Assessment of GHG Mitigation Measures on Energy, Environmental and Economic Aspects in Thailand towards 2050 using AIM/CGE Model

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Abstract

The main primary energy sources in Thailand are fossil fuels such as natural gas, petroleum and coal resulting in high greenhouse gas (GHG) emissions and environmental effects and climate change. By the concept of low-carbon society (LCS) or low-fossil fuel economy, many countries including Thailand have voluntary GHG mitigation policies to mitigate the climate change. This study uses a Computable General Equilibrium (CGE) model which is known as a tool for analysis of short-term and long-term economic implications on climate change. The AIM/CGE model, which has been developed by Asia-Pacific Integrated Model (AIM) team, has been used to analyze GHG mitigation measures and GHG reduction targets under emission trading policy and application of carbon capture and storage (CCS) technology. The GHG reduction targets of a climate policy in Thailand on Nationally Appropriate Mitigation Actions (NAMAs) are proposed at 60 Mt-CO_2 in 2020. The baseline of GHG emissions is projected to the year 2050 and supposed to reduce CO_2 emission of 20% from the baseline. In analyses, the input-output table in 2005 and energy balance table in 2005 are used as the base year. Results from analysis are presented of effects of climate change measures on economy such as Gross Domestic Product (GDP), GHG price, primary energy supply and total final consumption, and GHG mitigation towards 2050.

1. Introduction

Thailand have voluntary GHG mitigation policies to mitigate the climate change following the concept of low-carbon society (LCS) or low-fossil fuel economy like many other countries [1]. In the 15th Conference of the Parties (COP15) and the 5th Conference of the Member Parties to the Kyoto Protocol (CMP5), developed countries including Thailand have collaborated to drive developing countries to concern more on GHG mitigation under the framework called "Nationally Appropriate Mitigation Actions" (NAMAs). Thailand's NAMAs is focused on i) domestic NAMAs, which marginal abatement costs of mitigation are low and do not require international supports, and ii) internationally supported NAMAs, which marginal abatement costs are high and need capacity building, technology transfer and financing mechanism from international supports. In this study, Thailand's NAMAs consist of three approaches in the energy system: 1) renewable power generation, 2) energy efficiency in industries, and 3) wastes to energy. The GHG reduction targets of the Thailand's climate policy on Nationally Appropriate Mitigation Actions (NAMAs) are proposed at 60 Mt-CO_2 in 2020 [2]. The baseline of GHG emissions is projected to the year 2050 and supposed to be reduced by 20% from the baseline. In order to analyze the effects of GHG mitigation as proposed in NAMAs, a Computable General Equilibrium (CGE) model is used to analyze CO_2 emissions mitigation measures to energy consumption in Thailand towards 2050. The model has been developed by the AIM (Asia-pacific Integrated Model) team, so-called AIM/CGE [3]. The aim of this paper is to investigate the effect of GHG emission mitigation counter measures which are emission trading and carbon capture and storage (CCS) technology on economic and energy aspects in Thailand towards 2050 by using AIM/CGE model.

2. Methodology

2.1 AIM/CGE model

The Computable General Equilibrium (CGE) models are known as a tool for analysis of short-term and long-term economic implications of climate change, where price is an important signal that drives agents in an economy [4]. The fundamental of CGE model is optimization of demand and supply curves of goods and factors of production, which are equilibrium in the markets by flexible prices adjustment [5]. The model explains all of payments record in the Social Accounting Matrix (SAM) consisting of households and enterprises which the model structure is illustrated in Figure 1 [6].

The model structure consists of four blocks, i.e. production, income distribution, expenditure, and market. The production block represents the structure of the production functions which is a nested CES (Constant Elasticity of Substitution) function. In the income distribution block, incomes are distributed to three institutional sectors: enterprises, government, and households. The market block, the institution consumes goods as final consumption. Government expenditure and capital formation are defined as a constant coefficient function. The LES (Linear Expenditure System) function is used for household consumption. Finally, the CES function is applied to the import of goods and the CET (Constant Elasticity of Transformation) function is applied to the export of goods. A goods-consumption-and-supply equilibrium is achieved in each market.

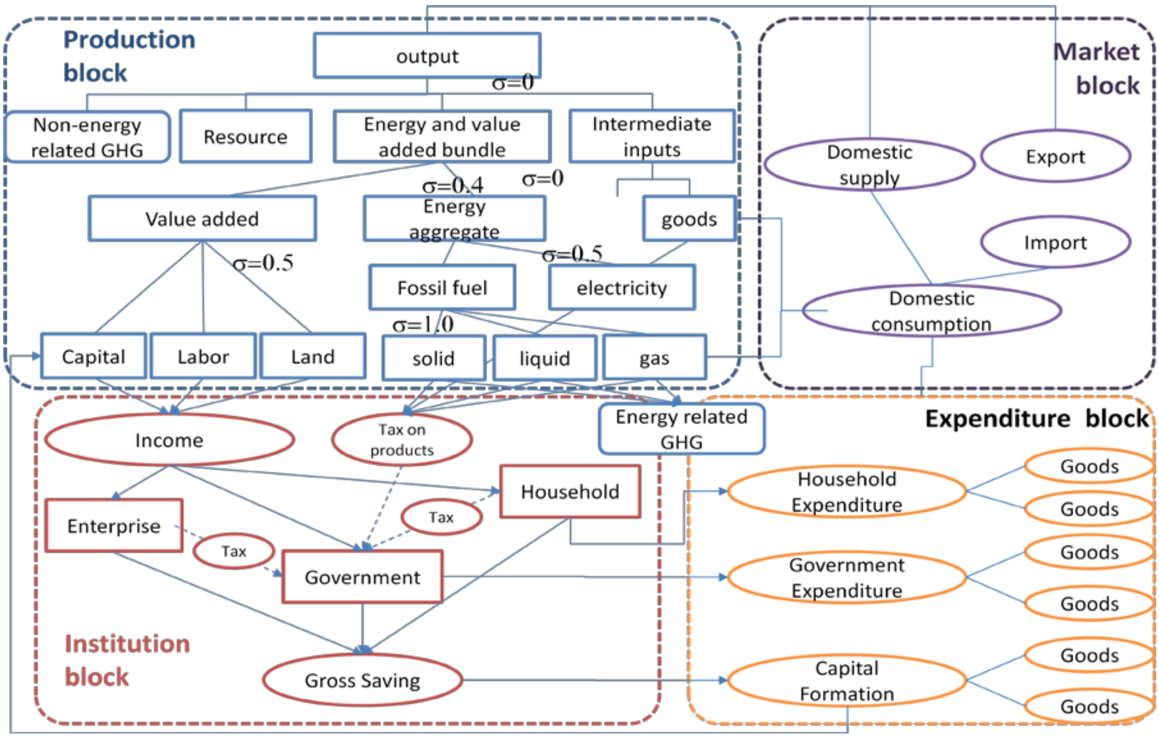

Figure 1 The AIM/CGE model structure for Thailand

The sector classifications are disaggregated to 17 non-energy sectors and 15 energy sectors. The energy sectors are classified into energy mining and refinery, power sector from various technologies, and gas manufacturing distribution. The sector classification is shown in Table 1 and data of each sector are based on Thailand's input-output table in 2005 [7]. In addition, the energy balance table is obtained from [8].

Table 1
Description of sector classification

Non-energy sectors		**Energy sectors**	
AGR	Agriculture	COA	Coal mining
FRS	Forestry	OIL	Oil mining
OMN	Mineral mining and other quarrying	GAS	Gas mining
FPR	Food products	P_C	Petroleum and coal refinery
TEX	Textiles and apparel and leather	E_COL	Coal-fired generation
LUM	Wood products	E_GAS	Oil-fired generation
PPP	Paper, paper products and pulp	E_OIL	Gas-fired generation
CRP	Chemical, plastic and rubber products	E_HYD	Hydroelectric power generation
		E_NUC	Nuclear electric power generation
NMM	Mineral products	E_SPV	Photovoltaic power generation
I_S	Iron and steel	E_WIN	Wind-power generation
NFM	Non ferrous products	E_GEO	Geothermal power generation
MCH	Machinery	E_BIO	Biomass-power generation
TRN	Transport equipment	E_ORN	Other renewable energy power generation
OMF	Other manufacturing		
CNS	Construction	GDT	Gas manufacture distribution
TRS	Transportation and communications		
CSS	Service sector		

2.2 Scenarios and assumptions

The 2005 data such as IO table, GDP, population, GHG emission are the basis data used for development of the Business-as-Usual (BAU) scenario in this study. The GDP and population growth rated from the base year (2005) towards 2050 are shown in Table 2.

Table 2
GDP and population growth rate

Year	**GDP**[1] (Annual growth rate)		**Population**[2] (Annual growth rate)	
base year (2005)	million US	176,285	thousand person	66,669
2005-2010		2.6%		0.72%
2011-2020		4.76%		0.42%
2021-2030		3.47%		0.17%
2031-2040		2.6%		-0.04%
2041-2050		2%		-0.27%

[1]*Source*: Electricity Generating Authority of Thailand (2010).
[2]*Source*: Office of the National Economic and Social Development Board (2007).

Referring to Thailand's NAMAs, the GHG mitigation target is 60 Mt-CO_2 (10.57%) in 2020 and increased to 20% of GHG emission mitigation from the BAU scenario in 2050. In order to investigate the effect of international emission trading and CCS technology on economy and energy system, twelve scenarios including the BAU scenario are determined. The former six scenarios are considered on emission trading option and the latter would be repeated with CCS technology option. The considered emission trading rates in this study are: 40%, 80% and 100% or free traded in 2050. The CCS technology involves capturing the CO_2 emissions from combustion or conversion of fuel or industrial processes and storing it at underground or deep sea level, which is away from the atmosphere for a very long period of time. The description of scenarios are shown in Table 3.

Table 3 GHG mitigation measures in all scenarios*

Scenario	GHG mitigation	Emission trading (%)	CCS technology
BAU	Off	Off	Off
CM1	On	Off	Off
CM2	On	On with 20%	Off
CM3	On	On with 40%	Off
CM4	On	On with 60%	Off
CM5	On	On with 80%	Off
CM6	On	On with 100%	Off
CM1-CCS	On	Off	On
CM2-CCS	On	On with 20%	On
CM3-CCS	On	On with 40%	On
CM4-CCS	On	On with 60%	On
CM5-CCS	On	On with 80%	On
CM6-CCS	On	On with 100%	On

* A "On" word indicates that the particular option/measure is considered in the scenario, while a 'Off' word shows that the particular option is not considered.

3. Results and Discussion

3.1 Economic Output and GHG reduction

In 2050, Thailand's population and GDP in the BAU scenario increase by 1.07 times (71,088 thousand person) and 3.84 times (677,625.28 billion US$2005) from the base year, respectively. The results of GDP due to GHG mitigation policy and counter measures in 2050 are illustrated in Figure 2. The counter measures would increase GDP when compared to the BAU scenario except the CM6 scenario. The CM6 scenario is considered in free emission trading market. The technology investement in order to achieve GHG mitigation target is the main reason to reduce GDP in this scenario. GDPs would slightly increase (0.13%) in the CM1 and the CM1-CCS scenarios. Both scenarios are not considered on emission trading option. The increaseing of emission trading value would increase GDP when 60% of trading which give the highest GDP (i.e., GDP increased by 11.30% and 12.08% in the CM4 and CM4-CCS scenarios, respectively).

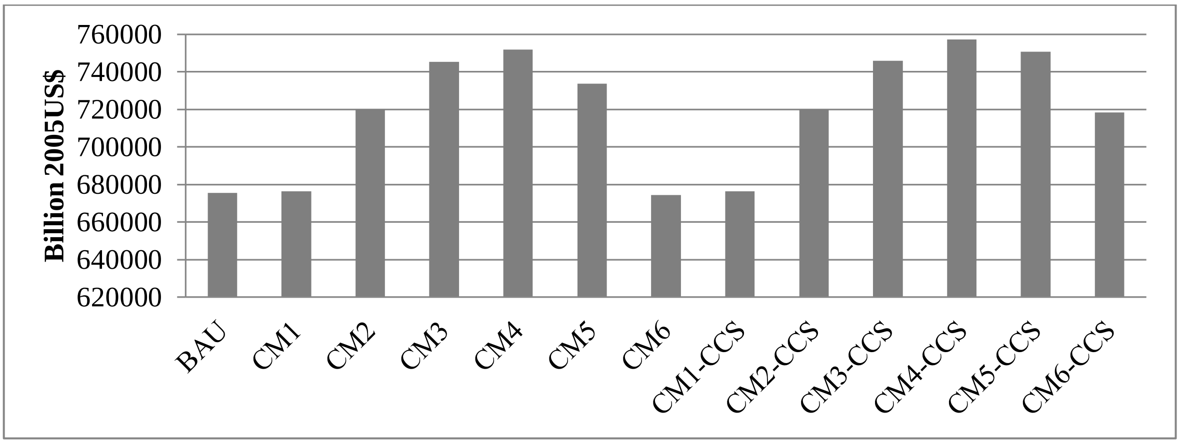

Figure 2 GDP due to GHG mitigation policy and counter measures in 2050

Results of GHG mitigation in all scenarios are illustrated in Figure 3. Although GHG mitigation target in all scenarios is the same level at 20% in 2050, results of GHG reduction in all scenarios are different. Results show that emission trading options obviously increase GHG mitigation especially in the free emission trading option (i.e., the CM6 and the CM6-CCS scenarios) which GHG emission would be reduced by 67.07% when compared to the BAU scenario. It was found that the CCS technologies do not effect on GHG mitigation level for all scenarios.

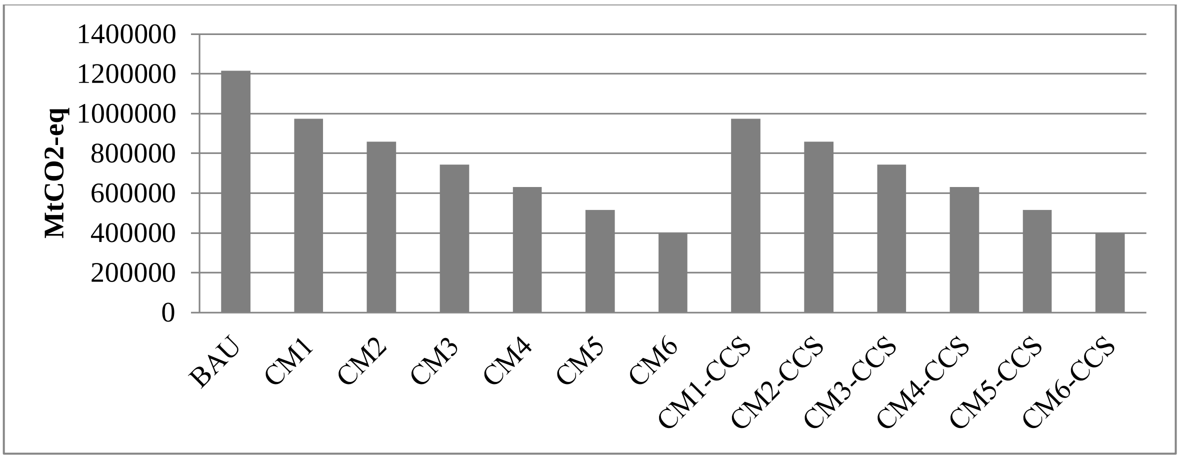

Figure 3 GHG mitigation in 2050

The prices of GHG emission due to counter measures are illustrated in Figure 4. The trend of price would increase when the rate of emission trading is increased. In high rate of emission trading (i.e., more than 40%), the scenarios with CCS technology result in lower GHG price when compared to the scenarios without the CCS technology. The maximum GHG prices are 283.98 US\$/tCO_2eq and 207.85 US\$/tCO_2eq for the CM6 and the CM6-CCS scenarios, respectively.

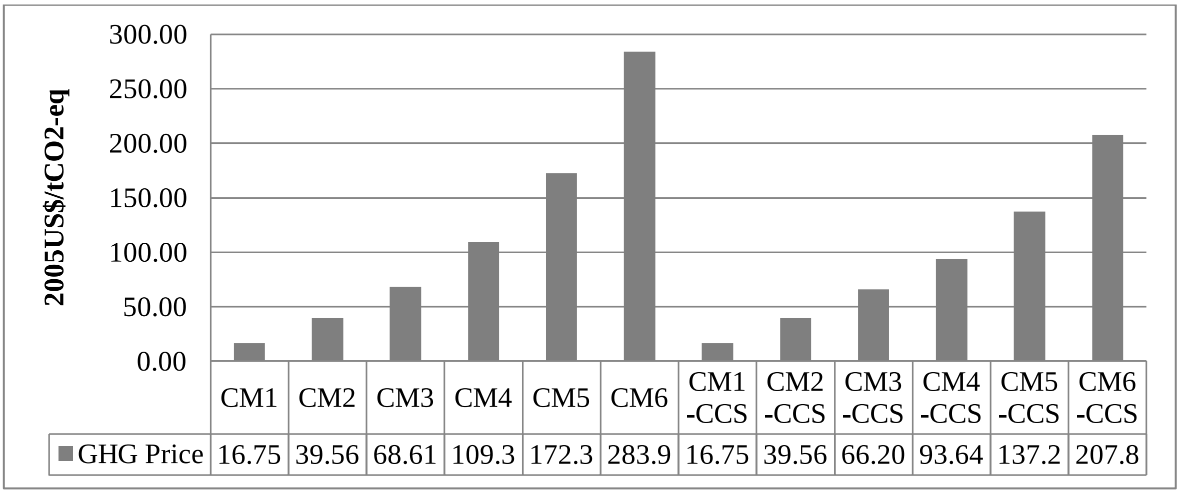

Figure 4 GHG prices in 2050

The GDP, GHG mitigation and GHG prices from the AIM/CGE model show that the emission trading options are the most important measure and the CCS technology is the tool for GHG mitigation measure. The free emission trading option would reduce GDP in 2050 in the CM6 scenario. However GDP should increase after the investment of the new technology for achievement of GHG reduction target.

3.2 Total Primary Energy Supply (TPES)

The total primary energy supply (TPES) in 2050 in all scenarios are illustrated in Figure 5. Results show that TPES is about 315.91 Mtoe in the BAU scenario in 2050. The ratio of fossil based supply and renewable energy supply is 90.7:9.3. The fossil based supplies are natural gas (36.40%), crude oil (28.87%), and coal (25.42%). The negative oil values are indicated as exported.

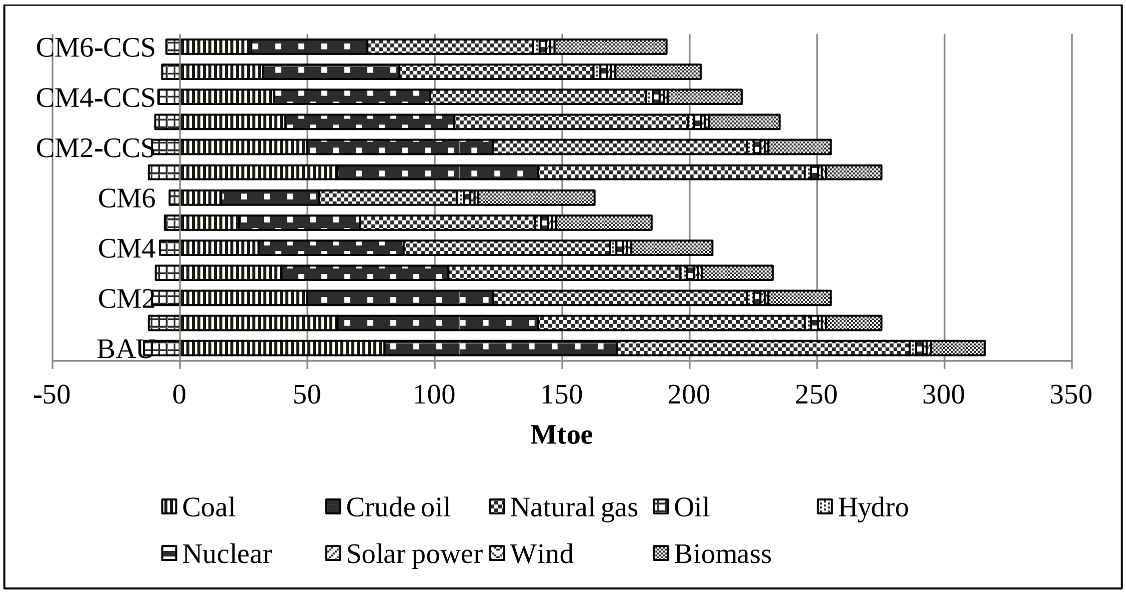

Figure 5 Total primary energy supply (TPES) in 2050

The TPES and energy supply from fossil based fuels would be reduced by the emission trading options. In the CM1 and CM2 scenarios, the share of energy supply are the same as in the BAU scenario but the TPES is reduced to 275.30 Mtoe and 255.60 Mtoe, respectively. In the CM3, CM4, and CM5 scenarios, the TPES are 232.74 Mtoe, 209.09 Mtoe, and 185.21 Mtoe in 2050. The increasing emission trading rate would obviously increase the renewable energy share in TPES. In the CM6 scenario, TPES is 162.90 Mtoe, and accounted for 48.4% reduction from the BAU scenario. Moreover the share of renewable and alternative energy increases to 33.1%. The TPESs with CCS technology are higher than the TPESs without CCS technology. It was found that the CCS technology can capture CO_2 emissions and it can achieve the GHG mitigation target without energy supply reduction.

3.3 Total final consumption by sector (TFCS)

The total final consumption by sector (TFCS) in 2050 in all scenarios are illustrated in Figure 6. In the BAU scenario, the industrial sector consumes energy almost half of TFCS (i.e., 48.72%). The transport sector consumes 27.95% and the other sectors consume 23.33%. The GHG mitigation policy without other options in the CM1 and CM2 scenarios would reduce small amount of energy consumption and the share of energy consumption in each sector is the same as in the BAU scenario. The increasing emission trading rate would slightly reduce the overall energy consumption and change the share of energy consumption in all sectors. The TFCSs in the CM3, CM4, and CM5 scenarios are 128.70 Mtoe, 114.01 Mtoe, and 98.98 Mtoe, respectively. In 2050, the share of energy consumption in the industrial and the transport sectors would decrease while it would increase in the residential and service sectors. In the CM6 scenario, the TFCS would be decreased by 54.11% when compared to the BAU scenario in 2050. The most energy consuming sector is the residential sector, and followed by the industrial, the service, and the transport sectors.

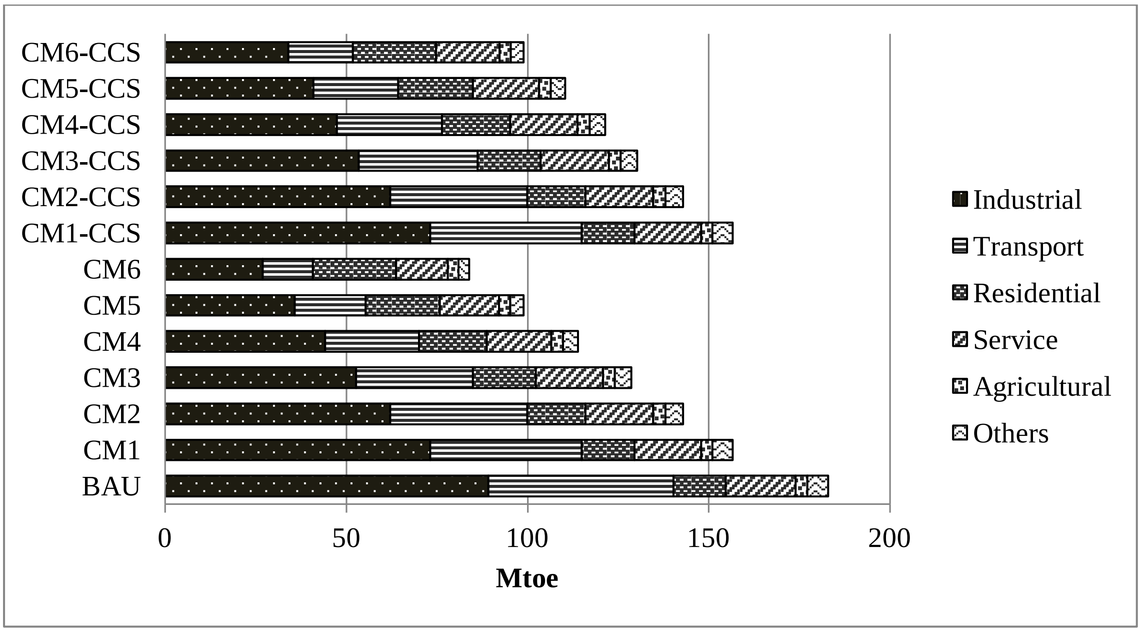

Figure 6 Total final consumption by sector (TFCS) in 2050

The CCS technology option would not effect on the TFCSs in the CM1 and CM2 scenarios. In the CM3, CM4, CM5 and CM6 scenarios, the TFCSs are increased with the CCS option. As the CCS technology would be installed in industries, therefore energy consumption in the industrial sector with the CCS technology option is higher than the scenarios without the CCS technology.

3.4 Electricity generation

The electricity generation by type of energy in 2050 for all scenarios are illustrated in Figure 7. In the BAU scenario, the electricity generation is 55.28 Mtoe which is generated from natural gas (50.18%), coal (24.25%), oil (8.18%), and alternative energy supplies (17.39%). In the scenarios without the CCS technology, the emission trading option is the important measure driving the reduction of electricity generation. The electricity generation from coal for counter measure scenarios is obviously decreased while biomass is more required especially in the CM6 scenario.

The CCS technology installation would be induced in the CM3, CM4, CM5, and CM6 scenarios. Otherwise the total of electricity generation with the CCS technology would decrease but they are higher than the scenarios without the CCS technology. It was found that the CCS technology could capture CO_2 emissions. Therefore, the GHG mitigation target could be achieved.

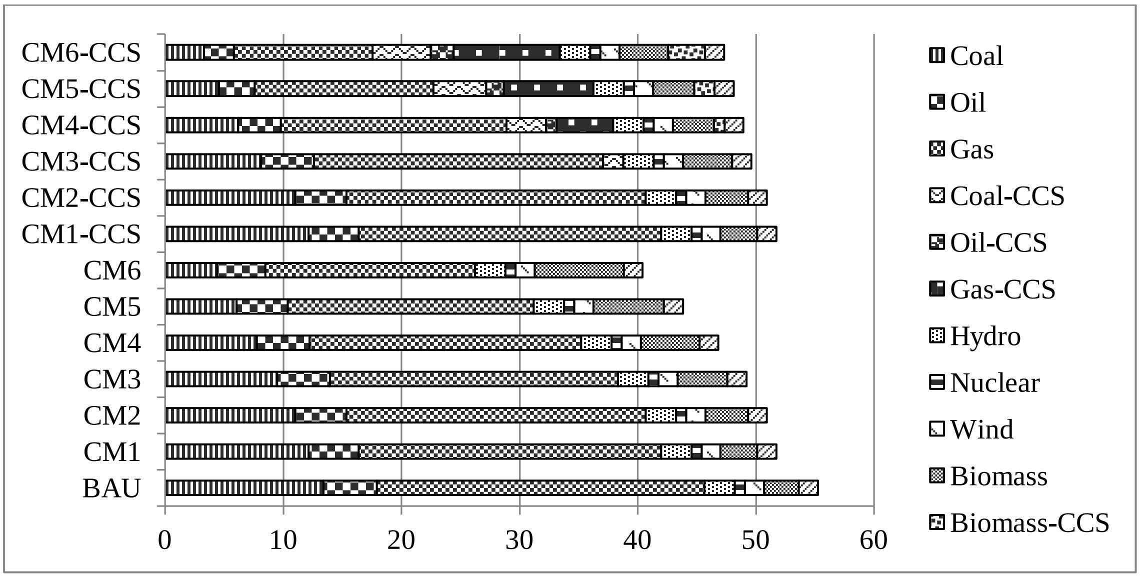

Figure 7 Electricity generation in 2050

3.5 GHG reduction measures

The GHG reduction measures of all scenarios are illustrated in Figure 8. In the CM1 scenario, GHG emission would be reduced from non-energy GHG activities about 45.26%. In the CM2 and CM3 scenarios, non-energy GHG activities would reduce GHG about 37.81% and 33.96%, respectively while end-use efficiency measure would reduce GHG about 43.02% and 46.17%, respectively. The end-use efficiency measure would play an important role in the CM4 to CM6 scenarios.

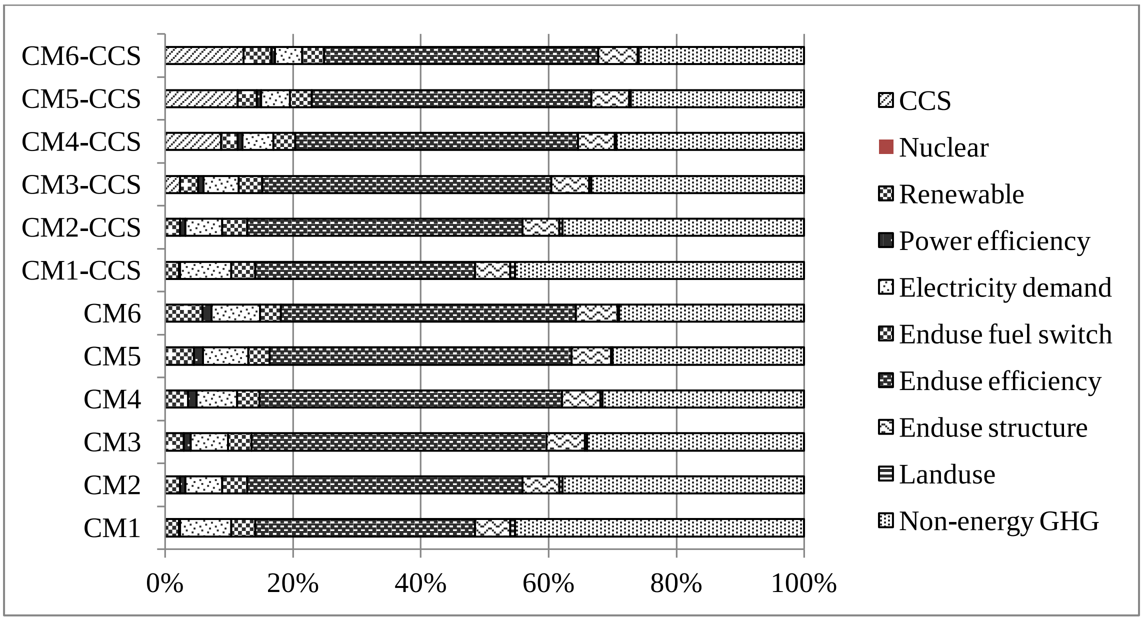

Figure 8 The GHG reduction measures in 2050

The CCS technology installation measure would also reduce GHG emission in the CM3 scenario about 2.38% and increased to 8.80%, 11.34%, and 12.32% in the CM4, CM5, and CM6 scenarios, respectively. It obviously shows that the free emission trading option would increase energy consumption from alternative energy sources and the CCS technology measure would play an important role in GHG mitigation.

4. Conclusion

In GHG mitigation target of Thailand's NAMAs, i.e., 60 Mt-CO_2 in 2020 and projected to 20% reduction towards 2050, the economic and energy system would be changed in order to achieve the target. GDP would be increased in all CM scenarios when compared to the BAU scenario except the CM6 scenario. Because the price of emissions in the CM6 scenario is high, the investments of technologies to reduce GHG are required. Therefore GDP in the CM6 scenario would be decreased. The emission trading measure is the important measure in increasing GHG mitigation and GHG prices.

In the energy aspect, the emission trading measure would play an important role in decreasing the fossil based energy and increasing alternative energy in the supply-side as well as in the demand-side. Moreover, the emission trading measure could make the CCS technology selected in the CM3 to CM6 scenarios. As the CCS technology is the expensive technology thus their high GHG prices are worthwhile to invest. Although the CCS technology is the one of technologies which can reduce GHG emission, it would reduce the end-use efficiency and renewable energy utilization.

The GHG mitigation policy should be determined with relevant measures such as the emission trading policy and the CCS technology in order to achieve the GHG mitigation target and improve the economic and energy system.

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