Mitigation of GHGs from Energy and Forestry Sector in Indonesia[1]

Agus Sugiyono, BPPT

Dadang Hilman, State Ministry of Environment

1. Introduction

1.1. Objectives of the Project

The objectives of project “Establishment of a Methodological Framework for Climate Change Mitigation Assessment” was elaboration of a new methodology for analyzing Greenhouse Gas (GHG) mitigation options in energy and forest sector through integration of the two sector using MARKAL model.

1.2. Institutional Working Group

The project was established within the framework of scientific cooperation between State Ministry for Environmental, Indonesia and United Nation for Environment Programs (UNEP) - RISO. The working group for this project has been organized on an inter-institutional concept and coordinated by State Ministry for Environment. The active participating institutions are:

- Agency for the Assessment and Application of Technology (BPPT),
- State Electricity Company (PLN),
- Directorate General for Electricity and Energy Development
- Center for Forest Research, Dept. of Forestry
- Development and Center for Environmental Studies - Agricultural Institute of Bogor.

This project consists of two working groups, technical working group for energy sector, and technical working group for forestry sector.

2. Methodology and Study Approach

2.1. Overview

Models tools for this analysis is use a least cost energy supply model call MARKAL. MARKAL is a large scale model intended for long term analysis of energy systems at the level of a province, state, country or region. It was develop in early 1980 by a consortium of researchers from more than a dozen countries, all of them is IEA members and working within the Energy Technology System Analysis Programme (ETSAP). Many modification already several time from the mainframe era to current PC computer era, the last modification progress is rewritten in GAMS with some additional ability. Even Indonesia doesn’t active in the ETSAP but Indonesia keep going used MARKAL as main tools for analyze energy system within country with collaboration with KFA, Germany, ABARE Australia also Decision Ware, US.

In this study, energy and forestry sector analyzed together using MARKAL model in term of balancing GHG concentration at the atmosphere. For energy system all activities from mining extraction, processing, transport of energy, conversion, and up to energy demand included in the analysis and for forestry sector include all various forestry

[1] Presented at Climate Change Mitigation in Asia and Financing Mechanism Conference, UNEP-GEF-World Bank, Goa, India, 4-6 May 1998.

management for selected plantation species, harvesting and milling. Figure 1 shows the schematic of energy and forestry link model. All activities that include into "Reference Energy System" (RES). Unit activity of the forest used here is distinguished as to different unit first use meter cubic of product for the timber forestry and another one use hectare land used for the reforestation activities.

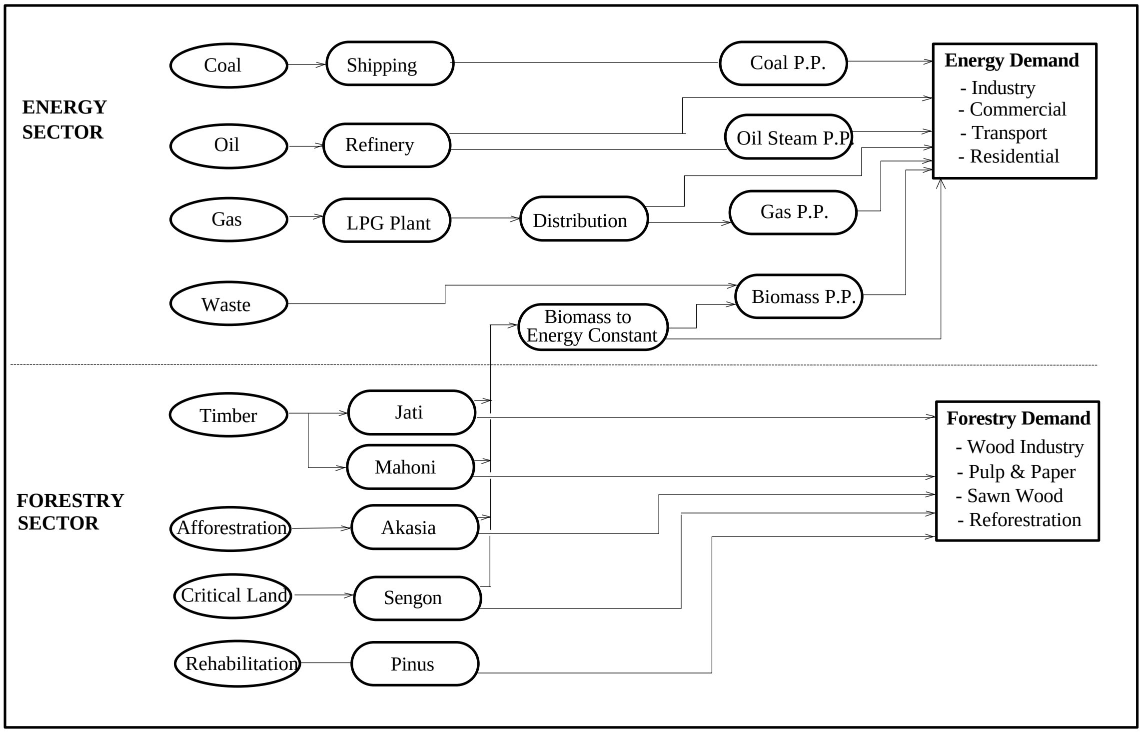


Figure 1: Schematic of Energy and Forestry Link Model

The model has an objective function to minimize total cost of energy supply and forest production or carbon sink. The mathematical formulation of the model can be presented as:

- Objective Function:

$$Minimize\ Z = \sum_{ij} c\ E_{ij} + d\ F_{ij}$$

- Subject to:

Energy Source (*E*)	$\leq$ Reserve
Forest (*F*)	$\leq$ Forest Availability
CO_2 Emission (Emission$_E$ + Sink$_F$)	$\leq$ Emission Target

- Where:

$c\ E_{ij}$ = Cost of energy supply
$d\ F_{ij}$ = Cost of forest production / carbon sink

In this study we develop 7 scenarios to analysis the impact of mitigation strategies.

- Baseline Scenario (BAU), without included mitigation technology into the model
- CO2 Emission Reduction from Energy Energy Sector :
  - ABAT1 : The years 2005 and 2020, are chosen as the future years, for which CO2 reduction targets of UNEP-RISO are assessed. The targets specified for the two reference years: 12,5 % reduction in 2005 and 25 % in 2020 for the first abatement case.
  - ABAT 2 : Analogously by requesting for a 15 % reduction in 2005 and a 30 % reduction of 2020.
- Enhanced CO2 Uptake from Energy Forestry Sector
  - FOR1 : The year 2000 and upward CO2 uptake is increase by 5 % than BAU scenario
  - FOR2 : The year 2000 and upward CO2 uptake is increase by 10 % than BAU scenario
  - FOR3 : The year 2000 and upward CO2 uptake is increase by 20 % than BAU scenario
  - FOR4 : The year 2000 and upward CO2 uptake is increase by 30 % than BAU scenario

Energy sector analysis is based on result of the “Environmental Impacts of Energy Strategies for Indonesia”, 1993 study, as a joint study between BPPT, Indonesia and KFA, Juelich, Germany. However, recently several data and calculations have been updated, for examples cost estimation, economics growth rate etc. While the forest data and mitigation options in forestry sector were established trough an comprehensive study on Java and Jambi forest situation by Centre for Forest Research, Dept. of Forestry, and Development and Centre for Environmental Studies - Agricultural Institute of Bogor.

2.2. Study Approach

The approach were used on implementation of this project were:

- the estimation of reasonable scenario for the future economic development
- the provision of detail sectoral and regional baseline energy demand projections based on the economic scenario
- establishment a baseline energy supply mix scenario
- mitigation options on energy and forestry sectors
- integration between energy and forest mitigation scenario
- calculation of the macro economic for mitigation assessment.

3. Social and Economical Aspects

Indonesia is the world's fourth most populated country with a population of 200 millions but, more than 60 % of the population lives in Java Island covered only 7 per cent of the land area of Indonesia. Through this condition, Java became the most populated area with density is roughly 850 peoples per square km. The population in 1990-1995 can be seen in Table 1. The declining of population growth rate is followed by an improvement of the wealthy of the people and successfully of the birth control program.

Table 1: Indonesian Population (in thousand)

YEAR	POPULATION	URBAN	RURAL
1990	179.250	55.434	123.816
1991	182.223	55.615	126.608
1992	185.259	55.792	129.467
1993	188.359	55.962	132.397
1994	191.524	56.127	135.397
1995	194.755	56.277	138.478

Source: Central Bureau of Statistic, 1996.

Stipulated by government deregulatory, market oriented policies, manufacturing and modern service sectors are making up an ever-greater proportion of Gross Domestic Product (GDP). Growth and structural change in the economy are being driven by private sector investment, both domestic and foreign. Industrialization and urbanization are concentrated in Java; while, the others islands and regions remains dependent on agriculture and its related activities.

As a matter of fact, in the end of fiscal year 1997, the Indonesia economics slump following extra ordinary of the decreasing rupiah's exchange rate to foreign currencies from 2475 rupiah per US Dollar to average of 8000 rupiah per US Dollar. It is predicted that Indonesia's economics will grow by minus 4 per cent per annum in the fiscal year 1998, but probably step by step will be normalized to "realistic" figures during next 1-2 years by. This project was not able to calculate the actual condition above.

The development of the growth rates GDP and population until the end of FYDP XI can be seen in Table 2. The GDP grows in six periods with an average growth of 5.9 % per year and the population grows with an average growth of 1.25 % per year.

Table 2: GDP and Population Growth in Indonesia During FYDP VI until FYDP XI High Scenario

Period	FYDP	Real GDP Growth (%/a)	Population Growth (%/a)	GDP/Capita (%/a)
1994-1998	VI	5.7	1.7	3.9
1999-2003	VII	6.3	1.5	4.7
2004-2008	VIII	5.1	1.3	3.7
2009-2013	IX	6.0	1.2	4.7
2014-2018	X	6.1	1.0	5.0
2019-2023	XI	6.2	0.8	5.4
1994-2023	VI-XI	5.9	1.25	4.57

4. Energy Reserves in Indonesia

As Indonesia have various types of energy, it is very important to analyst the reserves and utilization of the energy for long time periods, in order to fulfill the domestic energy demand in the future.

Indonesia were granted abundant and various energy sources as well as fossil energy and renewable energy. The total of proven and potential crude oil and condensate reserves in 1994 is 10,414.42 million barrels. Oil, which at present dominates on the energy consumption, due to very limited reserves, should be substituted and replaced with other sources of energy.

Indonesia's natural gas resources in 1994 are estimated 266 trillion cubic feet, in which 114.8 trillion cubic feet is classified as proven and probable. Since the proven reserves of natural gas are bigger than crude oil, considerable amounts of natural gas for domestic supply are available.

The total Indonesia coal resources in 1996 is about 38,720 million tones, in which 64 per cent is located in Sumatra and 35,4 per cent is located in Kalimantan, while the rests are spread in Jawa, Sulawesi, and Irian Jaya. Indonesia has four type of coal, i.e. anthracite, bituminous, sub-bituminous, and lignite. However, only anthracite, bituminous, and sub-bituminous, has utilized Indonesia.The crude oil, natural gas, and coal import, production, and export is shown in Table 3.

Indonesia has a large hydro power potential of 75 GW but most of the reserves are located in thinly populated areas where the demand is to low to justify large scale hydro power investments. Total potential of geothermal energy reserve has been estimated to be 16.1 GW, while Java and Bali (interconnection line) have nearly half of the reserves.

Table 3. The Commercial Energy Import, Production, and Export in Indonesia

Unit : PJ		1995	2000	2005	2010	2015	2020
Import	Coal	6.49	6.57	9.75	13.18	55.15	140.23
	Oil	564.18	798.22	1,375.48	1,918.88	2,921.93	4,596.04
Production	Coal	603.06	983.23	1,639.11	2,786.31	4,578.87	5,761.23
	Gas	2,379.01	3,004.87	3,242.98	3,479.14	3,423.41	3,438.55
	Oil	2,844.58	2,327.66	1,641.91	1,178.66	1,094.21	968.52
Export	Coal	268.26	522.88	642.01	775.60	938.90	25.48
	Gas	1,368.00	1,550.00	1,558.99	1,559.00	1,332.00	1,112.00
	Oil	1,620.00	898.00	389.00	0.00	0.00	0.00

Solar energy has been developed in Indonesia, especially for rural and remote area households that probably for next 10 years were not been electrified yet. Other renewable energy, i.e. wave energy, wind energy etc., is still under consideration and was not utilize yet as a commercial projects.

5. Projection of Baseline Energy Demand and Supply

In the baseline scenario, which is based on business as usual (BAU) scenario; there are no limitation of the GHG emission and introduction of GHG mitigation options.

Table 4: Baseline Primary Energy Supply

Type of Energy	Primary Energy Supply (PJ/year)					
	1995	2000	2005	2010	2015	2020
Biomass	1,113.11	1,209.59	1,301.69	1,425.77	1,540.76	1,688.83
Hydro/Geothermal	188.78	275.81	475.96	544.17	538.04	520.65
Coal	341.27	466.91	1,006.84	2,023.90	3,695.11	5,875.98
Gas	1,131.54	1,653.99	1,969.51	2,320.29	2,659.58	3,126.78
Oil	1,668.23	2,028.76	2,342.87	2,697.39	3,447.97	4,764.33
TOTAL	4,442.96	5,635.09	7,096.85	9,011.52	11,881.46	15,976.58

The utilization of oil grows during FYDP VI to FYDP XI on average at a rate of 4.3 per cent per year; this low growth due to oil has to diversify to coal & gas, and the availability of oil reserves, if there no new oil field found in oil exploration. It is predicted that the use of natural gas for LNG will reduce, then the potential of natural gas will be domestic energy supply option.

The sectoral of final energy consumption under baseline scenario is shown in Figure 2. The figure shows that household sector (including commerce and government sectors) has the highest final energy consumption in 1995, but at the end of the time horizon, the situation changes and industry sector will become highest energy consumption.

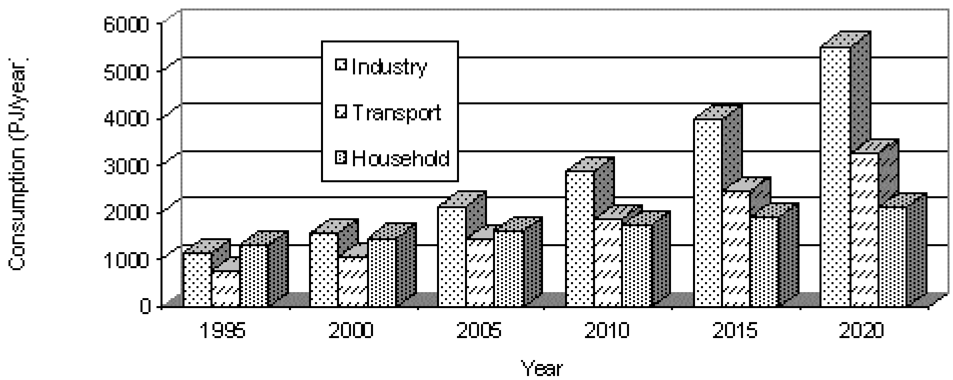


Figure 2: Final Consumption by sector in 1995-2020 (FYDP VI-XI)

The electricity sector plays a key role for the further development of the Indonesian economy. The development of the electric power plant capacities by different plant types is shown in Table 5.

Table 5. Baseline Electricity Generation Capacity

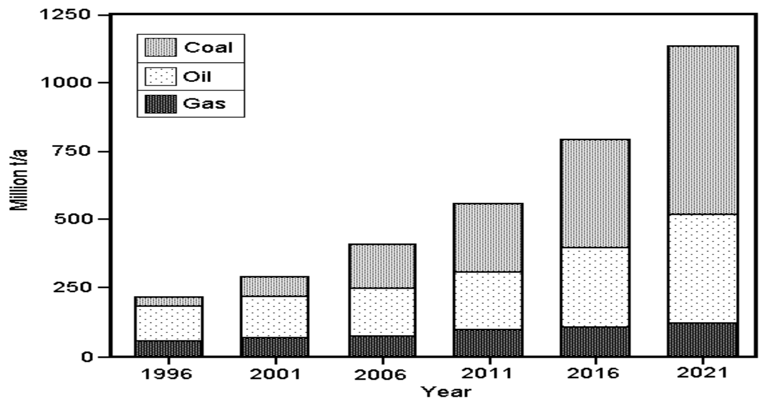
	Electricity Generation Capacity (GW/year)					
	1995	2000	2005	2010	2015	2020
Biomass	0.23	0.23	0.21	0.21	0.21	0.21
Coal Steam	3.54	4.45	12.09	26.30	48.02	74.81
Diesel	9.37	8.40	7.37	3.62	3.61	3.61
Gas CHP	0.00	0.79	0.94	0.94	0.94	0.94
Gas Comb. Cycle	4.21	7.67	7.67	10.95	12.74	22.94
Gas Turbine	2.72	2.63	4.82	5.63	7.84	6.84
Geothermal	0.39	0.44	0.43	0.37	0.29	0.04
Hydro	3.91	5.97	9.54	10.84	10.84	10.84
Oil Steam	2.63	2.22	1.09	0.54	0.02	1.67
T o t a l	27.00	32.8	44.16	59.4	84.51	121.9

Coal is Indonesia's cheapest primary energy resource up to a certain level of use, ash disposal or air pollution problem can be occurs. However, using more efficient technology and clean technology can mitigate the problem.

6. GHG Emissions

The CO_2 estimate is simply based on the quantity and the carbon contents of the individual energy carriers making up the total domestic primary energy consumption of Indonesia. 100 % of the carbon content of primary energy is assumed to be converted to CO_2.

Due to the increasing share of coal in total primary energy and due to a high specific carbon content as a mayor source of CO_2, the share of CO_2 emission in FYDP XI is 54 % from coal, 35 % from oil, and 11 % from natural gas.



Source: BPPT-KFA, Environtmental Impacts of Energy Strategy for Indonesia, 1993.

Figure 3. The Share of CO_2 Emission Produce by Type of Energy

7. Mitigation Scenario

7.1. Mitigation Option in Energy Sector

This chapter described the mitigation options will be introduced in the energy consumption sector such as, household, industrial, commercial, and electric power generation sectors. Table 6 shows the sectoral mitigation options.

Table 6: Mitigation Options in Energy Sector

Sector	Sub-sector	Mitigation Option
End-use Sector	Industry	Gas fired cogeneration : high and medium temperature heat
		Variable speed electric motors
	Households	Compact fluorescent lamps
		Electronic ballast for fluorescent lamps
		Refrigerators and air conditioning
		LPG Stoves for substituting kerosene stoves
		Photovoltaic (solar home systems)
	Commercial	Compact fluorescent lamps
		Electronic ballast for fluorescent lamps
		Refrigerating and air conditioning
		Solar collectors for water heating purposes
	Transportation	Turbo charger for Diesel & Gasoline Motor Vehicles
		CNG and LPG vehicles for public transportation
Power Sectors	Electricity	IGCC, PFBC
		Gas fired fuel cell

7.2. Mitigation Options in Forestry Sector

In the study, two forest areas, Java and Jambi, have been derived as study case. There are 11 mitigation options have been defined. The mitigation cost for one ton carbon varies considerable between the options, as described in Table 7.

7.3. Integrated Assessment of GHG Mitigation Options

The study has been progressed by introducing energy linked to the forest. In relation between energy and forestry, analysis of the forest as energy resource and forest as the CO_2 sink.

Urgency of integration of mitigation options into energy sector modeling are to get brief illustration and understanding about relationship between amount of CO_2 reduction and cost by introduction of such options. Cause forest is predicted only has capability to absorb CO_2, this study limited on CO_2 reduction only, and not consider to CH_4 reduction.
Since the energy sector was an emitter of CO_2 (not included CO_2 from biomass), integration between energy and forestry mitigation, principally can not change the amount of released CO_2 from energy sector, while forestry sector calculate net emission from forest sector as CO_2 sinker and as emitter.

Table 8 illustrates the amount of released CO_2 under baseline and mitigation scenarios of linked energy and forestry sectors. The study is not finished yet and need to extend to cover all regions in Indonesia. As a study case, emission from energy sector is calculated for total Indonesia, while CO_2 emission and uptake from forestry sector only calculate for Java island and Sumatera island.

Table 7. Mitigation Options in Forestry Sector

Option Category	Species*	Available Land	C-Abated t C/ha	NPV of Benefit		Endowment Cost	
				$/tC	$/ha	$/tC	$/ha
JAWA							
Timber Estae	Tectona grandis	1106189	159	0.39	62	0.52	83
	Pinus merkusii	597744	158	2.31	366	10.44	1650
	Swietenia sp.	74876	216	0.27	59	0.38	82
	Paraserienthes falcataria	6982	84	1.59	133	4.15	348
	Rimba	182018	112	-0.03	-4	0.73	82
Afforestration	Acacia Mangium	516274	114	12.81	1456	16.49	1974
	Paraserienthes falcataria	516274	84	7.71	876	16.69	1897
Critical Land	Tectona grandis	617027	434	-0.07	-32	0.07	32
Rehabilitation	Acacia Mangium	1821666	150	-0.21	-32	0.21	32
	Paraserienthes falcataria	1821666	92	-0.22	-31	0.22	31
JAMBI							
Critical Land	Acacia Mangium	184006	98	-0.34	-32	0.34	32
Rehabilitation	Pinus merkusii	184006	116	-0.18	-31	0.18	31
Forest Concess.	Rimba	184006	376	0.06	6	0.44	44
Reforestration	Acacia Mangium	149295	51	3.98	452	5.24	595
Rotation	Paraserienthes falcataria	149295	36	0.74	60	3.89	314
Afforestration	Acacia Mangium	24743	115	4.15	348	13.59	1140
	Pinus merkusii	24743	159	6.89	1082	32.29	5071
Forest Conversion	Forest Protection	258625	120	-5.69	-683	3.24	388
	Ruber	258625	204	3.51	770	2.57	563
	Palm Oil	258625	201	1.01	682	2.34	1578
	Coconut	258625	19	-0.36	-171	0.92	440

Table 8. Integrated Baseline and Mitigation Scenarios of Energy and Forestry Sectors (million Tons/Annum)

	Type	1995	2000	2005	2010	2015	2020
Baseline	Energy	218.10	286.08	377.10	529.65	746.54	1076.69
	Net uptake Forestry *)	33.34	24.70	17.00	16.91	18.32	19.86
	Total Emission Baseln.	184.76	261.38	360.10	512.74	728.22	1056.83
Uptake 5 %	Energy	218.10	286.08	377.10	529.65	746.54	1076.69
	Net Forestry	33.34	29.12	17.51	19.14	20.92	21.33
	Total Emission 5%	184.76	256.96	359.59	510.51	725.62	1055.36
Uptake 10 %	Energy	218.10	286.08	377.10	529.65	746.54	1076.69
	Net Forestry	33.34	31.52	19.45	21.75	21.73	24.64
	Total Emission 10%	184.76	254.56	357.65	507.90	724.81	1052.05
Uptake 20 %	Energy	218.10	286.08	377.10	529.65	746.54	1076.69
	Net Forestry.	33.34	34.09	22.15	24.78	24.26	28.47
	Total Emission 20%	184.76	251.99	354.95	504.87	722.28	1048.22
Uptake 30 %	Energy	218.10	286.08	377.10	529.65	746.54	1076.69
	Net Forestry.	33.34	35.57	23.80	26.77	30.12	35.08
	Total Emission 30%	184.76	250.51	353.30	502.88	716.42	1041.61

- Description : Net Forestry = Uptake - Emission
- CO_2 emission from energy sector is calculated for total Indonesia, while from forestry sector only calculate for Java island and Sumatera island.

Table 9 illustrates the total emission for 30 years between FYDP (five years development period) VI until XI.

Table 9. Total Emission in Indonesia between FYDP VI - XI (30 years) (Million Tons)

Item	Baseline	Uptake			
		+5%	+10%	+20%	+30%
Energy	16170.8	16170.8	16170.8	16170.8	16170.8
Net Forestry	650.7	706.8	762.2	835.5	923.4
Total Emission	16821.5	16877.6	16933.0	17006.3	17094.2

Description: Net Forestry = uptake - emission

8. Macro Economic Assessment

The macro economic assessment considers cost related to the CO_2 emission reduction by assessment of the mitigation options. Table 10 illustrates the total cost needs for baseline scenario and CO_2 reduction by mitigation's options (abatement 1 and 2).

Table 10. Total Discounted Cost for Energy and Forestry Sectors

Sector		Cost (mil. US$)	Diff.	Emission	Diff.	Reduct. %
Energy	Baseline	225140.25		16935.18		
	Abat 1	231010.86	5870.61	15198.67	-1736,51	10.25
	Abat 2	236711.30	11571.05	14769.57	-2165.61	12.79
Sector		Cost (mil. US$)	Diff.	Net Uptake	Diff.	Reduct. %
Forestry	Baseline	221043.83		853.65		
	Uptake+5%	221045.22	1.39	899.80	46.15	5.41
	Uptake+10%	221047.68	3.85	955.15	101.50	11.89

Further calculation from above tables indicates the additional investment need for CO_2 reduction as follows.

Table 11. Calculation of CO_2 Reduction

Sector	Additional Investment US $ /Ton CO_2	
	Abat 1 / Uptake +5%	Abat 2 / Uptake +10%
Energy	3.381	5.343
Forestry	0.030	0.038

This result proved that increasing CO_2 sink cheaper than CO_2 reduction, and increasing of the target of CO_2 reduction will increase the additional cost per ton CO_2 reduction.

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