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Indonesia Climate Change Sectoral Roadmap – ICCSR

Energy Sector part 1 (Java-Bali 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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Deputy of International Cooperation, Coordinating Ministry for Economy; Secretary of Minister, Coordinating Ministry for Public Welfare; Secretary General, Ministry of Energy and Mineral Resources; Secretary General, Ministry of Industry; Secretary General, Ministry of Transportation; Deputy of Economy, Deputy of Infrastructures, Deputy of Development Funding, Deputy of Human Resources and Culture, Deputy of Regional Development and Local Autonomy, National Development Planning Agency; and Chief of Secretariat of the National Council for Climate Change.

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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°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 rigorous 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

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<td>BAPPENAS</td>
<td>Badan Perencanaan Pembangunan Nasional (National Development Planning Agency)</td>
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<tr>
<td>BAT</td>
<td>best available technology</td>
</tr>
<tr>
<td>BAU</td>
<td>Business-as-Usual</td>
</tr>
<tr>
<td>bbl</td>
<td>barrel or “blue barrel” as set by Standard Oil, of 42 gallons</td>
</tr>
<tr>
<td>boe</td>
<td>barrel of oil equivalent</td>
</tr>
<tr>
<td>C</td>
<td>carbon</td>
</tr>
<tr>
<td>CBM</td>
<td>coal-bed methane</td>
</tr>
<tr>
<td>CCS</td>
<td>carbon capture and storage</td>
</tr>
<tr>
<td>CCT</td>
<td>clean coal technology</td>
</tr>
<tr>
<td>CDM</td>
<td>clean development mechanism</td>
</tr>
<tr>
<td>CER</td>
<td>certified emission reduction</td>
</tr>
<tr>
<td>CFBC</td>
<td>circulating fluidized bed combustor</td>
</tr>
<tr>
<td>CO₂</td>
<td>carbon dioxide</td>
</tr>
<tr>
<td>COP</td>
<td>Conference of the Parties</td>
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<tr>
<td>CTL</td>
<td>coal-to-liquids</td>
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<tr>
<td>DGEEU</td>
<td>Directorate General of Electricity &amp; Energy Utilization</td>
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<tr>
<td>DGMCG</td>
<td>Directorate General of Minerals, Coal &amp; Geothermal</td>
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<tr>
<td>DSM</td>
<td>demand side management</td>
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<tr>
<td>ECBMR</td>
<td>enhanced CBM recovery</td>
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<td>EGR</td>
<td>enhanced gas recovery</td>
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<td>EIA</td>
<td>Energy Information Agency, US DOE</td>
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<td>EOR</td>
<td>enhanced oil recovery</td>
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<td>ETS</td>
<td>Emissions Trading Scheme</td>
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<td>FGD</td>
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GHG  greenhouse gas
GoI  Government of Indonesia
GTZ  Deutsche Gesellschaft für 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 and 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  Los-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 Units
MMSCFD  million standard cubic feet per day
Mt  million tonnes
MtCO₂  million tonnes of CO₂
MWe  Megawatts electrical
NAMAs  nationally appropriate mitigation actions
NETL  National Energy Technology Laboratory (US DOE)
NGCC  natural gas combined cycle
N₂O  Nitrous Oxide
NPV  net present value
OECD  Organization for Economic Co-operation and Development
PC  pulverized coal
PF  pulverized fuel
Pertamina  Perusahaan Minyak & Gas Nasional (State-owned 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-owned 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)
SO₂  sulfur dioxide
SOₓ  sulfur oxides
TCF  terra cubic feet
TNA  Technology Needs Assessment
UCG  underground coal gasification
UN  the United Nations
UNEP  United Nations Environment Programme
<table>
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<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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<td>US DOE</td>
<td>United States Department of Energy</td>
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<td>WASP</td>
<td>Wien Automatic System Planning model</td>
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<td>WEC</td>
<td>World Energy Council</td>
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Introduction
BAPPENAS, the Indonesian National Development Planning Agency, formally recognized Climate Change as a major threat to mid- and long-term development in December 2007 when it issued the National Development Planning: Indonesia Responses to Climate Change (Bappenas (2008). This report was the first attempt in Indonesia to integrate adaptation and mitigation of climate change into National Development Planning Policies. This document was designed to bridge between The National Action Plan On Climate Change and the 5 year mid-term national development plan 2010-2014 (Bappenas (2009). It placed special focus on funding forestry, energy efficiency, food security, infrastructure and public health-related projects. Bappenas’ policy mandates that those efforts be supported by effective development planning and inter-ministerial coordination.
Background
2.1 Rationale

Global climate change is an issue that can no longer be ignored. On the global stage, this issue has been significantly propelled by the writings of Nobel Laureates Al Gore, former Vice President of the USA (Al Gore (2006)) and Steve Chu, currently the Secretary of US DOE (Kevin Conley (2009)). U.S. President Barack Obama declared to the United Nations General Assembly on 22 September 2009 that the US is a serious partner in combating global warming (Jakarta Post (2009)). Many related publications are available from numerous organizations, government agencies and so on, including the World Energy Council (WEC, 2007), Thomas Friedman (2008), Mark Lynas (2008), Michael Levi (2009), Wallack and Ramanathan (2009), Clifton Anderson (2009), PEW Center on the States (2006) and Michael Lemonick (2008).

Thomas Friedman, for example, explained how global warming, rapidly growing populations, and the astonishing expansion of the world’s middle class through globalization have converged to produce a planet that is “hot, flat, and crowded”. Already the earth is being affected in ways that threaten to make it dangerously unstable. Mark Lynas, in his book published by the National Geographic Society illustrates how an increase by even one degree will have significant consequences for this blue planet. One of the earliest and most important impacts will involve the accelerated melting of Arctic ice, as has been noted by McKenzie Funk (2009), James Gamble (2009), and Fred Pearce (2009). Potential future impacts of Arctic melting have been modeled by Schmidt and Wolfe (2009) and McGuffie and Henderson-Sellers (2005), among others. The potential impacts of climate change on national economies have been reviewed by Lord Stern in his seminal publication (Stern Review (2006)) and by Lester Brown (2001).

In Indonesia, some of the impacts of climate change are already visible and are expected to become more severe than previously anticipated. Indonesia, under the strains of economic growth, urbanization, and major industrial projects, suffers from a wide range of other environmental problems including poor air quality in cities, pollution over rivers and seas, inadequate disposal of solid wastes, land degradation, loss of biodiversity, and deforestation. Indonesia’s land use, land use change and forestry (LULUCF) was estimated to account for 60% of Indonesia’s total Greenhouse Gas (GHG) emission in the Government of Indonesia (GoI) First National Communication on Climate Change to the United Nations Framework Convention on Climate Change (UNFCC) in 1999. By contrast, the energy sector has contributed about 25% of Indonesia’s GHG emissions (IEA (2008)). The ongoing and anticipated impacts of climate change pose a serious threat to national environmental and socioeconomic development during the coming decades; these impacts are likely to affect all segments of society and future generations. One early study of the economic impacts of the GHG mitigation efforts in Indonesia was completed in 1999 (ME (1999)). This study explored the impacts of the GHG limitations on national economic growth. This study, combined with more recent analyses demonstrates that addressing climate change is an urgent development priority for Indonesia and requires a long-term commitment from all stakeholders in the nation.
In responding to the above concerns and in the context of national development planning priorities, the GoI has decided to focus the first tranche of response measures on a small number of priority sectors. These so called “priority sectors” are divided into mitigation and adaptation priorities. For mitigation, the priority sectors are: (a) energy and mining; and (b) forestry. With respect to adaptation, the priority sectors are: (a) agriculture; and (b) coastal areas, small islands, marine life and fisheries.

In order to reduce GHG emissions from the energy sector, Indonesia needs to properly address its heavily reliance on fossil fuels such as oil, coal and natural gas, that are primary contributors to CO₂ emissions. However, the GHG emissions from Indonesia’s energy sector must be managed carefully as this sector is of crucial importance to the Indonesian economy, responsible both for earning export/foreign exchange (forex) revenue and for fulfilling the need for domestic energy. In the past, the GoI has placed its emphasis on forex revenue, but since the beginning of the present decade, the GoI has shifted the emphasis of national energy policy towards meeting Indonesia’s demand for energy. In reality, however, the contribution of the energy sector to the state budget has been steadily decreasing. In 2008, the energy sector contributed IDR 346.35 trillion to the total state budget and revenue 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)).

Indonesia’s total annual GHG emissions of the three major gases, CO₂, CH₄ and N₂O was equivalent in 2005 to about 670 million ton of CO₂ (MtCO₂e) without LULUCF, or about 1120 MtCO₂e if one includes peat fires but not LUCF (defined as NE). Meanwhile, in 2005, Indonesia’s energy sector emitted at a level of 396 MtCO₂e, which is about 35.4% of the national total (SNC (2009)). Based on the conditions illustrated below in Figure 1 (SNC (2009)), the Ministry of Environment of Indonesia has announced in May 2008 that an absolute cut in GHG emissions is its unilateral goal. The current goal is to cut energy sector emissions by about 17% by 2025 (IEA (2008) and Jakarta Post (2008)) while implementing bold reductions in forest burning. Meanwhile, Indonesia will also increase emissions intensive coal in the domestic energy mix.
This ministerial commitment to emissions reductions was reinforced by President Susilo Bambang Yudhoyono in his address on climate change issues to the G-20 Summit in September 2009. President SBY explained that the implementation of Indonesian energy policies, including those related to LULUCF, would reduce the nation’s aggregate emissions by 26% by 2020, relative to a Business-as-Usual (BAU) scenario. If adequate international support is made available, Indonesia would increase its national target, aiming to reduce annual GHG emissions to as much as 41% below the BAU scenario. Indeed President SBY emphasized that these emission reduction targets are achievable because most of Indonesia’s emissions come from forest related issues, including forest fires and deforestation (SBY (2009)). Fortunately, Indonesia’s energy resources are quite diverse and the reserves available from non-fossil fuel-based energies are significant. These clean energy resources present an opportunity for Indonesia to develop its national economy along a low-emissions pathway as the nation moves into the future.

As stipulated in Presidential Decree no. 5, Year 2006 (illustrated in Figure 2 below), the share of coal in energy consumption will increase from about 15% in 2006 to approximately 33% by 2025. (This figure rises to 35% if one includes the 2% of primary energy that is expected to be derived from liquefied coal.). Figure 2 also shows the level of GHG emissions for the 2005 base year as around 350 MtCO2, based on a primary energy consumption of approximately 1 billion BOE.
Indonesia’s level of primary energy consumption is expected to grow, reaching around 3 billion BOE in 2025. This is projected to result in emissions of around 1150 MtCO$_2$e in the BAU scenario or around 950 MtCO$_2$e, if the Presidential Decree is fully implemented. Reducing GHG emissions by around 16% by 2025 will be difficult unless Indonesia can increase the share of renewable energy in the national primary energy mix. Indeed Figure 2 indicates that the non-fossil energy in 2006 is barely about 4.5% and must be increased to around 17% to meet the Presidential target. (The Presidential Decree implies that geothermal energy contributes 5%, renewable energy 5%, CTL 2% and biofuels 5% in 2025.)

On this crucial climate change issue, the UNFCCC has emphasized that all member parties should incorporate considerations of climate change into national development planning, each in accordance with its national sustainable development agenda. Indonesia has responded by formulating the national development planning document on climate change that covers multiple sectors and ensures horizontal as well as vertical coordination of the national development planning process.

As a matter of course, in Indonesia this process will be prepared and managed by Indonesia’s national development planning agency (BAPPENAS). Impacts arising from gradual climate changes need to addressed and immediately anticipated by formulating suitable spatial plans. A robust policy framework will be put in place to integrate climate change into spatial planning at both the national and local levels. The development of cross-cutting policies on climate change, and their incorporation into spatial plans will help to integrate consideration of climate into the development of sectoral policy (Bappenas (2008)).
In Indonesia, the energy sector consists of four major sub-sectors, namely transportation, industry, electric power and commercial and residential. In the sections that follow, this report describes a study, undertaken jointly by Energy Experts and BAPPENAS, to consider the issues for comprehensive GHG mitigation in Indonesia’s electric power sector. However, the scope of this report is limited due to the following constraints:

1. Limited time period of study of 6 months (and limited availability of funds);
2. Transportation, residential and commercial sectors are to some extent, very broad and require more time and resources to analyze; and
3. Industry, in principle, is very similar to the electric power sector in the sense that is composed of large centralized demands, but the limited time and resources available during the time period of study precluded the inclusion of the industry sector in this analysis.

2.2 Projection of Electric Power Supply and Demand in Java – Bali System

Sustaining a reliable and well distributed electricity supply requires a comprehensive and nation-wide power system planning process. The Rencana Umum Ketenagalistrikan Nasional (RUKN), so called National Electricity General Plan (DGEEU (2008)) can be considered as a general policy on integrated electricity supply for the country. This plan covers the demand and supply forecast, investment and funding policies, and directive measures on primary energy as well as renewable energy and other new energies utilization plans for the power sector.

RUKN is intended to be used as a guideline for the future development and construction of Indonesia’s power sector 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 increasingly critical in the face of constantly changing conditions at the local, national, regional and global levels.

In addition, the participation of private companies in the power sector is becoming more crucial due to the limitations placed on government funds for these activities. In many regions, that the role of the private sector in power generation is expected to increase. In these circumstances, the RUKN can serve to clarify which of the potential power sector projects should be conducted by PKUK (in this case PT PLN (Persero)) and by other parties. Furthermore, the dynamics of change in macro-economic forces that will affect the rate of growth of electricity demand in Indonesia is undeniable. Because the timeframe of RUKN is a 20 year planning span, it must be viewed as a form of dynamic guidance, to be reviewed annually in light of the relevant changes in macroeconomic conditions. In the context of the current law of electricity (No. 15, year 1985) and government regulation no 10 year 1989, the RUKN has been revised twice, leading to government regulation no 26 year 2006. This regulation requires that each business entities involved in electric power supply will prepare its Rencana Umum Penyediaan Tenaga.
Listrik (RUPTL), the so called Master Plan of Electricity Supply in its own business area, and that this plan shall refer back to the RUKN. Within this regulatory framework, PT PLN (Persero) prepares its own RUPTL which covers the period 2009 – 2018. This plan integrates corporate planning for power generation, transmission and distribution (PT PLN (Persero) (2009)). In its RUPTL, PT PLN (Persero) indicates those system development projects that will be implemented by the corporation itself (including some transmission and distribution, pumped storage and several thermal and hydro power plants). It also includes some power generation projects that Persero intends to invite private sector companies to build and to operate under a scheme of independent power producers (IPP). For instance, the projection of power generation development to meet the future demand in Java – Bali System (JBS) shows both projects to be done by PT PLN (Persero) and by IPP developers. These projects are illustrated in Table below.
The 10-year RUPTL, like the RUKN, will be reviewed annually to identify and address the dynamic changes in national macro-economic conditions. Having such an annual review, RUPTL can be updated and adjusted to follow the changes that affect its important planning parameters, thus ensuring that it
can be used as guidance in developing Indonesia’s future power system under the guidance of PT PLN (Persero)’s RUPTL.

Besides the Java – Bali System (JBS), the RUPTL covers another four regions of the country, namely the Sumatera, Kalimantan, Sulawesi and Nusa Tenggara-Maluku-Papua systems. The other four regional systems are referred to simply as Outside JBS. In preparing the power sector development plan=for RUPTL, there are some important assumptions and parameters that have been adopted as the general policies. For the power generation sector, this study will cover:

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

During the period when PT PLN (Persero) is still unable to supply all electricity demand, sales growth is limited by the available and capable generating capacity. For the years 2008 and 2009, the capability to supply demand is still under generation constraint due to the delay in constructing some power plants under the program called “Accelerated 10,000 MW Program, phase I”. Sales growth during this period is targeted at 6.5% for 2008 and 7.5% for 2009. On the demand side, the policies for demand side management (DSM) and energy efficiency have not been considered yet in the system planning of RUPTL 2009 – 2018.

The policy on development of generation capacity is based on the principle of least cost of power generation while maintaining the expected level of system reliability. The lowest generation cost is identified by minimizing the net present value of all electricity generation-related costs, such as investment, fuel, operation & maintenance, and idle capacity costs. The reliability constraint is established on the basis of the principles of Loss of Load Probability (LOLP) and Reserve Margin. Rental power generation and excess power supplied by others are excluded from the system planning.

Nevertheless, in line with the government policy to develop and utilize renewable energy resources in the areas where these sources are available= the least cost criterion may be partly or even completely ignored. In those areas, the development of geothermal and hydropower may enter into the mix of power system supplies despite their higher development cost compared to conventional thermal power plants.

Based on these general policies for system development, a capacity expansion plan for system development can be prepared so as to obtain reliable power generation during a certain period of time, simultaneously meeting the criteria of least cost on NPV and expected reliability. The least cost configuration is achieved through an optimization process that takes account of the NPV of investment, fuel, operations and maintenance, as well as idle capacity costs. Salvage value of some power generation equipment is also considered for the power plants which have reached the end of their economic life at the time the analysis is performed. Simulation and optimization are conducted using the Wien Automatic System Planning Model (or WASP).
Alternatively, a linear programming approach has been successfully used in the country’s energy planning based on MARKAL model. An alternative projection model that can be used for analyzing capacity expansion plans designed to meet long-term electricity demand has been proposed by Zuhal (Zuhal (1994)). Zuhal’s approach, based on Multi-objective Liner Optimization, and his model is called the Zuhal Optimization PLANning Model (or ZOPPLAN). However, in the Indonesian case, this multi-objective linear programming-based optimization, seems to be unable to handle the dynamics and complexity of the national power system and is not able to represent accurately known supply and demand behavior in the national system.

In terms of the reliability constraint in this analysis, the LOLP for the Java-Bali system has been set at < 0.274%, which is equivalent to a loss of load of 1 day per year. This means that the probability that the peak load exceeds the installed capacity is less than 0.274% and that the system experiences major unscheduled outages not more than 1 day per year. The estimation of generation capacity needed to meet this LOLP criteria results in an estimate of the required system reserve margin. This calculation depends on the expected availability of each generation unit, the number of units in the network, the capacity of each unit and the fuel type of each unit. For JBS, at LOLP < 0.274%, it gives a reserve margin > 25 – 30% based on expected net available capacity. If it’s based on the total installed capacity, the reserve margin may reach around 35%. For outside JBS, with the same arguments, the necessary reserve margin is around 40 – 50% due to the limitation on the number of units available, the derating of available power generation capacity, and continuing uncertainty about the timing of completion for many of the IPP projects.

For reliability analysis using the WASP model, renewable energy technologies like geothermal and hydropower are considered to be fixed or “must run” systems in the system simulation and optimization. This means that they must be included in the system dispatch plan, whenever these renewable resources are available. For JBS, the thermal power generation systems that are considered in the simulation and optimization process include a supercritical PC power plant of 1,000 MW and subcritical plants of 600 and 300 MW; a combined cycle Gas Turbine of 750 MW; one LNG-fired CCGT of 750 MW; and an oil-fired, open-cycle Gas Turbine of 200 MW. In addition, the representation of JBS includes one geothermal plant of 55 MW and one hydropower pumped storage facility of 250 MW. For outside JBS, the thermal power candidates include Pulverized Coal-fired power plants of 200, 100, 50 MW and smaller sizes; as well as a CCGT whose operational rating depends on the volume of natural gas that is available to supply the turbine.

The emission of CO₂ in the RUPTL has been calculated based on the amount of fuels consumed and converted into CO₂ emissions using the emission factors published by IPCC. Unfortunately, in the system planning process used for RUPTL 2009 – 2018, the cost of CO₂ emissions was not included in the NPV calculation and is not considered as one of cost parameters (PT PLN (Persero) (2009)). However, these costs may be considered by Persero, as the idea of inclusion of the Clean Development Mechanism (CDM) could lower the cost of generation (DGEEU as quoted in Bisnis Indonesia (2009))
and Investor Daily (2009)). Despite the omission of CO\textsubscript{2} emission as a cost factor, it is not totally ignored in the RUPTL. It could be reflected by the inclusion of several additional candidate geothermal and hydropower plants that can be “forced” to be part of power generation mix in RUPTL, even though they violate the least cost criteria. The introduction of supercritical boiler in JBS is another example of a possible measure that could be taken by PT PLN (Persero) to reduce the emission of CO\textsubscript{2} in their power generation mix in RUPTL. The results of this interpreted emission of CO\textsubscript{2} for the national power system under RUPTL is illustrated in Figure 3.

As shown in Figure 3, national emissions of CO\textsubscript{2} from power generation will increase from 116 million MtCO\textsubscript{2} in 2009 to around 270 million MtCO\textsubscript{2} by 2018. Of those 270 million MtCO\textsubscript{2}, about 228 million MtCO\textsubscript{2} (84.5%) is originally emitted by coal-fired power plants. The average grid emission factor for Indonesia in 2009 was around 0.787 kgCO\textsubscript{2}/kWh, which shall be improved by about 6% in 2018, to around 0.741 kgCO\textsubscript{2}/kWh.

For JBS, the situation is as shown in Figure 4 below. The emission of CO\textsubscript{2} from power generation will more than double, increasing from about 94 million MtCO\textsubscript{2} in 2009 to around 213 million MtCO\textsubscript{2} in 2018. The average grid emission factor for JBS in 2009 was around 0.798 kgCO\textsubscript{2}/kWh, which shall be improved by almost 7% in 2018, to around 0.744 kgCO\textsubscript{2}/kWh. The improvement of the emission level in JBS will be achieved through the increased usage of natural gas (including LNG), geothermal and supercritical boilers for coal-fired power plants.

The projection of CO\textsubscript{2} emission for Outside JBS shows a similar trend as the JBS. Emissions of CO\textsubscript{2} from power generation are expected to double from 2009 to 2018, increasing from 22 million MtCO\textsubscript{2} in 2009 to about 57 million MtCO\textsubscript{2} in 2018. The average grid emission factor for Outside JBS will improve from 0.745 kgCO\textsubscript{2}/kWh in 2009 to around 0.732 kgCO\textsubscript{2}/kWh in 2018. More details about the system Outside JBS will be described in Part 2 of the Completed Study Report.
Figure 3: Estimated Indonesia’s CO₂ emission for each type of fuel in power sector
Source: RUPTL PT PLN (Persero) 2009-2018

Figure 4: Java – Bali system’s CO₂ emission in power sector for each type of fuel
Source: RUPTL PT PLN (Persero) 2009-2018
3
Problem Statement and Objectives

ICCSR - ENERGY SECTOR PART 1 (JAVA-BALI POWER SYSTEM)
3.1 Problem Statement

As mentioned above, this study will only cover the electric power sub-sector. The GHG emissions from energy consumption in 2005 as shown in Figure 1 can be further categorized into 5 main sub-sectors as described in Figure 5 below. The contribution of the three fossil energy resources to GHG emissions is illustrated in Figure 6 and shows that coal’s share of electricity-related CO$_2$ emissions is steadily increasing during the period of projection. Thus, to reduce or at least to maintain the level of CO$_2$ emissions, special attention must be focused on coal use in the power sector. Commencing in 2010, some new coal-fired power plants come online as part of the Accelerated 10,000 MW Power Program -- Phase I. Although the upcoming Accelerated 10,000 MW Power Program -- Phase II will accommodate more renewable energy, especially geothermal power plants, the contribution of coal-fired power plants to electricity-related CO$_2$ emissions is expected to rise. Therefore, if there is no specific measure applied to the development of those coal-fired power plants, such as a requirement for the usage of supercritical boiler and/or the introduction of carbon capture and storage (CCS), the aggregate level of CO$_2$ emissions from the electric power sector will surely increase in the years ahead.

Indeed, the government has tried to prepare a scenario based on the Presidential 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)). Unfortunately, in particular in the RUPTL, the projection of future capacity expansion requirements is based on minimizing NPV without consideration of any cost attributed to CO$_2$ emissions. Therefore, in anticipating the target of at least 17% reduction on 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) some carbon value should be incorporated into the scenario to be compared to BAU scenario. Note that the base-case scenario shall follow the baseline definition as defined in several glossaries, such as IPIECA 2007, UNFCCC Resource Guide or IEA 2006 (Hardiv Situmeang (2009)). Having this in mind, thus the scope of this report shall cover a variety of scenarios with different emissions reduction schemes dictated by the level of required reduction and the “price” that is placed on carbon emissions.
Figure 5: GHG Emissions by Sectors in Energy Sector

Figure 6: Estimated GHG Emissions from Fossil Fuels
3.2 Overall Objectives

The objective of this study is to develop a strategy for mainstreaming climate change issues into Indonesia’s power sector, and along with its primary energy supplies into the national development plan. Achieving this objective will require coordination, synergy, monitoring and evaluation based on the scenarios proposed and prepared by the ESE team, which consists of several energy related experts and system simulation developers.

3.3 Special Objective

The particular objective of this study is to provide substantive and technical assistance to BAPPENAS on the process of developing the Indonesia Climate Change Sectoral Roadmap for the power sector. This study will advance that objective by considering its primary energy supply and demand scenario, in close consultation with other line ministries and in a timely, coordinated, and programmatic approach.
4 Methodology
This report describes a study designed to consider the issues related to comprehensive GHG mitigation in the power sector of the Republic of Indonesia. In designing this study, emphasis was placed on the identification of the optimal technology and policy portfolios for CO$_2$ mitigation, using the existing fleet of coal-fired power plants within the RUKN and RUPTL. The current status of the power plant mix is described, as are the existing plants. Under a base-case scenario that has been configured to minimize the NPV of all electricity production-related costs, the expectation is that power generation will be dominated by the use of coal-fired power plants, augmented by some use of natural gas-fired power plants plus a small proportion of renewable energy technologies.

However, with increasing international pressure to control and reduce CO$_2$, and in particular with the sudden jump in coal consumption in the power sector due to the Accelerated 10,000 MW Program Phase I and portion of Phase II, it seems likely that GoI will choose to adopt a different approach. An extensive modeling exercise was therefore undertaken to examine the impact of various policy measures on future capacity expansion planning decisions in order to achieve significant CO$_2$ emissions reduction.

In this study, ESE with the support of the power sector team of the Roadmap, proposed to conduct Integrated Modeling for Power Sector under Climate Change constraint, as shown in Figure 7 (Hardiv Situmeang (2009)). A similar study has been completed for the Korean Electric Power Research Institute (KEPRI) in April 2008 (Andrew Minchener (2008)). Therefore, this study will be the second of its kind but with many significant differences that reflect the contrasting nature of the energy supply systems in Indonesia and Korea. The latter heavily depends on exported fossil-based fuels for its power sector, such as coal and LNG, while the former consumes its local resources such as coal and to some extent natural gas. In Indonesia, while oil-based fuels constitute the higher fuel cost of about 67% of the electric utility company operational costs, they only contribute about 30% of the total electric energy generation.

Figure 7: Integrated Modeling for Power Sector Scenarios
Source: Hardiv Situmeang (2009)
The results obtained from this model projection will constitute the power sector scenarios and the basis for recommendations to assist GoI in establishing a sustainable energy portfolio within the power sector. The major targets of the integrated model are as follows:

- To build up the basis for the analysis of the CO\textsubscript{2} emissions reduction potential in the power sector;
- To assess sustainable approaches to CO\textsubscript{2} emissions reduction that can be introduced into Indonesia’s power sector;
- To investigate the effects of the several proposed scenarios for CO\textsubscript{2} emissions reduction; and
- To provide advice on strategies and policies for cost-effective CO\textsubscript{2} emission reduction in power sector.

Due to the scope of works to be covered in this study, the study was divided into the following sub-studies:

1. Power Sector and its Primary Energy Supply Roadmap for Java-Bali System (JBS)

2. Power Sector and its Primary Energy Supply Roadmap for Outside JBS

Each sub-study is basically equivalent in weighted assignment despite the fact that majority of power generation plants are in JBS. However, the primary energy sources are predominantly available in Outside JBS. Each sub-study shall be concluded within 3 (three) months of allowable period time.

During each period of 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 have been convened in June, July, August, September and October 2009. A Steering Committee meeting was held in September 2009 to enable the completion of this Final Report for JBS in October 2009. This report has been reviewed and finalized in October 2009. A similar approach was used for the Outside JBS study, and the Final Report was submitted in mid-November 2009.

During the Steering Committee meeting on 8 September 2009, the MEMR presented the climate-change related program and activities that have been proposed to fulfill the need for CO\textsubscript{2} emissions reduction in the power sector. Some of those activities/programs are listed below (Secretary General MEMR (2009)):

- Launching of Second 10,000 MW Accelerated Program which mainly depend on renewable resources such as geothermal and hydropower;
  1. Promoting the use of energy saving lamps;
  2. Replacing oil-based fuels with biofuels, mainly in transportation sector;
  3. Replacing oil-based fuels with CNG for transportation sector;
4. Developing city gas;

5. Converting kerosene-to-LPG program;

6. Establishing mass transport system which depend on natural gas vehicle, such as gaseous-fuel busway;

7. Developing energy self-sustainable village which taps local potential renewable resources such as wind, solar, and biomass; and

8. Reducing the gas flaring (which will be part of the study prepared by the ESE team).

4.1 Output and Activities

Based on the integrated model, modification will be performed as well on the objective function of the power generation optimization method. The least-cost NPV was constrained as well by the carbon value, an emerging challenge (or may be said as opportunity). This inclusion determines the scenario that is best-suited to meet the selected GHG emissions cap, technology, fund, and carbon values. The options to be covered include:

- A base-case scenario;
- A RUPTL scenario
- A scenario based on a sector-wide cap on total CO$_2$ emission with new technology and with/without NPP scenario; and
- A carbon value scenario.

4.2 Project Approach

The project was designed to consider the impact of internal and external factors on the viability of the various options for power generation technology introduction, with an emphasis on the potential for reduction of CO$_2$ emissions in the power sector. The RUPTL 2009 – 2018 has already included some interventions from the Government policies, either on the national energy mix policy and the two fast track accelerated programs of 10,000 MW, so despite the lack of a specific CO$_2$ emissions cap, it cannot be considered as the base-case scenario. Therefore, the base-case scenario shall be first established using the constraints as defined in IPIECA 2007, UNFCCC Resource Guide or IEA 2006 prior to mainstream the emission reduction scenarios into the Medium-term National Development Planning (RPJM) 2010 – 2015. This result can be then extended to be inclusive to the Long-term National Development Planning (RPJP) in accordance with the overall energy mix that is stipulated in Presidential Decree no 5 year 2006.
The approach adopted was to quantify the current power plant status, determine the likely increases in capacity demand for a range of scenarios and then to consider the likely energy mix and technologies required to ensure that such demand could be provided on a sustainable basis. From this position, the outcomes were analyzed and recommendations made.

4.2.1 Impact of 3Es on Emissions

To be successful in reducing GHG emissions, the relation among Indonesia’s Energy Security, Economic Growth and Environment Protection (3E) objectives must be put into an integrated equation that reflects the ultimate objective of sustainable development. The importance of the first two factors and the relationship between these factors has been recognized for decades -- even for Indonesia -- as expressed by the current Minister of Energy and Mineral Resources (Purnomo Yusgiantoro (2000)). The schematic interaction amongst those three aspects is illustrated in Figure 8 (Hardiv Situmeang (2008)) below.

The importance of the 3E factors is undeniable, in particular in the current era of changing climate and shrinking economies. In this period, Malthusian limits to growth are back – and squeezing us painfully, both as global citizens (Robert Engelman (2009)), and locally amongst Indonesian citizens. Whereas more people once meant more ingenuity, more talent and more innovation, nowadays it just seems to mean less for each, and it’s applied to Indonesia as well which its population is now the fourth in the world and steadily increasing.

![Figure 8: Relation between Energy, Environmental and Economic (3Es) Policies on National Energy System](image)

**Figure 8:** Relation between Energy, Environmental and Economic (3Es) Policies on National Energy System
4.2.2 Three Pillars of Climate Policy

Recognizing these three aspects of sustainable development, the pillars for Indonesia’s Climate Policy shall be established in order to ensure the GHG emissions reduction. The pillars are illustrated in Figure 9 (Hardiv Situmeang (2008)) below, as follows:

1. Carbon Pricing;
2. Technology Policy; and
3. Regulation Information

The first two pillars above will be depicted in more detail in the following sub-sections, including sub-section 4.4 on the needs for predictable carbon pricing and sub-section 4.5 on the needs for cleaner fossil fuel system.

![Figure 9: Three (3) Pillars for Supporting the Climate Policy](image)

4.3 Development of Scenarios for Reduction of CO2 Emission

To identify GHG emissions reduction potentials in the Energy Sector, we have used the framework illustrated in Figure 10 (Hardiv Situmeang (2008)) below. Blending historical assumptions based on economic, population data, and so on, with carbon value (pricing) and abatement cost estimates, with the results of Indonesia’s Technology Needs Assessment (TNA) (GoI (2009)), the requirements of the energy sector can be defined. Energy consumption can be divided among transformational activities and end-uses in the Power sub-Sector, Transportation sub-Sector, Industrial sub-Sector and other sub-Sectors. Following a careful analysis of these energy demand sub-sectors, the national energy demand can be projected for use in an integrated model. For the purposes of this study, our focus will be limited to the power sector and its primary energy supplies. Overall illustration of this methodology is depicted
in Figure 10 below.

Furthermore, based on this integrated modeling, the Power Sector projection can be assessed through some iterative simulations in order to identify the proposed strategies, objectives and approaches that need to be further defined through some FGDs.

Figure 10: Simulation process in the Integrated Modeling for CO$_2$ Emission Reduction Scenarios in Energy Sector

4.4 Needs for Predictable Carbon Value

As stated in the previous sub-section, one of the pillars of climate policy is Carbon Value. We note that it is difficult to implement a systematic climate policy without putting an economic value on carbon to stimulate the emission reduction. In this context, Indonesia recognizes that climate change can only be properly addressed by allocating specific funding to efforts to reduce the CO$_2$ emission. In the past, government activities targeting climate change were embedded into traditional development programs, with no specific national budget allocated to climate change; funding was instead mainstreamed into existing programs. Fortunately, the GoI now recognizes the need for carbon value which was proposed in the Blue Print of National Energy Management 2010-2025 and launched in 1 April 2009. In the Development Program, the GoI stipulated in its Main Program no. 4 that a Carbon Tax will be gradually applied so as to promote clean energy development (MEMR (2009)). In the power sector, the government recognizes that the sales of certified emission reduction (CER) from new and renewable energy, carbon trading through the Clean Development Mechanism (CDM) may be introduced into the cost structure of power generation (Bisnis Indonesia (2009)) and (Investor Daily (2009)).
However, with existing pressures on the state budget, it may be unrealistic to rely totally on domestic resources to fund climate change-related activities. International support will play a key role in enabling Indonesia to develop and implement climate change programs while avoiding an economic downturn and addressing the impacts of climate change. Nevertheless, this external cooperation and financing needs to be prepared appropriately and properly managed.

With regard to the external funding, Indonesia prioritizes grant utilization to finance climate change programming. Grants to fund climate change activities can originate directly from bilateral or multilateral donors or via a trust fund. Loan resources can be utilized when grant funding is insufficient. However, the utilization of loans should be the last alternative for Indonesia’s climate change financing. Having relying on and assessing such external funding for the climate change issue, in particular to attract as well the participation of private sector, another approach shall be defined.

In this circumstance, the CO₂ emissions can be discouraged by introducing a penalty mechanism, which is by represented by a carbon value incorporated into the capacity expansion planning scenario. In this scheme, the CO₂ emissions will be reflected by introducing a cost penalty for each power generation option that is proportional to its rate of CO₂ emissions. With this approach, the emitter can predict the carbon value that it would like to reduce in order to reduce or eliminate the cost of the carbon emission penalty. The impacts of carbon values on driving forces in the scenarios are shown in the following Figures 11 and 12 (Hardiv Situmeang (2008)), though there are many other scenarios have been proposed in the literature, for instance, (Sonia Labatt and Rodney White (2007), Joel Makower (2009), Chris Mooney (2009), Auden Schendler (2009), and Richard Asplund (2009)).

In the scenario shown in Figure 11, the investors and financial institutions (i.e., the lenders) may provide financial aid to develop a non-core CO₂ emission project. Without such financial aid, the non-core project will not be realized. In the scenario shown in Figure 12, the investors and financial institutions may provide financial aid to increase the viability of the CO₂ reduction-related project.

![Figure 11: Scenario of Carbon Value Introduction if Carbon is not the Main Driver](image-url)
Without such financial support, the carbon price will be too low, and the project may not be viable. The bottom line is that financial assistance is needed to create a predictable carbon value such that an emissions-reducing investment can be realized. On the global level, the scenario for carbon value introduced into a certain project with carbon credit component may be represented as shown in Figure 13 below.
4.5 Needs for Cleaner Fossil Fuel Systems

In order to reduce GHG emissions while maintaining the reliable electricity supply needed to support national economic development, in light of the relationships among Energy Security, Environment Protection and Economic Growth (3E), selection of technology-specific criteria are needed to guide both supply side and demand side analyses. For this study however, the emphasis is on the electricity supply side technology selection, in particular on power generation, as the main source of CO₂ emissions. In the case of electricity supply by PT PLN (Persero), high priority in selection of power generation technology to support the CO₂ emissions reduction is given to the followings:

1. Advanced coal technology / clean coal technology;
2. Geothermal technology; and
3. Biomass technology, in particular for direct combustion and co-firing applications.

Those technologies are selected due to their ability to support the current government policy, to enhance the utilization of coal in power generation to replace diesel and marine fuel oils up to 2025, and to increase diversity of primary energy supply by expanding the use of renewable energy resources to generate electric power while enhancing national economic development (GoI (2009) and MEMR (2009)). Nonetheless, burning more coal will create large increases in emissions of CO₂ and other air pollutants.

Since 1990, Indonesia has become the world’s second largest coal exporter, with about 80% of produced coal being shipped for consumption by coal-fired power plants mostly in the Far East region. The remaining 20% of local production is consumed in the domestic market. Therefore, reducing and/or offsetting emissions from the power sector should become a main consideration in national energy policy. This situation makes more urgent the need for new extraction and consumption technology. If successfully deployed, innovative technologies could enable the expanded use of coal by gasifying it underground and thus reducing coal’s carbon emissions; or they could allow coal to substitute for natural gas or oil-based products (William Halal (2009)). The technological options include Integrated Gasification with Combined Cycle (IGCC), Coal-to-Liquid (CTL), Underground Coal Gasification (UCG) and Carbon Capture and Sequestration (CCS) (Joel Makower, Ron Pernick and Clint Wilder (2006) and Richard Heinberg (2009)).

As the price of oil climbed during the 2007 and 2008, a hundred or more countries began to suffer, some acutely, from shortages of electricity. In many instances, blackouts occurred due (Richard Heinberg (2009)). This phenomenon simply reflects the role of oil in world energy supply, which can’t be easily changed. Although prices fell from close to USD $150/bbl in the summer of 2008 to under USD $34/bbl last winter, the price of oil more than doubled by Spring 2009 and was hovering around USD $60/bbl from July 2009 until the beginning of 2010.
The only reason the fall in oil prices hasn’t been deeper is that many people expect a continuing economic boom in China, fueled by Beijing’s aggressive economic stimulus plans. These days any hint of good news for China – even a slowdown in the decline of manufacturing – can unleash whoops of joy in the oil trading pits. However, there is good reason to believe that the world has just passed a turning point. The last boom in oil prices collapsed in 1979, when total spending on oil exceeded 7% of the global GDP. Last year in 2008, spending on oil hit a similar share of global GDP; and the price has since fallen by more than two thirds (Ruchir Sharma (2009)).

Most oil industry analysts expect high prices to return soon, along with economic recovery. This is probably a mistaken view. More likely, the price of oil and other commodities will be range-bound again (Edward Morse (2009)). However, a group of oil observers consider this volatility to be part of the “New Age of Oil.” Volatility also makes it more difficult to plan future energy investments, whether in oil and natural gas or in renewable and alternative fuels (Daniel Yergin (2009)). Yergin claims that although Cushing, Oklahoma (the gathering point for the light, sweet crude oil known as West Texas Intermediate – or just WTI), looks much the same as it did when his seminal publication The Prize (Daniel Yergin (1992)) first came out, the world of oil looks very different. Many talk today about having passed the inflection point of “peak oil,” after which the production of conventional oil resources are bound to decline Paul Roberts (2005), Kenneth Deffeyes (2005) and Mathew Simmons (2005). If so, others reply, the current period will involve a very long “goodbye.”

Either way, this new oil age has developed a split personality – with oil viewed both as a physical commodity and also as a financial asset Jeff Rubin (2009). Some even suggest that oil pricing will be a tactical element in a new form of global economic warfare (James Norman (2009)). Three defining characteristic of the new age of oil are:

1. globalization of the demand for oil, a vast shift from even a decade ago;
2. rise of climate change as a political factor shaping decisions in the future on how people use oil, and how much of it, and
3. a global drive for new technologies that could dramatically affect oil along with the rest of the energy portfolio.

In the case of Indonesia, indeed, the use of oil-based fuels (mainly HSD and MFO) have not deserted the annual budget of PT PLN (Persero) despite its contribution of about 30% to electricity production, as it absorbs almost 70% of the total annual fuel costs of this power company. Fuel diversification has become essential and there are two strong candidates for the diversification of primary energy supply, namely, natural gas (including non-conventional resources such as coalbed methane/CBM) and hydro power (including large-scale dams with reservoirs or mini- and micro-hydro). Neither of these energy resources is included in among priorities for new technology selection due to the fact that both technologies are commercially available. The main reasons that we have put these two technologies on slow pace of
utilization, despite their huge potentials and obvious capability to reduce CO\textsubscript{2} emission, are the lack of infrastructure support, regulation, and financial incentives.

Nonetheless, natural gas offers clear advantages over other fossil fuels. It burns cleaner than coal, and emits only 50 percent as CO\textsubscript{2} per unit of heat supplied. Environmentalists have tended to prefer natural gas to other fossil fuels because its combustion produces the fewest pollutants, including CO\textsubscript{2} (Julian Darley (2004)).

The arguments in favor of using more natural gas and less coal and petroleum are, at least at first glance, straightforward. Coal-fired power plants generate, for instance about 50% of the electricity used in the US, but they produce 82% of the US power industry’s CO\textsubscript{2} emissions. Natural gas is increasingly important for electricity generation and for many industrial purposes in the US, including the synthesis of chemical fertilizers. In addition, in contrast to oil, which is largely imported, domestically-supplied natural gas has inherent advantages for the United States from a national energy security perspective. These and other advantages have combined to make natural gas the second most important energy source in the US after oil.

From a technology point of view, natural gas and renewable sources, such as wind and solar, could complement each other well. Fast-responding natural gas-fired turbines could be used to generate electricity when the wind stops blowing or clouds block the sun. It’s also easy to substitute natural gas for gasoline or diesel fuel in cars, buses and trucks, again from a technological perspective. But the economic and political relationship between natural gas and renewable energy resources are more complicated. Using natural gas in vehicles would reduce greenhouse gas emissions, but not nearly as much as replacing coal in power generation. A natural gas car emits about 25% less CO\textsubscript{2} than a similar gasoline-powered vehicle, but since transportation accounts for only about one-third of US GHG emissions, even switching over all the country’s vehicles to natural gas would reduce overall emissions by just 8% (David Rotman (2009)).

For Indonesia, natural gas is the second largest energy resource, accounting for about 1.7% of the world’s proven reserves. In addition, CBM has the potential to supply around 453 TCF, as shown in Table 2 (Meirios Moechtar (2009a)). The main obstacles to the utilization of natural gas are lack of pipeline infrastructure and limited logistic facilities (in the case of LNG and CNG). Several factors contribute to the limited utilization of CBM resources including regulatory gaps and lack of detailed and verified geological information on the distribution of existing resources.
Table 2: Fossil Energy Reserves and Production in 2008

<table>
<thead>
<tr>
<th>FOSSIL ENERGY</th>
<th>RESOURCES</th>
<th>RESERVES</th>
<th>PRODUCTION</th>
<th>RSV/PROD RATIO (YEARS)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>56.6 billion barrels</td>
<td>8.2 billion barrels</td>
<td>357 million barrels</td>
<td>23</td>
</tr>
<tr>
<td>Gas</td>
<td>334.5 TSCF</td>
<td>170 TSCF</td>
<td>2.7 TSCF</td>
<td>63</td>
</tr>
<tr>
<td>Coal</td>
<td>104.8 billion tons</td>
<td>18.8 billion tons</td>
<td>229.2 million tons</td>
<td>82</td>
</tr>
<tr>
<td>Coal Bed Methane (CBM)</td>
<td>453 TSCF</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*) Assumes no new exploration activity and no new field discoveries

In terms of hydropower potential, Indonesia has the 5th largest freshwater resource in the world (Meirios Moechtar (2009b), Klaus Brendow (2009) and Tora Lohan (2009)). Recent estimates suggest a total hydropower resource potential of about 76 GWe in Indonesia. To date, however, Indonesia has been able to develop only about 4.2 GW of hydropower, as shown in Table 3 (Meirios Moechtar (2009a)). This can be compared to Brazil, which has the largest freshwater hydropower resource in the world (approximately 104 GWe), and has tapped around 77 GWe to date. The development of large-scale reservoir hydropower in Indonesia has been hindered by several constraints including limits on land clearance for reservoir development and conflicts with existing human settlements. In the case of mini- and micro-hydropower, the principal barriers revolve around issues of commercial viability. The complex relationship between water and energy, and to some extent environmental issues are undeniable and some illustration about it can be seen in Michael Webber (2008) and recently discussed on the blog (IEEE (2009)).

Table 3: Non-Fossil Energy Reserves and Installed Capacity in 2008

<table>
<thead>
<tr>
<th>NON-FOSSIL ENERGY</th>
<th>RESOURCES</th>
<th>INSTALLED CAPACITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>75.670 MW (e.q. 845 million BOE)</td>
<td>4.200 MW</td>
</tr>
<tr>
<td>Geothermal</td>
<td>27.000 MW (e.q. 219 million BOE)</td>
<td>1.052 MW</td>
</tr>
<tr>
<td>Mini/Micro Hydro</td>
<td>450 MW</td>
<td>84 MW</td>
</tr>
<tr>
<td>Biomass</td>
<td>49.810 MW</td>
<td>300 MW</td>
</tr>
<tr>
<td>Solar</td>
<td>4.80 kWh/m²/day</td>
<td>8 MW</td>
</tr>
<tr>
<td>Wind</td>
<td>9.290 MW</td>
<td>0.5 MW</td>
</tr>
<tr>
<td>Uranium</td>
<td>3.000 MW (e.q. 24,112 ton) for 11 year*</td>
<td>30 MW</td>
</tr>
</tbody>
</table>

*) The following sub-section illustrates some of the recent developments that affect proposed priority technologies.
4.5.1 Clean Coal Technology

In last decade, several clean coal technologies have been proposed and successfully implemented to supply electricity from a coal-fired power plant. These Clean Coal Technologies (CCT) can involve a coal upgrading technology in which the calorific value of a low rank coal is increased by removing the moisture content and other impurities, or a subcritical, fluidized-bed combustion technology. The most common example of this latter technology incorporates circulating fluidized-bed combustion (CFBC). These two technologies are highly relevant for advancing the current Indonesian policy (GoI (2009)) and electricity sector planning goals (PT PLN (Persero) (2009)). Either or both could help to increase utilization of Indonesia’s low rank coal (LRC) resources, which comprise about 60% total coal resources in Indonesia. Many commercial variations of these clean coal technologies have been introduced; there is even a planner’s guide offered by the World Bank to assist in selecting the right clean coal technology for each application (Karin Oskarsson, et al. (1997)).

Other CCTs, including supercritical, pulverized coal (PC) and ultra-supercritical PC may become important in the future and could further stimulate the utilization of medium-rank coal. Some of these may be applied as an alternative to the proposed decommissioning of old, inefficient coal-fired power plant in the Java-Bali System (JBS). Such decommissioning has been proposed in the RUPTL, for up to 1,000 MWe of existing capacity. The development and commercial prospects of these supercritical and ultra-supercritical PC plants have been reported in many publications (for example, Scott Smouse (2009) and Steve Mirsky (2009)). These advanced, clean coal technologies can reduce environmental impact and CO₂ emissions compared to the conventional PC technology that has widely operated in Indonesia during the last one decade. However, even these advanced coal-fired power plant will emit a large quantity of CO₂ emissions, and will contribute significantly to the increased level of GHGs in the atmosphere. In the medium-term (10 years), supercritical and ultra-supercritical PC power plant technology should be introduced to Java-Bali System, and may be introduced in the Sumatra system in the foreseeable future.

Implementation of CO₂ capture and sequestration technology (CCS) in the near future may further reduce the large quantity of GHG emissions from subcritical PC power plants. The schematic diagram of a CCS technology is illustrated in Figure 14, while the costs of various CCS components are as tabulated in Table 4 (Hardiv Situmeang (2008)). CCS technology in fact, has been proposed, demonstrated and reported by many institutions and researchers, for example WEC (2007), IEA Greenhouse Gas R&D Programme (2007), IEA Greenhouse Gas R&D Programme (2008), David Biello (2009), Robert Socolow (2005), Bill McKibben (2007), Joel Kurtzman (2009), Joel Makower, Ron Pernick and Clint Wilder (2006) and Richard Heinberg (2009).
There are some potential aquifers, onshore and offshore, available in Sumatra and Kalimantan and north of Jakarta that may be suitable for large-scale carbon sequestration, if coupled with mine-mouth coal power plants or natural gas, combined cycle (NGCC) power plants. As proposed by LEMIGAS (Hardiv Situmeang (2008)), the aquifers in South Sumatra and South Kalimantan are suitable for use in conjunction with mine mouth coal-fired power plants, while the offshore aquifer in North Jakarta could be allocated for use with the proposed NGCC power plant, as illustrated in Figure 15. Besides the availability of natural geological structures such as the aquifers, CO₂ injection may create an important business opportunity, as it can be utilized with either natural gas, oil or even CBM in conjunction with Enhanced Recovery, through application of advanced techniques for EGR (Enhance Gas Recovery), EOR (Enhance Oil Recovery) or Enhance CBM Recovery (ECBMR). Commercial experience with EOR schemes proven economical in many depleting oil fields, effectively increasing oil production.
Table 4: Costs of Various CCS Components

<table>
<thead>
<tr>
<th>CCS System Components</th>
<th>Cost Range</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>From a coal or gas fired power plant</td>
<td>15 – 75 US$/tCO₂</td>
<td>Net costs of captured CO₂ compared to the same plant without capture</td>
</tr>
<tr>
<td>From hydrogen &amp; ammonia production or gas processing</td>
<td>5 – 55 US$/tCO₂</td>
<td>Applies to high-purity sources requiring simple drying and compression.</td>
</tr>
<tr>
<td>From other industrial sources</td>
<td>25 – 115 US$/tCO₂</td>
<td>Range reflects use of a number of different technologies and fuels.</td>
</tr>
<tr>
<td>Transportation</td>
<td>1 – 8 US$/tCO₂</td>
<td>Per 250 km pipeline or shipping for mass flow rates of 5 (high end) to 40 (low end) MtCO₂/yr.</td>
</tr>
<tr>
<td>Storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geological storage*</td>
<td>0.5 – 8 US$/tCO₂</td>
<td>Excluding potential revenues from EOR or Enhanced Coal Bed Methane (ECBM).</td>
</tr>
<tr>
<td>Geological storage: monitoring &amp; verification</td>
<td>0.1 – 0.3 US$/tCO₂</td>
<td>This covers pre-injection, injection, and post injection monitoring, and depends on the regulatory requirements.</td>
</tr>
<tr>
<td>Ocean storage</td>
<td>5 – 30 US$/tCO₂</td>
<td>Including offshore transportation of 100-500 km, excluding monitoring and verification.</td>
</tr>
</tbody>
</table>

* Over the long-term, there may be additional costs for remediation and liabilities; Source: Carbon Dioxide Capture and Storage, Summary for Policymakers and Technical Summary, IPCC, 2006.

Last but not least, Integrated Gasification Combined Cycle (IGCC) technology remains less competitive compared to other CCTs due to the high investment cost and the state of development of the technology.
itself. However, the integration of IGCC technology with other energy production facilities, such as an oil refinery, will improve its economics.

4.5.2 Geothermal and Other New and Renewable Sources

Geothermal is considered a champion technology for renewable energy in Indonesia. It will be selected as a high priority for development due to the abundance of the resource but low utilization level. Increased use of these resources is highly consistent with GOI policy. The GOI is planning to enhance geothermal development by as much as 6,000 – 8,000 MWe over the next 10 years. With the world's largest geothermal resource, estimated at about 27,000 MWe and current installed capacity of about 1,052 MW, Indonesia will promote the continued development of geothermal technology. (See Table 3 below.)

The GOI launched its blueprint for geothermal development in 2006 (DGMCG (2008)). This ambitious plan will require international support in order to overcome the main barrier that deters the geothermal power development, the lack of an adequate policy framework that incorporates the environmental benefits of this renewable energy utilization, and provides adequate economic incentives to overcome the perception of technology risk. Despite the Geothermal Law in 2003 (Law no. 27/2003), which mandates that development of the future 22,000 MWe of geothermal power plant, up to this year (2010), no more than 300 MWe of new geothermal power capacity has been put into operation.

Other than geothermal energy, biofuels are the most prominent renewable energy technology that the GOI is likely to develop as a complement to, but not completely substitute for, oil. Biofuels are categorized into two main types: bioethanol, a fermentation product based on the digestion of crops by bacteria or yeast; and biodiesel, which is produced through a chemical process called trans-esterification. The crops used today to make bioethanol are mainly food staples, such as corn, palm oil, and soybean. There use as “energy crops” has created conflict and controversy over the diversion food as feedstock for liquid fuels. On the global stage, and especially in the US, corn has been the raw material of choice for manufacturing bioethanol because fermentation is a proven process and because of the availability of US government subsidies to bioethanol producers.

Most scientists today agree that the ethanol experiment hasn’t gone well. It takes about 21 pounds of corn to produce just one gallon of ethanol. And farming that corn requires half a gallon of fossil fuels as inputs to the farming enterprise. As a result, the production of corn-based fuels leads to price rises and food shortages. In addition, the process used to produce bioethanol is also inefficient and unlikely to reduce US oil import requirements. (Melinda Werner (2009) and National Geographic Collector’s Edition (2009)).

Brasilian producers have pioneered an alternative approach to producing bioethanol using sugarcane as the principal feedstock. Brasil has been burning some ethanol in the vehicles since the 1920s, but by the 1970s it was importing 75% of its oil (Ozires Silva and Decio Fischetti (2008)). When the OPEC...
oil embargo crippled the nation’s economy, the Brazilian dictator, General Ernesto Geisel, decided to kick the country’s oil habit. The general heavily subsidized the construction of new ethanol plants. He directed the state-owned oil company, PetroBras, to install ethanol tanks and fueling stations around the country. In addition, the government offered tax incentives to Brazilian carmakers as incentives to crank out cars designed to burn neat (100%) ethanol. By the mid-1980s, nearly all the cars sold in Brazil ran exclusively on alcool, i.e., bioethanol derived from sugarcane. Today, nearly 85% of cars sold in Brazil are flex-fuel vehicles, able to use gasoline, ethanol, or a blend of the two. (Joel K. Bourne, Jr. (2007)).

Sugarcane yields 6,000 to 8,000 liters of ethanol per hectare, more than twice as much as corn. Brazilian-based Dedini, the world leading EPC of sugarcane mills, envisions designs capable of producing 12,050 liters of hydrated ethanol per ha by 2011, using their DHR process (Meirios Moechtar (2009c)). Furthermore, most of Brazil’s usinas (sugar mills) are self-generating in terms of their on-site electricity demand; they consume no fossil fuel or electricity from the grid. To meet their steam and heat loads, these burn bagasse (cane waste) and typically generate a slight surplus of power, which can be sold into the nation’s interconnected electricity grid.

The second most important type of liquid biofuel is biodiesel. In the early usage of biodiesel, most people tried to use plant oil as a direct substitute for petroleum diesel in diesel engines. They soon realized that this practise was not especially good for the diesel engines. The problem was that, for almost a century, diesel engines had been gradually developed, adapted, and fine-tuned to the combustion characteristics of petroleum-based diesel fuel. One of the main problems with using straight plant or vegetable oil in a modern diesel engine is that the plant or vegetable oil is thicker, or more viscous than petroleum-based diesel. This is due to the fact that vegetable oil contains glycerin – a thick, sticky substance – in its chemical mixture. Every vegetable oil molecule is composed of fatty acid chains, so called esters, that is attached to a molecule of glycerin. In order to use plant or vegetable oils successfully in a modern diesel engine, the vegetable oil must first undergo a process called transesterification, which transforms the naturally occurring esters into a thinner form that is more suitable for use as a fuel for the modern diesel engine. Once separated from the glycerin molecules by the transesterification process, the alkyl ester chains are converted to a new form called biodiesel (Greg Pahl (2005)). The most common vegetable oils used in biodiesel production today are palm oil, canola oil, and soybean oil.

Those two types of biofuels, bioethanol and biodiesel, are called first generation biofuels and they are derived entirely from crops that can be used for human consumption. The only way to reap the benefits of biofuels without squeezing the food supply is to take food out of the picture. This would mean avoiding the use of corn kernels and sugarcane juice as the feedstocks for ethanol, and instead making alcohol from stalks, leaves and sawdust, or from non-food plants like switchgrass. These materials have a high proportion of cellulose fibers in their leaves and stems. Cellulosic fibers are the tough, long-chain molecules that make up plant cell walls. Breaking up those chains and fermenting the resulting sugars could yield a cornucopia of biofuels, without competing with food crops, leading to a new product called cellulosic alcohol (Joel K. Bourne, Jr. (2007))
Cellulosic alcohols are considered as the first of the second generation of biofuels, and may include such forms as butanol, isopentol and hexadecane. These new forms of cellulosic alcohol can contain more energy per unit volume than does corn-based ethanol; a car driving on a liter of ethanol will go only 67% as far as a car fueled by a liter of gasoline; on butanol the same car can go 80% as far as it would on gasoline. And unlike ethanol, these second generation fuels can be used directly in jet and diesel engines (Melinda Werner (2009)). The driving force behind cellulosic alcohol development is is the potential make it as cheap as gasoline but without taking food crops out of the market. So far, only a few pilot plants are making ethanol from cellulose in the US and none of these are operating at commercial scale. Dedini Brazil intends to make a commercial-scale plant in Brasil and to have it in operation by 2011 ((Meirios Moechtar (2009c)).

Now there is a prospect for third generation biofuels. Biofuels based on algae - single celled pond scum –is lead-free, almost sulfur-free, biodegradable and it can run many modern diesel engines. In addition, biodiesel produced from algae offer renewed hope for creating liquid fuels that can be produced at costs competitive with petroleum-based fuels and without reliance on food-related crops. Algae can grow in wastewater, even seawater, requiring little more than sunlight and CO₂ to flourish. Furthermore, while each hectare of corn produces around 3,000 liters of ethanol per year and soybean around 600 liters of biodiesel, algae can produce about 50,000 liter of biofuels each year. While corn and soybeans can be harvested in most environments just once a year, algae can basically be harvested every day. Thus, algae, which don’t require good agricultural land or lots of fresh water, or fossil fuel-rich fertilizer to thrive and grow happily, may become a part of the solution to Indonesia’s energy challenge (Michael Grunwald (2009)).

The relative yields of each type of vegetable oil that can be converted into biofuel is illustrated in Figure 16, while the evolution of biofuels is summarized in Table 5 ((Meirios Moechtar (2009c))).
The main obstacle to the commercial development of algae today is the capital cost of establishing a hectare of algae ponds. These capital costs are much higher than those for conventional vegetable oil crops that could be used to produce biodiesel or bioethanol. On the other hand, algae ponds require only a fraction of the amount of dedicated land area to produce a given volume of liquid fuel. That is a critical
advantage at a time when wide-spread biofuel production considered a major contributor to tropical deforestation and food shortages in developing countries, including in Indonesia.

Biodiesel also lessens global warming because it’s made from plants that absorb CO₂ while they are growing, thus compensating for the CO₂ released when the fuel is burned. One IEA study in 2006 includes maps of the global distribution of the three essential nutrient sources (i.e., for CO₂, wastewater, and sunshine), as well as maps of appropriate climates, flat and affordable lands, and lands with the required infrastructure to produce biofuels commercially (Robert McIntyre (2009)). A composite map of these resources shows that the greatest production potential for this technology is in China, southeast Asia (Indonesia), India, western Africa and the southeastern US. In some locations, such as the one in the territory of the Arizona Public Services utility, algae could extract the needed CO₂ from flue-gas emissions piped from a nearby coal-fired power plant.

Currently, the favored method for reducing CO₂ emission from power plants is the emerging technology of carbon capture with geological sequestration (CCS). In its study, the IEA estimates that CCS could significantly reduce CO₂ emissions by the year 2050, but would add USD $200 – 500 million (in today’s dollars) to the cost of a major new power plant built to incorporate this technology. At the US DOE facility in New Mexico, algae in mixed ponds consume more than 90% of injected CO₂. And most recent studies show that algae can also remove most of the nitrogen oxides (NOₓ), plus some heavy metals and sulfur oxides (SOₓ). However, it is worth noting that the ability of algae to consume CO₂ decreases in winter and ceases at night.

Finally, on the domestic applications of biodiesel, Indonesian government has given its commitment to utilize the first generation biofuels through its regulation on mandatory utilization biofuels, as depicted in Tables 6 and 7 (Saryono Hadiwidjoyo (2009)), below.

Table 6: Mandatory for Biodiesel Utilization

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Household</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Not determined yet</td>
</tr>
<tr>
<td>PSO Transportation</td>
<td>1 % (existing)</td>
<td>1 %</td>
<td>2.5 %</td>
<td>5 %</td>
<td>10 %</td>
<td>20 %</td>
<td>* Based on Total Needs</td>
</tr>
<tr>
<td>Non PSO Transportation</td>
<td>-</td>
<td>1 %</td>
<td>3 %</td>
<td>7 %</td>
<td>10 %</td>
<td>20 %</td>
<td></td>
</tr>
<tr>
<td>Industry and Commercial</td>
<td>2.5 %</td>
<td>2.5 %</td>
<td>5 %</td>
<td>10 %</td>
<td>15 %</td>
<td>20 %</td>
<td>* Based on Total Needs</td>
</tr>
<tr>
<td>Power Plant</td>
<td>0.1 %</td>
<td>0.25 %</td>
<td>1 %</td>
<td>10 %</td>
<td>15 %</td>
<td>20 %</td>
<td>* Based on Total Needs</td>
</tr>
</tbody>
</table>

** Specification is adjusted in line with global specification and domestic interests
Finally, if we would like to reduce GHG emissions, it seems that atomic energy which is virtually emission free (after the Uranium fuel is enriched) could be part of the solution. But nuclear power, unfortunately cannot fix the climate crisis because of the length of time it takes to build new light-water reactors. The OECD countries will need to make major cuts in emissions within a decade, and the first new US reactor is only scheduled for 2017 – unless it gets delayed in construction, like every US reactor before it has been. Elsewhere in the developed world, most of the talk about a nuclear revival has remained just talk. There’s no Western country with more than one nuclear plant under construction, and scores of existing plants will be scheduled for decommissioning in the coming decade. So there’s no way nuclear could make more than a small dent in electricity-related CO₂ emissions before 2020 (Michael Grunwald (2009)). The debate about building new nuclear power plants has been occurring in Indonesia for the last two decades with no sign of imminent resolution. This remains true despite the best efforts of many in the GOI to put new nuclear plants into the national electricity development plan and the national energy mix.

**Table 7: Mandatory for Bioethanol Utilization**

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<tbody>
<tr>
<td>Household</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Not determined yet</td>
</tr>
<tr>
<td>PSO Transportation</td>
<td>3 % (existing)</td>
<td>1 %</td>
<td>3 %</td>
<td>5 %</td>
<td>10 %</td>
<td>15 %</td>
<td>* Based on Total Needs</td>
</tr>
<tr>
<td>Non PSO Transportation</td>
<td>5 % (existing)</td>
<td>5 %</td>
<td>7 %</td>
<td>10 %</td>
<td>12 %</td>
<td>15 %</td>
<td>* Based on Total Needs</td>
</tr>
<tr>
<td>Industry and Commercial</td>
<td>-</td>
<td>5 %</td>
<td>7 %</td>
<td>10 %</td>
<td>12 %</td>
<td>15 %</td>
<td>* Based on Total Needs</td>
</tr>
<tr>
<td>Power Plant</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Not determined yet</td>
</tr>
</tbody>
</table>

** Specification is adjusted in line with global specification and domestic interests**

Anyone developing a new nuclear power plant may face two additional issues. First of all, any new nuclear construction would involve “merchant generators” – independent companies rather than large, monolithic utilities. Building nuclear power plants was simpler two decades ago, because utilities could build their own plants and could usually pass costs through to captive consumers no matter how large the cost overruns became. But in many countries, as in the US, the public service commission has separated the generation of electricity from power transmission & distribution, and there’s no longer cushion of cross-subsidies to support the management of a generation company that guesses wrong. New nuclear plants must sell electricity at whatever price the market will bear (Richard Galwin and Georges Charpark (2001)). And the owners of such plants may find it very difficult to compete with “merchant” plants burning natural gas.
Second, the potential of carbon regulation adds even more guesswork to the calculus used to estimate future fuel and electricity prices. Some governments are considering proposals to apply a flat tax on emissions or to institute a cap-and-trade system that would create an effective surcharge for emissions. A charge of USD $10/MtCO₂ would raise the consumer price of electricity by about a penny per kWh. So an addition of USD $20 or USD $30 per MtCO₂ would create a huge advantage for carbon free technologies such as nuclear power, compared to electricity generated from (Matthew Wald (2008)). In responding to such a problem and opportunity, the potential nuclear power developer will probably want to rely on standardized plant designs, identical right down to the carpeting and wallpaper. These standardized units could be manufactured and approved for less than the custom-designed reactors of the past. Modernization of nuclear power is also essential as the current plants ran only about 60% of the time when they were new and were assumed to have only a 40-year life. The next generation of nuclear power plants is expected to run more than 90% of the hours in a year and to operate for 60 years or longer.
5

Power System Modeling
This study of the power sector was designed to optimize the capacity expansion plan for JBS among the available primary energy supplies and was conducted according to the following organization:

### 5.1 ESE and Its Working Team

The ESE and its Working Team operated together for a period of about 6 months in pursuing this study. The organization for this study is as depicted in Figure 17 below.

![Figure 17: ESE and Its Working Team and Their Expertises](image)

### 5.2 Model Development Targets

The major targets of the model development were:

- to build up the basis for the analysis of CO$_2$ emissions reduction potential in the Indonesian power sector;
- to assess sustainable ways for CO$_2$ emissions reduction to be achieved by the Indonesian power sector;
- to investigate the impacts of several proposed scenarios for CO$_2$ emissions reduction;
- to provide advice on strategies and policies for cost effective CO$_2$ emissions reduction in the Indonesian power sector.

### 5.3 Stages of Model Development

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 expert team proceeded to develop their model in accordance with the approach set out in Figures 7 and 10 above.
Following this initial simulation scheme, the ESE team sought assistance from the Division of Planning of PT PLN (Persero). WASP experts helped to guide them in the acquisition of special input data, data processing capability, establishment of Indonesian Reference Power System (IRPS), and scenarios. With the support of these PT PLN (Persero)’s experts, the ESE team put in the data to the ANSWER data sheet, established the prototype IRPS, and modeled several scenarios for CO₂ mitigation. Subsequently, with further assistance from the PT PLN (Persero) in the form 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 that fits the baseline criteria as defined IPIECA 2007, UNFCCC Resource Guide or IEA 2006 that could be used as a reference model for the comparison with CO₂ emission reduction scenarios;
- development of a Base-case scenario model that fits the current National Electricity Master Plan;
- design of Power Systems based on PT PLN (Persero)’s existing RUPTL;
- development of CO₂ emissions reduction scenarios, including the introduction of a total carbon emission cap, the introduction of new power generation technologies (for example, advanced PF and CCS), additional nuclear power plants, and the imposition of a carbon value;
- investigation of the optimum scenario, which can reduce CO₂ emissions in the most cost-effective manner in the context of the Indonesian power sector; and
- recommendation of strategies and policies needed to put the optimum scenario into practice.

5.4 Model Scenarios

The WASP model was used to evaluate four scenarios, which were considered the most likely future options by the Power Sector team. (For details on the scenarios, please see sub-sections 4.1. and 4.2 above.)

The Base-case scenario assumes that electricity development follows the criteria defined in IPIECA 2007, UNFCCC Resource Guide and IEA 2006 (Hardiv Situmeang (2009)). The RUPTL scenario is maintained as a foundation for the base-case with the inclusion of CO₂ emission reduction scenario which has been proposed by the government. The New Technology Scenario considers the introduction of new power generation technologies which are expected to be used in the future, including CCS technology. The Carbon Tax Scenario is a scenario in which a tax on CO₂ emissions is levied on the power sector. The Total Carbon Emission Cap Scenario reflects the setting of a maximum level of CO₂ emissions for the power sector.

Once the more promising scenarios were identified, possible strategies and policies were considered that might allow such scenarios to be implemented successfully. As part of this study, the research team also
considered the correlation among factors affecting CO₂ emissions reduction by the Indonesian electricity industry. An overview of the findings of this modeling exercise is below.

5.5 Base-case Scenario Results

The main objective of the modeling in this study was to analyze the influence of carbon emissions mitigation options on the development of the Indonesian national electricity system for the years 2009 – 2020. Therefore, the scope of this first part of the study was limited to the PT PLN (Persero) electricity generation and supply system and its projected electricity demand, in particular in the Java – Bali System. The period of analysis was set at originally set at ten years from 2009 to 2018 and then was extended for two more years to 2020.

<table>
<thead>
<tr>
<th>Description of Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base-case Scenario</strong></td>
</tr>
<tr>
<td>This scenario is based on a projected level of future emissions against which reduction by project activities might be calculated; this scenario represents the emissions that would 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 an optimization program designed to identify the least-cost generation capacity expansion plan.</td>
</tr>
<tr>
<td><strong>RUPTL Scenario</strong></td>
</tr>
<tr>
<td>Only technologies either commercially available in 2009 or included in the Master Plan for Electricity Supply (RUPTL) 2009 - 2018 Plan were included in this scenario. Current trends for the introduction of renewable energy technologies (mainly geothermal) were reflected in this scenario. Constraints for some technologies were set to reflect expected resource constraints and geographical limits.</td>
</tr>
<tr>
<td><strong>Total Carbon Emission Cap with New Technologies and with/without NPP Scenario</strong></td>
</tr>
<tr>
<td>Four likely and speculative new technologies using coal and gas were added to the Base-case scenario for application in this scenario. Retrofitting of currently available technologies is also included in this scenario as well as the introduction of CCS technology. This scenario was used to test total carbon emission caps, of 10, 20 and 30 percents compared to the base-case scenario, as these were imposed on the RUPTL scenario with New Technology; and with or without additional Nuclear Power Plants (NPP). The impact of a total carbon emissions cap was analyzed when higher generation limit was allowed for geothermal power plants.</td>
</tr>
<tr>
<td><strong>Carbon Value Scenario</strong></td>
</tr>
<tr>
<td>Various carbon values (e.g., USD $25 and $50/ tCO₂) were imposed on both the Base-case scenario and the Total Carbon Emission Cap with New Technologies and with or without NPP Scenario.</td>
</tr>
</tbody>
</table>
Input data to establish the Base-case scenario were obtained from government publications, such as the Indonesian Statistical Yearbooks published by BPS (Central Bureau of Statistics(?)), RUKN and RUPTL. Overseas input data were obtained from IEA and US DOE reports. Therefore, the basic assumptions used in this Base-case scenario were built are tabulated in Table 9 below.

### Table 9: Basic Assumptions for the Simulation

<table>
<thead>
<tr>
<th>Macro-economic Assumptions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic growth at 5 – 6 %/pa</td>
</tr>
<tr>
<td>Electricity consumption growth at 9 – 10 %pa</td>
</tr>
<tr>
<td>Population growth at 1-1.5 %/pa</td>
</tr>
<tr>
<td>Fuel price:</td>
</tr>
<tr>
<td>Coal USD 40-60/Ton</td>
</tr>
<tr>
<td>Oil (ICP) USD 70-80/bbl</td>
</tr>
<tr>
<td>Natural Gas USD 3 – 5/MMBTU</td>
</tr>
<tr>
<td>LNG USD 10/MMBTU</td>
</tr>
<tr>
<td>Uranium USD 200/kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Micro-economic Assumptions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPC Cost of Power Plant (USD/kW)</td>
</tr>
<tr>
<td>PLTU Conventional 1,548</td>
</tr>
<tr>
<td>PLTU Supercritical 1,653</td>
</tr>
<tr>
<td>PLTU SC + CCS 3,011</td>
</tr>
<tr>
<td>PLTGU Conventional 850</td>
</tr>
<tr>
<td>PLTGU Conv. + CCS 1,165</td>
</tr>
<tr>
<td>PLTG Oil-fired 650</td>
</tr>
<tr>
<td>PLTN (NPP) 3,600</td>
</tr>
<tr>
<td>PLTP (Geothermal) 1,500</td>
</tr>
</tbody>
</table>

These data were input to the integrated model as depicted in Figure 7, while the train of calculations inside the WASP model was as shown in Figure 18. Note that this Base-case scenario was developed from the assumption that the current conditions and plan of the electricity industry would continue without change as defined in the IPIECA 2007 or UNFCCC Resource Guide for the Baseline scenario. This Basecase scenario uses existing national data and projections of future electricity demand as well as of the energy mix by sources, constrained only by the need to find the lowest NPV of generation-related costs for the full scenario period. This scenario did not include any carbon emissions mitigation efforts such as a higher limit on renewable energy generation, the introduction of new and advanced power technologies, a market price for carbon emissions and a subsidy for new nuclear power plants. It can be easily predicted that coal-fired power plants will dominate the energy mix of national electricity in this scenario, beginning in 2009 and running straight through to the end of the observation period in 2020. The mix of fuels used in the power sector is illustrated in Figure 19. The principle results of the Base-case analysis are as follows:

1. An additional 27,000 MWe of coal-fired PLTU is introduced into the national electric grid, making coal combustion the source of about 72.8% of total power generation by 2020.
2. Annual CO₂ emissions from the power reach about 236 MtCO₂ by 2020.

3. The capital investment required to implement this scenario is estimated to be about USD $62.57 billion by 2020.

**Figure 18: Calculation of CO₂ Emissions Reduction in Integrated Model**

The analysis of this Base-case scenario provided information about the likely power generation capacity usage for each type of power plant fuel type that would be needed to meet the generation demand shown at the top figure of Figure 19. The total power demand required by the system is shown in the table presented below the chart in Figure 19. This table indicates that, by 2020, coal-fired power plants would provide about 73% of electric energy (in GWh) that is required to meet load on the system. The next largest share of demand will be served by gas-fired power plants (~21%), followed by hydro (3.8%), and geothermal units (2.5%).
5.6 RUPTL Scenario Results

This scenario is basically the one that has been published by PT PLN (Persero) on 19 January 2009. The only modification applied to this scenario is that its time horizon has been expanded from the original end-year, 2018, to year 2020. The main difference between this RUPTL scenario and Base-case scenario is the inclusion of Government Policies on energy, such as the revised national energy mix, plus two accelerated programs, each of which will add 10,000 MWe to the Indonesian power system. The results of the analysis of this RUPTL scenario are as follows, and are depicted graphically in Figure 20 below:
1. The contribution of coal-fired power plants to the RUPTL scenario decreases by 7% from the base-case scenario as these plants are displaced in the load dispatch order by the new geothermal power plants.

2. An additional 23,000 MWe of coal-fired conventional generating capacity is installed on the national grid; its contribution represents about 65.6% of total electricity supply by 2020, while the 3,500 MWe of new geothermal capacity supplies about 9.4% of total demand in 2020.

3. Annual CO₂ emissions from the power sector are around 218 MtCO₂ in 2020, a reduction of about 18 MtCO₂ compared to the Basecase scenario.

4. The capital investment required to implement this scenario is estimated to be about USD $63.5 billion by 2020.

The analysis of this RUPTL scenario provided information on the likely power generation capacity usage by fuel type that would be needed to meet the generation demand shown in the top-half of Figure 20. The breakdown of electric energy supplied by type of generator for the Java-Bali system is shown in the table below the graph in Figure 19. This table indicates that, by 2020, coal-fired power plants provide about 65% of electric energy (in GWh) that is needed by the system to meet total demand. This fuel share for coal can be compared to the contribution by coal power plants of about 73% in the Base-case scenario. The contribution of gas-fired power plants increased slightly in this scenario to 21.1%, while the contribution from oil-fired power plants remained at about 0.1% of total electric energy supplied. Both geothermal and hydropower resources increased their market share in this scenario, with geothermal contributing about 9.4%, compared to about 2.5% in the Base-case scenario. The contribution from hydro power remained the same at about 3.8%, mainly because there were no more additional capacity available. The slight increase in the utilization of geothermal power plants and gas-fired power plants accounted for the reduction of CO₂ emissions by about 18 MtCO₂, from 236 MtCO₂ in the Base-case scenario down to 218 MtCO₂ in the RUPTL scenario by 2020.
5.7 Results from the Total Carbon Emission Cap Scenario with New Technology and with or without NPP

In this scenario, the aim is to examine the impact of seeking to introduce new coal- and new gas-fired power generation technologies, some of which included CCS, along with the possibility of introducing nuclear power plant, into the power plant mix. The basis of their possible introduction should be on economic grounds only, without any political incentives to meet environmental limitations for CO₂ emissions. Since the analysis is focused on the mitigation of carbon emissions from the Java – Bali power system (which
is dominated by fossil fuel use), the introduction of new, advanced renewable energy technologies was not considered in this scenario; the scenario relied only on the introduction of conventional geothermal and hydropower plants. The principle rationale for excluding advanced renewable energy technologies is that these technologies are not yet ready for large-scale commercial use and there are concerns about the credibility of their technical and economic data when compared to that for CCT and CCS. Since nuclear power plants are used to meet base-load demand only, the introduction of new, advanced nuclear power technology would not affect the overall energy mix. For that reason, advanced nuclear power technology was also excluded from the analysis. Nonetheless, the technology associated with conventional light-water reactors is assumed to be included in the power plant mix of the Java – Bali System. The new technologies introduced in this study included supercritical coal-fired power plants with and without CCS (see Figure 15). In These technologies were also included by the IEA and EIA in their studies of opportunities for CO₂ Capture and Storage (Scott Smouse (2009), WEC (2007) and IEA Greenhouse Gas R&D Programme (2008)), as listed in Table 4 in the previous Chapter.

The simulation results show the amount of carbon emissions reductions achieved and are illustrated in Figure 21 (in which there is a restriction imposed on the use of NPP) and Figure 22 (in which there is no restriction imposed on the amount of nuclear power that is utilized in the scenario). For the scenario without the deployment of additional NPP, we conclude:

1. Approximately 19,000 additional MW of conventional coal-fired generating capacity are added to the JBS, accounting for about 61% of total power demand in 2020.

2. Annual CO₂ emissions fall to around 196 MtCO₂ by 2020, a decrease of about 40 MtCO₂. With the introduction of CCS at PLTU Indramayu and PLTGU Muara Tawar, CO₂ emissions are projected to decline by nearly 17% from the Base-case scenario.

3. The total capital investment required to implement this scenario is estimated to be approximately USD $63.9 billion.
In the parallel scenario with the deployment of additional NPP, at some time near the end of the simulation period (2020), the results are as follows:

1. The contribution of coal-fired generating capacity decreased by 6.7% in the constrained CO₂-case scenario (new technology) compared to the scenario that excluded nuclear power plants.

2. An additional 16,000 MW of conventional coal-fired generating capacity is added in this scenario, representing about about 55% of total generating capacity. This includes about 4,000 MWe of nuclear generating capacity and is equivalent to about 9.3% of total capacity in 2020.
3. Annual CO₂ emissions are estimated to be about 174 MtCO₂ by 2020. The introduction of CCS at PLTU Indramayu and PLTGU Muara Tawar along with the development of new nuclear plants reduce annual CO₂ emission by about 26% compared to the Base-case scenario.

4. The capital investment required to implement this scenario is estimated to be about USD $64.9 billion.
The comparison of the Base-case, RUPTL and Total carbon Cap with New Technology and with/without NPP can be summarized as follows:

1. In the Base-case scenario, annual CO$_2$ emissions increased by about 185% from the base-year, 2009, growing from 83 Mt CO$_2$ in 2009 to about 236 Mt CO$_2$ in 2020.

2. In the RUPTL scenario where the government intervenes to promote the introduction of geothermal and hydropower plants, annual CO$_2$ emissions are reduced by about 18 Mt CO$_2$ (approximately 7.6%) compared to the Basecase scenario. The additional investment required is estimated to be about USD $953 billion.

3. The New Technology scenario introduces the use of CCS technology at PLTU Indramayu and PLTGU Muara Tawar. In this scenario, annual CO$_2$ emissions are reduced by about 40MtCO$_2$ (or 17%) compared to the base-case scenario. The total investment required is estimated to be about USD $1,382 billion.

4. For the New Technology scenario with about 4,000 MW of additional nuclear power plants plus the introduction of CCS technology, annual CO$_2$ emissions are reduced by about 62 MtCO$_2$ (or 26.4%) compared to the Base-case scenario. The total investment required is estimated to be about USD $2,409 billion.

In general, both the scenarios with and without NPP demonstrate that more efficient fossil fuel technology, along with the attachment of CCS to the existing coal-fired power plants, can be introduced in the appropriate integrated modeling circumstances and will result in some decrease in CO$_2$ emissions. However, without some powerful drivers, including the widespread introduction of CCS, a significant CO$_2$ emissions reduction will not occur. The inclusion of CCS to either coal- or gas-fired power plants will decrease their fuel-to-electricity conversion efficiency, making CCS economically unattractive without either some form of financial subsidy or environmental regulations that would severely constrain CO$_2$ emissions. Similar constraints are applied to the introduction of nuclear power plants as part of the CO$_2$ emissions reduction scenario.
5.8 Carbon Value Scenario Results

This scenario considered sequentially the sensitivity of the carbon value approach by assessing its impact at two levels, namely by putting a price on carbon equivalent to USD $25/tCO₂ or alternatively a price set at USD $50/tCO₂. In both cases, we apply the specified carbon values in the Base-case scenario. This was followed by an examination of the introduction of new, advanced technologies, some including CCS, and then setting a higher maximum on geothermal power generation, still considering two levels of carbon value. To put these levels in context, when the burden of the carbon value is compared to the fuel price, the carbon value is equivalent to 68% - 139% of the current price of sub-bituminous coal or, similarly, is equivalent to 84% - 168% of the lignite price. In the case of natural gas, the selected carbon values are in the range of 25 – 30% of the current natural gas price. The description of this scenario is laid out in Table 10 below.

Table 10: Implication of Carbon Value to Fuel Price

<table>
<thead>
<tr>
<th>Carbon Value USD 25/Ton</th>
<th>Carbon Value USD 50 / Ton</th>
</tr>
</thead>
</table>
| **Coal type:** Sub bituminous  
  Heat content: 5100 kcal/kg (20,285 MJ/ton)  
  C content: 26.2 kg/GJ  
  CO₂ equivalency: 96,100 kg/TJ  
  Result: 1 ton of coal = 1.95 tCO₂ |
| **Type of coal:** Lignite  
  Heat content: 4200 kcal/kg (16,667 MJ/ton)  
  C content: 27.6 kg/GJ  
  CO₂ equivalency: 101,000 kg/TJ  
  Result: 1 ton of coal = 1.69 tCO₂ |
| **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 Lignite is USD 50/ton which will be reflected as fuel cost in power plant at USD 92/ton.** |
| **Gas price is USD 6/MMBtu will become USD 7.5/MMBtu** |
| **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 134/ton.** |
| **Gas price is USD 6/MMBtu will become USD 9 USD/MMBtu** |

The results, as expected, indicate that the utilization of cleaner fossil fuel and or renewable sources, including NPP, could have some significant impacts on Indonesia’s electricity generation mix in 2020. The simulation results of this scenario, for both the USD $25/tCO₂ carbon price and the USD $50/tCO₂ carbon prices are illustrated in Figures 23 and 24 below, respectively.
The results for a carbon price of USD $25/tCO₂ are as follows:

1. The increasing capacity of LNG-fired CCGT, leads to a decrease in the rate of growth of coal-fired electric generating capacity; this is equivalent to additions of only 11,000 MW of new conventional coal-fired generating capacity, compared to additions of around 27,000 MW in the Base-case scenario.

2. The construction of about 8,000 MW of new nuclear power plants occurs by 2020, as nuclear base load power plants are introduced to replace old coal-fired power plants.

3. This scenario will result in annual CO₂ emission reductions of 88.4 MtCO₂ (~37.4%) by 2020, compared to the Base-case scenario.

4. The capital investment required to implement this scenario is estimated to be about USD $73 billion, compared to the base-case of USD $62.5 billion by 2020.

The results for this scenario using a carbon price of USD $50/tCO₂ are as follows:

1. The increase of available in LNG-fired CCGT leads to a slower growth of conventional coal-fired capacity. The Java-Bali System adds about 11,000 MW of additional coal-fired capacity in this scenario, compared to about 27,000 MW in the Base-case scenario.

2. Approximately of 14,000 MW of new nuclear power capacity is added by 2020 as base-load power plants to replace retiring coal-fired PLTU.
3. Annual CO\textsubscript{2} emissions can be expected to reach only about 130 MtCO\textsubscript{2} by 2020, compared to about 236MtCO\textsubscript{2} in the Basecase scenario.

4. The capital investment required to implement this scenario is estimated to be about USD $62.5 billion, compared to USD $79.9 billion for the Base-case scenario by 2020.

![Figure 24: Carbon Value set at USD 50/tCO2 Scenario Results](image)

The impacts of setting a Carbon Price of USD $25/tCO\textsubscript{2} or USD $50/tCO\textsubscript{2} can be summarized as follows:

1. The higher reliance on geothermal power plants will reduce the CO\textsubscript{2} emissions by about 20 MtCO\textsubscript{2} by 2020.

2. With a carbon price of USD $25/ton, CO\textsubscript{2} emissions will be reduced by about 88 MtCO\textsubscript{2} in 2020 (or by about \sim 37\%). A carbon price of USD $50/ton will result in emissions of about 130 MtCO\textsubscript{2} (a decline of about \sim 53.8\%) and the required investment is estimated to be about USD $17.4 billion.

3. Based on these rough estimates, the investment required to achieve a CO\textsubscript{2} emissions reduction of 1 MtCO\textsubscript{2} is estimated to be about USD $73 million or about USD $77 million for carbon prices of USD $25 and $50/tCO\textsubscript{2}, respectively.
6 Carbon Mitigations in Java – Bali Power System
The integrated modeling of the Base-case scenario indicates that CO$_2$ emissions from the Java – Bali Power System in 2020 may reach 236 MtCO$_2$, or about 185% higher than the 2009 level of 83 MtCO$_2$. However, CO$_2$ emissions from the power sector, in particular in the Java - Bali System, contributes about 85% of total emissions by the national power sector. These must be reduced in accordance with or at least consistent with the statement of Indonesian President SBY at the G-20 meeting (SBY (2009)) in Pittsburgh, PA, USA on 25 September 2009. This study has shown that an emissions reduction of 26% can be achieved by selecting the most appropriate scenario amongst the results of the scenarios described above.

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 Java – Bali 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, even though electricity consumption is expected to keep increasing throughout the simulation period in order to underpin national economic growth. Therefore, it would be essential or even mandatory to some extent, to establish and implement a carbon emission mitigation strategy and policy for the Java – Bali Power System. therein the future there will be a need to:

1. Implement cross-cutting studies on the impacts of the most cost effective approaches to reducing CO$_2$ emissions. It may be possible to identify some tradeoffs that could help to determine the best way to meet the target of CO$_2$ emissions reduction in the Java – Bali power system, relative to other mitigation sectors.

2. Provide political support for ensuring diversity and security of primary energy supplies, as this will continue to be an important national security priority;

3. Establish a specific timetable and schedule for implementing a roadmap to achieve these goals;

4. Put in place procedures to ensure that these new technologies are available as and when required;

5. Ensure that likely technology selections will be required to conform to a low carbon technology mix. Conforming may include agreeing to likely timeframes for the introduction of new electricity generating capabilities into the existing power generation capacity mix; and

6. Put in place a framework to ensure that such technologies will become and remain competitive, covering policy initiatives, regulatory requirements, and financing options.
### Table 11: Matrix of Mitigation Actions

<table>
<thead>
<tr>
<th>No</th>
<th>Mitigation Actions Scenario</th>
<th>Total Mitigation Cost [billion USD]</th>
<th>Emission Reduction (Mt CO₂)</th>
<th>Abatement Cost [USD/t CO₂]</th>
<th>Required Policy Measures and Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>xx% Emissions Reduction</td>
<td>16.99</td>
<td>1,382</td>
<td>40.17</td>
<td>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).</td>
</tr>
<tr>
<td>2</td>
<td>Total Carbon Emission Cap with New Technologies with NPP Scenario</td>
<td>26.40</td>
<td>2,409</td>
<td>62.42</td>
<td>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); Socialization on public acceptance on NPP (N/A).</td>
</tr>
<tr>
<td>3</td>
<td>Carbon Value at USD 25/MT Scenario</td>
<td>37.39</td>
<td>4,358</td>
<td>88.42</td>
<td>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 NPP (N/A); Taxes or carbon charges on fossil fuel (coal) (PPU 4).</td>
</tr>
</tbody>
</table>
6.1 Policy Related Issues

The simulation results for all scenarios, except for the Base-case scenario, indicate that the Government of Indonesia needs to maintain a balanced energy supply mix in order to ensure security of supply. In the power sector, a balanced energy supply mix will include coal- and gas-fired power plants, with and without the CCS, and nuclear power plants, as well as LNG-fired, geothermal and hydropower plants and a relatively small proportion of oil-fired power plants. The simulation results of the proposed scenarios have indicated that this approach can meet the possible future CO\textsubscript{2} emissions target levels. It was also shown that, to achieve more significant CO\textsubscript{2} emissions reduction targets, the coal and gas/LNG technologies must be of advanced design incorporating integrated CCS technology. It was possible to meet these levels without some application of CCS and still maintain a meaningful fuel mix, even if all the geothermal resources have been utilized entirely, to avoid over dependence on nuclear and/or LNG-fired power plants.

There are already plans to install a substantial quantity of coal-fired and LNG-fired power plants. Along with the possibility of a connected HVDC link between South Sumatra – West Java by 2016, it is important to support all the required policy measures and instruments needed to achieve the targets of the Presidential Decree. Fortunately, the government of Indonesia already envisioned such requirements by launching the revision of its Blue Print of National Energy Management in April 2009 (MEMR (2009)). This revision includes programs that are very supportive of realizing the President's target levels of CO\textsubscript{2} emissions reductions. The program which is called Program Pengembangan Utama (PPU), meaning Main Development Program, incorporates some of the key elements which are listed in the far right column of Table 11 above and retabulated here. The key policies include:
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

There are two or more policies that still need to be defined in order to support further CO$_2$ emissions reductions in the power sector, for instance:

8. Increased public acceptance of NPP safety (N/A); and
9. Increased public acceptance of CCS safety (N/A).

Having such a framework for the required policies, with clear timeframes, and schedules to ensure their effectiveness, will increase the contribution of the power sector to Indonesia’s efforts to reduce CO$_2$ emissions. Furthermore, this scenario can be mainstreamed into the medium-term national development or beyond, which is the ultimate target of this study.
Conclusions and Recommendations
The simulation results of the integrated modeling of the Java – Bali Power System have indicated that the target levels of CO₂ emission reduction are reachable. The results also depicted the power generation capacity mix, the level of CO₂ emissions in each scenario and the possibilities for achieving further reductions, as well as the costs required to achieve each scenario and its respective CO₂ abatement.

To realize any of the simulation results of the selected scenarios, it is essential that the GOI supported all the necessary policies. Some of these policies have already been proposed in the Blue Print of National Energy Management, prepared by the Ministry of Energy and Mineral Resources. However, implementation strategies for many of these policies have to be clarified and provided with clear timescales and schedules.

As the Java – Bali System, emits about 85% of the total national CO₂ emissions from the power sector, the CO₂ emissions program for the JBS must be integrated with other mitigation and adaptation actions in order to achieve the most cost effective reductions of the national CO₂ emission. To ensure their success, these measures must be mainstreamed into the mid-term national development plan and beyond.
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