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Edited by:
Ir. Hari Suharyono, PhD.
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Jakarta, May 2002

Centre for the Assessment and Application of Energy Conversion and Conservation Technology
Agency for the Assessment and Application of Technology (BPPT)

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FOREWORD

Kyoto Protocol defines the role of Non Annex 1 parties in a meaningful participation in the Clean Development Mechanism (CDM), and to assist Annex 1 parties to comply with the UNFCCC requirement in GHG mitigation efforts. The cooperation of Non Annex 1 parties is very important to the Annex 1 parties to obtain the cost-effectively in their GHG emission mitigation program. For Non Annex 1, CDM implementation may assist the country to reach the national priorities on its sustainable development program.

Indonesia has a potential to be one of Certified Emission Reduction supplier, besides Mexico, Malaysia, Korea and Brazil. The main suppliers will be China and India. Therefor, The State Ministry of Environment was prepared The National Strategy Study (NSS) on the Clean Development Mechanism (CDM) in Indonesia for guidance of decision makers and all stakeholder.

The production of NSS on the Clean Development Mechanism (CDM) in Indonesia was carried overed by two teams. The first team was coordinated by Mr Johansyah Salim who ended the tasks in March 2001 and the second task (Clean Development Mechanism (CDM) Potential in Indonesia) was conducted by The Energy Planning Team of Agency for Assessment and Application of Technology (BPPT) that lead by Mr. Sidik Boedoyo.

The subject papers had been discussed and the materials of the discussion results had been proceeded by the State Ministry of the Environment of the Republic of Indonesia with title " National Strategy Study (NSS) on the Clean Development Mechanism (CDM) in Indonesia". Therefore, The Centre for The Assessment and Application of Energy Conversion and Conservation Technology, BPPT intends to publish all of Clean Development Mechanism (CDM) Potential in Indonesia in order to make clear the meaning of the National JL/CDM Strategy Studies Program (NSS Program) to explore the opportunities for and potential benefit of formulating their own positions regarding the Kyoto Protocol flexibility mechanisms.

The title of this publication is "Clean Development Mechanism (CDM) Potential in Indonesia". The book is financed by The Center for The Assessment and Application of Energy Conversion and Conservation Technology, BPPT. This book consists of some research papers that provides information on technical and economical strategies for Clean Development Mechanism (CDM) Potential in Indonesia.

Jakarta, Mei 1, 2002

The Center for The Assessment and Application of
Energy Conversion and Conservation Technology
Director,

Drs. Adjat Sudrajat, MSc

CONTENTS

GHG EMISSION IN ENERGY SECTOR: PROFILE AND PROJECTION

Endang Suarna and Nona Niode

Abstract

An increase of the greenhouse gases (GHG) such as CO_2, CH_4 and N_2O emissions in the atmosphere is mostly caused by human activities, and most of the GHG emissions from human activities are sourced from energy activities through fuels combustion and fugitive emissions. CO_2 is the most dominant emission among others GHG emissions. Fuel combustion from power plant, transportation, and industrial sectors respectively has dominant contribution of increasing CO_2 emission. In Indonesia, the potential for reducing GHG emissions from energy activities both in energy supply and demand during the next 25 years is large, and there are a variety of technologies and policies available for capturing that potential.

1. INTRODUCTION

Although there is still significant uncertainty surrounds the magnitude and specific impacts of the greenhouse effects, currently, global warming has been an international issue. However human activities that have caused increasing levels of greenhouse gases (GHG) such as CO_2, CH_4, and N_2O emissions in the atmosphere that will changes in climate has been an international scientific consensus. The emissions from human activities in energy sector through fuel combustion and fugitive emissions have a significant impact on the increase of the emission levels. While the rests of the GHG emissions are produced from other human activities such as deforestation; fertilizing croplands; and heating, air-conditioning, and lighting buildings [6].

Among GHG emissions, CO_2 emission is the greatest contributor on global warming, followed by CH_4, and N_2O emissions respectively. Also CO_2 emission has the greatest impact on global warming. Most of CO_2 emission is emitted from energy activities [5] that include industrial, transportation, and residential & commercial sectors. While forest and land use change and industrial process are the second and third largest of emission sources respectively. Energy use for industrial sector is the dominant cause of CO_2 emission for fuel combustion. Other important fuel combustion in energy activities is transportation and residential & commercial sectors respectively. While CO_2 emission from the energy activities can be estimated based on net calorific value and carbon emission factor of every type of energy used (oil, coal, gas, and biomass).

In response to the greenhouse gases impacts problem, a depth examination for reducing the GHG emissions in atmosphere especially from energy activities is necessary. The examination will be started by inventory of greenhouse gases from energy activities to give GHG emissions figures by sector for monitoring and abatement policy formulation. While the projection of GHG emissions in the next 25 years will be estimated based the energy demand projection made by MARKAL Model [2] to develop goals for controlling emission and to design specific strategies of technologies and policies for achieving those goals in Indonesia.

2. METHODOLOGY

The inventory of the GHG emissions from energy activities will be estimated based on two different methodological approaches such as Reference Approach (Energy Source) and Source Categories (Tier 1). Reference approach is accounting for carbon based on mainly on the supply of primary fuels and net quantities of secondary fuels brought into the total GHG emissions in the Indonesia. However Tier 1 (Source Categories) method is able to give information of GHG emission from fuel combustion by sector [7].

The methodologies for the calculation of GHG emissions are as follows.

1) The calculation of CO_2 emission from fuel combustion can be broken down into 5 steps.

a. Estimate annual fuel consumption per sector in energy units.
b. Multiply by emission factor to compute the Carbon content.
c. Compute Carbon stored.
d. Correct for Carbon unoxidized.
e. Convert Carbon oxidized to CO_2 emission.

While the equation used in the calculation for estimating CO_2 emission is as follows.

$$TE_{CO2} = (CC - CS) * FCO * (44/12) \quad (1)$$

While: $CC = EC * CEF$

Note:

TE_{CO2} : Total CO_2 Emission
CC : Carbon Content
EC : Energy Consumption
CEF : Carbon Emission Factor of Energy Carrier
CS : Carbon Stored
FCO : Fraction of Carbon Oxidized

2) The calculation of non CO_2 emissions such as CH_4 and N_2O can be divided into 3 steps.

a. Estimate annual fuel consumption per sector in energy units.
b. Estimate emission factor for each fuel per sector.
c. Estimate the emission.

While the equation used in the calculation for estimating CH_4 or N_2O emission is as follows.

$$TE_{CH4/N2O} = (EC * EF) \quad (2)$$

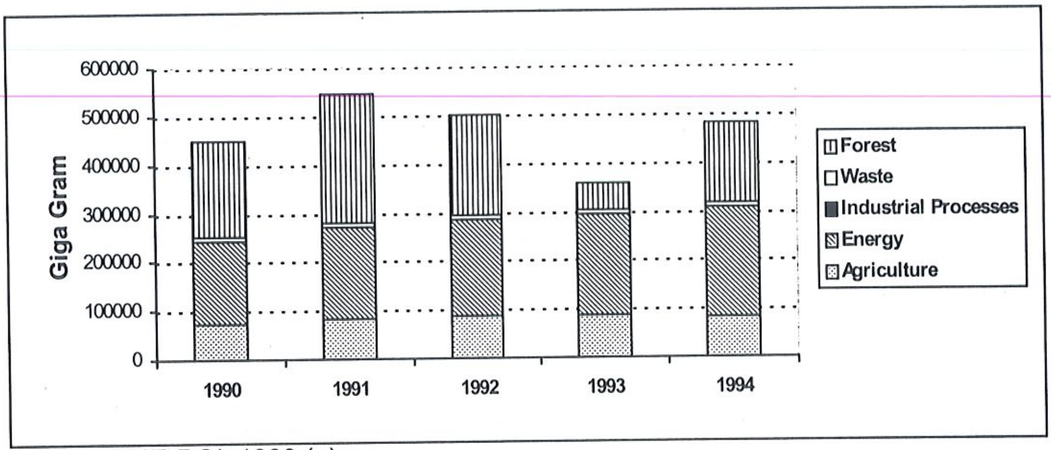
Note:

$TE_{CH4/N2O}$: Total CH4 or N2O emissions
EC : Energy consumption by fuel and by sector
EF : Emission Factor of every type of energy source.

The calculation of GHG emissions inventory for 1990 and 1994 is based on the energy balance tables of the Department of Mines and Energy, while the projection of GHG emission is based on the energy demand projection of the BPPT Energy Planning. The output of the MARKAL Model has been used in estimating the GHG emissions projection.

3. MACRO INVENTORY AND PROJECTIONS OF GHG EMISSION IN INDONESIA

The inventory of greenhouse gases (GHG) that consists of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in Indonesia will be analyzed based on the emissions from 1990 until 1994. However based on type of gas (in CO_2 equivalent emission unit), CO_2 is the most dominant GHG emissions among others. While CH_4 emission is the second largest GHG emissions after CO_2 emission, and finally followed by N_2O emission. Based on the GHG emissions sources, human activities such as energy and forestry sectors are the greatest contributor of GHG emissions in the atmosphere of Indonesia as shown in Figure 1.



Source: SME-ROI, 1999 (a)

Figure 1. CO_2-Equivalent Emission (CO_2, CH_4, N_2O) of Indonesia by Source

During 1990 until 1994 period, energy activity seems to be the most dominant contributor of GHG emission. While GHG emission from forestry is the second largest, even though forestry activity became the greatest GHG emission in 1991. The GHG emission from forestry fluctuated depend on the rate of wood harvesting, forest conversion, and forest fire incident [3]. Those GHG emissions by type of gas in Indonesia can be analyzed as follows.

3.1 Carbon Dioxide (CO_2)

Total CO_2 emission in Indonesia from 1990 until 1994 has increased from about 331000 Gigagram to 345000 Gigagram or increase with the rate of 1 percent/year as shown in Table 1. The CO_2 emissions originate primarily from the energy and forestry sectors. Industrial processes make a small contribution on the total emissions, while contributions from agriculture are negligible.

The table shows that most of CO_2 emission produced from the energy activities and followed from the forestry sectors. CO_2 emissions from the forestry sector were of the same order of magnitude as emissions from energy sector. Fluctuations in the levels of CO_2 emissions from the forestry sector reflect fluctuations in the rate of wood harvesting and forest conversion and also incidences of forest fire. Several assumptions underlie estimations of CO_2 removal by Indonesian forests - the critical assumption is based on tree growth stage. The data in the table below are based on the assumptions made by the ALGAS study [1] and The First National Communication under UNFCCC [3]. The main assumptions were that production forests under succession accounted for one third of the total logged-over forest, while in the community plantations half of the total area was logged-over. It is important to note that changes in these assumptions would certainly lead to very different figures.

Table 1. Indonesia Carbon Dioxide Emission 1990-1994 (Ggram)

Emission Sources	1990	1991	1992	1993	1994
Energy	128,398.20	140,410.40	149,925.60	158,321.90	170,016.30
Industry Processes	14,286.22	14,687.07	15,815.49	17,342.98	19,118.66
Forest & Land Use Changes	188,138.80	256,546.90	195,738.80	50,059.80	155,624.50
Agriculture	-	-	-	-	-
Total	330,823.22	411,644.37	361,479.89	225,724.68	344,759.46

Source: SME-ROI (1999a).

3.2 Methane (CH_4)

Methane formed as a result of anaerobic bacteria metabolism in swamp, human and animal digester, and land field. Methane is also produced from organic material combustion. Methane production is affected by temperature (5). However, agriculture is the main contributor to methane emissions. Water management in rice cultivation plays an important role in controlling emissions, as well as in determining crop yield. Fugitive emissions from fossil fuel exploration and mining (coal, oil, and gas production), energy combustion, industrial processes, and forestry and waste management also contribute to CH_4 emissions. Estimates of CH_4 emissions from energy combustion during the period 1990 -1994 are shown in Table 2.

Table 2. Indonesia CH_4 Emission 1990-1994 (Ggram)

Emission Sources	1990	1991	1992	1993	1994
Energy Combustion	325.20	332.70	341.20	350.10	357.60
Fugitive of Coal, Oil & Gas	1,562.60	1,778.40	1,881.10	1,940.00	2,038.20
Industrial Processes	0.46	0.43	0.32	0.46	0.51
Forest and Land Use Change	414.90	544.60	487.60	349.10	367.30
Agriculture	2,793.40	3,202.20	3,217.60	3,232.70	3,243.80
Total	5,096.56	5,858.33	5,927.82	5,872.36	6,007.41

Source: SME-ROI (1999a).

From 1990 to 1994, methane emission has increased with the rate of about 4 percent per year. Most of the methane emission is emitted from agricultural activities and followed from fugitive sources such as coal, oil, and gas mining. While, the third contributor of the methane emission is forest and land use change and followed by energy combustion and industrial processes respectively. As oil, gas, and coal are main export commodities in Indonesia, Indonesia has a great effort on coal, oil, and gas exploration and mining that resulted the highest increase of methane emission with the rate of 7 percent/year and followed with the growth rate of methane emission from agricultural and industrial processes activities with the rate of about 4 percent/year. While methane emission from forest and land use change has the lowest rate among others.

3.3 Nitrous Oxide (N_2O)

N_2O emission produced from burning biomass, microbiological activities in de-nitrification and nitrification processes, and ocean. N_2O emission from agriculture and forestry is affected by several factors such as soil type, temperature, rainfall, and tree or crop type. N_2O is also produced from fossil and biomass fuel combustion or energy sector. N_2O emission in Indonesia from 1990 to 1994 is relatively stable in the total about 61 Gigagram of N_2O emission as shown in Table 3.

Table 3. Indonesia N_2O Emission 1990-1994 (Ggram)

Emission Sources	1990	1991	1992	1993	1994
Energy Sector	5.08	5.27	5.43	5.59	5.73
Industrial Processes	0.01	0.01	0.01	0.01	0.01
Forest and Land Use Change	2.85	3.74	3.35	2.40	2.52
Agriculture	53.03	52.71	55.75	54.73	52.86
Total	60.97	61.73	64.54	62.73	61.12

Source: SME-ROI (1999a).

N_2O emissions are mainly produced by agricultural activity. Nitrogenous fertilizers (synthetic nitrogenous fertilizers, animal manure and crop residue) appear to be the main culprits. As using an organic fertilizer increases, the N_2O emission from agricultural sector also increases. Limited N_2O emissions come from energy, industrial processes and forestry. N_2O emissions from the energy sector come mainly from the burning of biomass. Decreases in emissions of N_2O from the forestry sector reflect decreasing rates of forest conversion during the period.

4. RESULT ANALYSIS

4.1 Economic Projection

In the decade before the Asian economic crisis, Indonesia's economy was growing rapidly. The crisis resulted in a severe devaluation of the country's currency, the Rupiah. By late 1997 the crisis had spread from the currency market to the capital markets. Intensification of the crisis during 1998 resulted in widespread company closures, mass job losses and soaring inflation. In the period before a new government took office at the end of 1999, Indonesia was hit by political, economic and social instability.

As a result of the events described above Indonesia's economy suffered a severe contraction in real terms, by 13.2 percent in 1998. However, recovery is predicted over the coming three to four year period (2002 to 2004) (Economic Inteligent Unit, Indonesia Country Report 1999). Growth of 3 percent in gross domestic product (GDP) is projected for 2002 as shown in Table 4; thereafter, economic recovery is expected to be smooth. GDP will increase by more than 4 percent in 2003, and should reach 5 percent by 2004. By 2010 Indonesia will move from being an oil exporter to a net oil importer, with a consequent drop in real GDP growth. By 2012 real GDP growth is forecast to approach a normal level of about 5 - 6 percent. The leading contributors to economic recovery are expected to be exports and investment growth. However, the current political crisis creates a lot of uncertainty, and these projections may be overly optimistic.

Table 4. Projection of the Indonesia's GDP Growth

Year	%	Year	%	Year	%	Year	%
1991	8.9	2001	0.7	2011	4.4	2021	5.5
1992	7.2	2002	3.0	2012	5.9	2022	5.5
1993	7.3	2003	4.8	2013	5.2	2023	5.5
1994	7.5	2004	5.0	2014	5.2	2024	5.5
1995	8.2	2005	5.0	2015	5.2	2025	5.5
1996	8.0	2006	5.0	2016	5.3	2026	5.6
1997	4.7	2007	5.0	2017	5.3	2027	5.6
1998	-13.2	2008	5.2	2018	5.3	2028	5.6
1999	+0.23	2009	4.4	2019	5.4	2029	5.6
2000	-0.9	1010	4.3	2020	5.5		

Source: SME-ROI (1999b).

4.2 Greenhouse Gas Emission Projection

GHG emissions that produced from the energy activities based the energy demand in Indonesia from 1990 to 1994 will be analyzed. The emission calculation used methodology from IPCC (1996) , and the results are as follows.

4.2.1 Carbon Dioxide (CO_2)

Taking a sector-by-sector approach (based on the IPCC Sectoral or Tier 1 approach), CO_2 emissions from fuel combustion in the energy demand sectors and the energy transformation sectors have been calculated. The energy demand sectors are: industrial, household, transport, and the energy industry (extraction). Energy transformation comprises power generation, refineries and LNG plants. CO_2 emissions from fuel combustion between 1990 and 1994 are shown in Table 5.

Table 5. CO_2 Emission from Fuel Combustion in Demand Sector 1990 – 1994 (Ggram)

Sectors	1990	1991	1992	1993	1994
Industry	36,953.4	39,902.8	42,975.6	46,371.5	50,014.4
Transport	34,588.3	37,580.8	39,881.1	42,007.6	47,047.2
Residential & Commercial	19,555.3	20,150.3	21,346.3	21,548.7	22,252.5
Energy Industry	37,301.2	42,776.5	45,722.6	48,394.0	50,702.2
Total	**128,398.2**	**140,410.4**	**149,925.6**	**158,321.9**	**170,016.3**

Source: SME-ROI (1999b).

CO_2 emissions from fuel combustion in the transport sector were almost as high as the emissions from the industrial sector during the same period. However, the rate of increase of emissions in the transport sector was faster than in the industrial sector. Gasoline and diesel oil combustion contributed more than 40 and 50 percent respectively of total CO_2 emissions in the transport sector.

It should be noted that residential and commercial (ResCom sector) energy users consumed more energy than indicated, because these sectors were responsible for the majority of energy consumption during the period. However, most of the energy consumed by the sector was supplied from biomass (fuel wood and agricultural wastes), therefore CO_2 emissions from residential and commercial sector in Table 5 are the emissions just from kerosene, LPG, and natural gas or city gas. Nevertheless, CO_2 emissions from this biomass were listed only as a memo item in the national GHG inventory. More than 99 percent of CO_2 emissions from this sub-sector were from kerosene, which generally is used for cooking and lighting. Between 1990 and 1994 the energy production sector (electricity generation, refinery, LPG Plant, and LNG Plant) was responsible for about 30 percent of national CO_2 emissions. The highest CO_2 emissions growth rate was in the electricity generation sub-sector.

4.2.2 Methane (CH_4)

CH_4 or methane emissions from the energy demand sectors are produced as a result of energy combustion and leaks during exploration and production processes. Emissions occur because of incomplete combustion of hydrocarbon in fuel. CH_4 emissions from energy combustion are affected more by temperature in the demand devices (such as stove, kiln, or boiler) than fuel content. Estimates of CH_4 emissions from energy combustion and leaks for the 1990 to 1994 period are shown in Table 6.

Fugitive sources have the biggest potential applying CH_4 emission reduction in energy sector. More than 82 percent of the total CH_4 emission every year from 1990 to 1994 is produced from fugitive sources that including the emission from coal mining, crude oil mining and refining, and natural gas production and processing. However, natural gas production and processing is the main source of CH_4 emission among others of the fugitive sources. Residential and commercial sector is the second biggest contributor of the emission with share about 15 percent/year in the period, while other sources such as industry and transportation sectors contribute less than 1 percent in average every year from 1990 to 1994.

Table 6. CH_4 Emissions from Energy Demand Sectors between 1990 and 1994 (Ggram)

Emission Sources	**1990**	**1991**	**1992**	**1993**	**1994**
Industry	1.6	1.8	1.9	2.0	2.3
Transport	5.6	6.1	6.4	6.7	7.5
ResCom	317.4	324.1	332.0	340.5	347.0
Industry Energy	0.6	0.8	0.8	1.0	0.8
Fugitive	1,562.6	1,778.4	1,881.1	1,940.0	2,038.2
Coal Mining	6.7	9.0	14.7	17.7	20.5
Crude Oil Mining & - Refining	1.1	1.2	1.1	1.1	1.1
Natural Gas Production & Processing	1,554.8	1,768.2	1,865.3	1,921.2	2,016.6
Total	**1,887.8**	**2,111.0**	**2,222.3**	**2,290.1**	**2,395.7**

Source: SME-ROI (1999b).

4.2.3 Nitrous Oxide (N_2O)

N_2O emissions from different fuel sources used in the energy demand sector are shown in Table 7. The table shows that total N_2O emissions from energy combustion increased at a rate of 3 percent per year between 1990 and 1994. The residential and commercial sector was responsible for the majority of N_2O emissions, mainly a result of biomass combustion. N_2O emissions in the residential sector were more than ten times greater than N_2O emissions in the transport sector over the period 1990 - 1994. The N_2O emissions in transport sector were about twice as high as emissions in the industrial sector.

Table 7. N_2O Emission from Energy Activity in 1990 to 1994 (Ggram)

Sectors	1990	1991	1992	1993	1994
Industry	0.15	0.18	0.19	0.20	0.23
Transport	0.33	0.35	0.38	0.40	0.44
ResCom	4.36	4.45	4.57	4.68	4.77
Electricity Generation	0.24	0.28	0.30	0.31	0.28
Total	**5.08**	**5.27**	**5.43**	**5.59**	**5.73**

Source: SME-ROI (1999b).

4.3 The Projections of GHG Emissions from Energy Sector.

The residential and commercial sector dominated energy demand in Indonesia in 1995, accounting for 41 percent of national energy demand (3,340 PJ). The industry and transport sectors were responsible for 37 percent and 22 percent of national demand respectively. Over the next 15 years the industrial sector is projected to be the major energy consumer in Indonesia. Consequently, energy consumption in the transport sector will also increase. By 2025, Indonesia's energy demand is forecast to exceed 7,500 PJ. The industrial sector will account for 44 percent of the national demand, followed by the transport sector at 31 percent and the residential and commercial sector at 26 percent.

A model - the MARKAL model - has been used for a number of years by the Agency for the Assessment and Application of Technology (BPPT) to analyze data on energy use in Indonesia. MARKAL has been used to make various predictions about future energy in Indonesia. The model establishes the optimal energy supply solution for Indonesia and calculates the total cost, based on the energy source and technology mix selected. The model also allows for analyses of future emissions for a given energy supply scenario.

Energy demand is estimated based on the economic activities of different sectors and on population projections. The technology mix used in the model is based on technology currently available on the world market. Population growth is projected at 1.5 percent per year. The projection of Indonesia primary fuels mix to 2025, as presented in the First National Communication to UNFCCC (4), is based on the cheapest energy supply combination and is shown in Table 8.

Table 8. Projected Energy Supply by Source and Estimated Use by Sector

Energy Use	Final Energy Supply (PJ/year)							Growth Rate
	1995	2000	2005	2010	2015	2020	2025	%/year
Industry	**1,232.3**	**1,211.7**	**1,369.7**	**1,606.8**	**2,051.1**	**2,588.6**	**3,334.6**	**3.4**
Coal	176.7	197.4	244.8	291.1	415.0	539.4	746.7	4.9
Electricity	203.1	216.4	253.9	334.1	441.9	576.4	725.8	4.3
Natural Gas	400.1	397.0	435.5	502.9	599.9	722.5	899.5	2.7
Refinery Product	312.8	253.7	247.3	248.9	310.4	391.7	499.6	1.6
Biomass	139.7	147.3	188.2	229.8	283.8	358.7	463.0	4.1
Transportation	**748.6**	**753.8**	**834.0**	**1,046.4**	**1,358.2**	**1,775.7**	**2,333.6**	**3.9**
CNG&LPG	-	3.2	7.5	17.3	41.2	94.3	147.8	16.6
Electricity	1.0	1.0	1.2	1.5	2.0	2.8	3.8	4.5
Refinery Product	747.6	749.6	825.4	1,027.6	1,315.0	1,678.6	2,182.0	3.6
ResCom	**1,359.0**	**1,417.2**	**1,505.2**	**1,600.2**	**1,707.4**	**1,816.8**	**1,951.6**	**1.2**
Biomass	962.6	1,004.9	1,034.9	1,071.5	1,103.1	1,126.4	1,161.7	0.6
Gas (City Gas)	0.6	1.8	2.4	3.2	4.2	10.9	11.0	10.1
Electricity	95.0	121.3	159.2	208.1	281.9	375.3	438.9	5.2
Refinery Product	300.8	289.1	308.6	317.4	318.2	304.2	340.0	0.4
Total Consumption	**3,339.9**	**3,382.7**	**3,708.9**	**4,253.4**	**5,116.7**	**6,181.1**	**7,619.8**	**2.8**

Source: SME-ROI (1999b).

Major greenhouse gas emissions (CO_2, N_2O, and CH_4) are estimated from the MARKAL model's optimal energy system, and by using adapted IPCC 1996 methodology. The method used is Tier 1 with IPCC default uncontrolled emission factor. GHG emissions are based on projections of energy consumption by the energy demand and energy conversion sectors (power plants and refineries are excluded from the industry sector).

Total emissions were estimated at 277 Teragram CO_2 equivalent in 1995. Emissions are not expected to increase significantly up to 2005; thereafter a yearly increase of 4.5 percent is predicted. Emissions will reach 740 Teragram by 2025. CO_2 will be the major contributor to Indonesia's GHG emissions. Detail description of GHG emission projection from energy production and consumption are as follows.

4.3.1 Carbon Dioxide (CO_2)

CO_2 emission from energy demand projection in Indonesia that disaggregated by sector can be shown in Table 9. The CO_2 emission is estimated based on the energy demand projection from 1995 until 2025. During that period, the CO_2 emission is projected to increase in the rate of almost 4 percent/year. Most of the increase is supported by the increase of CO_2 emission from power generation sector that rocketed by the rate of almost 6 percent/year. The fastest increase of CO_2 emission from power plant sector has made this sector dominates the total CO_2 emission among those from other sectors from 2010 to 2025. While from 1995 to 2005, the share of CO_2

emission is dominated from industrial sector. Transportation sector has the second fastest of increasing CO_2 emission after power plant sector. Therefore the share of the CO_2 emission from the transportation sector increases from about 24 percent in 1995 to 25 percent in 2025. The CO_2 emission from transportation sector is mostly caused by the use of oil products such as diesel and gasoline.

Table 9. Projection of Total CO_2 Emission from Energy Demand in Indonesia

Sector	Total Emission Carbon Dioxide (CO_2) (Teragram)							Growth Rate
	1995	2000	2005	2010	2015	2020	2025	(%/year)
Industry	61.53	58.18	66.29	73.17	90.88	108.92	141.26	2.81
ResCom	21.86	21.05	22.48	23.10	23.17	22.41	24.98	0.45
Transport	51.47	54.91	60.92	76.07	98.82	127.96	167.58	4.01
Power plant	48.38	53.69	65.76	90.40	151.93	219.57	275.06	5.96
Energy Industry	32.49	39.87	30.44	34.93	26.88	47.54	63.43	2.25
Total	**215.73**	**227.70**	**245.89**	**297.67**	**391.68**	**526.40**	**672.31**	**3.86**

Source: SME-ROI (1999b).

Based on the energy supply, CO_2 emission is estimated based on the Reference Approach (IPCC, 1996) and the results are presented in Table 10. The table shows that fossil fuels such as coal, oil (petroleum), and gas are the main sources of CO_2 emission from energy activity. CO_2 emission from biomass is also presented in the table. CO_2 emission from petroleum such as diesel, gasoline, and kerosene has the biggest share of the total emission in the early period 1995 to 2010, however from 2015 to 2025, the emission from petroleum becomes the second after the emission from coal. While the share of CO_2 emission from natural gas decreases from 26.5 percent in 1995 to 14.3 percent in 2025. The estimation is excluded of CO_2 emission from biomass. However if the CO_2 emission from biomass included, biomass is the largest of CO_2 emission source after petroleum in 1995, and the third largest of CO_2 emission source after coal and petroleum in 2025.

Table 10. Projection of CO_2 Emission from Energy Activities (Reference Approach)

Emission Sources	1995		2000		2005		2010		2015		2020		2025	
	Tg	%	Tg	%	Tg	%	Tg	%	Tg	%	Tg	%	Tg	%
Coal	41	17.8	63	27.2	78	31.1	105	35.1	178	45.1	283	53.2	374	55.0
Natural Gas	61	26.5	64	27.7	74	29.8	81	27.1	85	21.5	86	16.1	98	14.3
Petroleum	136	59.6	114	49.2	108	43.2	126	41.9	148	37.3	183	34.4	234	34.4
Stock in Product*)	-9	-3.8	-9	-4.1	-10	-4.1	-12	-4.1	-16	-4.0	-20	-3.8	-26	-3.8
Total	229		232		249		300		395		532		680	
BIOMAS	106	31.7	120	34.2	128	33.9	138	31.5	145	26.8	153	22.3	165	19.5
Total + Biomass	335		352		378		438		540		685		845	

Source: SME-ROI (1999b).

4.3.2 Methane

Methane or CH_4 emission from energy activities is mostly produced from fugitive sources such as oil, gas, and coal production or exploitation. Even though the share of CH_4 emission from fugitive sources decreases from 1995 to 2025, the fugitive source is still the major contributor of the emission during that period. In the same period of 30 years, residential and commercial sector (ResCom) as the second largest CH_4 emission contributed about 14 percent to 15 percent of the total emission from energy activities. While the rests of the CH_4 emission from the activities are produced from transportation, industry, and power plant sectors respectively as shown in Table 11.

Table 11. Projection of CH_4 Emission from Energy Sector in Indonesia

Sector	CH_4 Emission (Gigagram)							Growth Rate
	1995	2000	2005	2010	2015	2020	2025	(%/year)
Industry	3.28	3.85	6.13	7.3	9.48	13.13	16.7	5.8
RESCOM	333.76	343.05	347.64	365.02	383.42	391.87	424.11	0.8
Transport	7.19	8.95	7.76	12.06	12.77	20.56	22.39	4.0
Power Plant	0.78	0.67	0.83	1.10	1.78	2.46	3.06	4.8
Fugitive	2054.91	2117.27	2337.96	2394.65	2307.46	2238.14	2287.44	0.4
Total CH_4 Emission	2399.92	2473.79	2700.32	2780.13	2714.91	2666.16	2753.70	0.5

Source: SME-ROI, (1999b)

4.3.3 Nitrous Oxide (N_2O)

N_2O emission from energy activities from 1995 to 2025 has been estimated to increase in the rate of about 3 percent per year that cause of increase more than double from about 6 to 13 Gigagram of N_2O emission as shown in Table 12. Even though residential and commercial sector is the majority of N_2O emission contributor from energy activity, the growth rate of the emission from this sector is the lowest among others. While, transportation sector has highest growth rate of N_2O emission that lead the sector to be the second highest of N_2O emission contributor in 2025 from the third highest contributor of N_2O emission in 1995 as shown in Table 12.

Table 12. Projection of N_2O Emission from Energy Sector

Sectors	N_2O Emission (Gigagram)							Growth Rate
	1995	2000	2005	2010	2015	2020	2025	(%/year)
Industry	0.89	0.90	1.19	1.36	1.78	2.29	3.03	4.2
RESCOM	4.04	4.17	4.30	4.46	4.61	4.69	4.83	0.6
Power Plant	0.29	0.45	0.36	0.59	0.59	1.04	1.01	4.3
Transport	0.48	0.66	0.81	1.19	2.07	3.16	3.98	7.3
Total N_2O	5.70	6.18	6.66	7.60	9.05	11.18	12.85	2.8

Source: SME-ROI (1999b).

5 CONCLUSION

Green house gases (GHG) emissions such as CO_2, CH_4, and N_2O emissions in Indonesia has increased at the rate of 1.8 percent per year that caused by human activities including energy production and consumption, industrial process, forest & land use changes, and agricultural cultivation. While, CO_2 is the most dominant emission among other GHG emissions.

Energy combustion and fossil exploitation is the greatest contributor among human activities on increasing the GHG emission in the atmosphere, therefore the energy activities have a high potential for reducing GHG emission. Most of the energy is consumed to meet the energy demand in residential and commercial sector, followed by industrial, and transportation sectors respectively. However, most of the energy consumption in the residential and commercial sector is supplied from biomass (firewood and agricultural waste) energy.

Based on the inventory of GHG emissions in the energy demand, industrial sector has greatest CO_2 emission, followed by transportation and residential & commercial sectors respectively. However, biomass energy in residential & commercial sector is not included in the calculation of CO_2 emission. The inventory just calculated the CO_2 emission produced from fossil fuel products such as diesel, gasoline, kerosene, coal, and gas combustion not included biomass. CH_4 is second largest GHG emissions that mostly produced from energy exploitation such as coal mining, crude oil mining and refining, and natural gas production and processing that can be called as the fugitive source. While N_2O is mainly produced from the residential and commercial sector as a result of biomass combustion.

In the next 25 years, energy consumption in industrial sector will increase with the rate of 3.4 percent per year that causes the industrial sector replaces the residential and commercial sector. While, the residential and commercial sector increases with the rate of 1.2 percent per year in the period. In the other hand, the energy consumption in the transportation sector is estimated will increase with the rate of 3.9 percent per year in the period.

The increase of the energy consumption from 1995 until 2025 has caused an increase of GHG emissions that dominated by CO_2 emission. The CO_2 emission is estimated to increase from 216 to 672 Teragram or increase with the rate of 3.3 percent per year in the period. Most of the CO_2 emission is produced by power generation activities, followed by transportation and industrial sectors respectively. The amount of the GHG emission from energy activities shows that the wide range of technical options for reducing GHG emissions in the energy demand sector available to apply in CDM programs

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GHG EMISSION AND MITIGATION OPTION FOR INDUSTRIAL PROCESSES SECTOR

La Ode M Abdul Wahid and Erwin Siregar

Abstract

Industrial processes sector analyzed is only for cement, limestone, dolomite, soda ash, ammonia, calcium carbide, magnesium & aluminium, iron/steel, nitrit acid and carbon black. GHG emissions (comprising CO_2, CH_4, N_2O, CF_4 and C_2F_6) for industrial processes sector is projected for the next 25 years. There are a variety of technologies and policies available as option to mitigate the emission.

1. INTRODUCTION

The industrial processes as a part of this report will cover only the greenhouse gas inventory of industries. No identification of mitigation option was made for industrial processes due to the lack and limitation of data and information of the appropriate mitigation technologies.

The projection of GHG emissions (comprising CO_2, CH_4, N_2O, CF_4 and C_2F_6) can be analysed for industrial process in this paper is only a part of industrial sector, such as cement, limestone, dolomite, soda ash, ammonia, calcium carbide, magnesium & aluminium, iron/steel, nitrit acid and carbon black. While for mitigation option, the pulp & paper industry, textile industry, cement industry, strach/tapioca industry, sugar industry and palm oil industry can be analysed.

The problem for estimating GHG emission is that most of the industries statistic are not separated and combined in one industrial group. Therefore, estimating for the other industry excluding the four largest sources of GHG emissions (cement, ammonia, steel and aluminium) needs extra effort for data colllection.

2. METHODOLOGY

The estimated of GHG emission in this assessment will follow the IPCC Reference Manual, a Revised 1996 Guidelines for National GHG Inventories. For the assessment , the data of production and good consumption will be the basis for the GHG emission in industrial processes.

1) CO_2 Emission (ton)

- CO_2 Emission for Cement Production = 0.4985 x Cement Production (ton)
- CO_2 Emission for Lime Production = 0.7850 x Lime Production m^3 x Specific Gravity (ton/m^3)
- CO_2 Emission for Limestone Use = 0.4400 x Limestone Use (ton) x Ca CO_3 purity
- CO_2 Emission for Dolomite Use = 0.4770 x Dolomite Use(ton) x Dolomite purity
- CO_2 Emission for Soda Ash Use = 0.4150 x Soda Ash Use (ton)
- CO_2 Emission for Ammonia Production = Gas Consumption for Ammonia Production (m^3) x Carbon Content (ton c/TJ) x Calorific Value (MJ/ m^3) x Molecule Value of CO_2 /C (44/12)

- CO_2 Emission for Calcium Carbide Production = 0.7600 x Calcium Carbide Production (ton)
- CO_2 Emission for Iron/Steel Production = 1.6000 x Iron/Steel Production (ton)
- CO_2 Emission for Aluminium Production = 1.5000 x Aluminium Production (ton)

2) CH_4 Emission (ton)

- CH_4 Emission for Carbon Black Production = 0.0110 x Carbon Black Production (ton)
- CH_4 Emission for Methanol Production = 0.0020 x Methanol Production (ton)

3) N_2O Emission (ton)

- N_2O Emission for Acid Nitric Production = 0.002 x Acid Nitric Production (ton)

4) CF_4 Emission (ton)

- CF_4 Emission for Aluminium Production = 0.0014 x Aluminium Production (ton)

5) C_2F_6 Emission (ton)

- C_2F_6 Emission for Aluminium Production = 0.00014 x Aluminium Production (ton)

6) SF_6 Emission (ton)

- SF_6 Emission for Aluminium & Magnesium Production = 0.01 x SF_6 Contained in the Existing stock of Equipment in year t + 0.7 x Quantity in Equipment Macnufactured in the year t-30

3. GHG EMISSION

3.1 Historical

The yearly Large and Medium Manufacturing Statistics of the Indonesian Statistical Bureau (BPS) is used for estimating production of industrial process. Based on the emission coefficient supplied by IPCC and production level of various the industries, the emissions of CO_2, CH_4, N_2O, and PFC (CF_4 and C_2F_6) for 1990 – 1995 were estimated.

The results are shown in Table 1 and Table 2. The largest source of CO_2 emissions was the cement industry. CO_2 emissions from cement, ammonia and steel production accounted for almost 94 percent of total CO_2 emissions in 1994.

Table 1. CO_2 Emission by Type of Industry 1990 – 1995 (Tg)

Industries	1990	1991	1992	1993	1994	1995
Mineral Product	8.44	8.61	9.26	10.21	11.82	8.44
Cement	7.87	8.05	8.61	9.44	10.92	7.87
Lime	0.45	0.41	0.54	0.63	0.58	0.45
Limestone use	0.05	0.02	0.08	0.09	0.24	0.05

Table 1. (continued)

Industries	1990	1991	1992	1993	1994	1995
Dolomite use	0.03	0.01	0.00	0.01	0.02	0.03
Soda Ash use	0.04	0.12	0.03	0.05	0.07	0.04
Chemical Industry	4.88	4.79	4.75	4.91	4.88	4.88
Gas for Ammonia	4.86	4.77	4.73	4.89	4.86	4.86
Calcium Carbides	0.02	0.02	0.02	0.02	0.02	0.02
Metal Product	0.97	1.29	1.80	2.23	2.42	0.97
Iron & Steel	0.68	1.02	1.51	1.92	2.08	0.68
Aluminum	0.29	0.26	0.28	0.31	0.34	0.29
T o t a l	**14.29**	**14.69**	**15.56**	**17.34**	**19.12**	**14.29**

Source: Estimated

Table 2. CH_4, N_2O, CF_4, C_2F_6 Emission in Industrial Process 1990-1995 (Gg)

Emission Sources	1990	1991	1992	1993	1994	1995
CH_4 Emission	**0.46**	**0.43**	**0.32**	**0.46**	**0.51**	**0.40**
Carbon Black	*0.06*	*0.05*	*0.08*	*0.07*	*0.13*	*0.11*
Methanol	*0.40*	*0.38*	*0.24*	*0.39*	*0.37*	*0.29*
N_2O Emission	**0.01**	**0.01**	**0.01**	**0.06**	**0.01**	**0.12**
Nitric Acid	*0.01*	*0.01*	*0.01*	*0.06*	*0.01*	*0.12*
CF_4 Emission	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Aluminum	*0.27*	*0.25*	*0.26*	*0.29*	*0.31*	*0.33*
C_2F_6 Emission	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
Aluminum	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*

Source: Estimated

3.2 Projection of emissions

Future GHG emissions are estimated using the production of the 21 industrial groups presented as the output of the MACRO (Macro Economy) Model, BPPT. Table 3 shows production growth rates for those industries that will produce GHG emission during the industrial process. The GHG emissions projections shown in Table 4 were derived using these production projections.

Table 3. Growth rate of Industrial Product 1995 – 2025

Industries	Growth rate (%)						
	1995	2000	2005	2010	2015	2020	2025
Agriculture	1.2	-4.4	2.9	3.2	3.7	3.9	4.0
Food	3.4	-5.6	2.7	3.8	4.1	4.2	4.2
Textile	-17.1	-22.0	3.4	3.7	5.4	6.3	6.4
Wood	1.9	2.2	3.2	3.4	4.6	5.5	6.0
Paper	-5.1	-1.9	3.2	4.1	4.9	5.1	6.0
Chemical	8.9	-7.9	2.3	6.7	5.9	6.6	7.2
Non Metal	15.7	2.7	4.6	6.0	6.5	6.5	6.5
Machine	-3.2	-0.7	3.9	4.3	4.7	5.4	5.9
Cement	-0.2	-0.7	3.2	4.1	5.1	6.1	7.9
Fertilizer	-0.5	-2.3	1.1	2.0	3.6	4.0	7.3
Iron & Steel	-18.9	-0.2	5.1	6.0	6.2	6.0	7.3
Aluminum	3.0	-1.0	5.6	5.3	3.3	3.2	0.1

Source: Estimated

Table 4. Projection of CO_2 Emission by Type of Industry (Tg/Year)

Industries	CO_2 Emission Projection by Industrial Process and Year (Tg)						
	1995	2000	2005	2010	2015	2020	2025
Mineral Product	**12.4**	**12.5**	**12.9**	**13.4**	**14.1**	**15.0**	**15.9**
Cement	*11.5*	*11.7*	*12.0*	*12.5*	*13.2*	*14.0*	*14.8*
Lime	*0.7*	*0.6*	*0.6*	*0.7*	*0.7*	*0.7*	*0.8*
Limestone use	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Dolomite use	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Soda Ash use	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Chemical Industry	**5.2**	**5.1**	**5.1**	**5.2**	**5.4**	**5.6**	**5.8**
Gas for Ammonia	*5.2*	*5.0*	*5.1*	*5.2*	*5.4*	*5.6*	*5.8*
Calcium Carbides	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Metal Product	**2.4**	**2.4**	**2.6**	**2.8**	**2.9**	**3.1**	**3.3**
Iron&Steel	*2.1*	*2.1*	*2.2*	*2.3*	*2.5*	*2.7*	*2.8*
Aluminum	*0.3*	*0.3*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
Total	20.0	20.0	20.6	21.4	22.4	23.7	24.9

Source: SME-ROI, 1999 (c)

The projection of GHG emissions (comprising CO_2, CH_4, N_2O, CF_4 and C_2F_6) from industrial processes can be estimated as shown in Table 5. CO_2 emissions will increase by an average of 0.76 percent per year over the period. The majority of CO_2 emissions still come from the cement, ammonia, steel, lime and aluminum industries.

Table 5 Projection of CH_4, N_20, CF_4, and C_2F_6 Emissions (Gg/Year)

Emission Sources	1995	2000	2005	2010	2015	2020	2025
CH_4 Emission	**0.4560**	**0.4180**	**0.4200**	**0.4250**	**0.4300**	**0.4360**	**0.4430**
Carbon Black	*0.0984*	*0.0795*	*0.0815*	*0.0865*	*0.0915*	*0.0975*	*0.1045*
Methanol	*0.3576*	*0.3385*	*0.3385*	*0.3385*	*0.3385*	*0.3385*	*0.3385*
N_2O Emission	**0.0114**	**0.0098**	**0.0100**	**0.0107**	**0.0113**	**0.0120**	**0.0129**
Nitric Acid	*0.0114*	*0.0098*	*0.0100*	*0.0107*	*0.0113*	*0.0120*	*0.0129*
CF_4 Emission	**0.2840**	**0.3227**	**0.3674**	**0.3888**	**0.4013**	**0.4018**	**0.4018**
Aluminum	*0.2840*	*0.3227*	*0.3674*	*0.3888*	*0.4013*	*0.4018*	*0.4018*
C_2F_6 Emission	**0.0284**	**0.0323**	**0.0367**	**0.0389**	**0.0401**	**0.0402**	**0.0402**
Aluminum	*0.0284*	*0.0323*	*0.0367*	*0.0389*	*0.0401*	*0.0402*	*0.0402*

Source: Estimated

4. RESULT ANALYSIS

4.1 Total of GHG Emissions

The largest of CO_2 emissions of industrial process was the cement industries, followed by ammonia, steel, lime and aluminium. Estimations of total GHG emissions (given as CO_2 equivalents) by industrial processes are shown in Tables 6. While the projection of CO_2 and CO_2 Equivalent in Industrial Process in 1995 – 2025 (Gg/Year) is shown in Table 7.

Table 6. CH_4, N_2O, CF_4, C_2F_6 Emission during Industrial Process 1990-1995

Emission Types	CO_2,CH_4, N_2O, CF_4, S_2F_6 Emission (Gg)				
	1990	1991	1992	1993	1994
CO_2	14,286	14,687	15,815	17,343	19,119
CH_4 as CO_2-e	10	9	7	10	11
N_2O as CO_2-e	4	1	2	18	3
Total CO2-e	14,300	14,697	15,824	17,370	19,132

Source: Estimated

Total CO_2-e emissions (CO_2, CH_4 & N_2O) are predicted to grow from approximately 14.3 Tg in 1990 to about 25 Tg by 2025. Most GHG emissions from industrial processes come from Per Fluorinated Hydrocarbons (PFCs) in the form of Tetra Fluoride (CF_4); however, to allow for comparison with the emissions from the other sector CO_2-e here only comprise CO_2, CH_4 & N_2O.

Table 7. Projection of CO_2 and CO_2 Equivalent in Industrial Process in 1995 – 2025 (Gg/Year)

Emission Types	Projection of CO_2 and CO_2 Equivalent in Industrial Process(GWP)						
	1995	2000	2005	2010	2015	2020	2025
CO_2	20,028	19,967	20,575	21,386	22,447	23,655	24,939
CH_4 as CO_2-e	10	9	9	9	9	9	9
N_2O as CO_2-e	11	10	10	11	11	12	13
Total CO2-e	20,049	19,986	20,593	21,406	22,467	23,676	24,961

Sources: Estimated

4.2 Mitigation Option

4.2.1 Mitigation Option in Pulp & Paper Industry

Most pulp and paper industries take advantage of the combustibility of wood waste, thus, energy used for the production is recovered energy rather than purchased energy. The energy goes mainly to the boilers to produce steam in the process. Possible mitigation options in pulp and paper industries are briefly explained below.

Installing a new technology by combining black liquor gasification with gas turbine co-generation could replace the traditional recovery boilers, increase the energy recovery rate and partially replace the steam boiler. The steam can be used to produce electricity in steam turbine plants with an estimated overall efficiency of 23 percent.

Alternatively, economizers or preheaters for boilers operated with a flue gas temperature greater than 218 °C could be used. The potential energy saved by using the economizers or preheaters is about 88 MJ per ton of paper production.

Other options include propagation of the technology for paper sludge and solid waste utilization (energy efficiency). An Indonesian AIJ project is using this technology. Construction of a pilot incineration plant was finished in January at PT. Fajar Surya Wisesa, a pulp and paper plant with output capacity of 500,000 t per year. The recovered steam will save approximately 9000 tons of crude oil per year. This energy saving in turn leads to reductions of approximately 9000 t per year of CO_2, and 3200 t per year of methane (which would otherwise be generated from the land filed solid wastes).

Using co-generation for the combustion of waste in pulp and paper mills is another option. Energy conservation in Thai Kraft pulp and paper plant with a pulp and paper output capacity of 440,000 tons per year claimed to reduce the consumption of crude oil by approximately 6,000 tons per year. This leads to a reduction in CO_2 emissions by 23,000 tons per year, and reducing methane emission by 3,100 tons per year.

Another alternative is the installation of continuous pulp digester units, which are more economical if applied in mills with a capacity of at least 630 to 730 tons per day of paper product. A conventional batch digester requires about 42 percent of steam and 50 percent of electricity.

Details of the mitigation options for the pulp and paper industry are presented in Table 8.

Table 8. Cost Data for GHG Mitigation Option in Pulp & paper

Option Technology	Capacity	Electricity Generation	Steam per ton of pulp	Estimated cost for the average system	Annual saving for an average system	Estimated Primary Energy Savings	Invest. cost	GHG Reduction 10^3 t CO2 per annum
Existing Process	n. a	n. a	n. a	n. a	n. a	n. a	n. a	n. a
Installing a new technology Black liquor gasification combined with gas turbine Cogeneration	n. a	n. a	n. a	n. a	n. a	n. a 1.477 GJ per ton pulp	n. a	n. a
Using economizers or pre-heaters for boilers Install Cogeneration systems in existing boiler		Approximately 97 TWh				1076 TJ	16 MW (two gas turbine units install) 7.6 million US$ (Cost: 8.6 US$/ t CO_2)	64 (year operation: 14) (fuel saving: 14700 tons)
Propagation of the utilization technology of paper sludge and solid waste Waste incinerator plant/fuel switching , Samarkand (400 thousand tons of municipal wastes per year							45 million US$ (Cost: 17 US$/ t CO_2)	175 (year operation: 15)

Table 8. (countinued)

Option Technology	Capacity	Electricity Generation	Steam per ton of pulp	Estimated cost for the average system	Annual saving for an average system	Estimated Primary Energy Savings	Invest. cost	GHG Reduction 10^3 t CO2 per annum
To dispense the technology of heat from the combustion Black liquor gasification (Swedish pulp mill commercial)		1,630 kWh	9.495 GJ	$100 million	$20 million	5.275 GJ per ton pulp	n. a	n. a
Purchasing and installation Continuous Pulp Digester Unit	630-730 t/day	50% of electricity required by conventional batch digester	42% of steam required by conventional batch digester	50 million $92; 18 $92 per m tonne pulp for electricity and other fuels	Slight operating cost savings from higher throughput, maintenance is similar to batch systems	Carbon emissions none	n. a	n. a

Source: Klarer 1999, STAPPA-ALAPCO 1999

4.2.2 Mitigation Options in Textile Industry

Electricity for the textile industry is supplied from captive power (diesel oil and fuel oil) and PLN. In general, textile industry processes comprise spinning, weaving, dying and printing. The spinning process uses electricity for fibre production. Then the fibre is woven, dyed, and printed by using electricity and steam to produce actual textile fabric. Total electricity consumption needed to produce 2,100 balls of textile is about 1.8 - 1.9 GWh.

The main mitigation options available to the textile industry are fuel switching (from captive power to low-carbon fossil fuels) and installation of co-generation systems. The latter could increase the energy recovery rate and partially replace the function of the steam boiler. Steam can be used to produce electricity in steam turbine plants with an estimated overall efficiency of 23 percent. Table 9 shows the cost of mitigation options in the textile industry. The table presents economic and technical characteristic of the options.

Table 9. Cost Data for Mitigation Option in Textile Industry

Type of Mitigation Option	Total cost (also M&O)	Life Time	CO_2 reduced	Cost (US$/t CO_2)
Switching the type fuels for captive power to use low-carbon fossil fuels (heavy fuel oil to natural gas, industrial energy 3MW in Mincovna a.s Kremnica)	1) 1164,000 US$ 2) 43,000 US$ (cost of JI component	20 years	AIJ (Activities Implemented Jointly) component: 300 t/a	7.65
Installing cogeneration system: Two gas turbines unit (16 MW), reconstruction of heating system in Tashkent	7600,000 US$	14 years of operation	64 t/a (fuel saving 14700 t)	8.60

Source: Klarer 1999

4.2.3 Mitigation Options in Cement Industry

Hydraulic cement, including portland, compound, and natural cement, is powder formed by heating limestone, sand, clay, and other materials in a kiln. Generally two types of cement processing are used: the wet process (uses slurry of raw materials during grinding and blending), and the dry process (uses dry materials), but in Indonesia the dry process is more commonly used. The largest energy consumer in portland cement production is the kiln. The production of portland cement contributes CO_2 emission to the atmosphere due to energy use and the freeing of carbon from the limestone. Mitigation options in cement industry include improvements in energy efficiency and changes in product specification.

Improvements in energy efficiency could be carried out through changes in the kiln process, such as converting from dry to precalciner processes. The pre-heater could be coupled with the precalciner, integrated between the kiln and the pre-heater. The precalcinator is a burner chamber, in which 80 to 90 percent of the calcium carbonate can be dissociated before entering the kiln, thus reducing energy consumption by 5 to 10 percent. The addition of a precalciner will generally increase the capacity of the plant, and reduce the specific fuel consumption. Overall, a preheater system can reduce energy consumption, and CO_2 emissions by 11 to 15 percent.

Blended cements have lower emissions and use less energy because clinker use is reduced. For each percent of clinker that is replaced, a corresponding reduction in GHG emissions of approximately 1 percent will be obtained. The prices are still lower than the cost of producing clinker, which are estimated at approximately US$ 30 to 36 per ton in the United States (see Table 10).

4.2.4 Mitigation Options in the Starch/Tapioca Industry

The process of making tapioca from cassava is basically a mechanical process. The tapioca can be utilized as raw material in chemical industries to produce glucose (by hydrolysis process), high fructose syrup (by isometric process), alcohol, acetic acid, acetone, nitrate acid, lactate acid, monosodium glutamate, itaconate, and glycerol. In the production process both liquid waste (wastewater) and solid wastes (wet pulp and dry pulp) are produced. The total amount of waste depends on the capacity of industry and technology, the chemical characteristics of the materials, and the technology used in that industry. Mitigation options in this industry include:

Table 10. Cost of Mitigation Options in Cement Industry

Technology Option	Changes in product specifications		Improvements in energy efficiency	
	Dry Process	Blended Cement	Multi Stage Pre heater	Precalciner
Fuel Saving (GJ/t)	2.0	n/a	0.4	0.4
Electricity Savings (kWh/t)	9.0	0.0	0.0	0.0
Primary Energy Savings (GJ/t)	1.9	n/a	0.4	0.4
Annual Operating Cost Savings ($/t)	Savings	Savings	Savings	Savings
Capital Cost ($/t of capacity)	133.0	n/a	30.0-40.0	25.0
Specific NO_x Emission Reduction (Kg/t)	0.9	n/a	0.2	0.2-0.3
Carbon Emission Reduction (kg CO_2/t)	330	n/a	75	75

Source: Environment 1991b

- Utilization of biogas from methane reactor in flash dryer for wet pulp dry and starch dryer;
- Improved waste management in tapioca plants.

For example, a tapioca industry in Ponorogo, East Java with a capacity of 200 tones tapioca per day and inputs of cassava of about 800-1000 tones per day produces solid waste of 300-350 tones per day. Waste from the industry results in GHG emissions, especially CH_4, equivalent to 61,635 tones of CO_2 per year. Solid waste generates 1,331 ton of CH_4 emissions per year; wastewater generates 1,604 tones of CH_4 per year. The fuel (heavy oil) used in starch drying generates 7,467 tones of CO_2 emissions per year. Total CO_2 emissions from this tapioca mill are equivalent to 69,102 ton of CO_2 per year. It is estimated that waste treatment can reduce GHG emissions from the tapioca industry.

4.2.5 Mitigation Option in Sugar Industry

Processing sugar cane into sugar involves several stages. First, the canes are crushed to extract their juice, which is then screened to extract fibre, soil and other undesired materials. The juice is then refined to produce sugar. In Indonesia, three refining processes are commonly used:

- Defection process to produce raw sugar: the juice is heated and defecated with lime to free the juice from impurities.
- Sulphitation process to produce refined sugar: lime and sulphur are used as the cleansing materials. The raw juice is mixed with lime and is later neutralized with sulphur.
- Carbonation process to produce refined sugar: lime and carbon dioxide are used. Carbon dioxide works to dissolve the excess lime in the form of calcium carbonate, which in turn absorbs non-sugar materials. The carbonation process also uses cokes to evenly spread the temperature during the firing. Coke requirement is estimated at 8 to 10 percent of the weight of lime used.

Evaporation of juice, the crystallizing of the sugar, and granulating of the crystal sugar follow the refining process. These processes use steam and boiler-generated electricity. In general, conventional boilers are still used in sugar factories in Indonesia. They often have difficulty getting spare-parts. The boiler is operated manually. Feedback control systems are not used yet. The boilers used in sugar factories in Indonesia need to be modernized to increase the efficiency of the factory.

A modern cane sugar factory, producing raw sugar and designed for fuel economy (bagasse), would require 30 kWh of power and 300 kg of exhaust steam per ton of cane. Under these conditions 50 percent of the bagasse produced will be surplus and can be used for electricity generation. With an efficient medium pressure bagasse fired boiler and condensing turbo-alternator one metric ton of bagasse (at 50 percent content) can generate about 450 kWh. Mitigation options in this industry included the following:

- Improving boiler design, using low GHG emission and low cost fuels such as bagasse.
- Utilization of co-generation.

Co-generation will increase overall (heat) efficiency of the boiler from 50-60 percent to 80-85 percent. This technology will provide steam and electricity at the same time. High-pressure steam from a steam generator flows to a backpressure turbine to generate electricity. Thereafter, medium pressure steam coming from the turbine can be utilized as a source of heat for processing purposes. Data on mitigation options in the sugar industry are presented in Table 11.

Table 11. Cost of Mitigation Options in Sugar by Utilization of Cogeneration

Type of Mitigation Option	Total cost (Invt. & O&M)	Life Time	CO_2 reduced	Cost (US$/t CO_2)
Installing cogeneration system: Two gas turbines unit (16 MW), reconstruction of heating system in Tashkent	7.6 million US$	14 years of operation	64 t/a (fuel saving 14700 t)	8.60

Source : Klarer 1999

4.2.6 Mitigation Options in the Palm Oil industry

Palm oil is produced in palm oil mills. The main by-products of the palm oil production process are empty fruit bunches (EFB), palm oil mill effluent, fibers, shell, boiler ash and clinker. Empty fruit bunches used to be incinerated at the mill to produce an extremely alkaline bunch ash. As the incineration causes air pollution, this practice has been discontinued. Instead, empty fruit bunches are now widely used as mulch and organic fertilizer for oil palm and other crops. Every tonne of oil produced creates 2.5 tones of palm oil mill effluent, which has an average biochemical oxygen demand (BOD) of about 25,000 ppm. The BOD level must be reduced to below 100 ppm before treated palm oil mill effluent can be discharged into waterways. Treated palm oil mill effluent can be used as a fertilizer substitute. Other by-products from the effluent including sludge cake and biogas from anaerobic digestion are also treated in treatment plant. Biogas can be recovered from the anaerobic closed tank digester. A 60 tonne EFB per hour oil mill is capable of producing about 20,000 cubic meters of biogas per day. This could generate about 1 MW of electricity continuously. Fibre and kernel shell are currently the main sources of energy in the palm oil mill. Their combustion in boilers produces more than sufficient energy to meet the oil mill's energy demand. Excess energy is used for domestic consumption in the plantation, while surplus shell is normally used for roof surfacing. Burning of fibre and shell produces small quantities of boiler ash and clinker. Mitigation options in this industry are:

- Improving waste management.
- Improving digester technology.
- Improved boiler technology.

Data on these mitigation options are presented in Table 12.

Table 12. Cost of Mitigation Option in Palm Oil

Type of Mitigation Option	Invest.cost (million US$)	Years of operation	GHG reduction (1000 t CO_2/a)	Cost (US$/t CO_2)
a) Waste management	n/a	n/a	n/a	n/a
b) Improving the technology of digester	n/a	n/a	n/a	n/a
c) Improving the boiler technology.	(fuel saving 189000 tons)	n/a	185	1.6
Boiler improvements, installation of boilers, burners and control equipment;	219			
Enterprise for construction of boilers and production of burners.	143			15.6

Source: Klarer, 1999

5. CONCLUSION

Manufacturing and industrial sector processes release GHGs such as CO_2, CH_4, N_2O, and SF_6. CO_2 is the major pollutants from the industries. The largest source of CO_2 emission is the cement industries.

The GHG emitted in the carbon black and methanol production is CH_6 and the emission from Aluminium industrries are CF_4 and CF_6 . Most of GHG emission from industrial sector is Perfluorinated Hydrocarbons (PFCs) in form of Tetra Flouride (CF_4), this gas emitted from the aluminium process. While N_2O emission source in the industrial process is only coming from the nitric acid industry.

Technologies such as *electric motor drives, heating*, and *evaporation* have been used in many industries, and offer opportunities for large energy savings and GHG emission reductions. Total costs for these technologies vary, depending on the application, configuration of the system, and size of the system.

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MARGINAL ABATEMENT COSTS

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Abstract

Some GHG migation option technologies are compared with a base case technology. There are two different base cases applied, i.e. coal as energy source, and average energy mix in 2000. The abatement cost is obtained by subtracting the costs associated with the mitigation technologies from the costs of the base case technologies and then dividing the number by the different between the GHG emission of the base case technology and that of the mitigation technologies. Then, the abatement cost will be ranked and presented in aggregate marginal abatement cost curve.

1. INTRODUCTION

BPP Teknologi is responsible for the assessment, demonstration and implementation of technology. New cost effective technological solution can be expected from research and development activities of the international community of nations coping with the greenhouse gas (GHG) issue.

Reducing GHG emissions in the energy sector would require more efficient technologies than those currently used or expected to be used in the future. The use of resources and the mix of installed and utilized technologies should change for achieving a specified level of emission reduction and what costs will be incurred. Many of the technological options for GHG emission reduction will prove to be suitable for coping with other urgent policy issues such as fuel diversification, supply security, environment protection and cost-effectiveness.

The cost of installing new technologies to reduce emissions (either by new installation or retrofit) compared with business-as-usual costs (the 'base case') is usually termed the abatement cost.

2. METHODOLOGIES

The abatement costs for mitigation options in Indonesia's energy sector will be estimated using two different base cases:

1) assuming the use of coal as energy source; and

2) 2) average energy (source and technology) mix in 2000.

The costs for all mitigation options that can be applied in Indonesia are calculated by using data collected from a range of sources, as comprehensive and comparable data does not exist. Where data were unavailable, reference data (i.e., global standard data) were used.

For some technology options, the calculated abatement costs have been compared to the costs calculated using MARKAL modeling tool. MARKAL takes a system-wide approach, and takes into account macro economic parameters and the costs associated with utilization of the mitigation technologies such as fuel transportation costs, etc. The comparison seeks to highlight the differences between macro and micro approaches affect project economy, and calculation of GHG emissions reductions.

3. PROJECT-BASED ABATEMENT COSTS

Unlike the MARKAL model, project-based abatement cost calculates associated costs such as transport and transmission costs. Associated costs estimated for each technology/project are an average, typical value only; actual cost would almost certainly be different. For example, geothermal associated costs would be site specific, ranging from 6-8 cents$/kWh, depending on type used, such as steam generated, steam treatment, and well condition.

The mitigation options/project types are selected from assorted mitigation technologies that have high potential for application in Indonesia. These options are presented in three categories, i.e. energy supply sectors, energy demand sectors, and 'other mitigation options' category.

A coal power plant with a capacity of 600MW is used as the first base case. The second baseline is the average energy mix in 2000. Associated costs for each mitigation technology are calculated in terms of unit cost per unit output (US$/kWh).

Total potential CO_2 reduction from the energy supply and demand sectors up to end of study period is estimated by using information in the following subsections.

3.1 Co-generation

Currently utilization of co-generation in industries in Indonesia is very limited. However, it is expected that in the future co-generation practices will increase, particularly in industries like pulp and paper, textile and sugar. Reduction of fuel subsidies that leads to fuel prices increase will contribute to increased the use of co-generation. In this exercise two categories of steam are treated, i.e., steam with temperature > 450° C (HT:High Temperature Co-generation) and steam with temperature between 130 °C – 200 °C (LT: Low Temperature Co-generation). Considering that small and medium scale industries are more numerous than large-scale industries, and that investment cost of low temperature steam (2218 US$/kW-el) is lower than that of high temperature steam (4690 US$/kW-el) the opportunity for LT steam application is greater[3].

According to the output of the MARKAL BPPT-GTZ study (1995), before the economic crisis the maximum potential of cogeneration from HT steam in Jawa and outside Jawa was 20 percent and 10 percent of the total demand for HT in Indonesia respectively. Meanwhile, the cogeneration potential from LT steam in Java and outside Java was 30 percent and 15 percent of the total demand for LT in Indonesia respectively. In this exercise, taking the effect of economic crisis into account, it is assumed that co-generation will start in 2005 when it will account for 30 PJ or 10 percent of the total indirect heat generation in Indonesia. By 2025 the figure will rise to 251 PJ or 25 percent. The assumed ratio of HT: LT is approximately 40 : 60 percent.

3.2 Electric Motors

In 1995 energy consumption by electric motors was estimated at 118 PJ; by 2025 the energy consumption is projected to reach 480 PJ. A more efficient electric motor (electric drive) is introduced and will account for 50 percent of all electric motors used. In this exercise the maximum possible number (taken as equal to the number of variable motor used) is used.

3.3 Solar Thermal

It is assumed that solar collectors will replace conventional heaters used for heating water. A study carried out by BPPT-GTZ predicted that, by 2000, 0.81 percent (0.06 PJ) of the total warm water needs would be met by solar collectors. The figure was forecast to increase gradually, reaching 6.71 percent (1.8 PJ) by 2025.

3.4 Efficient Light Bulbs

Three technology types have identified: the Standard Fluorescent Lamp (SFL); the Compact Fluorescent Lamp (CFL); and the Advanced Compact Fluorescent Lamp (ACFL). Two studies have analyzed the use of these technologies: PLN (State Electricity Company) - Arkonin Engineering Manggala Pratama, and the BPPT-GTZ study. Both studies conclude that not all incandescent lamps would be replaced by efficient light bulbs.

3.5 Hydro Power (Large and Small)

The national potential of mini hydro is 0.460 GW, and large hydro is 75 GW (DGEED 1995). Due to technical and economic constraints, not all of the potential can be realized. It is estimated that 0.03 GW of mini hydropower would be realized by 2005, increasing to 0.3 GW 2025 (i.e., about 65 percent of potential). For large hydro, the predicted figures are 0.14 GW and 0.42 GW by 2005 and 2025 respectively. The main limiting factor for small hydropower is remoteness of location.

3.6 Gas Combined Cycle and Gas Turbines

Gas reserve is estimated at 112 Trillion Cubic Feet (TCF). Gas is used domestically and is also exported to ASEAN countries. Gas Combined Cycle (GCC) capacity is expected to increase from 2.44 GW in 1995 to 5.14 GW in 2025 in the base case scenario. Due to strong competitions with other technology options, it is assumed that the additional capacity of new gas combined cycle and gas turbines are 0.1 GW and 0.2 GW respectively by the end of the period.

3.7 Geothermal Power Plants

The potential of geothermal energy in Indonesia is estimated at 20.3 GW, comprising reserves (8.7 GW) and unidentified resources (11.6 GW). Out of the 8.7 GW reserves, only 1.1 GW represent proven reserve, including those that have been developed to date (0.790 GW current installed capacity, API data).

Geothermal power plants have good potential for CO_2 emission reduction. For the purposes of our calculations it has been assumed that geothermal power plants will be developed in stages to reach capacity of 5 GW by 2025. The assumption is based on the fact that the current module of geothermal power plant development is of 55 MW unit; also development of geothermal energy in Indonesia would face strong competition from energy sources such as gas and oil. The later alternatives have the advantage of simpler arrangement for their development, i.e., only two parties, project developer and electricity buyer (i.e., PLN), are involved. Development of geothermal power, on the other hand, would involve three parties: Pertamina as the steam owner, the project developer, and the electricity buyer.

Illustrative of the difficulties facing development of geothermal power in Indonesia are the figures for expected and realized capacity for 2000: 1.2 GW and 0.79 GW respectively. The 2005 target of 2.03 GW install capacity (API, 2000) is unlikely to be reached.

3.8 Biomass Power Plants

Biomass is mostly used to fulfill the household needs, especially in rural areas. Currently only a very small fraction of biomass is used for electricity generation, and this phenomena is expected to continue.

For our analysis it is assumed that no net atmospheric CO_2 build-up accrues from using sustainably grown biomass for power generation; thus, emission from biomass power plants is taken as zero.

3.9 New Coal Power Plants

Indonesia has a large amount of coal resources, but maximum utilization is impeded by the fact that it is not an environmentally benign fuel (coal emission factor is 26.2 ton carbon/TJ coal). Hence even though the generation of electricity from coal is relatively cheap (US$ 0.052/kWh), the expansion of use will be limited.

3.10 Refrigerators

In the base case scenario the improved refrigerators are used with an assumed efficiency of 1. For mitigation options, higher efficiency refrigerator technology is introduced (eff. = 1.54 through 1.98), hi-tech refrigerator technology (eff. =2.38), compact refrigerator (eff. = 2.78), and compact panel refrigerator (eff. = 3.65) [3].

4. RESULT ANALYSIS

4.1 Supply side

Using available costing data and the information above a variety options for reducing CO_2 emissions in the energy supply sector were reviewed. The cost of each option and the potential emission reduction are given in Table 1 and Table 2.

By using the average energy mix in 2000 as the baseline, potential CO_2 emission reduction is significantly reduced. This is presumably due to the larger portion of gas-fired plants in the energy mix composition. For the most part, the cost of abatement also changes significantly depending on the baseline used. While the 'average energy mix' is a probably a more realistic baseline, using it will be probably reduce the interest of project promoters and investors.

Table 1. Abatement Cost and Potential CO2 Reduction by 2025 for Energy Supply Mitigation Options – Base: Coal Steam Power Plant

Technology Option	CO2 reduction (kg/kWh)	Additional cost ($/kWh)	Abatement cost ($/ton CO2)	Capacity (GWh)	Total CO2 reduction (Mill. tons)
Coal steam PP	0.0	0.0		126,144	-
Gas Gas Turbine	0.325	0.0089	27.48	6,570	2.0
Geothermal PP	0.816	0.0280	30.58	258,157	237.0
Gas Combined Cycle	0.398	-0.0126	-31.62	6,132	2.4
Biomass Steam PP	0.916	0.0413	45.08	43,099	39.5
Hydro PP	0.916	-0.0135	-14.73	18,396	16.9
Mini Hydro	0.916	-0.0126	-13.79	9,855	9.0
Solar Thermal	0.916	0.0859	93.74	500	0.5
Cogeneration LT	0.688	-0.0054	-7.81	41,834	28.8
Cogeneration HT	0.688	0.0257	37.39	27,889	19.2

Note: Generation cost for coal power plant as the base is 0.0517US$/kWh, while its emission factor is 0.916 kg CO_2/kWh.

Table 2. Abatement Cost and Potential CO2 Reduction by 2025 for Energy Supply Mitigation Options – Base: Average Energy Mix 2000

Technology Option	CO_2 reduction (kg/kWh)	Additional cost ($/kWh)	Abatement cost ($/ton CO2)	Capacity (GWh)	Total CO2 reduction (Mill. tons)
Coal steam PP	-0.376	-0.0012	3.23	126,144	-47.0
Gas Gas Turbine	-0.051	0.0077	-150.79	6,570	0.0
Geothermal PP	0.540	0.0268	49.64	258,157	139.4
Gas Combined Cycle	0.022	-0.0138	-629.11	6,132	0.1
Biomass Steam PP	0.540	0.0401	74.25	43,099	23.3
Hydro PP	0.540	-0.0147	-27.25	18,396	9.9
Mini Hydro	0.540	-0.0139	-25.65	9,855	5.3
Solar Thermal	0.540	0.0847	156.81	500	0.3
Cogeneration LT	0.312	-0.0066	-21.15	41,834	13.0
Cogeneration HT	0.312	0.0245	78.64	27,889	8.7

Note: Generation cost for energy mix 2000 as the base is 0.0529US$/kWh, while its emission factor is 0.54 kg CO_2/kWh.

4.2 Demand Side

On the demand side, unique baselines are assigned for each technology option. For example, all refrigerator technologies listed in Table 3 are compared with the current most popular 'better efficiency' refrigerators (electricity consumption of 324 kWh/y in replacement of the more conventional ones with 500 kWh/y).

Emission reductions are calculated based on the electricity saved as a result of using the better technology option, relative to baseline cases. Additional costs are calculated as the difference in the investment costs and electricity consumption costs between the two corresponding technologies.

To estimate total potential CO2 reduction by 2025, the same capacity assumptions as described previously have been used. Estimates of abatement costs and potential reductions in CO2 emissions for the energy supply sectors relative to each of the two baselines are presented in Table 3 and Table 4.

Table 3. Mitigation Cost and Potential CO2 Reduction until 2025 for Energy Demand Mitigation Options – Base: Coal Steam Power Plant

Technology Option	CO2 reduction (kg/kWh)	Additional cost ($/kWh)	Abatement cost ($/ton CO2)	Capacity (PJ)	Total CO2 reduction (Mill. tons)
Improved Refrigerator	0.2036	0.0416	204.08	10.0	0.57
Hitch Refrigerator	0.3224	0.0826	256.22	12.0	1.07
Compact Refrigerator	0.4072	0.1359	333.59	3.5	0.39
Compact Panel Refrigerator	0.5289	0.2366	447.42	4.0	0.59
Incandescent to fluorescent (SFL)	0.5390	-0.0212	-39.38	21.0	3.14
Incandescent to CFL	2.6179	-0.0782	-29.88	90.0	65.00
Variable Speed Motor	0.1027	-0.0002	-2.06	480.0	13.70

Table 4. Abatement Cost and Potential CO2 Reduction until 2025 for Energy Demand Mitigation Options – Base: Average Energy Mix 2000

Technology Option	CO2 reduction (kg/kWh)	Additional cost ($/kWh)	Abatement cost ($/ton CO2)	Capacity (PJ)	Total CO2 reduction (Mill. tons)
Improved Refrigerator	-0.1200	0.0416	346.29	10.0	1.49
Hitch Refrigerator	0.1900	0.0826	434.76	12.0	0.63
Compact Refrigerator	0.2400	0.1359	566.06	3.5	0.23
Compact Panel Refrigerator	0.3117	0.2366	759.21	4.0	0.35
Incandescent to fluorescent (SFL)	0.3176	-0.0212	-66.81	21.0	1.85
Incandescent to CFL	1.5429	-0.0782	-50.70	90.0	39.00
Variable Speed Motor	0.0605	-0.0002	-3.49	480.0	8.10

Additional costs ($/kWh) for all refrigeration technology options as seen in the above tables are so high that if combined with the relatively small potential emission reduction, these options may not be favorable.

On the other hand, new variable speed motors and fluorescent lamps (both standard and compact) provide no-regret options.

4.3 Other Potential Mitigation Activities

This section will review other potential GHG mitigation options for Indonesia. To construct the aggregate abatement cost curves, only technologies on which there is sufficient information will be considered. One potential activity is energy industry. This activity includes Oil & Gas, Coal Power Plant and Advance Power Plants. Mitigation options that exist are:

- Improving natural gas distribution and reduction of gas flaring in oil & gas industry.
- Coal upgrading and capture of coal-bed methane, in coal fired power plants.

Apart from renewable energy, production processes in the energy industry are always related with GHG emissions. Future CO_2 emissions would depend on industrial output, structure of industrial growth, average energy intensity of specific products, and the fuel mix used in industry.

4.3.1 Mitigation Options in the Oil & Gas Industry

Improving the efficiency of the natural gas distribution system through the introduction of gas metering, control equipment and tariff rationalization could reduce the use of natural gas up to 20 percent. An alternative is to improve energy management. In general more efficient management of energy utilization and the crude distillation process could save between 3 and 15 percent of energy [7].

In Indonesia, approximately 5.6 percent of gas production is still flared, compared to < 3 percent in industrialized countries. Currently, the country flares approximately 4.98 billion m^3 of gas per year, roughly equivalent to 1 Mt of CH_4. Utilization this flared gas as a substitute other commercial fuels could reduce CO_2 emissions at little or no cost. In most offshore facilities in the country, the substitution technology has been adopted; thus, the potential remains with the onshore sites.

Detail information, including cost data for each mitigation option in oil and gas field (assosiate gas and non- assosiate gas), is given in Table 5. The assosiate gas is natural gas that produce in the oil plant.

Table 5. Cost Data for GHG Mitigation Option in Oil & Gas Fields

Mitigation Option	Annual gas flare (associated + non associated) (billion m^3)	Annual CO_2 reduction (million ton)	Saving of Energy Use (%)	Estimated Incremental Cost of mitigation (US$/t CO_2)
a) 1. Rationalization of Natural Gas tariff		1- 2	1-4	-
2. Introduction of gas metering				0.6
b) Improving the energy management	-	n. a	3-15	-
c) Utilization of flared gas from natural gas production; and d) Minimize the flaring of associated gas in offshore oil field to enhance energy conservation in oil and gas industry. The gas can be fully recovered, processed and transport for production use as a fuel.	4.8 (Indonesia Oil and Gas Statistics 1993-1998). Directorate General of Oil and Gas).	10.5	n. a	8.6

Sources: ALGAS 1998 and STAPPA-ALAPCO 1999

4.3.2 Mitigation options in coal-fired power plants

Coal upgrading is one of steps in coal preparation, which is carried out to meet demands of consumer and the recently more stringent environmental constraints. Coal preparation involves a process of grinding, sizing, and washing. The process should be carefully planned to avoid degrading the quality of the coal product. Poor coal handling may cause several environmental problems such as uncontrolled GHG emissions and other pollutants. GHG emissions may occur at the coal plant, during storage and transportation, or from direct combustion. The mitigation options that will be discussed here are

- Capacity Increment
- Process Management

Capacity Increment involves increasing coal preparation capacity and improving coal quality, which is expected to yield positive impacts both in terms of cost and environment. Improved preparation could also make transportation more efficient, saving up to of 5 percent of the rail system volume. However, changes in coal preparation processes are constrained by regulatory and institutional barriers, which limit the ability of coal buyers and sellers to negotiate coal quality and reflect quality in prices.

Process management involves the use of an integrated computer control system. Improved process management could reduce energy consumption by between 3 and15 percent. More detailed data is presented in Table 6.

Table 6. Cost Data of GHG Mitigation Options for Coal Upgrading, Coal Storage and Coal Transportation

Mitigation Option	Annually coal saving (billion m^3)	Capital Cost Based on 3 Mt/y run of mine (ROM) US$(1978)	Capital Cost/ton ROM Straight line depreciation of 10 years US$(1978)/ton	O&M Cost/ton ROM US$('78)/ton
a) Coal upgrading:				
Crushing & Screening for lignite/sub-bituminous;	-	6,800,000	0.23	0.10
Rotary breaker;	-	5,800,000	0.20	1.08
Coarse cleaning only;	-	12,000,000	0.40	0.25
Coarse and simple fines cleaning;	-	18,000,000	0.60	0.60
Coarse and fines cleaning and flotation closed circuit for bituminous;	-	25,000,000	0.83	1.00
Cleaning all sizes, fines crushing, multistage closed circuit for reduce environmental.	-	50,000,000	1.66	2.00
b) Process management	reducing energy consumption about 3-15%	-	-	-

Source: Osborne 1988

4.3.3 Mitigation Options in Coal Bed Methane

During underground mining operations methane is released while the coal layer is being cut. This methane is usually diluted by ventilation air before being released into the atmosphere. Less methane is released during strip mining, also called open cut or open cast mining.

Underground coal mining has been plagued for its entire history by the hazards of gas explosions. Explosions of what the miners called `firedamp' have been the cause of most of the worst disasters in coal mining history. Firedamp's main constituent is methane, the simplest of the alkane series of hydrocarbons. However, in recent years the methane in coal seams, rather than being seen as a hazard or, at best, a by-product of mining, has been considered as a resource in its own right.

Linked with CO_2 sequestration programs, is a technology called Enhanced Coal Bed Methane Recovery. CO_2 produced from mine mouth power plants or other sources is injected into the deep coal bed seam to produce more methane. The injected CO_2 is absorbed into the coal matrix and remains in the ground after completion of methane production. Options for further GHG mitigation are as follows:

- Utilization of de-gasified methane in boiler-house of the coal mine;

- Enhanced coal-bed methane recovery (CO_2 sequestration)

Table 7 provides detailed information on mitigation options in relation to coal mine and coal utilization.

Table 7. Cost Data of GHG Mitigation Option for coal bed methane

Mitigation Option	Total project capital costs (US$) (Pervomayskaj)	Estimated Incremental Cost (US$)	Project's technical Life time (year)	Total emissions reduction over the technical life time (ton CO_2)
a) Utilization of de gasified methane in boiler-house of the coal mine	1,702,000	460,000	10	1,796,200
b) Enhanced Coal bed Methane Recovery	n.a.	n.a	15 (appr).a	

Source: Atwood 1998

4.3.4 Mitigation Options in Power Plants

Large-scale power generation operations that use fossil fuels have an average power generation efficiency in the range of 35 to 50 percent. The efficiency determines the level of GHG emissions. Improving combustion efficiency or using advanced technology can increase the overall efficiencies of the power plants. The mitigation options for power plants are as follows:

- Improving the combustion efficiency or using advanced technology, such as *Integrated Gasification Combined Cycle* (IGCC), *Pressurized Fluidized Bed Combustion* (PFBC), Fuel Cell, or Gas Fired Combined Cycle.

- Fuel switching to low-carbon fossil fuels or nuclear power, and suppressing emissions.

New technology for improving combustion efficiency offers a considerable increase in conversion efficiency. The efficiency of conventional power generation can be increased to more than 60 percent in the longer term. The use of combined heat and power production also increases fuel conversion efficiency that will lead to a reduction of the energy input. The costs of using advanced technology are sometimes higher than the cost of reference technology, but it would significantly reduce CO_2 emissions. Taken as a rule of thumb, increasing one (1) percent of power generation efficiency would result in 2.5 percent reduction of CO_2 emissions.

In addition to improving combustion efficiency, the installation of new technologies such as fuel cell, nuclear power, and gasifier also have the potential to reduce CO_2 emissions. In the gasifier, CO_2 and hydrogen in gas produced from gasification are separated to obtain hydrogen used as fuel. After the separation, the hydrogen-rich fuel is burned in a combined cycle to generate electricity. The CO_2 emission factor of the fuel would be less than 15 kg CO_2/GJ, compared to 88 kg CO_2/GJ for coal.

Based on a demonstration scale, IGCC has an efficiency of 42 percent with total CO_2 emissions of 800 g CO_2/kWh. However, working with available technology, the IGCC has lower efficiency but captures more CO_2, or reduces emissions of CO_2. Efficiency is 36 percent, while the 75 g CO_2/kWh are emitted. Electricity production costs could increase by 30-40 percent, but removal costs of 19 $/t CO_2 would be avoided. The hydrogen from gas separation can also be used as a fuel in fuel cell to generate electricity. Therefore, this gasifier can be integrated with fuel cell.

Switching fuels from coal to oil or natural gas, and from oil to natural gas, can reduce GHG emissions. Switching from coal to natural gas would reduce carbon emissions by 20 per cent, if efficiency were kept constant. Of all fossil fuels, natural gas has the lowest CO_2 emission per unit of energy produced (50 kg CO_2/GJ). CO_2 emissions from oil combustion are about 75 kg CO_2/GJ, and the emissions from coal are about 90 kg CO_2/GJ. In general, the use of low-carbon fuels offers greater potential efficient emission reductions. The CO_2 emission equivalent released from a nuclear power plant is just 1/10 to 1/100 of that released from fossil fuel plants. Details on the GHG mitigation option in power plants is given in Table 8.

Table 8. Cost Data for GHG Mitigation Option in Power Generation

Power Generation Option	Investment cost/unit US$/MW	Reduction Potential (ton Co_2 eq/GJ) (kg Co_2 eq/MWh)		Marginal cost per unit output (US$/MWh)	Marginal cost per reduced GHG US$/t CO_2
a) Improving the combustion efficiency or using advance technology					
IGCC	1.5×10^6	0.02	61.5	6.70	100
PFBC			5	24.10	4.810
b) Fuel switching to low-carbon fossil fuels or nuclear and suppressing emissions					
LWR Nuclear	3.5×10^6	0.27	1000	- 5.36	- 5
LWFR Nuclear	3.5×10^6	0.27	1000	13.65	14
Gas Combined Cycle	5.2×10^5	0.15	550.4	- 4.53	- 8

Source: Algas 1998

Note: The reference technology of power plant is pulverized coal power plant.

4.4 Aggregate Marginal Abatement Cost Curve

The technology options listed in Table 9 are those considered to have the best potential for use in Indonesia. It is important to note that these figures are not projections or formal estimates from relevant authorities/ institutions. Most institutions do not have such estimates; many of them are not yet aware of the potential for GHG emission reductions or of the CDM. Furthermore, given the economic and political uncertainties facing Indonesia at the moment, even if certain institutions did have full information, it would be difficult for them to make any useful predictions.

The following data and assumptions underlie the data in Table 9.

- 10 percent of flared gas is associate gas and 50 percent of flared gas is released on offshore facilities. Therefore, only the 40 percent of gas flared onshore has potential for use over the 20 years from year 2005.

Table 9. Potential of other technology for GHG emission reduction

Mitigation Technology/Project Type	Mitigation cost* (US$/ton)	CO2 reduction (MT)
Utilisation of flared gas from NG production	8.5	84
Integrated Gasification Combined Cycle	100.0	4.9
Waste incineration/fuel switch in pulp & paper plant	17.0	7.0
Cogen&heating system reconstruction in textile industry	8.6	8.0
Improvement of waste management in starch factory	10.0	4.0
Boiler improvement in palm oil plant	21.6	14.0

Note: * reference values, taken from previous tables before

- Addition of 0.1GW per year, starting from 2005 until the end of period, is assumed for Integrated Gasification Combined Cycle.
- The mitigation cost for waste incineration/fuel switch in pulp and paper plant, is taken from the Samarkand case. In Indonesia, an AIJ project in Bekasi applying a similar technology has claimed that the activity could potentially reduce GHG emissions by up to 91,000 tones per year. The potential over the next twenty years assumes that five other pulp and paper plants of capacity 500,000 tones per year will implement the technology.
- The mitigation cost for co-generation and heating system reconstruction is based on the Tashkent case. Total capacity over the 20 years from 2005 assumes co-generation systems with equivalent capacity will be installed in twenty textile plants.
- A study on the improvement of waste management in starch factories suggests that 20,000 tons of CO_2-equivalent emission reduction could be achieved (Ponorogo starch plant). Mitigation cost is roughly estimated, and for the next twenty years it is assumed that 10 plants with a similar capacity will apply the technology
- With regard to boiler improvement in palm oil plants, including co-generation activities, it is assumed that boiler improvement/co-generation with capacity around 10MW will be applied in 10 large palm oil plants.

The marginal abatement costs of various technology options additional project types with respect to the coal baseline are presented in Table 10 and Figure1and Figure 2.

Table 10. Marginal Abatement Costs for Mitigation Options/Project Types – Baseline: Coal

	Mitigation Option/Project Type	Total CO2 reduction (Mio tons)	Abatement cost ($/ton CO2)
1	Incandescent to fluorescent (SFL)	3.10	-39.4
2	Gas Combined Cycle	2.40	-31.6
3	Incandescent to CFL	65.40	-29.9
4	Hydro PP	16.90	-14.7
5	Mini Hydro	9.00	-13.8
6	Cogeneration LT	28.80	-7.8
7	Variable Speed Motor	13.70	-2.1
8	Coal Steam PP	0.00	0.0
9	Utilization of flared gas from NG production	84.00	8.5
10	Cogen&heating system reconstruction in textile industry	38.00	8.6
11	Improvement of waste management in starch factory	4.00	10.0
12	Waste incineration/fuel switch in pulp&paper plant	7.00	17.0
13	Boiler improvement in palm oil plant	14.00	21.6
14	Gas Gas Turbin	2.00	27.5
15	Geothermal PP	237.00	30.6
16	Cogeneration HT	19.20	37.4
17	Biomass Steam PP	39.50	45.1
18	Solar Thermal	0.50	93.7
19	Integrated Gasification Combined Cycle	4.90	100.0
20	Improved Refrigerator	0.57	204.1
21	Hitch Refrigerator	1.07	256.2
22	Compact Refrigerator	0.39	333.6
23	Compact Panel Refrigerator	0.59	447.4

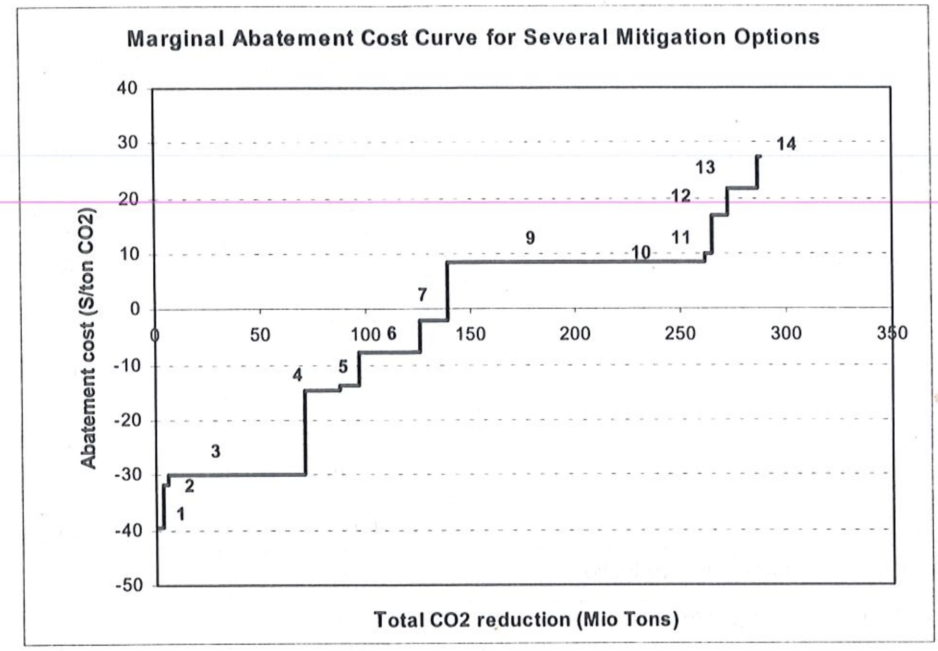

Figure 1. Aggregate Marginal Abatement Cost Curve for Several Mitigation Options – Coal Baseline

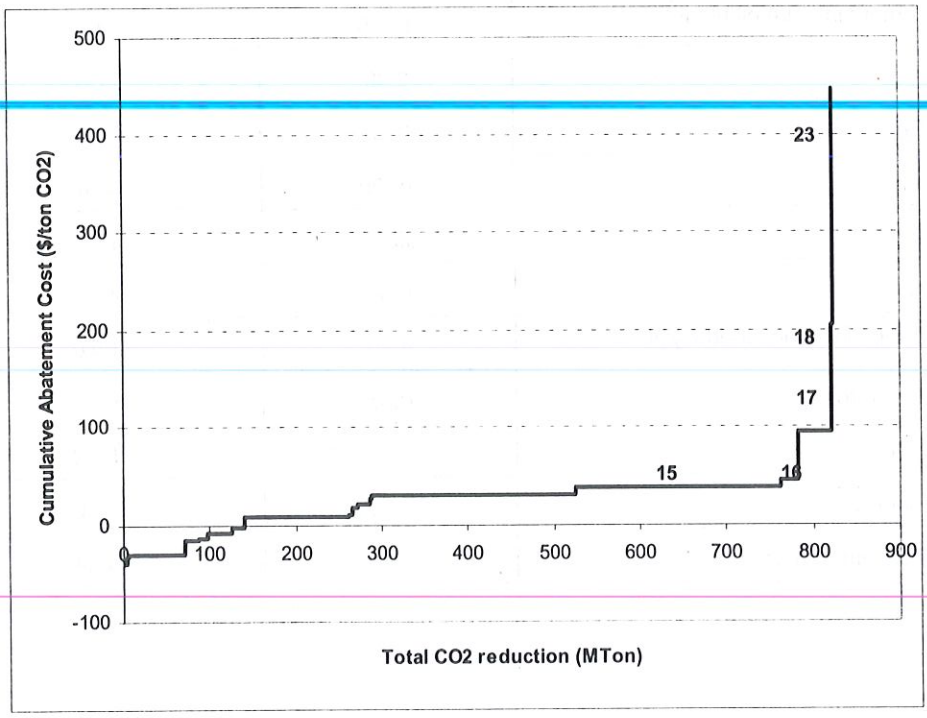

Figure 2. Aggregate Marginal Abatement Cost Curve for All Mitigation Options – Coal Baseline

Meanwhile, with respect to the average energy mix in 2000 baseline, the ranking of the cost has only changed slightly. Coal power plant and gas-gas turbine projects no longer appear to produce emissions higher than the baseline scenario. Gas Combined Cycle tops the list, replacing SFL technology, as in the coal baseline (see Table 11, Figures 3 and 4).

Table 11. Marginal Abatement Costs for Mitigation Options/Project Types – Baseline: Average Energy Mix 2000

	Mitigation option/Project type	Total CO2 reduction (Mio tons)	Abatement cost ($/ton CO2)
1	Gas Combined Cycle	0.10	-629.1
2	Incandescent to fluorescent (SFL)	1.85	-66.8
3	Incandescent to CFL	38.57	-50.7
4	Hydro PP	9.90	-27.2
5	Mini Hydro	5.30	-25.6
6	Cogeneration LT	13.03	-21.1
7	Variable Speed Motor	8.07	-3.5
8	Utilization of flared gas from NG production	84.00	8.5
9	Cogen&heating system reconstruction in textile industry	38.00	8.6
10	Improvement of waste management in starch factory	4.00	10.0
11	Waste incineration/fuel switch in pulp&paper plant	7.00	17.0
12	Boiler improvement in palm oil plant	14.00	21.6
13	Geothermal PP	139.40	49.6
14	Biomass Steam PP	23.30	74.2
15	Improved Refrigerator	1.49	77.3
16	Cogeneration HT	8.69	78.6
17	Integrated Gasification Combined Cycle	4.90	100.0
18	Solar Thermal	0.27	156.8
19	Hitch Refrigerator	0.63	434.8
20	Compact Refrigerator	0.23	566.1
21	Compact Panel Refrigerator	0.35	759.2

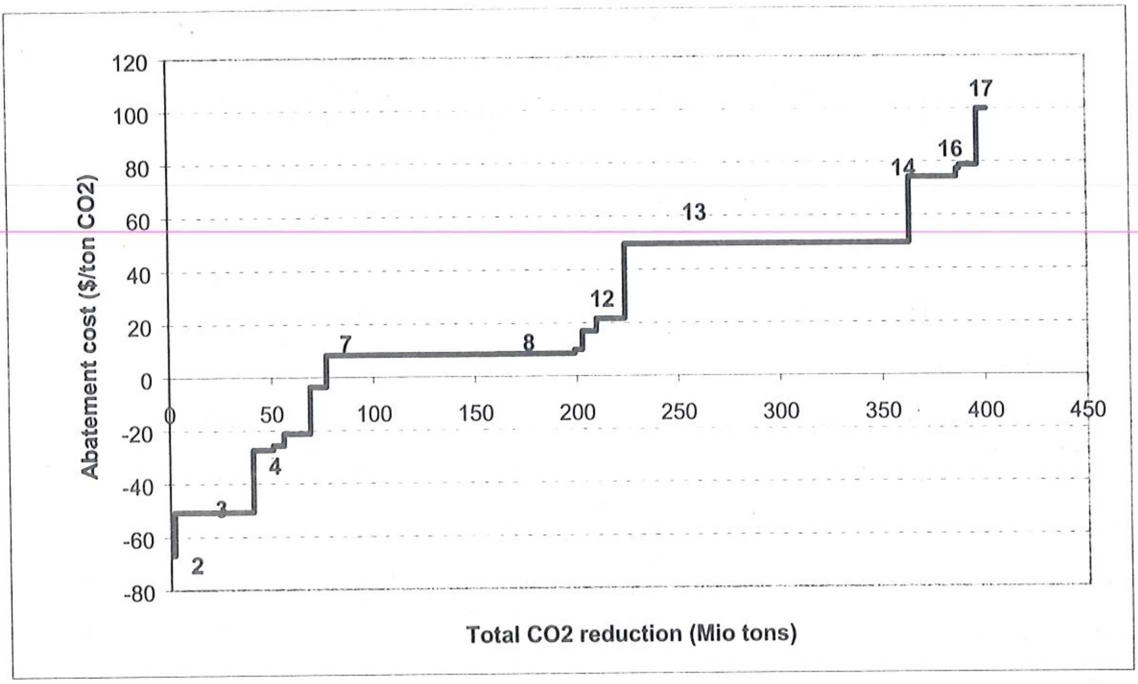

Figure 3. Aggregate Marginal Abatement Cost Curve for Several Mitigation Options – Average Energy Mix 2000 Baseline

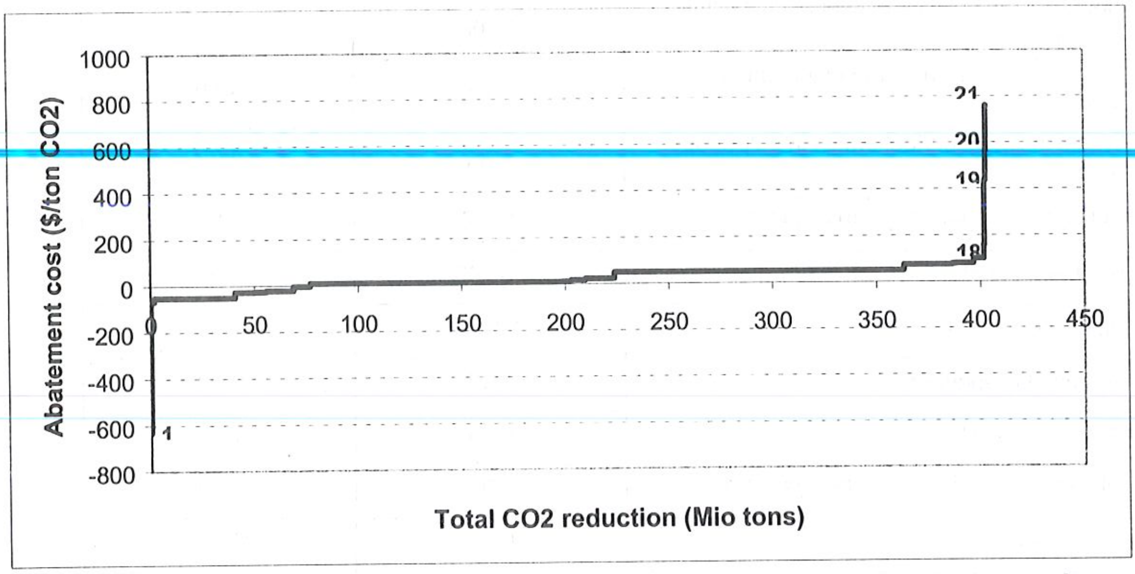

Figure 4. Aggregate Marginal Abatement Cost Curve for All Mitigation Options – Average Energy Mix 2000 Baseline

5. CONCLUSION

Some mitigation options have negative costs, representing no-regret options, such as switching to the use of compact and standard fluorescent lamps. However, these mitigation options face certain barriers. For instance, public awareness on the medium-term benefits of substituting incandescent lamps with fluorescent lamps is low. Many are discouraged by the higher price that they have to pay to change their bulbs.

Hydro developments cannot be realized due to lack of investments. Small hydro faces additional difficulties, including remoteness of location, far from PLN's grid. If power is meant to supply only the neighboring community, the development is usually not commercially attractive.

Energy efficiency initiatives, e.g., the use of new electric motors and application of co-generation in plants/factories, are limited in Indonesia. Business awareness on the benefits of energy efficiency is very low. In the present crisis most industries are struggling to survive and consider that initial investment in energy efficiency initiatives would only add to their cash flow problems. In general, only large corporations/industries have pursued energy efficiency initiatives.

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SYSTEM WIDE MODELING OF GHG MITIGATION ANALYSIS IN ENERGY SECTOR

M. Sidik Boedoyo and Agus Cahyono Adi

Abstract

MARKAL's result presents the least-cost of the business as usual scenario, it is taken as the base case scenario for estimating the CO_2 emission levels. In the mitigation scenario, the model will be introduced by some possible alternate technology and enhanced renewable resources. The alternate technology is more efficient or non fossil base technology that produces less CO_2 emission levels but higher cost than the base case. The additional cost per ton CO_2 reduction will be ranked to show marginal abatement costs of possible alternate technology.

1. INTRODUCTION

The abatement costs for some of the mitigation options discuss in the other paper have been compared with those obtained from MARKAL. MARKAL is a computer model that can be utilized to predict an energy scenario in the future. The model can answer certain questions, such as 'what is the least-cost scenario?' or 'what energy scenario would produce the least amount of CO_2?' For the purposes of our analysis the least-cost scenario has been modeled. The model performs calculations based on the entire energy system (i.e. based on all the information input), not on individual energy sectors or technologies.

MARKAL's input parameters include macro economic parameters (such as growth rate of GDP, industrial, population and transportation); techno economic of the energy production facilities; and operation characteristic of the facilities. The information of individual technologies are comprise of investment costs, operation and maintenance costs, fuel costs, load factor, etc. MARKAL then calculates different scenarios showing the optimal mix of energy generators under scenario assumption condition to fulfill the energy demand required in the future. The amount of CO_2 emitted can also be calculated for each of scenario to be analyses. Then marginal costs of CO_2 reduction in the alternate scenario compare to the baseline can be calculated easily.

The energy sector analyzed in this paper covers only power generation, industry, household and commercial sectors. Transportation sector is analyzed in other paper.

2. METHODOLOGY

The analysis is to estimate the abatement cost of introducing advanced technology for fulfillment energy demand projection of Indonesia between year 1995 up to the year 2020 and to compare with the technology mix of the baseline scenario. To simplify the optimization process, the analysis period between the year 1995 and 2025 is divided into six five-year intervals.

The least-cost of the business as usual scenario is taken as the base case scenario for estimating the CO_2 emission levels. Projection of the technology mix in the base case considers only conventional technologies with an assumption that there is no ability to build advanced technology. While in the mitigation scenario, the model will be introduced by some possible alternate technology and enhanced renewable resources. The alternate technology is more efficient or non fossil base technology.

Due to the lack of the analysis time between study time and base year taken, the 1995 data are actual data, while the 2000 data are derived from actual data as long as possible (for several mitigation options) and based on some estimates/ projections.

The cost of energy system and the amount of CO_2 released are the base parameters for analyzing the mitigation cases. Their simulation and calculation are using computer model MARKAL. Each candidate of GHG mitigation technology with their possible utilization is simulated individually to fulfill the desired energy demand projection. The system-wide abatement/reduction cost of each candidate is line up in order to establish the cost of emission reduction (CERI) curve. The CERI curve of all sectors is the basis of prioritizing the technologies that have the lowest additional costs and largest CO_2 emission reductions.

3. BASE SCENARIO AND MITIGATION CASES

GHG mitigation option will analyze for each sector by comparing base scenario/case and mitigation scenario/case.

3.1 Base Scenario

3.1.1 Power Generation

Power generation capacity in Indonesia is estimated to increase by 3 percent per annum from 1995 to 2025, as a result of economic crisis. The growth is largely attributable to the increased capacity of coal steam power plants and biomass power plants, which are predicted to increase by almost 8 percent and 9 percent per year, respectively, during that period. Table 1 shows the base case technology mix, including projections for based case power generation up to 2025. This information will be used as a base for analyzing the effect of various technologies that aim for reducing emissions.

The capacities of combined cycle power plants and hydro power plants during the period will increase by 3 percent and 4 percent per year respectively. Conversely, the capacities of diesel, gas steam, oil steam, gas turbine, and oil steam power plants are expected to decrease, as a result of the Indonesian Government policy supporting exportable energy conservation. For the renewable based power generation, the capacities of mini hydro and geothermal power plants are predicted to remain constant due to the high capital costs attached to building new plants.

For reducing GHG emission in the power generation sector, the most promising technology options are improving combustion efficiency in power plants and fuel switch (fossil to non-fossil fuel).

Table 1. Base Case Power Plant Capacities Projection (Giga Watt)

Technology Type	1995	2000	2005	2010	2015	2020	2025
Coal Steam PP	4.13	6.00	9.81	13.91	19.96	29.53	39.71
Gas Steam PP	2.61	2.38	2.23	2.23	2.23	-	-
Oil Steam PP	2.17	1.99	1.01	0.56	0.15	-	-
Diesel	10.46	9.62	9.15	9.80	5.92	7.73	8.13
Gas Turbine	2.01	1.98	1.80	1.48	0.90	0.85	0.87
Geothermal	0.41	0.41	0.41	0.41	0.41	0.36	0.36

Table 1. (continued)

Technology Type	1995	2000	2005	2010	2015	2020	2025
Gas Combined Cycle	2.44	2.44	2.44	2.44	1.84	3.74	5.14
Mini Hydro	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Hydro	3.63	5.08	6.17	7.50	10.07	12.13	13.96
Biomass	0.05	0.05	0.18	0.35	0.68	0.68	0.68
Total Power Plant	27.94	29.98	33.23	38.71	42.19	55.05	68.88

Source: MARKAL Output. November 24, 2000

3.1.2 Industry

Technology of energy utilization in industry consists of indirect heat, direct heat and electric drive. Table 2 shows list of technologies used in various industries that have potential for energy saving and GHG emission reduction. The total capacity of industry (steam and heat production) will increase by about 5 percent per year between 1995 and 2025. Indirect heat capacities in 2025 will be predominantly from coal boilers, with the remaining are coming from natural gas and biomass boilers.

3.1.3 Household and Commercial

The type of technology and fuel used in the household and commercial sectors that have significant opportunities for reducing GHG emissions is refrigerator, lighting and steam (indirect heat). Cooking stove is not considered in this categories. Tabel 3 shows the technology mix used in the household and commercial sector. The energy demands of the household and commercial sector will increase slightly between 1995 and 2025. Increased demand in this sector will result in increased use of fuels such as kerosene, LPG and electricity.

Table 2. Base Case Industry Capacities Projection of Base Case (PJ/Year)

Technology Type	1995	2000	2005	2010	2015	2020	2025
Indirect Heat Coal	*17.87*	*24.19*	*46.00*	*72.01*	*126.67*	*254.88*	*395.33*
Indirect Heat Biomass	*106.18*	*127.53*	*146.58*	*169.63*	*206.63*	*247.26*	*301.51*
Indirect Heat Diesel	*13.21*	*4.14*	*5.28*	-	-	-	-
Indirect Heat FO	*17.74*	*12.88*	*8.04*	*6.64*	*7.27*	-	-
Indirect Heat Natural Gas	*42.13*	*58.98*	*85.94*	*118.37*	*165.17*	*222.95*	*305.76*
Indirect Heat LPG	*72.65*	*47.48*	*72.58*	*21.76*	*43.60*	*0.68*	*1.18*
Indirect Heat Kerosene	*9.03*	*2.41*	*3.89*	-	-	-	-
Total Indirect Heat	**278.81**	**277.61**	**368.81**	**388.41**	**549.34**	**725.77**	**1003.78**
Ind. Electric Drive	**118.39**	**129.67**	**155.13**	**208.29**	**279.85**	**377.31**	**480.62**

Table 2. (continued)

Technology Type	1995	2000	2005	2010	2015	2020	2025
Direct Heat Coal	*2.93*	*7.11*	*12.49*	*22.30*	*40.52*	*74.78*	*130.41*
Direct Heat Biomass	*9.32*	*12.22*	*16.10*	*21.33*	*28.46*	*38.29*	*51.98*
Direct Heat Diesel	*5.44*	*6.19*	-	-	-	-	-
Direct Heat Kerosene	*5.06*	-	-	-	-	-	-
Direct Heat FO	*2.24*	*2.83*	*1.69*	*2.26*	-	-	-
Direct Heat Gas	*16.87*	*22.48*	*32.31*	*37.65*	*42.41*	*34.49*	*11.20*
Direct Heat Coke	*0.50*	*1.01*	-	-	-	-	-
Direct Heat LPG	*0.50*	*0.71*	-	-	-	-	-
Total Direct Heat	**42.86**	**52.55**	**62.59**	**83.54**	**111.39**	**147.56**	**193.59**
TOTAL INDUSTRIES	**440.06**	**459.83**	**586.53**	**680.24**	**940.58**	**1250.64**	**1677.99**

Source: MARKAL Output. November 24, 2000

Table 3. Base Case Household Capacities Projection; Cooking Stove not considered (PJ/year)

Technology Type	1995	2000	2005	2010	2015	2020	2025
Standard Refrigerator	*17.56*	*19.69*	*18.46*	*13.04*	*0.86*	*0*	*0*
Improve Refrigerator	*1.43*	*4.23*	*10.19*	*20.65*	*39.62*	*44.48*	*50.94*
Total Refrigerator	**18.99**	**23.92**	**29.65**	**33.69**	**40.48**	**44.48**	**50.94**
Lighting Mix	*70.00*	*73.28*	*78.83*	*83.96*	*85.04*	*78.59*	*90.03*
Lighting Mix Non Electric	*101.14*	*84.79*	*71.76*	*61.83*	*49.33*	*35.61*	*40.81*
Commercial indirect heat	*7.18*	*8.45*	*10.48*	*13.38*	*17.45*	*22.94*	*26.30*
Total Household	**197.31**	**190.44**	**190.72**	**192.86**	**192.30**	**181.62**	**208.08**

Source: MARKAL Output. November 24, 2000

3.2 Mitigation Cases

The analysis in the mitigation cases is comparing CO_2 emission reduction cost of alternate option to the CO_2 emision and the energy system cost in the base scenario. The difference of energy system cost and the difference of CO_2 amount released of both cases are calculated to get specific CO_2 emission reduction cost. This section will analyze 19 different alternate technologies for GHG mitigation.

The abatement system cost of each technology option curve for all sectors is derived on the basis of prioritizing those technologies that have the lowest additional costs and largest CO_2 emission reductions.

The condition the technology, penetration rate applied and assumption of those technology option will be describe individually in the following sections.

3.2.1 Co-generation Technology

Co-generation is the common process that utilized exhaust heat of gas turbine as fuel for recovery boiler. Its technology is very efficient. The GHG abatement analysis for this option is valuation of reducing fuel and the abatement cost required for install and operate the technology. The abatement cost is indicated a difference of the total system cost in the option with its cost in the base scenario. The penetration rate for utilization of co-generation technology is started at period three (2005) will replace 10 percent of steam generation capacity. The penetration rate of the year 2025 will become 251 PJ (25 percent of the capacity in base scenario).

3.2.2 Advanced Motor Electric Technology

The advanced Motor Electric Technology is the enhanced motor technology with higher efficiency. The penetration rate for the analysis of this technology has a capacity install of 118 PJ started in the first period, then it will rise to about 480 PJ per annum in the final period (2020 - 2025).

3.2.3 Solar Thermal Technology

Solar thermal technology is used for boiling warm water as an alternative of electric or gas water heater. The penetration will be started in the second period, solar thermal technology is estimated to be more competitive price, but its capacity will remain low, at about 0.06 PJ per annum. By 2025 the capacity is expected to be about 1.8 PJ per annum.

3.2.4 Compact Fluorescent Lamp (CFL) Technology

In the future, CFL with electronic ballast which is very efficient lighting will be more attractive to the household sector because its price is more competitive than the conventional lighting price. The penetration of CFL used in the household and commercial sectors started in the second period is expected to account for 5 PJ per annum. It will reach 90 PJ per annum by 2025. CFL has very high potential for reducing CO_2 emissions. A financial scheme that could reduce the initial cost of CFL would promote this option.

3.2.5 Improved Refrigerator Technology

Starting in the third period, improved refrigerator technology will reduce CO_2 emissions. The capacity of this option will only be about 5 PJ per annum but by the end of period this capacity is expected to more than double.

3.2.6 Hitch Refrigerator Technology

The hitch refrigerator will be introduced in the third period and usage will account for 5 PJ per annum. The use of hitch refrigerator technology will increase to account for 12 PJ per annum by the end of the period.

3.2.7 New Mini Hydro Power Plants

In the baseline, the capacity of mini hydro power plants are estimated to be constant during their lifetime. However, if new technology is used, the capacity of mini hydro power plants will increase every period, from 0.03 GW in the first period to 0.3 GW in the final period. Total mini hydro potential is about 460 MW (DGEED,1997), but some of the potential locations are outside Java, in areas that have low electricity demand.

3.2.8 New Hydro Power Plant

By the third period hydro power plants will have a total output capacity of 0.14 GW. This will increase to 0.42 GW output capacity by 2025.

3.2.9 New Gas Combined Cycle Power Plant

The enhancement of gas combined cycle will have thermal efficiency nearly 50 percent. This technology will become available starting in the third period. The install capacity of this technology will increase over the period, the install capacity yearly rate addition of this technology in this period is about 0.1 GW. Total capacity of New NGCC by the end of the period will be 5 GW.

3.2.10 Advanced Compact Fluorescent Lamp (ACFL) Technology

ACFL is more efficient compact fluorescent lamp but their price is more expensive. ACFL will become attractive to the educated household sector because of its cost-benefit price. During the second period, ACLF used in the household and commercial sectors is expected to account for 5 PJ per annum. By the end of the period the figure is 60 PJ.

3.2.11 Compact Refrigerator (CR) Technology

The principle of compact refrigerator technology is reducing chilled compartment. CR technology will be introduced in the fourth period. The rate of technology penetration for GHG abatement analysis is installation of 3.45 PJ energy use capacity per annum with a limited gradual increase in use in the household sector thereafter.

3.2.12 Compact Panel Refrigerator (CPR)Technology

As the CR Technology, CPR Technology also used enhanced insulation. Due to the status of technology and their price, the CPR is likely to be more competitive in the fifth period. The penetration rate is installation of 4 PJ per annum linearly starting from fifth period.

3.2.13 New Biomass Power Plant Technology

Biomass is considered a clean fuel. However, biomass power plants are not expected to contribute much to energy generation; just 0.18 GW in the third period rising to 1 GW by 2025.

3.2.14 New Gas Turbine Power Plant Technology

New gas turbine power plant is a technology of power plant designed for small unit size. The penetration ratio of this technology for analyzing GHG mitigation is set not so high. The maximum installation of the new gas turbine technology in the year 2025 about 0.2 GW.

3.2.15 Geothermal Power Plant Technology for Base Case

Geothermal potential in Indonesia is estimated at about 20 GW. However, identified as proven and potential reserves is only 4,3 GW (about 20 percent).

In the analysis, geothermal technology penetration will start in the third period, while their generation capacity is expected to be approximately 0.9 GW. The install capacity is expected to increase up to 5 GW in 2025.

3.2.16 New HSD Gas Turbine Power Plant technology

The new HSD gas turbine power plant is usually used for support during peak time in the area that does not have natural gas grid line. When natural gas grid transmission in the area is available, the technology is not interesting. Due to this limitation, the install capacity that can be proposed is about 0.27 GW for GHG mitigation penetration.

3.2.17 New Coal Power Plant 600 MW Technology

Start in the third period, new coal power plant of 600 MW technology will account for only 2.4 GW of energy generation. Capacity is not expected to increase over the remainder of the period.

3.2.18 New Coal Power Plant 400 MW Technology

In the first period, new coal power plant of 600 MW technology will account for just only 1.6 GW of energy. Capacity is estimated to increase up to 2.4 GW by the end of the period.

3.2.19 Standard Fluorescent Lamp (SFL) Technology

This technology will account for 17.7 PJ per annum of energy use in the second period, rising to about 21 PJ per annum during the last period (2020 – 2025).

4. OUTPUT OF SYSTEM-WIDE MODELLING ANALYSIS

4.1 General

The output of the MARKAL model run for power generation, industry, household and commercial sectors in respect to the base case and mitigation case is presented in Table 5 and Figure 1. It represents a scenario in which the maximum CO_2 emission reduction is achieved at a minimum additional cost.

Adopting more efficient technologies and substituting fossil fuels with non fossil fuels leads to lower CO_2 emissions than the use of conventional technology and fossil fuels. However, the new efficient technology has higher investment costs than the conventional technology.

4.2 Trends Observed in the Modeling Output.

Use of motor electric technology could reduce CO_2 emissions by up to 35 MT of over the 30-year period, with a marginal economic gain of 11.4 US$ per ton of CO_2. However, this technology would be dispersed across hundreds of industries; thus capturing data on emission reductions would require some kind of pool mechanism.

Solar thermal technology will only reduce CO_2 emissions by 3 MT over the period. Meanwhile, substitution of CFL and ACFL for conventional lamps would offer significant CO_2 emission reduction potential at a reasonable cost.

The combined capacity of gas turbine and gas combine cycle with improved combustion efficiency would still lead to reductions in total CO_2 release. Its combination will have significant contribution to GHG mitigation.

Additional new coal power plants will increase the total capacity of coal steam power plants almost ten-fold over the 30 years period. However, new coal power plants will increase the system costs, although they are still cheaper than binary geothermal, new hydro and new biomass options.

When the project-based approach is compared with the results obtained from the MARKAL model abatement, costs for almost all technology options (with the exception of fluorescent lamp technology, gas combined cycle, and hydro plants) appear higher under the project-based approach. This result is the effects of fuel subsidies which are counted in the project-based approach. Project-based calculations are therefore less likely to be attractive to investors.

Table 5. Marginal Abatement Cost of Several Cases (system-wide)

Case	The Total of CO_2 Reduction (MT)	Additional Total Cost (million US $ 95)	Marginal Abatement Cost (US $ 95/Ton)
Base*)	0	0.0	-
Cogeneration	61	-3,939.0	-64.6
New Motor Electric	35	-398.8	-11.4
Solar Thermal	3	-34.0	-11.3
CFL	198	-571.4	-2.9
Improved Refrigerator	13	-8.0	-0.6
Hitch Refrigerator	16	-6.6	-0.4
New Mini Hydro P.P	29	6.0	0.2
New Hydro P.P	34	72.2	2.1
New Gas C.Cycle P.P	7	19.0	2.7
ACFL	81	224.5	2.8
Compact Refrigerator	10	47.1	4.7
Compact Panel Refrigerator	8	48.9	6.1
New Biomass P.P	9	62.3	6.9
New Gas Turbine P.P	4	29.4	7.4
Geothermal	370	4,429.0	12.0
New HSD Gas Turbine	4	212.4	53.1
New Coal Power Plant 600 MW	9	349.2	87.3
New Coal Power Plant 400 MW	11	1,512.0	137.5
SFL	7	1,088.0	155.4

*) Total Cost and Total Emission of Baseline Indonesia's Energy System

Source: Output MARKAL Model. November 24, 2000

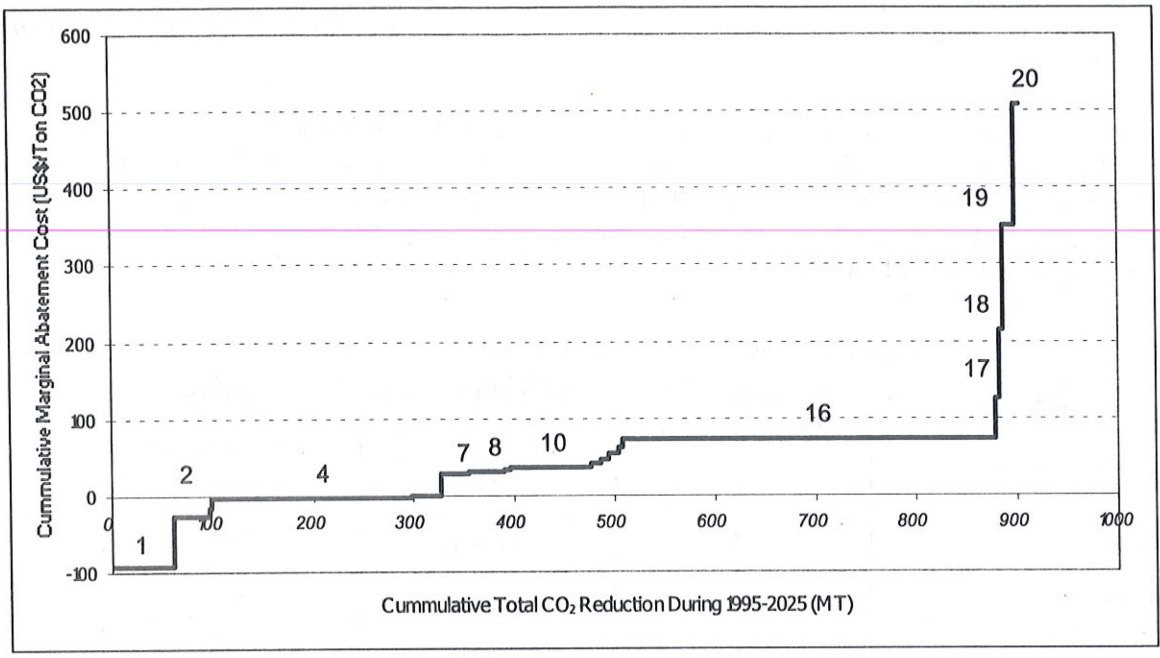

Figure 1. Energy System-wide Marginal abatement Cost Curve

Note of Figure 1:

1: Cogeneration

2: Motor Electric

3: Solar Thermal

4: CF Lamp

5: Advanced Refrigerator

6: Hitech Refrigerator

7: Base

8. New Mini Hydro

9: New Hydro

10: Gas Combined Cycle

11: ACFL Lamp

12: Compact Refrigerator

13: Compact Panel Refrigerator

14: New Biomass

15: New Gas Turbine

16: Geothermal

17: New HSD Gas Turbine

18: New Coal PP600 MW

19: New Coal PP 400 MW

20: SFL Lamp

The differences in abatement cost between the project-based approach and MARKAL are generally quite significant. The project-based approach always compares mitigation options with the cost of using coal or the average energy mix. However, MARKAL only looks at the relative differences between system configuration costs – and emissions reductions - under different sets of assumptions.

A specific example of the difference between project-based and MARKAL calculations is provided by refrigeration technology. Potential reduction of emissions as a result of using improved refrigeration technology is higher according to MARKAL, compared with the project-based approach. This is because MARKAL considers the *system wide* impacts of any change and calculates emissions reductions based on cumulative changes in the *system*. The project-based approach only takes into account the emission reductions that come from energy saving due to refrigeration improvement.

5. CONCLUSION

In all sector of energy use, there are options to reduce GHG emission from the simpliest one such as management of energy utilization up to an advance one such as compact panel refrigerator technology. In general, implementation of GHG mitigation technology will increase the cost.

The amount of CO2 reduced and the cost of the technologies applied are varied. It is a user wish to use a low cost technology but can reduce a large amount CO2. MARKAL model is utilized to find an optimal result for a selected case. The results can provide invaluable information about which technology of GHG mitigation should be pursued in a short, medium and long time.

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GHG MITIGATION OPTION IN TRANSPORTATION SECTOR

Hari Suharyono

Abstract

The least-cost of the business as usual scenario of MARKAL's result in transportation sector is taken as the base case scenario for estimating the CO_2 emission levels. Some possible alternate technology will be introduced in the mitigation scenario. The alternate technology is more efficient or produces less CO_2 emission levels but higher cost than the base case. The additional cost per ton CO_2 reduction will be ranked to show marginal abatement costs of possible alternate technology.

1. INTRODUCTION

Transportation sector is an important economic activities. During 1994-1999 period, transportation sector consumes in average about 21 percent per year of the total final energy in Indonesia. This sector consumes more than 50% of the total refinery products and almost all of the demand is refinery product.

During 1994-1999 period, the average per year of greenhouse gases (GHGs) carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions from transportation sector are 23.8 percent, 0.3 percent and 8.4 percent respectively of the total individual gas that establishes GHG emission. Total of CO_2 emission calculated excludes CO_2 emission from biomass utilization. It is predicted that the average growth rates per year of CO_2, CH_4, and N_2O are 3.4 percent, 3.4 percent and 3.4 percent respectively.

Most of the GHG mitigation in the energy sector requires more efficient technologies than currently used or will be use in a future business-as-usual case. Implementation of those technologies by either new installation or retrofit will result in cost difference compared to the technology used now. The cost difference of the GHG reduction action can be called marginal cost. In the same words, marginal abatement costs can be obtained by dividing the difference of total cost through the difference of total CO_2 release of two technological options. A marginal abatement cost curve can thus be constructed by looking at different technologies and evaluating their cost difference to the cheapest technology.

This paper will present the methodology to calculate the system-wide abatement/reduction cost of each mitigation candidates and to establish the cost of emission reduction (CERI) curve optimal mix of energy supply in transportation sector.

2. METHODOLOGY

MARKAL Model is used to estimate the total cost required and the total CO2 emission released for fulfillment energy demand projection of Indonesia between year 1995 up to the year 2025. To simplify the optimization process, the analysis period between the year 1995 and 2025 is divided into six five-year intervals.

In selected cases , some technology candidate are forced to be chosen to dominate the future Indonesia energy system depending on the case selected. As the method analysis of MARKAL Model is least cost, analyzing the marginal cost of the application of CO_2 reduction technologies can be conducted by defining the capacity of the efficient technology and compare to the base case capacity mix. In the base case, conventional technologies or existing technologies remain to be used. Then, system-wide abatement/reduction cost of each candidate is ranked in order to establish the cost of emission reduction (CERI) curve. The CERI curve of the technology candidate is the basis of prioritizing the technologies that have the lowest additional costs and largest CO_2 emission reductions.

3. BASE SCENARIO AND MITIGATION CASES

GHG mitigation option will analyze for transportation sector by comparing base scenario/case and mitigation scenario/case.

3.1 Base Scenario

The base case for the transport sector is different from the base case for other sectors. In this sector, the base case technology efficiency is expected to increase; while, in other sectors, the base case technology efficiency remains the same. There is not enough data to analysis technology in rail and air transportation modes, therefore those two transportation modes are not analyzed further. Projections on transport sector base case capacity are given in Table 1. The table shows that refined products, such as gasoline and diesel remain the predominated fuel sources for the sector. In the context of CO_2 emission reductions, substitution to LPG and CNG as fuel in the transport sector will be considered in the future.

Table 1. Base Case Projection of Transport Capacities

Technology Type	Periods (PJ/annum)						
	1995	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**
Diesel (Truck+Bus)	5.98	5.81	10.42	16.84	24.29	33.03	45.99
Gasoline (Truck+Bus)	14.17	15.56	14.36	15.44	19.34	25.87	35.86
CNG (Truck+Bus)	20.15	21.37	24.78	32.55	44.01	59.43	82.69
Diesel Car	3.65	5.47	7.61	9.30	12.45	16.89	23.58
Gasoline Car	16.62	15.23	14.64	17.17	21.51	27.90	38.92
LPG Car	0.00	0.00	0.28	1.03	1.68	2.24	3.13
CNG Car	0.00	0.13	0.45	1.05	1.62	2.01	2.81
Total	**40.42**	**42.20**	**47.76**	**61.10**	**81.27**	**108.47**	**151.13**

Source: Output MARKAL Model, November

Due to lack of data, most of the mitigation options for the transport sector cannot be analyzed in detail. Even for Mass Rapid Transit, which has high potential for GHG mitigation, there no detailed data are available in Indonesia.

3.2 Mitigation Cases

The abatement cost of the options selected will be analyzed relative to the total system cost projected by the MARKAL model. Based on the available data of GHG mitigation options in transport sector are:

3.2.1 Improved Efficiency of Trucks and Buses Using Gasoline Fuel

To reduce the total CO_2 released from the energy system, the efficiency of trucks and buses that use gasoline has to be improved. Energy efficiency trucks and buses will account for 13.71 PJ energy use per annum in the first period and 63.3 PJ per annum at the end of the period.

3.2.2 Improved Efficiency of Trucks and Buses Using Diesel Fuel

The total capacity of this appropriate efficiency technology will be 5.98 PJ per annum in the first period increasing to 45.99 PJ per annum by 2025.

3.2.3 Improved Efficiency of Cars Using Gasoline Fuel

The total capacity of this appropriate efficiency technology will be 15.71 PJ per annum in the first period increasing to 60.76 PJ per annum in the final period.

3.2.4 Increased Use of CNG Car

Cars using CNG would be relatively cleaner than other car, but construction CNG stations is needed to support this type of vehicle. CNG cars are expected to represent energy consumption of 3.13 PJ per annum by 2025.

3.2.5 Improve Efficiency of Cars Using Diesel Oil Fuel

The efficiency of cars using diesel fuel needs to be improved. Improved diesel efficiency will represent an energy consumption of 0.92 PJ per annum in the first period and 38.92 PJ per annum in the final period.

4. OUTPUT OF THE MODEL

4.1 Cases

The selected cases, GHG mitigation option in transportation sector, represents the maximum CO_2 emission reduction achieved at a minimum additional cost. The output of the MARKAL model run for transportation sector in respect to the base case and mitigation case is evaluated further to know CO_2 emission reductions, abatement costs and the abatement costs for each GHG mitigation option. The details is shown in Table 2 and the curve is shown in Figure 1.

4.2 Trends Observed in the Modeling Output.

Approximately 80 percent of GHG emissions from the transport sector are CO_2, released from burning fuel. The remainder comes from chlorofluorocarbon (CFC) used in vehicle fabrication and air conditioning. A number of measures could be introduced to reduce CO_2 emissions from this sector, such as promoting more efficient modes of transport, fuels switching to low or no carbon fuels, and improving transportation management. The most effective way to mitigate the CO_2 emissions from this sector is by integrating those measures with government regulations. Promoting the use of low carbon emission fuels would be hindered by subsidies on oil.

Table 2. Marginal Abatement Cost per Ton CO_2 Reduction of Several Cases In The Transportation Sector

Cases	Total of CO_2 Release (MT)	The Total of CO_2 Reduction (MT)	Total System Cost (million US $ 95)	Additional of Total Cost (million US $ 95)	Marginal Abatement Cost (US $ 95/Ton)
Base	12633	0	455010.28	0.00	0.0
ImpTBGSL	12519	114	453894.51	-1115.77	-9.8
ImpTBADO	12569	64	454665.14	-345.14	-5.4
ImpCarGSL	12590	43	454920.45	-89.83	-2.9
CarCNG	12632	1	455017.76	7.48	7.5
ImpCarADO	12621	12	455115.60	105.32	8.8

Source: Output MARKAL Model, November 2000

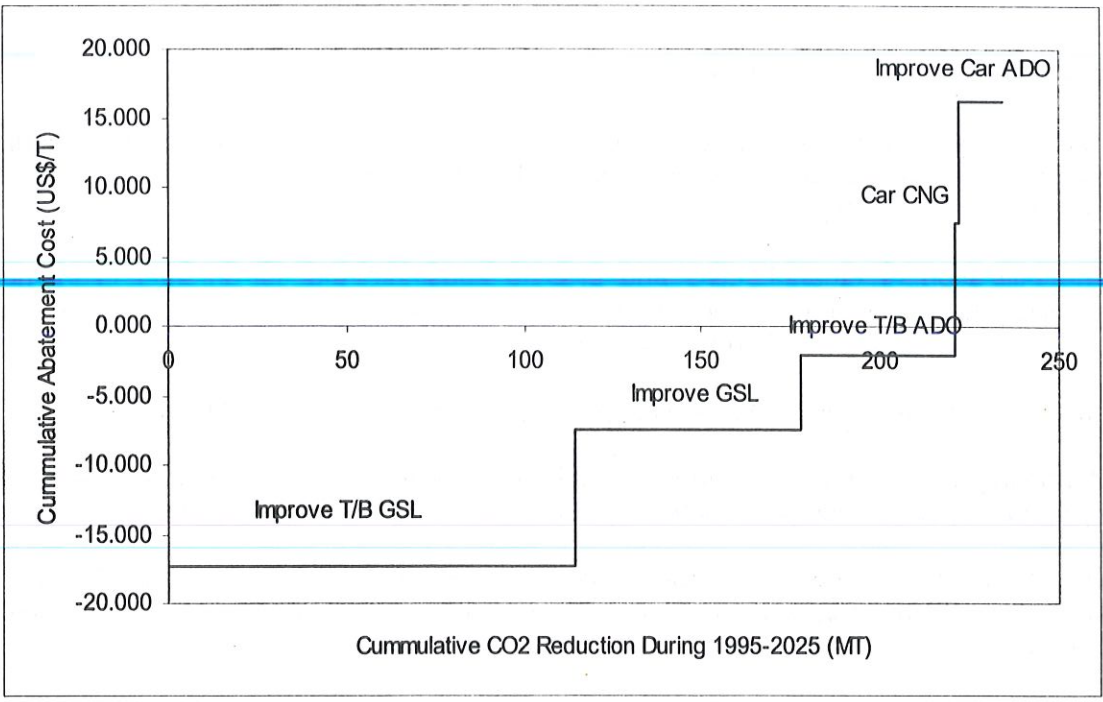

Figure 1. Marginal Abatement Cost of Several Cases In Transport Sector

Note of Figure 1:

1: Improve T/B GSL (Improved of efficiency of trucks and buses using gasoline fue)l

2: Improve GSL (Improved efficiency of car using gasoline fuel)

3: Improve T/B ADO (Improved efficiency of trucks and buses using diesel oil fuel)

4: Car CNG (Increased use of CNG car)

5: Improve Car ADO (Improve efficiency of cars using diesel oil fuel)

Vehicle speed has a significant effect on fuel consumption. The lowest fuel use per kilometer (therefore the lowest CO_2 emissions per kilometer) occurs in a speed range of 56 to 72 kilometers (km) per hour. Traveling at 104 km per hour typically results in 20 to 25 percent more CO_2 emissions per km than traveling at 88 km per hour. Traveling at 120 km per hour results in about 50 percent more emissions. While a speed lower than 56 km per hour is often the resulting of traffic congestion, low speeds also cause higher emissions.

Options to reduce GHG emissions in the transport sector through policies and measures as identified by IPCC (1996) are:

- Reduction of energy intensity through the use of more efficient vehicle technology, changes in the vehicle use, or changes in the transport mode.
- Controlling emissions of carbon monoxide, volatile hydrocarbon compound, NO_X, N_2O and methane.
- Switching to alternative energy sources with lower carbon content.
- Reducing the use of motorized transport by promoting alternatives (e.g. telecommunication).

The possible mitigation initiatives include:

1. Use of turbo changer for diesel and gasoline motor vehicles. A turbo charger would increase combustion efficiency by around 10 to 15 percent and possibly reduce the fuel use about 8 – 10 percent.
2. The utilization of ethanol, LNG and LPG to substitute the current fuel might not significantly reduce the use of commercial fuel such as gasoline and diesel oil, but would reduce CO_2 and CH_4 in the exhaust gas.
3. Improved vehicle technology, for example use of electric and fuel cell technology.
4. Promoting mass transport. Reliable mass transport options could reduce the use of oil by up to 30 percent compared with a system based on private cars and buses.
5. Fuel switching. Switching from oil based products, such as gasoline and diesel, to alternatives. Indonesia has a program to switch from oil products to compressed natural gas and liquid petroleum gas for taxis, buses and private cars.

More detail descriptions of mitigation options in transport sector is presented in Table 3.

Table 3. Cost Data of GHG Mitigation Option in Transport Sector

Vehicle Option	Investment cost/unit	Reduction Potential (ton Co_2 eq/GJ) (kg Co_2 eq/MWh)		Marginal cost per unit output (US$/MWh)	Marginal cost per reduced GHG (US$/t CO_2)
a) Application of turbo changer for diesel & gasoline motor vehicle					
b) Use of non oil vehicles such as ethanol, CNG and LPG					
CNG Vehicle	1.1×10^4 US$/car	0.13	483.9	120	248
LPG Vehicle					

Table 3. (continued)

Vehicle Option	Investment cost/unit	Reduction Potential (ton Co_2 eq/GJ)	(kg Co_2 eq/MWh)	Marginal cost per unit output (US$/MWh)	Marginal cost per reduced GHG (US$/t CO_2)
Ethanol Vehicle	1.1 x 10^4 US$/car	0.46	1693.6	45	27
Ethanol Vehicle Capital & Installation $(91) Fuel	$0-500 more than comparable gasoline cars $ 0.04 – 0.4 per liter gasoline eq	0.0076 kg Co_2 eq /km (70% decrease from baseline gasoline vehicle)			
c) Improved vehicle technology, such as electric and fuel cell					
Electric cars	1.3 x 10^4 US$/car	0.26	967.8	151	156
Fuel Cell Vehicle	1.5 x 10^4 US$/car	0.56	2080.7	450	216
d) Promoting of the mass transport					
GHG Mitigation Option and Opportunities (Klarer 1999)					
e) Fuel switch in transport. Fuel switching: 33% of cars to use natural gas, construction of 700 Gas Filling Stations.	52700	14	600	Petrol saving: 0.50	600

Source: ALGAS, 1998

4. CONCLUSION

The results represent only a partial situation in transportation sector. Due to limitation of the available data, only improve efficiency of cars, trucks and buses, and improve use of CNG are being evaluted. While the other transportation modes are not analyzed further.

There are options to mitigate emission in transportation sector, from a simple one such to maintain a stable speed around 64 kilometers (km) per hour to a complicated one such as to utilize a fuel cell vehicle. In general, a complicated mitigation option requires a higher cost and more difficult to achieve than a simple one.

The Abatement Costs of transportation sector are varied. There are several cases that will give benefit to the energy system national, if they are followed throughly in the long run. However, their implementation may not be easy, because the implementation needs capital, while most of cars, trucks and buses are owned by individual or private sector.

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