Republic of Indonesia

Indonesia Climate Change Sectoral Roadmap
ICCSR

Energy Sector Part 2
(Sumatera Power System)

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Indonesia Climate Change Sectoral Roadmap – ICCSR
Energy Sector part 1 (Sumatera Power System)

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The Indonesia Climate Change Sectoral Roadmap (ICCSR) is meant to provide inputs for the next five year Medium-term Development Plan (RPJM) 2010-2014, and also for the subsequent RPJMN until 2030, laying particular emphasis on the challenges emerging in the forestry, energy, industry, agriculture, transportation, coastal area, water, waste and health sectors. It is Bappenas policy to address these challenges and opportunities through effective development planning and coordination of the work of all line ministries, departments and agencies of the Government of Indonesia (GoI). It is a dynamic document and it will be improved based on the needs and challenges to cope with climate change in the future. Changes and adjustments to this document would be carried out through participative consultation among stakeholders.

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Remarks from Minister of National Development Planning/ Head of Bappenas

We have seen that with its far reaching impact on the world's ecosystems as well as human security and development, climate change has emerged as one of the most intensely critical issues that deserve the attention of the world's policy makers. The main theme is to avoid an increase in global average temperature that exceeds $2^{\circ}C$, i.e. to reduce annual worldwide emissions more than half from the present level in 2050. We believe that this effort of course requires concerted international response – collective actions to address potential conflicting national and international policy initiatives. As the world economy is now facing a recovery and developing countries are struggling to fulfill basic needs for their population, climate change exposes the world population to exacerbated life. It is necessary, therefore, to incorporate measures to address climate change as a core concern and mainstream in sustainable development policy agenda.

We are aware that climate change has been researched and discussed the world over. Solutions have been proffered, programs funded and partnerships embraced. Despite this, carbon emissions continue to increase in both developed and developing countries. Due to its geographical location, Indonesia's vulnerability to climate change cannot be underplayed. We stand to experience significant losses. We will face – indeed we are seeing the impact of some these issues right now- prolonged droughts, flooding and increased frequency of extreme weather events. Our rich biodiversity is at risk as well.

Those who would seek to silence debate on this issue or delay in engagement to solve it are now marginalized to the edges of what science would tell us. Decades of research, analysis and emerging environmental evidence tell us that far from being merely just an environmental issue, climate change will touch every aspect of our life as a nation and as individuals.

Regrettably, we cannot prevent or escape some negative impacts of climate change. We and in particular the developed world, have been warming the world for too long. We have to prepare therefore to adapt to the changes we will face and also ready, with our full energy, to mitigate against further change. We have ratified the Kyoto Protocol early and guided and contributed to world debate, through hosting the 13th Convention of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), which generated the Bali Action Plan in 2007. Most recently, we have turned our attention to our biggest challenge yet, that of delivering on our President's promise to reduce carbon emissions by 26% by 2020. Real action is urgent. But before action, we need to come up with careful analysis, strategic planning and priority setting.

I am delighted therefore to deliver *Indonesia Climate Change Sectoral Roadmap,* or I call it ICCSR, with the aim at mainstreaming climate change into our national medium-term development plan.

The ICCSR outlines our strategic vision that places particular emphasis on the challenges emerging in the forestry, energy, industry, transport, agriculture, coastal areas, water, waste and health sectors. The content of the roadmap has been formulated through a rigorius analysis. We have undertaken vulnerability assessments, prioritized actions including capacity-building and response strategies, completed by associated financial assessments and sought to develop a coherent plan that could be supported by line Ministries and relevant strategic partners and donors.

I launched ICCSR to you and I invite for your commitment support and partnership in joining us in realising priorities for climate-resilient sustainable development while protecting our population from further vulnerability.

Minister for National Development Planning/
Head of National Development Planning Agency

Prof. Armida S. Alisjahbana

Remarks from Deputy Minister for Natural Resources and Environment, Bappenas

To be a part of the solution to global climate change, the government of Indonesia has endorsed a commitment to reduce the country's GHG emission by 26%, within ten years and with national resources, benchmarked to the emission level from a business as usual and, up to 41% emission reductions can be achieved with international support to our mitigation efforts. The top two sectors that contribute to the country's emissions are forestry and energy sector, mainly emissions from deforestation and by power plants, which is in part due to the fuel used, i.e., oil and coal, and part of our high energy intensity.

With a unique set of geographical location, among countries on the Earth we are at most vulnerable to the negative impacts of climate change. Measures are needed to protect our people from the adverse effect of sea level rise, flood, greater variability of rainfall, and other predicted impacts. Unless adaptive measures are taken, prediction tells us that a large fraction of Indonesia could experience freshwater scarcity, declining crop yields, and vanishing habitats for coastal communities and ecosystem.

National actions are needed both to mitigate the global climate change and to identify climate change adaptation measures. This is the ultimate objective of the *Indonesia Climate Change Sectoral Roadmap*, ICCSR. A set of highest priorities of the actions are to be integrated into our system of national development planning. We have therefore been working to build national concensus and understanding of climate change response options. The *Indonesia Climate Change Sectoral Roadmap* (ICCSR) represents our long-term commitment to emission reduction and adaptation measures and it shows our ongoing, inovative climate mitigation and adaptation programs for the decades to come.

Deputy Minister for Natural Resources and Environment
National Development Planning Agency

U. Hayati Triastuti

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Acronyms and Abbreviations

BAPPENAS	*Badan Perencanaan Pembangunan Nasional* (National Development Planning Agency)
BAT	best available technology
BAU	business as usual
bbl	barrel or "blue barrel"as set by Standard Oil, of 42 gallons
boe	barrel oil equivalent
C	carbon
CBM	coalbed methane
CCS	carbon capture and storage
CCT	clean coal technology
CDM	clean development mechanism
CER	certified emission reduction
CFBC	circulating fluidized bed combustor
CO_2	carbon dioxide
COP	conference of party
CTL	coal to liquid
DGEEU	Directorate General of Electricity & Energy Utilization
DGMCG	Directorate General of Mineral, Coal & Geothermal
DSM	demand side management
ECBMR	enhance CBM recovery
EGR	enhance gas recovery
EIA	Energy Information Agency, US DOE
EOR	enhance oil recovery
ETS	Emissions Trading Scheme
FGD	Focus Group Discussion
GHG	greenhouse gas
GoI	Government of Indonesia
GTZ	*Deutsche Gesellschaft fur Technische Zusammenarbeit* (German Technical Cooperation)
GWe	Gigawatts electric
GWh	Gigawatt hours
IEA	International Energy Agency
IEA CCC	IEA Clean Coal Centre

IEEE	Institute of Electrical and Electronics Engineers
IGCC	integrated gasification combined cycle
IPCC	Intergovernmental Panel on Climate Change
KNI – WEC	*Komite Nasional Indonesia* (Indonesian Member Committee) - WEC
LEMIGAS	*Pusat Penelitian dan Pengembangan Teknologi Minyak dan Gas Bumi*
LNG	liquefied natural gas
LOLP	loss of load probability
LULUCF	land-use, land-use change and forestry
MARKAL	market allocation
MEMR	Ministry of Energy and Natural Resources, Republic of Indonesia
ME	Ministry of Environment
MMBTU	million British Thermal Unit
MMSCFD	million standard cubic feet per day
Mt	million tones
$MtCO_2$	million tones of CO_2
MWe	megawatts electrical
NAMAs	nationally appropriate mitigation actions
NETL	National Energy Technology Laboratory (US DOE)
NGCC	natural gas combined cycle
NO_2	nitrogen dioxide
NPV	net present value
OECD	Organization for Economic Co-operation and Development
PC	pulverized coal
PF	pulverized fuel
Pertamina	*Perusahaan Minyak & Gas Nasional* (State-own Oil & Gas Company)
PGN	*Perusahaan Gas Negara* (National Gas Company)
PKUK	*pemegang kuasa usaha ketenagalistrikan*
PIUKU	*pemegang ijin usaha ketenagalistrikan untuk kepentingan umum*
PLN	*Perusahaan Listrik Negara* (State-own Electric Power Company)
ppm	parts per million
R&D	research and development
R, D & D	research, development and demonstration
RE	renewable energy
REDD	Reducing Emissions from Deforestation and Degradation

RPJM	*Rencana Pembangunan Jangka Menengah* (medium-term development plan)
RPJP	*Rencana Pembangunan Jangka Panjang* (long-term development plan)
RUKN	*Rencana Umum Ketenagalistrikan Nasional* (National Electricity General Plan)
RUPTL	*Rencana Umum Penyediaan Tenaga Listrik* (Electricity Supply Master Plan)
SO_2	sulfur dioxide
SO_x	sulfur oxides
TCF	terra cubic feet
TNA	Technology Needs Assessment
UCG	underground coal gasification
UN	the United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US DOE	United States Department of Energy
WASP	Wien Automatic System Planning
WEC	World Energy Council
WTI	West Texas Intermediate

1 Introduction

BAPPENAS, as the Indonesian National Development Planning Agency, took up Climate Change as a major threat to mid- and long-term development in December 2007 by issuing the report, *National Development Planning: Indonesia Responses to Climate Change* (**Bappenas (2008)**), This report aimed at integrating adaptation and mitigation of climate change into National Development Planning PoliciesIt is meant to bridge between The National Action Plan On Climate Change and the 5 year mid-term national development plan 2010-2014 (**Bappenas (2009)**). It lays particular focus on funding forestry, energy efficiency, food security, infrastructure and health. Bappenas' policy is that those efforts have to be supported by effective development planning and coordination.

2 Background

2.1 Rationale

As already described in the Part 1 of this study, global climate change can no longer be denied. On the global stage, and in Indonesia, the impacts of climate change are already visible and are expected to become more severe more quickly than initially anticipated. Indonesia, under the strains of economic growth, urbanization, and major industrial projects, suffers from a wide range of environmental problems – aside from climate change -- including poor air quality in cities, pollution of rivers and seawaters, inadequate disposal of solid wastes, land degradation, loss of biodiversity, and deforestation. Land use, land use change and forestry (LULUCF) in Indonesia was estimated to account for 60% of Indonesia's total Greenhouse Gas (GHG) emissions. The energy sector contributed about 25% of Indonesia's total GHG emissions (**IEA (2008)**). The ongoing and expected impacts of climate change and climate disruption pose a serious threat to national environmental and socioeconomic development for the coming decades. These impacts will be faced by all segments of society and future generations. One study on the economics of GHG limitations in Indonesia was completed in 1999 (**ME (1999)**). It shows the impacts of the GHG limitations to the national economic growth [to be ???].

However, the GHG emissions from Indonesia's energy sector must be managed as this sector is crucial in to the Indonesian economy, both for earning foreign exchange (forex) revenue and for meeting domestic needs for energy. In the past, the emphasis has been on forex revenue, but since early in this decade, there has been a paradigm shift by GoI giving higher priority to meeting the domestic demand for energy. Although its contribution to state budget has been steadily decreasing, the energy sector contributed IDR 346.35 trillion to the total 2008 state budget (APBN) of IDR 962.48 trillion, according to the Minister of Energy and Mineral Resources in his end of the year press conference (**Bisnis Indonesia (2008)**). For all these reasons, addressing climate change demands urgent actions and requires a long-term commitment from all involved stakeholders..

The energy sector emitted about 396 $MtCO_2$, in 2005. This is about 35.4% of the total national GHG emissions in 2005, which was about 668,8 million ton of CO_2 ($MtCO_2$) without consideration of emissions from LULUCF or 1,119.8 $MtCO_2$ if you include emissions from peat fire but ignore emissions from LUCF (defined as NE) (**SNC (2009)**). Based on the conditions shown in Figure 1 (**SNC (2009)**), the Ministry of Environment of Indonesia announced in May 2008 its unilateral goal of an absolute cut in GHG emissions. The goal is to cut energy sector emissions by 17% by 2025 (**IEA (2008)** and **Jakarta Post (2008)**) and to implement bold reductions in forest burning. How the cuts are to be achieved is not entirely clear, but it as appears as though Indonesia will also increase emissions-intensive coal consumption in the domestic energy mix during this period.

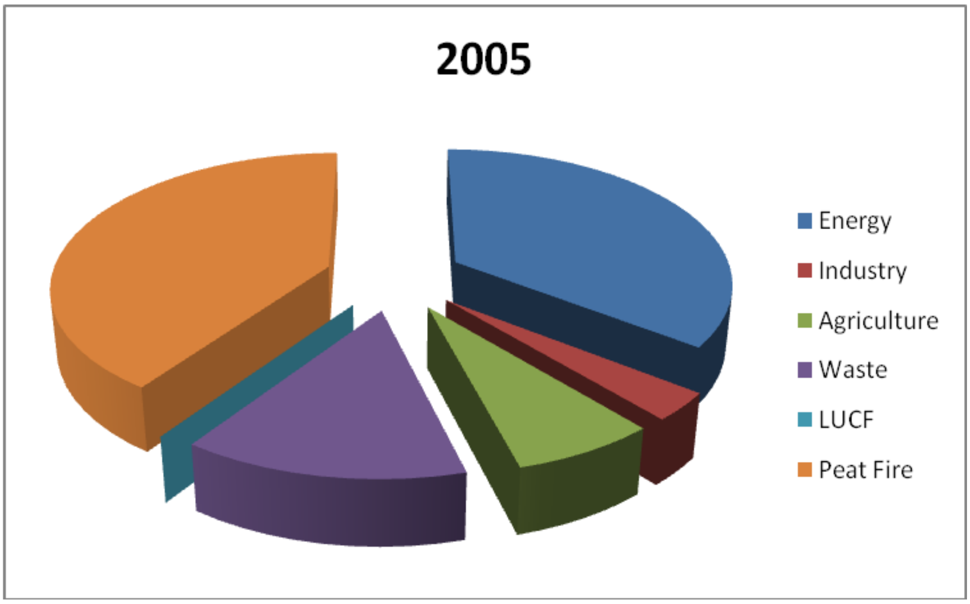


Figure 1: Indonesia's total GHG Emissions
Source: Table 1b, SNC 2009

This commitment was re-stated in September 2009 by President Susilo Bambang Yudhoyono in his address to the G-20 on climate change issues. President SBY explained that the implementation of Indonesian energy policy, including LULUCF, would reduce the nation's CO_2 emissions about 26% by 2020, compared to a Business-as-Usual scenario(BAU). With international support, Indonesia claimed to be able to reduce emission even further during this period, by as much as 41% compared to the BAU scenario. Indeed, President SBY emphasized that these emission reduction targets are achievable because most of the Indonesian emissions come from forest related activities, including as forest fires and deforestation (**SBY (2009)**). Fortunately, a diverse array of reserves from non-fossil fuel-based energies is available and presents an opportunity for Indonesia to develop environmentally-friendly energy technologies over the next several decades.

The UNFCC has emphasized the importance of member parties incorporating climate change into national development planning, consistent with their sustainable development agendas. Indonesia responded to these queries by developing the national development planning document on climate change that covers multiple sectors and ensures horizontal as well as vertical coordination of these issues into the national development planning process. Naturally, in Indonesia, this process shall be prepared by the Indonesian national development planning agency (BAPPENAS). A robust policy framework will also be put in place to integrate climate change into spatial planning at the national and local levels. The development of cross-cutting policies on climate change in spatial plans can integrate climate into the development of sectoral policy at both the national and provincial levels (**Bappenas (2008)**).

This Part 2 report describes a study, undertaken jointly by Energy Experts and BAPPENAS, to consider the implications of comprehensive GHG mitigation in the Sumatra power generation sector of the Republic of Indonesia. This report will cover only the electric power sector, including its primary energy supplies, due to the following constraints:

1. Limited time period of study, 6 months (and limited availability of fund);
2. The transportation, residential, and commercial sectors are very broad and require more time and resources to analyze than are available at this time; and
3. Although the Industry sector is, in principle, very similar to the electric power sector as a centralized demand, but with the limited time and resources available cannot be covered in the time period of this study.

2.2 Projection of Electric Power Supply and Demand in Sumatra System

The goal of this study is to identify a sustainable, reliable and well distributed electricity supply system, based on a comprehensive and nation-wide power system planning approach. For these purposes, the Rencana Umum Ketenagalistrikan Nasional (RUKN), and the National Electricity General Plan (**DGEEU (2008)**) can be considered as a general policy on integrated electricity supply for the country. These documents cover at least the demand and supply forecast, investment and funding policies, and directive measures on primary energy and renewable and new energies utilizations for power generation. The RUKN is intended to be used as a guideline for the future development and construction of power sector plans by the Government of Indonesia (GoI), local government, Pemegang Kuasa Usaha Ketenagalistrikan (PKUK) and Pemegang Izin Usaha Ketenagalistrikan untuk Kepentingan Umum (PIUKU). The role of RUKN becomes more critical with the constant changing of strategic conditions on the local, national, regional and global levels.

Furthermore, the dynamics of the community, in particular the steady change of macro-economics conditions will affect the rate of growth of electricity demand between now and 2020. Although the RUKN has a 20 year planning horizon, it will be reviewed annually to accommodate changing macroeconomic conditions. According to the current Law of Electricity no 15 of year 1985 and Government Regulation no 10 year 1989, (the latter has been revised twice and evolved to become government regulation no 26 year 2006), each electric power supply entity must a Rencana Umum Penyediaan Tenaga Listrik (RUPTL), or so called Master Plan of Electricity Supply for its own business area (which we shall refer to by its Bohasa acronym as RUKN). Within such a regulatory framework, PT PLN (Persero) prepares its own RUPTL which currently covers the period 2009 - 2018 for corporate planning purposes related to power generation, transmission and distribution (**PT PLN (Persero) (2009)**). In the current RUPTL, PT PLN (Persero) indicates the system development projects that will be conducted by the corporation itself (in general it includes some transmission and distribution, pumped storage and several thermal and hydro power plants). The plan also covers some power generation projects that will be offered to the private sector under a scheme that supports independent power producers (IPP). The RUPTL will be similarly reviewed annually to take account of the changes in national macro-economic conditions. Having such an annual review, RUPTL can be updated and adjusted for use as ultimate guidance in developing the power system that is under the supervision of PT PLN (Persero)'s RUPTL.

Besides the Java – Bali System (JBS) described in Part 1 of this study, the RUPTL is divided into four additional regions, namely Sumatera, Kalimantan, Sulawesi and Nusa Tenggara-Maluku-Papua systems. For this Part 2 of the study, the examination will focus on Sumatra System due to the following reasons:

1. Sumatra System is the second largest system (15.5%) within the Indonesian power sector and when it is combined with the Java – Bali System, together comprise around 90% of the total power generation capacity in the country;
2. Sumatra System is an interconnected system such that it can be considered as a single system in terms of CO_2 emissions; and
3. There's a plan to interconnect both Sumatra and Java – Bali System in year 2016-2017 such that both systems will then be considered as a single lumped system in the future.

In preparing the power sector development planning of the RUPTL, there are some important assumptions and parameters that have been adopted. For the power generation sector, the general policy will cover only the followings:

1. Sales and demand growth; and
2. Development of power generation capacity.

In terms of the sales and demand growth, during the period when PT PLN (Persero) is still unable to supply the total electricity demand, sales growth is constrained by the amount of available and functioning capacity. For the year 2008 and 2009 when the capability to supply demand is still under generation constraint due to delays in construction of some power plants under the Accelerated 10,000 MW Program phase I, the sales growth is set at 6.5% for 2008 and 7.5% for 2009. On the demand side, the policy on demand side management (DSM) and energy efficiency have not been considered yet in the system planning of RUPTL 2009 – 2018.

In terms of meeting the challenge of capacity expansion planning, the guiding principle is the *principle of least cost of power generation,* taking into consideration the required level of system reliability. The lowest generation cost is reached by minimizing the net present value of all electricity generation costs, such as investment, fuel, operation & maintenance, and idle capacity costs. The reliability constraint is imposed throughout the planning period and is set based on the principles of minimal Loss of Load Probability (LOLP) and adequate Reserve Margin. Rental power generation and excess power supplied by others are excluded from the system planning simulation. Based on these two policies only, the simulation of power generation capacity expansion to meet future demand in Sumatera System includes both projects to be implemented by PT PLN (Persero) and by projects brought on stream by IPP developers. All of these projects are illustrated in Table 1 below.

Based on these general policies for system development, then the least-cost capacity expansion plan can be identified that meets the least-cost NPV criteria while sustaining minimal system reliability. The least cost configuration will be identified through an optimization process that takes account of the costs of investments, fuel consumption, operations and maintenance, and idle capacity costs. Salvage value of some power generation is also considered for those power plants that have reached the end of their economic life during the simulation period. For this study, the simulation and optimization processes were conducted using the **Wien Automatic System Planning** (WASP) model.

For the purposes of maintaining system reliability, an LOLP criterion was set at $p \leq 0.274\%$, meaning that the probability that the peak load exceeds the installed capacity is less than 0.274%.. This is equivalent to maintaining a loss of load probability of less than 1 day per year. The calculation of generation capacity in the context of this LOLP criteria implies a certain system reserve margin. The size of the reserve margin depends on the availability of each generation unit, the number of units, the capacity of each unit, and other characteristics of each unit. Outside the Sumatra System, an LOLP criteria of $p \leq 0.274\%$, implies a reserve margin of around 40 – 50%, due the limitation on the number of units available, derating of power generation equipment and uncertainty on the completion of the IPP projects.

For the purpose of generation capacity expansion planning in the Sumatra System, renewable energy technologiess such as geothermal and hydropower are considered as fixed, "must run" systems in the system simulation. This means that the output from these units must be included in the system dispatch order whenever they are available. This is fully consistent with current government policy to develop and utilize renewable energy resources, but may imply that the least cost criterion may be partly or even completely ignored under some conditions.

Table 1: Electric Power Balance of Sumatera System

No	Supply and Demand		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	**1.Demand**												
	Sales	GWh	17,342	18,931	20,826	2,272	24,858	2,706	29,476	32,142	34,998	3,816	41,608
	Load Factor	%	63	63	63	63	63	64	64	64	65	65	65
	Gross Peak Load	MW	3,134	3,444	3,785	4,106	4,477	4,853	5,265	5,710	6,185	6,744	7,354
2	**2.Supply**												
	Installed Capacity		3,760	3,760	3,074	3,074	2,410	2,410	2,410	2,410	2,410	2,410	2,410
	2.1 PLN												
	Hydro PP	MW	859	859	859	859	859	859	859	859	859	859	859
	Mini Hydro	MW	8	8	8	8	8	8	8	8	8	8	8
	CFPP	MW	945	945	685	685	685	685	685	685	685	685	685
	GTPP	MW	550	550	123	123	123	123	123	123	123	123	123
	CCGT	MW	8,818	8,818	8,818	8,818	506	506	506	506	506	506	506
	Diesel	MW	351	351	351	351							
	2.2 IPP												
	CCSG	MW	150	150	150	150	150	150	150	150	150	150	150
	GT		80	80	80	80	80	80	80	80	80	80	80
3	**Additional Capacity**												
	3.1 PLN												
	Ongoing Project	MW											
	Labuhan Angin	CFPP	115	115									
	Rental phase I	Diesel	30		(30)								
	Rental phase II	Diesel	65		(65)								
	Floating GT	GTPP		30		(30)							
	Floating Diesel	Diesel		65		(65)							
	MFO Diesel	Diersel		60		(60)							
	Crash Program	GTPP	170				(170)						
	Indralaya	CCGT	40										
	Keramasan	CCGT				86							
	Planning												
	Lhokseumawe	CCGT			40	60							
	Peusangan 1-2	HEPP					86						
	Asahan III	HEPP					174						
	New CFPP(Sumbagut)	CFPP					200	200					
	Meulaboh (Perpres)	CFPP			100	100							
	Pangkalan Susu (Perpres)	CFPP			400								
	Sumbar Pesisir (Perpres)	CFPP			100	100							
	Sumbar Pesisir (Perpres 2)	CFPP			200								
	Tarahan (Perpres 2)	CFPP				200	200						
	Seulawah	GEPP					40						
	Ulubelu	GEPP				55	55	55	55				
	Lumut Balai	GEPP				55	55	55	55				
	Hululais #1,2	GEPP					110	55					
	Sungai Penuh	GEPP				55							
	3.2 IPP												
	Ongoing Project	MW											
	Teluk Lembu	GTPP	20										
	Planning												
	Keramasan	GTPP			100								
	Gunung Megang, ST Cycle	CCGT			40								
	New Sumut	CFPP										200	400
	Sumut Infrastructure	CFPP					200						
	NAD	CFPP			30								
	Sumsel-4	CFPP				114	114						
	Sumsel-1	CFPP				100	100						
	Sumsel-2	CFPP					100	100					
	Sumsel-5	CFPP							150	150			
	Mulut Tambang (HVDC)	CFPP									200	200	
	Riau Mulut Tambang	CFPP									150	150	
	Sibayak	GTPP		10									
	Sorik Merapi	GTPP					55						
	Sarula	GTPP			60	110	160						
	Pusuk Bukit	GEPP							55	55			
	Simbolon	GEPP								55	55		
	Sipaholon	GEPP					30						
	Rajabasa	GEPP					55	55					
	Wai Ratai	GEPP							55	55			
	G. Talang	GEPP										55	
	Kerinci	GEPP				20							
	Muara Laboh	GEPP											
	Asahan I	HEPP			180								
	Merangin	HEPP									350		
4	IPP Potential Project												
	Sumut-1	CFPP								150	150		
	Sumut-2	CFPP					225						
	Sumbar-1	CFPP					200						
	Sumsel-3	CFPP										113	113
	Sumsel-6	CFPP						300	300				
	Rantau Dadap	GTPP											
5	**Total Supply**	MW	4,200	4,480	4,948	5,868	6,768	7,258	7,858	8,173	8,928	9,533	9,933
6	**Reserve Margin**	%	34	30	31	43	51	51	49	43	44	41	35

Source : RUPTL PT PLN (Persero) 2009-2018

For the Sumatra System, some of the power generation units that are considered in the simulation include conventional pulverized coal (PC) power plants of 200, 100 and 50 MW or even smaller capacity, as well as combined cycle gas turbine (GT) units whose operational capacity depends on the availability of natural gas supply.

For the system planning process for RUPTL 2009 – 2018, the cost of CO_2 emissions was not included in the calculation and not considered as one of the cost parameters (**PT PLN (Persero) (2009)**). However, it may be considered in the coming years as the idea of including Clean Development Mechanism (CDM) projects has been considered to lower the cost of generation (**Bisnis Indonesia (2009)** and **Investor Daily (2009)**).Despite of the omission of CO_2 emission as a cost variable, it is not totally ignored in the RUPTL. It can be reflected in the inclusion of several possible geothermal and hydropower plants that are included in the power generation plan of the RUPTL even though they violate the least cost criteria. The emissions of CO_2 in the RUPTL are calculated from the amount of fuels consumed and converted into CO_2 emission in according to the emissions factors published by IPCC. The resulting estimated CO_2 emissions under the RUPTL scenario for all of Indonesia are shown in Figure 2 below. For the Sumatra System, the emissions are shown in Figure 3 below.

The projection of CO_2 emissions for Outside the Java-Bali System (JBS) has a similar trend to that seen in the JBS. Emissions of CO_2 from outside JBS are projected to double from 2009 to 2018, increasing from 22 million $MtCO_2$ to about 57 million $MtCO_2$. Average grid emission factor for Outside JBS is expected to decline from 0.745 $kgCO_2/kWh$ in 2009 to 0.732 $kgCO_2/kWh$ in 2018. More details about the JBS are available in Part 1 of this Report.

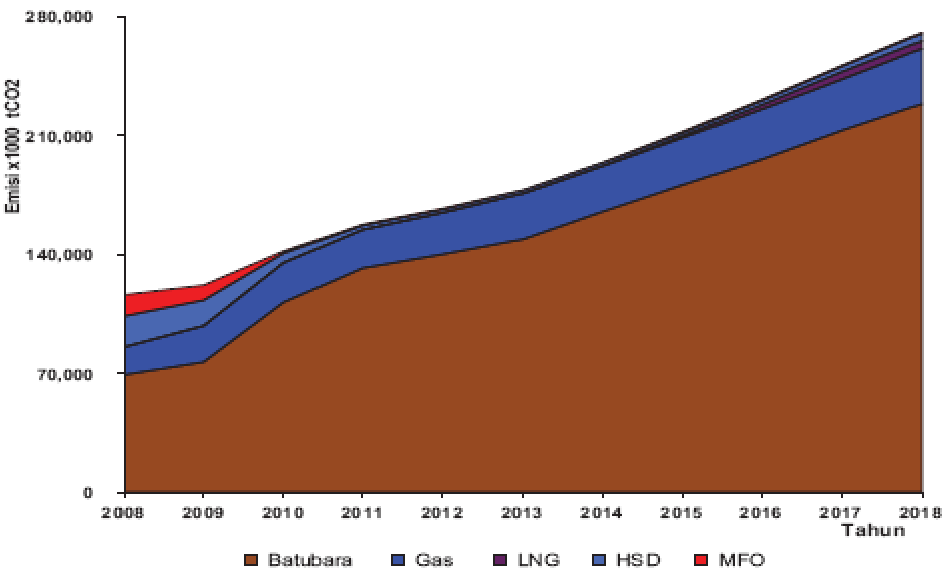


Figure 2: Indonesia's Estimated CO_2 emission for each type of fuel in power sector in the RUPTL scenario
Source: RUPTL PT PLN (Persero) 2009-2018

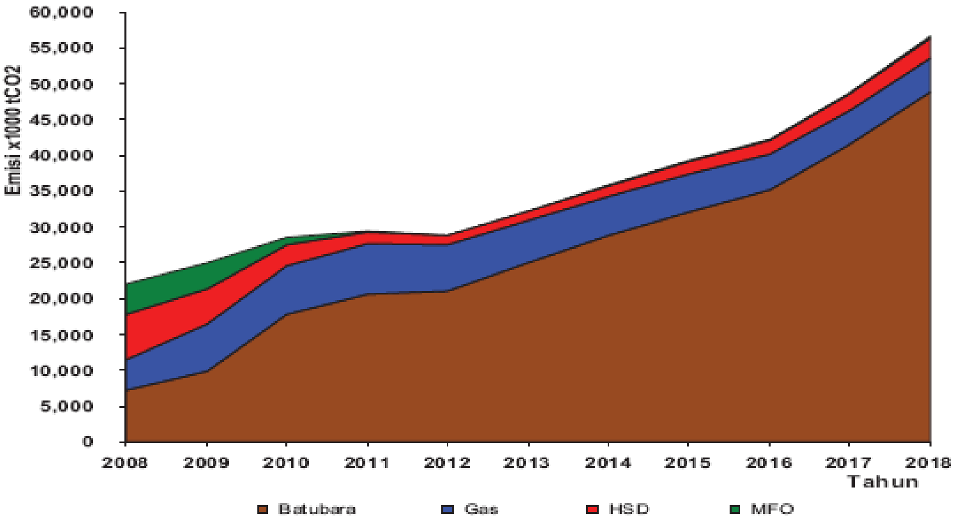


Figure 3: Sumatra's Estimated CO_2 emissions from the power sector for each type of fuel in the RUPTL scenario
Source: RUPTL PT PLN (Persero) 2009-2018

3 Problem Statement and Objectives

3.1 Problem Statement

As mentioned above, this study covers only the electric power sub-sector due to limitations on time and the availability of funds. The GHG emissions from energy consumption in 2005 is shown in Figure 1 and can be further categorized into 5 main sub-sectors that are illustrated in Figure 4 below. The contribution of three principal fossil energy resources to GHG emissions is tabulated in Figure 5. This figure shows that coal consumption for energy use is steadily increasing over the projection period . Thus, to reduce or even just to maintain the current level of CO_2 emissions, special attention must be focused on the power sector. Beginning in 2010 when new coal-fired power plants come online, this sector will be the major consumer of coal, in part as a result of the Accelerated 10,000 MW Power Program Phase I. Alhough the Phase II of the Accelerated 10,000 MW Power Program Phase will encourage greater reliance on renewable energy technologies, especially geothermal power plants, nonetheless, the use of coal-fired power plants is expected to increase by around 4,000 MWe. Therefore, if nothing is done to change the course of development for these new coal-fired power plants (such as the usage of supercritical boiler and/or the introduction of carbon capture and storage (CCS)), the level of CO_2 emissions from coal-fired electricity generation will surely increase in the coming years.

The Government of Indonesia (GoI) has developed a scenario based on the President Decree on Energy Mix through its Master Plan of National Electric Power (RUKN) 2008-2027 (**DGEEU (2008)**) and the PT PLN (Persero)'s RUPTL 2009 – 2018 (**PT PLN (Persero (2009)**). In the case of the RUPTL, the projection of power generation is based strictly on application of a least-cost NPV criterion with no cost included in the optimization process to represent the imputed price of CO_2 emissions. However, to achieve the target of at least 17% reduction of GHG emissions in energy sector by 2025 as advised in G-8 Environment Ministers meeting in May 2008 (**IEA (2008)** page 64 and **Jakarta Post (2008),** a price will have to be put on carbon and integraed into the generation capacity expansion planning process. Furthermore, for Indonesia to be able to reduce emission by as much as 41% in 2020 relative to the BAU scenario, new technologies will be necessary.

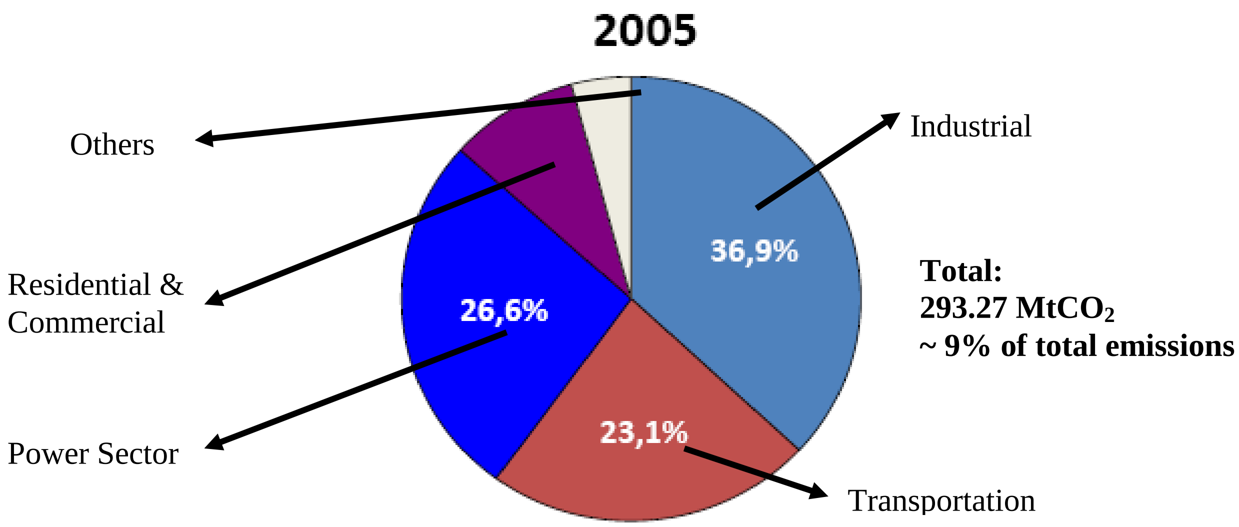


Figure 4: GHG Emissions by Sectors in Energy Sector
Source: Handbook of Energy and Economic Statistics of Indonesia 2006.

3.2 Overall Objectives

To develop a strategy for mainstreaming climate change issues into power sector planning, and further into national development plans, the GOI must include consideration of the scenarios developed by the ESE and its team of energy experts.

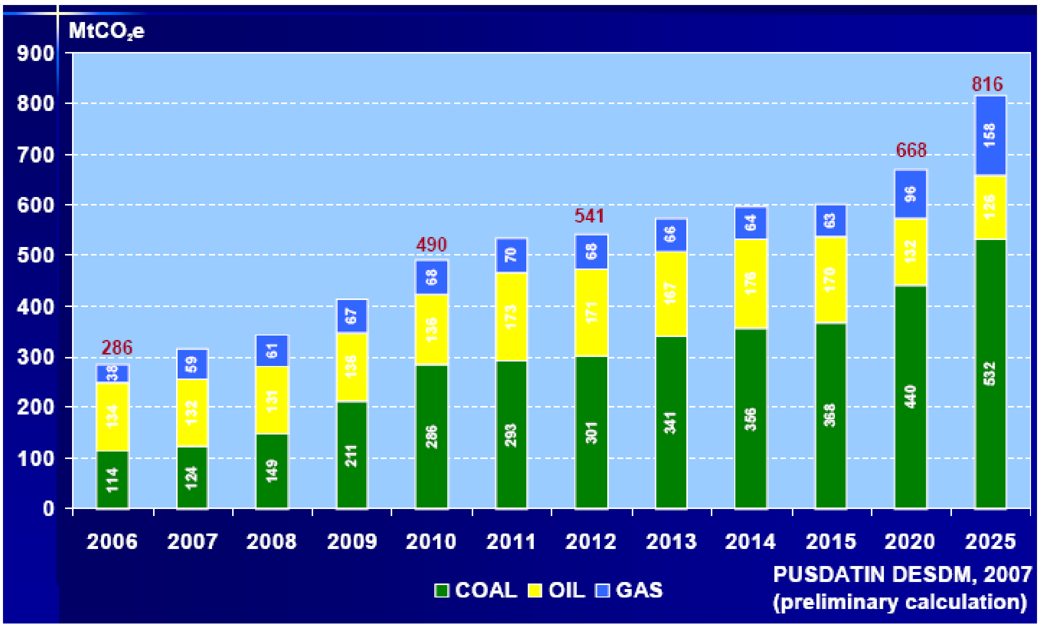


Figure 5: Estimated GHG Emissions from Fossil Fuels

3.3 Special Objective

The specific objective of this study is to provide substantive and technical assistance to BAPPENAS in the process of developing the Indonesia Climate Change Sectoral Roadmap for the power sector. The ESE role in that process focuses on the primary energy supply and demand scenarios. In evaluating these scenarios, the ESE team has worked in close consultation with line ministries to develop a timely and coordinated approach.

4 Methodology

This report describes a study designed to consider the implications of comprehensive GHG mitigation in the power sector of the Republic of Indonesia. Emphasis was placed on the identification of preferred technologies and policy portfolios for CO_2 mitigation in the electric power sector within the RUKN and RUPTL. The current status of the power plant mix is described, as are the existing plants. A base-case scenario identifies the combination of power plants that achieves the least-cost NPV of total operating costs. This Base-case scenario is dominated by the use of coal-fired power plants, with some use of natural gas-fired power plant plus a small proportion of renewable energy technologies. However, with increasing international pressure to reduce CO_2 emissions, and in particular with the sudden jump in coal consumption in power sector due to the Accelerated 10,000 MW Program Phase I and portion of Phase II, it seems likely that GoI will have to adopt a different approach. An extensive modeling exercise was therefore undertaken to examine the impact of various policy measures on the introduction of the utility's capacity expansion plan in order to identify the changes that could lead to significant CO_2 emissions reductions. The ESE, with support from the power sector team of the Indonesia Climate Change Sectoral Roadmap (ICCSR), conducted a study of Integrated Modeling for Indonesia's Power Sector under Climate Change constraint. The structure of the study is illustrated in Figure 6 below (**Hardiv Situmeang (2009)**).

A similar study was conducted for the Korean Electric Power Research Institute (KEPRI) in April 2008 (**Andrew Minchener (2008)**). Therefore, this study is the second of its kind, tuned specifically to the nature of the power sector in Indonesia. While Korea depends on imported fossil-based fuels for its power sector, such as coal and LNG, Indonesia consumes mostly local resources such as coal and to some extent natural gas. In Indonesia, while the oil-based fuels contribute most to fuel costs, and represent about 67% of the electric utility company operational costs, oil-burning power plants contribute only about 30% of the total power generation.

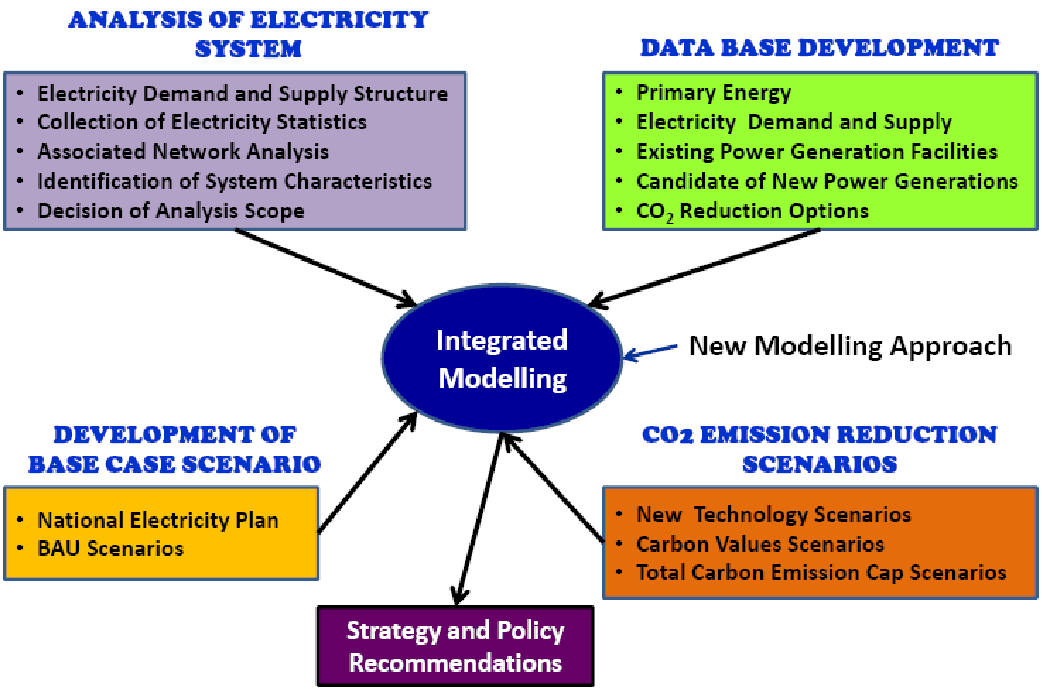


Figure 6: Integrated Modeling for Power Sector Scenarios
Source: Hardiv Situmeang (2009)

The results obtained from this simulation process constitute the power sector scenarios used in this study and form the basis for recommendations to assist GoI in establishing a sustainable energy portfolio within the power sector. The major goals of the simulation study are:

- To build up the basis for the analysis of CO_2 emissions reduction potential in Indonesia's power sector;
- To assess sustainable ways for CO_2 emissions reduction to be introduced into Indonesia's power sector;
- To investigate the effects of the several scenarios on CO_2 emissions reductions; and
- To provide advice to the GoI on strategies and policies for cost-effective CO_2 emissions reductions in Indonesia's power sector.

The study is divided into regional sub-studies, specifically:

1. Power Sector and its Primary Energy Supply Roadmap for Sumatra System (JBS)
2. Power Sector and its Primary Energy Supply Roadmap for Outside JBS

Each sub-study is basically equivalent despite the fact that majority of power generation plants are in JBS. However, the primary energy sources are predominantly available in Outside JBS.

For each of the sub-studies, at least two Focus Group Discussions (FGDs) were conducted by ESE and the team. Each FGD was facilitated by BAPPENAS and accommodated by GTZ.

The FGDs were conducted in June, July, August, September, October and November 2009 and Steering Committee meetings were held to discuss the results in September and November 2009. The advice obtained during these meetings has enabled the ESE team to complete this Final Report for Sumatra System on November 2009.

4.1 Output and Activities

For this study, the objective function based on least-cost NPV was further constrained by an imputed carbon price. The inclusion of a price for carbon dictates the scenario to meet the GHG emission cap, the choice of generation technology, fund, and carbon value. The options represented in the scenarios cover:

- A base-case scenario;
- An RUPTL scenario
- A scenario based on a sector-wide cap for total CO_2 emissions with new technology and with and without new nuclear power plants (NPP) ; and
- A carbon value scenario.

4.2 Project Approach

This sub-study was designed to consider the impact of internal and external factors on the viability of various options for power generation in Indonesia, with an focus on the potential for reducing future CO_2 emissions from the power sector outside the Java-Bali System. The RUPTL 2009 – 2018 has already included some interventions driven by Government policies, both on the national energy mix and the two fast track accelerated programs of 10,000 MW. The study doesn't impose an explicit CO_2 emissions reduction target in the base-case scenario. Thus, the base-case scenario is established using the constraints as defined in IPIECA 2007, UNFCCC Resource Guide or IEA 2006. This result of the Base-case scenario optimization are then extended to include elements of the Long-term National Development Planning (RPJP), driving the overall energy mix in the direction stipulated in Presidential Decree no 5 year 2006.

This approach was adopted to quantify the current power plant status, determine the likely increases in capacity demand, then consider a range of scenarios as well as the technologies required to ensure that future demand could be met on a sustainable basis, consistent with the scenario constraints described above. With these constraints in mind, each scenario was analyzed and recommendations made.

Other supporting materials such as the Factors of 3Es on emissions, three (3) pillars of climate policy; development of scenarios for reduction of CO_2 emission; the needs for predictable carbon value; the needs for cleaner fossil fuel systems; clean coal technology; and geothermal and other new & renewable sources have been elaborated to some details in Part 1 of this study.

5 Power System Modeling

5.1 ESE and Its Working Team

The organizational structure illustrated in Figure 7 was used to perform this study for the power sector and its primary energy supplies. The ESE team acted as coordinators of the work.

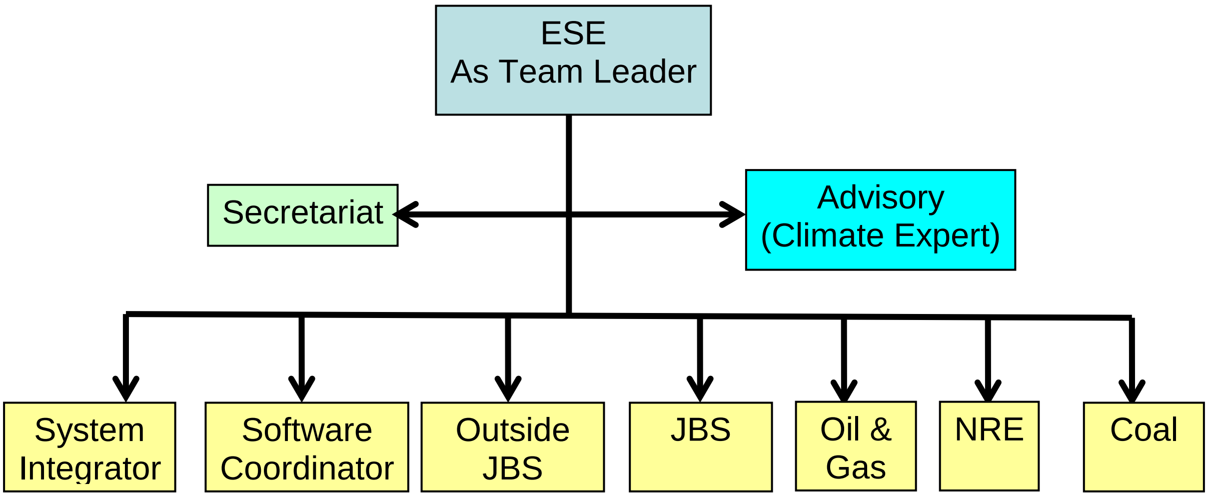


Figure 7: ESE and Its Working Team and Their Expertises

5.2 Model Development Targets

The specific objectives of this simulation study included:

- to build up the basis for analysis of future CO_2 emissions reduction potential in the Indonesian electricity Industry outside the Java-Bali System (JBS);
- to assess sustainable approaches to CO_2 emissions reduction that could be introduced into the Indonesian electricity industry outside the JBS;
- to investigate the effects of the several proposed scenarios for CO_2 emission reduction on the power sector outside the JBS;
- to provide advice on strategies and policies for cost effective CO_2 emissions reduction in the Indonesian power sector outside the JBS.

5.3 Model Development Steps

After extensive discussions with various energy modeling experts, the team selected the WASP modeling package as being appropriate for their needs. The team then took out a permit for the WASP modeling package with the nominated organization, namely PT PLN (Persero). Subsequently, the ESE team proceeded to develop their model in accordance with the approach set out in Figure 6 in the previous Chapter.

Following this initial simulation scheme, the ESE team sought the assistance of the WASP experts in the Division of Planning of PT PLN (Persero) to guide them in the acquisition of special input data, data processing requirements, and configuration of the Indonesian Reference Power System (IRPS) for the scenarios. With the support of these PT PLN (Persero)'s experts, the ESE team input the data to the ANSWER data sheet, established the prototype IRPS, and modeled several scenarios for CO_2 mitigation. Subsequently, with assistance from the PT PLN (Persero) through the provision of various data sets, the ESE team members fine-tuned the model and completed the intended program of studies. This comprised:

- development of a Base-case scenario model that fits the baseline criteria as defined IPIECA 2007, UNFCCC Resource Guide or IEA 2006 that could be used as a reference model for comparison with the CO_2 emissions reduction scenarios;
- development of a Base-case scenario model that is consistent with the current National Electricity Master Plan;
- design of Power Systems based on PT PLN (Persero)'s RUPTL;
- development of CO_2 emissions reduction scenarios, such as the introduction of a total carbon emission cap, the introduction of new power generation technologies and the imposition of a carbon value;
- investigation of the optimum scenario to reduce CO_2 emissions in the most cost-effective manner for the Indonesian power sector; and
- development of recommendations for strategies and policies to put the optimum scenario into practice.

5.4 Model Scenarios

Four scenarios were developed in addition to the Base-case scenario. Therefore, the Base-case scenario assumes that the current electricity development follows the criteria as defined in IPIECA 2007, UNFCCC Resource Guide and IEA 2006 (**Hardiv Situmeang (2009)**). The RUPTL scenario was introduced as a bridge between the Base-case scenario and the CO_2 emissions reductions scenarios. The New Technology Scenario considers the introduction of new power generation technologies which are commercially available today and are expected to be used in the future, including CCS technology. The Carbon Tax Scenario imposes a tax on CO_2 emissions that affects the relative price of fuels for power generation. The Total Carbon Emission Cap Scenario assumes the setting of a maximum level of CO_2 emissions from the Indonesian power sector.

- Once these scenarios were identified, possible strategies and policies were considered that might allow such scenarios to be established successfully. The ESE research team considered many factors affecting CO_2 emissions reduction in the Indonesian electricity industry. A description of the scenarios is presented in Table 2 below.

Table 2: Proposed Scenarios for Power Sector

Description of Scenarios	
Base-case Scenario	This scenario is developed based on a projected level of future emissions against which reduction by project activities might be determined, or the emissions that would not occur without policy intervention as defined IPIECA or in UNFCCC Resource Guide for preparing the National Communications of Non-Annex I Parties). Thus it is prepared by using free optimization based on least cost principle.
RUPTL Scenario	Only technologies either current in 2009 or included in the Master Plan for Electricity Supply (RUPTL) 2009 - 2018 Plan were included. Current trend for renewables (mainly geothermal) introduction was reflected in the model. Constraint for some technologies were set according to the resource limit and geographical limit.
Total Carbon Emission Cap with New Technologies and with/without NPP Scenario	Four likely and speculative new technologies using coal and gas were added to the Base-case scenario for application with in the life time considered in the mode. Retrofitting is also included in this scenario as well as CCS in these new technology variants. Yielded total carbon emission caps, such as 10, 20 and 30 percents compared to base-case scenario level were imposed on the RUPTL scenario with New Technologies. Effect of total carbon emission caps was analyzed when higher generation limit was set on geothermal power plant.
Carbon Value Scenario	Various carbon values (USD 25 and 50/tCO_2) were imposed for both the Base-case scenario and the Total Carbon Emission Cap with New Technologies.

5.5 Base-case Scenario Results

The over-arching objective of the modeling in this study was to analyze the influence of carbon emission mitigation options on the development of the national electricity system for the years 2009 – 2020. Therefore, the scope of this study was limited to the PT PLN (Persero) electricity generation system and its projected electricity demand. This particular sub-study focused on the Sumatra System. The horizon of analysis was originally set at ten years, from 2009 to 2018, and was subsequently extended for two years, to 2020.

Input data to establish the Base-case scenario were obtained from government publications, such as the Indonesian Statistical Yearbooks published by BPS (Bureau of Statistical Center), RUKN and RUPTL. Overseas input data were obtained from IEA and US DOE reports for non-conventional coal-fired power plants. Therefore, the basic assumptions used in this base-case scenario are illustrated in Table 3 below.

Table 3: Basic Assumptions for the Simulation

Macro-economic Assumptions:

- Economic growth at 5 – 6 %/pa
- Electricity consumption growth at 9 – 10 %pa
- Population growth at 1-1.5 %/pa
- Fuel price:
  - Coal USD 40-60/Ton
  - Oil (ICP) USD 70-80/bbl
  - Natural Gas USD 3 – 5/MMBTU
  - LNG USD 10/MMBTU
  - Uranium USD 200/kg

Micro-economic Assumptions:

EPC Cost of Power Plant (USD/kW)

PLTU Conventional	1,548
PLTU Supercritical	1,653
PLTU SC + CCS	3,011
PLTGU Conventional	850
PLTGU Conv. + CCS	1,165
PLTG Oil-fired	650
PLTN (NPP)	3,600
PLTP (Geothermal)	1,500

These data were input to the WASP model depicted in Figure 6. The model simulations followed the structure outlined in Figure 8 to identify the optimal mix of generating plants to support a least-cost NPV with CO_2 emissions reductions. Note that this Base-case scenario did not include any carbon emission mitigation efforts such as a higher target for renewable energy generation, or the introduction of new and advanced power technologies, or a price on carbon or encouragements for nuclear power plants. Under existing circumstances, one can easily predict that coal-fired power plants will dominate the energy mix of national electricity from the commencing year of 2009 and continuing to the end of the observation period in 2020. The primary results of the Base-case scenario analysis suggest:

1. An additional 2,400 MW of conventional coal-fired power plants (PLTU) will be added to the Sumatra System along with of, 800 MW of combined cycle gas turbines (CCGT) and 800 MW of LNG CCGT of by 2020.
2. CO_2 emissions will reach about 28.8 $MtCO_2$ by 2020.
3. The capital investment required to achieve this scenario is estimated to be about USD $8.60 billion by 2020.

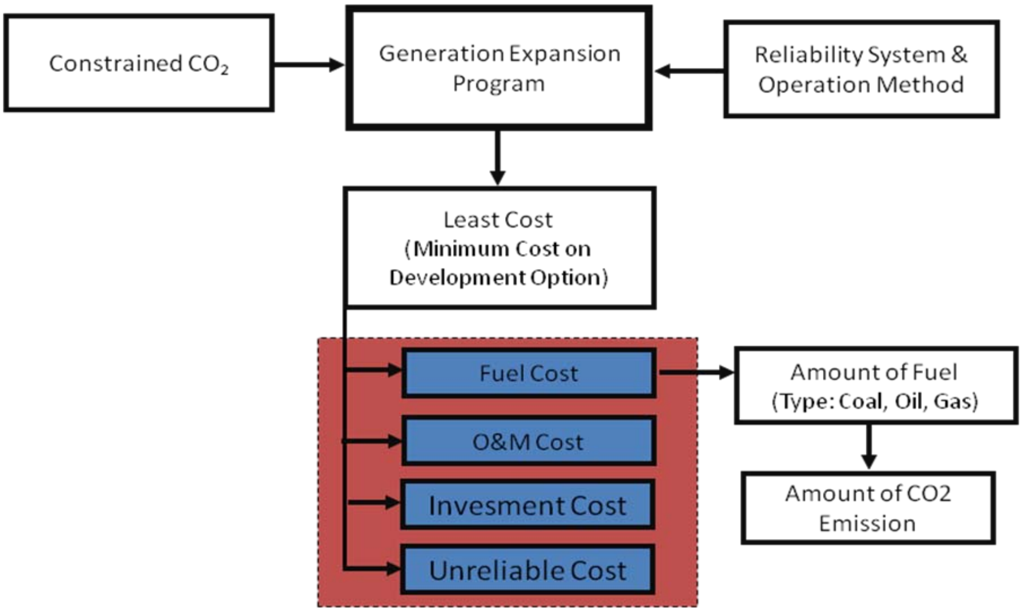
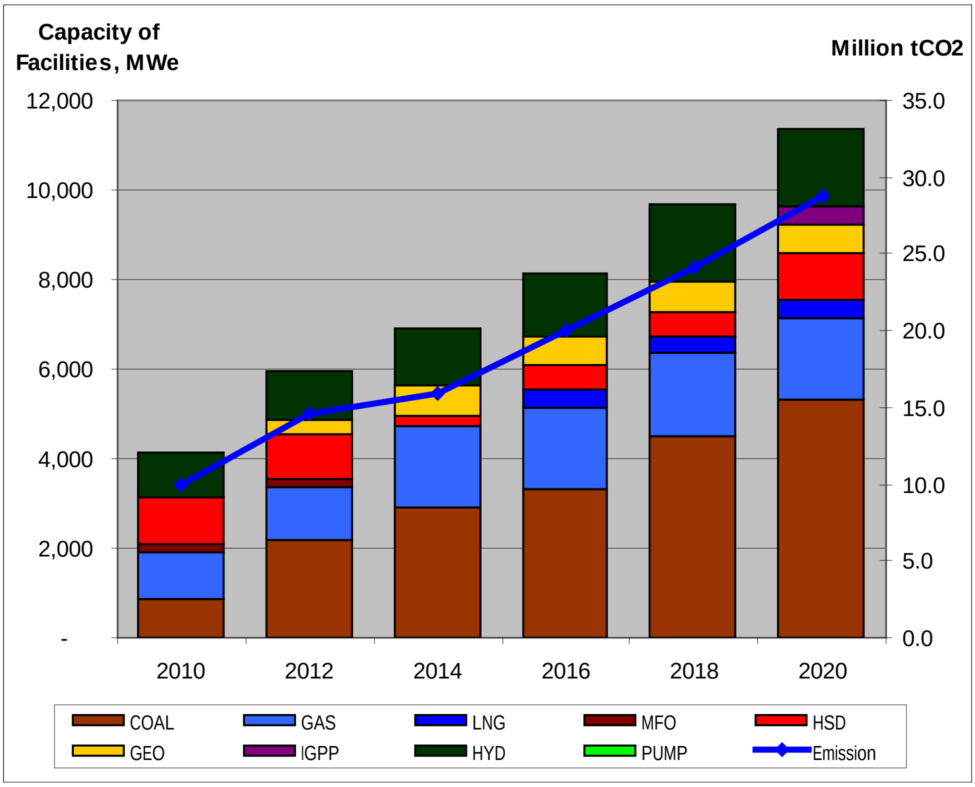


Figure 8: Calculation of CO_2 Emission Reduction in Integrated Model

This Base-case scenario simulation also provided the information on the likely power generation capacity usage by fuel type that would be needed to meet future electricity demand. The total electric energy required by the system is shown in the bottom table of Figure 9. This table indicates that by 2020 coal-fired power plants would provide about 60.2% of the electric energy (in GWh) supplied by the system, with natural gas- and LNG-fired power plants providing about 17%. Renewable energyin the form of geothermal and hydropower would contribute about 10.1% and 13.6%, respectively to electric energy supply.



Fuel	Unit	2010	2016	2020	Prod. (%)
COAL	GWh	5,731	19,026	27,207	60.2
GAS	GWh	5,382	3,665	4,121	9.1
LNG	GWh	-	64	316	0.7
MFO	GWh	668	-	-	-
HSD	GWh	2,974	15	103	0.2
GEO	GWh	-	4,588	4,588	10.1
IGPP	GWh	-	-	2,735	6.0
HYD	GWh	3,608	4,925	6,161	13.6
Total Production	GWh	18,363	32,283	45,231	
Obj. Function	M USD	2,082	6,340	8,605	

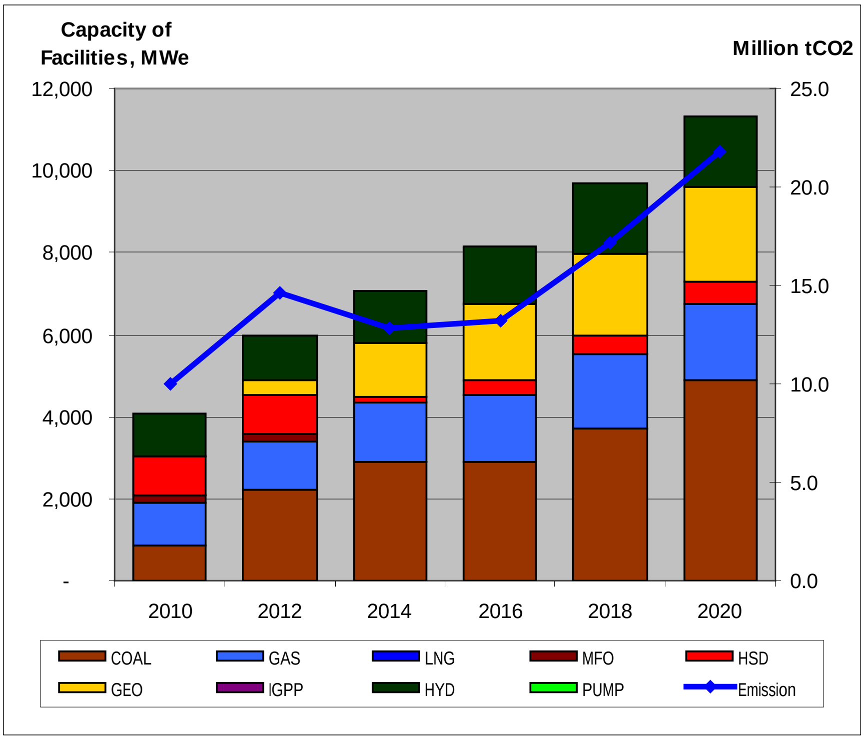
Figure 9: Base-case Scenario Results

5.6 RUPTL Scenario Results

The RUPTL scenario is based on the scenario published by PT PLN (Persero) on 19 January 2009. The principal modification applied to the published scenario was the extension of its time horizon by two years, from 2018 to 2020. The main difference between this RUPTL scenario and Base-case scenario is the inclusion of Government Policies on energy, such as the directives to upgrade the national energy mix and the two accelerated programs to add 10,000 MW each to the national power system in Indonesia. The results of the RUPTL scenario simulation can be summarized as follows:

1. The contribution of coal-fired PLTU on RUPTL decreases by 13.5% from the base-case scenario and the output from coal plants is largely replaced by electricity from the geothermal power plants.
2. An additional 2,000 MW of conventional coal-fired power capacitycontributes about 46.7% of total energy supplied by 2020. Additions of 1,650 MW of new geothermal power contributes about 36.3% of total electricity supply.
3. Total CO_2 emissions are about 21.8 $MtCO_2$ in 2020.
4. The capital investment required to implement this scenario is estimated to be approximately USD $8.76 billion by 2020.

This RUPTL scenario simulation provided information on likely power capacity usage by fuel type that would be needed to meet the electricity demand shown at the top figure of Figure 10. The electric energy required by the Java-Bali system was as shown at the bottom table of Figure 19. This indicated that by 2020 that coal-fired capacity would provide about 47% of the electric energy (in GWh) required by the system, compared to the coal-fired contribution of about 60% in the Base-case scenario. The contribution of gas-fired power plants also decreased significantly in this scenario, to 3.3%. No LNG-fired power is required, nor is any there a need for any capacity contribution from oil-fired power plant. The estimated contribution from renewable sources of geothermal and hydropower rose to about 36% from only around 10% in the Base-case scenario. In terms of electricity from hydro power, the contribution remained about the same at around 14%, with no additional capacity available. The increase in utilization of geothermal power plants combined with the increase in gas-fired generation led to a reduction in estimated CO_2 emissions of about 7 $MtCO_2$, from 28.8 $MtCO_2$ in the Base-case scenario to 21.8 $MtCO_2$ in the RUPTL scenario by 2020.



Fuel	Unit	2010	2016	2020	Prod. (%)
COAL	GWh	5,731	12,480	21,139	46.7
GAS	GWh	5,382	1,608	1,493	3.3
LNG	GWh	-	3	-	-
MFO	GWh	668	-	-	-
HSD	GWh	2,974	-	3	0.0
GEO	GWh	-	13,266	16,434	36.3
IGPP	GWh	-	-	-	-
HYD	GWh	3,608	4,925	6,161	13.6
Total Production	GWh	18,363	32,282	45,230	
Obj. Function	M USD	2,082	6,642	8,759	

Figure 10: RUPTL Scenario Results

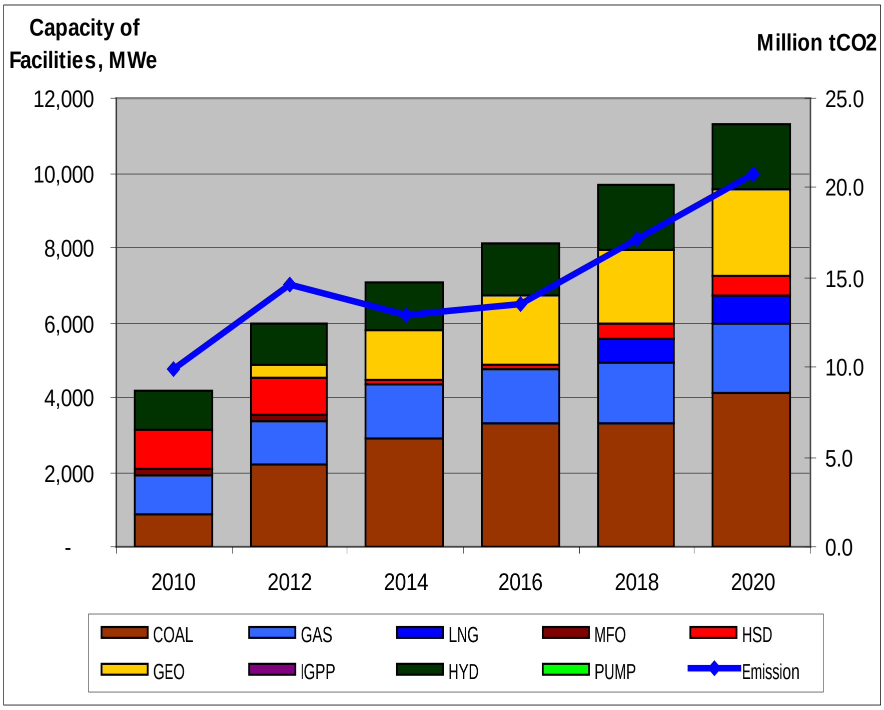
5.7 Total Carbon Emission Cap with New Technologies Scenario Results

This scenario examines the impact of introducing new coal- and new gas-fired power generation technologies, some of which include CCS into the power plant mix. These technologies are introduced solely on the basis of their economic costs and without any political incentives. Since the analysis is focused on the mitigation of carbon emissions from the Sumatra power system, which is dominated by fossil fuel use, the introduction of new, advanced renewable energy technologies was excluded, but conventional geothermal and hydropower plants were allowed to operate in the system. The main reason is most of such renewable technologies are not yet ready for large-scale use in the market and there are concerns about the credibility of their technical and economic data when compared to that for CCT and CCS. The new technologies introduced in this study included coal-fired power plant with and without CCS due to the limitation of CCS geological availability in Sumatra System (see Figure 15 of Part 1 of the this Study). They were those researched by the IEA and EIA in their studies of prospects for CO_2 Capture and Storage (**Scott Smouse (2009)**, **WEC (2007)** and **IEA Greenhouse Gas R&D Programme (2008)**). Figure 11 below shows the results of this simulation:

1. An additional 400 MW of conventional coal-fired power plants (PLTU) are added in this scenario, of about, as well as 400 MW of supercritical coal power plants, , and 800 MW of combined cycle gas turbines (CCGT). These are supplemented by, 200 MW of CCGT with CCS, , 800 MW of LNG-CCGT plus 1,650 MW of new geothermal plants by 2020.
2. Total CO_2 emissions in this scenario are around 20.8 $MtCO_2$ by 2020.
3. The total capital investment required is estimated to be about USD $9 billion.

The comparison of simulation results among the Base-case, RUPTL and Total carbon Cap with New Technology can be summarized as follows:

1. In the Base-case scenario, total CO_2 emissions increase from about 10 $MtCO_2$ in base-year 2009 to about 29 $MtCO_2$ in 2020.
2. In the RUPTL scenario where government intervention encourages the introduction of new geothermal and hydropower plants, CO_2 emissions are reduced by about 7 $MtCO_2$ (24%) from the Base-case level. This requires an additional investment of about USD $8.76 billion.
3. In the New Technology scenario with CCS, total CO_2 emissions are reduced by 8 $MtCO_2$ (28%) from the Base-case level. This reduction is achieved with a total investment of about USD $8.95 billion.



Fuel	Unit	2010	2016	2020	Prod. (%)
COAL	GWh	5,731	14,036	21,921	48.5
GAS	GWh	5,281	46	709	1.6
LNG	GWh	-	-	4	0.0
MFO	GWh	711	-	-	-
HSD	GWh	3,032	-	1	0.0
GEO	GWh	-	13,276	16,434	36.3
IGPP	GWh	-	-	-	-
HYD	GWh	3,608	4,925	6,161	13.6
Total Production	GWh	18,363	32,283	45,230	
Obj. Function	M USD	2,082	6,702	8,953	

Figure 11: Total Carbon Cap without NPP Scenario Results

In general, this scenario demonstrates that more efficient fossil fuel technology, along with the attachment of CCS to the existing CCGT power plants, can be shown to result in some decrease in CO_2 emissions. However, without some powerful external drivers, the introduction of CCS will not occur. The retrofitting of CCS to either coal- or gas-fired power plant will decrease power plant efficiency. These effects can make CCS economically unattractive unless either some form of financial incentive is applied or strict environmental regulations are imposed to severely constrain CO_2 emissions.

5.8 Carbon Value Scenario Results

This scenario explores the sensitivity of Sumatra System to the imposition of a carbon price set at two levels, namely USD \$25/tCO_2 and at USD \$50/tCO_2. The Carbon Value scenario also incorporates the introduction of new, advanced technologies, some including CCS, and encourages expanded use of geothermal power generation. To put this in context, when carbon emissions carry a price of USD \$25 or USD\$ 50 per ton of emissions, **the carbon value is equivalent to 68% - 139%** of the sub-bituminous coal price or similarly to 84% - 168% of the lignite price. In comparison to the price of natural gas, these carbon prices are equivalent to 25 – 30% of the current (2010) natural gas price. These comparisons are shown in Table 4 below.

The results of the Carbon Value simulation illustrate an expected increase in the utilization of cleaner fossil fuels and renewable energy technologies in the electricity supply mix of the Sumatra System by 2020. The simulation are illustrated in Figures 12 and 13, respectively. The results for acarbon value of USD 25/tCO_2 can be summarized as follows:

1. Additional coal-fired PLTU capacity, along with increasing capacity on gas-fired CCGT.
2. This scenario will result in a reduction of total CO_2 emissions of 10.7 $MtCO_2$ (~37.1%) by 2020.
3. The capital investment required is estimated to be about USD \$73.5 billion compared to the base-case of USD \$2.36 billion by 2020.

Table 4: Implication of Carbon Value to Fuel Price

Carbon Value USD 25/Ton	Carbon Value USD 50 / Ton
• Coal type : Sub bituminous Heat content : 5100 kcal/kg (20,285 MJ/ton) C content: 26.2 kg/GJ CO_2 equivalency: 96,100 kg/TJ Result 1 ton of coal ≈ 1.95 tCO_2	• Type of coal : Lignite Heat content: 4200 kcal/kg (16,667 MJ/ton) C content: 27.6 kg/GJ CO_2 equivalency: 101,000 kg/TJ Result : 1 ton of coal ≈ 1.69 tCO_2
• Price of Sub bituminous coal is USD 70/ton (5100 Kcal/kg) which is reflected as fuel cost for power plant at USD 118/Ton.	• Price of Sub bituminous coal is USD 70/ton (5100 Kcal/kg) which is reflected as fuel cost for power plant at USD 167 /ton.
• Price of Lignite is USD 50/ton which will be reflected as fuel cost in power plant at USD 92/ton.	• Price of Lignite is USD 50/ton which will be reflected as fuel cost in power plant at USD 134/ton
• Gas price is USD 6/MMBtu will become USD 7.5/MMBtu	• Gas price is USD 6/MMBtu will become USD 9 USD/MMBtu

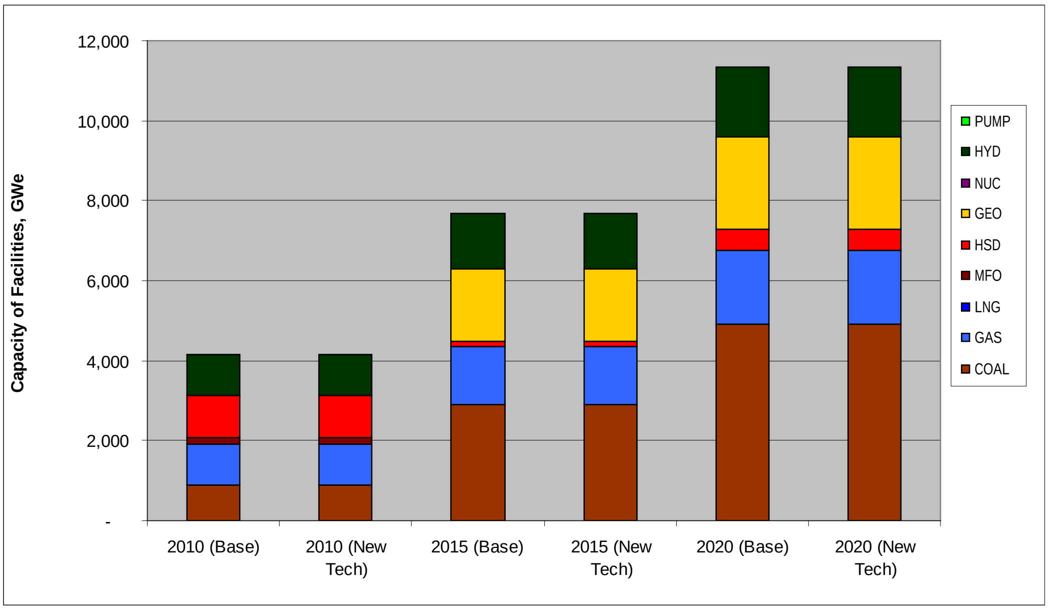


Figure 12: Carbon Value set at USD 25/tCO_2 Scenario Results

The results for a carbon price of USD \$50/tCO_2 are:

1. A decrease by 400 MW of conventional coal-fired capacity (PLTU). This capacity is replaced by supercritical coal-fired power plants (PLTU) by 2020.
2. The expected CO_2 emissions reduction reaches about 41.7 $MtCO_2$ (~ 41.7%) by 2020.
3. The capital investment required is estimated to be about USD \$62.5 billion compared to USD \$5.04 billion on base-case by 2020.

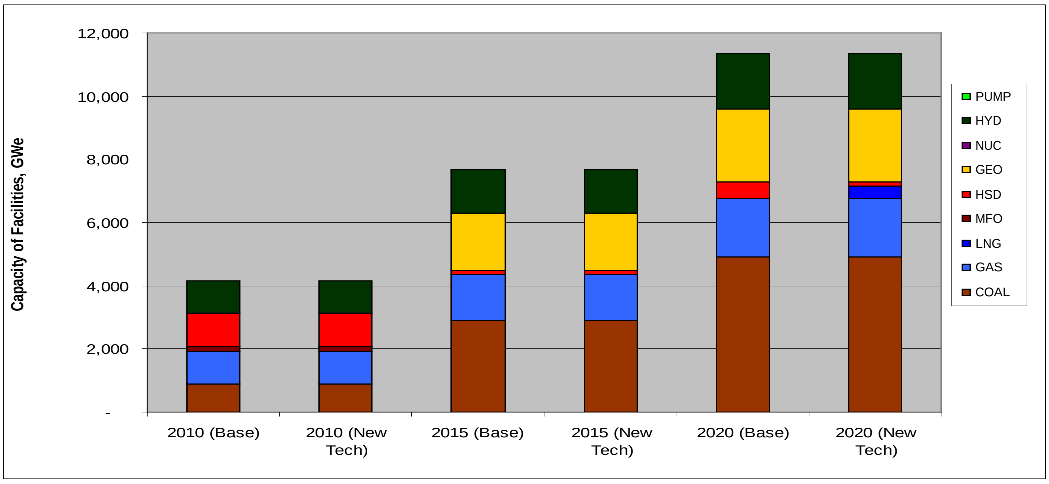


Figure 13: Carbon Value set at USD \$50/tCO_2 Scenario Results

Comparing the Carbon Value scenarios with carbon prices of USD \$25/tCO_2 and USD \$50/tCO_2 leads to the following observations:

1. With a carbon emissions price of USD \$25/ton, estimated CO_2 emissions are reduced by approximately 11 MtCO_2 by 2020 (~ 37% below the Base-case), whereas with a carbon price of USD \$50/ton, estimated CO_2 emissions are reduced by by about 12 MtCO_2 (~ 42% below the Base-case).
2. As a rough estimate, achieving the last ton of CO_2 emissions reductionrequires an investment estimated to be about USD \$18.53 million and USD \$17.86 million for carbon emissions prices of USD \$25 and \$50/tCO_2, respectively.

6 Carbon Mitigations in Sumatra Power System

This simulation modeling study suggests that, in the Base-case scenario, the Sumatra Power System CO_2 emissions in 2020 are expected to increase by about 10 $MtCO_2$ from the 2009 level, to about 28.8 $MtCO_2$. To reduce future CO_2 emissions from the Sumatra System at a level consistent with the statement of Indonesian President SBY at the G-20 meeting (**SBY (2009)**) in Pittsburgh, PA, USA in 25 September 2009, a reduction of 26% emission would be needed. This can be achieved by selecting the most appropriate scenario amongst the results of proposed scenarios as shown in Table 5 below.

Should such a target be set, there will be an increasing need for the Government of Indonesia to set in place a robust plan for Sumatra Power Sector to constrain CO_2 emissions. There will be a particular focus on the power generation sector since this is currently the major CO_2 emitter. In addition, since electricity consumption is expected to keep increasing in the foreseeable future in order to underpin national economic growth. Therefore, it would be essential to establish and implement a carbon emission mitigation strategy and policy for the Sumatra Power System, as this system emitted more than 8% (**Indonesia CCS SWG (2009)**) of Indonesia's CO_2 emissions from the power sector. This implies a need to:

1. Implement cross-cutting studies on the most cost effective ways to reduce CO_2 emissions from the Sumatra power system, relative to other mitigation opportunities.
2. Provide political support for ensuring diversity and security of primary energy supplies;
3. Establish a specific timetable and schedule for implementing the roadmap;
4. Put in place procedures to have such technologies available as and when required;
5. Ensure that technologies that will be required to establish the low carbon technology mix are available ; and
6. Put in place a policy framework to ensure the required technologies will be competitive

Table 5: Matrix of Mitigation Actions

No	Mitigation Actions Scenario xx% Emissions Reduction	Total Mitigation Cost [billion USD]	Emission Reduction ($MtCO_2$)	Abatement Cost [USD/tCO_2]	Required Policy Measures and Instruments
Total Carbon Emission Cap with New Technologies					
1	27.6	349	8	18.88	Introduction of new and cleaner coal technology (PPU 11); Renewable energy obligation (PPU 2, 17, 18); Renewable Energy Pricing Policy (PPU 1.3); Mandatory bio-fuel blending (PP 17); Fairness on fossil fuel pricing (PPU 1.1); Development of fuel (gas) supply infrastructure (PPU 10); Socialization on public acceptance on CCS safety (N/A).
Carbon Value at USD 25/MT Scenario					
2	37.11	2,354	10.67	18.53	Introduction of new and cleaner coal technology (PPU 11); Renewable energy obligation (PPU 2, 17, 18); Renewable Energy Pricing Policy (PPU 1.3); Mandatory bio-fuel blending (PP 17); Fairness on fossil fuel pricing (PPU 1.1); Development of fuel (gas) supply infrastructure (PPU 10); Taxes or carbon charges on fossil fuel (coal) (PPU 4).
Carbon Value at USD 50/MT Scenario					
3	41.74	5,038	12	17.86	Introduction of new and cleaner coal technology (PPU 11); Renewable energy obligation (PPU 2, 17, 18); Renewable Energy Pricing Policy (PPU 1.3); Mandatory bio-fuel blending (PP 17); Fairness on fossil fuel pricing (PPU 1.1); Development of fuel (gas) supply infrastructure (PPU 10); Taxes or carbon charges on fossil fuel (coal) (PPU 4).

6.1 Policy Related Issues

The simulation results for all scenarios reinforce the conclusion that the Government of Indonesia must maintain a balanced energy mix to provide security of supply. This balance is likely to include coal- and gas-fired power plants, with and without CCS and new nuclear power plants together with LNG-fired, geothermal and hydropower plants, and a relatively small proportion of oil-fired power plants. The simulation results have indicated that such a balance supply approach can meet the future CO_2 emissions target levels outlined recently by President SBY. The simulations also suggest that, for more significant CO_2 emissions reduction scenarios, the coal and gas/LNG technologies needed to be of advanced design with integrated CCS technology. In this study, it was not possible to meet these higher levels of CO_2 emissions reductions without some application of CCS though all available geothermal resources have been utilized, while avoiding over-dependence on nuclear and/or LNG-fired power plants.

Since there are already plans to install a substantial quantity of coal-fired and LNG-fired power plants and there has been discussion of the possibility of intern\connected HVDC link of South Sumatra – West Java by 2016, it will be important to consider the full range of policy measures and instruments that might be required to achieve these objectives. Fortunately, the government of Indonesia has already envisioned such requirements by launching the revision of its Blue Print of National Energy Management in April 2009 (**MEMR (2009)**) which covers the programs that needed for realizing a high level of CO_2 emissions reductions. The program which is called *Program Pengembangan Utama* (PPU), meaning Main Development Program, consists the following elements:

1. Fairness on fossil fuel pricing (PPU 1.1);
2. Renewable Energy Pricing Policy (PPU 1.3);
3. Renewable energy obligation (PPU 2, 17, 18);
4. Taxes or carbon charges on fossil fuel (coal) (PPU 4);
5. Development of fuel (gas) supply infrastructure (PPU 10);
6. Introduction of new and cleaner coal technology (PPU 11); and
7. Mandatory bio-fuel blending (PP 17).

There are two or more policies that need to be defined in order to support this mitigation on power sector, for instance:

8. Socialization on public acceptance on CCS safety (N/A).

Having an appropriate policy framework will ensure the contribution of power sector to reducing national CO_2 emissions. Furthermore, this framework can be mainstreamed into the medium-term national development or beyond, which is the ultimate target of this study.

7 Conclusions and Recommendations

The simulation results of the integrated modeling of the Sumatra Power System have indicated that the target levels of CO_2 emission reduction are reachable. The results also show the power generation capacity mix, the level of CO_2 emissions that would be expected in each scenario, and the investments required to achieve the targeted abatement costs.

To realize any of these simulation results, it is essential that an appropriate policy framework be supported by the GoI. Some of the necessary policies have already been proposed in the BluePrint of National Energy Management, prepared by the Ministry of Energy and Mineral Resources. However, these policies must be clarified and provided with clear timescales and schedules.

As the Sumatra System emits about 8% of the total CO_2 emissions from the national power sector, it future evolution, and in particular, it capacity expansion plan must be an integral part of the overall national CO_2 emissions reduction strategy. The capacity expansion plan for the Sumatra System must coordinated with other mitigation and adaptation actions in order to achieve the national target of reducing the national CO_2 emissions, while advancing Indonesia's medium- and long-term national economic development goals.

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