Economics of Greenhouse Gas Limitations

COUNTRY REPORTS

Indonesia Country Study

Ministry of Environment
Republic of Indonesia

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ADB	Asian Development Bank
ADO	Automotive Diesel Oil
ALGAS	Asian Least Cost Gases Abatement Strategy
BAU	Business as Usual
BPPT	Agency for the Assessment and Application of Technology
CFL	Compact Fluorescent Lamp
CHP	Combined Heat and Power
DGFU	Directorate General and Forest Utilization
FAO	Food and Agricultural Organization
FYDP	Five Year Development Plan
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GNP	Gross National Product
GTZ	Deutsche Gesellshaft fuer Technische Zusammenarbeit Gmbh
GW	Giga Watt
ha	Hectares
HID	High-Intensity Discharge
HPH	Concession Forest
IDO	Industrial Diesel Oil
IPB	Bogor Agricultural University
IPCC	Inter-governmental Panel on Climate Change
ITB	Bandung Institute of Technology
JEA	Japan Environment Agency
KFA	Nuclear Research Center
LPG	Liquefied Petroluem Gas
MARKAL	Market Allocation
MoF	Ministry of Forestry
PERHIMPI	Indonesian Association of Agricultural Meteorology
PJ	Peta Joule
PLN	State Electricity Company
TWh	Tera Watt hour
UNEP	United Nations Environment Programme
SHS	Solar Home System
SPM	Suspended Particulate Matters
VHC	Volatile Hydrocarbon
WALHI	The Indonesian Forum for the Environment
yr	year

Executive Summary

Indonesia is a tropical country with land area of about 193 million hectares. Forests cover about 55% of the total land. About 43% of the forest area is designated as production forest excluding convertible production forest, about 23% as convertible forest and the remaining as reservation and protection forests. In the period of 1960-1990, production forest is the main source of timber supply (about 90% of total supply). During the period, annual log production was about 20 millions m^3. In the future the role of production forest as timber supplier will be gradually reduced. In 2030, it is projected that the production forest will supply only 24% of the total wood demand while the remaining will come from plantation forests and non-forest sources. On the other hand, supply of primary energy is expected to grow quite rapidly, i.e. 5.6% per annum in the period 1990-2020. In 2020, the primary energy supply will be about 15,906 PJ per annum. The increase in energy supply will lead to increase in CO_2 emission while the forest acts as both source and sink of CO_2.

This study demonstrated the use of MARKAL model in carbon mitigation analysis for both energy and forestry sector. Four scenarios were used namely :

1. EbFb (baseline scenario). In this scenario, mitigation technologies in the energy sector were not included in the model and no target was set up for increasing net carbon uptake by forest activities.
2. EmFb. Mitigation technologies in the energy sector were included with the target of reducing cumulative net carbon emission by about 13 **%** and activities in the forestry sectors were the same as those in baseline
3. EbFm. Mitigation technologies in the energy sector were not included and the forestry activities were targeted to increase the carbon uptake so that the cumulative net carbon emission decreased by 13**%.**
4. EmFm. Mitigation technologies in the energy sector were included as well as forestry sector with target of reducing cumulative net carbon emission by about 35**%.**

Mitigation of CO_2 in the energy sector is carried out by applying fuel diversification in the power generation mix with nuclear and natural gas, replacing polluted fuel such as coal and petroleum products with biomas, energy conservation and the management of demand side. List of mitigation option for each sub-sector is presented in Table 1.

Carbon emission from industry, residential and commercial sectors were reduced by increasing the utilization of industrial waste heat recovery with co-generation (combined heat and power, CHP) technology, more efficient lamp, motors and refrigerator and also fuels diversification. In the commercial sector the carbon reduction resulted from the installation of solar thermal heater and replaced boiler for bath and laundry hot water. In the household sector, the mitigation is carried out through use of firewood for cooking, compact fluorescent lamp (CFL), electronic ballast and CFL, Solar Home System (SHS) for the non-electrified rural household replace kerosene lamp and improving refrigerator performance.

Table S.1: Mitigation Options in Energy Sector

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

In forestry sector, activities included in the analysis were harvesting and planting of plantation forest, harvesting of production forest, planting and harvesting of afforested and reforested lands, and planting of critical land. The first two activities are designated for wood production while the last two activities for carbon mitigation as well as wood production and the last activity only for carbon mitigation. The tree species used in the afforestation, reforestation and rehabilitation of critical land were *Acacia mangium, Paraserienthes falcataria, Tectona grandis,* and *Pinus mercusii*.

In the analysis, some of the calculations were carried outside the MARKAL model as the current MARKAL model is not able to accommodate such formulation. A case is pointed in the delayed emission of forest products. Therefore, the output from MARKAL model need to be corrected. After correction is made, the percent net carbon emission reduction for the mitigation scenarios EbFm, EmFb and EmFm increased by about 0.6%, 0.9% and 3.9**%** from the targets respectively.

The cumulative net CO_2 emission of the four scenarios is presented in Figure 1. It is shown that there is a slight difference between scenario EmFb and EbFm, although the model target of emission reduction of these two scenarios has been set to be the same in the model. This slight difference is due to the inclusion of delayed emissions from wood products and soil carbon emission uptake. For future analysis using the MARKAL model, it should be revised such that the estimation of delayed emissions and soil carbon emission is done inside the Model.

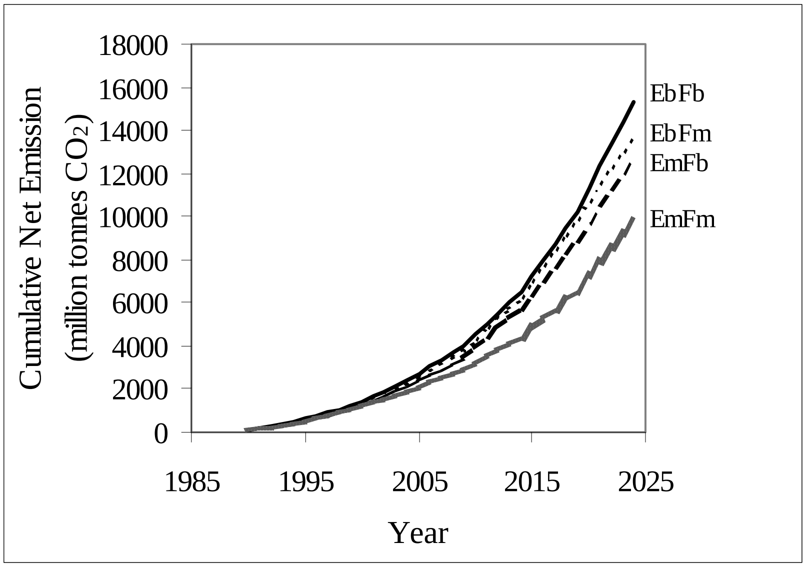


Figure S.1. Cumulative net CO_2 emission by scenarios

From the analysis it was found that cost of carbon emission reduction in energy sector is more expensive than in the forestry sector (Table 2). It was also shown that costs per tonne carbon abated in EbFm, EmFb and EmFm were different indicating the dependency of mitigation cost on the mitigation technology used and mitigation penetration. Higher mitigation cost is required if the mitigation penetration is increased. The mitigation cost (US$ per ton CO_2 abated) in energy and forestry sectors will not change if the mitigation technologies selected in each scenario are the same and the proportion of carbon reduced by each selected technology remains the same.

Table S.2. Mitigation Cost

Scenario	CO_2 reduction (billion ton)	Additional Cost (million US$)	Mitigation Cost (US$/ton CO_2)
EbFm	2078	3882	1.87
EmFb	2121	5271	2.48
EmFm			
- From baseline	5947	34643	5.83
- From EmFb	3826	29371	7.68
- From EbFm	3869	30760	7.95

In developing the scenarios, it was assumed that all the available critical land for rehabilitation will be planted within 35 years (1990-2024), and the rate of planting for all species in all scenarios is also assumed to be the same. Therefore, in the MARKAL program, change in planting and/or harvesting rate only allowed for afforestation and reforestation programs, plantation forest, and production forest as indicated in Table 3

Table S.3. Rate of planting of tree species in Java and Sumatra by scenarios

Forest Activities	Spesies	Unit	EbFb	EbFm	EmFb	EmFm
Rehabilation	Tectona grandis(Java)	Million ha	0.35	0.35	0.35	0.35
		ha/year	10000	10000	10000	10000
	Acacia mangium (Java)	Million ha	0.70	0.70	0.70	0.70
		ha/year	20000	20000	20000	20000
	Acacia mangium (Sumatera)	Million ha	0.70	0.70	0.70	0.70
		ha/year	20000	20000	20000	20000
	Paraserianthes falcataria (Java)	Million ha	0.70	0.70	0.70	0.70
		ha/year	20000	20000	20000	20000
	Pinus merkusi(Sumatera)	Million ha	0.35	0.35	0.35	0.35
		ha/year	10000	10000	10000	10000
Afforestation	Acacia mangium (Java)	Million ha	0.171	0.184	0.171	0.184
		ha/year	17100	18400	17100	18400
	Acacia mangium (Sumatera)	Million ha	1.697	1.758	1.686	1.758
		ha/year	169700	175800	168600	175800
	Paraserianthes falcataria (Java)	Million ha	0.117	0.261	0.144	0.261
		ha/year	11700	26100	14400	26100
	Pinus merkusi(Sumatera)	Million ha	0.70	0.85	0.70	0.75
		ha/year	20000	24286	20000	21429
Reforestation	Paraserianthes falcataria (Sumatera)	Million ha	0.229	0.233	0.229	0.233
		ha/year	22900	23300	22900	23300
	Acacia mangiumi(Sumatera)	Million ha	0.456	0.505	0.456	0.505
		ha/year	45600	50500	45600	50500
Forest Plantation Concession	Acacia mangium (Java)	Million ha	0.171	0.184	0.171	0.184
		ha/year	17100	18400	17100	18400
	Paraserianthes falcataria (Java)	Million ha	0.005	0.005	0.005	0.005
		ha/year	500	500	500	500
	Tectona grandis(Java)	Million ha	0.607	0.699	0.607	0.699
		ha/year	17343	19971	17343	19971
	Pinus merkusi(Java)	Million ha	0.23	0.451	0.23	0.451
		ha/year	6571	12886	6571	12886
	Switenia spp.(mahoni)	Million ha	0.027	0.032	0.027	0.032
		ha/year	771	914	771	914
	Others Spesies (Java)	Million ha	0.079	0.179	0.079	0.179
		ha/year	2633	5967	2633	5967
	Others Spesies (Sumatera)	Million ha	5.655	6.246	5.655	6.246
		ha/year	188500	208200	188500	208200

This study indicates that the MARKAL model has the potential to be used for mitigation analysis for both energy and forestry sectors. However, there are some limitations encountered during the study. The program is not able to accommodate the delayed emission from the forestry sector in a manner consistent to the treatment of emissions in the energy sector. In addition, there are some technical problems that still need to be resolved such as the inclusion of soil carbon uptake calculation in the model and the verification of carbon uptake calculation. In this study, all carbon uptakes was assumed to occur at the time of planting.

1. Introduction

The Establishment of a Methodological Framework for Climate Change Mitigation Assessment project involved six institutions in Indonesia, i.e.: Agency for the Assessment and Application of Technology (BPPT), State Electricity Company, Directorate General for Electricity and Energy Development, Center for Forest Research, Development and Center for Environmental Studies – Bogor Agricultural University and State Ministry for Environmental as coordinator. The project consists of two working groups, technical working group for energy sector, and technical working group for forestry sector.

The main objective of the project is to develop a new methodology for analyzing Greenhouse Gases (GHG) mitigation options in energy and forestry sector through integration of the two sectors using MARKAL model.

Indonesia, as a tropical country with huge tropical forest area, plans to utilize the forest resources extensively but safely. This development plan is not only to achieve its national sustainable development but also to protect the environment for the region and the world. As mitigation options, Indonesia plans to convert some forest areas to Industrial forests, to plantation, and also undertake reforestation and afforestation programs, maintaining protection forest and urban forest. Energy sector releases CO_2 to the atmosphere that may influence the global climate, while forest acts as both a source and sink of CO_2.

This study, tries to link the energy sector as a CO_2 emitter with forest sector as a source and sink. The difference between individual energy model and energy-forest model in term of material flow is biomass supply. In the individual energy model, biomass is supplied by firewood and agricultural waste. These two suppliers have different sources and unit costs. In the energy-forest model, firewood source is only from forestry system. The unit activity used in forestry sector is product volume (in m^3) for forest plantation, afforestation and reforestation, and area (in hectare) for rehabilitation program. In the energy system biomass fuel is used for cooking in the residential, direct and indirect heating in the small/medium industry, and biomass steam power plant.

The MARKAL model finds the optimum system cost and determines the final energy supply mix, CO_2 release, as well as the technology or mitigation options mix. This study consist of two scenarios, baseline scenario and mitigation scenario. The objective function of the base line scenario is to define a condition that will happen in the future as a function of energy supply mix and released CO_2 emissions from energy sector. The objective of mitigation scenario is to determine the steps to reduce CO_2 emission by introducing several mitigation options, either in the supply side or in the demand side.

Energy sector analysis is based on result of the *Environmental Impacts of Energy Strategies for Indonesia* study in 1993, as a collaborative study between BPPT, Indonesia and KFA, Juelich, Germany. However, recently several data and calculations have been updated, for example, cost estimation, economics growth rate, etc.

2. Country Profile

2.1. Geography and Climate

Indonesia is an island country and lies between latitude 6°N and 11°S and between 95°E and 141°E. There are about 17,000 islands and 6,000 are permanently inhabited. Total land area is about 191 million hectares. The total coastline length of the islands is about 81,000 km (about 14% of all the coastline in the world). The size of islands varies considerably. There are five big islands, namely, Sumatra (47,530,900 ha), Java (13,257,100 ha), Kalimantan (on Borneo; 53,583,400 ha), Sulawesi (18,614,500 ha) and Irian Jaya (on New Guinea; 41,480,000 ha). Group of much smaller includes Nusa Tenggara and Maluku (Figure 2.1).

Figure 2.1. Map of Indonesia.

Climate of Indonesia is strongly controlled by the Indian and Pacific Oceans (Dick, 1991). Annual rainfall in Kalimantan, in all of Sumatra except the northern coastal strip, in all of Irian Jaya except the south-eastern region, in the central part of Sulawesi, in Halmahera and Aru islands of Maluku, and in south-western Java, range between 2,500 and 4,000 mm. The other regions of Indonesia have semi-arid or monsoonal climates with the driest parts being found in Nusa Tenggara. The annual rainfall of these regions is about 700 mm (MoF and FAO, 1991).

2.2. Social and Economical Aspects

Indonesia is the world's fourth most populated country with a population of 200 millions but, more than 60 % of the population lives in Java Island covered only 7 % of the land area of Indonesia. Through this condition, Java became the most populated area with density is roughly 850 peoples per square km.

Family planning program in Indonesia has been successful, by reducing the population growth rate from 2.10 % per annum in 1967-1970 to 1.9 % per annum in 1990-1995. The population in 1990-1995 is given in Table 2.1. The reduction of population growth rate is accompanied by an improvement of the wealth of the people.

The death rate decreased from 19.1 per thousand people in 1967-1970 to 7.9 per thousand people in 1993. The birth rate has also decreased from 5.6 children per woman in 1967-1970 to 2.87 children per woman in 1993.

The distribution of people who live in rural and urban areas is given in Table 2.1. Most Indonesians live in rural area, with a slight increase form 69% in 1991 to 71% in 1995. In 1995, the population of male was 49.8 % of the total population. In 1995, about 152.51 million of the population had age older than 10 years. Out of this number, 80.11 million were employed, and 6.25 million were seeking employer. The rest were attending school, housekeeping and other activities. Of the 80.11 million working people, about 44 % were working in the agriculture sector, 12.6 % in manufacturing sector, 17.4 % in trading sector, 15.1 % in services sector and 10.9 % in other sector.

Table 2.1: Indonesian Population (in thousand)

Year	Population	Urban	Rural
1990	179.25	55.43	123.82
1991	182.22	55.61	126.61
1992	185.26	55.79	129.47
1993	188.36	55.96	132.40
1994	191.52	56.12	135.40
1995	194.75	56.27	138.48

Source: Central Bureau of Statistic, 1996.

Indonesia's economic growth and development are increasingly capturing the attention of the wider world and those involved in the energy sector are no exception. Indonesia has long been part of the international oil industry - the archipelago has been a major oil exporter for more than a century, and in the 1990s export of gas and coal have also become important.

As a new developing country, Indonesia enjoys strong and consistent growth of around 5-6%, governed by government deregulation, market oriented policies, manufacturing and modern service sectors are making up an ever-greater proportion of Gross Domestic Product (GDP). Growth and structural change in the economy are being driven by private sector investment, both domestic and foreign. Table 2.2 illustrates the economic development in Indonesia from 1990 to 1995. In this economic activity, mining and quarrying sector is divided into oil and gas, non-oil and quarrying. Manufacturing industry sector is also divided into oil and gas, and non-oil and gas. Services sector is divided into public, private and defense. Manufacturing industry's (not including oil) contribution on the national GDP in 1990 was 10 %, and in 1995 reached 14.7 %. Share of agricultural in the GDP was about 20.2 % in 1990; while, the combined contribution from agricultural, forestry and fishery was only 16.7 % in the 1995. Despite of the fact that the share of agriculture in national GDP is expected to continue declining, its role in the economy is still vital since it is the major source of employment.

There is a sharp increase of middle and upper income family number in the last 10 years. However, the majority of these are located in large cities, such as Jakarta, Bandung, Surabaya and Medan. About 15-20 % of the population of these cities belong to the middle and upper income groups. The average annual per capita GDP is about $ 1000 in 1996. Industrialization and urbanization are concentrated in Java; while, the other islands and regions remain dependent on agriculture and related activities.

The share of oil product, combined in mining and quarrying sector and manufacturing industry sector, in GDP decreases moderately, in which the share of oil in

GDP was 11.6 % in 1990 and became 9.6 % in 1995. Exports have diversified to a wide range of manufactured products from the earlier reliance on oil. In the last ten year, Indonesia has a GDP growth rate above 5 % per annum. Non oil exports must be the engine for economic growth during 1995-2023 period, should oil exports decline and finally end in the year 2008. Assuming that non-oil exports grow at a reasonable rate, the domestic market will have gained enough momentum to allow solid economic growth. The expected growth rate of selected sectors during 1995-2023 period are shown in Table 2.3.

Table 2.2: GDP by Industrial Origin (Billions Rupiah) 1993 Constant Market Price

No.	INDUSTRIAL ORIGIN	1990		1991		1992		1993		1994		1995	
		(Rp)	(%)	(Rp)	(%)	(Rp)	(%)	(Rp)	(%)	(Rp)	(%)	(Rp)	(%)
1	Agricultural, Livestock, Forestry & Fishery	53056	20.2	54583	19.0	58002	18.9	58963	17.9	59291	16.7	61885	16.1
2	Mining and Quarrying	26628	10.1	29969	10.5	30461	9.9	31497	9.6	33262	9.4	35502	9.3
3	Manufacturing Industry	54211	20.6	59941	20.9	66042	21.5	73556	22.3	82649	23.3	91637	23.9
4	Electricity, Gas and Water Supply	2508	1.0	2720	0.9	2961	1.0	3290	1.0	3703	1.0	4292	1.1
5	Construction	15226	5.8	17486	6.1	19664	6.4	22513	6.8	25858	7.3	29198	7.6
6	Trade, Hotel & Construction.	41725	15.8	46669	16.3	50344	16.4	55298	16.8	59504	16.8	64231	16.7
7	Transportation & Communication	18474	7.0	20040	7.0	21618	7.0	23249	7.0	25189	7.1	27329	7.1
8	Banking, Build. Rental & Fin. Service	21479	8.2	24309	8.5	26164	8.5	28048	8.5	30901	8.7	34313	8.9
10	Services	29956	11.4	31049	10.8	32220	10.5	33361	10.1	34285	9.7	35406	9.2
11	Gross Domestic Product	263262	100.0	286765	100.0	307474	100.0	329776	100.0	354641	100.0	383792	100.0
12	GDP Growth Rate/Annum			9		7		7		8		8	
	Petroleum Product (including 2. & 3.)	30549	11.6	33195	11.6	32807	10.7	32915	10.0	33988	9.6	33502	8.7
	GDP Non Petroleum	232713		253570		274667		296861		320652		350290	

Source: Central Bureau of Statistics, 1996

Table 2.3: Average Annual Growth Rates in 1990-2020 period of Selected Economic Sectors

No.	S e c t o r	Growth Rate (% / year)
1.	Agriculture	4.2
2.	Textile Industry	7.6
3.	Chemical Industry	8.6
4.	Paper Industry	8.7
5.	Machinery & Equipment	9.1
6.	Coal, Oil and Natural Gas	2.6
7.	Petroleum Refining	5.2
8.	Electricity & Water	7.7
9.	Commerce	6.7

Source: BPPT-KFA, Environmental Impact of Energy Strategies for Indonesia, 1993.

Based on the current oil export situation, the export is declining significantly during the Five Year Development Programs (FYDP) VI, 1994-1998, and will fall more sharply in later years for the simple reason that oil reserves are limited. A projection of oil export and import in Indonesia based on BPPT-KFA study in 1993 can be seen in Figure 2.2. The Figure shows that oil export is declining and oil import is increasing. In the year 2002, there will be a balance between oil import and export. Then, Indonesia must import all oil to fulfill domestic demand in 2010.

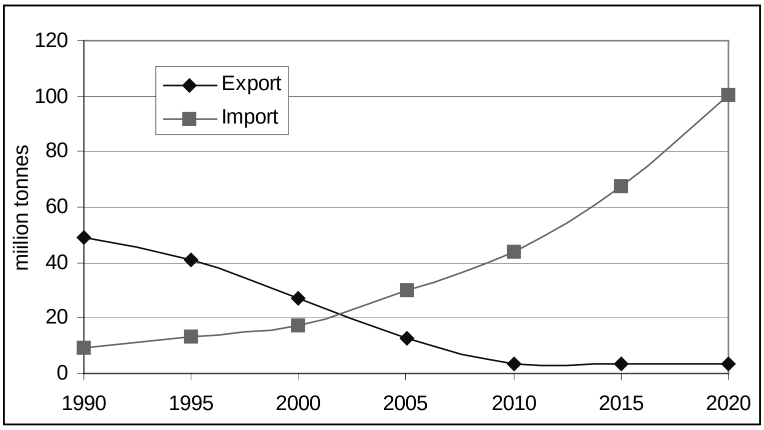


Figure 2.2: Development of Oil Export and Import in Indonesia

Since the mid's of 1980s, oil and non-oil exports has been engine of economics growth. Although at present, the Indonesia's economics is not dominated by oil income anymore, but the influence of oil import and export to the GDP is assumed to remain until the beginning of the 21^{st} century.

As a matter of fact, in the end of fiscal year 1997, the Indonesian economy slumped following the extra ordinary decreasing of rupiah's exchange rate to foreign currencies from 2,475 rupiah per US Dollar to an average of 8000 rupiah per US Dollar. It is predicted that Indonesia's economy will shrink by 4 % in the fiscal year 1998. The main macroeconomic variables affected by the change of exchange rate include the gross domestic product (GDP), general prices (inflation), the employment rate, the interest rate, and the wage rate. However, if Indonesian government is able to perform a tight reform program successfully, in the next 2-3 years, the economic condition should be back to normal.

The GDP in 1995-2000 include the affect of the "GDP slump" in 1997, that decreases GDP rates from 7 percent per annum in 1994-1996 to 5.7 % in 1994-1998. The growth rates of GDP and population until the end of 2020 can be seen in Table 2.4. The GDP grows in six periods with an average growth rate of 5.93 % per annum and the population grows with an average growth of 1.43 % per annum. Because of an increasing population, the GDP per capita grows at a lower rate of 4.33 % per annum on average.

Table 2.4: GDP and Population Growth in Indonesia During1990-2020

Period	Real GDP Growth (%/a)	Population Growth (%/a)	GDP/Capita Growth (%/a)
1990-1995	6.4	1.9	4.0
1995-2000	5.7	1.7	3.9
2000-2005	6.3	1.5	4.7
2005-2010	5.1	1.3	3.7
2010-2015	6.0	1.2	4.7
2015-2020	6.1	1.0	5.0
1990-2020	5.93	1.43	4.33

2.3. Energy Sector

Table 2.5 shows the energy balance in Indonesia for the year 1990. In this table, the primary supply is included any activities for domestic supply either before or after transformation, import, export and international bunker. Transformation is any activities to convert primary energy to secondary energy. This activity can be done with/without physical change of the energy form, such as oil refinery, LPG refinery, LNG refinery, electric generation, city gas refinery, gasification/liquefaction and other transformation. The input of this activity has a negative sign; while, the output has a positive sign. Own use and losses are included own used in the field, transformation and distribution, and any losses in every activities.

The total final consumption consists of final energy use and non-energy use. The final energy use is divided into three sectors, i.e. industry, transportation, and residential & commercial. The non-energy use is any use for feed stock or chemical, such as natural gas for feed stock of fertilizer industry and coal for reductor in metal industry. Statistical difference is the difference between total final consumption and supply energy. It is also taking into account transformation, own use and losses. Theoretically, there were no differences between supply and consumption. However, the difference is present due to the changing of stock in which the data is difficult to obtain.

Table 2.5 shows clearly that the primary energy supply is dominated by oil products. Biomass and natural gas are the second and the third sources of the primary energy supply in Indonesia, respectively. The contribution of coal to the energy supply is relatively small. In the last 10 years, the share of oil consumption was declining; there was significant increase in the role of natural gas and coal in the energy supply.

Table 2.5: Energy Balance 1994 (Baseline) in million BOE

	Coal	Crude Oil	Oil Products	Natural Gas	LPG	Hydro Power	Geo-thermal	Electri-city
Production	43.40	530.70		325.00		17.30	1.70	
Imports	5.00	45.70	23.80		0.00			
Exports	(17.90)	(286.50)	(0.10)	(191.30)	(22.20)			
International Bunker			(4.70)					
Stock Change	n.a.	n.a.	n.a		n.a			
Primary Supply	30.40	289.80	19.00	133.80	(22.20)	17.30	1.70	
Refineries		(273.60)	188.90	0.00	2.80			
Power Plant	(16.90)		(28.20)	(2.00)		(17.30)	(1.70)	23.10
Others			(0.0)	(42.50)	20.60			
Transformation	(16.90)	(273.60)	160.60	(44.50)	23.40	(17.30)	(1.70)	23.10
Own Use & Losses	(0.10)	(1.00)	(4.10)	(87.40)	(0.00)			(4.40)
Statistic Difference	(4.80)	(15.20)	(1.10)	41.70	1.50			(0.00)
Final Consumption	8.60		174.30	43.60	2.70			18.70
Final Energy Use	8.30		174.30	22.70	2.70			18.70
Industry	8.30		46.60	22.70	0.80			10.50
Transportation	0.00		81.80	0.00	0.00			0.00
Residential & Comm.Commercial	0.00		46.00	0.00	1.90			8.20
Non Energy Use	0.30			20.90	0.00			

Source: Planning Bureau, Department of Mining and Energy, 1995.

2.4. Forestry Sector

Indonesian forest is the third largest of tropical forest in the world after those in Brazil and Zaire. Based on consensus of several ministries, total of forest area is agreed to be 144.9 million hectares and it has been classified into five main categories, i.e. protection forest, reservation forest, limited production forest, non-convertible forest and convertible production forest (Table 2.6). The last three categories are forests that can be harvested for log production. Based on forestry studies, it has been estimated that in 1990 the area of natural forest in Indonesia is about 108.6 million hectares, about 55% of the total land area (MoF and FAO, 1990).

Table 2.6. Area of forestland based on its category by islands

Islands	Protection forest	Reservation forest	Limited production forest	Non-convertible forest	Convertible production forest	Total Production forest	Total Forest Area
	(1)	(2)	(3)	(4)	(5)	(6) =(3+4+5)	(7) =(1+2+6)
Sumatra	5,772,249	4,049,225	6,179,561	6,695,416	7,348,187	20,223,164	30,044,638
Java	554,113	445,093	0	2,014,243	0	2,014,243	3,013,449
Kalimantan	6,923,471	4,174,084	11,347,825	14,229,084	8,810,196	34,387,105	45,484,660
Sulawesi	4,475,015	1,394,368	4,704,003	1,487,198	1,494,015	7,685,216	13,554,599
Irian Jaya	8,648,610	8,311,820	4,732,360	7,123,480	11,775,420	23,631,260	40,591,690
Other islands	3,218,975	778,406	2,604,907	1,849,796	3,787,145	8,241,848	12,239,229
INDONESIA	29,592,433	19,152,996	29,568,656	33,399,217	33,214,963	96,182,836	144,928,265

Source : Center for Forest Inventory (1996)

Protection forest is defined as forestland that is extremely vulnerable to soil and water degradation. The primary role of these forests is to provide protection to land. These forests are often located on very steep slopes. Protection forests are not available for forest product supply. Reservation forest is defined as forestland that is reserved for use as scientific reserves, parks and wildlife refuges. Limited production forest is defined as forestland that is vulnerable to soil and water degradation but less so than those classified as protection forest. These forests can be managed for material supply but only with very extensive and relatively unobtrusive forms of management. Non-convertible forest is defined as forestland that is considered to be sufficiently robust to be used as industrial forest under state of the art forest production and management practices. Convertible production forest is defined as forest land that is not destined to be a part of the permanent forest estate but is projected to be deforested for conversion to agriculture.

Based on the characteristics of the vegetation, forests of Indonesian can be classified into 10 forests namely : (1) coastal forests on beaches and dunes, (2) tidal forests, including mangrove, nipa and other coastal palms, (3) heath forests associated with sandy, infertile soils, (4) peat forests associated with organic soils with peat layers at least 50 cm deep, (5) swamp forests seasonally inundated by fresh water, (6) evergreen forests, including moist primary lowland, riparian and dry deciduous forests, (7) forests on rocks that contain basic minerals (pH more than 7), (8) mountain forests, (9) bamboo forests, and savannah forests.

Growing stock, which refers to the estimated gross standing volume of wood in a forest stand, varies from region to region. Based on random samples of inventory reports from the Green Books of the Ministry of Forestry, the volume of 50 cm dbh and above in limited and non-convertible production forest for unlogged areas ranged from 57.9 m^3 to 117.4 m^3 and for logged areas ranged from 46.5 m^3 to 94.5 m^3 (Table 2.7).

Table 2.7. Estimated volume per hectare of unlogged and logged production forest of mixed hardwood in regular and limited production forest

No.	Island	Species Group	Volume (m^3/ha) of 50 cm dbh and above	
			Unlogged	Logged
1	Sumatra [1]	Commercial Dipterocarps	27.02	16.21
		Commercial Non-Dipterocarps	28.69	22.95
		Non-Commercial	13.59	11.55
		Total	69.30	50.71
2	Sumatra [2]	Commercial Dipterocarps	18.74	11.24
		Commercial Non-Dipterocarps	58.24	46.59
		Non-Commercial	18.62	15.83
		Total	95.60	73.66
3	Kalimantan	Commercial Dipterocarps	51.10	30.66
		Commercial Non-Dipterocarps	48.08	38.46
		Non-Commercial	18.22	15.49
		Total	117.40	84.61
4	Sulawesi	Commercial Dipterocarps	8.38	5.02
		Commercial Non-Dipterocarps	58.48	46.78
		Non-Commercial	50.64	43.04
		Total	117.50	94.84
5	Maluku	Commercial Dipterocarps	3.12	1.87
		Commercial Non-Dipterocarps	31.66	25.33
		Non-Commercial	40.22	34.19
		Total	75.00	61.39
6	Irian Jaya	Commercial Dipterocarps	3.11	1.87
		Commercial Non-Dipterocarps	31.67	25.33
		Non-Commercial	23.12	19.65
		Total	57.90	46.85
7	Nusa Tenggara	Commercial	36.00	25.20
		Non-Commercial	25.00	21.25
		Total	61.00	46.45

[1] Aceh, Riau, Jambi, South Sumatera, Bengkulu, Lampung, [2] North Sumatra, West Sumatra; Source : DGFU and FAO (1990a).

Determination of the productivity of Indonesian mixed natural forest is quite difficult because of their mixed age, stratification and morphological diversity. Even if one limits the estimation of productivity to dominant trees there is still difficulty in determining the age and the increment of trees. Based on observation from several sites it was found that the whole tree-volume of the tropical lowland rainforest ranged from 198 to 239 m^3/ha, tropical rainforest from 188 to 434 m^3/ha and tropical montane rainforest about 759 m^3/ha (Table 2.8). Furthermore, Soerianegara (1996) estimated that the productivity of the Indonesian hardwood in the lowland is about 5.8 t/ha/year (range from 0.86 to 7.30 t/ha/year), and that in montane rainforest is about 12.4 t/ha/year (range from 5.90 to 19.96 t/ha/year).

Table 2.8. Stem biomass of selected forest in Indonesia

No	Sites	Characteristics of site	Main tree Species	Whole-tree volume (m^3/ha)	Stem Biomass (t/ha)
1	Tropical lowland forest, Riau	• Rainfall : 2422 mm/yr • Temperature 26^{o}C • Soil : organosols at weter site and podzolic soils at drier site • Elevation : 0-50 m a.s.l.	*Shorea* spp, *Hopea* spp, *Palaquium, Tetramerista glabra, Koompasia malaccensis, Durio carinatus, Dryobalanops aromatica, Hopea* spp, *Cotylelobium* spp, *Eugenia* spp.	198 - 239	142 – 183
2	Tropical rainforest at Semangus, South Sumatra	• Rainfall : 3000 mm/yr • Temperature 26oC • Soil : red-yellow podzolic soils at most area and organosols along the Keruh river • Elevation : 150 m a.s.l.	*Shorea* spp, *Triomma malaccensis, Hopea, Anisoptera, Dipteocarpus* spp, *Koompasia malaccensis*	188	128
3	Tropical rainforest at Nunukan and Tarakan, north-east Kalimantan	• Rainfall : 3874 mm/yr • Temperature 25.9-26.3oC • Soil : gley soils • Elevation : 50-500 m a.s.l.	*Shorea* spp, *Shorea laevifolia, Dryobalanops* spp, *Dipteocarpus* spp, *Eusideroxylon zwageri*	320 - 434	214 - 293
4	Tropical rainforest at Sangkuliran g, north-east Kalimantan	• Rainfall : 1625 mm/yr • Temperature 26oC • Soil : yellow and red-yellow podzolic soils • Elevation : 0-50 m a.s.l.	*Shorea* spp, *Dryobalanops* spp, *Dipteocarpus* spp, *Eusideroxylon zwageri*	246	170
5	Agathis forest at Sampit, Central Kalimantan	• Rainfall : 2621 mm/yr • Temperature 26oC • Soil : 0.2-4.0 m of peat overlying a quartz sand layer of about 80 cm thick • Elevation : 10 m a.s.l.	*Shorea uligonosa, Palaquium* spp., *Combretocarpus motleyi, Mezzettia leptopeda, Tetramerista glabra, Agathis borneensis, Tristania obovata*	193 - 429	132 – 216
6	Tropical montane rain forest, West Java	• Rainfall : 4300 mm/yr • Temperature 17.7oC • Soil : Andosol • Elevation : 1100-1500 m a.s.l.	*Altingia exelca, Magnolia blumei, Michelia* spp., *Rhodamnia cinerea, Dysoxylum* spp, *Castanea* spp., *Quercus* spp., *Eugenia* spp., *Schima noronhae, Podocarpus* spp., *Engelhardtia spicata, Calophylum teysmanii, Glochidion* spp., *Elaeocarpus* spp.	759	549

Source : Soerianegara (1996).

In the period of 1960-1990, production forest is the main source of timber supply (about 96% of total supply). In the future the role of production forest as timber supplier will be gradually reduced. Its role will be replaced by industrial timber plantation, tree plantation (rubber, palm oil and coconut) and private forests (see chapter 6). In the FYDP VI (1994-1999), it has been targeted that about 30% of log production will be from industrial timber plantation, rubber tree plantation and private forest (Sekab, 1995).

Based on DGFU and FAO study (1990a), in 2030 the production forest will only supply 24% of the total demand while the remaining will come from plantation forests and non-forest sources.

The Indonesian forest is considered as one of the world's mega-diversity ecosystem and therefore the importance for forest conservation and protection for the benefit of present of future generation can not be overstated. Up to present time, Indonesia has declared the protection of 95 species of mammals, 379 species of birds, 30 species of reptiles, 20 species of insects, and 6 species of fish (Dirjen PHPA, 1997). In addition, 21.5 million hectares has been reserved as conservation areas (Table 2.9).

Table 2.9. The conservation areas in Indonesia, 1996/1997

		Number	Area (million ha)
A	**Land Parks**		
1	National Park (*Taman Nasional*)	30	10.397
2	Natural Recreation Park (*Taman Wisata Alam*)	76	0.286
3	High Forest Park (*Taman Hutan Raya*)	11	0.237
4	Hunting Park (*Taman Buru*)	13	0.235
5	Nature Reserve (*Cagar Alam*)	172	2.210
6	Wildlife Sanctuary (*Suaka Margasatwa*)	45	3.577
	TOTAL A	347	16.942
B	**Marine Parks**		
1	Marine National Park (T*aman Nasional Laut*)	6	3.683
2	Marine Recreation Park (*Taman Wisata Laut*)	13	0.597
3	Marine Nature Reserve (*Cagar Alam Laut*)	5	0.195
4	Marine Wildlife Sanctuary (*Suaka Margasatwa Laut*)	3	0.065
	TOTAL B	27	4.540

Source : Dirjen PHPA (1997).

3. Overview of Other National Climate Change Studies

Indonesia has been quite active in the field of GHG studies. There are several studies that have been completed or being conducted or planned on the analysis of the greenhouse gas issues in Indonesia. An overview of these studies is as follows.

3.1. Climate Change Study with Japan

Japan Environment Agency, Overseas Environmental Cooperation Center cooperated with the Ministry of State for Population and Environment of Indonesia to conduct a two phase of two year studies on the determination of the adverse effects of global warming and the formulation of the response actions in Indonesia (JEA and MSPE, 1993).

Phase I

The first phase of the study entitled *The Basic Study on Strategic Response Against Global Warming, Climate Change and Their Adverse Effects* was conducted in 1991. The objective of this study was to assist the government of Indonesia in preparing a national response strategy against global warming and climate change. The scope of this study were:

a. To estimate the present conditions of carbon emission by source.
b. To built up the future scenario of CO_2 emission.
c. To identify the priority fields of response actions to limit carbon dioxide emission.

Phase II

Phase II of this study entitled *The Study Response Actions Against the Increasing Emission of Carbon Dioxide in Indonesia* was completed in March 1993. The objectives of the second phase of the study were:

a. To identify and assess the sources of CO_2 emission by estimating the amount of emission for each specified activity concerned.
b. To formulate the possible response actions to limit CO_2 emission.

While the scope of work was:

a. To revise 1991 estimation of CO_2 emission by each sector and estimate the present CO_2 emission by each activity sources.
b. To built up the future scenario of CO_2 emission based on the production of the future trend of human activities.
c. To identify the priority fields in which immediate response actions to limit CO_2 emission need to be taken.
d. To propose possible response actions and technologies to be applied in Indonesia to limit CO_2 emission.

The study with Japan was partly based on the data of the Energy Study on Energy Strategies, Energy R+D Strategies, Technology Assessment for Indonesia that was conducted by cooperation between BPPT of Indonesia and KFA of Germany.

3.2. ADB Regional Impacts Strategy Project

This study has been carried out by the State Ministry for Population and Environment as the implementing agency, assisted by Wahana Lingkungan Hidup

Indonesia (WALHI, The Indonesian Forum for the Environment), and in collaboration with Pelangi Indonesia (The Policy Research Institute for Sustainable Development). The Study is entitled *Sosio-economic Impact of Climate Change and a National Response Strategy*. This study represents the Indonesian country study of the Regional Study of Global Environmental Issues Project Sponsored by Asian Development Bank (ADB) (MSPE & Pelangi, 1993).

The scope of the study is:

a To evaluate socio-economic impacts of climate change.

b. To develop a National response strategy on climate change.

3.3. UNEP Project on Socio-Economic Impacts of Climate Change

Indonesia has completed a cooperative project with United Nations Environment Programme (UNEP) on the socio-economic effects on climate change in Indonesia, Malaysia, and Thailand. The study was carried out in the period of 1988-1991, resulted in a report entitled *The Potential Socio-Economic Effects on Climate Change in South-East Asia* (Parry & Blantaran de Rozari, 1991). The UNEP studies focus on socioeconomic impacts whereas the proposed study focused on technology assessment for CO_2 reduction.

The long-term objectives of the study were:

a. To enable governments of Indonesia, Malaysia, and Thailand to adopt appropriate policies and strategies to respond the possible future climate change.

b. To increase awareness of the possible adverse impacts of global climate change.

In addition, the short term objectives were:

a. To understand and characterize regional vulnerability and adaptability to climate change in the context of South-East Asia.

b. To evaluate the impact of climate change on members of economic and social systems in Indonesia, Malaysia, and Thailand in order to facilitate the taking of appropriate measures to mitigate those impacts.

The scope of the study was :

a. The impact of possible future global climate change on agriculture, water resources management, and water quality and availability.

b. The impact of possible future changes in sea level on marine culture and prawn production; the tourist industry especially coastal resort; and salt intrusion in estuaries, deltas, and the impact of increased storm frequency.

3.4. BPPT-KFA Study on Environmental Impacts of Energy Strategies

The study has been conducted by BPPT (Agency for the Assessment and Application of Technology) of Indonesia cooperated with KFA (Nuclear Research Center) of Germany. The study is entitled *Environmental Impacts of Energy Strategies for Indonesia* completed in May 1993. The objectives of the study were:

a. To demonstrate that Java would run into severe environmental problems if no significant efforts are made in the future to reduce air pollution (worst case analyses)

b. To develop proposals for environmentally compatible energy supply strategies for Indonesia in order to support decision makers in Indonesian authorities (optimistic scenario).

The study used MARKAL (Market Allocation) model in order to find optimal energy supply strategies for the national Indonesian energy system under the condition of probable economic scenarios with different political objectives. In addition to this model, the study also used supporting model such as DISDEP model for estimating concentration and deposition of pollutants emission, MACRO model for estimating economic development, DEMI model for estimating energy demand, and GIS for estimating critical land areas and recommendation for emission reduction. By using those models, the present and projected future primary energy consumption, and pollutants emission of energy utilization such as SO_2, NOx, SPM (Suspended Particulate Matters), and VHC (Volatile Hydrocarbon) were calculated in the study. The air pollution from energy utilization in the next 30 years both with and without counter measures was estimated in the study. The study also provides information about emission reduction strategies for a cleaner future energy supply including technological options for reducing those air pollutants. Information on time period for application of the technological options is also provided in this study. In addition, the study also calculated and analyzed the present and projected the quantity of CO_2 releases from energy utilization.

3.5. BPPT-GTZ Study on CO_2 Reduction Strategies

The study has been carried out by BPPT (Agency for the Assessment and Application of Technology) in collaboration with GTZ (*Deutsche Gesellschaft fuer Technische Zusammenarbeit Gmbh*). The study was entitled *Technology Assessment for Energy Related CO_2 Reduction Strategies for Indonesia* that completed in July 1995. This was a continuation of BPPT-KFA study on environmental impacts of energy strategies for Indonesia, however this study was more stressed on technological options for CO_2 reduction from energy sector. The study also used MARKAL Model for estimating the future technology and energy mix with the related costs as well as the development of CO_2 emission from energy utilization in the next 30 years. The objectives of this study could be summarized as follows:

a. To obtain a detailed inventory of the energy related CO_2 emission sources and information on the possible future trends of CO_2 emission in Indonesia depending on detailed energy consumption forecast.
b. To analyze the effect of several CO_2 emission counter measures, such as technological options, energy conservation, energy substitution, and regional planning, on the overall reduction of CO_2 emissions.
c. To study the economic costs of CO_2 reduction measures.
d. To formulate recommendations to curb the greenhouse gas emissions.

3.6. ALGAS Project

The ALGAS (*Asia Least Cost Greenhouse Gas Abatement Strategy*) project was implemented by State Ministry of Environment as a main counterpart, assisted by Bogor Institute of Agriculture (IPB), Bandung Institute of Technology (ITB), Indonesian Association of Agricultural Meteorology (PERHIMPI), and Yayasan Pelangi. The project was completed in 1997. The project was assigned to develop national greenhouse gases inventory and to develop technology options for abating greenhouse gas emissions from all the major sectors including energy, agriculture, and forestry and land use sectors. The main objectives of the project was to strengthen the national capacity including:

a. To develop the necessary and reliable information on greenhouse gases source and sinks
b. To assess, analyze, and verify the information and report the results to the secretariat of the UNFCCC
c. To identify, formulate, and evaluate viable greenhouse gases abatement strategies, and cost of emission reduction initiative
d. To assist in securing the resources to implement the most cost-effective, i.e. least-cost greenhouse gases abatement options.

4. SUPPLY-DEMAND PROJECTION

4.1. Energy Sectors

As Indonesia possesses various types of energy, it is very important to analyst the reserves and utilization of the energy for long time periods, in order to fulfill the domestic energy demand in the future. This chapter will describe reserves and production of primary energy types, especially fossil fuels, projection of primary energy supply, and renewable energy.

4.1.1. Prospect of Fossil and Renewable Energy

Indonesia were granted abundant and various energy sources as well as fossil energy and renewable energy. Oil, which at present dominates on the energy consumption, with very limited reserves, should be substituted and replaced by other sources of energy. On the other hand, renewable energy, that very important to be developed especially in rural and remote area, is not developed yet because of high cost and technology.

This section will describe the conditions and prospects of fossil fuels, i.e. oil, coal and natural gas, and renewable energy, i.e. hydropower, geothermal, etc.

4.1.1.a. Oil

Domestic consumption of oil is 63 % of total oil production. The crude oil and condensate production during 1990 to 2020 is declining at average rate of 3.7 % per annum from 3,037.26 PJ per annum in 1990 to 968.52 PJ per annum in 2020. However, the import of crude and refined products will increase with an average rate of 8.7 % per annum. The increasing import of crude and refined products are due to increasing utilization of refined product for domestic use during 1990 to 2020. The average growth rate of oil domestic use is 5 % per annum, while the crude oil reserves is limited. The total of proven and potential crude oil and condensate reserves in 1994 was 10,414.42 million barrels.

4.1.1.b. Natural Gas

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

Production of natural gas during 1990 to 2020 grows at an average rate of 2.2 % per annum from 1,776.20 PJ per annum in 1990 to 3,438.55 PJ per annum in 2020. Over 65.5 % of the total production in 1990 were exported in the form of liquid (LNG and LPG), and the rest of natural gas production was to fulfill the energy demand for final use such as heat and feedstock, and electricity generation. In 2020, gas export is projected to be about 32 % of the total production. At present, gas for the domestic market consumption is almost exclusively consumed by industries. In the past, gas consumption for electricity generation was high. However, the biggest future market for gas in Indonesia is industry (heat and feedstock), that is located in the island of Jawa, but the reserves near Jawa are not sufficient. Therefore, the future utilization of the Natuna gas field for Jawa will become an option of supply. However, the Natuna gas fields are far away from Jawa and the gas has a CO_2 content of about 70 %. Therefore, the utilization of the Natuna gas field will become very expensive.

4.1.1.c. Coal

The total coal resource in 1996 was about 38,720 million tones, in which 64 % was located in Sumatra and 35,4 % was located in Kalimantan, while the rests were spread in Jawa, Sulawesi, and Irian Jaya. Indonesia has four types of coal, i.e. anthracite, bituminous, sub-bituminous, and lignite. However, only anthracite, bituminous, and sub-bituminous, has been utilized in Indonesia.

The coal production during 1990 to 2020 grows at an average rate of 10.6 % per annum from 281.74 PJ per annum in 1990 to 5,761.23 PJ per annum in 2020. At present, over 44.5 % of the total production are exported, but the priority of coal utilization in the future is to fulfill the domestic energy demand for cement industry, and electricity generation.

Total domestic coal use will increase from 194.37 PJ per annum in 1990 to 5,876.98 PJ in 2020, in which domestic use of coal for electricity generation has a growth rate of 13.2 % per annum from 72 PJ per annum in 1995 to 1,610 PJ in 2020. The emissions, such as SO_2, NO_x and dust from coal utilization can be kept within tolerable limits if clean technologies are used.

The crude oil, natural gas, and coal import, production, and export is shown in Table 4.1. and Figure 4.1.

Table 4.1: The Crude Oil, Natural Gas, and Coal Import, Production, and Export

		(PJ/year)						
		1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Import	Coal	8.13	6.49	6.57	9.75	13.18	55.15	140.23
	Oil	385.86	564.18	798.22	1,375.48	1,918.88	2,921.93	4,596.04
	Sub-Total	393.99	570.67	804.79	1,385.23	1,932.06	2,977.08	4,736.27
Production	Coal	281.74	603.06	983.23	1,639.11	2,786.31	4,578.87	5,761.23
	Gas	1,775.20	2,379.01	3,004.87	3,242.98	3,479.14	3,423.41	3,438.55
	Oil	3,037.26	2,844.58	2,327.66	1,641.91	1,178.66	1,094.21	968.52
	Sub-Total	5,094.20	5,826.65	6,315.76	6,524,00	7,444.11	9,096.49	10,168.30
Export	Coal	95.50	268.26	522.88	642.01	775.60	938.90	25.48
	Gas	1,162.82	1,368.00	1,550.00	1,558.99	1,559.00	1,332.00	1,112.00
	Oil	1,989.00	1,620.00	898.00	389.00	0.00	0.00	0.00
	Sub-Total	3,247.32	3,256.26	2,970.88	2,590.00	2,334.60	2,270.90	1,137.48

4.1.1.d. Renewable Energy

Actually Indonesia has a large hydropower potential of 75 GW but most of them are located far away from the demand, i.e Mambramo river in Irian Jaya, in 1990 only 2.0 GW was used while in 1995 increase to 3.9 GW. Most of the reserves are located in thinly populated areas where the demand is too low to justify large scale hydropower investments. Therefore, it is very important to select and allocate such industry to utilize this energy potential, and increase the job opportunity in the area.

The total geothermal potential has been estimated to be 16.1 GW, while Java and Bali (interconnection line) have nearly half of the reserves. In 1995, only 390 MW of the potential or nearly 2.4 % of the total reserves was used.

Solar energy has been developed in Indonesia, especially in rural and remote area. This program, called as *One Million Households Photovoltaic Rural Electrification* was launched by The President of the Republic of Indonesia in June 1997. It is predicted that the utilization of Solar Photovoltaic for lighting and water pumping and solar drying for agricultural products will expands in the future, although the amount of energy is very small compared to the total energy consumption. Other renewable energy, i.e. wave energy, wind energy etc., are still under consideration and are not utilize yet as a commercial projects.

4.1.2. Projection of Baseline Energy Demand and Supply

In the baseline scenario, which is based on business as usual (BAU) scenario; there are no limitation of the GHG emission and introduction of GHG mitigation options. This chapter consists of development of baseline primary energy supply, energy carriers and final energy consumption. But further, in mitigation scenario, this study will introduce some options regarding CO_2 abatement technologies, i.e. compact fluorescent lamps, refrigerators, solar home system, IGCC, PFBC, fuel cell technology, etc. In addition, reflection of an evolution between business as usual, high efficiency or near complete efficiency is postulated included in the model.

The primary energy supply for domestic market grows in line with economic expansion. Oil, which at present (1996) dominates with 37 % of the domestic market, will reach a level nearly 2.8 times higher in the year 2020 as compare to 1996, though its share will decline to 30%. Gas consumption grows by 4.1 % from 1996 to 2020, annually leading to a decline into share in total primary energy. In the future, coal will play a dominant role.

4.1.2.a. Development of Baseline Primary Energy Supply

The average annual growth rates of the primary energy supply in Indonesia during 1990 to 2020 is 5.6 % per annum, from 3,138 PJ per annum in 1990 to 15,906 PJ per annum in 2021. The domestic primary energy supply by individual energy carriers is shown in Table 4.2.

The utilization of oil grows during 1990 to 2020 at a rate of 4.8 % per annum. This low growth is due to diversification to coal & gas, and the scarcity of oil reserves, if there are no new oil fields discovered.

After the year of 2015, the share of gas in the primary energy supply will decline and coal starts to take a dominant role. Natural gas with a low specific carbon content has a potential to be candidate as primary energy supply. However, the use of natural gas for LNG reduces, the potential of natural gas as a domestic power generation.

Table 4.2: Baseline Primary Energy Supply

Type of Energy	**Primary Energy Supply (PJ/year)**						
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Biomass	1,014.42	1,125.66	1,210.72	1,289.36	1,435.87	1,550.32	1,697.77
Hydro/Geothermal	141.75	188.78	280.92	481.38	544.17	538.04	520.65
Coal	194.37	342.11	458.57	1,003.83	2,012.03	3,691.27	5,871.55
Gas	651.64	1,108.63	1,667.66	1,982.59	2,330.97	2,663.16	3,104.15
Oil	1,135.77	1,397.57	1,735.22	2,056.48	2,403.92	3,240.66	4,711.72
TOTAL	3,137.95	4,162.75	5,353.09	6,813.64	8,726.96	11,683.45	15,905.84

Table 4.2 shows that biomass and oil dominate the primary energy supply for domestic market in 1995. The domination of primary energy supplies change gradually by time. At the end of the time horizon projection, coal dominates the primary energy supply and the share of biomass in the primary energy supply declines significantly.

The contribution of non-fossil fuels such as hydropower and geothermal energy to the total domestic primary energy supply increases at an average rate of 4.4 % per annum. The growth is mainly contributed by hydropower, because the geothermal power generation can not compete with the steam power generation.

4.1.2.b. Development of Baseline Energy Carriers

The contribution of energy carriers to domestic consumption in Indonesia in the baseline scenario is shown in Table 4.3.

Table 4.3: Development of Baseline Energy Carrier

Type of Energy Carrier	Final Energy Carrier (PJ/year)						
	1990	1995	2000	2005	2010	2015	2020
Biomass	1,002.15	1,113.74	1,199.39	1,278.62	1,425.57	1,540.65	1,688.84
Coal	77.97	117.95	172.77	240.57	323.62	525.15	884.44
Natural Gas	267.00	378.16	561.84	758.07	965.48	1,254.64	1,578.05
Electricity	186.92	286.77	429.32	618.30	878.54	1,278.76	1,874.68
FO	52.72	74.42	89.61	127.47	168.28	232.67	301.09
Gasoline	232.18	311.74	411.08	536.42	706.51	933.27	1,202.52
Kerosene	294.80	325.40	363.36	415.68	479.14	546.99	658.21
Middle Distillate	287.49	436.97	584.94	780.94	1,000.68	1,307.55	1,705.65
LPG	79.04	150.96	240.05	343.26	469.40	653.16	909.74
Lube Oil	14.02	19.24	26.32	35.29	45.91	60.86	81.28
Total	2,494.29	3,215.35	4,078.68	5,134.62	6,463.13	8,333.70	10,884.50

4.1.2.c. Development of Baseline Final Energy Consumption

The baseline final energy carriers utilization in Indonesia are firewood, gas, oil products (LPG, gasoline, kerosene, middle distillates, and fuel oil), coal, coke, briquettes, and electricity. The shares of biomass and oil products decline while coal, gas, and electricity increase.

The sectoral details of final energy consumption under baseline scenario are shown in Table 4.4. The table shows that household sector (including commerce and government sectors) has the highest final energy consumption in 1990, but at the end of the time horizon, the situation changes and industry sector will become the highest energy consumption.

Table 4.4: The Baseline sectoral of Final Energy Consumption

Sectoral Consumption	Final Energy Consumption (PJ/year)						
	1990	1995	2000	2005	2010	2015	2020
Industry	786.91	1,142.63	1,570.72	2,127.19	2,885.51	3,987.77	5,526.76
Transport	537.28	754.98	1,044.95	1,414.66	1,851.19	2,457.00	3,263.18
Household	1170.10	1,316.22	1,463.25	1,593.08	1,726.57	1,889.40	2,094.80
Total	2494.29	3,213.83	4,078.92	5,134.93	6,463.27	8,334.17	10,884.74

4.1.2.d. Household Sector

The share of energy consumption in the households sector in 1990 is 87.4 % for cooking, 8.9 % for lighting, and 1.3 % for other appliance, and 2.4 % for commerce & government. In 2020, the share becomes 70.9 % for cooking, 6.7 % for lighting, 9.8 %

for others electric appliance, and 12.6 % for commerce & government. For both, the biggest share is consumed for cooking.

Table 4.5: The Baseline Energy Consumption in Household Sector

Type of Energy	**Energy Consumption in Household Sector (PJ/year)**						
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Biomass	863,94	963.98	1,051.12	1,097.90	1,142.12	1,184.92	1,225.64
Electricity	58,70	88.42	129.30	183.56	247.80	349.57	499.24
Kerosene	235,02	248.22	263.78	288.38	311.27	324.04	332.27
LPG	10,64	12.58	14.98	17.82	21.16	25.29	29.98
Middle Distillate	1,26	1.68	2.24	2.95	3.80	5.03	6.90
Town Gas	0,54	1.34	1.83	2.47	0.42	0.55	0.77
Total	1170,10	1,316.22	1,463.25	1,593.08	1,726.57	1,889.40	2,094.80

The energy carrier mix for household during 1990 until 2020 is shown in Table 4.5. Table 4.5 shows that until 2020, the utilization of biomass in total energy consumption is still dominant. The second important energy carrier is kerosene during 1990 to 2010, electricity replaced kerosene to be the second energy carrier in 2015 and 2020. Besides kerosene, LPG and middle distillate will also increase at about 3.5 % per annum and 5.8 % per annum, respectively, during 1990 until 2020. However, town gas increased in 1995 but will decrease about 2.2 % per annum in the future. LPG, middle distillate, and town gas market are still relatively low. The reason of limited utilization of town gas is the lack of distribution grids. While, LPG and electricity are mainly utilized in urban household.

4.1.2.e. Industry Sector

The total energy carrier mix of the industrial sector under baseline scenario during 1990 to 2020 is shown in Table 4.6. The table shows that the energy mix is highly diversified. The highest contribution is natural gas, which is included in the utilization as feedstock for fertilizer production and steel industries.

Table 4.6: The Baseline Consumption of Energy Carriers in Industry Sectors

PJ/year	**Energy Consumption in Industry Sector (PJ/year)**						
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Biomass	138,21	149.15	158.46	203.80	283.63	355.85	463.20
Coal	77,77	117.46	179.05	242.57	342.94	548.66	884.86
Electricity	127,70	197.35	298.79	432.94	628.71	926.39	1,371.06
FO	42,13	54.94	65.48	76.16	95.15	114.70	120.42
Gasoline	0,13	0.14	0.15	0.16	0.16	0.17	0.18
Kerosene	13,65	11.66	9.62	5.40	9.15	6.75	30.75
LPG	68,40	138.38	222.61	318.62	444.12	627.87	879.76
Middle Distillate	35,56	73.20	72.89	78.32	93.83	115.47	117.65
Natural Gas	269,34	381.11	537.35	733.93	941.91	1,231.05	1,577.60
Lube Oil	14,02	19.24	26.32	35.29	45.91	60.86	81.28
Total	786,91	1,142.63	1,570.72	2,127.19	2,885.51	3,987.77	5,526.76

The average growth of electricity consumption is 8.2 % per annum during 1990 to 2020. Coal, which is mainly used in the cement industry, has the highest growth rate and is estimated to increase at 8.4 % per annum, from 117.46 PJ per annum in 1990 to

884.86 PJ per annum in 2020. While, biomass (wood and bagasse) consumption in this sector during 1990 to 2020 slightly increases at 4.1 % per annum. The increase of biomass consumption is mainly due to the rapid growth of the wood industry. The utilization of oil products that mainly consist of diesel oil and fuel oil, shows moderate growth because of the limitation of crude oil reserves.

4.1.2.f. Transport Sector

This sector includes the sub-sectors of road transport, air transport, sea transport, and rail transport. In 1990, the main demand fraction of about 78.9 % arose from the road transport, but the contribution of railway transport was minuscule. The development of the final energy consumption of the whole transport sector is shown in Table 4.7.

The two dominating fuels are gasoline and middle distillate (including automotive diesel oil - ADO and industrial diesel oil - IDO), they always account for more than 89.8 % of consumption in 1990 and 85.3 % of consumption in 2020. In the long term, there is a small potential for LPG and CNG cars.

Table 4.7: The Baseline Consumption of Energy Carrier in Transport Sectors

	Energy Consumption in Transport Sector (PJ/year)						
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Coal	0.20	0.49	0.83	1.28	1.82	2.58	3.60
Electricity	0.52	1.00	1.39	1.87	2.43	3.27	4.43
FO	10.59	19.48	32.49	51.14	76.81	116.86	176.52
Gasoline	232.05	311.60	412.39	537.63	706.35	933.10	1202.34
Kerosene	43.25	61.98	87.15	119.07	158.09	215.54	295.19
LPG	0.00	0.00	2.60	6.82	4.12	0.00	0.00
Middle Distillate	250.67	360.43	508.10	696.85	901.57	1185.65	1581.10
Total	537.28	754.98	1,044.95	1,414.66	1,851.19	2,457.00	3,263.18

4.1.2.g. Electric Power Plant

The electricity sector plays a key role for further development of the Indonesian economy. The gross generation of electricity in Indonesia is projected to grow at a rate of 7.8 % per annum from 222 PJ (62 TWh) per annum in 1990 to 2088 PJ (580 TWh) per annum in 2020 (Table 4.8). Nearly 65.5 % of the average electricity produced (PLN and private industries/captive power) in the 1990 was generated in Jawa. The reasons were the more intensive economic development in Jawa and the availability of an interconnected grid. The development of the electric power plant capacities base on the minimum cost optimization by different plant types is shown in Table 4.9.

Table 4.8 Baseline Electricity Generation

	Gross Electricity Generation (TWh/year)						
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Electricity	62	93	137	195	275	397	580

Table 4.9: Baseline Electricity Generation Capacity

	Electricity Generation Capacity (GW/year)						
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Biomass	0.23	0.23	0.23	0.21	0.21	0.21	0.21
Coal Steam	1.75	3.54	4.45	12.09	26.30	48.02	74.81
Diesel	9.84	9.37	8.40	7.37	3.62	3.61	3.61
Gas CHP	0.00	0.00	0.79	0.94	0.94	0.94	0.94
Gas Comb. Cycle	0.92	4.21	7.67	7.67	10.95	12.74	22.94
Gas Turbine	2.06	2.72	2.63	4.82	5.63	7.84	6.84
Geothermal	0.15	0.39	0.44	0.43	0.37	0.29	0.04
Hydro	2.86	3.91	5.97	9.54	10.84	10.84	10.84
Oil Steam	2.66	2.63	2.22	1.09	0.54	0.02	1.67
Total	20.47	27.00	32.8	44.16	59.4	84.51	121.9

Table 4.9 shows that geothermal power plant capacity increases slightly and reaches a peak of 0.44 GW in the year 2000 and after that there is no more new installation due to high cost, since the objective function is minimum cost without environmental constraint. While, hydropower plants will reach a capacity of 10.84 GW, whereas the capacity of gas turbines will reach a capacity of 22.94 GW and the most important are the gas combined cycle power plants. Diesel generators will gain a high share of 48.1 % in 1990 and will decline to 3.0 % in 2020.

Therefore, after 2005 it is proposed to install considerable coal power plant capacities, reaching a total capacity of 74.81 GW in 2020 that producing 61% of electricity. Coal is Indonesia's cheapest primary energy resource up to a certain level of use, where ash disposal or air pollution problem become limiting. However, more efficient technology and clean technology can mitigate the problem.

Use of solar energy can be made by a newly introduced options i.e. solar collectors for hot water preparation and photovoltaic systems, although, the amount of electric energy from solar is very small compared to the total electricity. Meanwhile, nuclear power in Indonesia is not competitive. Besides the nuclear power plant cost, the discount rate and CO_2 emission reduction are the most sensitive parameters for competition with conventional options.

Biomass energy can be used as fuel for electricity generation in certain areas, for example in wood product, paper industries, etc.

4.2. Forestry Sector

Contribution of forestry sector to the social and economic welfare is significant. Indonesian forest provides essential raw materials to a large number of industries. Some, such as sawmilling, plymilling and pulp and paper, are direct consumers of timber from natural and plantation forest. In addition to timber, there are a lot of non-forest product such as rattan, pine resin, sandalwood oil, honey and others extracted from the forests. All of these taken together, constitute a very important sector of the Indonesia economy. They contribute to employment, the development of backward and remote regions, foreign exchange revenues, and provision of goods for other sectors of the economy and for Indonesian consumers. In Pelita VI (1994/95-1998/99), income from export of forest products is expected to be US$52 billion (Sekab, 1995), i.e. US$6 billions from sawnwood, US$33 billion from plywood, US$7 billion from furniture, US$2 billion from rattan and US$4 billion from other forest products.

4.2.1. Supply and Demand for Industrial Wood

Balance between supply and demand is useful for planning. It can be used for identifying needs for, and bringing about, government interventions. DGFU and FAO (1990a) has projected potential timber supply and demand as presented in Table 4.10. Projection of industrial wood demand is based on the relationship between GDP and consumption level reflected in income elasticity. The income elasticity is assumed to decline overtime, to reflect the commonly observed fact that they are lower at higher income per capita. The GDP growth rate is assumed to be 5% per annum until year 2000 and by 4% per annum after that year. It is shown that the timber supply of Java in particular can not meet the demand. The deficit is quite substantial and it increases at a rate of about 0.81 million m^3 per year. All of industrial wood surplus of Sumatra can not offset the deficit of Java. Additional wood import from other island is, therefore, required.

Other potential islands that can offset the deficit in Java are Kalimantan and Irian Jaya. Since Java is closer to Kalimantan than to Irian Jaya, the wood import should be taken from Kalimantan. Furthermore, after year 2010 the increased supply can not fulfill the increased demand (Table 4.10). The deficit was estimated to be 3.8, 5.3 and 2.9 million m^3 in year 2010, 2020 and 2030, respectively.

Table 4.10. Baseline projection of supply and demand of industrial timber (million m^3)

Islands		**1995**	**2000**	**2010**	**2020**	**2030**
Sumatra	Industrial timber demand	4.65	5.96	8.43	10.86	13.31
	Industrial timber supply	13.34	15.00	17.72	24.35	31.93
	Surplus/Deficit	8.69	7.04	9.29	13.49	18.62
Jawa	Industrial timber demand	19.88	25.45	36.02	46.39	56.89
	Industrial timber supply	8.32	11.87	14.37	15.04	15.71
	Surplus/Deficit	-11.56	-13.58	-21.65	-31.35	-41.18
Nusa Tenggara	Industrial timber demand	0.85	1.08	1.53	1.97	2.42
	Industrial timber supply	0.10	0.08	0.07	0.07	0.06
	Surplus/Deficit	-0.75	-1.00	-1.46	-1.90	-2.36
Kalimantan	Industrial timber demand	1.21	1.55	2.20	2.83	3.47
	Industrial timber supply	13.47	13.10	14.63	19.25	26.80
	Surplus/Deficit	12.26	11.55	12.43	16.42	23.33
Sulawesi	Industrial timber demand	1.27	1.62	2.30	2.96	3.63
	Industrial timber supply	2.44	2.33	2.39	2.73	3.49

Islands		**1995**	**2000**	**2010**	**2020**	**2030**
	Surplus/Deficit	1.17	0.71	0.09	-0.23	-0.14
Maluku	Industrial timber demand	0.14	0.18	0.26	0.33	0.40
	Industrial timber supply	2.03	2.25	2.35	2.30	2.33
	Surplus/Deficit	1.89	2.07	2.09	1.97	1.93
Irian Jaya	Industrial timber demand	0.20	0.25	0.36	0.46	0.57
	Industrial timber supply	8.82	6.64	7.58	8.98	10.32
	Surplus/Deficit	8.62	6.39	7.22	8.52	9.75
Other Islands	Industrial timber demand	23.30	20.31	20.30	20.30	20.31
	Industrial timber supply	10.48	8.83	8.49	8.08	7.46
	Surplus/Deficit	-12.82	-11.48	-11.81	-12.22	-12.85
Indonesia	Industrial timber demand	51.50	56.40	71.40	86.10	101.00
	Industrial timber supply	59.00	58.10	67.60	80.80	98.10
	Surplus/Deficit	7.50	1.70	-3.80	-5.30	-2.90

4.2.2. Sources of Timber Supply

Until now natural forest is still the main source of timber supply in Indonesia. At the end of Repelita V (1993/94), the contribution of natural forest to total round wood production was about 68%. The remaining came from plantations, estate crops and private forest. Plantation contributed about 4% of the total production. However, in the future the role of forest plantations will increase. At the end of Repelita VI (1998/99), it is targeted that the contribution of forest plantation to total round wood production is 13% (Sekab, 1995).

Furthermore, DGFU and FAO (1990) estimated that by 2030, contribution of forest plantations to the total wood production would be about 55.6%. The contribution of wood residues (peelable residues from natural forest and pulp log residues) is also significant, i.e. 7.6% of the total production, down from about 20% in 1990. The total potential industrial wood supply by source is presented in Figure 4.1.

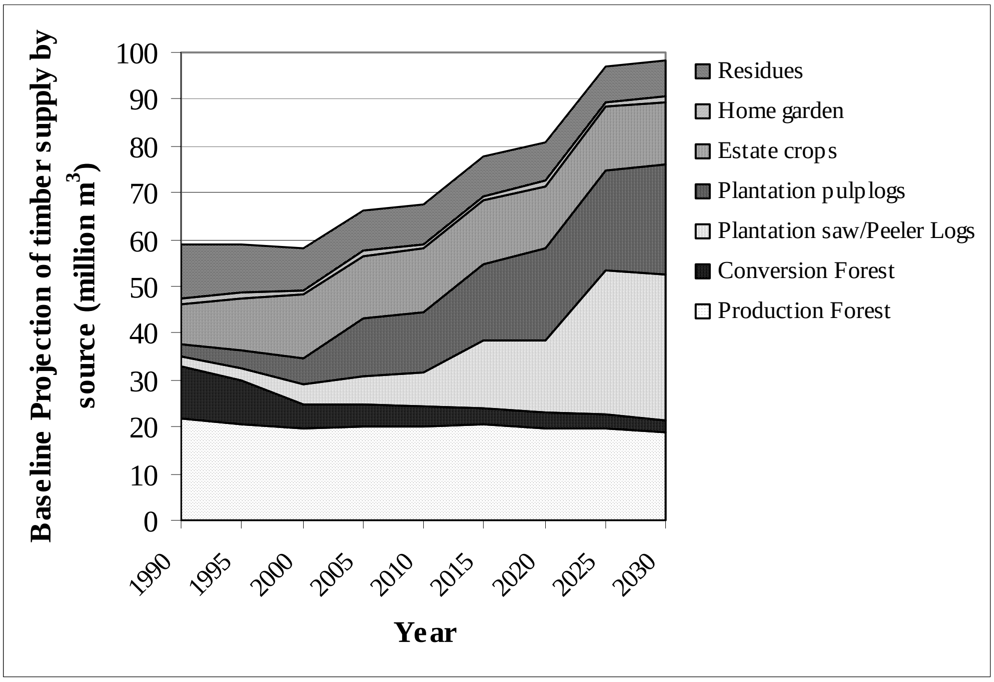


Figure 4.1. Baseline projection of timber supply by sources (DGFU and FAO, 1990)

Supply and Demand of Fuelwood

Traditionally, Indonesian households in rural areas use fuel wood as main energy source for cooking. Historically demand for fuel wood is highly correlated with level of income. Increase in economic growth will reduce the use of fuel wood. DGFU and FAO (1990) estimated that in Indonesia the demand for fuel wood may continuously increase even though the GNP increases. This is due to the rapid population growth. Demand for fuel is estimated to increase from 126.4 million m3 in 1995 to 181.2 million m3 in 2030 (net volume).

Fuel wood supply is mainly from mixed garden and followed by forest, plantation and other sources (Nurhayati *et al.*, 1998; Figure 4.2). From forest, fuel woods are mainly produced from thinning and logging activities, such as branches and wood waste from sawn mills. From plantations, fuel wood result from thinning, wood processing and other wood energy.

The potentiality of production forests, conversion forests, home gardens, agrofo-restry farms and private farmlands have been studied by DGFU and FAO (1990). It was estimated that about 35 million m^3 of wood in the form of logs come out of Indonesia's production forest every year and about a volume equivalent to 65-70 % of this is left in the forest as logging residues. While this volume is potential fuel wood source, the economics of transport will not permit such to happen, at least not in the short term.

Conversion forests with an area of about 30 million hectares is available for eventual conversion to agriculture use and human settlements. When these forests are cleared, some of the extracted wood will be used for industry and some for energy and some left to decompose. As production forest, about 65-70% of the extracted log volume or even more will be available for fuel wood. A new program called 'sengonisasi' (*Albizia falcataria* planting program) which is intended to promote wood production from home garden has also been found to be a potential source for fuel wood especially in Java. A similar program has also been launched in Sumatra for pine planting.

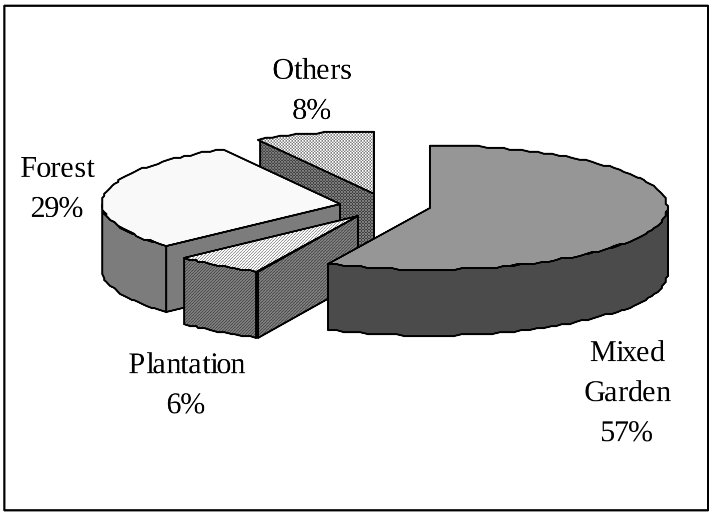


Figure 4.2. Fuel wood Supply

Home garden and agriculture crop lands (rubber, coconut, oil palm, coffee, cashew etc.) although are not part of the forest estate, grow the majority of wood for firewood. These agriculture crop lands and home garden produce between 86 million and 91 million m^3 of wood per year and about 64% of it comes from home garden alone.

5. GHG EMISSIONS

Each greenhouse gas has a specific global warming potential as a result of its physical properties and the length of time of atmospheric residency.

Two important gases leading to global warming from energy sub-sector are CO_2 and CH_4. CO_2 , the most important GHG, comes from fossil energy combustion process. Meanwhile, CH_4 is released during energy production process and from waste decomposition. This gas is mostly released during the coal mining both underground and open pit mining, oil and gas mining as well as during processing

5.1. Energy Sector

5.1.1. Current GHG Emission.

CO_2 Emission. It is estimated that the present and the future CO_2 concentration in the earth atmosphere cause 50 % of the so-called greenhouse effect. About 80 % of the CO_2 released from human activities arise from energy production and energy use. Furthermore the utilization of fossil fuels as sources of energy, power and electricity will also produce CO_2 emission.

CO_2 is formed as the result of the combustion of fossil fuels and biomass. The gas is also produced by forest clearing and other changes in the land use although their contributions are much more uncertain than the combustion of fossil fuels.

The formation of CO_2 is mainly determined by the content of carbon (C) in the fuel. A complete or incomplete energy combustion releases CO_2 as a result of a chemical reaction between carbon and oxygen. Different fuels will produce different amount of CO_2. Natural gas is so far the cleanest of the fossil fuel since it almost exclusively consists of CH_4 and other simple hydrocarbons. Complete combustion accomplished relatively easy with a gaseous fuel, will leave more or less only water from the hydrogen content of the hydrocarbons, CO_2 from the carbon content and nitrogen oxides from the N_2O in the air. The actual amount of CO_2 per Peta Joule of natural gas is less than for other fossil fuels, because of the lower carbon/hydrogen ratio in natural gas compared to higher hydrocarbons, i.e. oil or coal.

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

Total CO_2 emission from energy combustion is the amount of fossil fuels consumption multiplied by the emission factor (carbon emission coefficient) for the type of fuel. Then, the result must be multiplied by a factor (44/12) to convert the weight of C to the weight of CO_2. The emission factors of fossil fuels according to the data given by IPCC (Intergovernmental Panel for Climate Change) guideline, are given as illustrated in the Table 5.1.

Based on energy balance 1994, greenhouse gas (GHG) emission inventory for the corresponding energy carrier can be calculated. In this study, the GHG evaluated is CO_2 and CH_4. The emission factor used are based on IPCC guidelines. According to IPCC method, CO_2 emission is calculated by using top down approach. No distinction is made between energy uses and non-energy uses. CO_2 released from biomass combustion is not taken into account. The result of the calculation for CO_2 emission can be seen in Table 5.2. The energy carrier that releases the most CO_2 is oil; i.e., about 61.11 % of the total CO_2 emission. Natural gas and coal release 30.75 % and 8.14 % of the total CO_2 emission, respectively.

Table 5.1: Carbon Emission Coefficient for Each Type of Fuel

Fuel Type	Carbon Emission Coefficient (kg C/GJ)	Fuel Type	Carbon Emission Coefficient (kg C/GJ)
Crude Oil	20.0	Other Oil	20.0
Natural Gas Liquids	17.2	Anthracite	26.8
Gasoline	18.9	Cooking Coal	25.8
Jet Kerosene	19.5	Bituminous Coal	25.8
Other Kerosene	19.6	Sub-bituminous Coal	26.2
Gas/Diesel Fuel	20.2	Lignite	27.6
Residual Fuel Oil	21.1	Peat	28.9
LPG	17.2	BKB & Patent Fuel	25.8
Ethane	15.8	Coke	29.5
Naphtha	20.0	Natural gas (Dry)	15.3
Bitumen	22.0	Solid Biomass	29.9
Lubricants	20.0	Liquid Biomass	20.0
Petroleum Coke	27.5	Gas Biomass	30.6
Refinery Feedstocks	20.0		

Source: IPCC/OECD, 1995.

Table 5.2: CO_2 emission in 1994, (calculated by using top down approach)

ENERGY CARRIER	(10^6 ton)	Share (%)
Coal	17.9	8.1
Oil	134.4	61.1
Natural Gas	67.6	30.7
Total	219.9	100.00

CH_4 Emission. In estimating CH_4 emission from energy production system such as oil, coal and natural gas system, IPCC method is used. The general approaches are to determine the energy production (oil, coal and natural gas) from various activities, for the type of oil activities, refinery product, natural gas systems, and coal for demand sectors, such as industry, household & commercial, transportation, and electricity generation.

The emission factors for CH_4 released (Table 5.3) from energy use by sectors are taken from the ALGAS study mentioned in section 3.6 .

Table 5.3: CH_4 Emission Factors from Energy Use by Sectors (Kg/TJ)

Sector	Industry	Household & Commercial	Transport	Electricity
Type of Energy				
Biomass	n.a	200.00	-	-
Coal	2.40	-	0.60	0.60
Electricity	n.a	-	-	-
Fuel Oil	2.90	-	0.01	0.70
Gasoline	-	-	-	-
Kerosene	5.00	5.00	-	-
LPG	1.00	1.100	-	-
Mogas	-	-	0.01	-
Natural Gas/City Gas	1.40	1.40	-	0.10
IDO	5.00	-	0.01	-
ADO	-	-	0.00	0.03
Geothermal	-	-	-	-
Hydropower	-	-	-	-

Source: PPLH-IPB, ALGAS PROJECT, 1997.

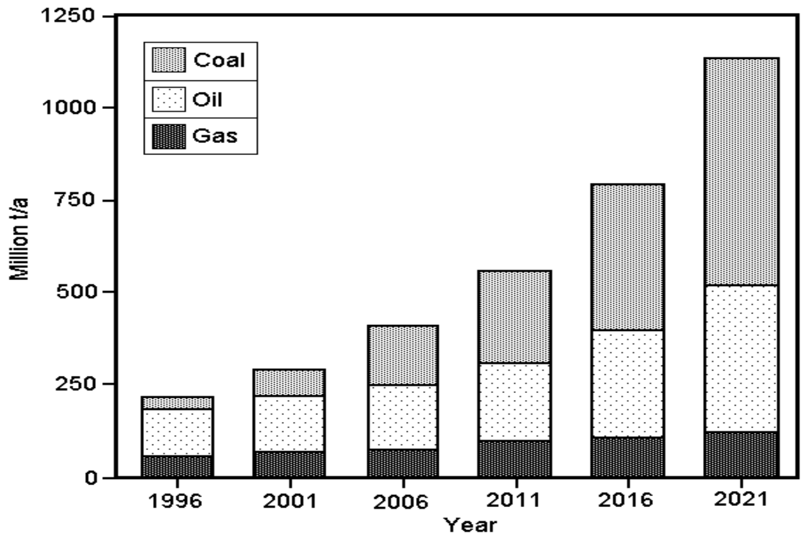
The result of the calculation for CH_4 emission can be seen in Table 5.4. Based on CH_4 emission sources of the fossil fuels, i.e. oil, gas and coal, the energy user sector, such as transportation, industry, residential and commercial release almost 100% of the total CH_4 emission. While, transformation and own use and losses of the upstream energy (mining and production) release only 1.5 % of the total CH_4 emission. Most of the CH4 emission is released from biomass (97%), petroleum only 2 % and another 1% is released from coal and natural gas.

Table 5.4: CH_4 emission in 1994 (Ton p.a.)

	Biomass	Coal	Petroleum	Gas	Total
Household	192,796		1,242	2	194,040
Industry	29,830	70	584	534	31,018
Transport		0	313		313
Mining/Production		303	2,385	513	3,201
Total	222,626	374	4,524	1,048	228,572

5.1.2. GHG Emission Projection

CO_2 Emission. Based on energy demand-supply projection, the CO_2 emission can be calculated by the model. Figure 5.1 and Table 5.5 show that the Indonesian CO_2 emission will increase from 219.68 million ton per annum during the FYDP VI (center year 1996) to 1076.16 million ton per annum during FYDP XI. This result has an average growth rate of 6.56 % per annum. The share of oil, gas, and coal is 58 %, 25 %, and 17 % in FYDP VI, respectively. Since the demand of energy in every FYDP increases, the total of CO_2 emission will increase to, however the share of energy consumption by type of primary energy will change, coal becomes the most important energy sources. Due to the increasing share of coal in total primary energy and due to a high specific carbon content as a mayor source of CO_2, the share of CO_2 emission in FYDP XI is 54 % from coal, 35 % from oil, and 11 % from natural gas.



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

Figure 5.1. The Share of CO_2 Emission Produce by Type of Energy

Table 5.5. Baseline CO_2 Emission by Type of Energy (million ton per annum)

	1996		2001		2006		2011		2016		2021	
	Mill ton/a	%	Mill ton/a	%	Mill ton/a	%	Mill ton/a	%	Mill ton/a	%	Mill ton/a	%
Coal	37.35	17	68.46	27	150.17	40	233.42	45	374.39	50	581.13	54
Oil	127.41	58	150.61	51	163.20	43	188.03	36	269.26	36	376.66	35
Gas	54.92	25	68.46	22	65.28	17	97.26	19	105.13	14	118.38	11
Total	21968	100	287.53	100	378.65	100	518.71	100	748.78	100	1076.17	100

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

CH_4 Emission. The total of emission CH_4 comes from industrial, household, transportation, and electricity generation sectors can be calculated in MARKAL model based on the emission coefficients in Table 5.3.

a. Industrial Sector

The total of CH_4 emission from energy use in the industry sector from FYDP VI until FYDP XI is shown in Table 5.6. and Figure 5.2. Table 5.6 shows that in every FYDP, without considering utilization of biomass, natural gas and coal are the main source of CH_4 . The total CH_4 emission from coal and natural gas from FYDP VI to FYDP XI increase 8.41% per annum and 5.85% per annum respectively. The CH_4 emission from coal increases from 281.90 ton per annum in FYDP VI to 2123.66 ton per annum in FYDP XI. While, the CH_4 emission from .Natural gas increases from 533.55

ton per annum in FYDP VI to 2208.64 ton per annum in FYDP XI. The least source of CH_4 emission in the industry sector is gasoline.

Table 5.6: The Total of CH_4 Emission by Type of Fuel in Industrial Sector (Ton/Year)

Average of FYDP	Coal	Fuel Oil	Gasoline	Kerosene	LPG	MD	Natural Gas	Total
VI (1994-98)	281.9	159.3	0.00154	58.3	138.4	212.3	533.6	1383.8
VII (1999-2003)	429.7	189.9	0.00165	48.1	222.6	211.4	752.3	1854.0
VIII (2004-08)	582.2	220.9	0.00176	27.0	318.6	227.1	1027.5	2403.3
IX (2009-13)	823.1	276.0	0.00176	45.7	444.1	272.1	1318.7	3179.7
X (2014-18)	1316.8	332.6	0.00187	33.7	627.9	334.9	1723.5	4369.4
XI (2019-23)	2123.7	349.2	0.00198	153.7	879.8	341.2	2208.6	6070.2

FYDP = Five Years Development Plan.

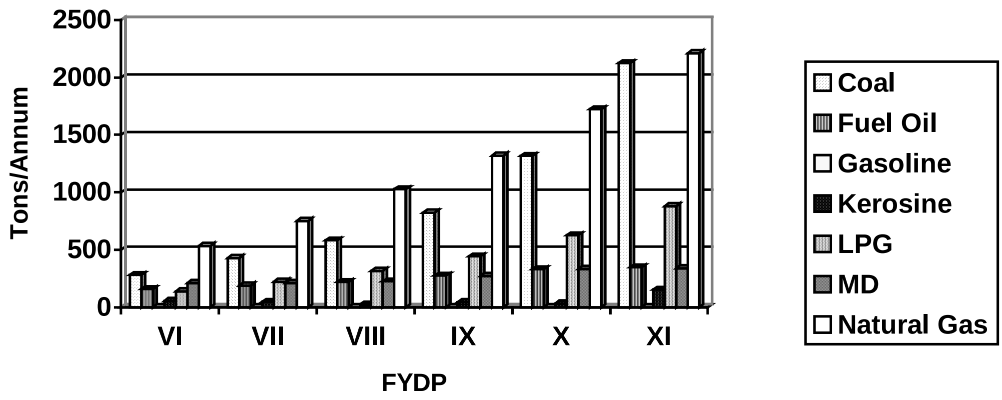


Figure 5.2: The Total of CH_4 Emission by Type of Fuel in the Industry Sector

B. Household &Commercial Sectors

The energy consumption to fulfill the demand for energy in the household & commercial sectors are biomass, electricity, Kerosene, LPG, middle distillate (IDO and ADO), and natural gas. Ignoring the utilization of biomass and middle distillate, as energy in these sectors, the main source of the CH_4 emissions are produced by kerosene and LPG. Table 5.7 shows the CH_4 emission by type of commercial energy , but the CH_4 emission for electricity, biomass, and middle distillate are not given.

Table 5.7: Total of CH_4 Emission by Type of Fuel in Household and Commercial Sector (Ton/Year)

Average of FYDP	Kerosene	LPG	Natural Gas
VI	1241.10	13.84	1.88
VII	1318.90	16.48	2.56
VIII	1441.90	19.60	3.46
IX	1556.35	23.28	0.59
X	1620.20	27.82	0.77
XI	1661.35	32.98	1.08

Table 5.7 also shows that until year 2020 (FYDP XI) CH4 emission from kerosene still dominates in household and commercial sector.

c. Transport Sector

The energy consumption to fulfill the demand energy in the transport sector is coal, electricity, fuel oil (FO), gasoline, Kerosene (including avtur), LPG and middle distillate. Ignoring electricity as energy in the transport sector, kerosene is the main source to produce the CH_4 emission. Table 5.8 shows the total CH_4 emission by type of energy in transport sector.

Table 5.8: Total of CH4 Emission by Type of Energy in Transport Sector (Ton/Year)

Average of FYDP	Coal	Fuel Oil	Gasoline	Kerosene	LPG	MD
VI	0.29	0.19	3.43	309.9	0	3.60
VII	0.5	0.32	4.54	435.75	0.26	5.08
VIII	0.77	0.51	5.91	595.35	0.682	6.97
IX	1.09	0.77	7.77	790.45	0.412	9.02
X	1.55	1.17	10.26	1077.7	0	11.86
XI	2.16	1.77	13.23	1475.95	0	15.81

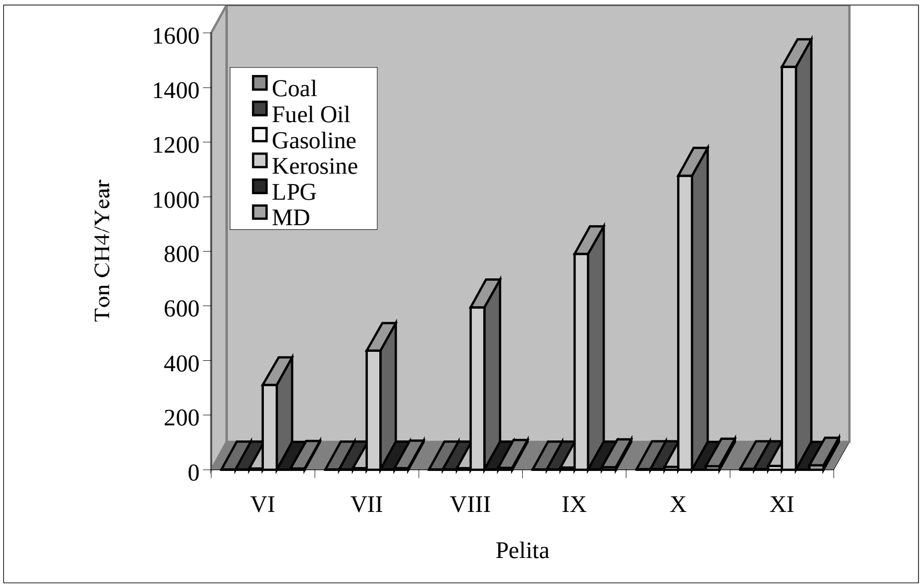


Figure 5.3: The Total of CH_4 Emission by Type of Fuel in the Household & Commercial Sector.

d. *Electricity Generation*

In the energy consumption for electricity generation, coal is an important supply for the electricity generation in the future. The increase in coal utilization in the power plant is followed by increasing CH_4 emission. Table 5.9 shows the total of CH_4 emission by type of fossil-fueled technology, but CH_4 emission from renewable energy, such as biomass, hydropower, and geothermal are not included.

Table 5.9. CH_4 Emission by Type of Technology in Electricity Generation (Tons/Year)

Average of FYDP	Coal Steam	Oil Steam	Gas Turbine	Gas Cogenaration	Combined Cycle
VI	43.37	31.255	3.33	0	7.43
VII	55.27	30.982	4.06	1.74	15.52
VIII	156.49	15.239	4.21	2.10	15.28
IX	341.6	3.101	3.78	2.10	14.97
X	617.78	0.294	2.5	2.10	14.97
XI	966.16	23.912	8.21	2.10	14.02

5.2. Forestry Sector

5.2.1. Current Emissions

Greenhouse gas emissions from forest mostly occur during the logging and conversion of the forest. The gases are emitted to the atmosphere through combustion and decomposition processes. Therefore, high deforestation rate is responsible for high GHG emissions. In most developing countries which have forest resources including Indonesia, reduction of forest cover resulting from planned and unplanned deforestation is unavoidable. Conversion of forests to agricultural land due to population pressure, shifting cultivation and spontaneous transmigration are categorized as unplanned deforestation, whereas conversion of forests to transmigration, plantation estate, resettlements and other type of development project are categorized as planned deforestation. Rate of deforestation reported by some studies is presented in Table 5.10.

The rate of deforestation has been reported to increase from year to year. In the early 1970s, rate of deforestation in Indonesia was estimated to be about 300,000 ha, and in the early 1980s to be about 600,000 ha (MoF and FAO, 1990) and in the early 1990s has been estimated to be about 1 million ha (Sorensen, 1993). However, some studies estimated that rate of deforestation in the early 1990s was lower than 1 million hectares (Table 5.11). Based on forest database (MoF 1998), the area of deforestation in 1994 was about 721 thousand hectares, close to Dick's (1991) estimate. Due to government regulation, improvement of control systems and ecolabelling, the rate of deforestation in the future may not increase significantly from the current rate.

Table 5.10: Estimate of forest conversion (deforestation) in Indonesia (**thousands of ha**)

Activity	Source						
	WB (1990)	FAO (1990)	TAG (1991)	Dick (1991)	MoFr (1992)	MoFr (1996)	Forest Data base (1998)
Transmigration development		300	65	78.4	300	100-150	146.4
Estate development	200-300	274	11.5	11.4	160	210-250	
Swamp development		85	30.4	30.4			
Spontaneous Transmigration	350-650	461	156.5	178.5	300		
Shifting cultivation				135.5		200-300	151.0
Forest harvest	80-150	80	NE[a/]	120	77		
Forest Fires	70-100	113	NE[a/]	70	478[b/]		161.8
Agriculture/Palm tree plantation						350	234.8
Others: illegal logging							27.2
TOTAL	700-1200	1315	262.9	623	1315	900-950	721.2

[a/] NE : not estimated, [b/] Fire damage average excluding Kalimantan fire forest. Transmigration is reallocation of people particularly from Java to other island in Indonesia and organized by the government, while spontaneous transmigration is organized by transmigrants.

Uptake of CO_2 from the atmosphere occurs when trees are growing. Therefore, planting bare land and critical land through reforestation, afforestation, timber estate plantation and any other tree planting can offset the emission due to deforestation. During Pelita V (1989-1994), total area of Indonesia's critical land which was afforested and reforested amounted to 2.57 million ha and 0.32 million ha, respectively. The remaining critical land that can be allocated for afforestation and reforestation are 5.50 million ha and 5.46 million ha, respectively.

ALGAS Study (1998) indicated that using IPCC methodology, in 1990 Indonesian forest is able to uptake about 686 Mt. of CO_2, greater than the emissions. However, it is noted that the result of the study is sensitive to the change of mean annual increment used for production and conversion forests. For the study, a value of MAI of 2 t B/ha was used. If the MAI was reduced to 1 t B/ha Indonesian forest is becoming net emitter. Therefore, a careful measurement of MAI for production and conversion forest is encouraged. In addition, the present IPCC methodology does not account the carbon emission resulting from the decomposition of past wood products. This exclusion may have significant impact on the accuracy of the emission calculation.

Table 5.11: CO_2 uptake and released-CH_4, CO, N_2O and NOx emissions from Indonesia forestry sector (Gg)

	CO_2	CO_2	Emissions			
	Uptake	**Released**	**CH_4**	**CO**	**N_2O**	**NOx**
Change in forest and other woody biomass stock[1]	575,390.64	26,846.60				
Forest and grassland conversion[2]	-	312,601.48	524.74	4,591.51	3.61	130.39
Abandonment of managed land[3]	111,100.00	-	-	-	-	-
TOTAL	686,490.64	339,448.08	524.74	4,59.51	3.61	130.39

[1] Carbon uptake is calculated from the growing trees of timber estate plantation, afforested and, reforested land, production and conversion forests. [2] Two activities considered to cause forest conversion to pasture and crop land are transmigration and shifting cultivation. Total area of forest and grassland converted into crop lands was about 0.46 million ha. [3] Carbon uptake is calculated from the growing trees of abandoned lands. Source : ALGAS Study (1998).

5.2.2. GHG Emissions Projection

Projection of GHG emissions has also been developed by the ALGAS Study (1998). Indonesian forests has been estimated to be net sink until year 2020 (Table 5.12). Some assumptions have been used, namely :

1. Rate of the deforestation is assumed to be 1.1 Mha/yr from 1990 to 1995 and 700.000 ha/yr from 1996-2000.
2. Area of forest and grassland converted into Agriculture land was assumed to be 465.000 ha/yr.
3. Rate of timber estate development is assumed to be 250.000 ha/yr and no more development when the area of timber estate attain 6.2 million ha.
4. Rate of reforestation and afforestation is assumed to be 65.000 and 350.000 ha/yr respectively.
5. MAI of tree species after year 2000 increase by 5% as result of using AYU (high yield species) and reduce impact logging.
6. Wood demand (industrial wood and fuel wood) followed scenario given by MoF& FAO (1990)
7. Total area that is naturally generated is assumed to be 7,000,000 ha.
8. The emissions from the decomposition of past forest products are not accounted for.

Table 5.12: Projection GHG emission and uptake from forestry sector (Gg)

Activity		GHG	1990	2000	2010	2020
Change in forest and other woody biomass stock	Uptake	CO2	575,390.63	649,007.28	707,100.09	732,846.90
	Emission	CO2	26,846.59	111,599.20	144,075.82	176,793.49
Forest and grassland conversion	Emission	CO2	312,601.47	277,149.02	262,534.09	271,014.04
On site-burning	Emission	CH4	524.74	422.91	371.99	364.72
		CO	4,591.51	3,700.47	3,254.95	3,191.30
		N2O	3.61	2.91	2.56	2.51
		NOx	130.39	105.09	92.43	90.63
Abandonment of managed land	Uptake	CO2	111,100.00	111,100.00	111,100.00	111,100.00
Total CO2-eq. Emission			351,586.70	398,531.43	415,215.30	456,244.75
Total CO2-eq. Uptake			686,490.63	760,107.28	818,200.09	843,946.90
Total net CO2-eq. Uptake			334,903.93	361,575.85	402,984.79	387,702.15

Note : CO and NOx are excluded (except in the On-site burning).

6. Mitigation Options

6.1. Energy Sector

The purpose of the GHG mitigation is to reduce the CO_2 and CH_4 released to the atmosphere. The main activity of the mitigation option in the energy sector are, to reduce the use of fossil fuels is through fuel diversification or energy conservation, introduction of clean technologies and utilize renewable energy as much as possible in the country. For each energy consumption sector, there are different mitigation options considered in the model, as described below.

6.1.1. Mitigation Options in Energy Consumption Sectors

This chapter describes the mitigation options to be introduced in the energy consumption sector such as, household, industrial, commercial, and electric power generation sectors. Table 6.1 shows the sectoral mitigation options.

Table 6.1: Mitigation Options in Energy Sector

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

6.1.1.a. Residential sector

In this sector, the options that can be applied to reduce the energy consumption are:

- substitution of electronic ballast's of fluorescent lamps for conventional ballast's
- substitution of compact fluorescent lamps (CFL) for incandescent light bulb
- substitution of solar home system (SHS) for kerosene lamp
- improvement of efficiency for refrigerator
- improvement of efficiency for air conditioning
- substitution of LPG stove for kerosene stove.

Lighting

Lighting is the most important options to reduce energy in the residential sector. Expanded use of compact fluorescent lamps, which require less electricity than standard incandescent lamp to produce the same light output, could have a major impact in reducing energy consumption of the sector. A ballast lamp is needed to provide a suitable starting voltage, there after limiting current flow during the operation of fluorescent (and mercury) lamps. Ordinary magnetic ballast dissipates about 20 % to 30 % of the total power entering fixture. More efficient electronic ballast (also known as core/coil ballast) makes use of better materials to reduce ballast losses to about 10 %. Such ballast will increase the efficiency of the ballast/lamp system by approximately 20 % to 25 % relative to system uses an ordinary ballast.

Most solar home system (SHS) is 50 kWh per system. It uses solar collector and battery that can operate 3 unit fluorescent lamps (6-10 watt), a radio cassette and 1 B/W television set.

For electrified households in Indonesia, the assumption was that per household uses 2 light bulb of 40 W during 4 h/d, 2 light bulb of 25 W during 6 h/d and 2 fluorescence lamp of 20 W during 5 h/d. Non-electrified household was assumed to consume 100 liter kerosene per house per annum. About 10 % of non-electrified household will be the potential users of SHS.

The total cost of CFL (including the cost of the lamp and the electricity to power it) is roughly one fourth the cost of an incandescent bulb. However, the initial capital cost for a CFL is ten times the incandescent bulb. The initial capital cost of electronic ballast for fluorescent lamps is three times higher than conventional ballast.

Table 6.2 shows the parameters of today's lamps and its replacement options. Some households have apply this option especially in the urban household. The penetration of this option for Mitigation scenario is about 5 % in 1995 and will increase to 30 % in 2010 and 60 % in 2020.

Table 6.2: The parameters of today's lamps and its replacement options

	Lamp type/parameter	Conventional	Replacement
1.	Bulb	Incandescent lamp	CFL
	Power consumption	40 Watt	11 Watt
	Life time	1000 hours	8000 hours
	Cost per unit	0.5 $ US	5.5 $ US
	Investment Cost (8000 h)	4 $ US (8 x 0.5 $ US)	5.5 $ US
	Inv. per household per annum	1.5 $ US	2 $ US
	Electricity cost per annum	5.8 $ US	1.6 $ US
	Total cost per annum	7.3 $ US	3.6 $ US
2	Fluorescent tubes	Conventional ballast	Electronic ballast
	Power consumption	20 Watt	20 Watt
	Life time	8000 hours	8000 hours
	Cost per unit	2.5 $ US	7.5 $ US
	Inv. per household per annum	1.1 $ US	3.4 $ US
	Electricity cost per annum	4.9 $ US	3.7 $ US
	Total cost per annum	4.8 $ US	7.1 $ US

Note : Electricity cost per-kWh 0.05 $ US (PLN Regulation).

Another option for lighting is switching from kerosene to electric lighting. In rural area, the use of kerosene is not only for cooking but also for lighting. In new electrified household most people change from kerosene lamp to electric lighting. Switching from kerosene lamp to incandescent bulb saves energy in many applications (depending in part on size of electric T&D losses) and also improves lighting quality. Using a small fluorescent tube or a CFL is more efficient, although it is a more expensive option.

Refrigeration

Refrigerator is a key appliance to target for efficiency improvement, since their significant electricity use is growing rapidly. Application of energy efficient features such as increased insulation, more efficient compressors, and improved door gaskets can reduce their energy use significantly.

The estimated 60 % of urban household and 3 % of rural household that uses refrigerators in 1995 will increase to 75 % and 5 % in 2010 and 90 % and 10 % in 2020. The estimated number of refrigerators in operation in Indonesia will increase from 2.5 million in 1995 to 25 millions in 2010 and 50 million in 2020

For the consumption of electricity, based on the refrigerator technology improvement and public awareness the assumption was that the availability of the refrigerator (time of operation per annum) is 90 % or 7884 hours per annum. On the basis of this assumption, the specific electricity consumption of an average refrigerator in 1995 is 100 watt, 70 watt in 2010 and 60 watt in 2020. For all mitigation scenarios, in 1995 all capacity refrigerator is 100 watt. In 2010, about 90 % of the refrigerator operate by 80 watt, and 10 % by 100 watt. In 2020, 60 % of refrigerator operate by 65 watt and 40 % operate by 80 watt. The annual consumption of a typical refrigerator in 1995 is 788 kWh/a, 646 kWh/a in 2010 and 578 kWh/a

6.1.1.b. Industrial Sector

GHG mitigation options identified in the industrial sector of Indonesia are using variable speed motor, and cogeneration of heat and power for captive power. Motors are the dominant appliances in the industrial sector. There is a big energy saving potential through industrial motor’s efficiency improvement. Motors are assumed to consume 75 percent of the total industrial electricity consumption. In the mitigation scenario we assume that use of the variable speed motors will replace ordinary motors step by step; all new motors installed after the year 2000 will use efficient motor or variable speed motor. In the year 1995, variable speed motor already accounted for 10 % of the total motor installation, in the year 2010 it will reach 25 % share, and finally accounting for 50 % in the year 2020.

Utilizing variable speed motor can save electricity consumption. Ordinary motors in Indonesia that have an average utilization of 20 hp, availability of 60 % (5256 hours p.a.), capacity factor of 80 %, and a load factor of 60 % will require 37.64 MWh p.a. of electricity. Utilizing variable speed motor, under the same condition, will reduce electricity requirement to 33.20 MWh p.a., or a 12 % saving.

Cogeneration and diesel combined cycle is heat waste recovery technologies. Cogeneration is conversion technology that produces electricity and heat/steam simultaneously. This system can improve efficiency from 30 % to 80 %. Generation of heat/steam is through the utilization of heat waste from conventional power generation. Usually industries with diesel fuel just throw away the heat waste to the atmosphere directly. This heat waste can actually be used for heating hot water or producing steam. Theoretically, heating hot water utilizes 80 % of the total heat waste from industry, however, generating steam can utilize only 60-70 %.

Due to the complicated modification need for cogeneration installation, in the year 1995 cogeneration utilization in the industrial sector accounted for 5 % only. In the future, new industrial design will assume to use cogeneration. Share of cogeneration boiler utilization in the industrial sector will assume to reach 25 % in the year 2010 and increase to 40 % in the year 2020 for the Mitigation scenario. In term of the energy consumption, fuel for the power generation will save about 2.5 % in the year 1995, 12.5 % in the year 2010, and 20 % in the year 2020.

6.1.1.c. Commercial Sector

The study of the Research Agency of Bandung Institute of Technology and BPPT Energy Laboratory (LSDE) shows that:

- Energy consumption in hotels is 49 % for air conditioning system, 17 % for lighting system, 19 % for utilities system, 8 % for transportation system, 2 % for laundry system and others 5 %.
- Energy consumption in office building is 56 % for air conditioning system, 15 % for lighting system, 17 % for utilities system, 15 % for transportation system and 3 % for others.
- Energy consumption for public building (such as hospitals) is 57 % for air conditioning system, 19 % for lighting system, 16 % for utilities and 3 % for laundry system.

Lighting

Energy consumption for lighting in commercial, public and office building is about 15 % - 19 % of total energy consumption in these sectors.

There are three types of systems for lighting in commercial building: incandescent, fluorescent and high-intensity discharge (HID). As with residential applications, replacing incandescent lamps with CFLs in commercial building is a viable option. Fluorescent lighting systems are the most common type of lighting in commercial buildings.

A number of energy saving lighting control is now on market, including multilevel switches, timers, photocell control, occupancy seniors and daylight dimming system.

The penetration of this option in the mitigation scenario are an electronic ballast will be replaced 60 % of the magnetic ballast share; replacing incandescent lamp with CFLs is about 80 % of incandescent in the year 2020; and installing control system and reflector will have potential about 40 % of the lamp installation.

Air Conditioning

About 49-57 % of the electricity consumption of this sector is for air conditioning. The reduction of energy consumption in this technology can be done by efficiency improvements including better internal insulation in the equipment, larger heat exchanger, higher evaporator temperatures, dual speed or variable speed compressor motors to reduce on-off cycling, more efficient rotors and compressors, advanced refrigerants and more sophisticated electronic sensors and controls.

For the mitigation scenario, the previous potential option assume automatically dominating the market share in the future. The air conditioning technology improvement in the future assume the specific electricity consumption will be 50 % - 70 % of the current available technology.

Solar Collector

The use of solar collector is for heating warm water (< 50^oC) in hotels. Due to the geographical position of Indonesia, this option has great potential. The usual ways for heating warm water consume 130 kJ per liter, which shows that this purpose consumes about 10 % of the total energy demand for heating.

This equipment in the mitigation scenario has maximum potential about 20 % in the year 2000 and increase to 60 % in the year 2020 replacing of fuels for preparing warm water.

6.1.2. Power Generation

Power generation technology is growing, and the development of the power plant technology is designed to be more environmental friendly. The latest power plant technology is more efficient and environmental friendly than previous technology. Power plant technology options such as gas combined cycle, coal fired with fuel gas desulphurization and denitrification, nuclear, coal fluidized-bed combustion, gas turbine and other conventional power plants have been taken into consideration. Technology mix result of the Baseline scenario was purely based on the economic perspective; i.e. in this scenario the model only finds the optimal solution based on minimum cost. The efficient technology, such as nuclear power plant and coal fluidized-bed combustion did not come into the solution due to their high cost requirements.

In the mitigation scenario the advanced power plant technology such as integrated coal gasification combined cycle, pressurized coal fluidized-bed combustion, and fuel cell was introduced to the model as additional to technology options that were already included in the model.

With regard to the non-fossil fuels, Indonesia has potential for 75 GW of hydropower, and 16 GW of geothermal. Actually, Indonesia also has big reserves of natural gas, but because the resources are far away from the demand (geographical constraint), natural gas is not considered to be used at its maximum for meeting the domestic demand. This is due to the high transportation cost, making natural gas not economically competitive.

6.2. Forestry Sector

6.2.1. Mitigation Options

Activities in forestry sector which have been known to be able to mitigate the GHG emissions are (i) planting trees, (ii) fire protection, and (iii) resettlement (for reducing shifting cultivation practices). Types of program which are related to the three activities are as follows:

a. *Afforestation*. Any planting trees program taking place in non-forest area can be categorized as afforestation program. This program is particularly aimed at rehabilitating critical lands and grasslands of non-forest area. The activities which have been done related to this program also include urban forest development, private forest and a one million tree planting movement.

b. *Reforestation*. This program is the same as afforestation but it takes place in forest area. The activities that can be categorized as reforestation are timber estate development, agroforestry and social forestry.

c. *Enhanced natural regeneration.* Enhanced natural regeneration includes enrichment planting (*pengkayaan*), i.e. planting a number of tree species (commercial species) in logged-over area. This program is carried out if number of seedling is less than 400 seedlings/ha or number saplings less than 200 saplings/ha or number of poles is less than 75 poles/ha or if seedlings, saplings or poles are not evenly distributed. Thus if number of seedlings is more or equal to 400 seedlings but not evenly distributed, the form of enrichment activities will be reallocating seedlings.

d. *Reduced impact logging.* Uncontrolled logging of trees results in excessive damage to the residual forest (Ewel and Conde, 1980). Pinard and Putz (1996) reported that logging activities would destroy unharvested trees <60 cm DBH by about 41%. This leads to the decrease in future biomass increment and yields of marketable timber. By improving logging technique, the tree damage could be reduced significantly. It was found that by reduced-impact logging trees damage (uprooted and crushed) could be reduced from 41% to 15%. Furthermore, it was stated that one year after harvest, conventional and reduced-impact logging contained biomass equivalent to about 44% and 67% of pre logging-level, respectively. Reduced Impact Logging includes all efforts to minimize damage to both the soil and the residual stand during selective logging, such as harvest planning, pretelling vine cutting, directional felling and other environmentally sound management techniques.

e. *Forest Squatters Resettlement.* The resettlement of forest squatters will reduce shifting cultivation activities. Resettling one forest squatter may reduce rate of deforestation by 0.5 ha per year. The program is carried out through training activities and demo plot. The squatters are trained to be able to practice intensive agriculture. However this program is not very successful. The level of understanding of the resettled cultivators to the system of intensive agriculture is still low since the extension program is not intensive and regular. On the other hand, it was found that the contribution of the squatters (shifting cultivators) to the national rice supply can not be ignored. For example in some of the provinces, such as central Kalimantan, South Sumatra and Jambi, big part of provincial rice supply come from the shifting cultivation activities (Fagi, 1997). It is indicated that agroforestry system is found to be a potential option in which growing annual crops together with perennial crops as a sources of income. The perennial trees commonly used are rubber, palm oil and fruit trees.

f. *Bioelectricity.* At most of forest companies, wood waste is not used and they are left to decay. This waste could potentially be used for bioelectricity. Based on Lestari report (1997), wood waste produced by one of pulp industrial company in Jambi was able to operate three power plants and the electricity produced were already more than the components power demand. If the tree planting activity is intended to supply biomass for electricity, the option will have two direct benefits in terms of C-abated, i.e. increasing C sequestered in soil and vegetation and avoiding carbon emission from fossil fuel generated electricity.

6.2.2. Implementation of Mitigation Options

a. *Rehabilitation of critical land*. At the end of Pelita V (1994/95), area of critical land in forest area was reported to be about 3.76 Mha while that of non-forest area was about 8.76 Mha (Table 6.3). The target during Pelita VI (1994/95-1998/99) was to reforest and afforest about 0.94 Mha and 2.62 Mha, respectively (Table 6.3). In the selection of tree types for afforestation and reforestation, there are three factors taken into consideration, namely (1) the ability of the trees in conserving soil and water, (2) economic and social values of the trees and (3) the rate of growth. The trees that have high economic value, good ability to conserve soil and water and high growth rate are recommended.

Table 6.3: Critical land planted and remaining to be planted under reforestation and afforestation

No		Reforestation	Afforestation
1	Area of critical land (1994/95)	3,759,257	8,758,375
2	Area to be planted in Pelita VI	941,680	2,626,475
3	Remaining critical land after Pelita VI	2,817,577	6,131,900

Note : Critical land is degraded lands located on a steep slope. Source : MoF (1996)

b. *Forest Plantation.* This system was established in Java since 1880. Most of tree species used are long rotation (between 25 and 80 years; Table 6.4), i.e. *Tectona grandis* (Teak), *Switenia marcophylla* (Mahagony), *Dalbergia* spp. (rosewood), *Altingia* spp., *Agathis* spp., *Pterocarpus* spp., *Rhiszophora* spp, etc. Food crops are introduced to the system for a period of l to 3 years before the tree closes canopy. At present, total area of forest plantation in Java is about 1,967,809 ha with a rate of harvesting and planting of about 8526.4 ha/year.

Table 6.4: Total area of forest plantation by species and annual rate of harvesting and planting

No.	Species	Total Area (ha)	Rate of planting/harvesting (ha)
1	Tectona grandis	1,106,189	5,259.2
2	Pinus merkusii	597,744	2,516.8
3	Swietenia sp.	74,876	27.6
4	Paraserienthes falcataria	6,982	414.8
5	Rimba	182,018	308.0
	Total	1,967,809	8,526.4

Source : Perum Perhutani (1996)

c. *Timber Estate Plantation*. There are three main categories in this system, namely (1) long rotation timber plantation, (2) short rotation timber plantation and (3) non-timber product plantations. Long rotation plantations are mostly established in Java since 1880 as pointed out in above.. Short rotation plantations are mostly fast growing species, such as *P. falcataria* (Sengon) and *Acacia mangium* (akasia). In non-timber plantation, the species used area rattan, pine resin, kayu putih (*Melaleuca* spp), tannin, honey and medicinal plants. About dozen or so have attained commercial scales. Total area which has been developed for timber estate at the end of 1994 is about 1002729 ha (Table 6.5). It is targeted that by year 2006, total area planted would be about 3.6 Mha and by year 2020 it would be 6.2 million ha.

Table 6.5. Planted area of timber estate at the end of 1994 (ha)

No	**Type of estate**	**Immature**	**Mature**	**Total**
1	Transmigration timber estate	386039	1524	387563
2	Non-transmigration timber estate	567144	48022	615166
3	Timber estate (Total)	953183	49546	1002729

Source : BPS (1997)

d. *Private Forest and Social Forestry*. Based on a decree of Forest Minister, private forest is defined as land with an area of at least 0.25 hectare, owned by local people, and covered by forest crown at least by 50% or planted by trees at least 500 trees per hectare. Private forest is developed in non-forest area, therefore this activity can be defined as afforestation program. Wood of this forest can be harvested. On average about 30% of afforested areas can be categorized as private forest. Social forestry is defined as forest managed based on this function by involving local people. Social forestry takes place in forest area that is already allocated for this activity. The involved people in this activity are people in which forest is their a source of income. The products that can be utilized by the involved people are only non-timber products, such as rattan, bamboo, fruits, resin, honey or food crops planted between the trees. This system can be called agroforestry.

Attention to the social forestry and private forest development started just recently, i.e. at the beginning of Pelita V. However, its potential in forestry development has been considered since 1980s. In Java, social forestry and private forest have been practiced since long time ago, particularly since the land was becoming limited, whereas outside Java, it is not well known. Therefore, the development of social forestry and private forests outside Java needs an intensive evaluation. In north-Sumatra for example, based on intensive field survey, it was found that social forestry is not well practiced and the information on this is very limited (Gintings, 1996).

Tree species used for private forest development are mainly species that have multipurpose function. The multipurpose species fulfill the following criteria: (i) able to produce various kinds of product, (ii) high productivity, (iii) fast growing, (iv) easy to regenerate, (v) can be integrated with other commodities such as domestic animal, (vi) able to increase soil fertility and conserve water, and (vii) easy to market.

e. Forest Squatters Resettlement. It has been mentioned that the resettlement of forest squatters may reduce deforestation indirectly. It is expected that the squatters who have been trained with intensive agriculture may not practice shifting cultivation. On average, number of forest squatters trained was 400 people annually. This is expected to reduce rate of deforestation by 200 ha per year, as the capacity of one forest squatter to open the forest was 0.5 ha per year. Type of trees used by the resettled cultivators are mainly rubber, palm oil and fruit trees.

7. Integrated Assessment of GHG Mitigation Options

There have been a number of economic assessment of GHG mitigation studies carried out in Indonesia (Sasmojo *et al*., 1998; Boer *et al.*, 1998; Pawitan *et al*., 1998). Several alternative mitigation options for energy and non-energy sectors have been described and the economic assessment of the options has been done for each sector. However, most of the past economic assessments particularly those in non-energy sectors were not based on minimizing the net GHG emission subject to provision of forest products and services, but rather on identifying the options which will cost the least per unit of GHG mitigated.

A program called MARKAL developed by a consortium of energy specialists from more than a dozen countries (Fishbone, 1981) in the early 1980s, is a program that can be used for optimization, so that the least cost options for providing energy services could be selected. Indonesia has used this program intensively for energy system analysis. Attempt to use this program for other sector has not been done as this program was deliberately designed for energy sector. This study uses MARKAL model to optimize both the energy and forestry sectors. Using MARKAL for sectors other than energy force all activities of the other sectors be treated as energy activities.

7.1. Activities in Forestry Sector

In this study, area covered for forestry sector was only Java and Sumatra. Forest activities in Java were divided into four types :(1) plantation forest, (2) afforestation and (3) rehabilitation of critical land. The first two activities are intended for wood production while the last activities for land conservation (no harvesting). For Sumatra, data were derived from Jambi data. Thus forest activities and species used in each activity in Sumatra is assumed to be the same as those in Jambi. The activities include (1) reforestation, (2) afforestation, (3) concession forest (HPH) and (4) rehabilitation of critical land. As in Java, the first three activities are intended for wood production.

Forest Plantation. In Java, forest plantation has been started since 1880 using teak and between the two world wars plantation work was continued and the range of species was extended to a number of hardwood species, and more recently also to indigenous and exotic fast growing species (Table 7.1). The responsibility of managing the timber estate in Java is the State Forest Enterprise (Perum Perhutani). Forest area available for timber production is about 1.97 million ha. Baseline rate of harvesting is still lower than the sustainable rate. In this study, the sustainable rate is assumed to be 70% of maximum rate of harvesting. The maximum rate is calculated as the available land divided by rotation.

Afforestation, Reforestation and Rehabilitation. Any planting activities taking place in non-forest area is defined as afforestation while that in forest area is reforestation. Most of the two programs are carried out in critical lands. Both programs are often referred to rehabilitation of critical land. In this study rehabilitation is defined as any planting activity taking place in critical land of forest and non-forest area with no harvesting, while for the former two programs are any planting activities taking place in bare land, unproductive land or critical land with harvesting. In Java, it is assumed that 30% of the total critical land in non-forest area is allocated for afforestation while the remaining area of critical land in forest area is allocated to rehabilitation. In Sumatra, all area of critical land in forest area are allocated for rehabilitation, and all area of critical land in non forest area is for afforestation. Furthermore, unproductive land such as grassland and degraded overlogged forest is allocated for reforestation. The total area available for each activity and tree species used in each activity are presented in Table 7.1.

Concession Forest. Concession forest is natural forest which is allocated for concession companies. This forest is normally defined as production forest (Table 7.1). In this analysis, the biomass of over logged forest is assumed to recover to normal at the end of rotation.

Table 7.1. Total area available in Java and Sumatra for forest activities and tree species used in each activity

Activities	Species	Available Land (ha)	Mean annual increment (tB/ha/yr)	Rotation (year)
JAVA				
Plantation forest	*Tectona grandis* (Teak)	1,106,189	3.90	40
	Pinus mercusii (Pine)	597,744	6.93	35
	Switenia spp (Mahoni)	74,876	7.97	40
	Paraserienthes falcataria (Sengon)	6,982	19.07	10
	Others (Rimba)	182,018	4.30	30
Afforestation	*Acacia mangium* (Akasia)	206,510	25.00	10
	Paraserienthes falcataria (Sengon)	309,764	19.07	10
Rehabilitation of critical land	*Tectona grandis* (Teak)	400,000	3.90	-
	Acacia mangium (Akasia)	710,833	25.00	-
	Paraserienthes falcataria (Sengon)	710,833	19.07	-
SUMATRA				
Reforestation	*Acacia mangium* (Akasia)	723,368	25.00	10
	Paraserienthes falcataria (Sengon)	310,015	19.07	10
Afforestation	*Pinus mercusii* (Pine)	885,707	6.93	35
	Acacia mangium (Akasia)	1,799,983	25.00	10
Concession forest	Others (Rimba)	9,105,709	1.88	30
Rehabilitation Critical land	*Pinus mercusii* (Pine)	306,630	6.93	-
	Acacia mangium (Akasia)	715,470	25.00	-

[1/] In the rehabilitation program, there is no harvesting taking place and therefore the rotation is not given.

7.2. Data

For the energy sector, input data is sectoral energy demand and this was highlighted in Table 4.4. For forestry sector, data for each activity described in section 7.1. were collected from Perum Perhutani and Forest District Office in West Java, Central Java and East Java, Forest Companies in Jambi, and Department of Forestry, Jakarta. Data collected include production data, harvesting and planting area for each tree species, area of critical lands, C-soil organic, biomass after and before conversion, rotation, mean annual increment and cost data. Cost data used in this study are presented in Table 7.2.

Table 7.2. Cost for forest activities

No	Component	Location	Species	Amount	**Unit**
A	Initial cost [1/]	Sumatra	Teak	-	-
			non-Teak	103.3	US $/ha
		Java	Teak	75.0	US $/ha
			Non-Teak	62.5	US $/ha
B	Recurrent cost [2/]	Sumatra	All species	20.1	US $/ha
		Java	All species	16.1	US $/ha
C	Cost of monitoring [3/]	Sumatra	All species	2.1	US$/ha/year
		Java	All species	1.5	US$/ha/year
D	Cost of log harvesting	Sumatra and Java	Teak	13.7	US$/m^3
			Non-teak	10.8	US$/m^3
E	Cost of fuel wood harvesting	Sumatra & Java	Teak	4.1	US$/m^3
			Non-teak	1.7	US$/m^3
F	Cost of resin harvesting[4/]	Sumatra & Java	Pine	257.3	US$/ton

[1/] Initial cost consists of cost for land preparation, tree seedlings and planting. In the forest plantation of Java, there is additional cost for planting of food crops, i.e. for 1st year US$104 per ha and for the 2nd year US$108 per ha. [2/] Recurrent cost consist of maintenance cost. Maintenance cost for the 2nd year for both Java and Sumatra US$14.8/ha. [3/] Monitoring is carried out for three years in the rehabilitation programs, and only one year in the reforestation program. [4/] In the calculation of present value of cost for pine, harvesting cost of resin is included.

7.3. Method of Analysis

In this study, energy and forestry sector analyzed together using MARKAL model to minimize the cost of energy and forest protection services with constraints on net CO_2 emission. For energy system all activities from mining extraction, processing, energy transport, conversion, up to energy demand were included in the analysis. For forestry sector, the activities included in the analysis are described in Table 7.1.

The objective function for the model is to minimize total cost of energy supply and timber/biomass production. The mathematical formulation of the model can be simplified in the form of objective function as follows :

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

Subject to:

Energy Source (E) $\leq$ Reserve

Forest (F) $\leq$ Forest Availability

CO_2 Emission (Emission + Sink) $\leq$ Net Emission Target

where:

$c\ E_{ij}$ = Cost of energy supply

$d\ F_{ij}$ = Cost of timber/biomass production

Schematically, link between energy and forestry sector is presented in Figure 7.1. The unit activity used in forestry sector is volume (m3) of product for forest plantation, afforestation and reforestation, and area (ha) of land for the rehabilitation.

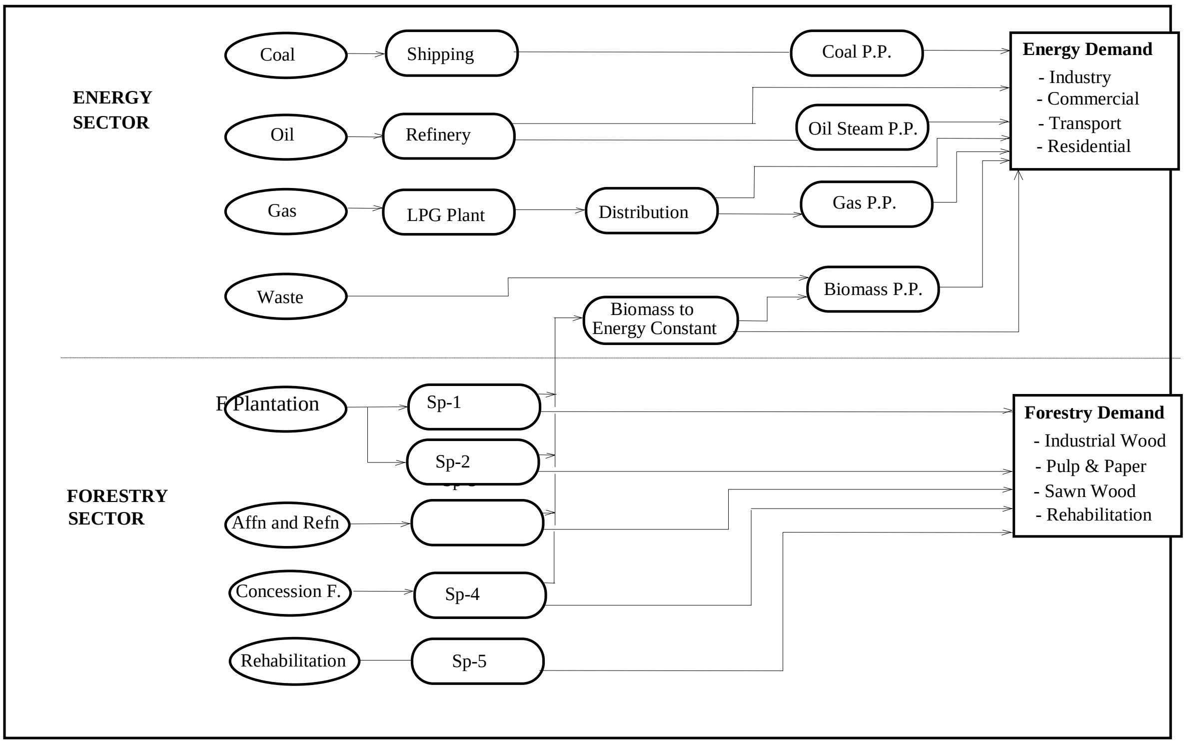


Figure 7.1. Schematic of Energy and Forestry Link Model

In the least cost model, activities cost is the main parameter driving the model. Since MARKAL is an energy supply optimization model, all activities of the forestry sector should be treated as energy activities. In the energy system there are four main different activities, i.e. extraction, processing (i.e. energy-transport, and form changed), conversion (power generation), and demand. Each of these activities has unique characteristic. For the forestry sector model, forest activities were categorized as "extraction" that require total present value of cost of planting, maintenance and harvesting. Harvesting processes that produce timber and biomass for energy is categorized as "process" activity. In this "process" detail costing with regard to the activities including their machinery cost and technical characteristic could be introduced. Since cost of harvesting has been included in the 'extraction" this costing capacity of the "process" was not applied for this project. Lastly for the wood demand and rehabilitation target are categorized as "demand" activities. COMAP model (Sathaye *et al.*, 1995) has been used to produce present value of cost in the forest activities.

Calculation of CO_2 emission and Uptake. In this study only carbon dioxide is considered. Sources of CO_2 emissions are from the "extraction" process of the energy system and from biomass burning. The total carbon uptake is calculated by multiplying mean annual increment (t B/ha/year; see Table 7.1) with rotation, area of growing forest (ha) and carbon fraction of the biomass (a value of 0.5 was used). In this model, the total uptake occurs at the time of planting. Carbon stored in the forest products and in soils is also considered as carbon sink. In this study it is assumed that the rate of carbon stored in the soil in reforestation, afforestation and rehabilitation of critical land is about 2 t C/ha/year, while for forest plantation and forest concession it was assumed that there is no increase in soil carbon. Total accumulated soil carbon was calculated by multiplying the rate with area and rotation. The maximum accumulated soil carbon was set up at 60 tC/ha. Calculation of accumulated soil carbon was carried out outside MARKAL. Therefore the carbon uptake output from the MARKAL was corrected with the total accumulated soil carbon. The delayed emission from the forest product through decomposition process was also calculated outside the MARKAL model since this model was not able to handle the delayed emissions directly.

In this study, forest products were divided into four types namely sawn wood, industrial wood, pulp/paper and residues or waste. The fraction of biomass allocated for log, fuel wood and residues was set in certain range. This is to allow the MARKAL to find optimal log allocation for each product so that the demand could be met. The range of log allocation for each of product is presented in Table 7.3.

Table 7.3. Fraction of biomass allocated for log, fuel wood and waste, and fraction log allocated for sawn timber, industrial wood, pulp/paper, and waste produced from log processing

	Fraction of biomass (%) for[1/]			Fraction of log (%) for[2/]			
Species	Log	Fuel wood	Residue	Sawn timber	Other Industrial wood	Paper/ pulp	Waste
Tectona grandis (Teak)	40.0	49.0	11.0	4.5-20.6	44.5-62.0	0	33.5
Pinus mercusii (Pine)	34.0	36.0	30.0	25.0-44.5	0	31.1-45.5	30.5
Switenia spp. (Mahoni)	32.0	28.0	40.0	0.0-22.1	45.0-67.0	0	33.0
Paraserienthes falcataria (Sengon)	36.0	38.0	26.0	32.1-44.8	5.9-11.0	32.1-44.8	15.4
Others (Rimba)	32.0	28.0	40.0	0-47.9	0.0-54.1	11.6-44.8	28.5
Acacia mangium (Akasia)	36.0	38.0	26.0	7.2-77.4	0	7.2-64.4	14.0

[1/] The fraction were considered based on expert judgment. [2/] The fraction was set up for allowing MARKAL to find optimal solution.

Furthermore, fractions of wood in-use that decay or burn each year for the sawn wood, pulp/paper, and other industrial wood are assumed to be 0.02, 0.10, and 0.07, respectively (Winjum *et al.*, 1998) ; while for residue and waste is assumed to be 0.25. Thus all of carbon stored in the sawn wood, pulp/paper, industrial wood and waste will be released to the atmosphere within 50, 10, 14 and 4 years, respectively. Calculation of emissions from Stock follows the following formula:

$$Em_{24}(t) = (2024 - t) / lf * S(t)$$

$Em_{24}(t)$ is the cumulative carbon emission from stock harvested in year t between a period of year t and 2024, $S(t)$ stock harvested in year t, and lf life time of the stock. The total emission from stock is calculated as follows:

$$TEm_{24} = \sum_{t=1990}^{2024} Em_{24}(t); \quad t = 1990, 1991, 1992, \ldots\ldots, 2024$$

The calculation of emission and uptake of CO_2 was performed when wood demand increased from the baseline wood demand. This method of calculation was adopted with the assumption that before the base year, the uptake and emission of CO_2 from plantation forest and concession forest is assumed to be in balance since the activity has been taking place ever since long time ago with sustainable management.

Furthermore the carbon emission from energy sector follows the standard method described in IPCC methodology.

Demand Projections. Wood demand projection for Java and Sumatra used in this study followed the demand projection estimated by MoF and FAO (1990). The wood demand projection for sawn timber, paper/pulp and other industrial wood is presented in Table 7.4. Furthermore, for simplicity it was assumed that all of critical land that is available for rehabilitation, would be planted on the trees within 30 years. Demand projection for energy was described in Chapter 4.

Table 7.4. Wood demand projection for Sumatra and Java

Jenis	1990	1995	2000	2005	2010	2015	2020
Sumatra							
Sawnwood	1.15	1.58	1.98	2.36	2.73	3.11	3.49
Paper/pulp	0.11	0.27	0.42	0.56	0.71	6.72	5.94
Other Industrial wood	2.08	2.92	3.71	4.46	5.21	5.93	6.65
Total Demand	**3.34**	**4.77**	**6.11**	**7.38**	**8.65**	**15.76**	**16.08**
Java							
Sawnwood	4.87	6.71	8.45	10.03	11.63	13.25	14.86
Paper/pulp	0.5	1.16	1.8	2.42	9.22	9.22	10.97
Other Industrial wood	8.94	12.49	15.82	19.05	22.25	25.32	28.41
Total Demand	**14.31**	**20.36**	**26.07**	**31.5**	**43.1**	**47.79**	**54.24**

Note : Wood demand projection used in the analysis is a little bit higher than the MoF and FAO study (see Table 4.1) as the GDP growth rate used is slightly higher than that used in the MoF ad FAO study.

7.4. Mitigation Scenarios

In this study we develop four scenarios. The first scenario is baseline scenario (EbFb), and the other three are mitigation scenarios (EbFm, EmFb and EmFm). The description of the scenarios is as follows:

5. EbFb (baseline scenario). In this scenario, mitigation technologies in the energy sector were not included the model and no target was set up for increasing net carbon uptake by forest activities.
6. EmFb. Mitigation technologies in the energy sector were included with the target of reducing cumulative net carbon emission by about 13 % and activities in the forestry sectors were the same as those in the baseline
7. EbFm. Mitigation technologies in the energy sector were not included and the forestry activities were targeted to increase the carbon uptake so that the cumulative net carbon emission decreased by 13%.
8. EmFm. Mitigation technologies in the energy sector were included as well as forestry sector with target of reducing cumulative net carbon emission by about 35%.

7.5. Results of Analysis

7.5.1. Carbon Emissions and Uptake

In section 7.3, it was mentioned that the emissions from forest products and carbon accumulation in the soil in the afforestation, reforestation and rehabilitation programs were calculated outside the MARKAL model. As consequence, outputs from MARKAL should be corrected. After the carbon emission from forest products and carbon uptake by soils were taken into account, the percent net carbon emission reduction for the scenario EbFm, EmFb and EmFm increased by about 0.6%, 0.9% and 3.9% from the targets respectively (Table 7.5).

Table 7.5. Summary of total carbon uptake and emission from both energy and forestry sector by scenarios (million tonnes CO_2)

	Unit	EbFb	EbFm	EmFb	EmFm
Total Uptake	Million tonnes CO_2	+5,037	+5,629	+5,058	+5,905
Total Emission	Million tonnes CO_2	-20,337	-18,851	-18,238	-15,258
Total Net Emission	Million tonnes CO_2	-15,300	-13,222	-13,179	-9,353
Reduction of CO_2 net emissions from the baseline scenario	%		13.6	13.9	38.9

In the four scenarios, total amount of carbon stored in forest products is between 11 % and 13 % of total carbon uptake, in the soils between 10% and 11% and in the vegetation between 76% and 79 % (Figure 7.2). The role of forest product as carbon sinks could be increased by increasing the life time of products and by reducing wood waste during processing. In this study, the age of the sawn wood, pulp/paper and other industrial wood has been assumed to be equal for all species. For the future improvement of the model, this assumption should not be used and types of wood products should be extended, such as derivative products of sawn wood (Table 7.6). In implementing its, there are many additional inputs required such as type of derivative product, cost of further processing of sawn wood, etc.

Table 7.6. Further processing of sawnwood

	Secondary processing	Tertiary processing
Action	• Sawing/sawnwood, smoothing, shaping, • Planning, profilling, turning, carving with or withouth surface finishing	• Assembling, incorporation of other wood-based and non-wood materials • Finishing
Products	• Tongued and grooved boarding • Mouldings • Beading, • Dowelling • Strip and block flooring, parguet flooring • Panelling • Furniture components • Other components (e.g. vehicle bodies, boatbuilding and repair)	• Packaging-crates, boxes and pallets • Doors, door and wondow frame, • Laminated board and beams • Furniture, including kitchen and bathroom cabinets, assembles or R.T.A. • Prefabricated building

In this study share of forestry sector to the total carbon emission compare with that of energy sector is much smaller (energy sector about 83% and forestry sector about 17%). ALGAS Study (1998) has indicated that the share of forestry sector to the total Indonesian carbon emission is relatively the same as energy sector. This big difference is because the carbon emission from energy sector was calculated for all Indonesian regions while from forestry sector was only calculated for Java and Sumatra. Of 16%, about 10% was the emission from biomass burning for energy and about 6% was the emission from decomposition of the wood products and wastes (Figure 7.3).

As it is shown in Table 7.5, the net emission reduction in scenario EmFb and EbFm is slight different (Figure 7.4). Whereas in the MARKAL model, target of emission reduction of these two scenarios has been set the same. As it is mentioned previously, this slight difference is due to the inclusion of delay emission of wood products and soil carbon. For future development of the MARKAL model, the estimation of delay emission and soil carbon should be done inside the Model not outside the model.

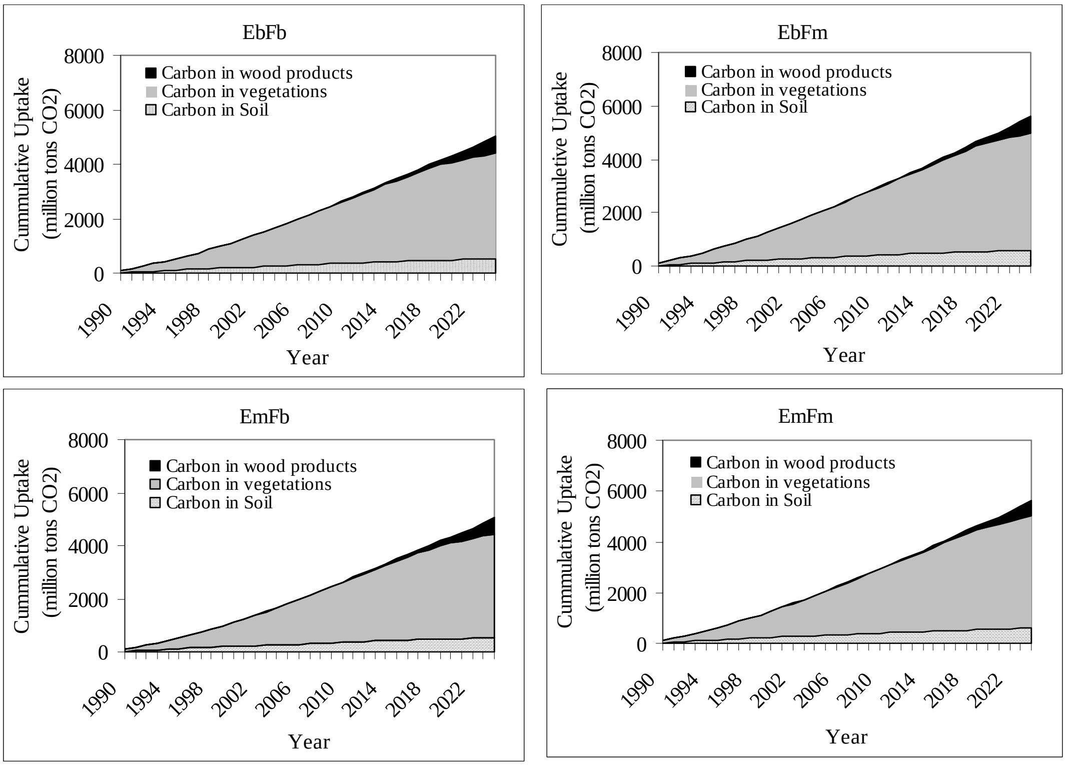


Figure 7.2. Cumulative uptake of CO_2 by scenario

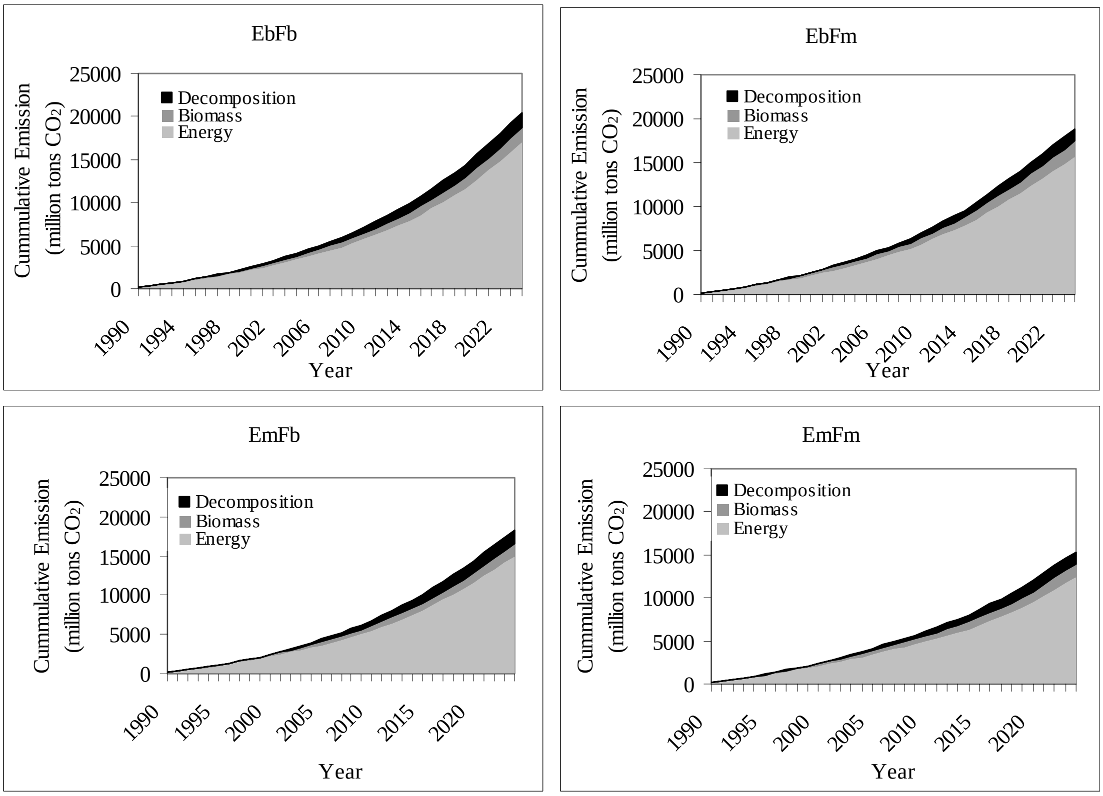


Figure 7.3. Cumulative emission of CO_2 by scenario

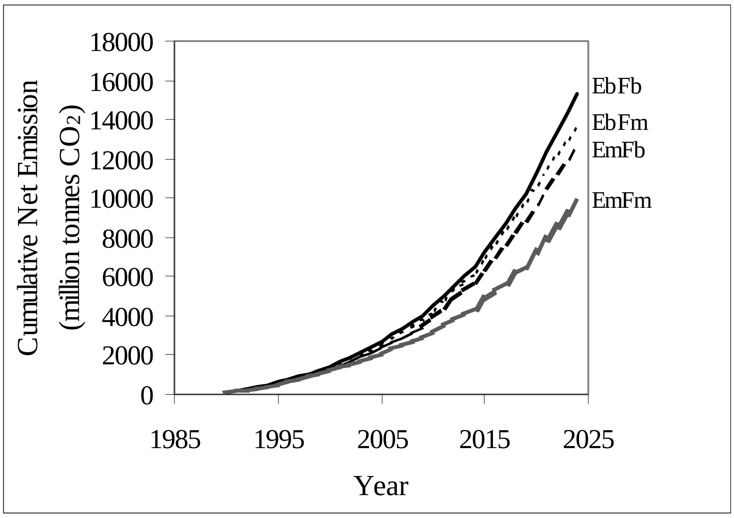


Figure 7.4. Cumulative net emission of the four scenarios

7.5.2. Mitigation Scenarios in Forestry Sector

Carbon uptake occurs mainly in afforestation, reforestation and rehabilitation programs as these activities involve planting trees in bare lands or critical lands. Whereas harvesting woods from standing forests such as plantation forest and production forest, will result in carbon emissions as much as half of standing biomass approximately. However the amount of carbon emitted could be diminished if planting activities are carried out in the harvested area and most of harvested wood are converted into log products.

In this study the cost used in the analysis is present value of cost in term of dollars per hectare (Table 7.7). Thus the selection of options will be based on this cost. However, the use of net present value of benefit of the options may be preferable. With this approach, the selection of the options will be based on the net benefit of the options. A set of options that gave maximum benefit will be selected. In this study this approach is not used as some of the options gave negative benefits. The MARKAL model developed was not able to accommodate the negative values.

Table 7.7. Present value of cost and Present value of benefit in the forest activities.

Activities	**Species**	**PV Cost**	**PV Benefit**
	JAVA	$/ha	$/ha
Plantation forest	*Tectona grandis* (Teak)	83	145
	Pinus mercusii (Pine)[1/]	1650	2016
	Switenia spp (Mahoni)	82	141
	Paraserienthes falcataria (Sengon)	348	481
	Others (Rimba)	82	78
Afforestation [1/]	*Acacia mangium* (Akasia)	595	1047
	Paraserienthes falcataria (Sengon)	1140	1488
Rehabilitation of critical land[1/]	*Tectona grandis* (Teak)	32	0
	Acacia mangium (Akasia)	28	0
	Paraserienthes falcataria (Sengon)	28	0
	SUMATRA		
Reforestation[1/]	*Acacia mangium* (Akasia)	595	1047
	Paraserienthes falcataria (Sengon)	314	374
Afforestation[1/]	*Pinus mercusii* (Pine)	5071	6153
	Acacia mangium (Akasia)	1897	2773
Concession forest	Others (Rimba)	138	17692
Rehabilitation Critical land[1/]	*Pinus mercusii* (Pine)	57	0
	Acacia mangium (Akasia)	31	0

[1/] Cost of harvesting resin as well as benefit from resin is included in the analysis.

In terms of wood demand and supply, in Sumatra for all scenarios, the supply is over the demand for all industrial woods (sawn wood, pulp/paper and other industrial wood). Whereas in Java, there is a big deficit particularly for other industrial woods (Figure 7.5 and 7.6). In the baseline scenario (EbFb), the surplus for other industrial wood in Sumatra is not able to offset the deficit in Java in 2000, 2005, 2010, 2015 and 2020. The surplus in Sumatra are about 54%, 24%, 12%, 6% and 1% of deficit in Java, respectively. Therefore import from other islands is required, i.e. 2.29, 6.33, 10.22, 13.77 and 17.46 million m^3 for year 2000, 2005, 2010, 2015 and 2020, respectively. For sawn wood the surplus in Sumatra can meet the deficit in Java, while for pulp and paper the surplus is over the deficit in Java so that it can be exported to other islands (Figure 7.6). DGFU and FAO (1990) estimated that under the baseline scenario, the surplus of industrial wood in Sumatra was about 52.0% (7.05 million m^3), 42.9% (9.29 million m^3) and 43.0% (13.49 million m^3) of the deficit in Java for year 2000, 2010 and 2020, respectively. Therefore, import from other islands is still required at an amount of 6.52, 12.31 and 17.85 million m^3 for the respective years. These results show that there is an agreement between the two studies. DGFU and FAO (1990) stated that besides Sumatra, Kalimantan is the major wood exporter for Java.

Referring to Table 7.5, it is shown that under the baseline scenario total emission from energy and forestry sectors in the period of 35 years (1990-2024) is about 20,337 million tons CO_2. Activities in forestry sector in the two islands (Java and Sumatra) are able to offset the emission by 25% (5,037 million tons). In this baseline scenario, total areas of critical and bare lands to be planted through rehabilitation, afforestation and reforestation are about 2.8, 2.7 and 0.7 million hectares, respectively (Table 7.8). In order to reduce the net baseline emission by 13.6% through forest activities (EbFm), the total area of critical and bare lands need to be planted should be increased by 0.421 million hectares from the baseline (afforestation 0.368 million ha and reforestation 0.053 million ha). Furthermore, reduction of net carbon emission by about 38.9% (EmFm) from the baseline net emission, the area needed to be allocated for afforestation and reforestation were almost the same as in EbFm. It indicates that most of carbon emission reduction in EmFm was carried out via energy sector. This occurred because the available land was limited. In EbFm, almost all of the available land has been used for the activities.

The mitigation scenarios did not affect planting area for the rehabilitation program. Total planting area of rehabilitation for each four scenarios is 2.8 million hectares. This is because all available land for rehabilitation is assumed to be planted all within the time frame of the study irrespective of scenarios. Therefore, the increase in carbon uptake was carried out mostly through reforestation and afforestation programs. Rate of planting for each species by region, by species and by forest activity is presented in Table 7.8.

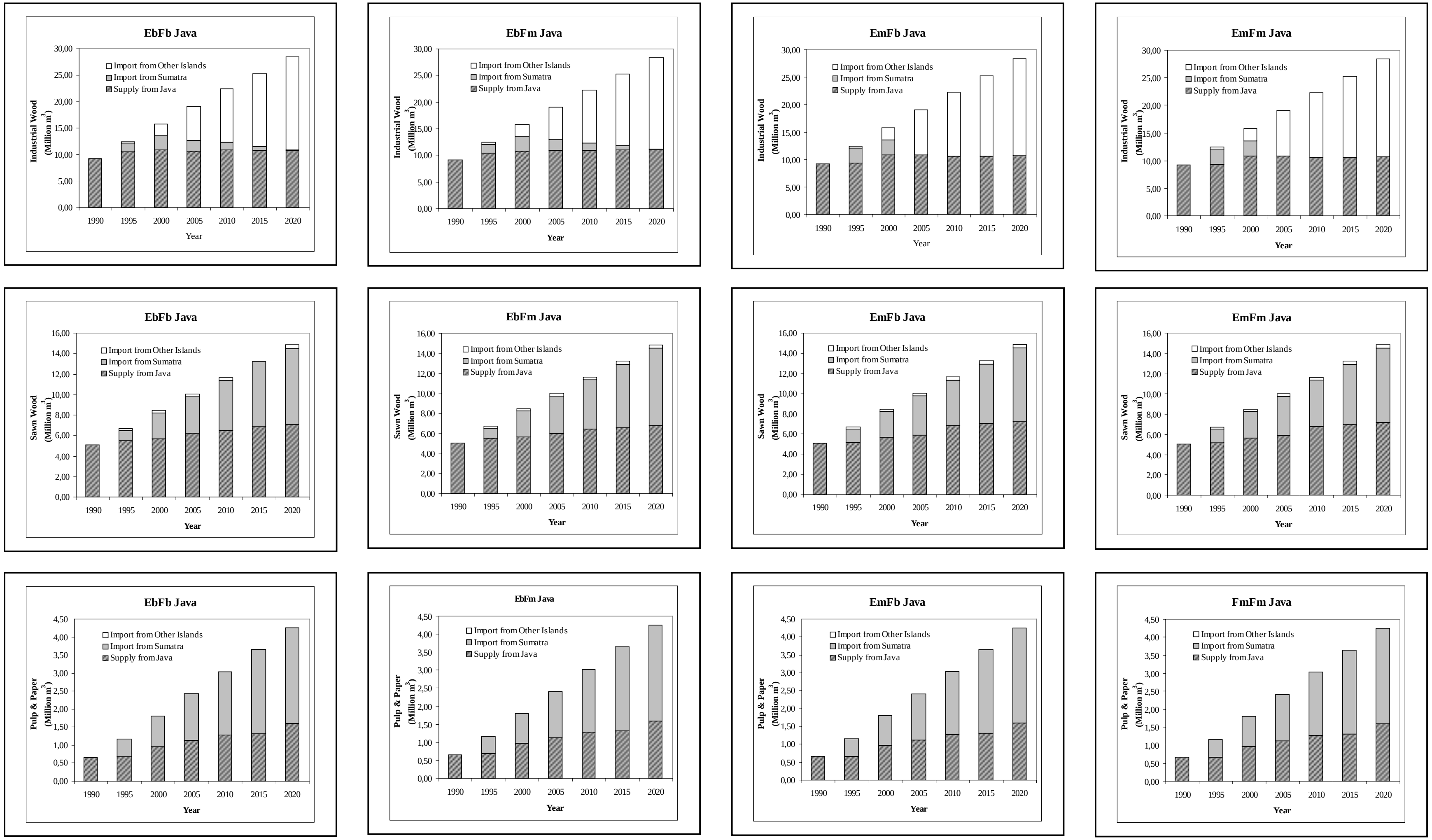


Fig. 7.5. Sources of wood supply for Java

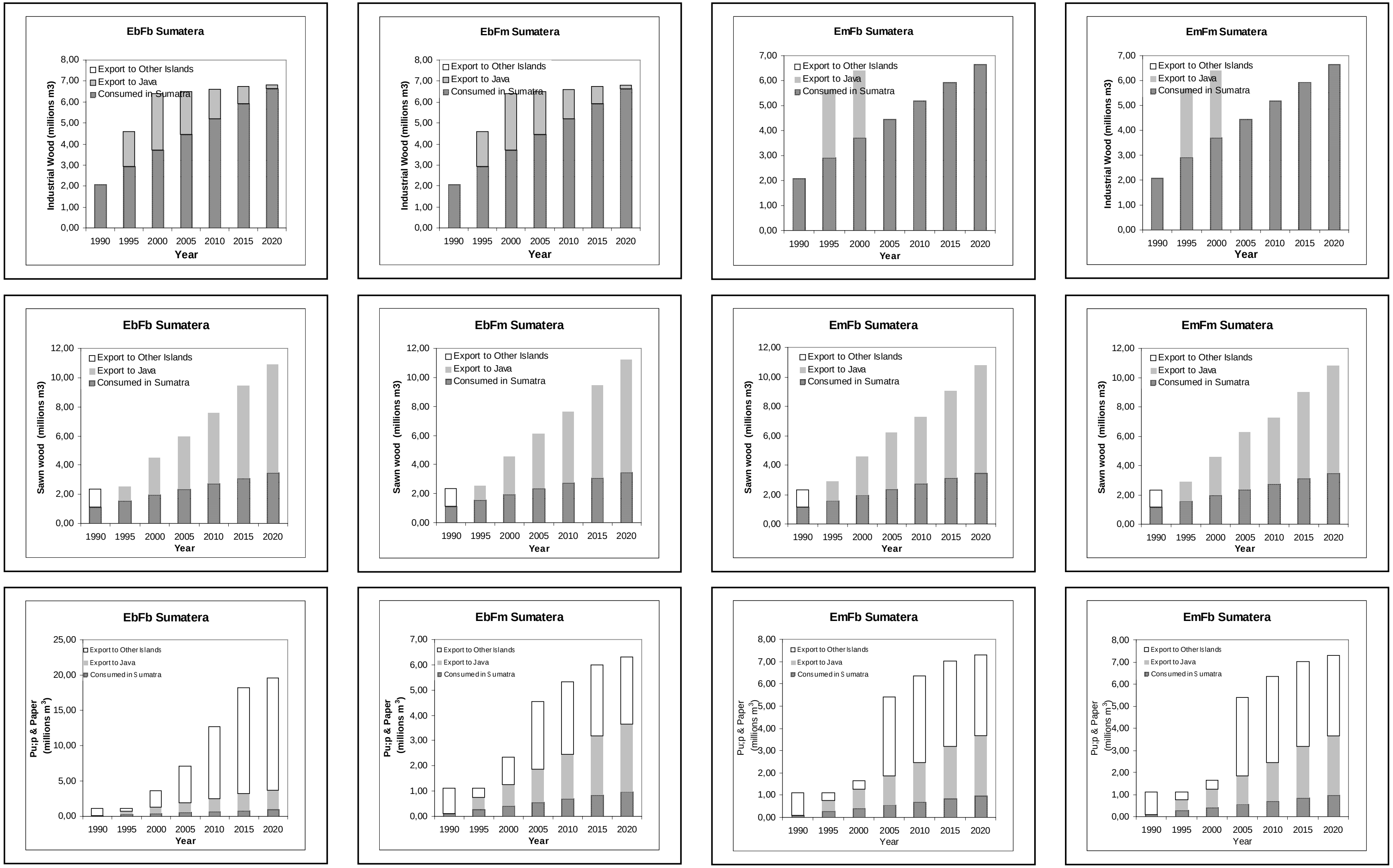


Fig. 7.6. Allocation of wood supply in Sumatra

Table 7.8. Rate of planting by forest activities

Forest Activities	Spesies	Unit	EbFb	EbFm	EmFb	EmFm
Rehabilation	Tectona grandis(Java)	Million ha	0.35	0.35	0.35	0.35
		ha/year	10000	10000	10000	10000
	Acacia mangium (Java)	Million ha	0.70	0.70	0.70	0.70
		ha/year	20000	20000	20000	20000
	Acacia mangium (Sumatera)	Million ha	0.70	0.70	0.70	0.70
		ha/year	20000	20000	20000	20000
	Paraserianthes falcataria (Java)	Million ha	0.70	0.70	0.70	0.70
		ha/year	20000	20000	20000	20000
	Pinus merkusi(Sumatera)	Million ha	0.35	0.35	0.35	0.35
		ha/year	10000	10000	10000	10000
Afforestation	Acacia mangium (Java)	Million ha	0.171	0.184	0.171	0.184
		ha/year	17100	18400	17100	18400
	Acacia mangium (Sumatera)	Million ha	1.697	1.758	1.686	1.758
		ha/year	169700	175800	168600	175800
	Paraserianthes falcataria (Java)	Million ha	0.117	0.261	0.144	0.261
		ha/year	11700	26100	14400	26100
	Pinus merkusi(Sumatera)	Million ha	0.70	0.85	0.70	0.75
		ha/year	20000	24286	20000	21429
Reforestation	Paraserianthes falcataria (Sumatera)	Million ha	0.229	0.233	0.229	0.233
		ha/year	22900	23300	22900	23300
	Acacia mangiumi(Sumatera)	Million ha	0.456	0.505	0.456	0.505
		ha/year	45600	50500	45600	50500
Forest Plantation & Concession	Acacia mangium (Java)	Million ha	0.171	0.184	0.171	0.184
		ha/year	17100	18400	17100	18400
	Paraserianthes falcataria (Java)	Million ha	0.005	0.005	0.005	0.005
		ha/year	500	500	500	500
	Tectona grandis(Java)	Million ha	0.607	0.699	0.607	0.699
		ha/year	17343	19971	17343	19971
	Pinus merkusi(Java)	Million ha	0.23	0.451	0.23	0.451
		ha/year	6571	12886	6571	12886
	Switenia spp.(mahoni)	Million ha	0.027	0.032	0.027	0.032
		ha/year	771	914	771	914
	Others Spesies (Java)	Million ha	0.079	0.179	0.079	0.179
		ha/year	2633	5967	2633	5967
	Others Spesies (Sumatera)	Million ha	5.655	6.246	5.655	6.246
		ha/year	188500	208200	188500	208200

7.5.3. Mitigation Scenarios for Energy Sector

The result of EmFb, EbFm and EmFm scenario shows that reducing CO_2 emission will change the primary energy supply (Table 7.9). The total primary energy for EmFb, EbFm and EmFm would be similar with the Baseline (EbFb) scenario. The optimal primary energy table under EbFm scenario suppose to be not different from that of the baseline in term of the total and also energy mix but due to the maximum uptake capacity of the Jawa and Sumatra forestry system not sufficient to mitigate as much as EmFb scenario in the last five year analysis (2020-2025), the energy contribute by reduce coal and sift to hydropower, biomass, natural gas, and nuclear. In the Baseline scenario, coal and oil dominant as an energy supply followed by natural gas. In the EmFb scenario, coal would decline and substitute with hydropower, geothermal, biomass and nuclear, the magnitude of the EmFm is similar with the EmFb but the substitution rate more high than that in the EmFb scenario.

Table 7.9: Comparison of Primary Energy Supply in Peta Joule

Energy Source	Scenario	1990	1995	2000	2005	2010	2015	2020
Biomass	EbFb	1014	1126	1211	1289	1436	1550	1698
	EmFb	1016	1149	1266	1356	1461	1624	2347
	EbFm	1015	1142	1231	1291	1435	1582	2329
	EmFm	1018	1158	1274	1739	1923	2106	2329
Hydropower & Geothermal	EbFb	142	189	281	481	544	538	521
	EmFb	142	189	322	516	544	597	1667
	EbFm	142	189	290	474	544	538	1769
	EmFm	142	197	505	1062	1845	2610	2690
Coal	EbFb	194	342	459	1004	2012	3691	5872
	EmFb	193	340	455	445	1662	2365	2498
	EbFm	194	343	504	1023	2022	2994	2864
	EmFm	192	339	339	271	311	411	614
Natural Gas	EbFb	652	1109	1668	1983	2331	2663	3104
	EmFb	641	1059	1571	2352	2510	2995	3591
	EbFm	651	1085	1617	1964	2300	2993	3844
	EmFm	633	1019	1581	1998	2489	3179	3831
Oil	EbFb	1136	1398	1735	2056	2404	3241	4712
	EmFb	1144	1414	1716	1901	2471	3695	5381
	EbFm	1136	1401	1717	2047	2462	3512	4628
	EmFm	1119	1417	1536	1821	2222	3370	5866
Nuclear	EbFb	0	0	0	0	0	0	0
	EmFb	0	0	0	30	30	201	402
	EbFm	0	0	0	0	0	0	402
	EmFm	0	0	0	80	80	201	402
Total	EbFb	3138	4163	5353	6814	8727	11683	15906
	EmFb	3136	4151	5330	6599	8678	11478	15886
	EbFm	3138	4158	5359	6799	8763	11619	15835
	EmFm	3104	4130	5235	6973	8870	11878	15731

Under the Baseline scenario cumulative CO_2 emission from the energy system along 35 years period between year 1990-2025 is 16.9 billion ton, for the EmFb scenario the cumulative CO_2 emission will be reduce by 12%, in the comprehensive mitigation on the energy and forestry (EmFm) that emission decline 12.4 billion ton (27% reduction), and for EbFm decline to 15.7 billion Ton (7% less than EbFb). The annual projected total CO_2 emission from energy sector grow at the rate of 6.6, 5.8, 5.7 and 5.3 % per annum respectively for EbFb, EmFb, EbFm, and EmFm scenarios. For the EbFm scenario, CO2 emission only decline in the last period compare to the EbFb. The comparison of the annual CO_2 emission from energy system shows in Figure 7.7.

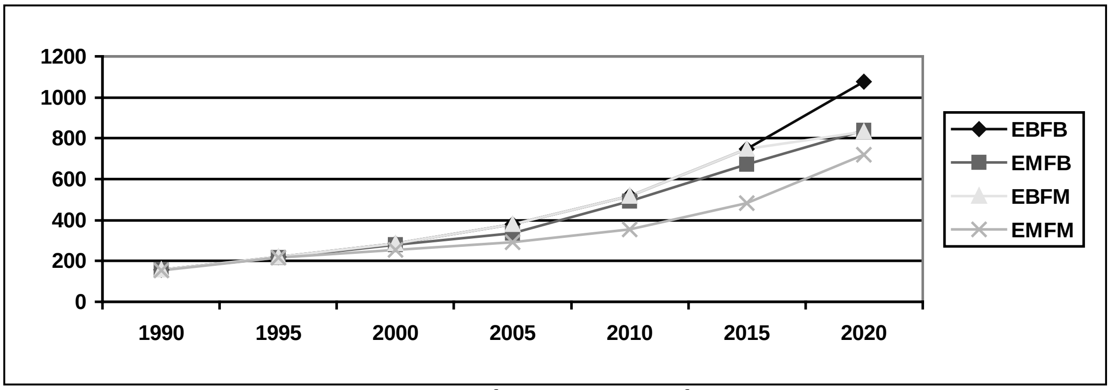


Figure 7.7: Comparison of CO_2 Emission from Energy Sector

CO_2 mitigation in the energy system is selected from the mitigation option in the power generation, industrial sector and also residential & commercial sectors, which are describe in previous chapters. Selection of the option is based on the optimal result under respective total CO_2 constraint in the different scenario.

This CO_2 mitigation is accumulation of the fuel diversification, energy conservation and also demand side management. Interaction of the energy conservation and demand side management proved in the final energy mix, utilization of most fuels decline compared to the baseline scenario (see Table 7.10). Fuel diversification is applied in the power generation mix, i.e. Hydropower, natural gas, biomas and nuclear are the fuels alternative to replace more carbon intent fuels such as coal and petroleum product. Regarding fuel diversification there are interesting pattern, biomass as the best fuel option in the EmFm consume less than the other scenario. This change is due to the fuel for electricity generation requirement. This pattern indicates that mitigation in the power generation is more effective than demand sector but they require more cost expenditure.

Capacity mix of Indonesia power generation is different for each energy mitigation scenario and baseline scenario (see Table.7.11). This different capacity mix is for accommodate the CO_2 emission through the diversification of the power plant fuel input, even the total capacity increase but total CO_2 emission from this sector becomes lower due to the more utilization of the non-carbon fuels.

The mitigation result of the demand sectors such as industry, residential and commercial are from the utilization of industrial waste heat recovery with cogeneration (combined heat and power, CHP) technology, more efficient lamp, motors and refrigerator and also fuels diversification. In the commercial sector the main mitigation is from the installation of the solar thermal heater replaced boiler for bath and laundry hot water.

Mitigation in the household sector for cooking is by utilizing more efficient stove. The main mitigation in this sector are more efficient lamp, such as compact fluorescent lamp (CFL) and regular fluorescent replacing incandescent, and replace fluorescent’s coil ballast with electronic ballast one for electrified household. For the non-electrified rural household area one CO2 mitigation option involves installation of Solar Home System (SHS). The mitigation results on lighting in electrified household of the EmFm scenario also indicate that advance compact fluorescent lamp become economically feasible. In the non-electrified household the SHS installation only feasible in the EmFm scenario with capacity kerosene replacement as much as 0.56 Peta Joule in the year 2010, and 38 Peta Joule in the year 2020.

Table 7.10. Final Energy Supply Mix

Peta Joule

Fuels	Scenario	1990	1995	2000	2005	2010	2015	2020
	EbFb	1002	1114	1199	1279	1426	1541	1689
Biomass	EmFb	1004	1137	1255	1345	1451	1573	1641
	EbFm	1002	1130	1220	1280	1425	1573	1708
	EmFm	1005	1138	1255	1355	1476	1023	1189
	EbFb	78	118	173	241	324	525	884
Coal	EmFb	76	117	169	224	338	464	704
	EbFm	78	119	173	248	336	483	632
	EmFm	76	115	165	221	289	400	606
	EbFb	240	361	519	746	1047	1511	2176
Electricity	EmFb	240	361	519	717	1042	1515	2209
	EbFm	240	361	519	744	1045	1513	2206
	EmFm	238	361	521	723	1032	1499	2197
	EbFb	0	0	39	64	64	64	64
Heat CHP	EmFb	0	0	39	92	92	133	163
	EbFm	0	0	39	81	81	103	220
	EmFm	0	0	39	102	131	170	220
	EbFb	267	378	562	758	965	1255	1578
Natural Gas	EmFb	267	374	529	726	921	1216	1561
	EbFm	267	374	554	742	950	1235	1582
	EmFm	267	375	531	722	946	1254	1616
	EbFb	908	1244	1626	2112	2702	3502	4557
Petroleum	EmFb	908	1229	1609	2076	2672	3475	4568
Product	EbFm	908	1234	1614	2102	2689	3485	4520
	EmFm	907	1225	1589	2046	2618	3664	4713
	EbFb	2494	3215	4117	5199	6527	8398	10949
Total	EmFb	2494	3218	4119	5179	6517	8376	10845
	EbFm	2494	3217	4118	5198	6526	8392	10867
	EmFm	2494	3215	4100	5167	6491	8011	10540

Another mitigation result of the residential sector is by increasing refrigerator performance by improving insulation and use of efficient compressor. In this option assume that refrigerator technology autonomously become more efficient. The result of penetration of the refrigerator market for the EmFb scenario is after year 2010 all the new refrigerator installed already use the efficient refrigerator, and in the EmFm scenario this efficient refrigerator will use 5 years ahead.

For industrial sector, CO_2 mitigation result is by utilization of the efficient motors with the maximum potential. In the indirect heating process biomass fuel also utilize in the maximum potential for mitigation scenario (EmFb, and EmFm). The biomass use for indirect heating processes is 86 PJ in the year 1990 and 104, 130, 158, 196, 246, and 310 peta joule for the 5 respectively year up to the year 2020. Beside that cogeneration have a lot of mitigation contribution, cogeneration capacity installed as the result of optimization in respective scenario can be seen in the Tabel 7.12.

Table 7.11. Capacity Mix of Indonesia Power Generation in Giga Watt

Power Generation Type	Scenario	1990	1995	2000	2005	2010	2015	2020
Biomass Steam PP	EbFb	0.23	0.23	0.23	0.21	0.21	0.21	0.21
	EbFm	0.23	0.23	0.23	0.21	0.21	0.21	12.53
	EmFb	0.23	0.23	0.23	0.21	0.21	1.02	13.97
	EmFm	0.23	0.39	0.36	7.78	9.35	22.03	23.28
Coal Steam PP	EbFb	1.75	3.54	4.45	4.35	5.23	10.23	15.19
	EbFm	1.75	3.54	4.45	4.35	5.11	4.85	3.07
	EmFb	1.75	3.54	4.45	4.35	5.14	4.19	2.41
	EmFm	1.75	3.54	4.45	4.35	3.64	2.69	0.91
Coal SPP (abatement) with deSOx & deNOx	EbFb	0.00	0.00	0.00	7.74	21.19	38.15	59.60
	EbFm	0.00	0.00	0.72	7.92	21.31	34.48	34.48
	EmFb	0.00	0.00	0.00	0.00	15.48	25.61	25.61
	EmFm	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diesel Generator	EbFb	9.84	9.37	8.41	7.38	3.62	3.61	3.61
	EbFm	9.84	9.38	8.41	7.38	3.62	3.61	3.61
	EmFb	9.85	9.39	8.42	7.39	3.62	3.61	3.61
	EmFm	9.76	9.30	8.33	7.30	3.62	3.61	12.43
CHP Gas Fuelled	EbFb	0.00	0.00	0.79	0.94	0.94	0.94	0.94
	EbFm	0.00	0.00	0.79	1.45	1.45	2.12	4.49
	EmFb	0.00	0.00	0.79	2.02	2.02	3.25	4.14
	EmFm	0.00	0.00	0.79	2.08	2.67	3.48	4.49
Gas Combined Cycle	EbFb	0.92	4.21	7.66	7.66	10.93	12.71	6.52
	EbFm	0.92	4.21	6.88	7.12	10.42	15.64	14.44
	EmFb	0.92	4.21	7.66	15.72	18.73	19.34	13.15
	EmFm	0.92	4.39	9.09	9.43	14.92	23.93	26.19
Gas Turbine	EbFb	2.06	2.72	2.53	4.74	5.51	7.52	23.46
	EbFm	2.06	2.51	2.38	4.88	5.66	13.22	24.37
	EmFb	2.06	2.21	1.80	1.53	1.25	15.23	35.25
	EmFm	2.06	1.72	1.37	1.16	0.75	1.08	21.67
Geothermal	EbFb	0.15	0.39	0.44	0.43	0.37	0.29	0.04
	EbFm	0.15	0.39	0.44	0.43	0.37	0.29	8.60
	EmFb	0.15	0.39	0.44	0.43	0.37	0.29	6.26
	EmFm	0.15	0.39	0.44	2.30	11.89	13.59	13.60
Hydropower	EbFb	2.86	3.91	6.05	9.62	10.84	10.84	10.84
	EbFm	2.86	3.91	6.15	9.48	10.84	10.84	11.84
	EmFb	2.86	3.91	6.74	10.24	10.84	11.54	11.84
	EmFm	2.86	3.91	10.25	11.37	11.84	11.84	11.84
Nuclear	EbFb	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	EbFm	0.00	0.00	0.00	0.00	0.00	0.00	6.72
	EmFb	0.00	0.00	0.00	0.50	0.50	3.36	6.72
	EmFm	0.00	0.00	0.00	1.34	1.34	3.36	6.72
Oil/Gas Steam PP	EbFb	2.66	2.63	2.22	1.09	0.54	0.02	1.70
	EbFm	2.66	2.63	2.22	1.09	0.54	0.02	0.00
	EmFb	2.66	2.63	2.22	1.09	0.54	0.02	4.78
	EmFm	2.66	2.63	2.22	1.09	0.54	0.11	9.93
Total Capacity	EbFb	20.47	27.00	32.78	44.16	59.38	84.52	122.11
	EbFm	20.47	26.80	32.67	44.31	59.53	85.28	124.15
	EmFb	20.48	26.51	32.75	43.48	58.70	87.46	127.74
	EmFm	20.39	26.27	37.30	48.20	60.56	85.72	131.06

Table 7.12. Total Cogeneration Capacity Mix in Peta Joule per annum

Scenario	2000	2005	2010	2015	2020
EbFb	48.65	90.45	103.38	119.39	141.48
EmFb	48.65	119.54	130.42	187.42	239.38
EmFm	48.65	126.37	170.29	225.78	297.67

In term of the capacity installed by fuel type most boiler fuel such as coal, petroleum product and conventional gas have significant potential to decrease inline with lower total CO_2 constraint, these capacity taken by cogeneration technology gas fuelled.

Still in the industrial sector, direct heating processes have no specific technology option as the indirect heating processes. The CO_2 mitigation result in this demand process only fuels switching from coal to petroleum product and natural gas.

8. Economic Implication

Economic assessment is used to evaluate additional cost to reduce the emission of CO_2 in Indonesia. CO_2 emissions reduction was analyzed using MARKAL model. Two case were used to estimate the additional discounted system cost to released 1 ton CO_2 in the next 35 years, i.e., enhanced CO_2 uptake from forestry sector, and reduction emission from energy sector.

This case describes relationship between CO_2 emission from energy combustion and CO_2 absorption by forest. CO_2 emission is resulted from combustion of all fuels which have carbon, such as coal, oil, natural gas and biomass. The amount of CO_2 emission is determined by carbon content, technology, and the amount of energy used.

CO_2 emission released to the atmosphere can be reduced by technology use and also by natural absorption of forest during regeneration. In this scenario, all forest are considered to absorb CO_2 emission. Although Indonesian is divided into four regions (Java, Sumatra, Kalimantan, and other Islands) in MARKAL Model, this scenario, only choose two regions, Java and Sumatra. Both regions are chosen because the energy consumption is almost 80% of the total energy consumption in Indonesia.

According to the optimization result for energy and forestry link in the baseline scenario (EbFb), the net CO_2 emissions is 14.4 billion tons with total discounted system cost of 228 billion US $ (cost for 35 year s period with 10% discount rate; Figure 8.1). In scenario EmFb, more advance technologies and more efficient energy use were introduced so that the emission from energy sector decreased by about 2099 million ton CO_2. This effort increases the total discounted system cost by 2.32% from the baseline cost (equivalent to 5.272 billion US$). This indicates that the mitigation cost in the energy system is about 2.48 US$/ton CO_2.

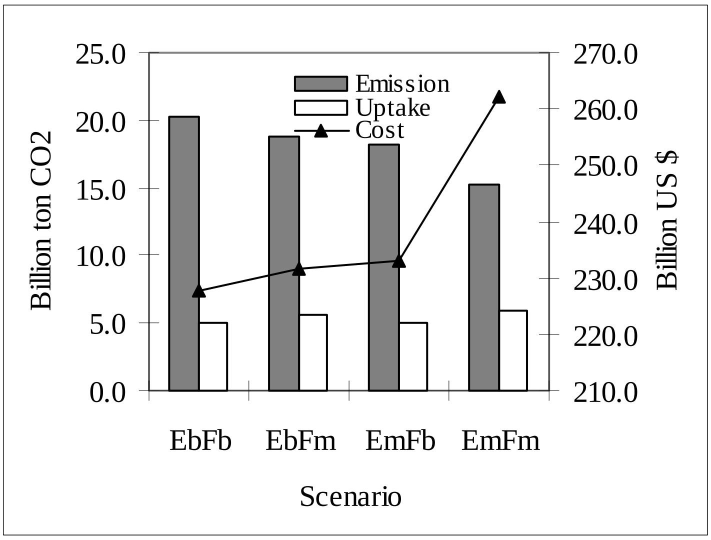


Figure 8.1. CO_2 emissions and uptake and cost for CO_2 emission reduction for the four scenarios

In forestry sector, efforts to reduce the net emission is by increasing the carbon uptake by forests. In this study, the carbon uptake was increased by increasing the rate of planting of the bare or critical lands through rehabilitation, afforestation and reforestation programs (see Section 7.4.2). The cost required for reducing the CO_2 net emission to the level of the net emission in EmFb, is not as much as that of the EmFb (Figure 8.1). The additional cost required is only about half of that of EmFb.

Further net emission reduction to a level of about 71% of EmFb or about 61% of EbFb by reducing carbon emission from energy sector and by increasing carbon uptake by forestry sector, a total cost of 262 billions US $ is required (Figure 8.1). Thus, additional cost required to reduce the net emission from baseline net emission to EmFm net emissions is about 34.6 billion US$ and from EmFb is 29.4 billion US$.

In term of cost per ton CO_2 abated, the scenario EbFm requires 1.87 US$ and EmFb 2.48 US$. This indicates that the cost of carbon emission reduction in energy sector is more expensive than that of forestry sector (Table 8.1). For scenario EmFm, the cost required for abating per ton of CO_2 is about 5.83 US$ if the emission is reduced from a level of baseline emission to a level of EmFm emission and about 7.68 US$ if it is reduced from a level of EmFb emission to a level of EmFm emission (Table 8.1). The amount of CO_2 emission reduced in energy sector from EbFb to EmFm is 5947 million ton and from EmFb to EmFm is 3826 million ton. As the mitigation technologies and increase in the total carbon uptake in the forestry sector from EbFb to EmFm and from EmFb to EmFm are relatively the same, the difference in cost of mitigation in EmFb and EmFm therefore indicates the dependency of mitigation cost on the mitigation penetration. Higher mitigation cost is required if the mitigation penetration is increased. The mitigation cost (US$ per ton CO_2 abated) in energy sector will not change if the mitigation technologies selected in each scenario are the same and the proportion of carbon reduced by each selected technology remains the same.

Table 8.1. Mitigation Cost

Scenario	CO_2 reduction (billion ton)	Additional Cost (million US$)	Mitigation Cost (US$/ton CO_2)
EbFm	2078	3882	1.87
EmFb	2121	5271	2.48
EmFm			
- From baseline	5947	34643	5.83
- From EmFb	3826	29371	7.68

9. Conclusion and Recommendation

The total CO_2 emission of energy system resulted in the baseline scenario in the whole time horizon (35 years) is 16,932 million tons. Application of energy mitigation technologies in the scenario EmFb reduced the emission by about 1,947 million ton of CO_2 with an additional discounted system cost of about 5.281 billion US$. This suggests that the mitigation cost in the energy system is about 2.48 US$/ton CO_2 abated. Further increase in emission reduction (scenario EmFm) increases the mitigation cost of the energy sectors. This is because the share of each selected mitigation technologies to the total carbon emission reduction also changes with the level of mitigation, while the mitigation cost varies with type of technologies. Furthermore, reducing the baseline emission by increasing net carbon uptake in the forestry sector by about 592 million ton CO_2 (EbFm) increases the discounted system cost by about 3.883 billion US$ or equivalent to 1.87 US $/ton CO_2 abated.

Mitigation of CO_2 in the energy sector is carried out by applying fuel diversification in the power generation mix nuclear and natural gas, replacing polluted fuel such as coal and petroleum products with biomas, energy conservation and the management of demand side.

In the power generation, the mitigation result is the different capacity mix as accommodation the CO_2 emission through the diversification of the power plant fuel input, even the total capacity increase but total CO_2 emission from this sector become lower due to more utilization of the non-carbon fuels. The power plant type chosen is non fossil fuel (i.e. hydro power, geothermal, biomas steam, and nuclear), gas base power plant (gas combine cycle).

The carbon mitigation of the demand sectors such as industry, residential and commercial are from the utilization of industrial waste heat recovery with co-generation (combined heat and power, CHP) technology, more efficient lamp, motors and refrigerator and also fuels diversification. Solar thermal heater (commercial sector), (CFL), fluorescent lamp, fluorescent's electronic ballast, SHS for lighting, and efficient refrigerator are in the residential sector.

In forestry sector, the carbon uptake is increased by increasing the planting rate in the bare and critical lands. There are three programs proposed, namely, rehabilitation of critical land, afforestation and reforestation. The tree species used in the programs include *Acacia mangium*, *Paraserienthes falcataria*, *Tectona grandis*, and *Pinus mercusii*. In the rehabilitation program, it is targeted that all of the available critical land will be planted within 35 years (1990-2024), therefore the rate of planting is the same between the scenarios (Table 9.1). Most of carbon uptake occurs in the afforestation and reforestation. In plantation forest (Jawa) and production forest (Sumatra), carbon uptake may not exceed carbon emission. These forests are designated for fulfilling wood demand. Rate of harvesting and planting in these forests are also presented in Table 9.1.

The use of MARKAL model to link between Energy and Forestry sectors is very worthwhile. It provides an optimum solution for the selection of mitigation technologies both in energy and forestry sectors. However, there are some limitations encountered during the study. The program is not able to accommodate the delay emission from forestry sector. In addition, there are some technical problem still need to be solved such as the inclusion of soil carbon uptake calculation in the model and the verification of carbon uptake calculation. In this study, all carbon uptakes occur at the time of planting. The most important finding is that this study demonstrates the possibility of using MARKAL for linking the energy in forestry sector for the carbon mitigation analysis.

Table 9.1. Rate of planting of tree species in Java and Sumatra by scenarios

			EbFb	EbFm	EmFm
Rehabilitation	*Tectona grandis* (Jawa)	ha/year	10000	10000	10000
	Acasia mangium (Jawa and Sumatra)	ha/year	40000	40000	40000
	Paraserienthes falcataria (Jawa)	ha/year	20000	20000	20000
Afforestation	*Pinus mercusii* (Sumatra)	ha/year	20000	24286	21429
	Acasia mangium (Jawa)	ha/year	17100	18400	18400
	Acasia mangium (Sumatra)	ha/year	169700	175800	175800
Reforestation	*Paraserienthes falcataria* (Sumatra)	ha/year	22900	23300	23300
	Acasia mangium (Sumatra)	ha/year	45600	50500	50500
Plantation Forest and	*Acacia mangium* (Jawa)	ha/year	17100	18400	18400
	Paraserianthes falcataria (Jawa)	ha/year	500	500	500
	Tectona grandis(Jawa)	ha/year	17343	19971	19971
	Pinus merkusi(Jawa)	ha/year	6571	12886	12886
	Switenia spp.(Jawa)	ha/year	771	914	914
	Others Spesies (Jawa)	ha/year	2633	5967	5967
Production forest	Mixed Spesies (Sumatra)	ha/year	188500	208200	208200

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