土木学会論文集G(環境), Vol. 67, No. 5, I_161-I_169, 2011.

20. Potential of GHG emission reduction in Vietnam and its implications

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This paper takes Vietnam as an example of rapidly emergent economy, to explore the feasibility of implementing climate change mitigation measures by 2050. The model we use is a quasi-recursive dynamic general equilibrium (CGE) model with an extension of production function and the well-disaggregated energy sectors, especially in power generation. Three countermeasure scenarios are simulated in comparison with the Business-as-usual in order to analyze the reduction potential and the feasibility of major mitigation measures in Vietnam.

In order to achieve the GHG emission reduction to around 70% of the business-as-usual (BaU), which is about 0.23GtCO_2-eq (2005's level), end-use-relevant reduction measures and carbon capture and storage (CCS) technology play very important roles. Furthermore, the implementation of CCS technology in power generation would help to maintain the power supply towards reducing the emission. Under this strict target 0.23GtCO_2-eq, our calculation show very high domestic marginal abatement cost for Vietnam (600-800 USD/tCO_2-eq), together with the total cost for achieving the reduction target would be 14% and the possible GDP loss is about 8-11% (of the total GDP in BaU). The 70% reduction of total BaU's emission in target year 2050 is difficult in this study, however, is not impossible if we take into account the reduction potential from land-use, land-use change and forestry (LULUCF) sector.

Keywords : *marginal abatement cost, GHG emissions, socio-economic implications, new and renewable energy, carbon capture and storage.*

1. INTRODUCTION

Long-term scenarios development and socio-economic implication analysis of energy and climate mitigation policies by 2050 become critical concerns of not only researchers but also policy makers in Vietnam. In this paper, we answer partly to these questions that how much GHGs Vietnam will emit in the future and the possible socio-economic implications of Vietnam if the country implements climate change mitigation measures, and what could be major countermeasures for Vietnam to reduce the GHG emission without or with minimum compromising its development targets.

Followed this section 1 for the introduction, section 2 is for the review of Vietnam future development strategies that will be considered in the simulation. Section 3 describes the methodology applied for this study while section 4 focuses on the analysis of the Vietnam marginal abatement cost, emission reduction potential and possible implication to the socio-econbomic. Conclusion remark is written in section 5.

2. REVIEW OF VIETNAM FUTURE DEVELOPMENT STRATEGIES

According to Vietnam Ministry of Planning and Investment, Vietnamese Government focuses on transforming the economic structure, upgrading the level of technology and management, both at macro and micro levels, in order to achieve 7% per year growth rate, until 2030[1)]. The country also put target on reducing the population growth rate through the "two-child policy", to maintain the 1% per year during the next one decade[1)]. However, the country does not have specific long-term targets until 2050.

The country puts more efforts on applying advanced technology, not only in industrial sectors but also in agriculture through the "National Target Program on Energy Conservation and Efficiency"[2], ratified in 2006. The energy efficiency issue was later put into law in 2010, however, with very general rules for industrial and lighting, transportation, agricultural, residential and commercial sectors[3].

Besides the national energy development strategy[4] and master plan for renewable energy development[5], Vietnamese Government also ratified the "Master plan to implement nuclear power application strategy for peaceful purposes towards 2020"[6]. The desired target is to increase the contribution of renewable energy (NRE) and nuclear power in the commercial energy structure mix, up to 11% and 15-20% by 2050, respectively. So far, Vietnam Government approved the "National Target Program to adapt to Climate Change"[7], and currently the country also put more effort on the climate change mitigation.

3. METHODOLOGY

(1) Review of CGE model application

Chan *et al.* (1998)[8], Dung (2002)[9], Chan and Dung (2002)[10], and Harris *et al.* (2007)[11] apply the CGE model in Vietnam, however, only focus on analyzing the effects of tax reform and trade liberalization, without any focus on the energy and climate change analysis. Moreover, they use the 1996's input-output table (IOT) and 1997's SAM which are outdate since the latest available IOT and SAM of Vietnam is for 2005.

Dai *et al.* (2011)[12] use CGE model to analyze the contribution of China's non-fossil energy plan up to 2020 to carbon intensity reduction, and the impacts of China's climate commitment on its economic development, energy consumption, CO_2 emissions and the dynamics of electricity generation technologies. His purpose of using CGE model is similar to us, however, the model he use is a hybrid static CGE model that does not take into account the dynamic feature of an economy.

In our study, we use the dynamic CGE model to analyze the feasibility of climate change mitigation measures with the data for base year is in 2005. Detail of the CGE model we use in this study is described in latter subsections.

(2) Model description

We use a quasi-recursive dynamic general equilibrium model with inputs for base year 2005 are Social Accounting Matrix (SAM) and Energy Balance Table (EBT).

Generally, Computable General Equilibrium (CGE) models have an advantage as they can describe the whole economic activity with consistency. This advantage makes it possible to calculate the GHG emission price and GDP losses. This CGE model[13] is a quasi-recursive dynamic general equilibrium model with an extension of production block in comparison to our previous study[14]. In order to analyze climate mitigation policy and the energy situation, the energy sectors, especially power sector are disaggregated very detail as shown in **Table 2**.

The production function in this study is treated differently from that in previous study based on the idea of Hyman[15]. In **Fig.1**, at the top level, the production function of non-energy sectors consists of non-energy-relevant GHG emission caused by the production and conventional inputs. Conventional inputs technology is specified by a Leontief function of the quantities of energy and value-added bundle, aggregate non-energy intermediate and resource input. Energy and value added bundle is nested by valued added and energy inputs. Value added is itself a Constant Elasticity of Substitution (CES) function of primary factors. The aggregated energy inputs is specified with a CES function of electricity and aggregated fossil fuel inputs. The aggregated fossil fuel input is again nested with CES function of each fossil fuel input. The aggregate intermediate input is a Leontief function of disaggregated intermediate inputs.

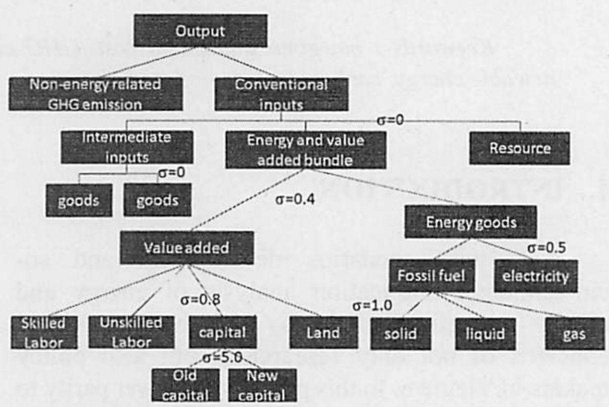

Fig.1 Production structure (Non-energy transformation sectors)

The energy transformation sectors such as power and petroleum refinery sectors are assumed different production function from the other. The structure is similar to the non-energy production sectors but the energy bundle is different (as shown in **Fig.2**).

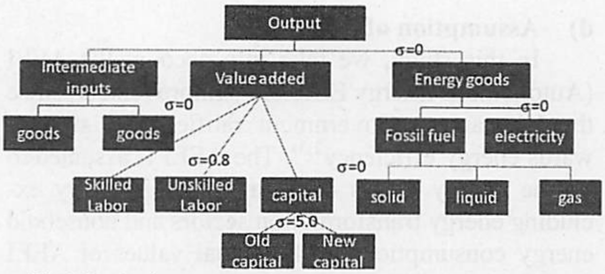

Fig.2 Production structure (Energy transformation sectors)

In our CGE model, the default classification has both non-energy sectors and energy sectors as shown in **Table 1** and **Table 2**.

Table 1 Non-energy sectors classification

Default code	Original Social Accounting Matrix: Code	Description
AGR	AGH	Agriculture
	FSH	Fishery
FRS	FRS	Forestry
FPR	OMT	Meat products
	VOL	Vegetable oils and fats
	MIL	Dairy products
	SGR	Sugar
	OFD	Food products nec.
	B_T	Beverages and Tobacco
TEX	TEX	Textiles, Apparel and Leather
LUM	LUM	Wood products
PPP	PPP	Paper, Paper products and Pulp
CRP	CRP	Chemical, Plastic and Rubber products
NMM	NMM	Mineral products nec.
I_S	I_S	Iron and Steel
NFM	NFM	Non Ferrous products
MCH	FMP	Metal products
	OME	Machinery
	ELE	Electric equipment
TRN	MVH	Motor Vehicles
	OTN	Other transport nes.
OMF	OMF	Other Manufacturing
TRS	TRS	Transport and communications
CNS	CNS	Construction
CSS	WTR	Water
	TRD	Trade and whole sale and retail
	FIR	Finance, Insurance, Real estate, etc.
	CSS	Community, Social services nes.

(3) Input assumption and sources

Data for base year 2005 is obtained from the reconciled SAM developed by Fujimori and Matsuoka (2008[16], 2009a[17], and 2009b[18]). This SAM contains all production and consumption of commodities and services, income, savings and investment for a region with the energy and GHG emissions are in physical volume.

In addition, we also borrow the results from other studies for the price of Carbon Capture and Storage (CCS) technology and the end-use-relevant GHG emission. The idea for emission trading permission obtained in this study is also explained within this section.

Table 2 Energy sectors classification

	Default code	Original Social Accounting Matrix: Code	Description
	COA	COA	Coal mining
	OIL	OIL	Oil mining
	GAS	GAS	Gas mining
	OMN	OMN	Mineral mining and other quarrying
	P_C	P_C	Petroleum and Coal refinery
	GDT	GDT	Gas manufacture distribution
Electricity	E_COL	E_COL	Coal-fired generation without CCS
		C_COL	Coal-fired CHP plant
		H_COL	Coal heat supply plant
	E_OIL	E_OIL	Oil-fired generation without CCS
		C_OIL	Oil-fired CHP plant
		H_OIL	Oil heat supply plant
	E_GAS	E_GAS	Gas-fired generation without CCS
		C_GAS	Gas-fired CHP plant
		H_GAS	Gas heat supply plant
	E_NUC	E_NUC	Nuclear electric power generation
		C_NUC	Nuclear CHP power generation plant
	E_HYD	E_HYD	Hydro electric power generation
	E_GEO	E_GEO	Geothermal power generation
		C_GEO	Geothermal CHP power generation plant
		H_GEO	Geothermal heat supply plant
	E_SPV	E_SPV	Photovotaic power generation
	E_ORN	E_TID	Wave-activated power generation
		E_ORN	Other RE power generation
		C_ORN	Other RE CHP power generation plant
		H_ORN	Other RE heat supply plant
	E_WIN	E_WIN	Wind power generation
	E_BIO	E_BIO	Biomass power generation
		C_BIO	Biomass CHP power generation plant
		H_BIO	Biomass heat supply plant
	EC_COL		Coal-fired generation with CCS
	EC_OIL		Oil-fired generation with CCS
	EC_GAS		Gas-fired generation with CCS
	EC_BIO		Biomass-fired generation with CCS

a) Socio-economic assumption

According to Fujimori *et al.* (2011)[13], the parameter representing the Total Factor Productivity (TFP) is adjusted in CES function. The value-added CES bundle is defined in equation (1).

$$QVA_{r,a} = \alpha^{va}_{r,a} \cdot \left(\sum_{f \in F} \delta^{va}_{r,a} \cdot QF_{r,f,a}{}^{-\rho^{va}_{r,a}} \right)^{-\frac{1}{\rho^{va}_{r,a}}} \quad (1)$$

Where:

$f \in F(=F')$: a set of production factors,

$QVA_{r,a}$: quantity of value added of activity a,

$QF_{r,f,a}$: quantity demanded of factor f from activity a,

$\alpha^{va}_{r,a}$: efficiency parameter (total factor productivity) in the CES value-added function,

$\delta^{va}_{r,a}$: CES value-added function share parameter for factor f in activity a,

$\rho^{va}_{r,a}$: CES value-added function exponent.

The actual growth rates of Vietnam total population and GDP are assumed in **Table 5**. According to above valued added CES bundle, the adjusted total factor productivity $\alpha^{va\,*}_{r,a}$ is calculated as in equation (2) and it is used in the following year's calculation of the GDP.

$$\alpha_{r,a}^{va\,*} = \frac{QVA_{r,a}^{t-1} \cdot \left(1 + gdp_r^{t\,*}\right)}{\left(\sum_{f \in F} \delta_{r,a}^{va} \cdot \left(QF_{r,f,a}^{t-1} \cdot \left(1 + fac_{r,f}^{t\,*}\right)\right)^{-\rho_{r,a}^{va}}\right)^{-\frac{1}{\rho_{r,a}^{va}}}} \quad (2)$$

Where;

$\alpha_{r,a}^{va}$: adjusted efficiency parameter in the CES value-added function,

$gdp_r^{t\,*}$: expected GDP growth (annual growth rate),

$fac_{r,f}^{t}$: expected factor input growth rate.

t denotes set of year.

b) Assumption of CCS price

In our model, we consider CCS technology as one of the effective mitigation options. However, since CCS is still in the experiment stage for most countries including Vietnam, we do not have specific information about the future cost of CCS in Vietnam. Therefore, in this study, we borrow the prices of CCS technology from IEA (2010)[19] (as shown in **Table 3**). This CCS technology cost is kept to be constant in all simulated periods.

Table 3 CCS technology cost

	sectors	price (US$/tCO2)
Manufacturing	petroleum refinery coal transformation	100
	non-metal and mineral	200
	paper and pulp	150
	chemical	150
Power	Coal fired	50
	Oil fired	50
	Gas fired	70
	Biomass fired	70

c) End-use-relevant emission reduction potential

As mentioned earlier, one of the purposes of this study is to analyze the potential of emission reduction measures, of which most of them are from end-use sectors. We obtain the results or the non-energy related GHG emissions reduction such as agricultural CH_4 and N_2O emissions from the bottom-up type model (Akashi *et al.*, 2011)[20]. **Table 4** provides description for the countermeasures analyzed in this study.

Table 4 Description of GHG emission reduction measures

Series	Definition
Non-energy GHG	Non-energy related emission reduction
Landuse	Reduction of land-use change related emissions
Enduse_activity_level	End use sector's activity level change factor (normally GDP loss)
Enduse_structure	End use sector's structure change factor (Industrial shift)
Enduse_efficiency	End use sector's energy intensity improvement factor
Enduse_fuel_switch	End use sector's fuel switch factor
Electricity_demand	Electricity generation change factor
Electricity_efficiency	Electricity conversion efficiency mainly due to fired power plants transformation efficiency improvement
Renewable	Renewable energy share change factor
Nuclear	Nuclear energy share change factor
CCS	CCS technology deployment
Import	Emission trading (amount of import)
Export	Emission trading (amount of export)
Emission	Actual amount of emission

d) Assumption of AEEI

In this study, we take into account the AEEI (Autonomous Energy Efficiency Improvement) since the Vietnamese Government ratified the laws towards energy efficiency[2)3)]. The AEEI is assumed to be the energy goods consumption of industry excluding energy transformation sectors and household energy consumption[13)]. The actual values of AEEI for Vietnam used in this model are referred from IEEJ's Asia World Energy Outlook[21)] (as shown in **Table 5**). The quota of energy inputs for Vietnam is estimated using IEEJ's assumption[21)], particularly total final consumption and total electricity generation.

e) Emission trading permission and price

The emission trading in our assumption for this study is the full GHG emission trading permission among countries in the world, meaning that importers and exporters can fully buy or sell the tradable emission amount from the market.

$$ET_r^{imp} \geq 0 \perp DMAC_r \geq GMAC \quad (3)$$

$$ET_r^{exp} \geq 0 \perp DMAC_r \leq GMAC \quad (4)$$

Where:

ET_r^{imp} : import emission trading

ET_r^{exp} : export emission trading

$DMAC_r$: domestic Marginal Abatement Cost

$GMAC$: global Marginal Abatement Cost

According to equations (3) and (4), import happens when domestic marginal abatement cost (hereafter domestic MAC) is higher than that of international market (or global MAC). Vice versa, if the domestic MAC is lower than global MAC then export will occur. The assumption of global MAC is shown in **Fig.3**. The MAC is estimated to be equal across all sectors and technologies for all different pollutants.

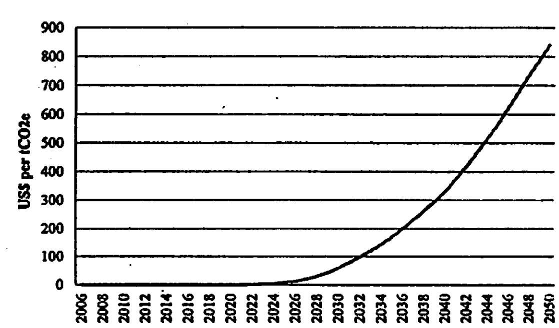

Fig.3: Assumption of Global Marginal Abatement Cost

(4) Scenario assumptions

A set of scenarios are simulated in order to analyze the potential of achieving the 2050's GHG emission target, and the role of NRE and CCS technology in contributing to meet this target. Emission trading is also simulated to determine the change of MAC in Vietnam.

Table 5 describes main assumptions of the four scenarios to be analyzed. These scenarios are divided into 2 main groups which are Business-as-Usual (BaU) and Countermeasure (CM). BaU is a scenario for usual development of Vietnam considering more on the achievement of socio-economic development as mentioned in our main assumptions. In addition to BaU (scenario A), the CM (scenario B) also takes into account the GHG emission constraint and additional climate change mitigation measures. Under the CM umbrella, there are two sub-countermeasures CM1 (scenario B1) and CM2 (scenario B2) that consider the contribution of Carbon Capture and Storage (CCS) technology; and New and Renewable Energy (NRE), respectively.

Table 5 Main assumptions for scenario simulation

1. Quantitative assumptions				Scenarios			
		Unit	Year/Period	BaU	CM1	CM2	CM3
Population	Total in base year 2005	thous. person	2005	82394			
	Growth rate (r_p)	%/year	2005-2010	1.22			
			2011-2020	1			
			2021-2030	0.8			
			2031-2040	0.6			
			2041-2050	0.44			
GDP	Total in base year 2005	mil. US2005$/yr	2005	52900			
	Growth rate (r_g)	%/year	2005-2010	7.2			
			2011-2020	7.2			
			2021-2030	6			
			2031-2040	5			
			2041-2050	5			
AEEI (Autonomous Energy Efficiency Improvement)				Coal: 1.1%/yr Oil: 1.1%/yr Gas: 2.4%/yr Electricity: 5.1%/yr			
GHG emission constraint (r_r)				-	1. Start the emission constraint since post-2020: reduce 1.2%/yr compared to previous year 2. Emission in 2050 is limited to 0.23GtCO2-eq (as base year 2005)		
Emission trading ratio to the GHG emission cap (r_t)			2005-2010	-	0	0	0
			2011-2020		0	1	1
			2021-2030		0	1	1
			2031-2040		0	1	1
			2041-2050		0	1	1
2. Qualitative assumptions							
Counter Measures	Emission Trading			off	off	on	on
	Contribution of new & renewable energy			off	on	off	on
	CCS (Carbon Capture & Storage)			off	on	on	off
-	AEEI (Autonomous Energy Efficiency Improvement)			middle			
	CCS (Carbon Capture & Storage)	Start year		-	2020	2020	-
		Installation speed			middle (3%/yr)		

a) Scenario A (BaU) – Business as Usual

As shown in **Table 5**, the BaU contains our assumptions of population and GDP growth rate, that are the reduction of the population growth rate and achieving the economic development in sustainable manner. The GDP is assumed, follows the national government, to grow rapidly in the first 15 years (2005-2020)[1]. However, we assume that the Vietnam economic growth will slow down to more stable rate in the later 30 years (2021-2050) to ensure the possibility of the development trend, even the government declares 7% per year until 2030[1] and there is no specific target until 2050.

The annual depreciation rate for capital stock is assumed to be 4% in all periods. The total final productivity is estimated for all sectors in the economy. These above assumptions are the same for all scenarios. However, the BaU case does not consider the GHG emission constraints, emission trading permission, the contribution target of NRE, and the implementation of CCS technology in industry and power plant.

b) Scenario B (CM) – Emission constraint without emission trading permission

Besides the quantitative assumptions as in scenario A, the main assumption of scenario B is the total emission constraint. We assume that Vietnam starts to reduce the GHG emission after 2020. The reduction rate is 1.2% per year, that limits the total emission in 2050 to 0.23GtCO_2-eq. This means that we want to limit the 2050's emission to be same as the base year 2005's as constraint. Scenario B also considers not only the possibility of NRE contribution but also the CCS implementation from 2020. However, this scenario doesn't consider the emission trading with rest of the world.

c) Scenario B1 (CM1) – Contribution of CCS technology together with emission trading

In scenario B1, beside the quantitative assumptions and emission constraint, full emission trading with rest of the world is also allowed. However, in this scenario, we do not consider the energy switch to NRE sources rather than only the contribution of CCS technology. This CM1 case is analyzed in order to understand the influence from not introducing NRE into the power generation.

d) Scenario B2 (CM2) – Contribution of NRE together with emission trading

Scenario B2 is a similar case of scenario B2, but without considering the implementation of CCS technology in the industrial activities and power plant. This CM2 case helps to understand clearer about the role of CCS technology and its possibility in Vietnam.

4. ANALYTICAL RESULTS

(1) Marginal Abatement Cost of Vietnam

As mentioned earlier, in our model, the difference between global and domestic MAC will determine whether a country will buy or sell emission quotas. **Fig.4** shows that, when Vietnam does not consider the emission trading (in CM case), the domestic MAC is higher than the global MAC during 2021-2035. After this period, the domestic MAC is very much lower than the global MAC. In 2050, the domestic MAC is around 600USD/tCO_2-eq while the global MAC is more than 800USD/tCO_2-eq.

When assuming that Vietnamese Government agrees to have full emission trading with rest of the world, then during 2021-2035, Vietnam would become importer and latter is exporter of emission right. As shown in **Fig.4**, the domestic MAC of CM1 and CM2 cases increase rapidly to reach the same value, and equal to the global MAC. The feasibility of emission reduction measures and the role of emission trading in Vietnam as well as their implications are analyzed in the next sections.

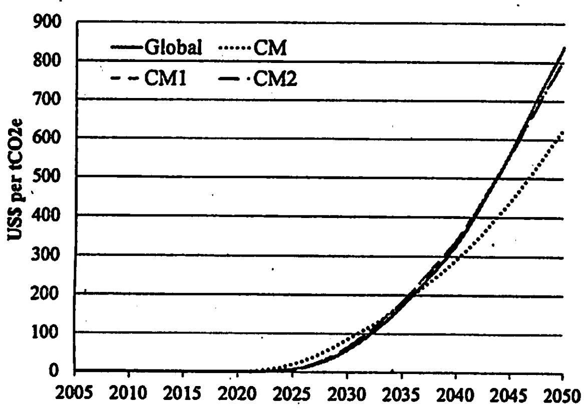

Fig.4 Marginal Abatement Cost

(2) Potential of GHG emission reduction

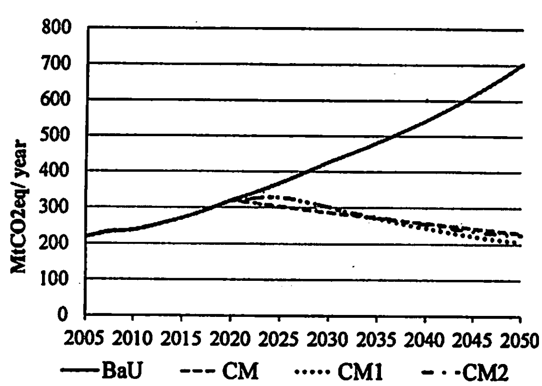

Fig.5 Total GHG emission scenarios of Vietnam

Fig.5 shows the total domestic GHG emission (includes target emission plus the imported emission permit and minus the exported emission permit) of Vietnam in 4 scenarios. The total domestic GHG emission in 2050 of all the CM cases are very close to the 2005's value as reduction target set in this study. In 2050, CM and CM2 cases show similar results with nearly 67% reduction of emission compared to BaU. Meanwhile, at the same MAC (as shown in **Fig.4**), CM1 case with the contribution of CCS technology shows higher potential of emission reduction, which can achieve 71% reduction compared to BaU.

CM1 case is chosen to analyze the reduction potential since it shows the lowest emission amount in the target year 2050 among all scenarios. As shown in **Fig.6**, the major countermeasures contributing to the emission reduction in Vietnam are: (1) end-use energy efficiency, and (2) non-energy GHG emission; of which their shares in total reduced amount are 30% and 20%, respectively. Meanwhile, the total contribution of CCS and NRE is nearly 16%.

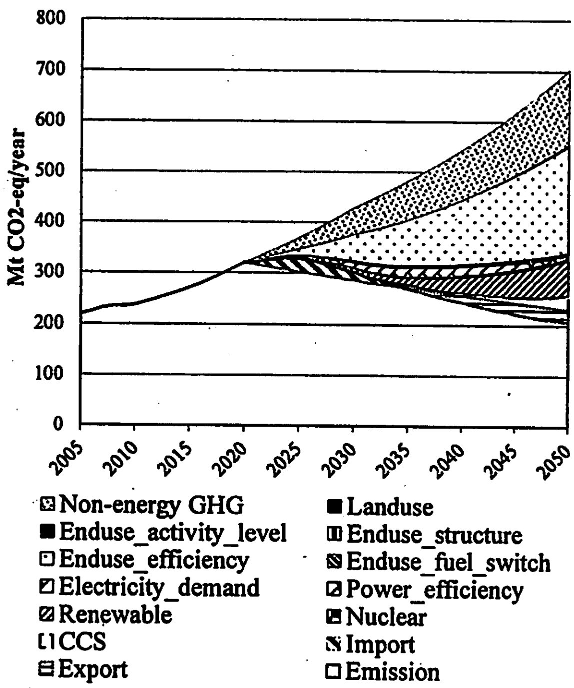

Fig.6 GHG emission reduction measures in CM1 case

In term of emission trading, **Fig.6** shows the amount of emission imported and exported by Vietnam during two periods 2021-2035 and post-2035, respectively as explained by using the MAC in **Fig.4.** Firstly, during the import period, the imported amount is calculated about 0.5% to 6.6% of total emission, in which Vietnam will import the highest amount in 2026, around 6.6% of total emission of that year.

Secondly, during the export period, the estimated exported amount is around 0.1% to 3.6% with the highest potential is in 2047. It can be seen from CM1 case that Vietnam starts to export since 2034 and the total emission of CM1 in post-2035 period would be same as CM and CM2 cases. **Fig.6** also shows the contribution of CCS in reducing the GHG emission, starting since 2031 with the proportion to the total emission is about 0.1% in 2031 to the highest 7.5% in 2050.

More detail of the emission reduction potential in 2050 through different countermeasures is shown in **Fig.7** for different CM cases. While there is similar contribution of end-use-relevant countermeasures in all CM cases (the first eight measures listed in **Table 4**), the contribution of remaining measures including NRE, CCS, and emission trading seems to be different, especially in terms of CCS and export for the case of CM and CM1 scenarios.

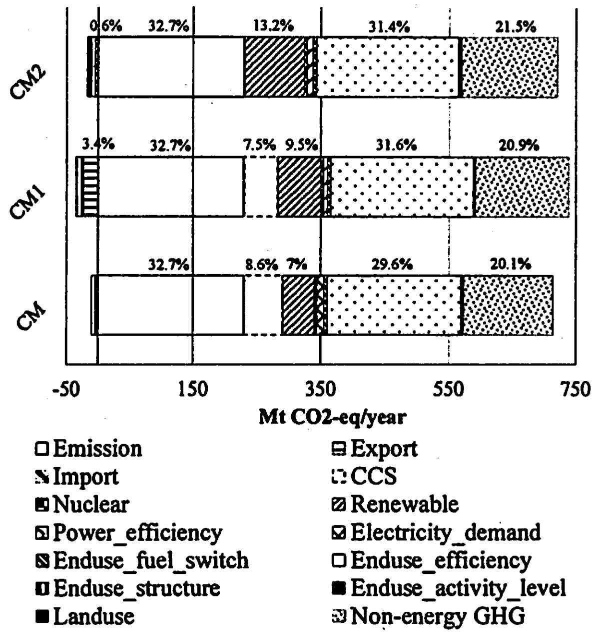

Fig.7 GHG emission reduction measures in 2050

(3) Socio-economic implications

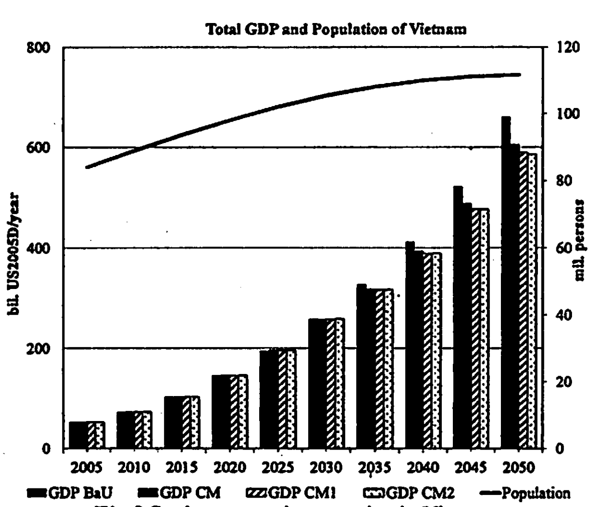

Fig.8 Socio-economic scenarios in Vietnam

Fig.8 shows the slow increase in population until 2050, with only 1.33 times within 45 years. Meanwhile, the total GDP of Vietnam in 2050 of BaU case has increased around 12 times, reach nearly 660bil.USD. However, in CM scenarios, the total GDP is projected to be lower than BaU case, especially after 2030. In order to reduce the emission in target year 2050, the total direct cost of mitigation measures is calculated to be around 14% of the total GDP in BaU.

Table 6 shows the implication to the GDP of Vietnam in different CM cases. Positive value means the country gains in term of GDP, vice versa negative value shows the GDP loss, both are in percentage of total GDP in BaU case. The Vietnam's economy suffers losses since 2025 when it starts to reduce the GHG emission. At target year 2050, there would be around 8.4% GDP loss (compared to BaU) in order to achieve the emission reduction target.

Table 6 Implication to the GDP (% of GDP in BaU)

	CM	CM1	CM2
2020	0.2	0.0	0.2
2025	0.9	0.8	1.0
2030	-0.5	-0.3	0.1
2035	-2.6	-3.2	-2.9
2040	-4.5	-5.8	-5.6
2045	-6.4	-8.5	-8.6
2050	-8.4	-10.7	-11.2

With the emission trading permission, Vietnam would suffer even more (about 10-11% GDP loss compared to BaU). The reason leading to more GDP loss when Vietnam participates in emission trading is the increase of domestic MAC following the global MAC. When the domestic MAC is increased, industries have to increase their payment for energy consumption under constraint budget. Therefore the income of capital and labor paid by industries would be reduced, leading to the reduction in savings, and thus, investment and next year's capital stock are also reduced. Even though the revenue from emission tax is given to households (as assumed in our model), this revenue cannot fulfill the income loss supposed to be paid by the industry. Such behavior treated in our model causes the difference in GDP loss between non-trading and trading scenarios, explaining why Vietnam economy would suffer higher loss when joining the international emission trading.

(4) CCS technology in power generation

Since the final consumption of electricity in Vietnam is projected to be increased drastically in the future, it is important to analyze the power generation by energy type that may affect the total GHG emission. Therefore, in order to analyze the contribution of NRE and CCS in power sector, the CM scenario is chosen to analyze the power generation by energy sources since it considers the contribution from both of them.

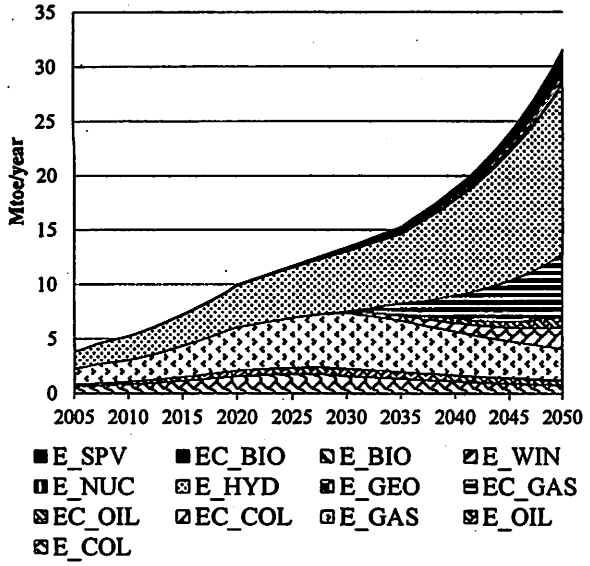

Fig.10 Power generation in CM case

In CM case (as shown in **Fig.10**), power generation is considered with the contribution of not only CCS technology but also the RE and nuclear power. While the share of traditional fuel decreases, there is increase of hydro contribution up to 49% in the year 2050. The total contribution of natural gas is 28%, in which 19% is from the gas-fired with CCS. In the year 2050, the total contribution of NRE increases from 4% in BaU case to more than 11% in CM case, which is compatible with the national policy towards cleaner energies. However, the country still cannot reduce its dependence on the hydro power. With the contribution of CCS in power sector, Vietnam would maintain the power supply while reducing the GHG emission to meet the emission reduction target in 2050.

5. CONCLUSIONS

By using a quasi-recursive dynamic general equilibrium model with an extension of production function and the well-disaggregated energy sectors, especially in power generation, we focus on analyzing the potential of GHG emission reduction and the implication of mitigation measures to the Vietnam's economy towards 2050. Input data for base year 2005 is a very detail reconciled SAM containing all production and consumption of commodities and services, income, savings and investment for a region with the energy and GHG emissions are in physical volume.

In this study, the limitation of GHG emission in target year 2050, which is same level of 2005 (70% reduction compared to BaU), is quite strict for Vietnam's economy. Under this strict target $0.23GtCO_2$-eq, our calculation show very high domestic marginal abatement cost for Vietnam (600-800 USD/tCO_2-eq), together with the total cost for achieving the reduction target would be 14% (of the total GDP in BaU), with the possible GDP loss is about 8-11% (of the total GDP in BaU). The feasibility of our results in term of technology and economy is shown across the paper, however, the acceptability of these results is very much depended on the decision-makers whether which direction they prefer.

Moreover, the 70% reduction of total BaU's emission in target year 2050 is difficult in this study, however, is not impossible if we take into account the reduction potential from land-use, land-use change and forestry (LULUCF) sector. We will consider these points in our future works.

ACKNOWLEDGMENT: This study was supported by the "Global Environmental Research Fund" (A-0808) by the Ministry of Environment of Japan. The authors would like to acknowledge the generosity of this fund.

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(Received April 11, 2011)
(Accepted Jun 22, 2011)