Butyl Ether) in gasoline with ethanol so as to boost the octane number. With this phase, the production of ethanol should be amplified to 1.155 million liter per day. 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 every sector. 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 importation 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% Biodiesel, B5 and all gasoline will be substituted by 20% of ethanol blended gasoline or 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. 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 June 2007. This paper is aimed to measure the CO_2 emission factors in various economic sectors and to compare its factors in 2015 when the policy of promotion of biofuel utilization is fully implemented.

In addition, there are certain assumptions required in this study. 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 of gasohol is used by road transportation (sector 5). Trucks, trailers, railway and water transportations use diesel as a main source of fuel and Air transportation uses kerosene (sector 6). Third, ethanol biodiesel are 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 sectors 1, 5 and 6. Fifth, the engine or technology efficiency is constant.

Input-Output Analysis

In this research 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 describe the relationship among X_i, Y_i and z_{ij} in each sector *i* can be expressed in Eq. (1) as

$$X_i = z_{i1} + z_{i2} + \cdots + z_{in} + Y_i . \tag{1}$$

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

$$a_{ij} = \frac{z_{ij}}{X_j} . \tag{2}$$

Then, we define

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

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

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

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

$$(I - A)X = Y , \tag{5}$$

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,

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

and the matrix $(I - A)^{-1}$ is referred as Leontief inverse. The total CO_2 emissions generated from all production of goods and services are derived with the Leontief inverse matrix (Limmeechokchai and Suksuntornsiri, 2007).

A matrix of energy consumption in each of 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 1. Then, each element, F_{ki}, is multiplied by its corresponding conversion factor obtained from Guidelines to Defra's GHG conversion factors as shown in Eq (7)

$$B_{ki} = F_{ki} * \textbf{conversion factor}_{ki} \tag{7}$$

The matrix B = (B_1kt) is a matrix of sectoral CO_2 emission. The study of [Bundit and Pawinee] supported that the emission factors of CO_2 relies on the fuel type k, and the total CO_2 emission factors or bCO_2 is obtained through a calculation in Eq (8)

(8)

Table 1. Matrix F of energy consumption in each of the 18 sectors

	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}	$F_{2,18}$

Data Preparation

For the analysis, all 180 sectors from the Input-Output table are reorganized and reduced to 18 sectors as shown in table 2. These sectors are significant to the forecasting of the impacts on final energy demand and on other issues at macroeconomic level.

Table 2. Reorganized Sectors

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

The final energy demand vector, , and the energy consumption matrix, F, are derived from the Energy Report 2007 (Department of Alternative Energy Development and Efficiency, 2008). While the conversion factors that used to obtain the matrix B is shown in table 3.

Table 3. The Conversion Factors

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

Because the implementation of the promotion of biofuel utilization is mainly focused on transport sector, the measure of CO_2 emission factors in this study is emphasized on three economic sectors – agricultural, road transportation, and other transportation. In addition, year 2005 is defined as a base year in order to compare the CO_2 emission factors 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, F^{2015}. The elements of matrix F^{2015} are the predicted gasoline and diesel consumption in each sector. Observe 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 added to agricultural sectors as ethanol and biodiesel are by product of agricultural sector. The overview of calculation is shown in table 4

Table 4. The Matrix F^{2015} and Its Adjusted F^{2015} that Reflect the Implementation of the Policy on Promotion of Biofuel Utilization in Transport Sector

	Sector 1	**…**	**Sector 5**	**Sector 6**	**…**	**Sector 18**
Gasoline (Liters)	F^{2015}_{11}		F^{2015}_{15}	F^{2015}_{16}		$F^{2015}_{1,18}$
Diesel (Liters)	F^{2015}_{21}		F^{2015}_{25}	F^{2015}_{26}		$F^{2015}_{2,18}$

↓ ↓ ↓

	Sector 1	**…**	**Sector 5**	**Sector 6**	**…**	**Sector 18**
Gasoline (Liters)	F^{2015}_{11} + F^{2015}_{15} x 0.20 + F^{2015}_{16} x 0.20		F^{2015}_{15} x 0.80	F^{2015}_{16} x 0.80		$F^{2015}_{1,18}$
Diesel (Liters)	F^{2015}_{21}+ F^{2015}_{15} x 0.05 + F^{2015}_{16} x 0.05		F^{2015}_{25} x 0.95	F^{2015}_{26} x 0.95		$F^{2015}_{2,18}$

Results and Discussions

The CO_2 emission factors of final consumptions in the base year of 2005, is presented in table 5. This study is aimed to measure the CO_2 emission factors in various economic sectors and to compare its factors in 2015 when the policy of promotion of biofuel utilization is fully implemented. The investigation is then focused on the predicted sectoral CO_2 emission factors in 2015, assuming that the policy is not implemented, and then compare the results to the predicted CO_2 emission factors in 2015, assuming that the policy of utilizing E20 instead of gasoline and utilizing B5 instead of diesel is fully implemented. The comparison of CO_2 emission factors in 2015 is also summarized in table 5.

The amount CO_2 emission factors in each economic sector depends on the amount of fuel and fuel types (gasoline and diesel). In 2005, road transportation (sector 5) is the highest CO_2 emission factors sector, followed by agricultural sector and other transportation sector (trucks, trailers, railway, air, and water transportations). The assessment of CO_2 emission factors from this case study reveals that consumption requirement of fossil-fuel directly affect the amount of CO_2 emission factors. Transportation sector (both sectors 5 and 6) is one of the highest fossil-fuel consumption in Thailand, and the high emission factor come from high direct combustion of fossil-fuel energy. The trend of CO_2 emissions would be lower in the case of successful utilization of renewable energy; particularly, in transportation sector. If the implementation of the policy on promotion of biofuel is successfully carried out in 2015, the CO_2 emission factors in road transportation sector (sector 5) could be lower by almost 10%.

Global warming becomes an important issue. The impacts of climate change may be physical, ecological, social or economic. 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 factors 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. In addition, Thailand is 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 this biofuel utilization would certainly reduce the amount of imported fuel and increase Thailand's energy independency.

The detailed analysis of CO_2 emission factors on all 180 economic sectors could not be done due to limitation of data availability. Therefore, findings of this study are tentative. Further study with a larger extension on field surveys on relevant economic sectors is suggested for a rigorous analysis.

Table 5. Trends of CO_2 emission factors of all 18 sectors

	CO2 Emission Factors (tonCO2/million Baht) in 2005	**CO2 Emission Factors (tonCO2/million Baht) in 2015**	
Sector	**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

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