USING THE QUERI MODEL - AIRPACTS PROGRAM TO ASSESS THE EXTERNAL COSTS OF THREE POWER PLANTS IN INDONESIA WITH THREE DIFFERENT ENERGY SOURCES

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ABSTRACT

The Indonesian government in an effort to meet the ever growing national demand for energy has initiated both short and long term projects involving the building of power plants that continue to use fossil fuels with more than 60% using coal as fuel. This thesis estimates the external costs (i.e. the negative impacts on human health) the QUERI Model-AirPacts Program in the SimPacts software of three Indonesian power plants fueled by coal, oil and gas respectively. The external costs are then added to the investment, operational and maintenance costs to assess feasibility. The results clearly show that the oil-fired power plant has the greatest external costs and is the least profitable with the coal-fired power plant not far behind. Eventhough the gas-fired power plant is the most feasible, its NO_2 emissions were extremely high having the greatest short term mortality rates. These results show that power plants using renewable energy sources, so that both national economic productivity and each individual's quality of life can be maintained, will be more competitive in the long term than those that use non-renewable energy sources.

Keywords: External cost; QUERI Model; AirPacts program; Power plants; Indonesia

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– Widia Kusumawati –

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Abbreviations and Synonyms

AGRIMAT	: Agriculture and Building Material
BMKG	: *Badan Meteorologi Klimatologi dan Geofisika*
	: Meteorological and Geophysical Agency of Indonesia
BPP	: *Biaya Pokok Penyediaan*
	: Cost of Electricity Supplies
BPPT	: *Badan Pengkajian dan Penerapan Teknologi*
	: Agency for the Assessment and Application of Technology.
BPS	: *Badan Pusat Statistik*
	: Central Bureau of Statistics Indonesia
BUMN	: *Badan Usaha Milik Negara*
	: State Owned Enterprise
CO_2	: Carbon Dioxide
DAM	: Decision Aiding Model
DESDM	: *Departemen Energi dan Sumber Daya Mineral*
	: Department of Energy and Mineral Resources of the Republic of Indonesia
EPA	: Environmental Protection Agency
ERF	: Exposure Response Function
FOM	: Fixed Operation and Maintenance
g/kWh	: Gram per kilowatt hour
GoI	: Government of Indonesia
GW	: Giga-Watt
GWh	: Giga-Watt hours
IAEA	: International Atomic Energy Agency
IPA	: Impact Pathways Analysis
IPP	: Independent Power Producers
IRR	: Internal Rate of Return
KEN	: *Kebijakan Energi Nasional*
	: National Energy Policy
KFA	: *Kernforschungsanlage Juelich GmbH*
	: Research center Juelich
km	: Kilometer
km^2	: Square kilometer
MFO	: Marine Fuel Oil

MW	: Megawatt
MWh	: Megawatt hour
NO_2	: Nitrogen Dioxide
NPV	: Net Present Value
PKUK	: *Pemegang Kuasa Usaha Ketenagalistrikan*
	: Authorized Agency of Electricity Business
PMK	: *Peraturan Menteri Keuangan*
	: Decree of the Minister of Finance
PM_{10}	: Particulate matter less than 10 micrometres
PPA	: Power Purchase Agreements
PPP	: Purchasing Power Parity
PPP GNI	: Purchasing Power Parity Gross National Income
PPP GNP	: Purchasing Power Parity Gross National Product
PSO	: *Penyediaan Tenaga Listrik bagi Kepentingan Umum*
	: Public Service Obligation
PT. PJB	: *PT. Pembangkitan Jawa Bali*
	: A Subsidiary of PT. PLN (Persero)
PT. PLN (Persero)	: *PT. Perusahaan Listrik Negara (Persero)*
	: State owned electricity company
QUERI	: Quick Estimation of Respiratory Health Impacts Model
RAD	: Restricted Activity Days
RUKN	: *Rencana Umum Ketenagalistrikan Nasional*
	: National Electricity General Plan
RUWM	: Robust Uniform World Model
SO_2	: Sulphur Dioxide
SUWM	: Simple Uniform World Model
TDL	: *Tarif Dasar Listrik*
	: Electricity Basic Tariff
TSCF	: Trillion Standard Cubic Feed
TWh	: Terawatt hours
URBAN	: Estimation of the Physical Impacts near an Urban Site
VOM	: Variable Operation and Maintenance
YOLL	: Years of Life Lost
μm	: Micrometre (10^{-6} meter)
$\mu g/m^3$	: Microgram per Cubic Meter

Affidavit

I hereby verify that work written in these pages is solely that of my own and that use of any dishonest, deceitful and unscrupulous methods has been in no means mode or manner used in the creation of this Master's Thesis. The ideas herein, other than my own, have been referred to and quoted according to recognized citation standards.

Freiberg, 15 May 2010

WIDIA KUSUMAWATI

Chapter 1
Introduction

1.1 Background

Energy plays an integral role in supporting Indonesia's national development. Energy utilization and consumption in Indonesia will continue to increase in line with the growth of its economy, population and national development. According to Indonesia's National Electricity General Plan (RUKN) 2008-2027, that takes both economic and population growth into account, it is expected that the electricity demand will have an average increase of 9.2% per year over the next two decades[1]. As a result, the Indonesian government has initiated both short and long term projects involving the building of power plants that continue to use fossil fuels like coal, gas and oil which will be evaluated in this thesis. However, it is coal that will be of particular interest because it is already the dominant energy source for power plants in Indonesia and is slated for even more wide-spread development across the nation.

Up until 1984, oil-fired power plants were mainly used in Indonesia but as oil and gas prices have continued to increase along with energy demands, coal-fired power plants have taken the lion's share of energy production. In the short term, this is expected to increase with the Indonesian government's mandate for the construction by the state owned electricity company PT. PLN (Perusahaan Listrik Negara Persero) of a further 60 large and small coal-fired power plants that will start producing a total of 10,000 MW across the nation by 2011[2]. The 10,000 MW program by Presidential Decree No. 71/2006 is known as the 10,000 MW crash program. However, it is predicted that, with the building of these new coal-fired power plants, emissions will increase by 60% in 2030[3].

The consumption of greater amounts of fossil fuels in the future will lead to direct negative impacts on not only the environment but human health as well. The impacts of pollutant emissions on human health are diverse depending on the type and amount of the pollutants produced by different types of energy sources used. If external costs namely the calculation of damage to human health are added to production costs of existing power plants,

1 Public data available at Department of Energy and Mineral Resources, only in Bahasa Indonesia. Web page for consultation:
http://www.esdm.go.id/prokum/kepmen/2008/Kepmen%20ESDM%202682%202008%20RUKN.pdf.

2 Based on the explanation of the former president director PT. PLN, Fahmi Mochtar, when signing the financing commitments with Finance Minister Sri Mulyani Indrawati and the domestic bank's senior executives on January 30, 2009. http://www.thejakartapost.com/news/2009/01/31/pln-secures-65-financing-first-10000-mw-program.html

3 Cited from the UN Climate Change Conference in Bali on December 11, 2007. Mr. Nobuo Tanaka, Executive Director of the International Energy Agency explained it based on the IEA World Energy Outlook 2007: Case study China and India. http://www.iea.org/textbase/press/pressdetail.asp?PRESS_REL_ID=246

the cost of the development of future power plants that use sources of renewable energy will be quite competitive in comparison.

1.2 Objectives

The main objective of this thesis is to estimate the external costs (i.e. the negative impact on human health) resulting from the emissions of three different power plants (i.e. coal, gas and oil) in Indonesia by using the QUERI Model-AirPacts Program in SimPacts software. The external costs from this analysis will be factored into current generation costs to assess the overall feasibility of these power plants. These higher generation costs can then be used as a scientific reference when comparing the feasibility of the development of power plants. Plants that use existing as well as alternative energy sources that are less harmful to human health will therefore be more attractive for future development.

1.3 Scope

This thesis only estimates the impacts on human health from emissions of three Indonesian power plants which are the Paiton coal-fired power plant, the Gresik gas-fired power plant and the Muara Karang oil-fired power plant. The impacts on agriculture and building materials by airborne exposure is neglected in the calculations due to lack of data and are not part of this thesis. The six most significant pollutants stemming from fossil fuel combustion are nitrogen oxide (NO_2), sulphur dioxide (SO_2), particulate matter (PM), nitrates, sulfates and carbon dioxide (CO_2). The environmental impacts of carbon dioxide are global, and are beyond the scope of this thesis; hence carbon dioxide will not be included in the analysis. The five targeted pollutants of this thesis are: nitrogen dioxide (NO_2), sulphur dioxide (SO_2), particulate matter <10 micrometers (PM_{10}), nitrates and sulfates.

Numerous adverse health effects are atributed to these pollutants such as higher cancer rates, increased frequency of visits and admissions to the hospital, increased number of cases of asthma problems among children and adults, higher incidence rates of chronic bronchitis and days of restricted activity and loss of life expectancy (Wilde, 2003).

All processes, operations and the analysis of external costs using the AirPacts Program were done at the Agency for the Assessment and Application of Technology (BPPT), Jakarta, Indonesia. The AirPacts program is under the licence of the International Atomic Energy Agency (IAEA). This thesis was prepared with the guidance of the Agency for the Assessment and Application of Technology (BPPT) Jakarta. Much of the data was provided by a subsidiary of PT. PLN (Persero), PT. Pembangkitan Jawa-Bali (PT. PJB), Surabaya, Indonesia. Other supplementary data were obtained from other agencies including the Central Bureau of Statistics Indonesia (BPS), the Meteorological and Geophysical Agency of Indonesia (BMKG), PT. Perusahaan Listrik Negara (PT. PLN) and the Department of Energy and Mineral Resources of the Republic of Indonesia (DESDM).

1.4 Outline

Chapter 2 presents the definitions of external costs, the descriptions of the targeted pollutants and an overview of the national electricity situation in Indonesia. In chapter 3, the methodological framework of the thesis is introduced and includes the theory of Impact Pathways Analysis (IPA) and the outline of the QUERI Model-AirPacts program processes. The chapter then continues with a detailed description of the data collection and analytical approach employed. The discussion of this thesis can be found in chapter 4 which commences with the outcomes of the QUERI Model-AirPacts Program. The external costs of the three power plants are estimated and compared. The end of the chapter lists the main electricity generation issues and policies in Indonesia. Chapter 5 serves to synthesize and summarize the findings of the thesis work namely the external costs as well as the feasibility of the three power plants are compared with suggestions of which energy sources should targeted for future energy development. The appendices contain all the relevant data, including: conversion factors, the complete layout results of the QUERI Model, photographs of the three power plants and background detail information on each site.

Chapter 2

Environmental View of Electricity Generation

2.1 Description of External Costs

External costs are damage costs imposed by the activities of power generation on the surrounding environment and inhabitants without the former providing compensation for the burden. Damage costs are the monetization of the physical impacts, the so called social burden. Physical impact is a physiological change or chemical deterioration due to the presence of a particular pollutant in the environment.

Generally, external costs of electricity generation represent the uncompensated monetary value of environmental damage and human health problems. These are a burden on society and the environment because they are not paid by the producer but by the general public or other parties. The operation of electricity generation contributes to major damage to human health, building construction, crops, forests and ecosystems, but the most investigated among these is the damage to human health. External costs of electricity generation differ greatly depending on the energy source and technology used in production as well as location. In this thesis, external costs will be used to describe only the negative impact on human health of emissions from electricity generation.

2.2 Description of pollutants and their impact on human health

Each type of pollutant has a different impact on human health. Environmental impacts increase significantly in areas that have greater population densities. The five targeted pollutant emissions of this thesis are nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and particulate matter < 10 micrometers (PM_{10}) as primary pollutants, nitrates and sulfates as secondary pollutants. Primary pollutants are those emitted at the source and secondary pollutants are those created downstream of the source as a result of chemical reactions in the atmosphere.

Nitrogen dioxide (NO_2), being reddish brown in color and having a pungent odor, can reside in the atmosphere for days. It is very dangerous to humans because it causes respiratory disorders. It may also cause eye, nose, and throat irritation; impaired lung function and increased respiratory infections in children. Sulphur dioxide (SO_2) has a characteristically strong smell and does not burn in the air. The primary effects of SO_2 on humans are respiratory system disorders, pneumonia and interference with vision.

Air pollution not only consists of gases, but also particulate matter pollutants (PM). The more particulate matter, the more attention is required for handling the air pollution problem. The size of particles is directly linked to their potential for causing health problems. This thesis will analyze particles that are 10 micrometers in diameter or smaller (i.e. particulate matter 10 μm (PM_{10})) because those are the particles that can stay suspended in the air for over a month and generally pass through the throat and nose to enter the lungs. Once inhaled, these particles can affect both the heart and lungs and cause serious health effects. Particulate matter may cause eye and throat irritation, bronchitis and respiratory damage. The main sources of particles are from power generation operation and transportation, followed by industrial processes. (EPA, 2008)

Nitrates can have the following negative effects on human health: hypotension (i.e. low blood pressure), acute respiratory infections, and may also increase the risk of bladder and ovarian cancer in women. Sulfates, once released into the atmosphere will remain there for years and can contribute to increased risks of asthmatic attacks.

2.3 The National Electricity Situation in Indonesia

The state owned electricity company, PT. PLN (Persero), supplies virtually all of Indonesia's electricity demands along with the assistance of private power companies, known as Independent Power Producers (IPP) through the use of Power Purchase Agreements (PPA). The total installed capacity of PT. PLN (Persero) power plants is 24.846 GW (Giga-watts), while IPP power generation capacity is at 5.83 GW. In addition, there are companies generating electricity for their own needs with what are called captive power plants that have the installed capacity of 9.3 GW. (PLN, 2006) National electricity needs are forecasted to grow an average of 9.2% per year over the next two decades. By 2027, electricity consumption which is expected to reach 813.3 TWh will require a capacity of at least 178.1 GW.

In accordance with the government's energy diversification policy the use of oil for power plants is slowly being replaced by other energy sources, such as coal, natural gas and renewable energy like geothermal and hydro so as to reduce energy costs. The government has taken into consideration that the national coal reserve potential is still extremely high and therefore cheap so coal is slated to play an increasingly dominant role in electricity generation as can be seen in Table 2.1.

Table 2.1 Composition Percentage of Primary Energy for Power Generation (%)

Primary Energy	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Coal	45	48	62	66	65	64	64	65	64	64	63
Oil	26	19	5	2	2	2	2	2	2	2	2
Gas	17	21	21	19	19	19	18	16	18	17	17
Geothermal	5	5	5	6	8	9	10	11	10	11	12
Hydropower	7	7	7	7	6	6	6	6	6	6	6

Source: PLN, 2008

The greatest fluctuations in Table 2.1 are with the non-renewable resouces of coal, oil and natural gas while the renewable energy resources of geothermal and hydropower remain almost dormant.

The use of coal in such large volumes deserves serious attention as coal has greater environmental impacts in comparison with those of oil and natural gas. Over the coming years, coal has been chosen to provide most of the primary energy needs for power plants because it is considerably cheaper than oil as well as being an abundant natural resource in Indonesia. The greatest increase over the shortest period of time in the use of coal as the primary energy for power gereration is between 2009 and 2011 from 48% to 66%. The reason for this sudden 18% jump is the governement's accelerated development of coal power plants with the total capacity of 10,000 MW all of which will be fully functioning by the end of 2010. In contrast to coal usage, oil consumption drops sharply by a total of 17% over the same period. The use of gas fluctuates little over 20 years due to problems of availability and infrastructure (PLN,2008).

The use of geothermal energy shows a slow and steady increase over 20 years. Geothermal energy utilization can be significantly increased if the main constraints of expansion into protected forests areas can be solved. Currently, there are twelve mine working areas have been established as geothermal sites by the Minister of Energy and Mineral Resources. Hydropower is the most stable. This is due to the development of hydropower focusing more on the utilization of river water flow rates (run of river) in place of constructing reservoirs or dams that have greater environmental and social impacts. In addition, the 1% decline of hydropower utilization can be attributed to reduced flow rates of reservoirs or dams due to erosion in the upper estuaries.

The government of Indonesia has issued a policy to keep the environmental impacts from electricity generation low. This policy is set out in the Decree of the Minister of Environment no.KEP-13/MENLH/3/1995, regarding emission standards for stationary sources. It sets the maximum allowable limits for power plant emissions of particulate matter (PM) at 150 mg/m^3, sulphur dioxide (SO_2) at 750 mg/m^3, and nitrogen dioxide (NO_2) at 850 mg/m^3 emissions as well as opacity rates at 20% (Sugiyono, 2000). As will be shown in this thesis, the Paiton coal-fired power plant can barely meet these standards.

Chapter 3
Research Methodology

3.1 Impact Pathways Analysis Methodology

By using the analysis of emission dispersion model, known as the Impact Pathways Analysis (IPA), external costs can be calculated. The IPA uses a four-step procedure for quantifying the physical impacts and damage costs on human health, crops and materials arising from environmental releases by observing the environmental impacts of the pollutants from their emission into the environment. The results gained from the IPA have been used in a large number of research projects and for policy making. As shown in Figure 3.1, this analysis has four calculation steps:

- emission quantification,
- transformation and dispersion,
- impact estimation and
- damage valuation.

Each calculation step has a margin of error that is directly related to the limitation of the data and model methodology.

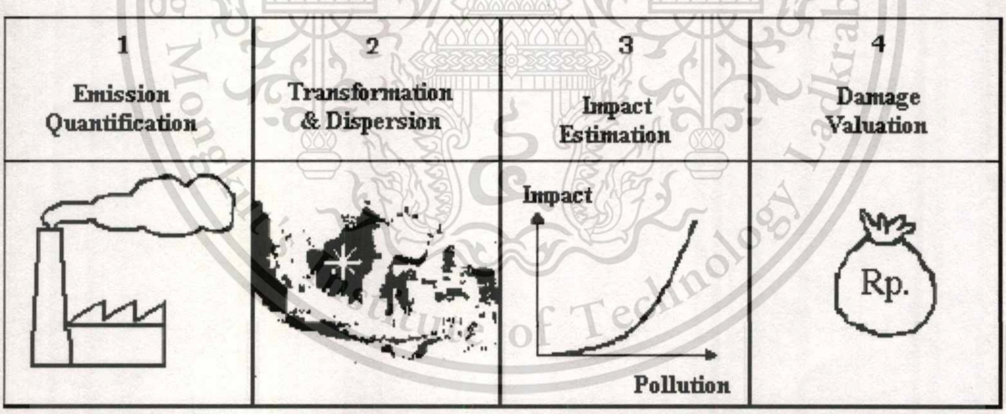

Figure 3.1 Impact Pathway Analysis Methodologies

Source: Sugiyono (2005)

The application of the Impact Pathways Analysis (IPA) starts with the calculation of emission quantification by indentifying the plant's location, determining the plant's characteristics and its analyzed pollutant emissions. Each power plant has a specific emission coefficient depending on the technology and the type of fuel used.

In the second step, the transformation and dispersion of plant emissions are calculated. Parameters that influence the amount of emission are the stack height, where the gas is released into the air, gas temperature and flow velocity. Parameters that affect the distribution pattern of emissions are meteorological parameters such as wind direction, wind speed and the Pasquill distribution class which shows whether atmospheric conditions are stable or turbulent.

The third step involves estimating environmental impact by using the dose response function. Pollutant concentrations that exceed allowable thresholds will affect pollutant receptors (i.e. humans, plants and buildings). In this thesis, impacts on humans will be calculated. Impacts on human health can be cancer, asthma, chronic bronchitis, premature death and so on. Each type of pollutant has a different effect on human health. The greater the population density, the higher the impacts will be.

The final step of the impact pathways analysis calculates damage valuation. The monetary value of environmental damage is determined based on the aggregate of physical impact quantification on health, plants and buildings. External costs can be determined by multiplying the physical impacts (e.g. asthma) with the unit cost (e.g. US$ per unit of asthma). Estimated health costs are inputs that determine the external costs. Data from developing countries like Indonesia are insufficient; therefore data from developed countries will be used to make adjustments to the value of income per capita in purchasing power parity (PPP).

3.2 The SimPacts Software

SimPacts is a software developed by the International Atomic Energy Agency (IAEA). SimPacts is a simplified approach of the EcoSense methodology for estimating environmental impacts from electricity generation. This software consists of four independent modules, namely AirPacts, NukPacts, HydroPacts and DAM.

The AirPacts program is used to predict the physical impacts and damage costs to human health, agricultural crops and building materials due to air emissions from a stationary source. The NukPacts module is used to analyze the impact of radioactive contamination on human health. The HydroPacts module is used to predict the damage cost of hydropower dams. DAM is a decision aiding model permitting multi-criteria policy analysis (Spadaro, 2002). This thesis will use the AirPacts program which can be run independently to measure the damage costs on human health only.

Physical impacts and damage costs are quantified in the AirPacts module using an assessment approach based on the Impact Pathways Analysis (IPA) so that the damage costs of the three power plants which run on coal, natural gas and oil respectively, can be measured and compared.

3.3 The AirPacts Program and QUERI Model

In the AirPacts program (version 1.0), there are four models, the QUERI, URBAN, RUWM and AGRIMAT, as shown in Figure 3.2.

The QUERI model assesses the respiratory impacts on human health and their associated damage costs due to primary and secondary pollutants present in the air. The model uses a semi-empirical approach in which correlations derived from existing IPA studies are used to approximate the impacts.

The URBAN model estimates the human health impacts and monetary costs due to air emissions from a source located near a city. Damages associated with primary and secondary pollutants can be assessed. Weather data for the local scale correspond to mean conditions and assume a uniform wind conditions. Local population data can be specified using actual values (5 by 5 km^2 resolution) or the distribution can be approximated using a Gaussian-shaped function.

The RUWM model approximates the physical impacts and costs to human health from exposure to primary and secondary atmospheric species. In contrast to QUERI, the RUWM model uses different simplifying assumptions to solve analytically the damage function equation. In the assessment, it is assumed that the local and regional populations are uniformly distributed throughout the appropriate impact domain. The meteorological data for the local scale refer to average or typical conditions and assume a uniform wind conditions.

The AGRIMAT model assesses the impacts and the resulting economic costs to agricultural crops and man-made structures from airborne exposure (no wet deposition) to sulphur dioxide (SO_2). Physical impacts include, for example, health cases, losses/gains in crop yield or square meters of damaged materials. Physical impact is a physiological change or chemical deterioration (response) due to the presence of a particular pollutant in the environment (exposure). Damage costs are expressed as US$ per kg or ton of crop loss/gain or US$ per square meter of damaged surface (Spadaro,2002).

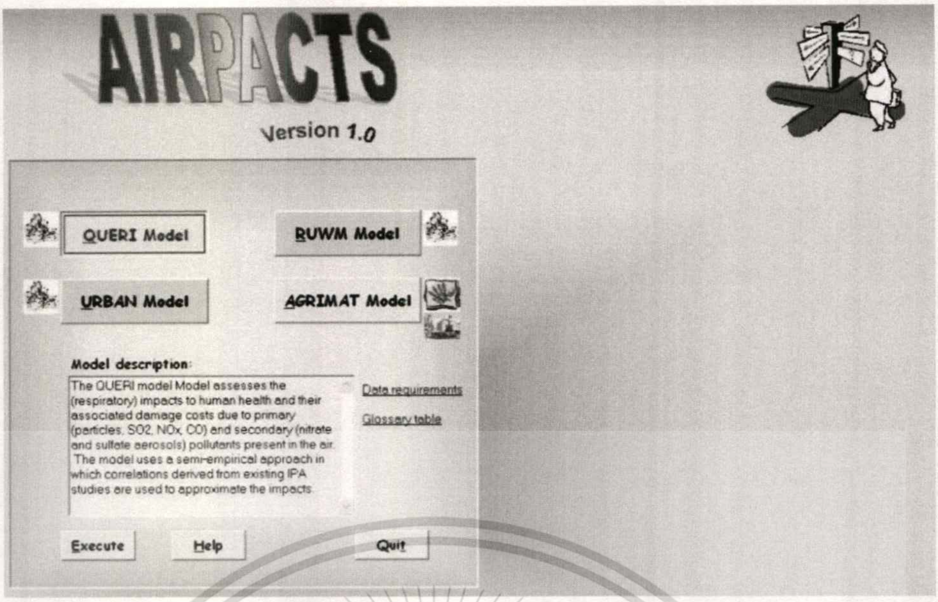

Figure 3.2 Four models in the AirPacts Program

This thesis will use the QUERI model as the URBAN and the RUWM models require highly comprehensive data which is simply not available. Since the AGRIMAT model calculates impacts to agriculture crops and exposed building materials, it is beyond the scope of this thesis and will not be used.

3.3.1 Case Study Descriptions

Case study notes are typed in the case study description menu, as presented in Figure 3.3. Although these case study comments are optional, a detailed case study description should be included as part of a complete dataset of input information. There is no limit as to the amount of text that may be entered and it can be amended at any time. Some of the information that may be included is the name of the observed project (e.g. name of the power plant) and other details that may offer information beyond the input parameters of the QUERI program (e.g. whether the project is located in a mountainous region at a high altitude or near a body of water etc.).

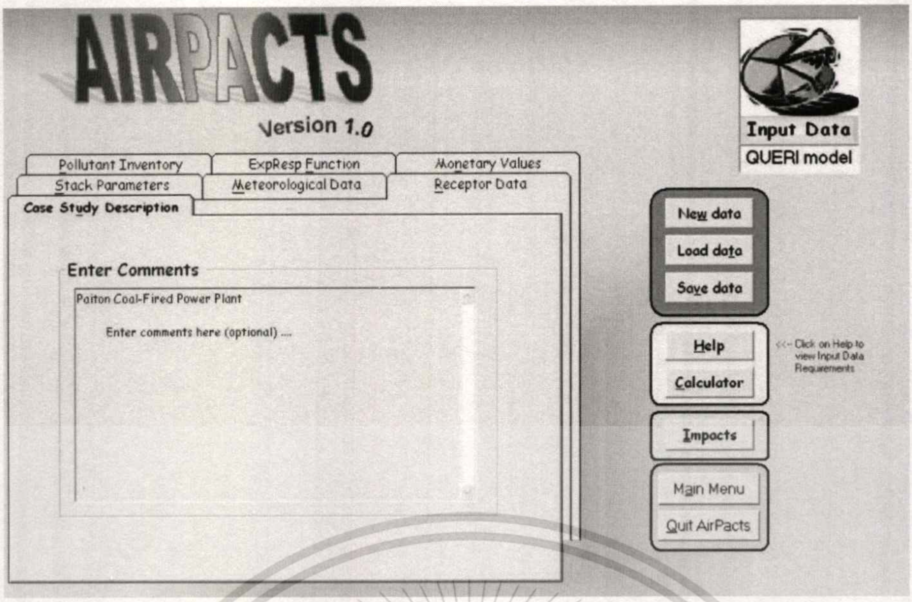

Figure 3.3 Case Study Description Menu

3.3.2 Stack Parameters

The six different source data that are required inputs in the stack parameters menu are as follows: the geographical coordinates, source location, stack height, stack diameter, flow velocity and gas temperature, as shown in Figure 3.4.

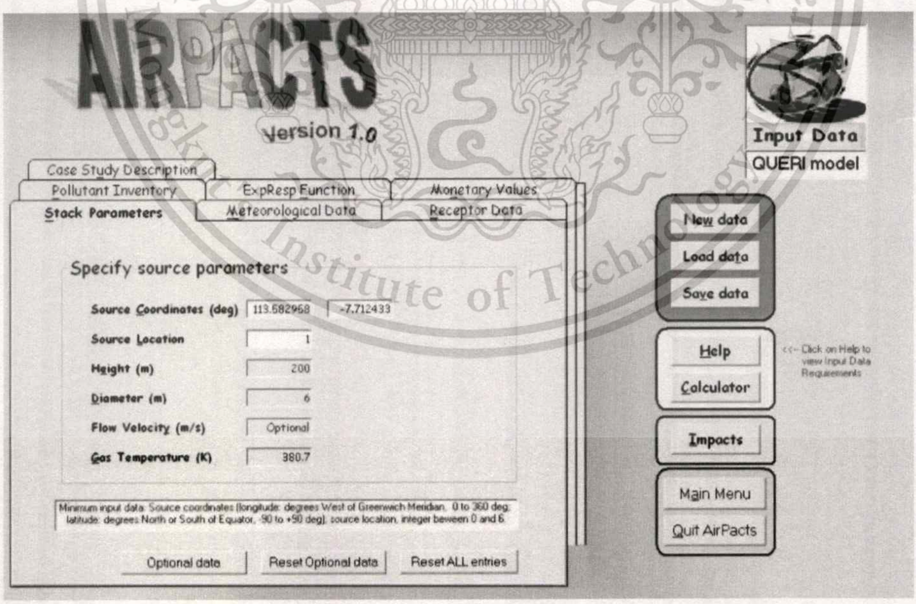

Figure 3.4 Stack Parameters Menu

Source geographical coordinates contain two types, longitude and latitude. Longitude is the degrees West of Greenwich meridian, 0 to 360 degree. Latitude is the degrees North or

South of Equator, -90 to +90 degree. Source location (site ID) is determined by the local-to-regional population density ratio. The site ID has seven categories which are as follows:

- ID zero is for rural sites,
- ID one, two and three are for small, medium and large cities respectively,
- ID four is for an area within 25 km of a large city,
- ID five is for a place within 40 km of a large city and
- ID six is for an area more than 40 km from a large city.

Stack height is the physical height at which pollutants are released into the atmosphere. The acceptable range of stack height in the AirPacts program is 25 to 300 meters. Stack diameter is the inner stack diameter at point of release, in meters. Flue gas velocity is the velocity of exhaust gases, in meters per second. Flue gas temperature is temperature of exhaust gases. The acceptable range of gas temperature in AirPacts program is 300 to 600 Kelvin (Spadaro, 2002).

3.3.3 Meteorological Data

Figure 3.5 is the input data screen for meteorological data in the AirPacts program. Damage estimates are much more robust when weather conditions are specified. Although more specific data can be input, this thesis due to the scarcity of such data, will use the average estimates of key parameters, such as the average of ambient temperature, wind speed and atmospheric stability or Pasquill classification. Ambient temperature is air temperature measured in Kelvin. The unit of wind speed strength in the AirPacts is in meters per second. Anemometer height which also must be supplied is the height at which wind speeds have been recorded; this parameter is typically ten meters for weather stations away from urban areas (Spadaro, 2000).

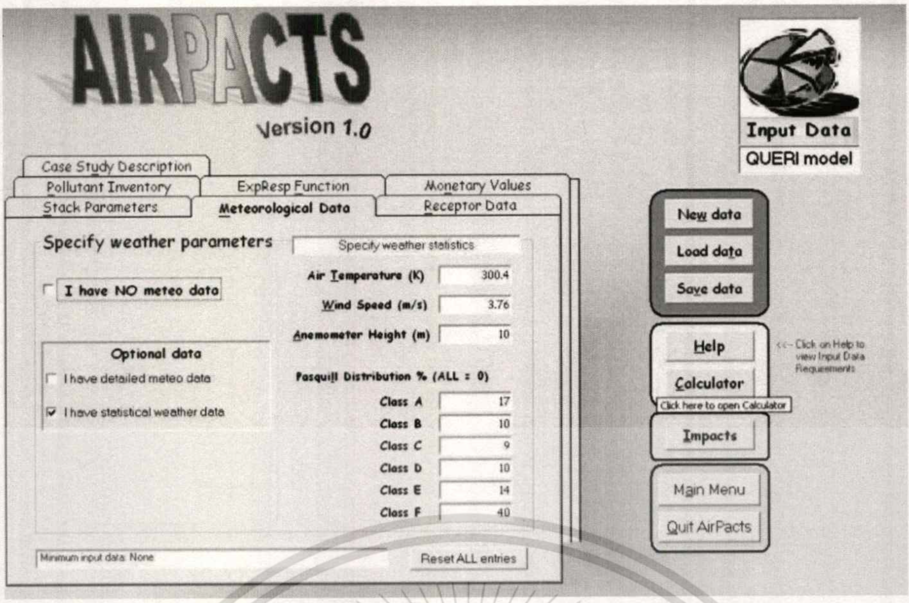

Figure 3.5 Meteorological Data Menu

Pasquill distribution classes are the atmospheric turbulence classification, as shown in Table 3.1. Atmospheric turbulence, which in turn affects pollutant dispersion, is identified by its Pasquill classification. There are six stability categories, ranging from unstable (A, B, C) to neutral (class D) to stable (E and F) conditions. The Pasquill statistics are specified as percentage of occurrence over the time period under consideration. The sum of all classes must equal 100%. Pasquill data are mandatory in the AirPacts program (Spadaro, 2000).

Classes A, B and C are used to describe unstable atmospheric conditions which prevail during daytime hours when solar irradiation along the earth's surface reaches its greatest value, i.e. during high solar insulation around noontime hours. Class D describes a neutral condition and occurs during daytime-nighttime transition periods when wind speed is high or during mostly cloudy conditions. Finally, classes E and F are used to describe a slightly unstable to moderately stable atmosphere. Stable conditions prevail at nighttime or during periods in which wind speeds are weak, less than 3 m/s (Gifford, 1962).

Table 3.1 Pasquill Distribution Classification

Surface Wind (m/s)	Daytime Incoming Solar Radiation			Nightime Cloudiness	
	Strong	Moderate	Slight	≥ 4/8	≤ 3/8
< 2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

Source : Gifford (1962)

3.3.4 Receptor Data

A receptor is an object that is positively or negatively affected by the presence of a particular pollutant (i.e. human health, agriculture crops, building materials, etc). For health impacts, a receptor or risk group can be an adult, child, elderly person, asthmatic, etc.

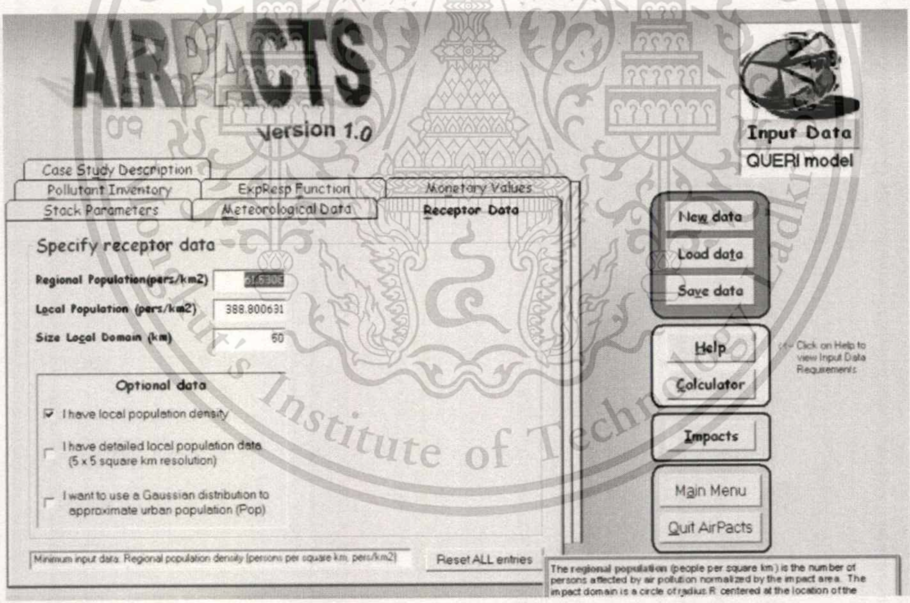

Figure 3.6 Receptor Data Menu

As presented in Figure 3.6, the input data for the receptor data menu in the AirPacts program requires regional and local population densities (person/km^2) as well as the size of the local domain (km) which are averaged over land and water areas. The regional population is the number of persons living within a 1000 kilometer radius. The local population is the number of persons residing within the local domain of a 50 kilometer radius. The size of a local domain is centered at the emission source or square area of 50 by 50 kilometers, with an equivalent radius of 50 kilometers. (Spadaro, 2000)

3.3.5 Pollutant Inventory

The pollutant inventory menu requires input data including the pollutant emission rate and depletion velocity of the specific pollutant, as shown in Figure 3.7. Depletion velocity is a characteristic velocity determining the rate at which a particular pollutant is removed from the atmosphere because of chemical transformation and deposition, either wet or dry. It is usually expressed in centimeters per second. For secondary pollutants (i.e. nitrates and sulfates) in this thesis, only the depletion velocity needs to be specified (Spadaro, 2000).

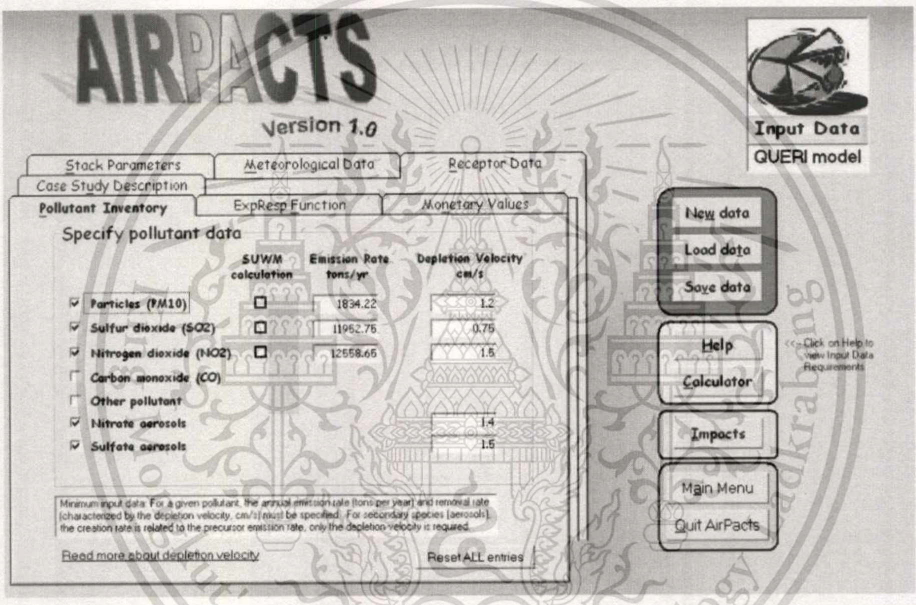

Figure 3.7 Pollutant Inventory Menu

The pollution is calculated based on emission characteristics and emission technologies. The emission rate can vary widely, and is dependant on fuel property, technology design and condition, operation mode, type of control technology as well as other parameters. The total emission rate of a pollutant from a source is obtained by multiplying the emission coefficient with the total electricity production which emits the pollutant. The emission coefficient, also called "specific emission" or "emission factor", is the average value which is related to the quantity of pollutants to the activity of an energy technology. This is then used to estimate and to predict the total amount of air pollutants from various sources. The emission rate is usually expressed in terms of weight of pollutant divided by a unit of time period, e.g. tons/year (Spadaro, 2000).

Measuring stack emission rates per pollutant (g/kWh) can be done in several ways either by taking a direct measurement of emissions at the site or by using the proximate-ultimate analysis[4] of the fuel used at each power plant. Both of these are highly technical methods that require time and expensive equipment hence, this thesis will use neither method. Instead, emissions coefficients from previous joint research studies by the Research Center Juelich (KFA), Germany and the Agency for the Assessment and Application of Technology (BPPT), Indonesia will be used as input. This research study states that the coefficients are assumed to be constant until 2021 (Kleeman, 1994). Therefore, these coefficients still can be used for this thesis.

3.3.6 Exposure Response Function

Exposure response function (ERF) is a function that describes correlations relating the response of a receptor to a change in environmental conditions such as an increase in air concentration of a particular pollutant. The exposure response function relates the pollutant's ambient concentration to the resulting impact on a receptor or sub-group at risk. The ERFs for health impacts are straight lines with no threshold, the line passes through the origin at zero concentration. Each type of pollutant has a different impact on human health. Due to the limitation of domestic exposure response data in Indonesia, this thesis will use the data available from the SimPacts core or recommended functions for assessing the impacts of air pollution on human health as shown in Table 3.2 below.

The ERF has units of incremental cases of disease normalized per year per person and per unit change in air concentration (i.e. $\mu g/m^3$). For mortality, the ERF measures the aggregated years of life lost (YOLL) over the exposed population. For morbidity effects, the ERFs estimate additional cases of illness per year. The number of Restricted Activity Days (RAD) is days when an individual's routine activity is disrupted. For long-term chronic bronchitis, the new cases per year of this disease are estimated in the exposed individuals, rather than the additional number of yearly bouts experienced by the population (Spadaro, 2002).

[4] The ultimate analysis gives the composition of the carbon, hydrogen and oxygen in wt%, as well as sulphur and nitrogen. The proximate analysis gives the content of carbon, volatile and ash.

Table 3.2 Value of Exposure Response Function for Health Impacts

Exposure Response Function	Unit	ERF Value
Mortality (long-term exposure) PM_{10}	YOLL/(yr-pers-µg/m^3)	0.00026
Mortality (long-term exposure) Nitrates	YOLL/(yr-pers-µg/m^3)	0.00026
Mortality (long-term exposure) Sulfates	YOLL/(yr-pers-µg/m^3)	0.000434
Restricted or limited activity days PM_{10}	cases/(yr-pers-µg/m^3)	0.022
Restricted or limited activity days Nitrates	cases/(yr-pers-µg/m^3)	0.022
Restricted or limited activity days Sulfates	cases/(yr-pers-µg/m^3)	0.0367
New cases of long-term chronic bronchitis PM_{10}	cases/(yr-pers-µg/m^3)	0.0000451
New cases of long-term chronic bronchitis Nitrates	cases/(yr-pers-µg/m^3)	0.0000451
New cases of long-term chronic bronchitis Sulfates	cases/(yr-pers-µg/m^3)	0.0000753
Respiratory hospital admissions PM_{10}	cases/(yr-pers-µg/m^3)	0.00000256
Respiratory hospital admissions Nitrates	cases/(yr-pers-µg/m^3)	0.00000256
Respiratory hospital admissions Sulfates	cases/(yr-pers-µg/m^3)	0.00000428
Lower respiratory symptoms (adult asthmatics) PM_{10}	cases/(yr-pers-µg/m^3)	0.0962
Lower respiratory symptoms (adult asthmatics) Nitrates	cases/(yr-pers-µg/m^3)	0.0962
Lower respiratory symptoms (adult asthmatics) Sulfates	cases/(yr-pers-µg/m^3)	0.161
Lower respiratory symptoms (children asthmatics) PM_{10}	cases/(yr-pers-µg/m^3)	0.041
Lower respiratory symptoms (children asthmatics) Nitrates	cases/(yr-pers-µg/m^3)	0.041
Lower respiratory symptoms (children asthmatics) Sulfates	cases/(yr-pers-µg/m^3)	0.0685
Mortality (short-term exposure) SO_2	YOLL/(yr-pers-µg/m^3)	0.0000023
Respiratory hospital admissions SO_2	cases/(yr-pers-µg/m^3)	0.00000284
Mortality (short-term exposure) NO_x	YOLL/(yr-pers-µg/m^3)	0.0000017
Respiratory hospital admissions NO_x	cases/(yr-pers-µg/m^3)	0.00000156

Source: Rabl (2001)

3.3.7 Monetary Valuation

The AirPacts program requires some unit costs factors, as shown in Figure 3.8. The required unit costs are the values of monetary unit costs in Indonesia in the year base 2008.

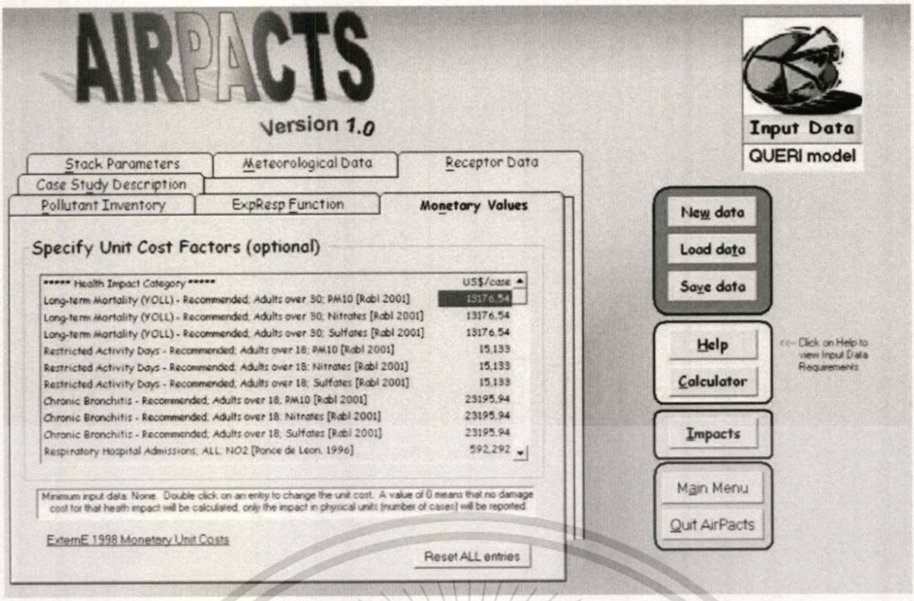

Figure 3.8 Monetary Valuation Menu

The economic valuation method is an approach for transferring monetary unit costs from one country to another. Monetary unit costs are for assessing health damage costs by monetizing the physical impacts and environmental burdens, for example, the cost per asthma attack or the cost per year of life lost (YOLL). The monetary value of these impacts is the quantification of physical impacts of power generation operation. In this thesis the unit costs are expressed in US dollars for the base year 2008. Usually unit costs are based on country-specific economic valuation studies. However, due to Indonesia's absence of such information, existing values will be transferred from Europe after proper adjustments have been made to account for differences in the purchasing power parity. The equation expressing the Purchasing Power Parity Gross National Income normalized per capita (PPP GNI) adjustment is performed as written below (Spadaro, 2002):

(Eq. 3.1) $$Unit\ Cost\ in\ Indonesia = Unit\ Cost\ in\ Europe \times \left(\frac{PPP\ GNI_{Indonesia}}{PPP\ GNI_{Europe}} \right)^{\gamma}$$

Previously, PPP GNI was known as Purchasing Power Parity Gross National Product (PPP GNP). The adjustment of PPP GNI is necessary to account for income differences between countries, and consequently, the willingness to pay regarding the valuation of health impacts by individuals in different parts of the world. The PPP GNI ratio may be raised to an exponent, the elasticity factor, which reflects an individual's commitment to spend a larger share of disposable income to protect against adverse health impacts. Typical values of the income elasticity coefficient, γ, range from 0.3 to 1. For example, γ less than 1 means that Indonesians commit to spend more of their income than Europeans in order to achieve the same health benefit. Since the Indonesians have less commitment to spend more of their personal spending income than Europeans, the value of the γ parameter is one, as its maximum value (Spadaro, 2002).

Monetization is a convenient method for aggregating environmental burdens that have different impacts units; e.g. asthma attacks and loss of life expectancy. Monetization is useful for internalizing the external costs. External costs can be determined by multiplying the impacts (e.g. asthma cases in children) with the unit cost (e.g. Rupiahs per asthma attack). Health cost estimation is used as an input so that external costs can be determined. As a developing country, Indonesia has limited data. Therefore, to fill the gaps, this thesis utilized several relevant data from developed countries, as shown in Table 3.3.

Table 3.3 Monetary Unit Costs in Europe year 2000

Health Impact	Unit	Value
Mortality (short-term exposure)	$US\$_{2000}$ per YOLL	101,000
Mortality (long-term exposure)	$US\$_{2000}$ per YOLL	174,000
Restricted activity days	$US\$_{2000}$ per incident	116
Long term chronic bronchitis	$US\$_{2000}$ per incident	177,800
Respiratory hospital admissions	$US\$_{2000}$ per incident	4540
Lower respiratory symptoms (adult)	$US\$_{2000}$ per incident	8
Lower respiratory symptoms (child)	$US\$_{2000}$ per incident	8

Source: Spadaro (2002)

3.3.8 QUERI Results

The QUERI model outputs, shown in Figure 3.10, each impact category can be viewed with its relevant background data and approximate breakdown of impact by domain, both local and regional ranges.

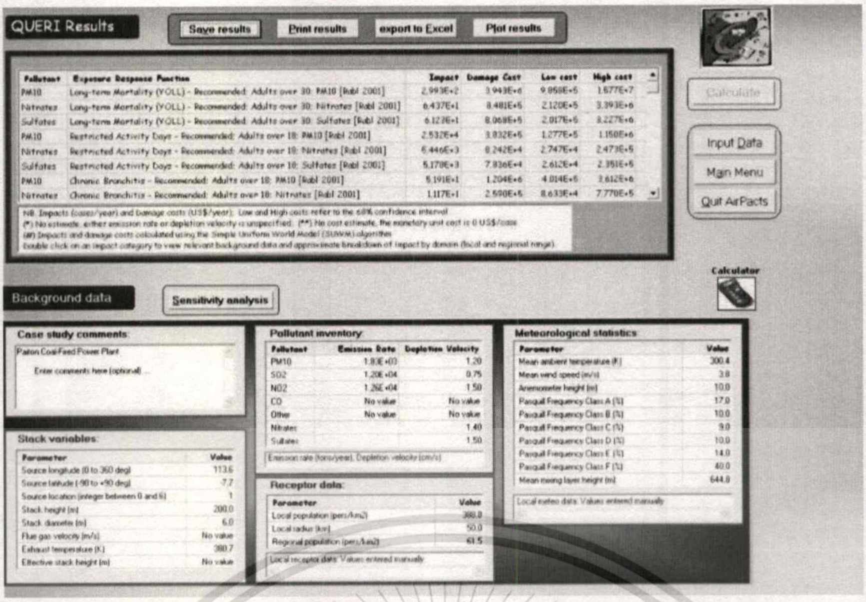

Figure 3.9 QUERI Results Screen

The QUERI results menu has four main result values which are the impacts rate (cases/year), damage costs (US$/year), low and high costs. Impacts and damage costs are calculated using the Simple Uniform World Model (SUWM) algorithm. Local details are ignored in the analysis. Impact costs for secondary pollutants are always calculated using SUWM formulation. The SUWM has four main assumptions: constant emission rate, uniform population distribution, uniform transport atmospheric parameters across the domain and a linier ERF with no threshold (Spadaro, 2002).

In the situation where R=1 (SUWM), a first order estimate of the impacts is obtained by simply multiplying the emission rate by the ERF for a particular health endpoint by the receptors at risk averaged over land and water for a circular area of a 500 to 1000 km radius centered at the source and then divided by the pollutant's depletion velocity. The SUWM underestimates the health impact by as much as a factor of six for typical stack heights (≈100m). SUWM, usually, overestimates the damage costs when sources are located near or along the coastline because the dispersed plume moves over water part of the time in which case the real health impacts are zero (Spadaro, 2002).

(Eq. 3.2) $$D = \frac{\rho_{avg} \, f_{ER} \, Q \, U_v}{k}$$

D : damage costs (US$/year)

ρ_{avg} : mean receptor density over a radius of 500 to 1000 km from the source (persons per km^2)

f_{ER} : exposure-response function (annual cases per persons per μg/m3)

Q : emission rate (μg/s)

U_v : unit cost (US$/year)

k : depletion velocity (m/s)

3.4 Power Plant Data

The data used to estimate the external costs arising from the operation of the Paiton, Gresik and Muara Karang power plants in Indonesia, discussed in this chapter, include the type and location of the power plant technology, the fuel used, electricity production, stack characteristics and emissions during the operation.

3.4.1 Power Plants and Stack Parameter Data

The Paiton coal-fired power plant consists of two steam plants with a total installed capacity of 800 MW which supplies power to the Java-Bali Interconnection System. This thesis will estimate one of the Paiton coal-fired power plant units that has the capacity of 400 MW.

The Gresik power plant has two gas plants, four steam plants and three combined cycle plants with a total installed capacity of 2,280 MW which supply the electricity demand in East Java. This thesis will discuss power plant unit I of the two gas-fired power plant units which has the capacity of 525 MW.

The Muara Karang is an oil-fired combined cycle power plant consisting of three identical units with the installed capacity of 100 MW and two identical units with the installed capacity of 200 MW which supplies the electricity demand for the Java-Bali Interconnection System. This thesis will study one of three oil-fired power plant units that has capacity of 100 MW.

A summary of three power plants with the detailed stack data of a single stack unit in each power plant is shown below in Table 3.4.

Table 3.4 Power Plant and Stack Data

Parameter	Unit	Gresik	Muara Karang	Paiton
Fuel		Gas	Oil	Coal
Installed Capacity	MW	525	100	400
Electricity Production	MWh/year	3,420,679.42	786,000.75	2,754,090
Stack Characteristics				
Physical height (m)	m	150	107	200
Stack Diameter (m)	m	3.05	2.85	6
Air Temperature (K)	K	300.4	301.5	300.4
Exit Temperature (K)	K	380.7	380.7	380.7
Anemometer Height (m)	m	10	10	10

Source: PT.PLN (Persero)

3.4.2 Meteorological Data

Meteorology data from the weather stations closest to each plant were obtained from Central Bureau of Statistics Indonesia (BPS). Data for the Muara Karang oil-fired power plant was obtained from Kemayoran weather station which provided fairly complete data that included hourly wind data for 2008. For the Gresik gas-fired power plant and the Paiton coal-fired power plant, the Juanda weather station could not provide comprehensive data since only daily wind data was recorded. As the Pasquill distribution data are difficult to find, it was assumed that the atmospheric turbulence situation across Java Island is similar. Hence, the wind data, used to determine Pasquill distribution values, are from the Kemayoran station.

Pasquill Distribution Class A: 17 %

Pasquill Distribution Class B: 10 %

Pasquill Distribution Class C: 9 %

Pasquill Distribution Class D: 10 %

Pasquill Distribution Class E: 14 %

Pasquill Distribution Class F: 40 %

The three power plants are located on Java Island as presented in Figure 3.1. Gresik is located near Surabaya with an average wind speed of 3.76 m/s and an average ambient temperature of 300.4°K. Muara Karang is located near Jakarta with a wind speed average of 2.61 m/s and an average air temperature of 301.5°K. Paiton located near Probolinggo with an average wind speed of 3.76 m/s and an average ambient temperature of 300.4°K.

3.4.3 Receptor Data

The Muara Karang oil-fired power plant (latitude 6°6'39" South and longitude 106°47'15" East) is located on the coast of North Jakarta in one of its main business and industrial areas. The local area of the Muara Karang power plant covers Jakarta, Banten, Tangerang, Depok Bogor, Bekasi and Karawang with the local population density calculated at 1,734.49 persons per square kilometer. The regional area of this power plant encompasses the islands of Sumatra, Java, Madura, Kalimantan, Bali, Singapore and some areas in Malaysia with a regional population density of 61.57 persons per square kilometer.

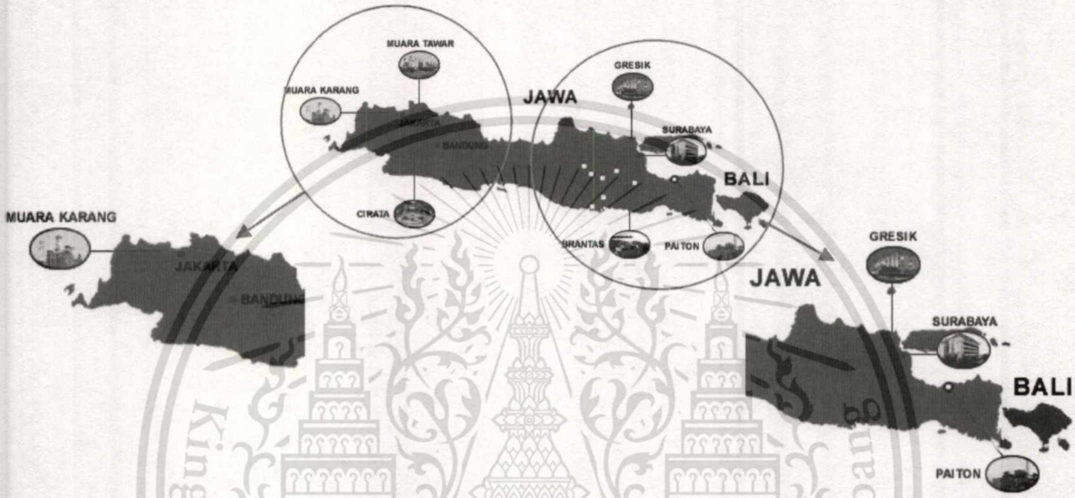

Figure 3.10 Locations of Gresik, Muara Karang and Paiton Power Plants

The Paiton coal-fired power plant (latitude 7°42'44.76" South and longitude 113°34'58.65" East) is located approximately fifty-two kilometers from Probolinggo or around 142 km toward east of Indonesia's second largest city, Surabaya. This power plant's local area includes the urban areas of Probolinggo, Situbondo, Bondowoso, Jember and Lumajang with a local population density of 388.80 persons per square kilometer. The regional area of the Paiton power plant covers the islands of Sumatra, Java, Kalimantan, Bali, Sulawesi, Lombok, Sumbawa, Sumba and Flores and has the regional population density calculated at 61.53 persons per square kilometer.

The Gresik gas-fired power plant (latitude 7°9'55.21" South and longitude 112°39'38.03" East) is located twenty five kilometers east of Surabaya, along the Northeast coast of East Java. The local area of the Gresik power plant encompasses the urban areas of Gresik, Mojokerto, Lamongan, Bangkalan, Surabaya, Sidoarjo, Lamongan, Jombang, and Pasuruan with a local population density of 1,868.39 persons per square kilometer. The regional area of the Gresik power plant includes the islands of Sumatra, Java, Kalimantan, Bali, Sulawesi, Lombok, Sumbawa, Sumba, Flores and Sarawak and has the regional population density of 61.53 persons per square kilometer.

3.4.4 Pollutant Inventory

The emission coefficients of the primary pollutants from all three power plants, shown in Table 3.5 below, were taken from the previous studies of Research Center Juelich (KFA), Germany and the Agency for the Assessment and Application of Technology (BPPT), Indonesia.

Table 3.5 Emission Coefficient of Three Power Plants

Type of Power Plant	Emission Coefficient (g/kWh)		
	SO_2	NO_2	PM
Paiton Coal-Fired Power Plant	4.34	4.56	0.67
Muara Karang Oil-Fired Power Plant	11.7	2.32	0.29
Gresik Gas-Fired Power Plant	0	1.79	0

Source: KFA-BPPT (1990)

Once the emissions coefficients are set, the emission rate of each pollutant in each power plant is calculated by multiplying the annual electricity production (kWh) with the emission coefficient (g/kWh) of each power plant. The results are listed in Table 3.6.

Table 3.6 the Value of Emission Rates of Three Power Plants

Pollutant Data	Unit	Gresik	Muara Karang	Paiton
SO_2 Emission Rate	tons/year	0	9,196.21	11,952.75
NO_2 Emission Rate	tons/year	6,123.02	1,823.52	12,558.65
PM_{10} Emission Rate	tons/year	0	226.37	1,834.22

Source: Self-Prepared

The depletion velocities values, listed in Table 3.7, were selected from the list of values available in the SimPacts program.

Table 3.7 Depletion Velocity Value

Depletion Velocity	Unit	Value
Sulphur dioxide (SO_2)	cm/s	0.75
Nitrogen oxides (NO_x)	cm/s	1.5
Particles (PM_{10})	cm/s	1.2
Nitrates Aerosols	cm/s	1.4
Sulfates Aerosols	cm/s	1.5

Source: Spadaro (2002)

3.4.5 Monetary Valuation

Since the calculation was based on the year 2008, the cost used was constant for that year. The following calculation was performed in order to transfer the existing unit costs in Europe data year 2000, as shown in Table 3.3, into unit costs in Europe year 2008 by using Equation 3.3 below.

(Eq. 3.3)

$$\textit{Unit Cost in Europe}\left(US\$_{2008}\right) = \textit{Unit Cost in Europe}\left(US\$_{2000}\right) \times \left(\frac{US\$\ Deflator_{2008}}{US\$\ Deflator_{2000}}\right)$$

Using the calculation results from equation 3.3, the transferring process the existing monetary unit costs of Europe year 2000 into the monetary unit costs of Europe year 2008, can be listed as shown in Table 3.8.

Table 3.8 Monetary Unit Costs in Europe year 2008

Health Impact	Unit	Value
Mortality (short-term exposure)	$US\$_{2008}$ per YOLL	123,646.22
Mortality (long-term exposure)	$US\$_{2008}$ per YOLL	213,014.28
Restricted activity days	$US\$_{2008}$ per incident	142.01
Long term chronic bronchitis	$US\$_{2008}$ per incident	217,666.32
Respiratory hospital admissions	$US\$_{2008}$ per incident	5,557.96
Lower respiratory symptoms (adult)	$US\$_{2008}$ per incident	9.79
Lower respiratory symptoms (child)	$US\$_{2008}$ per incident	9.79

Note: US\$ $Deflator_{2008}$ = 122.422; US\$ $Deflator_{2000}$ = 100

Source: Self-Prepared

In order to obtain the monetary unit costs in Indonesia year 2008, the monetary unit costs in Europe year 2008 from Table 3.8, were transferred into monetary unit costs in Indonesia 2008 by using Equation 3.1. The results of which are the monetary unit costs in Indonesia year 2008 as presented in Table 3.9.

Table 3.9 Monetary Unit Costs in Indonesia year 2008

Health Impact	**Unit**	**Value**
Mortality (short-term exposure)	$US\$_{2008}$ per YOLL	13,176.54
Mortality (long-term exposure)	$US\$_{2008}$ per YOLL	22,700.19
Restricted activity days	$US\$_{2008}$ per incident	15.13
Long term chronic bronchitis	$US\$_{2008}$ per incident	23,195.94
Respiratory hospital admissions	$US\$_{2008}$ per incident	592.29
Lower respiratory symptoms (adult)	$US\$_{2008}$ per incident	1.04
Lower respiratory symptoms (child)	$US\$_{2008}$ per incident	1.04

Note: PPP $GNI_{Germany}$ *= US$ 35,940; PPP* $GNI_{Indonesia}$ *= US$ 3,830*

Source: Self-Prepared

Chapter 4
Results and Discussion

4.1 Output of the QUERI Model-AirPacts Program

Here, the external costs calculated by the QUERI Model-AirPacts Program of three electricity power plants using three different energy sources (i.e. coal, oil and natural gas respectively) are evaluated and compared. When these external costs are broken down by electricity production (US$/kWh) and added to electricity production costs, it can be seen that this increase in external costs significantly reduces the competitiveness of these power generation sources on the electricity market.

The external costs calculated by the QUERI Model-AirPacts program are shown in Table 4.1 as the total impact of each of the pollutants on specific human health issues with their resultant damage costs in US dollars per year shown in Table 4.2. The outcomes differ depending on the fuel used and total population nearby the plants.

Table 4.1 Total Emission Impacts Cases of Three Power Plants (cases/year)

Exposure Response Function	Pollutant	Impacts (cases/year)		
		Gresik	Muara Karang	Paiton
Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10 [Rabl 2001]	PM10	0	537.50	299.30
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates [Rabl 2001]	Nitrates	64.37	64.41	64.37
Long-term Mortality (YOLL) - Recommended; Adults over 30; Sulfates [Rabl 2001]	Sulfates	0	61.28	61.23
Restricted Activity Days - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	0	45,480	25,320
Restricted Activity Days - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	5,446	5,450	5,446
Restricted Activity Days - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	0	5,182	5,178
Chronic Bronchitis - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	0	93.23	51.91
Chronic Bronchitis - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	11.17	11.17	11.17
Chronic Bronchitis - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	0	10.63	10.62
Respiratory Hospital Admissions; ALL; NO2 [Ponce de Leon, 1996]	NO2	52.36	14.64	6.41
Short-term Mortality (YOLL) - Recommended; ALL; SO2 [Rabl 2001]	SO2	0	179	19.94
Short-term Mortality (YOLL); ALL; NO2 [APHEA, 1997]	NO2	76.46	21.37	9.36
Lower Resp. Symptoms - Recommended; Asthmatic Adults; PM10 [Rabl 2001]	PM10	0	198,900	110,700
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates [Rabl 2001]	Nitrates	23,820	23,830	23,820
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Sulfates [Rabl 2001]	Sulfates	0	22,680	22,670
Lower Resp. Symptoms - Recommended; Asthmatic Children; PM10 [Rabl 2001]	PM10	0	84,750	47,190
Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates [Rabl 2001]	Nitrates	10,150	10,160	10,150
Lower Resp. Symptoms - Recommended; Asthmatic Children; Sulfates [Rabl 2001]	Sulfates	0	9,672	9,665
Respiratory Hospital Admissions - Recommended; ALL; PM10 [Rabl 2001]	PM10	0	5.29	2.95
Respiratory Hospital Admissions - Recommended; ALL; SO2 [Rabl 2001]	SO2	0	0.63	0.63
Respiratory Hospital Admissions - Recommended; ALL; Nitrates [Rabl 2001]	Nitrates	0.63	221.00	24.62
Respiratory Hospital Admissions - Recommended; ALL; Sulfates [Rabl 2001]	Sulfates	0	0.60	0.60
Total		39,620.99	407,324.76	260,702.11

Source: Self-Prepared

As can be seen in Table 4.1, the total cases of health problems per year from the Gresik gas-fired power plant are considerably less than those from the Muara Karang oil-fired power plant and the Paiton coal-fired power plant. The Gresik gas-fired power plant emits far fewer pollutants only nitrates and NO_2. Most of the health problems caused by these pollutants emitted at the Gresik gas-fired power plant are similar to the other two power plants except for the short-term mortality from NO_2 emissions which is more than triple. Both the Muara Karang oil-fired and the Paiton coal-fired power plants emit all five of the pollutants being examined in this thesis (i.e. sulfates and nitrate aerosols, SO_2, NO_2 and PM_{10}). Both plants cause a greater amount of health problems compared to the Gresik gas-fired power plant. The total number of health problems in adults and children including long-term mortality caused by PM_{10} emissions from the Muara Karang are often more than double than that of the Paiton coal-fired power plant. Overall the largest number of health problems due to pollutant emissions come from the Muara Karang oil-fired power plant which produces the least amount of power at 786 TWh/year while the smallest number comes from the Gresik gas-fired power plant which produces the greatest amount of power at 3,420.679 TWh/year. Electricity production at the Paiton coal-fired power plant is 2,754.09 TWh/year.

Table 4.2 Damage Costs per Year (US$/year)

Exposure Response Function	Pollutant	Damage Cost (US$/year)		
		Gresik	Muara Karang	Paiton
Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10 [Rabl 2001]	PM10	0	7,082,000	3,943,000
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates [Rabl 2001]	Nitrates	848,100	848,700	848,100
Long-term Mortality (YOLL) - Recommended; Adults over 30; Sulfates [Rabl 2001]	Sulfates	0	807,400	806,800
Restricted Activity Days - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	0	688,200	383,200
Restricted Activity Days - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	82,420	82,480	82,420
Restricted Activity Days - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	0	78,410	78,360
Chronic Bronchitis - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	0	2,162,000	1,204,000
Chronic Bronchitis - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	259,000	259,200	259,000
Chronic Bronchitis - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	0	246,600	246,400
Respiratory Hospital Admissions; ALL; NO2 [Ponce de Leon, 1996]	NO2	31,010	8,669	3,797
Short-term Mortality (YOLL) - Recommended; ALL; SO2 [Rabl 2001]	SO2	0	4,063,000	452,700
Short-term Mortality (YOLL); ALL; NO2 [APHEA, 1997]	NO2	1,736,000	485,100	212,500
Lower Resp. Symptoms - Recommended; Asthmatic Adults; PM10 [Rabl 2001]	PM10	0	207,600	115,600
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates [Rabl 2001]	Nitrates	24,860	24,880	24,860
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Sulfates [Rabl 2001]	Sulfates	0	23,680	23,660
Lower Resp. Symptoms - Recommended; Asthmatic Children; PM10 [Rabl 2001]	PM10	0	88,480	49,270
Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates [Rabl 2001]	Nitrates	10,600	10,600	10,600
Lower Resp. Symptoms - Recommended; Asthmatic Children; Sulfates [Rabl 2001]	Sulfates	0	10,100	10,090
Respiratory Hospital Admissions - Recommended; ALL; PM10 [Rabl 2001]	PM10	0	3,134	1,745
Respiratory Hospital Admissions - Recommended; ALL; SO2 [Rabl 2001]	SO2	0	375.60	375.40
Respiratory Hospital Admissions - Recommended; ALL; Nitrates [Rabl 2001]	Nitrates	375.40	130,900	14,580
Respiratory Hospital Admissions - Recommended; ALL; Sulfates [Rabl 2001]	Sulfates	0	357.90	357.70
Total		2,992,365.40	17,311,866.50	8,771,415.10

Source: Self-Prepared

In Table 4.2, although Gresik gas-fired power plant emits only two of the five pollutants being investigated in this thesis, nitrates and NO_2. Of these, NO_2 causes greater external costs than those emitted by Muara Karang oil-fired power plant and Paiton coal-fired power plant for the same health endpoints (i.e. short term mortality). The QUERI Model- AirPacts program outcomes also indicate that the external cost of asthmatic children is less than the external cost of asthmatic adults. This is caused by the number of asthmatic cases per year due from sulfates, nitrate and PM_{10} in children which is less than those in adults. This may indicate that children are more resistant to sulfates, nitrate and PM_{10} than adults.

Table 4.3 below shows that damage costs per electricity production (US$/kWh) which is obtained by dividing the results from Table 4.2 with each electricity production in a year.

Table 4.3 Damage Costs per Electricity Production (US$/kWh)

Exposure Response Function	Pollutant	Damage Cost (US$/kWh)		
		Gresik	Muara Karang	Paiton
Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10 [Rabl 2001]	PM10	0.00E+00	9.01E-03	1.43E-03
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates [Rabl 2001]	Nitrates	2.48E-04	1.08E-03	3.08E-04
Long-term Mortality (YOLL) - Recommended; Adults over 30; Sulfates [Rabl 2001]	Sulfates	0.00E+00	1.03E-03	2.93E-04
Restricted Activity Days - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	0.00E+00	8.76E-04	1.39E-04
Restricted Activity Days - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	2.41E-05	1.05E-04	2.99E-05
Restricted Activity Days - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	0.00E+00	9.98E-05	2.85E-05
Chronic Bronchitis - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	0.00E+00	2.75E-03	4.37E-04
Chronic Bronchitis - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	7.57E-05	3.30E-04	9.40E-05
Chronic Bronchitis - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	0.00E+00	3.14E-04	8.95E-05
Respiratory Hospital Admissions; ALL; NO2 [Ponce de Leon, 1996]	NO2	9.07E-06	1.10E-05	1.38E-06
Short-term Mortality (YOLL) - Recommended; ALL; SO2 [Rabl 2001]	SO2	0.00E+00	5.17E-03	1.64E-04
Short-term Mortality (YOLL); ALL; NO2 [APHEA, 1997]	NO2	5.08E-04	6.17E-04	7.72E-05
Lower Resp. Symptoms - Recommended; Asthmatic Adults; PM10 [Rabl 2001]	PM10	0.00E+00	2.64E-04	4.20E-05
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates [Rabl 2001]	Nitrates	7.27E-06	3.17E-05	9.03E-06
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Sulfates [Rabl 2001]	Sulfates	0.00E+00	3.01E-05	8.59E-06
Lower Resp. Symptoms - Recommended; Asthmatic Children; PM10 [Rabl 2001]	PM10	0.00E+00	1.13E-04	1.79E-05
Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates [Rabl 2001]	Nitrates	3.10E-06	1.35E-05	3.85E-06
Lower Resp. Symptoms - Recommended; Asthmatic Children; Sulfates [Rabl 2001]	Sulfates	0.00E+00	1.28E-05	3.66E-06
Respiratory Hospital Admissions - Recommended; ALL; PM10 [Rabl 2001]	PM10	0.00E+00	3.99E-06	6.34E-07
Respiratory Hospital Admissions - Recommended; ALL; SO2 [Rabl 2001]	SO2	0.00E+00	4.78E-07	1.36E-07
Respiratory Hospital Admissions - Recommended; ALL; Nitrates [Rabl 2001]	Nitrates	1.10E-07	1.67E-04	5.29E-06
Respiratory Hospital Admissions - Recommended; ALL; Sulfates [Rabl 2001]	Sulfates	0.00E+00	4.55E-07	1.30E-07
Total		8.75E-04	2.20E-02	3.18E-03

Source: Self-Prepared

According to Table 4.3, the damage costs due to the operation of the Muara Karang oil-fired power plant and the Paiton coal-fired power plant are higher than those of the Gresik gas-fired power plant. This can be partially attributed to generation capacity, fuel source characteristics and population density differences.

Gresik gas-fired power plant has a highest annual electricity production as well as having the highest local population density of the three power plants and yet still maintains the lowest total damage costs shown in Table 4.4, where the damage costs of electricity generation in Indonesia estimated per kilo watt hour (kWh) in 2008.

Table 4.4 External Costs of Observed Pollutant Releases

Pollutant	Unit	External Cost		
		Gresik (Gas)	**Muara Karang (Oil)**	**Paiton (Coal)**
PM_{10}	US$ cent/kWh	0	1.301	0.207
SO_2	US$ cent/kWh	0	0.517	0.016
NO_2	US$ cent/kWh	0.051	0.063	0.008
Sulfates	US$ cent/kWh	0	0.148	0.042
Nitrates	US$ cent/kWh	0.036	0.173	0.045
Total External Cost	**US$ cent/kWh**	**0.087**	**2.202**	**0.318**

Source: Self-prepared

The total estimated damage costs of the Gresik gas-fired power plant are still the lowest at 0.087 US$cent/kWh, while Muara Karang maintains the highest at 2.202 US$cent/kWh with Paiton in between at 0.318 US$cent/kWh. This is further illustrated in Figure 4.1 below, the highest external cost was at the Muara Karang power plant, which burns MFO (Marine Fuel Oil). The lowest external cost was at the Gresik power plant which uses natural gas.

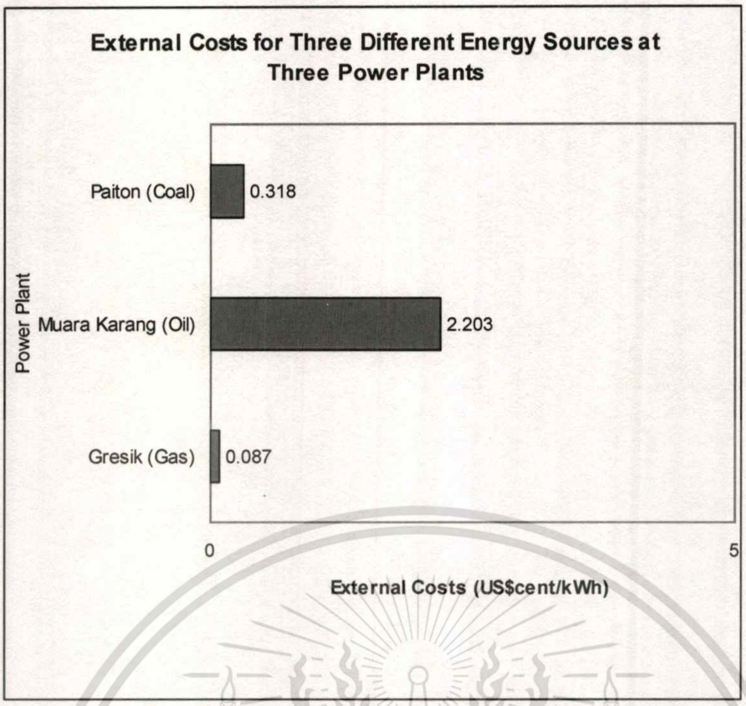

Figure 4.1 Estimation of External Costs at the Three Power Plants

Source: Self-Prepared

In Figure 4.2, the differences in local population density and generation capacity at the Muara Karang and the Paiton sites play only minor roles in PM_{10} damage costs. On the other hand, generation capacity differences between the Muara Karang and the Gresik sites play a more significant role in NO_2 emissions.

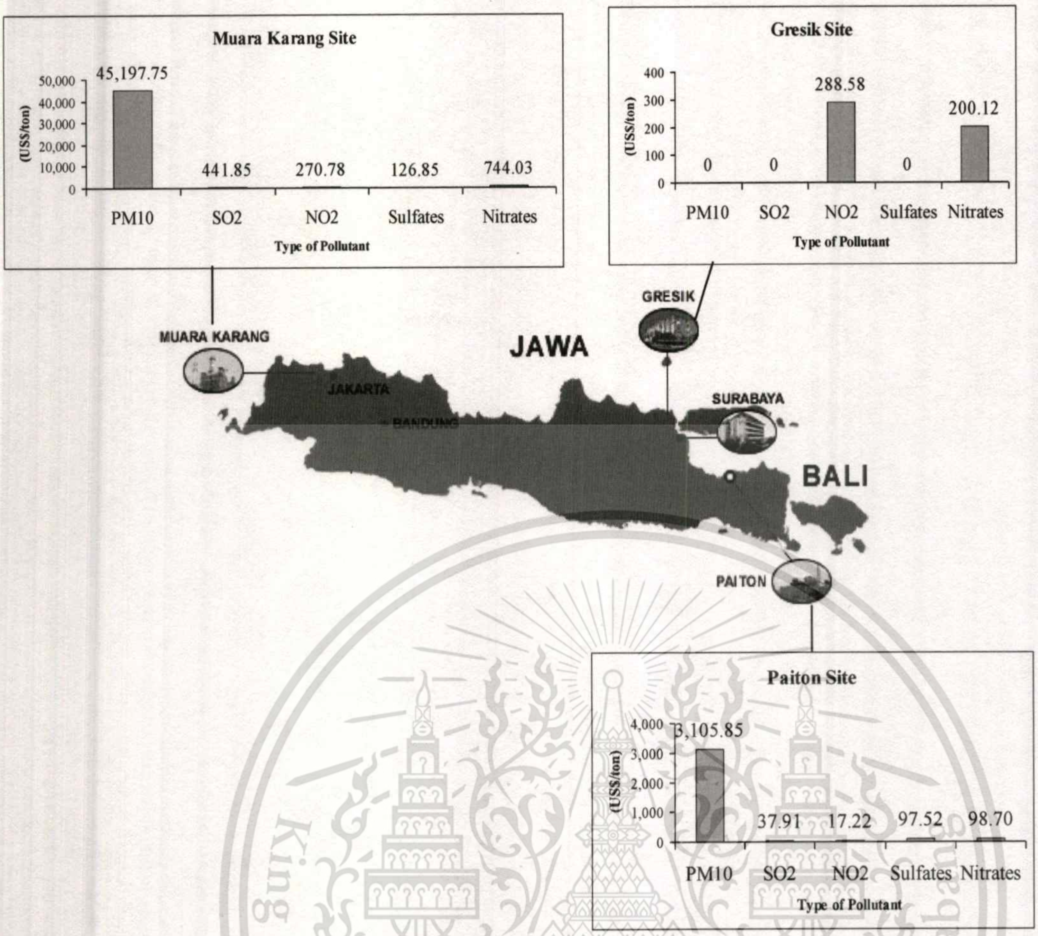

Figure 4.2 Damage Costs (US$ per ton of pollutant) on Java Island.

Source: Self-Prepared

Emitting less than a tenth of the amount of PM_{10}, the Paiton coal-fired power plant has four times the generation capacity and less than a third of the local population density of the Muara Karang oil-fired power plant. The NO_2 emissions at the Gresik gas-fired power plant are only slightly higher than those at the Muara Karang plant and yet the Gresik produces more than five times the energy of Muara Karang.

4.2 Electricity Basic Tariff (TDL)

In accordance with government regulations, the electricity basic tariff (TDL) is decided on by Presidential Decree. The state owned electrical company, PT. PLN (Persero), does not possess any authority to impose an electricity basic tariff based on its operational costs which can be greatly affected volatile market prices, particularly in primary energy supply which reduces financial performance. In order to prevent a more drastic decrease its financial ability, PT. PLN (Persero) has proposed to increase electricity basic tariff to the Government of Indonesia (GoI).

Signed on December 31, 2003, Presidential Decree No. 104/2003 formally regulates the electric selling price provided by PT. PLN (Persero). A new tariff, called TDL 2004, was put in place starting from January 1, 2004, with the purpose of reducing the burden on Indonesian citizens' lives by supplying longer periods of uninterrupted electricity to businesses and improving the quality of service.

The low basic electricity tariff has pushed up the selling price of electricity from Independent Power Producers (IPP). This is a major obstacle for investors who are interested in the electricity generation business. The current electricity sales price per kWh by PT. PLN (Persero) is varied depending on usage classifications. Based on Presidential Decree No.104/2003, electricity prices are under the following classifications: for public service, home, business, home industry, low to middle scale industry, middle to high scale industry, high scale industry, government office, public street lighting, Indonesian train corporation and companies with a license in electricity production. These basic electricity prices are much lower than the average electricity production costs. Nevertheless PT. PLN (Persero) is still able to survive because the difference in electricity sales prices and electricity production costs are covered by subsidies from state revenues. For adding capacity cost, maintenance, and new networks enhancement, PT.PLN (Persero) still lacks the availability of funds.

Although PT. PLN (Persero) continues to want the TDL raised, especially to balance the amount of electricity service needs with the generating capacity development, PLN's proposals have never obtained any positive response from the government. Related to this, in October 2009, the former Minister of Energy and Mineral Resources, Purnomo Yusgiantoro said that increasing capacity in line with the rise in electricity demand is a time-consuming discussion process and that making decisions about changes in the TDL takes time and must be done through coordinated effort with the government[5].

4.3 Power Plant Evaluations with External Costs

There are many parameters to consider when estimating the feasibility of electricity generation alternatives. The selection of power plant type is strongly influenced by the availability and price of fuel as well as the requirements of operation at base load times as well as peak load times. In addition, each type of power plant has a different efficiency, operational lifetime and ability to produce different amounts of electricity.

When looking at energy resource availability and price, it is critical to have a more readily available, inexpensive and easy access to a fuel source so that the price of transport of a resource for

[5] Web page for consultation: http://www.inilah.com/berita/ekonomi/2009/08/09/139681/haruskah-tarif-dasar-listrik-naik/

power generation is low. An example of this would be that of building a gas-fired power plant located in a region that has reserves of natural gas or a gas pipeline.

When considering base load times, coal power plants are usually used for this as they have a longer start time. Oil and gas power plants which have shorter start times are usually used at peak load periods.

Efficiency, operational lifetime and the amount of electricity demand can be quantified when comparing investment costs, fixed and variable operating and maintenance (O&M) costs as well as generation costs. These are subject to wide variations depending on the make and model of the plant, the operating regime, and the type of fuel used. The recommended values for investment costs, fixed and variable O&M costs, fuel price and generation costs for a selection of 17 types of plant technology are presented in Table 4.5.

Table 4.5 Performance and Costs Data of the Power Plants

Power Generation Type	Capacity	Investment Costs	Fixed Costs O&M	Variable Costs O&M	Lifetime	Efficiency	Fuel Price	Generation Costs
	MW	US$/kW	US$$/kW/yr	US$/MWh	Year	%		Mills US$/kWh
Coal	600	1218	14.13	9	25	37	80 US$/t	34.37
Oil	120	1,710.45	10.38	3.1	25	37	3250 Rp/liter	15.29
Steam and Gas	500	829.86	8.52	7	20	35	3 US$/MMBTU	39.22
Gas Turbine	120	437.14	6.6		20	35	2.5 US$/MSCF	38.69
Diesel	3.5	1,462.31	11.45	0.82	25	34	5900 Rp/liter	358.25
Nuclear	1,000	1,500.00	41.63		40	35	0.0036 US$/kWh	35.5
Geothermal	55	1245.19	35.95	5.6	25	38.5	6 US$/Juta kcal	53.07
Hydropower		1,676.47	13.57		50	38		29.79
Minihydro	1.5	4,802.50	24.01		50	38		82.91
Municipal Waste	25	3,000.00	50		20	25		57.42
IGCC	100	2,131.50	62.92	2.22	25	41.8	29 US$/t	54.83
Solar Non Grid		5,924.00	20		25	30		596.01
Solar Grid		3,240.00			25	29		243.99
Wind		3,505.56	41.67		15	30		210.45
Fuel Cell	0.2	4,000.00	400		10	30		99.08
Med Temp. Cogeneration	25	4,690.01	2.21		25	11		95.54
Low Temp. Cogeneration	25	2,217.61	3.38		25	35		45.6

Source: Energy Planning, BPPT (2006)

The impact of investment cost on electricity generation cost is crucial. If investment costs of a power plant are high, the electricity generation costs would also be high. Variable Operation and Maintenance Cost (VOM), defined by US$/MWh, refer to the incremental operations and maintenance costs incurred upon increasing the level of production by one unit. Of the power plants that use non-renewable energy sources, typically, a gas-fired plant has the lowest variable O&M costs and a coal-fueled plant has the highest costs associated with the cost of ash disposal and requirements for flue gas desulphurization. Fixed O&M (FOM) costs, defined by US$/kW/year, usually include all fixed operating costs such as spares, major periodic maintenance, insurance, O&M fees, property taxes and leases and owners costs such as wages. Fixed costs should not vary with changes in electricity generation levels. The economic lifetime of a power plant is the time period during which the power plant investment should pay itself back. The economic lifetime is used and the operation and maintenance costs do not include any special annual maintenance investments. The efficiency of electricity production is expressed as the annual efficiency corresponding to the whole year average (Wembridge, 2009).

There are several criteria that can be used to evaluate investment plans: the payback period, discounted payback period, accounting rate of return, profitability index, net present value (NPV) and internal rate of return (IRR). This thesis will only discuss and analyze the NPV and IRR as these are mostly concerned with feasibility as well as profitability.

The NPV is annual cash inflow and cash outflow. Investment cost is the cash outflow and the profits that are achieved every year as the cash flows in. When comparing projects with different capacities, the use of NPV is an important parameter to be considered. The greater the NPV, the better the project is. When NPV is more than zero, the investment is feasible. If the NPV is less than zero, the investment is rejected.

The Internal Rate of Return (IRR) is defined as the discount rate that makes the Net Present Value zero. If the IRR is greater than the discount rate, then the investment is profitable. When the IRR is less than the discount rate, the investment proposal is rejected. The greater the IRR value, the more profitable it is. However, if external costs are used as inputs in power plants' investment evaluations then the development of power plants that use renewable energy which is environmentally friendly will become more feasible when compared to those that use non-sustainable fossil fuels,

To obtain a positive NPV value which includes a discount rate of 10%, the electricity basic tariff should be modified repeatedly until a feasible NPV result for investment is obtained. By adding the external costs into the calculation, the NPV value decreases. In order to put NPV in a stable and positive value, the electricity basic tariff should be increased.

Table 4.6 Input Data Requirements for NPV and IRR Calculation

	Parameter	Unit	Paiton Coal-Fired	Gresik Gas-Fired	Muara Karang Oil-Fired
Data					
	Foreign exchange	Rp/US$	9,300	9,300	9,300
	Discount rate (r)	%	10	10	10
	Calorific value		21.9 MJ/kg	292.9 kWh/MMBTU	9500 kcal/l
			6.081 MWh/t		0.01104 MWh/l
	Electricity tariff	Rp/kWh	850	600	1,500
	External Cost	Rp/kWh	29.57	204.79	8.09
	Installed capacity	MW	400	100	525
	Investment cost	US$/kW	1,218	1,710	829.86
	Fixed O&M	US$/kW/yr	14.13	10.38	8.52
	Variabel O&M	US$/MWh	9	3.1	7
	Coal price	US$/t	80	3,250	3
	Availability factor	%	78.60	89.73	97.62
	Thermal efficiency	%	37	37	35
	Life time	yr	25	25	20
Calculation					
	Electricity production	MWh/yr	2,754,090	786,000	3,420,679
	Total investment cost	US$	487,200,000	171,000,000	435,676,500
	Total Fixed O&M cost	US$/yr	5,652,000	1,038,000	4,473,000
	Total Variabel O&M cost	US$/yr	24,787,296	2,436,708	31,426,807
	Total Fuel cost	US$/yr	97,916,281	67,246,764	131,382,055
	Total External cost	US$/yr	8,758,178	17,308,486	3,905,903
	Total Revenue	US$/yr	177,686,710	135,231,794	772,394,632

Source: Self-prepared

The currency conversion rate used for the purpose of this thesis is 1 US$ is equal to 9300 Indonesian Rupiah (Rp.). Electricity production is the annual electricity generated and is expressed in kilowatt or megawatt-hours. The equations used to obtain the parameter values in Table 4.6 are as follows:

(Eq.4.1) $$Electricity\ production = Installed\ capacity\ (MWh) \times Availability\ factor \times (24\ hours \times 365\ days)$$

(Eq.4.2) $$Total\ Investment\ Cost = Investment\ Cost\ (US\$/kW) \times Installed\ capacity\ (kW)$$

(Eq.4.3) $$Total\ fixed\ O\&M\ Cost = Fixed\ Cost\ (US\$/kW/yr) \times Installed\ capacity\ (kW)$$

(Eq.4.4) $$Total\ Variable\ O\&M\ Cost = Variable\ O\&M\ (US\$/MWh) \times Electricity\ production\ (MWh)$$

(Eq.4.5) $$Total\ Fuel\ Cost = \frac{(Oil\ price / Foreign\ exchange)}{Calorific\ value\ (MWh/l)} \times \frac{Electricity\ production\ (MWh)}{Thermal\ efficiency}$$

(Eq.4.6) $$Total\ External\ Cost = \frac{External\ Cost\ (Rp/kWh)}{Foreign\ exchange\ (Rp/US\$)} \times 1000 \times Electricity\ production\ (MWh/yr)$$

(Eq.4.7) $$Total\ revenue = \frac{Electricity\ tariff\ (Rp/kWh)}{Foreign\ exchange\ (Rp/US\$)} \times 1000 \times Electricity\ production\ (MWh/yr)$$

In addition, it is possible to calculate the internal rate of return and the net present value of each power plant at various electricity sales prices. The NPV of a project investment is the difference between the sum of the discounted cash flow which is expected from the investment and the amount which is initially invested. The first step in doing the investment calculation is to calculate the cash flow for each project as can be seen in the following equations.

(Eq.4.8) $$Cash\ Flow = (Total\ revenue - Total\ Cost) \times \frac{1}{(1+r)^t}$$

(Eq.4.9) $$Total\ Cost = Total\ Fuel\ Cost - Total\ Variable\ O\&M - Total\ Fixed\ O\&M - Total\ External\ Cost$$

The second parameter to analyze a project's feasibility is by calculating the Internal Rate of Return (IRR) which relies only on the cash flow of the project. The IRR is the required return that results in zero NPV when it is used as the discount rate. There is no mathematical approach to finding the IRR; the only way is by trial and error. The results of the NPV and IRR calculations are summarized in Table 4.7 below. The NPV result at which a power plant starts to become feasible is highlighted.

Table 4.7 NPV and IRR Results at Various Electricity Prices

Tariff		Discount Rate	Paiton Coal-Fired		Gresik Gas-Fired		Muara Karang Oil-Fired	
p/kWh)	(US$cent/kWh)	(%)	NPV (US$)	IRR (%)	NPV (US$)	IRR (%)	NPV (US$)	IRR (%)
450	4.84	10	-	-	-43,642,000	-1.36	-	-
500	5.38	10	-	-	161,852,717	4.68	-	-
550	5.91	10	-	-	367,347,433	10.17	-	-
600	6.45	10	-118,917,670	-3.03	572,842,149	15.42	-	-
650	6.99	10	15,488,111	0.37	778,336,865	20.56	-	-
700	7.53	10	149,893,893	3.49	983,831,581	25.65	-	-
750	8.06	10	284,299,674	6.46	1,189,326,298	30.71	-	-
800	8.60	10	418,705,455	9.35	1,394,821,014	35.76	-	-
850	9.14	10	553,111,236	12.18	1,600,315,730	40.80	-	-
900	9.68	10	687,517,017	14.99	1,805,810,446	45.84	-	-
950	10.22	10	821,922,799	17.78	2,011,305,162	50.88	-	-
1000	10.75	10	956,328,580	20.56	2,216,799,879	55.92	-	-
1050	11.29	10	1,090,734,361	23.33	2,422,294,595	60.96	-	-
1100	11.83	10	1,225,140,142	26.10	2,627,789,311	65.99	-	-
1150	12.37	10	1,359,545,923	28.87	2,833,284,027	71.03	-	-
1200	12.90	10	1,493,951,705	31.63	3,038,778,743	76.07	-49,423,150	-3.62
1250	13.44	10	1,628,357,486	34.40	3,244,273,460	81.10	-11063637	-0.77
1300	13.98	10	1,762,763,267	37.16	3,449,768,176	86.14	27,295,875	1.84
1350	14.52	10	1,897,169,048	39.92	3,655,262,892	91.18	65,655,388	4.33
1400	15.05	10	2,031,574,829	42.69	3,860,757,608	96.21	104,014,900	6.72
1450	15.59	10	2,165,980,611	45.45	4,066,252,324	101.25	142,374,413	9.07
1500	16.13	10	2,300,386,392	48.21	4,271,747,041	106.28	180,733,926	11.38
1550	16.67	10	2,434,792,173	50.98	4,477,241,757	111.32	219,093,438	13.67
1600	17.20	10	2,569,197,954	53.74	4,682,736,473	116.36	257,452,951	15.95

Source: Self-Prepared

As shown in the table above, a positive NPV value always includes a discount rate of 10%. At the Paiton coal-fired plant, a feasible tariff price begins at 9.14 US$cent/kWh with the IRR at 12.18% which is cheaper with a higher IRR than the Muara Karang oil-fired plant, where the electricity price is at 15.59 US$cent/kWh, the IRR is at 11.38%. However, the Gresik gas-fuelled plant has the lowest minimum sales price of all three power plants at 6.45 US$cent/kWh, with the highest IRR at 15.42% and is therefore the most feasible of the three.

The NPV of each project is in US$ and is illustrated in Figure 4.3 below. These differences greatly affect electricity sales prices. The higher the external cost, the greater the impacts are on human health and the higher the electricity sales prices.

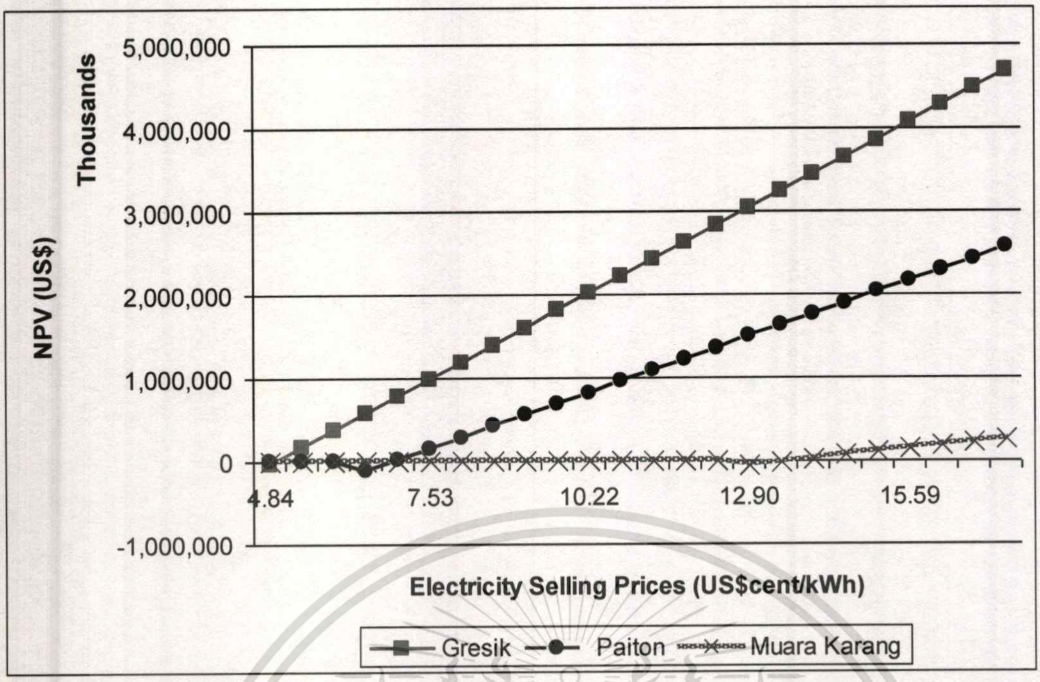

Figure 4.3 NPV of Three Power Plants Investment in Indonesia with Different Electricity Sales Prices

Thus, by comparing those NPV and IRR values can be concluded that the Gresik gas-fired power plant is the best investment plan which offers the highest profitability. The least feasible and profitable investment plan is on the Muara Karang oil-fired power plant.

4.4 Electricity Generation Issues and Policies

Indonesia possesses an abundance of energy resources that include not only limited fossil energy reserves such as oil, natural gas and coal which are still being exploited but also a great variety of limitless renewable energy with significant potential. The ever increasing population along with the sustained growth of the economy demands inputs of continually larger amounts of natural resources, as fuel and in the form of raw materials. In the meantime, fossil energy resources are finite, and efforts need to be undertaken to optimize the utilization of these. To achieve this objective, the utilization of energy resources need to be shifted in the stages from export of energy towards energy utilization in supporting the industrialization process such that sustainable development is attained so that optimum energy resource allocation can be achieved.

Renewable energy is difficult to develop in Indonesia for a number of reasons. The location of renewable energy sources, such as hydro and geothermal, is often far from markets, the processing costs of renewable energy are relatively high compared to conventional energy processing and finally there is a lack of experts. As a result, the utilization of renewable energy has not been intensively utilized.

Indonesia's Presidential Regulation No. 5/2006 on the National Energy Policy (KEN) is about ensuring the security of domestic energy supply and to support sustainable development. KEN's goals are to achieve energy elasticity of less than one and the realization of optimal energy mix by 2025 so that the share of each type of energy for national consumption will be as follows: oil will provide less than a 20% share while natural gas will provide more than a 30% and coal will have more than a 33% share. Bio-fuel and geothermal will provide more than 5% each, while new energy alternatives (nuclear power) and other renewable energy (biomass, hydropower, solar energy, and wind power) will provide more than 5% and liquefied coal will take on more than a 2% share.

The main policies of KEN include energy provision by guarantors of domestic energy supply, energy production optimization, implementation of energy conservation; efficient energy utilization, energy diversification; determination of the energy price policy towards economics of price, consider the small business capability, and assistance for poor communities for a period of time; and environmental conservation by applying the principles of sustainable development.

The supporting policies include the energy infrastructure development, including the increased access to energy consumers, the partnership between government and the business community, community empowerment, research development and, education and training development.

National energy policies must integrate development objectives across all economic sectors with the protection of the natural environment so that both economic productivity and each individual's quality of life can be maintained. Integration helps to assure full utilization of natural and human resource potentials, which in turn helps to assure efficient resource use consistent with natural resource conservation principles, and to optimize net overall benefits to the nation. It emphasizes the care that needs to be taken to maintain productive capacity. In general, energy resource management should seek to maximize the value added through optimizing resource utilization to support the sustainable development.

To support the long-term national development program and in light of recent changes in the global strategic environment, Indonesia has established an integrated energy policy comprising five principal policies and nine supporting policies. The five principal policies are: energy diversification, intensification of exploration for energy sources, energy conservation, average energy price adjustment and environment for sustainable development. Energy diversification is to diversify supply and utilize energy resources in order to optimize energy supply. Energy conservation is efficient and rational energy utilization, without reducing needed energy usage.

Indonesia's non-renewable as well as renewable energy reserves are as rich as they are diverse. Indonesia's oil reserves are currently estimated at around 9 billion barrels; these reserves may be exhausted in about 18 years. Gas reserves are at around 182.5 TSCF (trilion standard cubic feed): 94.78 TSCF proved reserves and 87.73 TSCF potential reserves which can be utilized for another 64 years. Indonesia possesses about 3.1% of the world's coal reserves at around 57 billion tons. The 19.3 billion tons of coal reserves that have been explored are estimated to last for another 147 years.

Energy resources which are considered to be renewable are biomass, biofuel, biogas, solar energy, geothermal, hydro power, wind energy, and tidal energy. Indonesia has a fairly large potential of biomass energy. The whole potential of biomass energy from the three sectors of forestry, agriculture and estates, amounts to the equivalent of about 50,000 MW.

The potential of solar energy is good, with a daily solar intensity of 4.8 kWh/m^2. To utilize solar energy potential, there are two technologies which have been applied, namely solar thermal energy and solar photovoltaic.

The potential of geothermal energy in Indonesia is very large. Almost all regions, except Kalimantan, are passed by a row of volcanoes. The total geothermal energy potential is around 20,000 MW, which is equal to 40% of world's geothermal energy resources. The Head of the Agency for Assessment and Application of Technology (BPPT), Marzan Aziz Iskandar, stated that in 2010, BPPT will develop a geothermal power generation plant in Cibuni, West Java. In a discussion with Tempo Magazine on November 19th, 2009, Marzan said that geothermal sites are available with the potential to produce electricity of 2.5 megawatts that could illuminate around 2500 houses. A thirty billion Rupiah investment is required, which can be taken from the state budget because the possibility of finding interested investors to invest in small capacity geothermal power generation is slim.

Hydro-power potential for electricity production is estimated to be quite substantial at about 75,000 MW. Meanwhile, the potential of wind energy is small on account of the generally low wind speeds of between 3 and 5 m/sec except in certain areas in the eastern part of Indonesia where wind speeds are higher than 5m/sec. The potential of tidal energy is good; however in-depth research into its potential has not yet been completed.

Many difficulties face the development of nuclear power because its realization is still constrained by at least five factors: the high risk of nuclear power plants that generate radioactive waste, the lack of community support as well as the unpreparedness to provide proper human resources, energy sources for nuclear power plant (i.e. uranium), and the inability to handle uranium enrichment technology. Furthermore, the government has not been very determined in developing nuclear power plant technology. Huge funds for the implementation of the nuclear power plants development are also not available. Regarding uranium enrichment technology, Indonesia as a developing country will also find it difficult to get support from developed countries that have power over these technologies. There are still concerns about nuclear usage for weaponry purposes. Moreover, the perception that nuclear power plant development is a clean and cheap technology is difficult to be achieved. Radioactive waste security and the accident risk from nuclear power plant operations which are no longer inexpensive investments.

To develop renewable energy, some key environmental policies should be reviewed. The handling of energy should be separated from the handling of mining issues. The idea of establishing nuclear power plants is actually being fuelled by the fear of a future energy crisis. Such fears should not be considered when taking into account the availability of energy resources in Indonesia which are still relatively stable and secure. However, some current problems arise from the inappropriate management and handling of primary energy sources. Exports of primary energy, for example coal, oil, or natural gas, are still supported for their foreign exchange earnings along with the mining of other resources. The export of primary energy is supported once domestic energy security is achieved.

An energy crisis occurs when the consumer demand for electricity can not be met in accordance with the needs in a timely manner. It is ironic that in some parts of Indonesia that have a high potential of abundant energy resource development, there is an electrical energy crisis. This condition proves that nuclear power plants are not urgently needed instead renewable energy should be exploited and developed.

Chapter 5
Conclusion

The investment, operational and maintenance costs of electricity generation and distribution are important criteria when making decisions about future electricity generation development. By estimating and then incorporating the external costs (i.e. the negative impact on human health) into the costs of oil, coal and gas-fired power plants currently operating, the overall feasibility of each plant can be more fully assessed as well as accurately compared. The long term feasibility of expanding the use of renewable energy in electricity generation can be clearly seen when the negative impacts on human health due to air pollution are adequately taken into account. This is particularly relevant since the Indonesian government has not only recently initiated a "fast-track program" program to have small and medium sized coal-fired power plants across Indonesia with a total capacity of 10,000 MW begin operation by the end of 2010 but also planned to have coal-fired power plants to take on 63% of Indonesia's electricity production by 2018.

The external costs of the Muara Karang oil-fired, the Paiton coal-fired and the Gresik gas-fired power plants were estimated by using the QUERI Model-AirPacts Program. The results were that the Muara Karang oil-fired power plant had the most expensive external costs at 2.202 US$cent/kWh, followed by the Paiton coal-fuelled power plant at 0.381 US$cent/kWh and finally the Gresik gas-fired power plant at 0.087 US$cent/kWh. These costs were then factored into the investment calculations of net present value (NPV) and internal rate of return (IRR) so that minimum tariffs could be calculated that would allow for profit. The results clearly show that the higher the external cost, the greater the impacts are on human health and the higher the electricity sales prices. The Muara Karang oil -fired power plant had the lowest NPV with the highest minimum tariff of 16.13 US$cents/kWh while the Gresik gas-fired power plant had the highest NPV with the lowest minimum tariff of 6.45 US$cents/kWh. The NPV along with the minimum tariff for the Paiton coal-fuelled power plant was between the other two at 9.14 US$cents/kWh.

It must be said, however, that these estimates were under the constraints of limited data. In future research works, the exposure-response and emission data could be more accurate by being researched in greater depth. All Indonesian weather stations should record hourly wind speeds. More detailed information on health cases and costs should be collected by the Indonesian Ministry of Health. Overall, when Indonesian departments can make available the most detailed, up to date, accurate data, calculations can be more precise. Another possible future research work would be to conduct an analysis on the utilization of QUERI model-AirPacts program on power plants that use other energy sources.

Nevertheless, it can be concluded that the 10,000 MW "fast-track program" using coal as its main energy source along with the government's plans to have coal taking the lead in future power production is neither the best nor the most appropriate long term plan. The use of natural gas and further development in the utilization of Indonesia's abundant renewable energy resources should be actively pursued.

The decision-making process in the planning of future power generation projects can be aided considerably when the external costs are taken into consideration because higher external costs on power generation increase the price of electricity for the end-users not only monetarily by also health wise. This thesis shows that social welfare can be measured on the energy market and proves that use of renewable resources for sustainable development in energy production is far more beneficial to society as well as national development.

By actively seeking to improve its capabilities in the mastery of science and technology, Indonesia can begin to explore and exploit its huge potential energy sources like geothermal, tidal, hydropower, solar, biogas, biomass and biofuel by working with expert research institutes in country and abroad.

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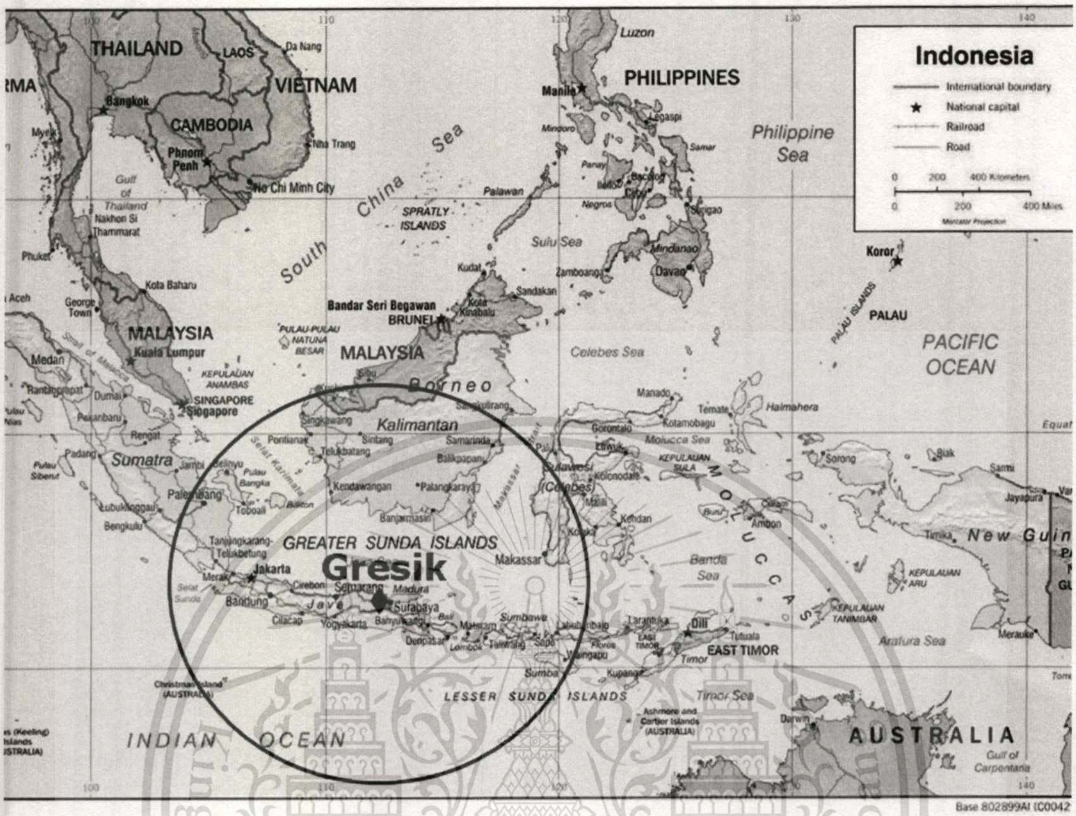
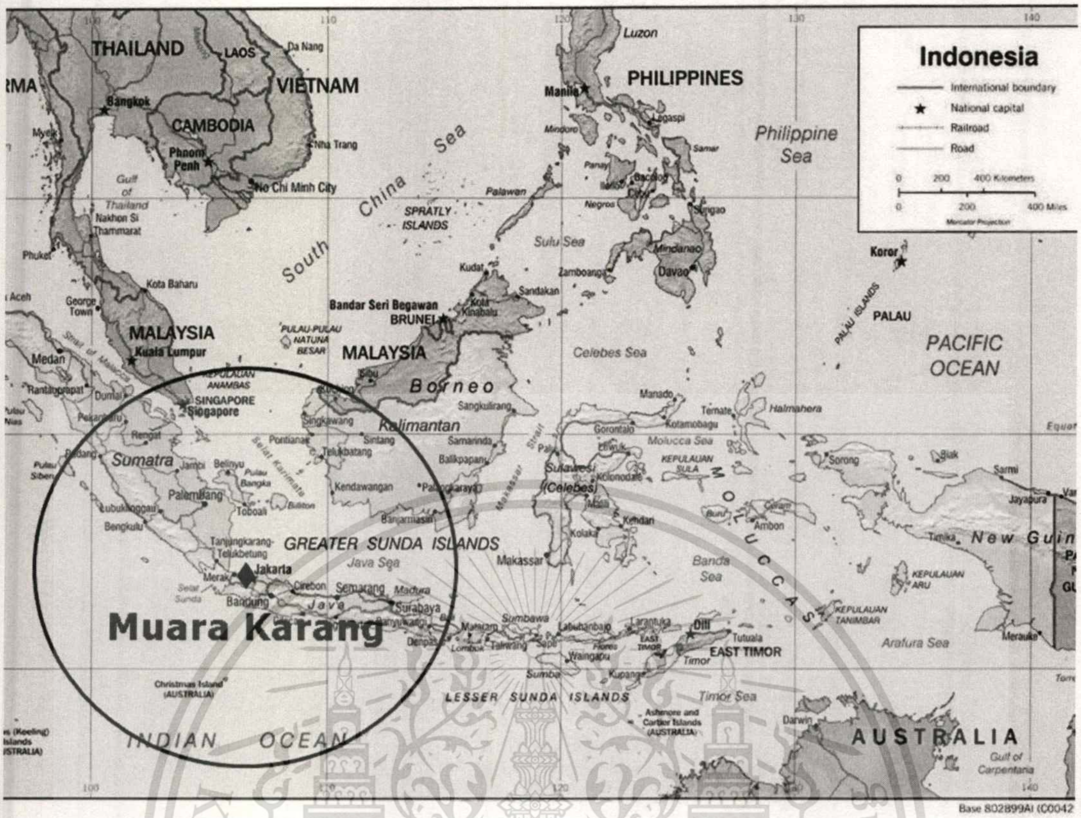
APPENDIX A: RADIUS OF LOCAL AND REGIONAL AREA

APPENDIX A.1: REGIONAL AREA OF GRESIK GAS-FIRED POWER PLANT

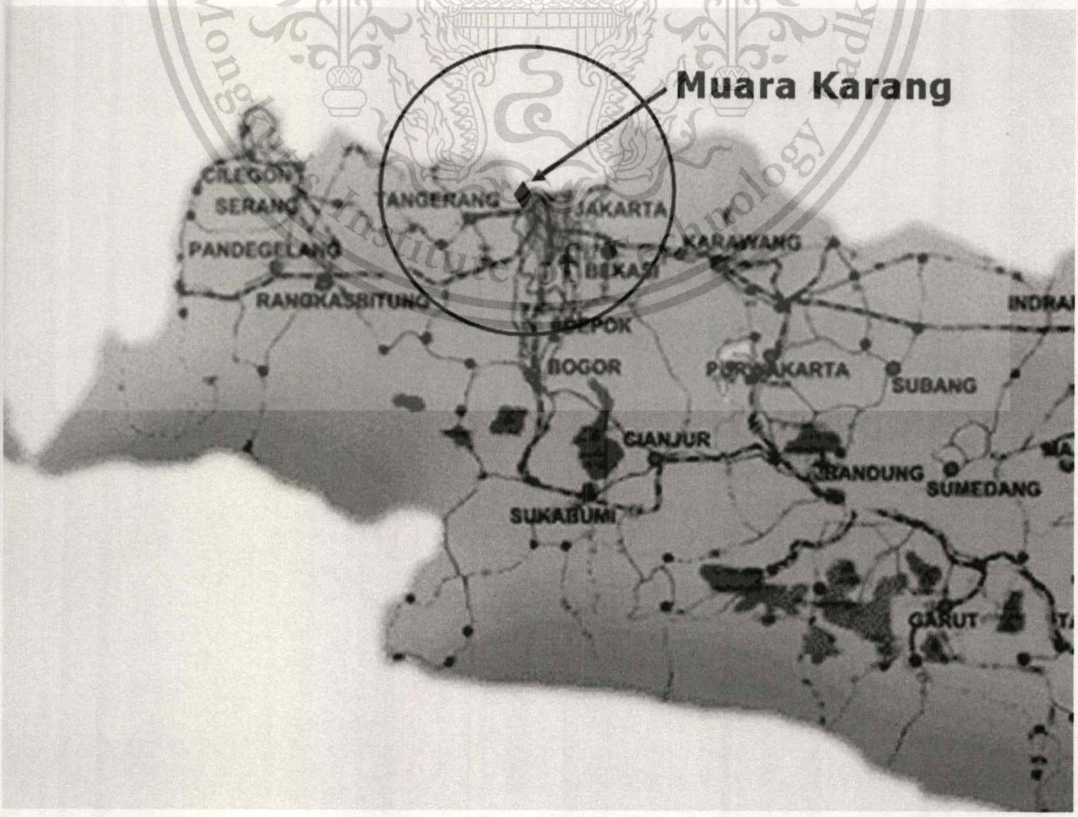


APPENDIX A. 2: LOCAL AREA OF GRESIK GAS-FIRED POWER PLANT

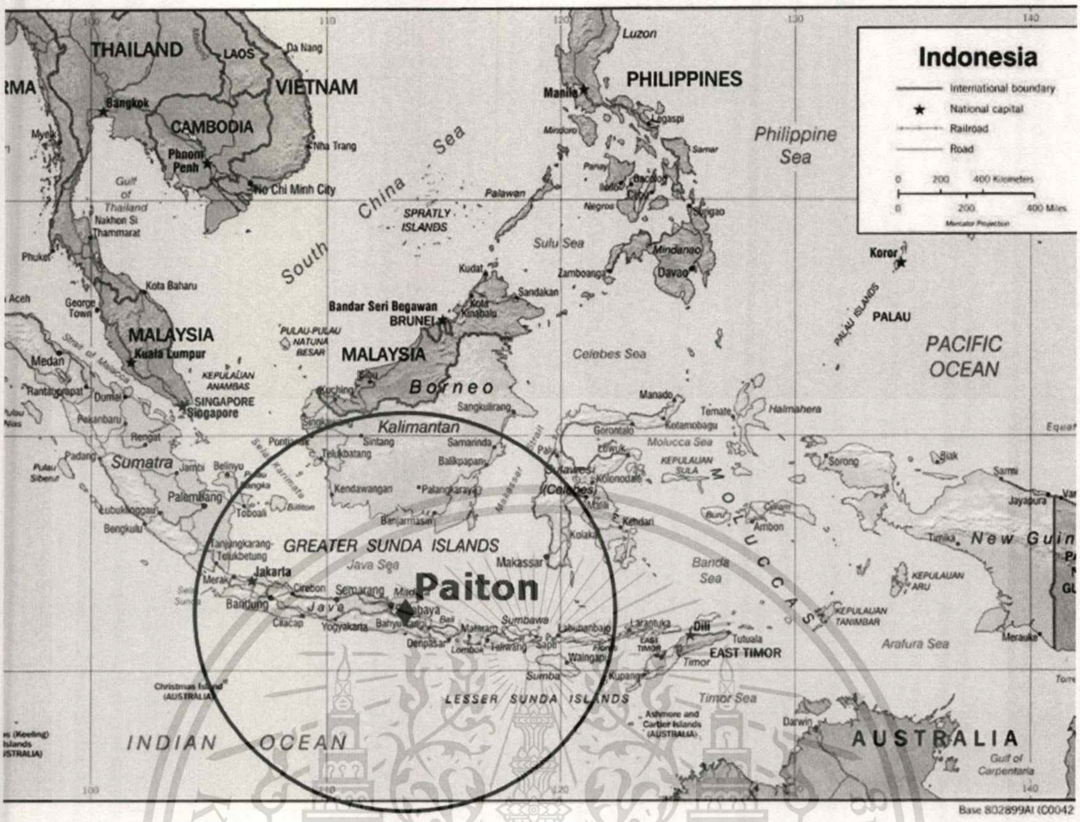
APPENDIX A.3: REGIONAL AREA OF MUARA KARANG OIL-FIRED POWER PLANT



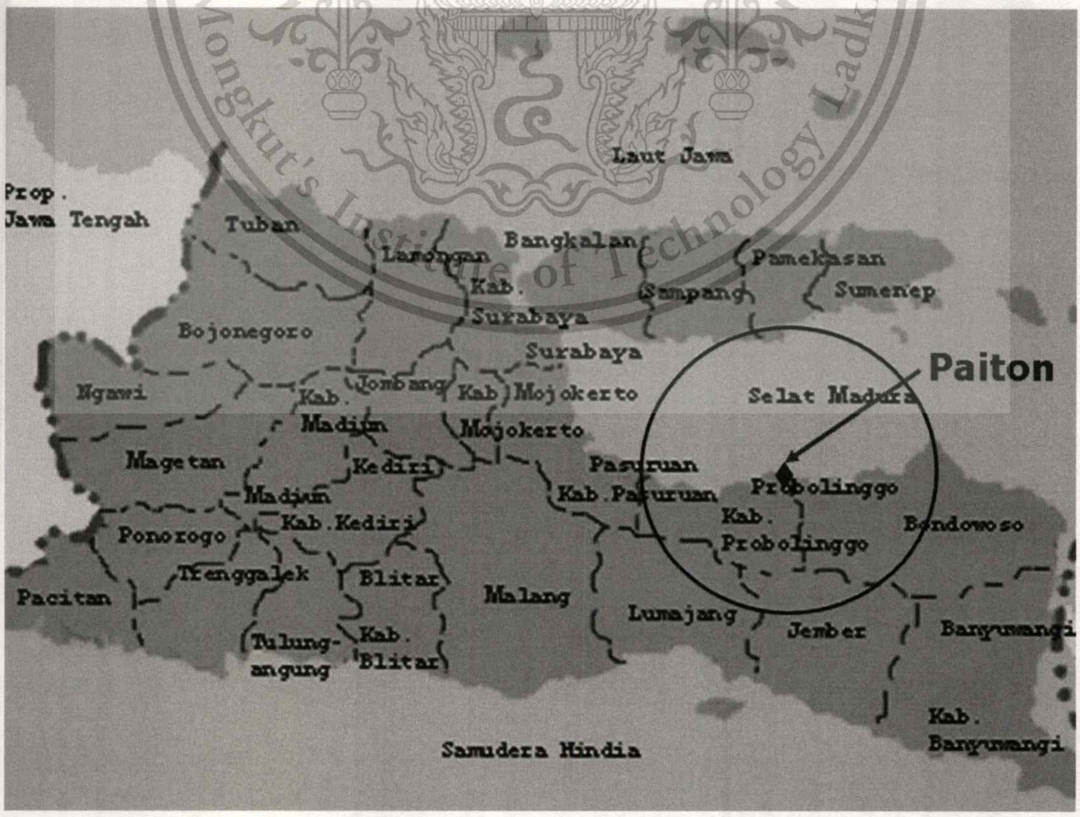
APPENDIX A.4: LOCAL AREA OF MUARA KARANG OIL-FIRED POWER PLANT



APPENDIX A.5: REGIONAL AREA OF PAITON COAL-FIRED POWER PLANT



APPENDIX A.6: LOCAL AREA OF PAITON COAL-FIRED POWER PLANT



APPENDIX B: BASIC ELECTRICITY COST (TDL)

APPENDIX B.1: CLASSIFICATION OF BASIC ELECTRICITY COST

PRESIDENTIAL DECREE, REPUBLIC OF INDONESIA

NO. : 104/2003

DATE: DECEMBER 31, 2003

NO.	TARIFF CLASSIFICATION TR/TM/TT *)	POWER LIMIT	NOTE
1	S-1/TR	220 VA	Cost classification for low electricity usage.
2	S-2/TR	250 VA - 200 kVA	Cost classification for public service low to middle electricity usage.
3	S-3/TM	Over 200 kVA	Cost classification for public service high electricity usage.
4	R-1/TR	250 VA - 2,200 VA	Cost classification for home - low electricity usage.
5	R-2/TR	2,200 VA - 6,600 VA	Cost classification for home - middle electricity usage.
6	R-3/TR	Over 6,600 VA	Cost classification for home - high electricity usage.
7	B-1/TR	250 VA - 2,200 VA	Cost classification for business - low electricity usage.
8	B-2/TR	2,200 VA - 200 kVA	Cost classification for business - middle electricity usage.
9	B-3/TM	Over 200 kVA	Cost classification for business - high electricity usage.
10	I-1/TR	450 VA - 14 kVA	Cost classification for home industry usage.
11	I-2/TR	14 kVA - 200 kVA	Cost classification for low to middle scale industry usage.
12	I-3/TM	Over 200 kVA	Cost classification for middle to high scale industry usage.
13	I-4/TT	Over 30,000 kVA	Cost classification for high scale industry usage.
14	P-1/TR	250 VA - 200 kVA	Cost classification for government office - low to middle electricity usage.
15	P-2/TM	Over 200 kVA	Cost classification for government office - high electricity usage.
16	P-3/TR		Cost classification for public street lighting usage.
17	T/TM	Over 200 kVA	Cost classification for Indonesia Train Corporation.
18	C/TM	Over 200 kVA	Cost classification for companies with a license in electricity production for public usage.
19	M/TR, TM, TT		Versatile cost classification for other users who need special quality service and by any means are not included in classification cost of S, R, B, I and P.

*) Note:

TR : Low power
TM : Middle power
TT : High Power

S : Public service
R : Home consumption
B : Business consumption

I : Industry
P : Government office

APPENDIX B.2: CLASSIFICATION OF BASIC ELECTRICITY COST FOR PUBLIC SERVICE

PRESIDENTIAL DECREE, REPUBLIC OF INDONESIA

NO : 104/2003

DATE : DECEMBER 31, 2003

NO.	TARIFF CLASS.	POWER LIMIT	POWER COST (Rp./ kVA/ month) Jan 1- Dec 31, 2004	ENERGY COST (Rp./ kWh) Jan 1- Dec 31, 2004
1	S-1/TR	220 VA	-	Subscription fee/ month (Rp.): Rp. 14,800
2	S-2/TR	450 VA	Rp. 10,000	Block I : 0-30 kWh : 123 Rp./kWh
				Block II : 30-60 kWh : 265 Rp./kWh
				Block III : >60 kWh : 360 Rp./kWh
3	S-2/TR	900 VA	Rp. 15,000	Block I : 0-20 kWh : 200 Rp./kWh
				Block II : 20-60 kWh : 295 Rp./kWh
				Block III : >60 kWh : 360 Rp./kWh
4	S-2/TR	1,300 VA	Rp. 25,000	Block I : 0-20 kWh : 250 Rp./kWh
				Block II : 20-60 kWh : 335 Rp./kWh
				Block III : >60 kWh : 405 Rp./kWh
5	S-2/TR	2,200 VA	Rp. 27,000	Block I : 0-20 kWh : 250 Rp./kWh
				Block II : 20-60 kWh : 370 Rp./kWh
				Block III : >60 kWh : 420 Rp./kWh
6	S-2/TR	2,200 VA- 200 kVA	Rp. 30,500	Block I : 0-60 hours operation : 380 Rp./kWh
				Block II : > 60 hours operation : 430 Rp./kWh
7	S-3/TM	> 200 kVA	Rp. 29,500	Block WBP = K x P x 325 Rp./kWh
				Block LWBP = P x 325 Rp./kWh

P : Multiplier factor for S-3 (social usage) and S-3 (commercial usage). Factor S-3 (social usage) P = 1, for S-3 (commercial usage) P = 1.17. Categorized for S-3 for commercial and S-3 for social is done by Director Board of Indonesian National Electric Company (PT.PLN) considered the economy and the business.

K : Ratio factor between WBP cost and LWBP cost are considered with the characteristic of the local electricity system load ($1.4<K<2$) defined by Directors of PT.PLN.

WBP : Peak power time.

LWBP : Outside peak power time.

H : Hour operation, kWh per month divided by kVA.

APPENDIX B.3: CLASSIFICATION OF BASIC ELECTRICITY COST FOR HOUSEHOLD CONSUMPTION

PRESIDENTIAL DECREE, REPUBLIC OF INDONESIA

NO : 104/2003

DATE : DECEMBER 31, 2003

NO.	TARIFF CLASS.	POWER LIMIT	POWER COST (Rp./ kVA/ month) Jan 1- Dec 31, 2004	ENERGY COST (Rp./ kWh) Jan 1- Dec 31, 2004
1	R-1/TR	0-450 VA	Rp. 11,000	Block I : 0-30 kWh : 169 Rp./kWh Block II : 30-60 kWh : 360 Rp./kWh Block III : >60 kWh : 495 Rp./kWh
2	R-1/TR	900 VA	Rp. 20,000	Block I : 0-20 kWh : 275 Rp./kWh Block II : 20-60 kWh : 445 Rp./kWh Block III : >60 kWh : 495 Rp./kWh
3	R-1/TR	1,300 VA	Rp. 30,100	Block I : 0-20 kWh : 385 Rp./kWh Block II : 20-60 kWh : 445 Rp./kWh Block III : >60 kWh : 495 Rp./kWh
4	R-1/TR	2,200 VA	Rp. 30,200	Block I : 0-20 kWh : 390 Rp./kWh Block II : 20-60 kWh : 445 Rp./kWh Block III : >60 kWh : 495 Rp./kWh
5	R-2/TR	2,200 VA- 6,600 VA	Rp. 30,400	560 Rp./kWh
6	R-3/TR	> 6,600 VA	Rp. 34,260	621 Rp./kWh

APPENDIX B.4: CLASSIFICATION OF BASIC ELECTRICITY COST FOR BUSINESS CONSUMPTION

PRESIDENTIAL DECREE, REPUBLIC OF INDONESIA

NO : 104/2003

DATE : DECEMBER 31, 2003

NO.	**TARIFF CLASS.**	**POWER LIMIT**	**POWER COST (Rp./ kVA/ month) Jan 1- Dec 31, 2004**	**ENERGY COST (Rp./ kWh) Jan 1- Dec 31, 2004**
1	B-1/TR	0-450 VA	Rp. 23,500	Block I : 0-30 kWh : 254 Rp./kWh Block II : >30 kWh : 420 Rp./kWh
2	B-1/TR	900 VA	Rp. 26,500	Block I : 0-180 kWh : 420 Rp./kWh Block II : >108 kWh : 465 Rp./kWh
3	B-1/TR	1,300 VA	Rp. 28,200	Block I : 0-146 kWh : 470 Rp./kWh Block II : >146 kWh : 473 Rp./kWh
4	B-1/TR	2,200 VA	Rp. 29,200	Block I : 0-264 kWh : 480 Rp./kWh Block II : >264 kWh : 518 Rp./kWh
5	B-2/TR	2,200 VA- 200 kVA	Rp. 30,000	Block I : 0-100 hours operation : 520 Rp./kWh Block II : > 100 hours operation : 545 Rp./kWh
6	B-3/TM	> 200 kVA	Rp. 28,400	Block WBP = K x 452 Rp./kWh Block LWBP = 452 Rp./kWh

K : Ratio factor between WBP cost and LWBP cost are considered with the characteristic of the local electricity system load ($1.4<K<2$) defined by Directors of PT.PLN.

WBP : Peak power time.

LWBP : Outside peak power time.

H : Hour operation, kWh per month divided by kVA.

APPENDIX B.5: CLASSIFICATION OF BASIC ELECTRICITY COST FOR INDUSTRY CONSUMPTION

PRESIDENTIAL DECREE, REPUBLIC OF INDONESIA

NO : 104/2003

DATE : DECEMBER 31, 2003

NO.	Tariff Class.	POWER LIMIT	POWER COST (Rp./ kVA/ month) Jan 1- Dec 31, 2004	ENERGY COST (Rp./ kWh) Jan 1- Dec 31, 2004
1	I-1/TR	0-450 VA	Rp. 26,000	Block I : 0-30 kWh : 160 Rp./kWh Block II : >30 kWh : 395 Rp./kWh
2	I-1/TR	900 VA	Rp. 31,500	Block I : 0-72 kWh : 315 Rp./kWh Block II : >72 kWh : 405 Rp./kWh
3	I-1/TR	1,300 VA	Rp. 31,800	Block I : 0-104 kWh : 450 Rp./kWh Block II : >104 kWh : 460 Rp./kWh
4	I-1/TR	2,200 VA	Rp. 32,000	Block I : 0-196 kWh : 455 Rp./kWh Block II : >196 kWh : 460 Rp./kWh
5	I-1/TR	2,200 VA- 14 kVA	Rp. 32,200	Block I : 0-80 hours operation : 455 Rp./kWh Block II : > 80 hours operation : 460 Rp./kWh
6	I-2/TR	14 kVA- 200 kVA	Rp. 32,500	Block WBP = K x 440 Rp./kWh Block LWBP = 440 Rp./kWh
7	I-3/TM	> 200 kVA	Rp. 29,500	0-350 hours operation: Block WBP = K x 439 Rp./kWh >350 hours operation: Block WBP = 439 Rp./kWh Block LWBP = 439 Rp./kWh
8	I-4/TT	> 30,000 kVA	Rp. 27,000	434 Rp./kWh

K : Ratio factor between WBP cost and LWBP cost are considered with the characteristic of the local electricity system load (1.4<K<2) defined by Directors of PT.PLN.

WBP : Peak power time.

LWBP : Outside peak power time.

H : Hour operation, kWh per month divided by kVA.

APPENDIX B.6: CLASSIFICATION OF BASIC ELECTRICITY COST FOR <u>GOVERNMENT OFFICE AND PUBLIC STREET LIGHTING</u>

PRESIDENTIAL DECREE, REPUBLIC OF INDONESIA

NO : 104/2003

DATE : DECEMBER 31, 2003

NO.	Tariff Class.	POWER LIMIT	POWER COST (Rp./ kVA/ month) Jan 1- Dec 31, 2004	ENERGY COST (Rp./ kWh) Jan 1- Dec 31, 2004
1	P-1/TR	0-450 VA	Rp. 20,000	575 Rp./kWh
2	P-1/TR	900 VA	Rp. 24,600	600 Rp./kWh
3	P-1/TR	1,300 VA	Rp. 24,600	600 Rp./kWh
4	P-1/TR	2,200 VA	Rp. 24,600	600 Rp./kWh
5	P-1/TR	2,200 VA- 200 kVA	Rp. 24,600	600 Rp./kWh
6	P-2/TM	> 200 kVA	Rp. 23,800	Block WBP = K x 379 Rp./kWh
				Block LWBP = 379 Rp./kWh
7	P-3/TR	-	-	635 Rp./kWh

K : Ratio factor between WBP cost and LWBP cost are considered with the characteristic of the local electricity system load ($1.4<K<2$) defined by Directors of PT.PLN.

WBP : Peak power time.

LWBP : Outside peak power time.

APPENDIX C: ENERGY CONVERSION AND CALORIFIC VALUE

APPENDIX C.1: ENERGY CONVERSION TABLE (INDONESIAN MARKAL PROJECT)

	Multiplication Factors											
To Convert: To From	KCE	TCE	Million TCE	BOE	TOE	Joule	kilo Joule	cal	k cal	Btu	MM Btu	kWh
1. KCE	1	10^{-3}	10^{-9}	$4.92x10^{-3}$	$0.684x10^{-3}$	$29.29x10^{6}$	$29.29x10^{3}$	$7x10^{6}$	$7.0x10^{3}$	$27.78x10^{3}$	$27.78x10^{-3}$	8.134
2. TCE	10^{3}	1	10^{-6}	4.92	0.684	$29.29x10^{9}$	$29.29x10^{6}$	$7x10^{9}$	$7.0x10^{6}$	$27.78x10^{6}$	27.78	8.134
3. Million TCE	10^{9}	10^{6}	1	$4.92x10^{6}$	$0.684x10^{6}$	$29.29x10^{15}$	$29.29x10^{12}$	$7x10^{15}$	$7.0x10^{12}$	$27.78x10^{12}$	$27.78x10^{6}$	$8.134x10^{9}$
4. BOE	203	0.203	$0.203x10^{-6}$	1	0.139	$5.95x10^{9}$	$5.95x10^{6}$	$1.461x10^{9}$	$1.461x10^{6}$	$5.64x10^{6}$	5.64	$1.698x10^{3}$
5. TOE	1.461	1.461	$1.461x10^{-6}$	7.195	1	$4.28x10^{10}$	$4.28x10^{7}$	$10.23x10^{9}$	$10.23x10^{6}$	$40.58x10^{6}$	40.58	$11.887x10^{3}$
6. Joule	$34.5x10^{-9}$	$34.5x10^{-12}$	$34.5x10^{-18}$	$1.68x10^{-10}$	$23.34x10^{-12}$	1	10^{-3}	0.239	$0.239x10^{-3}$	$9.478x10^{-4}$	$9.478x10^{-10}$	$2.777x10^{-7}$
7. kilo Joule	$34.5x10^{-6}$	$34.5x10^{-9}$	$34.5x10^{-15}$	$1.68x10^{-7}$	$23.34x10^{-9}$	10^{3}	1	$0.239x10^{3}$	0.239	$9.478x10^{-1}$	$9.478x10^{-7}$	$2.777x10^{-4}$
8. cal	$0.142x10^{-6}$	$0.142x10^{-9}$	$0.142x10^{-15}$	$0.684x10^{-9}$	$97.75x10^{-12}$	4.184	$4.184x10^{-3}$	1	10^{-3}	$3.968x10^{-3}$	$3.968x10^{-9}$	$1.162x10^{-6}$
9. k cal	$0.142x10^{-3}$	$0.142x10^{-6}$	$0.142x10^{-12}$	$0.684x10^{-6}$	$97.75x10^{-9}$	$4.184x10^{3}$	4.184	10^{3}	1	3.968	$3.968x10^{-6}$	$1.162x10^{-3}$
10. Btu	$0.036x10^{-3}$	$0.036x10^{-6}$	$0.036x10^{-12}$	$0.177x10^{-6}$	$24.65x10^{-9}$	$1.055x10^{3}$	1.055	252.1	$252.1x10^{-3}$	1	10^{-6}	$2.929x10^{-4}$
11. MM Btu	36	0.036	$0.036x10^{-6}$	0.177	$24.65x10^{-3}$	$1.055x10^{9}$	$1.055x10^{6}$	$252.1x10^{6}$	$252.1x10^{3}$	10^{6}	1	292.9
12. kWh	0.123	$0.123x10^{-3}$	$0.123x10^{-9}$	$0.589x10^{-3}$	$84.1x10^{-6}$	$3.601x10^{6}$	$3.601x10^{3}$	$0.86x10^{6}$	$0.86x10^{3}$	$3.414x10^{3}$	$3.414x10^{-3}$	1

Source: BPPT (2001)

TCE BCE based on Arabian Light (32 API, 10230 kcal/kg, 7.195 barrel/ton)
TCE based on International Standard Coal (7000 kcal/kg)
1 barreL = 159 liters; 1 Nm^3 = 37.899 Standard Cubic Foot; 1 Lb = 0.4536 Kg

Note : This is only a Conversion Table for unit of energy. The transformation of physical units from Domestic Statistics is done by using Domestic Energy Equivalents (Domestic Energy Equivalent Table)

APPENDIX C.2: ENERGY CONTENT OF FUEL (NET CALORIFIC VALUE)

Types	unit	kcal/ unit	toe/ 10^6 unit	MJ/ unit	10^3 Btu/ unit
Modern Energy					
1. Crude Oil	litre	8680	860.00	36.33	34.44
2. Condensate	litre	7900	782.72	33.07	31.35
3. Natural Gas					
3.1. Wet	scf	248	24.57	1.04	0.98
3.2. Dry	scf	244	24.18	1.02	0.97
4. Petroleum Produts					
4.1. LPG	litre	6360	630.14	26.62	25.24
4.2. Gasoline	litre	7520	745.07	31.48	29.84
4.3. Aviation Fuel	litre	8250	817.40	34.53	32.74
4.4. Kerosene	litre	8250	817.40	34.53	32.74
4.5. Diesel	litre	8700	861.98	36.42	34.52
4.6. Fuel Oil	litre	9500	941.24	39.77	37.70
4.7. Bitumen	litre	9840	974.93	41.19	39.05
4.8. Petroleum Coke	kg	8400	832.26	35.16	33.33
5. Electricity	kwh	860	85.21	3.60	3.41
6. Hydro-Electric	kwh	2236	221.54	9.36	8.87
7. Geothermal-Electric	kwh	9500	941.24	39.77	37.70
8. Coal (Import)	kg	6300	624.19	26.37	25.00
9. Coke	kg	6600	653.92	27.63	26.19
10. Anthracite	kg	7500	743.09	31.40	29.76
11. Ethane	kg	11203	1110.05	46.89	44.45
12. Propane	kg	11256	1115.34	47.11	44.67
13. Lignite					
13.1 LI	kg	4400	435.94	18.42	17.46
13.2. Karabi	kg	2600	257.60	10.88	10.32
13.3. Mae Moh	kg	2500	247.70	10.47	9.92
13.4. Chae Khon	kg	3610	357.67	15.11	14.32
Renewable Energy					
1. Fuel Wood	kg	3820	378.48	15.99	15.16
2. Charcoal	kg	6900	683.64	28.88	27.38
3. Paddy Husk	kg	3440	340.83	14.40	13.65
4. Bagasse	kg	1800	178.34	7.53	7.14
5. Garbage	kg	1160	114.93	4.86	4.60
6. Saw Dust	kg	2600	257.60	10.88	10.32
7. Agricultural Waste	kg	3030	300.21	12.68	12.02

Source: DEDP/OIL AND THAILAND 1996

Note:

1 kcal	= 4186	joules
	= 3.968	Btu
1 toe	= 10.093	Gcal
	= 42.244	GJ
	= 40.047 x 10^6 Btu	
1 barrel	= 158.99	liters
1 cu.m. of solid wood	= 600	kg
1 cu.m. of charcoal	= 250	kg
5 kg of wood	= 1 kg. Of charcoal product	
1 litre og LPG	= 0.53	kg

APPENDIX D: GNI PPP AND PRICE DEFLATOR

APPENDIX D.1: GROSS NATIONAL INCOME PER CAPITA 2008[1]

Ranking	Economy	Purchasing power parity (international dollars)
2	Luxembourg	64,320
4	Norway	58,500
5	Kuwait	*52,610*
7	Macao, China	*52,260*
9	Brunei Darussalam	*50,200*
10	Singapore	47,940
11	United States	46,970
12	Switzerland	46,460
16	Hong Kong, China	43,960
18	Netherlands	41,670
22	Sweden	38,180
23	Austria	37,680
24	Ireland	37,350
25	Denmark	37,280
27	Canada	36,220
28	United Kingdom	36,130
29	Germany	35,940
31	Finland	35,660
32	Japan	35,220
33	Belgium	34,760
34	France	34,400
35	Australia	34,040
37	Spain	31,130
39	Italy	30,250
43	Greece	28,470
44	Korea, Rep.	28,120
45	Israel	27,450
46	Slovenia	26,910
49	Iceland	25,220
50	New Zealand	25,090
51	Cyprus	*24,040*
52	Trinidad and Tobago	23,950
53	Saudi Arabia	22,950
54	Malta	22,460
55	Czech Republic	22,790
58	Oman	20,650
59	Portugal	22,080
60	Equatorial Guinea	21,700
61	Slovak Republic	21,300
63	Antigua and Barbuda	20,570
64	Seychelles	19,770
65	Estonia	19,280
66	Croatia	18,420
67	Lithuania	18,210
68	Hungary	17,790
69	Poland	17,310
70	Latvia	16,740
71	Libya	15,630
71	Russian Federation	15,630
73	St. Kitts and Nevis	15,170
75	Mexico	14,270
76	Argentina	14,020
77	Montenegro	13,920
78	Turkey	13,770
79	Malaysia	13,740
80	Romania	13,500
81	Chile	13,270
82	Botswana	13,100
83	Venezuela, RB	12,830
84	Uruguay	12,540
85	Mauritius	12,480
86	Gabon	12,270
87	Belarus	12,150
89	Bulgaria	11,950
90	Panama	11,650 c
91	Iran, Islamic Rep.	*10,840* a
92	Serbia	11,150
93	Costa Rica	10,950 c
94	Lebanon	10,880
95	Brazil	10,070
96	Macedonia, FYR	9,950
97	South Africa	9,780
98	Kazakhstan	9,690
99	St. Lucia	9,190 c
100	St. Vincent and the Grenadines	8,770 c
101	Bosnia and Herzegovina	8,620
103	Colombia	8,510
104	Dominica	8,300 c
105	Grenada	8,060 c
106	Peru	7,980
107	Albania	7,950
108	Algeria	7,940 c
109	Dominican Republic	7,890 c
110	Azerbaijan	7,770
111	Ecuador	7,760
112	Jamaica	7,360 c
114	Ukraine	7,210
115	Suriname	7,130 c
116	Tunisia	7,070
117	El Salvador	6,670 c
118	Armenia	6,310
119	Namibia	6,270
120	Turkmenistan	6,210 c
121	Belize	6,040 c
122	China	6,020
123	Thailand	5,990
124	Jordan	5,530
125	Egypt, Arab Rep.	5,460
126	Maldives	5,280
128	Angola	5,020
129	Swaziland	5,010
131	Bhutan	4,880
132	Georgia	4,850
133	Paraguay	4,820
134	Guatemala	4,690 c
134	Timor-Leste	4,690 c
136	Sri Lanka	4,480
137	Syrian Arab Republic	4,350
138	Samoa	4,340 c
139	Morocco	4,330
140	Fiji	4,270
141	Bolivia	4,140
142	Vanuatu	3,940 c
143	Philippines	3,900
144	Tonga	3,880 c
145	Honduras	3,870 c
146	Indonesia	3,830
147	Kiribati	3,660 c
148	Mongolia	3,480
149	Cape Verde	3,450
151	Moldova	3,210
153	Congo, Rep.	3,090
154	Micronesia, Fed. Sts.	3,000 c
155	India	2,960
156	Pakistan	2,700
156	Vietnam	2,700
158	Uzbekistan	2,660 c
159	Nicaragua	2,620 c

[1] PPP is purchasing power parity; an international dollar has the same purchasing power over GNI as a U.S dollar has in the United States. Source: World Development Indicators database, World Bank.

Ranking	Economy	Purchasing power parity *(international dollars)*
160	Solomon Islands	2,580 c
161	Guyana	2,510 c
162	Djibouti	2,330
163	Yemen, Rep.	2,210
164	Cameroon	2,180
165	Kyrgyz Republic	2,130
166	Mauritania	*2,000* a
167	Lao PDR	2,060
168	Lesotho	2,000
168	Papua New Guinea	2,000 c
170	Nigeria	1,940
171	Sudan	1,930
172	Tajikistan	1,860
173	Cambodia	1,820
174	São Tomé and Principe	1,780
175	Senegal	1,760
176	Côte d'Ivoire	1,580
176	Kenya	1,580
179	Benin	1,460
180	Bangladesh	1,440
181	Ghana	1,430
182	Myanmar	*1,290* a
183	Gambia, The	1,280
184	Tanzania	1,230
184	Zambia	1,230
187	Guinea	1,190
188	Haiti	1,180 c
189	Comoros	1,170
190	Burkina Faso	1,160
190	Chad	1,160
192	Uganda	1,140
193	Nepal	1,120
194	Mali	1,090
195	Madagascar	1,040
196	Rwanda	1,010
197	Ethiopia	870
198	Malawi	830
199	Togo	820
200	Mozambique	770
201	Sierra Leone	750
202	Central African Republic	730
204	Niger	680
205	Eritrea	630 c
206	Guinea-Bissau	530
208	Burundi	380
209	Liberia	300
210	Congo, Dem. Rep.	290
	Afghanistan	..
	American Samoa	..
	Andorra	..
	Aruba	..
	Bahamas, The	..
	Bahrain	..
	Barbados	..
	Bermuda	..
	Cayman Islands	..
	Channel Islands	..
	Cuba	..
	Faeroe Islands	..
	French Polynesia	..
	Greenland	..
	Guam	..
	Iraq	..

Ranking	Economy	Purchasing power parity *(international dollars)*
	Isle of Man	..
	Korea, Dem. Rep.	..
	Kosovo	..
	Liechtenstein	..
	Marshall Islands	..
	Mayotte	..
	Monaco	..
	Netherlands Antilles	..
	New Caledonia	..
	Northern Mariana Islands	..
	Palau	..
	Puerto Rico	..
	Qatar	..
	San Marino	..
	Somalia	..
	United Arab Emirates	..
	Virgin Islands (U.S.)	..
	West Bank and Gaza	..
	Zimbabwe	..
	World	**10,357**
	Low income	1,407
	Middle income	6,154
	Lower middle income	4,592
	Upper middle income	12,297
	Low & middle income	5,330
	East Asia & Pacific	5,398
	Europe & Central Asia	12,219
	Latin America & Caribbean	10,309
	Middle East & North Africa	7,308
	South Asia	2,734
	Sub-Saharan Africa	1,991
	High income	37,141
	Euro area	33,228

APPENDIX D.2: PRICE DEFLATOR[2]

Year	Price Deflator
1996	93.852
1997	95.414
1998	96.472
1999	97.868
2000	100
2001	102.399
2002	104.187
2003	106.404
2004	109.462
2005	113.034
2006	116.676
2007	119.816
2008	122.422

[2] Price deflator is used to convert nominal dollars to chained. Web page for related information: http://www.census.gov/ and http://www.bea.doc.gov/.

APPENDIX E: METEOROLOGICAL DATA FROM JUANDA AND KEMAYORAN WEATHER STATION

APPENDIX E.1: Wind Speed Data in 2007-2008 at Juanda Weather Station Surabaya

BMKG

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI JUANDA SURABAYA

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: DIRECTION AND WIND SPEED (Knot) YEAR 2007-2008

YEAR	PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
2008	AVG. SPEED	7.8	11.7	5.0	6.2	6.4	7.0	7.0	8.2	8.3	8.2	6.0	6.0
	AVG. DIRECTION	W	W	CALM	E	E	E	E	E	E	E	E	VRB
	MAX. SPEED	23	28	19	25	15	17	18	18	20	22	20	17.0
	DIRECTION	30	300	30	70	90	80	100	80	90	80	60	350

YEAR	PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
2007	AVG. SPEED	6.9	7.3	8.1	6.3	8.2	7.3	8.7	8.5	8.6	9.0	6.7	7.6
	AVG. DIRECTION	E	W	W	E	E	E	E	E	E	E	E	W
	MAX. SPEED	24	24	27	16	18	17	19	19	18	20	16	25
	DIRECTION	280	290	320	90	90	80	70	90	80	80	180	270

APPENDIX E.2: Ambient Temperature and Humidity in 2008 at Juanda Weather Station Surabaya

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI JUANDA SURABAYA

BMKG

To:
Energy Management Manager
PT. PJB

SURABAYA

METEOROLOGICAL DATA: TEMPERATURE (° C) YEAR 2008

YEAR	PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
2008	Average (C)	27.6	26.9	26.8	27.7	27.6	26.8	26.0	26.9	28.1	29.3	28.1	27.4
	Maximum (C)	34.8	34.1	33.2	32.8	33.4	32.8	32.6	34.1	34.6	36.7	34.2	33.5
	Minimum (C)	23.0	23.5	23.0	23.1	20.1	21.2	20.0	20.2	22.2	22.9	23.6	22.0

METEOROLOGICAL DATA: HUMIDITY (%) YEAR 2008

TAHUN	URAIAN	JAN	PEB	MAR	APR	MEI	JUN	JUL	AGS	SEP	OKT	NOP	DES
2008	Average	81	68	86	78	76	76	78	73	67	71	83	82
	Maximum	95	97	97	96	96	92	93	91	90	96	97	100
	Minimum	52	21	59	56	35	48	44	44	31	38	49	54

APPENDIX E.3: Rainfall and Air Pressure Data in 2008 at Juanda Weather Station Surabaya

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI JUANDA SURABAYA

BMKG

To:
Energy Management Manager
PT. PJB

SURABAYA

METEOROLOGICAL DATA: TOTAL RAINFALL (mm) YEAR 2008

YEAR	PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
2008	Total Rainfall (mm)	255.6	209.1	249.5	136.4	22.1	3.7	-	-	-	48.9	205.3	372.3
	Daily Rainfall	22	24	23	14	6	3	-	-	-	3	19	21
	Maximum (mm)	41.6	54.8	62.0	37.3	11.3	2.8	-	-	-	28.0	44.6	81.5

METEOROLOGICAL DATA: AIR PRESSURE (mm) YEAR 2008

YEAR	PARAMETER	JAN	FEB	MAR	APR	MEI	JUN	JUL	AGS	SEP	OCT	NOV	DEC
2008	Average	1009.3	1008.7	1009.2	1010	1010.9	1011	1012	1011.8	1011.9	1011.1	1009.3	1008.7
	Maximum	1011.9	1011.4	1011.5	1012	1013.2	1013	1014	1013.1	1013.4	1012.6	1011.3	1011.3
	Minimum	1007.3	1006.9	1007.1	1007	1009.3	1009	1009	1010.5	1010.3	1008.2	1006.8	1006.4

APPENDIX E.4: Solar Radiation Data in 2008 at Juanda Weather Station Surabaya

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI JUANDA SURABAYA

BMKG

To:
Energy Management Manager
PT. PJB

SURABAYA

METEOROLOGICAL DATA: SOLAR RADIATION (%) YEAR 2008

YEAR	PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
	Average	58	42	49	69	86	87	95	95	95	80	53	37
2008	Maximum	100	100	90	100	100	100	100	100	100	100	100	80
	Minimum	5	5	0	10	28	6	60	35	65	10	0	0.0

APPENDIX E.5: Wind Speed Data on January 2008 at Kemayoran Weather Station, Jakarta

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

BMKG

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) JANUARY 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	6	7	7	6	7	6	4	4	5	6	6	6	4	4	5	4	4	0	0	0	0	0	0
2	0	0	3	5	7	8	10	10	6	7	6	7	0	0	0	0	0	0	0	0	0	0	0	0
3	4	4	5	14	6	5	5	5	5	4	4	4	4	0	0	0	0	0	0	0	0	0	0	0
4	0	6	5	5	6	5	6	5	4	3	0	0	0	5	5	0	0	0	0	0	0	0	0	0
5	6	5	6	5	6	6	8	15	8	9	8	5	6	3	3	3	5	4	0	0	0	0	3	6
6	0	4	6	7	5	6	6	4	5	4	4	3	3	3	0	0	0	0	0	0	0	0	0	0
7	0	0	0	5	5	5	5	5	5	4	4	5	5	3	0	0	0	0	0	0	0	0	0	0
8	3	5	5	4	6	6	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	4	8	5	6	8	7	7	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0
10	0	0	5	6	5	7	7	8	14	8	5	5	5	5	5	4	0	0	0	0	0	0	0	0
11	0	0	0	4	4	6	7	5	6	4	5	3	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	4	5	4	4	5	6	5	5	5	5	5	5	4	0	0	0	0	0	0	0	0	0
13	3	5	5	6	7	7	8	7	8	8	6	5	0	0	0	0	0	0	0	0	0	0	0	0
14	0	4	6	7	8	7	8	7	7	6	5	4	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	4	5	7	7	6	6	5	5	4	3	3	0	0	0	0	0	0	0	0	0	0
16	0	5	6	7	10	8	10	7	5	6	6	8	9	8	0	0	0	0	5	6	5	4	0	5
17	0	0	0	2	7	8	5	5	6	6	5	5	5	0	0	0	4	0	0	0	0	0	0	0
18	0	0	0	7	6	5	5	9	8	6	7	5	5	5	5	0	0	0	0	0	0	0	0	0
19	0	0	0	4	5	5	4	5	5	5	5	5	5	5	4	0	0	0	0	0	0	0	0	0
20	0	4	5	5	4	5	6	5	6	6	5	0	4	4	0	0	0	0	0	0	0	0	0	0
21	0	4	5	6	7	12	12	7	5	6	6	7	3	4	5	5	4	0	0	0	0	0	0	0
22	0	0	5	7	7	6	6	5	7	6	6	5	4	0	0	0	0	3	0	0	0	0	3	4
23	3	3	4	6	12	10	12	10	10	8	8	6	5	5	5	4	0	0	0	0	0	0	0	0
24	0	0	0	4	5	0	3	7	8	0	0	0	0	0	0	0	0	0	5	4	0	0	0	0
25	0	0	0	0	0	3	3	4	3	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	5	4	4	4	5	5	4	4	0	0	4	5	5	4	4	0	0	0	0	0	0
27	0	0	0	0	4	7	5	5	6	9	0	0	0	4	4	3	0	0	0	0	0	0	0	0
28	0	5	5	6	6	7	6	12	12	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	4	4	4	4	6	5	6	4	5	4	4	4	4	0	0	0	0	0	0	0	0	0
31	0	4	5	6	6	5	6	4	4	6	3	5	3	5	5	4	3	4	0	0	0	0	0	0

APPENDIX E.6: Wind Speed Data on February 2008 at Kemayoran Weather Station, Jakarta

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

BMKG

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) FEBRUARY 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	0	5	8	8	8	9	10	9	8	4	5	0	4	3	0	0	0	0	0	0	0	0	0
2	0	0	0	4	3	5	5	12	10	12	10	5	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	4	4	4	6	7	9	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	4	5	4	6	6	8	7	7	6	5	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	5	6	7	6	6	5	6	5	5	4	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	5	0	4	4	6	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	3
7	0	3	4	5	6	5	7	7	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4	5	5	6
9	4	4	0	5	5	4	4	5	5	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	4	5	7	6	4	5	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	3	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
12	3	3	0	0	0	0	0	0	0	4	3	3	0	4	4	0	0	0	0	0	0	0	0	0
13	0	0	0	3	4	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	3	4	5	7	7	7	8	6	5	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	4	5	4	6	4	5	4	4	4	3	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	3	7	6	5	5	6	6	5	4	4	4	0	0	0	0	0	0	0	0	0
17	0	0	0	4	5	6	5	6	7	6	6	9	5	5	4	0	0	0	0	0	0	0	0	0
18	0	0	0	0	5	5	4	4	5	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	4	5	6	8	7	5	4	0	0	0	4	5	4	3	4	3	0	0	0	0	0
20	0	0	0	0	6	7	6	5	5	7	5	5	5	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	4	5	5	5	4	6	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	4	3	5	6	6	5	0	0	0	0	4	5	4	0	0	0	0	0	0
23	0	4	5	5	6	5	6	7	7	7	6	5	0	0	0	0	0	0	0	0	0	0	0	0
24	0	4	0	0	4	6	7	6	5	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	4	5	9	4	6	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	3	5	6	5	6	6	5	6	5	5	4	4	0	0	0	0	0	0	0	0	0
27	0	0	0	0	6	8	7	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	4	4	4	5	6	5	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX E.7: Wind Speed Data on March 2008 at Kemayoran Weather Station, Jakarta

BMKG

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) MARCH 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	0	0	0	0	5	5	7	7	6	6	5	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	3	4	5	6	7	5	5	5	6	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	4	4	4	7	7	7	0	0	4	0	0	0	4	6	4	4	0	0	0	0	0	0
4	0	0	0	3	4	5	6	5	6	7	5	0	0	0	0	0	5	4	0	0	0	0	0	0
5	0	0	0	0	4	6	7	0	0	4	5	6	5	8	10	5	0	0	0	0	0	0	0	0
6	0	0	5	0	0	5	6	6	7	5	5	4	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	5	5	8	5	8	7	6	5	5	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	4	5	6	5	7	5	6	5	5	4	5	4	4	0	0	0	0	4	5	4	0
9	4	4	4	5	6	4	5	4	4	6	4	4	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	3	5	7	5	8	6	6	4	4	0	0	0	0	0	0	0	0	0	0	0	0
11	0	4	5	5	6	7	7	8	8	9	8	7	6	5	4	0	0	0	0	0	0	0	0	0
12	0	0	5	6	7	8	9	5	6	4	7	5	4	4	0	0	0	0	0	0	0	0	0	0
13	0	0	4	6	7	7	6	7	9	8	4	4	0	0	0	0	0	0	0	0	0	4	4	4
14	0	0	0	4	5	6	8	7	8	6	5	4	5	4	0	0	0	0	0	0	0	0	0	0
15	0	0	4	4	5	8	6	5	6	8	7	6	3	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	4	5	5	5	6	8	7	5	5	6	3	0	0	0	0	0	0	0	0	0	0
17	0	4	4	5	7	9	8	6	6	5	3	3	4	0	0	0	0	0	0	0	4	5	0	0
18	0	0	0	0	0	5	4	5	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	5	6	5	6	4	5	4	4	3	3	0	0	0	0	0	0	0	0	0	0
20	0	0	0	3	4	5	5	5	5	5	5	4	0	0	4	4	0	0	0	0	0	0	0	0
21	0	0	0	3	4	3	5	7	6	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	3	5	6	6	6	4	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	6	5	6	6	5	6	6	5	10	5	6	5	4	0	0	0	0	0	0	0	0	0
24	0	0	0	0	5	4	4	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	3	5	5	6	6	5	4	4	8	4	0	0	0	0	0	0	0	0	0	0
26	8	5	5	0	0	0	0	0	4	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	4	5	5	6	6	5	4	6	5	4	6	5	0	0	0	0	0	0	0	0	0	0
28	0	5	4	4	7	5	5	5	0	6	8	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	4	4	4	5	6	6	7	4	6	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	4	4	3	5	4	5	5	4	5	0	4	4	4	4	4	5	5	5	0	0	0	0
31	5	4	7	8	8	7	6	6	7	11	10	7	5	5	4	3	0	0	0	0	0	0	0	0

APPENDIX E.8: Wind Speed Data on April 2008 at Kemayoran Weather Station, Jakarta

BMKG

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) APRIL 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	0	5	6	5	6	5	5	5	5	7	8	4	5	5	4	3	4	0	0	0	0	0	0
2	0	0	0	4	8	7	5	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	4	4	4	5	5	6	4	3	0	0	0	0	0	0	0	0	0	0	5	5	0	0
4	0	0	0	0	5	5	7	8	6	5	5	4	4	4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	5	6	5	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	5	0	5	6	5	5	5	4	4	4	4	0	0	0	0	0	0	0	0
7	0	0	0	4	4	6	5	5	6	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	4	5	4	5	4	3	3	4	3	0	0	0	0	0	0	0	0	0	0	0	0
9	0	3	4	5	3	4	3	6	6	7	6	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	3	4	7	5	3	4	5	3	3	0	0	0	0	0	0	0	0	0	0	0	0
11	0	3	0	4	5	5	4	5	6	5	6	5	5	3	0	0	0	0	0	0	0	0	0	0
12	0	0	0	3	4	4	4	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	3	5	5	0	0	6	5	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	4	4	4	7	6	5	5	5	4	0	0	4	4	4	0	0	0	0	0	0	0	0
15	0	0	0	5	5	6	5	7	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	4	3	3	3	0	5	6	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	5	6	8	3	4	6	3	3	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	5	6	6	9	5	5	5	3	3	4	0	0	0	0	0	0	0	0	0	0	0
19	0	0	5	4	4	5	5	6	6	7	7	6	4	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	4	5	4	4	3	4	5	4	3	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	4	5	5	6	5	6	7	6	6	6	4	3	0	0	0	0	0	0	0	0	0	0
22	0	0	3	5	5	4	4	5	3	4	5	4	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	5	6	6	8	6	5	5	4	5	5	0	0	0	0	0	0	0	0	0	0	0
24	0	0	4	5	5	6	6	6	6	5	5	5	4	0	0	0	0	0	0	0	0	0	0	0
25	0	5	5	6	6	6	7	6	4	3	3	8	0	0	0	0	0	0	0	0	0	0	0	0
26	0	3	3	5	3	7	5	6	6	5	4	0	0	3	4	3	0	0	0	0	0	0	0	0
27	0	0	7	7	4	6	3	4	5	4	3	3	5	4	0	0	0	0	0	0	0	0	0	0
28	0	0	4	5	6	7	6	7	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	4	6	7	6	6	6	7	6	7	7	6	5	0	0	0	0	0	0	0	0	0	0	0
30	0	0	4	6	5	6	5	6	5	4	4	5	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX E.9: Wind Speed Data on May 2008 at Kemayoran Weather Station, Jakarta

BMKG

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) MAY 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	5	8	6	4	6	5	6	6	4	4	4	3	3	0	0	0	0	0	0	0	0	0	0
2	0	5	8	7	6	6	6	3	3	4	3	4	0	0	0	0	0	0	0	0	0	0	0	0
3	0	4	5	6	5	5	5	5	3	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	4	0	0	0	5	5	5	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	4	5	6	5	6	4	4	4	4	4	0	0	0	0	4	5	0	0	0	0	0	0
6	0	0	0	0	4	6	6	5	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	4	5	4	5	5	5	5	4	0	0	0	0	0	0	0	0	0	4	5	4
8	5	4	4	5	6	6	6	6	8	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	3	5	5	7	6	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	5	4	7	5	4	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	4	4	4	6	5	6	5	4	4	4	4	0	0	0	0	0	0	0	0	0
12	0	0	0	0	5	6	5	5	5	5	4	4	5	5	4	0	0	0	0	0	0	0	0	0
13	0	0	0	4	5	6	6	5	6	6	5	4	4	4	4	4	0	0	0	0	0	0	0	0
14	0	0	4	5	8	6	5	6	5	5	5	4	4	4	4	0	0	0	0	0	0	0	0	4
15	4	3	4	5	5	6	5	7	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	4	6	5	6	6	4	0	6	5	4	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	4	7	5	6	6	5	5	6	6	4	4	0	0	0	0	0	0	0	0	0	0
18	0	0	6	6	5	5	7	7	5	7	5	4	4	0	0	0	0	0	0	0	0	0	0	0
19	0	8	4	4	6	8	7	8	9	8	5	6	7	0	0	0	0	0	0	0	0	0	0	0
20	0	8	7	6	5	4	7	6	6	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	5	5	6	6	7	6	5	5	4	0	0	4	5	5	4	4	0	0	0	0	0	0
22	0	4	5	8	6	8	8	7	6	6	5	5	0	0	0	0	0	0	0	0	0	0	0	0
23	0	6	6	7	7	5	6	6	8	7	8	7	6	5	5	4	0	0	0	0	0	0	0	0
24	0	0	4	5	5	6	6	6	6	6	5	5	4	4	5	4	0	0	0	0	0	0	0	0
25	0	3	5	5	5	5	6	6	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	7	6	6	6	4	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	5	6	5	6	6	4	7	5	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	4	5	5	6	7	6	5	5	4	4	5	5	4	4	0	0	0	0	0	0	0	0
29	0	0	4	4	6	5	5	6	5	5	5	4	4	4	0	0	0	0	0	0	0	0	0	0
30	0	0	6	7	5	4	5	6	6	5	5	5	5	4	0	0	0	0	0	0	0	0	0	0
31	0	0	5	6	5	5	7	6	6	6	5	4	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX E.10: Wind Speed Data on June 2008 at Kemayoran Weather Station, Jakarta

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

BMKG

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) JUNE 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	4	4	7	5	7	6	5	8	5	3	3	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	4	6	4	4	6	6	6	7	6	5	4	0	0	0	0	0	0	0	0	0	0	0
3	0	0	4	5	5	4	5	5	5	4	4	4	4	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	5	6	6	6	5	6	4	5	4	4	4	4	0	0	0	0	0	0	0	0	0
5	0	6	3	4	3	5	8	7	6	5	5	5	4	0	0	0	0	0	0	0	0	0	0	0
6	0	0	4	6	7	5	6	5	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	5	5	5	5	4	5	7	5	5	4	4	0	0	0	0	0	0	0	0	0	0	0
8	0	0	3	4	5	5	4	6	6	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0
9	0	0	4	6	6	7	10	6	4	5	4	10	4	3	3	3	0	0	0	0	0	0	0	0
10	0	0	3	12	3	5	4	5	6	6	5	5	4	5	5	4	4	0	0	0	0	0	0	0
11	0	6	7	6	12	14	9	6	7	4	4	3	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	4	5	5	6	6	8	7	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	4	5	5	5	6	6	6	5	5	4	4	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	5	6	0	3	5	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	5	6	3	0	4	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	3	0	0	3	5	0	3	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	4	5	5	5	5	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	4	5	0	6	3	5	4	6	6	5	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	4	5	6	6	7	0	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	3	4	3	3	3	5	5	6	5	4	0	3	3	5	3	0	0	0	0	3	4	3
21	3	4	3	5	5	5	6	5	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	5	3	5	5	4	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	4	5	5	6	6	5	6	7	5	0	0	5	4	4	0	0	0	0	0	0	0	0
24	0	0	0	5	5	4	7	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	3	3	4	3	4	6	4	5	4	5	5	4	4	5	5	4	0	0	0	0	0	0
26	0	4	5	6	6	5	6	3	4	4	5	4	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	4	6	5	5	5	7	6	5	4	3	3	0	0	0	0	0	0	0	0	0	0	0
28	0	0	3	8	6	6	4	6	5	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	5	5	3	3	6	4	3	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	5	0	0	3	7	8	5	6	8	5	0	0	0	0	0	0	0	0	0	0	0

APPENDIX E.11: Wind Speed Data on July 2008 at Kemayoran Weather Station, Jakarta

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

BMKG

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) JULY 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	0	0	5	5	6	2	8	3	5	4	3	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	4	5	5	6	4	4	6	5	4	3	3	4	5	3	0	0	0	0	0	0	0
3	0	0	0	3	3	2	6	7	7	6	6	5	4	4	0	0	0	0	0	0	0	0	0	0
4	0	0	0	3	0	5	7	6	5	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	3	3	5	6	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	5	5	5	5	3	3	5	3	0	0	0	6	6	0	0	0	0	0	0	0	0
7	0	0	4	5	6	5	5	6	6	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	5	5	4	4	3	4	4	4	4	3	4	3	0	0	0	0	0	0	0	0
9	0	0	5	7	8	8	6	6	5	5	7	5	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	3	4	6	5	5	4	5	4	4	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	6	5	4	4	3	3	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	4	5	5	6	5	7	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	4	4	4	5	6	5	5	0	0	4	4	0	0	0	0	0	0	0	0
14	0	0	5	5	5	6	5	4	6	6	5	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	4	4	6	5	4	8	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	3	5	3	4	5	6	5	6	5	4	8	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	4	5	5	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	3	4	7	6	5	6	6	6	7	7	6	5	5	3	0	0	0	0	0	0	0	0	0	0
19	0	0	5	6	6	7	6	7	6	5	6	5	5	4	0	0	0	0	0	0	0	0	0	0
20	0	0	3	4	0	6	5	4	6	5	4	0	0	5	4	4	5	5	4	4	3	3	0	0
21	0	0	0	3	4	5	0	0	0	3	4	5	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	4	5	6	5	5	4	3	4	3	3	0	0	0	0	0	0	0	0	0	0	0
23	0	4	3	0	4	6	5	6	6	5	5	5	4	4	3	0	0	0	0	0	0	0	3	0
24	0	0	3	3	4	5	5	6	6	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	4	5	6	5	5	5	6	6	6	5	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	3	3	0	3	5	6	5	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	4	5	4	6	7	5	3	3	3	0	0	0	0	0	0	0	4	4	0	0	4	4
28	4	4	4	4	5	6	6	6	6	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	4	4	3	4	5	6	6	5	6	5	4	0	0	0	0	0	0	0	0	0	0	0
30	0	0	4	5	6	6	5	6	6	5	6	5	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	4	4	5	6	6	5	4	4	3	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX E.12: Wind Speed Data on August 2008 at Kemayoran Weather Station, Jakarta

BMKG

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) AUGUST 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	0	4	0	4	6	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	5	4	6	5	5	6	6	7	5	5	5	6	5	0	0	0	0	0	0	0	0	0	0
3	3	3	5	5	3	3	4	6	5	0	0	5	4	5	4	0	0	0	0	0	0	0	0	0
4	0	0	3	0	3	3	3	5	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	3	3	4	5	6	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	5	3	4	6	5	5	4	4	3	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	5	4	5	5	3	5	3	3	0	0	0	0	0	0	0	0	0	0	0	3
8	4	4	0	0	4	5	4	3	4	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	3	3	4	4	5	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0
10	0	3	4	5	4	5	3	5	6	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	3	0	0	5	3	5	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	4	4	6	7	6	6	5	5	4	0	0	0	0	0	0	0	0	0	0
13	3	0	0	0	0	0	0	3	4	5	3	4	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	3	9	3	3	4	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	3	3	5	4	5	5	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	6	6	6	10	11	10	7	8	6	5	5	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	6	0	6	5	9	8	6	6	5	5	5	5	6	5	0	0	0	0	0	0	0	0
18	0	4	4	4	5	6	7	4	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	5	4	5	4	8	5	11	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	4	5	8	5	5	7	5	5	5	5	0	3	4	4	0	0	0	0	0	0	0	0	0
21	0	3	4	5	6	6	5	5	11	6	10	5	4	3	5	0	0	0	0	0	0	0	0	0
22	0	0	0	3	8	4	7	8	9	5	4	0	0	0	0	0	0	3	3	3	0	0	0	0
23	0	4	5	5	7	6	7	3	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	6	4	0	4	5	4	6	5	7	6	7	3	3	3	0	0	0	0	0	0	0	0
25	0	0	0	0	4	5	5	8	7	6	3	5	3	0	0	0	0	0	0	0	0	0	0	0
26	0	0	3	0	5	5	4	5	8	7	5	4	4	0	0	0	0	0	0	0	0	0	0	0
27	0	0	3	3	6	7	7	8	8	7	6	5	4	4	3	3	0	0	0	0	0	4	4	0
28	0	6	7	6	7	8	7	6	7	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	3	4	4	4	6	4	7	6	6	6	7	0	0	0	0	4	3	0	0	0	0	0	0
30	0	0	0	0	5	6	5	7	10	6	7	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	6	5	6	6	5	4	0	0	0	0	0	3	3	3	4	0	0	0	0	0	0

APPENDIX E.13: Wind Speed Data on September 2008 at Kemayoran Weather Station, Jakarta

BMKG

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) SEPTEMBER 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	4	4	5	4	5	5	6	6	5	5	5	0	0	3	3	0	0	0	0	0	0	0	0
2	0	0	0	0	4	5	3	4	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	5	4	6	7	4	4	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	5	6	5	6	5	7	6	7	6	6	0	0	0	0	0	0	0	0	0	0	0	0
5	0	5	4	6	6	6	7	8	5	5	6	5	4	0	0	0	0	0	0	0	0	0	0	0
6	6	4	5	5	4	4	6	6	6	5	5	5	4	0	0	0	0	0	0	0	0	0	0	0
7	0	4	2	5	5	2	6	7	7	6	4	0	4	4	4	0	0	0	0	0	0	0	0	0
8	0	0	3	5	7	6	6	7	5	3	3	4	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	4	5	4	8	4	6	4	4	4	4	0	4	6	0	0	0	0	0	0	0	0
10	0	0	4	5	6	7	7	6	7	7	6	5	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	4	5	6	6	6	7	7	6	6	5	5	6	4	0	0	0	0	0	0	0	0	0
12	0	4	2	4	5	6	5	6	5	5	4	4	4	4	0	0	0	0	0	0	0	0	0	0
13	0	0	4	5	6	6	6	6	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0
14	0	4	4	4	5	5	5	6	6	7	5	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	4	4	4	4	5	6	8	6	5	4	4	6	0	0	0	0	0	0	0	0	0	0	0
16	0	0	4	5	8	5	6	5	4	6	4	5	4	4	4	4	0	0	0	0	0	0	0	0
17	0	4	0	0	5	4	0	0	4	5	4	4	3	0	0	0	0	0	0	0	0	0	0	0
18	0	0	4	5	6	6	6	6	7	5	5	4	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	6	7	6	9	8	4	5	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	4	5	6	5	8	8	6	7	7	6	4	3	0	0	0	0	0	0	0	0	0	0	0
21	0	3	4	5	6	7	8	5	6	4	4	4	4	0	0	0	0	0	0	0	0	0	0	0
22	0	4	5	6	5	6	5	8	5	4	4	5	5	4	0	0	0	0	0	0	0	0	0	0
23	3	0	4	5	6	8	6	7	7	8	8	6	4	5	5	4	4	0	0	0	0	0	0	0
24	0	4	6	8	5	8	12	13	10	10	7	5	5	4	4	0	0	0	0	0	0	0	0	0
25	0	0	3	4	4	6	7	8	8	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	5	6	6	5	5	6	5	6	5	4	0	0	0	0	0	0	0	0	0	0	0
27	0	4	5	0	6	5	5	6	6	5	5	4	4	5	4	4	0	0	0	0	0	0	0	0
28	0	0	4	5	6	6	6	7	7	5	8	6	5	4	0	0	0	0	0	0	0	0	0	0
29	0	0	4	5	6	6	8	7	8	8	7	5	4	4	4	0	0	0	0	0	0	0	5	5
30	0	4	5	5	6	4	7	7	6	5	6	7	6	5	0	0	0	0	0	0	0	0	0	0

APPENDIX E.14: Wind Speed Data on October 2008 at Kemayoran Weather Station, Jakarta

BMKG

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) OCTOBER 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	0	4	5	5	5	8	5	5	4	5	4	4	4	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	6	6	7	6	6	5	5	5	4	4	3	0	0	0	0	0	0	0	0	0
3	0	0	2	3	5	5	6	5	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	5	6	7	8	5	6	4	4	2	0	0	0	0	0	0	0	0	0	0	0
5	0	4	5	4	5	6	5	5	5	6	6	5	5	5	7	4	2	0	5	5	7	4	2	0
6	0	0	5	4	6	5	7	5	4	6	4	4	3	4	3	3	0	0	0	0	0	0	0	0
7	0	0	0	0	5	6	6	5	6	5	4	4	3	3	3	0	0	0	0	0	0	0	0	0
8	0	4	4	6	5	7	6	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0	4	3
9	0	0	0	4	4	5	5	3	6	5	2	2	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	4	6	4	7	5	6	6	6	5	5	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	5	6	6	5	10	5	6	4	3	3	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	7	0	4	8	4	6	0	4	3	3	0	0	0	0	0	0	0	0	0	0	0
13	3	0	5	3	6	5	7	5	10	6	5	6	0	0	0	0	0	0	0	0	0	0	0	0
14	4	4	4	4	5	6	3	5	6	8	8	6	3	3	4	3	0	0	0	0	0	0	0	0
15	0	0	3	5	5	6	7	7	6	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	5	5	6	5	6	5	5	5	4	5	4	3	0	0	0	0	0	0	0	0	0
17	0	0	0	4	5	5	5	5	4	4	4	4	4	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	4	8	4	6	0	0	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	4	5	5	6	7	13	7	0	0	6	4	0	4	3	0	0	0	4	4	0	0
20	0	0	4	5	6	5	6	7	8	8	7	6	3	4	5	3	0	0	0	0	0	0	0	0
21	3	0	4	6	8	8	6	5	6	6	3	6	7	6	5	4	0	0	0	0	0	0	0	0
22	0	0	0	2	4	4	5	5	5	5	5	0	0	0	0	0	3	3	0	0	0	0	0	0
23	0	0	6	8	6	6	5	3	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
24	0	0	3	8	6	6	12	6	3	3	0	0	0	0	0	0	3	4	4	4	4	0	0	4
25	3	5	6	5	6	6	6	7	0	6	0	0	0	3	3	0	0	0	0	0	0	0	0	0
26	0	0	4	5	5	6	6	6	7	3	13	6	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	4	5	4	5	5	4	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	4	5	5	6	6	5	3	0	3	4	3	0	0	0	4	6	0	0	0	0	0	0
29	0	0	0	0	4	5	5	0	0	3	0	3	5	4	4	0	0	0	0	0	0	0	0	0
30	0	0	0	0	3	4	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	4	4	4	5	6	5	6	4	6	0	0	0	0	0	0	3	3	0	0	0	0

APPENDIX E.15: Wind Speed Data on November 2008 at Kemayoran Weather Station, Jakarta

BMKG

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) NOVEMBER 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	0	4	6	4	5	5	5	5	5	5	5	4	4	0	0	0	0	0	0	0	0	0	4
2	3	3	4	4	6	7	6	5	6	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0
3	0	7	7	6	6	7	7	4	4	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0
4	0	4	4	4	4	4	6	7	6	7	5	5	0	0	0	0	0	0	0	0	0	0	0	0
5	0	4	5	6	7	7	7	6	6	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	4	4	4	5	5	5	5	5	4	4	0	3	0	0	0	0	0	0	0	0	0	0	0
7	0	4	4	5	4	4	6	4	6	6	5	8	5	0	0	0	0	0	0	0	0	0	0	0
8	0	7	6	7	5	7	7	5	6	7	6	5	6	4	5	4	5	5	4	0	0	0	0	0
9	3	0	4	5	4	4	4	7	8	7	8	9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	4	3	4	5	5	4	4	3	4	4	4	0	0	0	0	0	0	0	0	0	0	0
11	0	5	6	5	6	5	7	6	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	7	4	5	6	4	5	5	6	5	5	4	4	0	0	0	0	0	0	0	0	0	0	0	0
13	0	7	6	7	8	8	7	6	7	6	5	6	4	4	0	0	0	0	5	0	0	0	0	0
14	0	0	3	4	5	4	5	4	8	6	7	6	5	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	3	5	6	7	5	4	6	4	4	3	0	0	0	0	0	0	0	0	0	0	0
16	0	0	4	3	4	2	6	5	6	5	5	4	3	0	0	0	0	0	0	0	0	0	3	4
17	6	5	5	5	5	6	5	6	6	7	4	4	5	4	0	0	0	0	0	0	0	0	0	0
18	0	0	0	5	5	7	6	7	7	6	6	5	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	4	4	6	4	6	6	6	5	6	5	5	5	0	0	5	5	5	4	5	4	4	0
20	0	0	4	5	5	4	0	4	6	9	5	6	0	0	0	0	0	0	0	0	0	0	0	0
21	6	7	5	6	5	7	4	5	0	7	6	5	4	4	3	0	0	0	0	0	0	0	0	0
22	0	4	4	4	6	9	12	10	11	8	8	6	8	7	6	4	0	0	0	0	0	0	0	0
23	0	0	4	5	7	6	6	10	8	5	6	6	6	4	5	3	0	0	0	0	0	0	0	0
24	0	4	4	4	4	5	4	8	7	6	5	4	6	7	6	5	6	6	0	0	0	0	0	0
25	0	0	0	3	0	5	4	5	4	0	4	4	4	4	4	0	0	0	0	0	0	0	0	0
26	4	3	2	0	0	2	5	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	5	5	5	4	5	4	5	3	2	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	4	4	4	6	5	5	5	4	6	5	0	0	0	0	0	0	0	0	0	0	0
29	0	0	3	4	4	5	4	5	5	6	5	4	0	0	0	0	0	0	6	4	5	4	0	0
30	4	5	10	11	11	12	10	8	7	15	9	6	4	4	4	0	0	0	0	0	0	0	0	0

APPENDIX E.16: Wind Speed Data on December 2008 at Kemayoran Weather Station, Jakarta

BMKG

BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA
STASIUN METEOROLOGI KEMAYORAN JAKARTA

To:
Energy Management Manager
PT.PJB
SURABAYA

METEOROLOGICAL DATA: WIND SPEED (Knot) DECEMBER 2008

Date/ Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00:00	1:00	2:00	3:00	4:00	5:00	6:00
1	0	0	4	7	6	6	7	10	9	6	7	5	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	4	5	6	6	7	3	3	3	4	6	4	3	0	0	0	0	0	0	0	0	0	0
3	0	0	5	9	11	10	9	6	7	6	7	6	6	10	5	3	3	3	0	0	0	0	0	0
4	0	0	0	3	5	5	6	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	4	5	4	4	5	6	6	4	7	6	5	4	5	5	5	4	4	4	4	4	4	4	4
6	0	0	5	6	5	5	6	7	3	6	4	4	7	6	5	4	0	0	0	0	0	0	0	0
7	0	0	0	4	5	4	5	5	0	6	4	3	3	0	0	0	0	0	0	0	0	0	0	0
8	0	0	3	4	5	4	6	5	4	5	5	4	0	0	0	0	0	0	0	0	0	0	0	0
9	0	3	3	4	4	4	5	3	4	5	6	4	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	4	5	6	5	5	5	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	3	8	7	7	6	7	8	7	5	0	0	0	0	0	0	0	0	0	0
12	0	0	5	5	4	6	5	4	4	5	6	5	0	0	0	0	0	0	0	0	0	0	0	0
13	0	7	8	9	9	10	12	10	11	12	12	13	7	5	4	8	3	3	0	0	0	0	0	0
14	5	5	4	5	6	7	9	9	8	5	5	5	5	4	0	0	6	6	0	0	0	0	0	0
15	0	4	7	6	6	4	3	4	0	0	0	0	0	5	5	5	4	4	4	4	4	4	4	4
16	4	4	4	4	3	7	6	5	6	6	5	5	5	5	4	0	0	0	0	0	0	0	0	0
17	0	4	3	3	3	4	4	3	4	3	3	3	3	4	4	0	0	0	0	0	0	0	0	0
18	4	5	5	7	8	9	6	5	8	4	3	3	3	5	3	3	3	4	3	0	0	0	4	3
19	3	0	4	5	5	6	5	7	4	8	6	5	4	0	0	0	0	0	0	0	0	3	4	5
20	4	6	6	7	7	6	7	12	10	8	9	6	6	5	4	4	0	0	0	0	5	5	6	7
21	8	6	5	4	7	0	0	6	7	6	7	8	6	4	4	3	0	0	0	0	0	0	0	0
22	5	5	3	3	5	3	3	3	3	4	4	4	3	4	6	0	0	0	0	0	0	0	0	0
23	4	5	5	8	7	6	7	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	4	4	8	6	6	5	6	5	5	4	4	3	0	0	0	0	0	0	0	0	0	0
25	0	3	4	3	5	3	3	5	6	11	0	3	3	4	4	0	0	0	0	0	0	0	0	0
26	0	0	3	3	3	3	3	4	4	0	4	4	4	4	3	3	0	0	0	0	0	0	0	3
27	3	3	0	3	3	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	6	7	6	7	8	4	4	4	0	0	0	3	3	0	0	0	0	0	0	0	0	0
29	0	4	4	7	5	6	8	12	8	10	8	7	6	4	4	3	0	0	3	5	0	0	3	4
30	4	5	4	5	5	6	6	8	3	4	5	4	3	0	0	0	0	0	0	0	0	0	0	0
31	0	3	3	4	3	3	3	4	5	6	6	5	5	3	4	3	0	0	0	0	0	0	0	3

APPENDIX F: QUERI MODEL – AIRPACTS PROGRAM RESULTS

APPENDIX F.1: QUERI Model Result of Gresik Gas-Fired Power Plant

AirPacts (Ver 1.0; April 2002) **Tuesday, October 20, 2009 09:27**

A tool for assessing the environmental impacts and damage costs to human health, agricultural crops and man-made structures from exposure to routine atmospheric emissions
Dr. J.V. SPADARO (J.Spadaro@iaea.org or c/o Dr. RABL at rabl@cenerg.ensmp.fr), April 2002 (C)

CASE STUDY COMMENTS

Gresik Gas-Fired Power Plant

Enter comments here (optional) ....

STACK VARIABLES

Source Longitude (deg):	112.6605606
Source Latitude (deg):	-7.165336132
Source Location:	1
Stack Height (m):	150
Stack Diameter (m):	3
Exhaust Stack Velocity (m/s):	No value
Exhaust Gas Temperature (K):	380.7
Effective Stack Height (m):	No value

NB, ...

(1) Longitude: 0 to 360 deg; positive direction is West of Greenwich Meridien.

(2) Latitude: -90 to +90 deg about the Equator.

(3) Location: 0 = rural site

1, 2, 3 = near small, medium or large city

4 = 25 km or less from a large urban center

5 = 40 km or less from a large city, and

6 = more than 40 km from a large city.

(4) Effective height is the sum of actual stack height and plume rise.

(5) No value = Unavailable information or could not calculate a value based on input data.

POLLUTANT INVENTORY

Name	Emission Rate (tons/year)	Depletion Velocity (cm/s)
PM10	No value	No value
SO2	No value	No value
NO2	6.12E+03	1.5
CO	No value	No value
Other	No value	No value
Nitrates		1.4
Sulfates		No value

(6) Other pollutant: None specified

NB, ...

(7) Precursor pollutant for Nitrates is NO2.

(8) Precursor pollutant for Nitrates is SO_2.

(9) The pollutant removal rate is characterized by the depletion velocity, which accounts for 'dry' & 'wet' deposition and chemistry.

RECEPTOR DATA

Regional Receptor Density (pers/km):	61.53079987
Local Receptor Density (pers/km2):	1868.4
Radius of Local Domain (km):	50

Local receptor data: Values entered manually

NB, ...

(10) Regional density is estimated using a radius of 500-1000 km about the source. This surface area covers both land and water.

(11) Local receptors are the number of persons living within the local domain (100 by 100 km2), with the source located at the coordinate origin. The local population resolution scale is 5 by 5 km2.

METEOROLOGICAL STATISTICS

Mean Air Temperature (K):	300.4
Mean Local Wind Speed (m/s):	2.61
Anemometer Height (m):	10
Pasquill Distribution Class A (%):	17
Pasquill Distribution Class B (%):	10

Pasquill Distribution Class C (%):	9
Pasquill Distribution Class D (%):	10
Pasquill Distribution Class E (%):	14
Pasquill Distribution Class F (%):	40
Mean mixing layer height (m):	644.8

Local meteo data: Values entered manually

NB, ...

(12) Air and wind data are mean values during the impact assessment period.

(13) Anemometer height is the height at which the wind speed is measured.

(14) Pasquill classes are a measure of atmospheric turbulence level during pollutant transport. Class types include:

A, B, C = Very to Slightly Unstable;

D = Neutral, and

E, F = Slightly to Stable atmospheric conditions.

(15) Mixing height is the layer of air above the ground (troposhpere) where mass and energy transport is significant.

HUMAN HEALTH ENDPOINT PARAMETERS

- Exposure Response Function Slope in [cases/(yr.person.ug/m3)]
- Monetary Unit Costs in [US$/case]

Exposure Response Function	Pollutant	ERF Slope	Type of Impact	Unit Cost
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates [Rabl 2001]	Nitrates	0.00026	Long-term mortality	13176.54004

Restricted Activity Days - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	0.022	Morbidity	15.13300037
Chronic Bronchitis - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	4.51E-05	Morbidity	23195.93945
Respiratory Hospital Admissions; ALL; NO2 [Ponce de Leon, 1996]	NO2	0.000000858	Morbidity	592.2919922
Short-term Mortality (YOLL); ALL; NO2 [APHEA, 1997]	NO2	1.25283E-06	Short-term mortality	22700.18945
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates [Rabl 2001]	Nitrates	0.0962	Morbidity	1.04400003
Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates [Rabl 2001]	Nitrates	0.041	Morbidity	1.04400003
Respiratory Hospital Admissions - Recommended; ALL; Nitrates [Rabl 2001]	Nitrates	0.00000256	Morbidity	592.2919922

QUERI MODEL RESULTS

- Impact estimates in cases/year; Damage Costs in US$/year
- Damage cost range refers to the 68% confidence interval
- (*) No estimate as either the emission or depletion velocity is unspecified
- (**) No damage value because the monetary unit cost is zero
- (#) Estimates calculated using the Simple Uniform World Model (SUWM)

Exposure Response Function	Pollutant	Impact	Damage Cost	Lower Cost	Upper Cost
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates [Rabl 2001]	Nitrates	6.44E+01	8.48E+05	2.12E+05	3.39E+06
Restricted Activity Days - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	5.45E+03	8.24E+04	2.75E+04	2.47E+05
Chronic Bronchitis - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	1.12E+01	2.59E+05	8.63E+04	7.77E+05
Respiratory Hospital Admissions; ALL; NO2 [Ponce de Leon, 1996]	NO2	5.24E+01	3.10E+04	1.03E+04	9.30E+04
Short-term Mortality (YOLL); ALL; NO2 [APHEA, 1997]	NO2	7.65E+01	1.74E+06	2.89E+05	1.04E+07
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates [Rabl 2001]	Nitrates	2.38E+04	2.49E+04	8.29E+03	7.46E+04
Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates [Rabl 2001]	Nitrates	1.02E+04	1.06E+04	3.53E+03	3.18E+04
Respiratory Hospital Admissions - Recommended; ALL; Nitrates [Rabl 2001]	Nitrates	6.34E-01	3.75E+02	1.25E+02	1.13E+03

***** End of Report *****

APPENDIX F.2: QUERI Model Result of Muara Karang Oil-Fired Power Plant

AirPacts (Ver 1.0; April 2002) **Tuesday, October 20, 2009 09:29**

A tool for assessing the environmental impacts and damage costs to human health, agricultural crops and man-made structures from exposure to routine atmospheric emissions
Dr. J.V. SPADARO (J.Spadaro@iaea.org or c/o Dr. RABL at rabl@cenerg.ensmp.fr), April 2002 (C)

CASE STUDY COMMENTS

Muara Karang Oil-Fired Power Plant

Enter comments here (optional) ....

STACK VARIABLES

Source Longitude (deg):	106.7874985
Source Latitude (deg):	-6.110833168
Source Location:	1
Stack Height (m):	107
Stack Diameter (m):	2.9
Exhaust Stack Velocity (m/s):	No value
Exhaust Gas Temperature (K):	380.7
Effective Stack Height (m):	No value

NB, ...
(1) Longitude: 0 to 360 deg; positive direction is West of Greenwich Meridien.

(2) Latitude: -90 to +90 deg about the Equator.

(3) Location: 0 = rural site

1, 2, 3 = near small, medium or large city

4 = 25 km or less from a large urban center

5 = 40 km or less from a large city, and

6 = more than 40 km from a large city.

(4) Effective height is the sum of actual stack height and plume rise.

(5) No value = Unavailable information or could not calculate a value based on input data.

POLLUTANT INVENTORY

Name	Emission Rate (tons/year)	Depletion Velocity (cm/s)
PM10	2.26E+02	1.2
SO2	9.20E+03	0.75
NO2	1.82E+03	1.5
CO	No value	No value
Other	No value	No value
Nitrates		1.4
Sulfates		1.5

(6) Other pollutant: None specified

NB, ...

(7) Precursor pollutant for Nitrates is NO2.

(8) Precursor pollutant for Nitrates is SO2.

(9) The pollutant removal rate is characterized by the depletion velocity, which accounts
for 'dry' & 'wet' deposition and chemistry.

RECEPTOR DATA

Regional Receptor Density (pers/km):	61.57440186
Local Receptor Density (pers/km2):	1734.5
Radius of Local Domain (km):	50

Local receptor data: Values entered manually

NB, ...

(10) Regional density is estimated using a radius of 500-1000 km about the source.
This surface area covers both land and water.

(11) Local receptors are the number of persons living within the local domain (100 by 100 km2),
with the source located at the coordinate origin. The local population resolution
scale is 5 by 5 km2.

METEOROLOGICAL STATISTICS

Mean Air Temperature (K):	301.5
Mean Local Wind Speed (m/s):	2.61
Anemometer Height (m):	10
Pasquill Distribution Class A (%):	17

Pasquill Distribution Class B (%):	10
Pasquill Distribution Class C (%):	9
Pasquill Distribution Class D (%):	10
Pasquill Distribution Class E (%):	14
Pasquill Distribution Class F (%):	40
Mean mixing layer height (m):	644.8

Local meteo data: Values entered manually

NB, ...

(12) Air and wind data are mean values during the impact assessment period.

(13) Anemometer height is the height at which the wind speed is measured.

(14) Pasquill classes are a measure of atmospheric turbulence level during pollutant transport. Class types include:

A, B, C = Very to Slightly Unstable;

D = Neutral, and

E, F = Slightly to Stable atmospheric conditions.

(15) Mixing height is the layer of air above the ground (troposhpere) where mass and energy transport is significant.

HUMAN HEALTH ENDPOINT PARAMETERS

- Exposure Response Function Slope in [cases/(yr.person.ug/m3)]
- Monetary Unit Costs in [US$/case]

Exposure Response Function	Pollutant	ERF Slope	Type of Impact	Unit Cost
Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10 [Rabl 2001]	PM10	0.00026	Long-term mortality	13176.54004
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates [Rabl 2001]	Nitrates	0.00026	Long-term mortality	13176.54004
Long-term Mortality (YOLL) - Recommended; Adults over 30; Sulfates [Rabl 2001]	Sulfates	0.000434	Long-term mortality	13176.54004
Restricted Activity Days - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	0.022	Morbidity	15.13300037
Restricted Activity Days - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	0.022	Morbidity	15.13300037
Restricted Activity Days - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	0.0367	Morbidity	15.13300037
Chronic Bronchitis - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	4.51E-05	Morbidity	23195.93945
Chronic Bronchitis - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	4.51E-05	Morbidity	23195.93945
Chronic Bronchitis - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	7.53E-05	Morbidity	23195.93945
Respiratory Hospital Admissions; ALL; NO2 [Ponce de Leon, 1996]	NO2	0.000000858	Morbidity	592.2919922
Short-term Mortality (YOLL) - Recommended; ALL; SO2 [Rabl 2001]	SO2	0.0000023	Short-term mortality	22700.18945
Short-term Mortality (YOLL); ALL; NO2 [APHEA, 1997]	NO2	1.25283E-06	Short-term mortality	22700.18945
Lower Resp. Symptoms - Recommended; Asthmatic Adults; PM10 [Rabl 2001]	PM10	0.0962	Morbidity	1.04400003
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates [Rabl 2001]	Nitrates	0.0962	Morbidity	1.04400003
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Sulfates [Rabl 2001]	Sulfates	0.160654	Morbidity	1.04400003
Lower Resp. Symptoms - Recommended; Asthmatic Children; PM10 [Rabl 2001]	PM10	0.041	Morbidity	1.04400003
Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates [Rabl 2001]	Nitrates	0.041	Morbidity	1.04400003
Lower Resp. Symptoms - Recommended; Asthmatic Children; Sulfates [Rabl 2001]	Sulfates	0.0685	Morbidity	1.04400003
Respiratory Hospital Admissions - Recommended; ALL; PM10 [Rabl 2001]	PM10	0.00000256	Morbidity	592.2919922
Respiratory Hospital Admissions - Recommended; ALL; Nitrates [Rabl 2001]	Nitrates	0.00000256	Morbidity	592.2919922
Respiratory Hospital Admissions - Recommended; ALL; SO2 [Rabl 2001]	SO2	0.00000284	Morbidity	592.2919922
Respiratory Hospital Admissions - Recommended; ALL; Sulfates [Rabl 2001]	Sulfates	4.28E-06	Morbidity	592.2919922

QUERI MODEL RESULTS

- Impact estimates in cases/year; Damage Costs in US$/year
- Damage cost range refers to the 68% confidence interval
- (*) No estimate as either the emission or depletion velocity is unspecified
- (**) No damage value because the monetary unit cost is zero
- (#) Estimates calculated using the Simple Uniform World Model (SUWM)

Exposure Response Function	Pollutant	Impact	Damage Cost	Lower Cost	Upper Cost
Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10 [Rabl 2001]	PM10	5.38E+02	7.08E+06	1.77E+06	2.83E+07
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates [Rabl 2001]	Nitrates	6.44E+01	8.49E+05	2.12E+05	3.40E+06
Long-term Mortality (YOLL) - Recommended; Adults over 30; Sulfates [Rabl 2001]	Sulfates	6.13E+01	8.07E+05	2.02E+05	3.23E+06
Restricted Activity Days - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	4.55E+04	6.88E+05	2.29E+05	2.07E+06
Restricted Activity Days - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	5.45E+03	8.25E+04	2.75E+04	2.47E+05
Restricted Activity Days - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	5.18E+03	7.84E+04	2.61E+04	2.35E+05
Chronic Bronchitis - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	9.32E+01	2.16E+06	7.21E+05	6.49E+06
Chronic Bronchitis - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	1.12E+01	2.59E+05	8.64E+04	7.78E+05
Chronic Bronchitis - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	1.06E+01	2.47E+05	8.22E+04	7.40E+05
Respiratory Hospital Admissions; ALL; NO2 [Ponce de Leon, 1996]	NO2	1.46E+01	8.67E+03	2.89E+03	2.60E+04
Short-term Mortality (YOLL) - Recommended; ALL; SO2 [Rabl 2001]	SO2	1.79E+02	4.06E+06	6.77E+05	2.44E+07
Short-term Mortality (YOLL); ALL; NO2 [APHEA, 1997]	NO2	2.14E+01	4.85E+05	8.09E+04	2.91E+06
Lower Resp. Symptoms - Recommended; Asthmatic Adults; PM10 [Rabl 2001]	PM10	1.99E+05	2.08E+05	6.92E+04	6.23E+05
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates [Rabl 2001]	Nitrates	2.38E+04	2.49E+04	8.29E+03	7.46E+04
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Sulfates [Rabl 2001]	Sulfates	2.27E+04	2.37E+04	7.89E+03	7.10E+04
Lower Resp. Symptoms - Recommended; Asthmatic Children; PM10 [Rabl 2001]	PM10	8.48E+04	8.85E+04	2.95E+04	2.65E+05
Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates [Rabl 2001]	Nitrates	1.02E+04	1.06E+04	3.54E+03	3.18E+04

Lower Resp. Symptoms - Recommended; Asthmatic Children; Sulfates [Rabl 2001]	Sulfates	9.67E+03	1.01E+04	3.37E+03	3.03E+04
Respiratory Hospital Admissions - Recommended; ALL; PM10 [Rabl 2001]	PM10	5.29E+00	3.13E+03	1.05E+03	9.40E+03
Respiratory Hospital Admissions - Recommended; ALL; Nitrates [Rabl 2001]	Nitrates	6.34E-01	3.76E+02	1.25E+02	1.13E+03
Respiratory Hospital Admissions - Recommended; ALL; SO2 [Rabl 2001]	SO2	2.21E+02	1.31E+05	4.36E+04	3.93E+05
Respiratory Hospital Admissions - Recommended; ALL; Sulfates [Rabl 2001]	Sulfates	6.04E-01	3.58E+02	1.19E+02	1.07E+03

**** End of Report *****

APPENDIX F.3: QUERI Model Result of Paiton Coal-Fired Power Plant

AirPacts (Ver 1.0; April 2002) **Tuesday, October 20, 2009 09:32**

A tool for assessing the environmental impacts and damage costs to human health, agricultural crops and man-made structures from exposure to routine atmospheric emissions
Dr. J.V. SPADARO (J.Spadaro@iaea.org or c/o Dr. RABL at rabl@cenerg.ensmp.fr), April 2002 (C)

CASE STUDY COMMENTS

Paiton Coal-Fired Power Plant

Enter comments here (optional) ....

STACK VARIABLES

Source Longitude (deg):	113.5829544
Source Latitude (deg):	-7.712432861
Source Location:	1
Stack Height (m):	200
Stack Diameter (m):	6
Exhaust Stack Velocity (m/s):	No value
Exhaust Gas Temperature (K):	380.7
Effective Stack Height (m):	No value

NB, ...
(1) Longitude: 0 to 360 deg; positive direction is West of Greenwich Meridien.

(2) Latitude: -90 to +90 deg about the Equator.

(3) Location: 0 = rural site

1, 2, 3 = near small, medium or large city

4 = 25 km or less from a large urban center

5 = 40 km or less from a large city, and

6 = more than 40 km from a large city.

(4) Effective height is the sum of actual stack height and plume rise.

(5) No value = Unavailable information or could not calculate a value based on input data.

POLLUTANT INVENTORY

Name	Emission Rate (tons/year)	Depletion Velocity (cm/s)
PM10	1.83E+03	1.2
SO2	1.20E+04	0.75
NO2	1.26E+04	1.5
CO	No value	No value
Other	No value	No value
Nitrates		1.4
Sulfates		1.5

(6) Other pollutant: None specified

NB, ...

(7) Precursor pollutant for Nitrates is NO2.

(8) Precursor pollutant for Nitrates is SO2.

(9) The pollutant removal rate is characterized by the depletion velocity, which accounts for 'dry' & 'wet' deposition and chemistry.

RECEPTOR DATA

Regional Receptor Density (pers/km):	61.53079987
Local Receptor Density (pers/km2):	388.8
Radius of Local Domain (km):	50

Local receptor data: Values entered manually

NB, ...

(10) Regional density is estimated using a radius of 500-1000 km about the source. This surface area covers both land and water.

(11) Local receptors are the number of persons living within the local domain (100 by 100 km2), with the source located at the coordinate origin. The local population resolution scale is 5 by 5 km2.

METEOROLOGICAL STATISTICS

Mean Air Temperature (K):	300.4
Mean Local Wind Speed (m/s):	2.61
Anemometer Height (m):	10
Pasquill Distribution Class A (%):	17
Pasquill Distribution Class B (%):	10

Pasquill Distribution Class C (%):	9
Pasquill Distribution Class D (%):	10
Pasquill Distribution Class E (%):	14
Pasquill Distribution Class F (%):	40
Mean mixing layer height (m):	644.8

Local meteo data: Values entered manually

NB, ...

(12) Air and wind data are mean values during the impact assessment period.

(13) Anemometer height is the height at which the wind speed is measured.

(14) Pasquill classes are a measure of atmospheric turbulence level during pollutant transport. Class types include:

A, B, C = Very to Slightly Unstable;

D = Neutral, and

E, F = Slightly to Stable atmospheric conditions.

(15) Mixing height is the layer of air above the ground (troposhpere) where mass and energy transport is significant.

HUMAN HEALTH ENDPOINT PARAMETERS

- Exposure Response Function Slope in [cases/(yr.person.ug/m3)]
- Monetary Unit Costs in [US$/case]

Exposure Response Function	Pollutant	ERF Slope	Type of Impact	Unit Cost
Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10 [Rabl 2001]	PM10	0.00026	Long-term	13176.54004

			mortality	
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates [Rabl 2001]	Nitrates	0.00026	Long-term mortality	13176.54004
Long-term Mortality (YOLL) - Recommended; Adults over 30; Sulfates [Rabl 2001]	Sulfates	0.000434	Long-term mortality	13176.54004
Restricted Activity Days - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	0.022	Morbidity	15.13300037
Restricted Activity Days - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	0.022	Morbidity	15.13300037
Restricted Activity Days - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	0.0367	Morbidity	15.13300037
Chronic Bronchitis - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	4.51E-05	Morbidity	23195.93945
Chronic Bronchitis - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	4.51E-05	Morbidity	23195.93945
Chronic Bronchitis - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	7.53E-05	Morbidity	23195.93945
Respiratory Hospital Admissions; ALL; NO2 [Ponce de Leon, 1996]	NO2	0.000000858	Morbidity	592.2919922
Short-term Mortality (YOLL) - Recommended; ALL; SO2 [Rabl 2001]	SO2	0.0000023	Short-term mortality	22700.18945
Short-term Mortality (YOLL); ALL; NO2 [APHEA, 1997]	NO2	1.25283E-06	Short-term mortality	22700.18945
Lower Resp. Symptoms - Recommended; Asthmatic Adults; PM10 [Rabl 2001]	PM10	0.0962	Morbidity	1.04400003
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates [Rabl 2001]	Nitrates	0.0962	Morbidity	1.04400003
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Sulfates [Rabl 2001]	Sulfates	0.160654	Morbidity	1.04400003
Lower Resp. Symptoms - Recommended; Asthmatic Children; PM10 [Rabl 2001]	PM10	0.041	Morbidity	1.04400003
Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates [Rabl 2001]	Nitrates	0.041	Morbidity	1.04400003
Lower Resp. Symptoms - Recommended; Asthmatic Children; Sulfates [Rabl 2001]	Sulfates	0.0685	Morbidity	1.04400003
Respiratory Hospital Admissions - Recommended; ALL; PM10 [Rabl 2001]	PM10	0.00000256	Morbidity	592.2919922
Respiratory Hospital Admissions - Recommended; ALL; Nitrates [Rabl 2001]	Nitrates	0.00000256	Morbidity	592.2919922
Respiratory Hospital Admissions - Recommended; ALL; SO2 [Rabl 2001]	SO2	0.00000284	Morbidity	592.2919922
Respiratory Hospital Admissions - Recommended; ALL; Sulfates [Rabl 2001]	Sulfates	4.28E-06	Morbidity	592.2919922

QUERI MODEL RESULTS

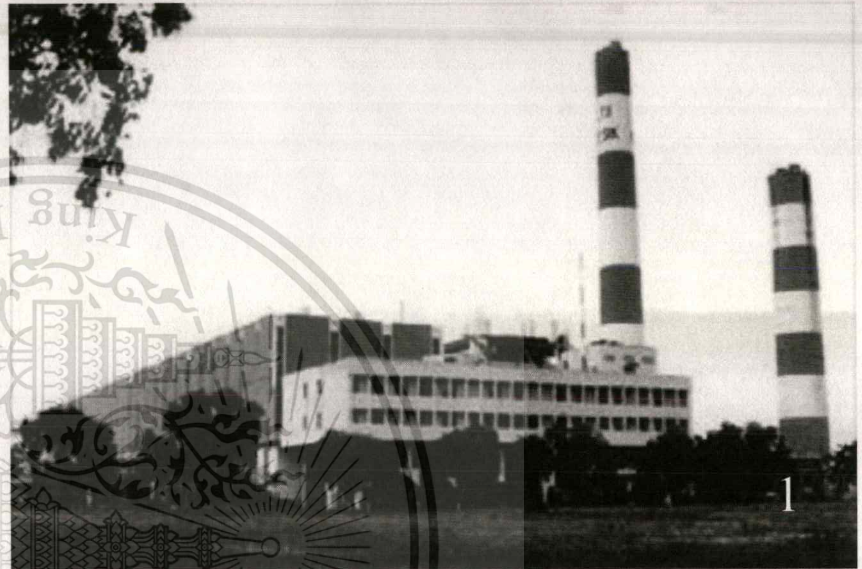
- Impact estimates in cases/year; Damage Costs in US$/year
- Damage cost range refers to the 68% confidence interval
- (*) No estimate as either the emission or depletion velocity is unspecified
- (**) No damage value because the monetary unit cost is zero
- (#) Estimates calculated using the Simple Uniform World Model (SUWM)

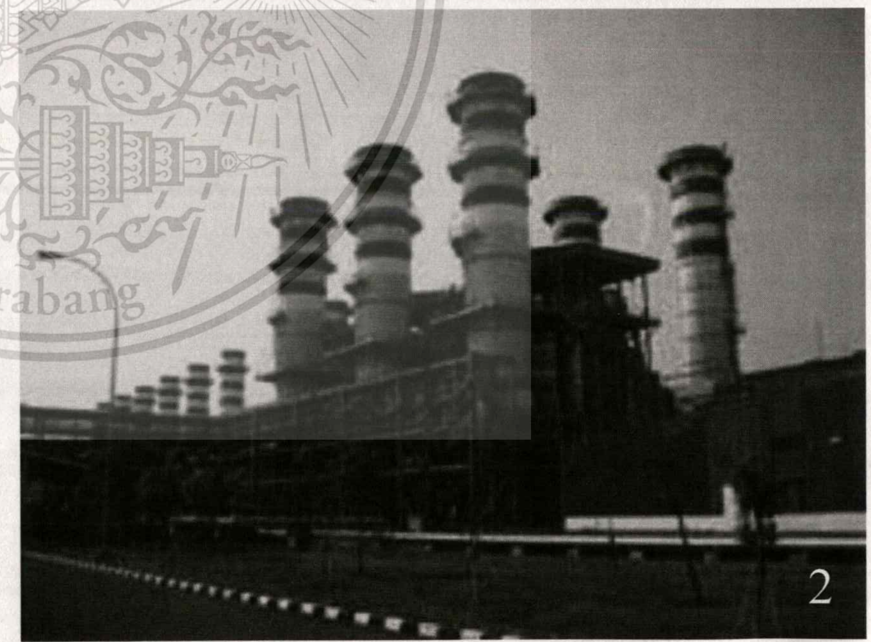
Exposure Response Function	Pollutant	Impact	Damage Cost	Lower Cost	Upper Cost
Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10 [Rabl 2001]	PM10	2.99E+02	3.94E+06	9.86E+05	1.58E+07
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates [Rabl 2001]	Nitrates	6.44E+01	8.48E+05	2.12E+05	3.39E+06
Long-term Mortality (YOLL) - Recommended; Adults over 30; Sulfates [Rabl 2001]	Sulfates	6.12E+01	8.07E+05	2.02E+05	3.23E+06
Restricted Activity Days - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	2.53E+04	3.83E+05	1.28E+05	1.15E+06
Restricted Activity Days - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	5.45E+03	8.24E+04	2.75E+04	2.47E+05
Restricted Activity Days - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	5.18E+03	7.84E+04	2.61E+04	2.35E+05
Chronic Bronchitis - Recommended; Adults over 18; PM10 [Rabl 2001]	PM10	5.19E+01	1.20E+06	4.01E+05	3.61E+06
Chronic Bronchitis - Recommended; Adults over 18; Nitrates [Rabl 2001]	Nitrates	1.12E+01	2.59E+05	8.63E+04	7.77E+05
Chronic Bronchitis - Recommended; Adults over 18; Sulfates [Rabl 2001]	Sulfates	1.06E+01	2.46E+05	8.22E+04	7.39E+05
Respiratory Hospital Admissions; ALL; NO2 [Ponce de Leon, 1996]	NO2	6.41E+00	3.80E+03	1.27E+03	1.14E+04
Short-term Mortality (YOLL) - Recommended; ALL; SO2 [Rabl 2001]	SO2	1.99E+01	4.53E+05	7.54E+04	2.72E+06
Short-term Mortality (YOLL); ALL; NO2 [APHEA, 1997]	NO2	9.36E+00	2.13E+05	3.54E+04	1.28E+06
Lower Resp. Symptoms - Recommended; Asthmatic Adults; PM10 [Rabl 2001]	PM10	1.11E+05	1.16E+05	3.85E+04	3.47E+05
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates [Rabl 2001]	Nitrates	2.38E+04	2.49E+04	8.29E+03	7.46E+04
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Sulfates [Rabl 2001]	Sulfates	2.27E+04	2.37E+04	7.89E+03	7.10E+04
Lower Resp. Symptoms - Recommended; Asthmatic Children; PM10 [Rabl 2001]	PM10	4.72E+04	4.93E+04	1.64E+04	1.48E+05
Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates [Rabl 2001]	Nitrates	1.02E+04	1.06E+04	3.53E+03	3.18E+04
Lower Resp. Symptoms - Recommended; Asthmatic Children; Sulfates [Rabl 2001]	Sulfates	9.67E+03	1.01E+04	3.36E+03	3.03E+04
Respiratory Hospital Admissions - Recommended; ALL; PM10 [Rabl 2001]	PM10	2.95E+00	1.75E+03	5.82E+02	5.24E+03

Respiratory Hospital Admissions - Recommended; ALL; Nitrates [Rabl 2001]	Nitrates	6.34E-01	3.75E+02	1.25E+02	1.13E+03
Respiratory Hospital Admissions - Recommended; ALL; SO2 [Rabl 2001]	SO2	2.46E+01	1.46E+04	4.86E+03	4.38E+04
Respiratory Hospital Admissions - Recommended; ALL; Sulfates [Rabl 2001]	Sulfates	6.04E-01	3.58E+02	1.19E+02	1.07E+03

***** End of Report *****

APPENDIX G: PICTURES OF GRESIK[1], MUARA KARANG[2] AND PAITON POWER PLANTS[3]





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BIOGRAPHY OF THE AUTHOR

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- Double Degree Master Program (2007-2010):
  MBA/M.Sc in International Management of Resources and Environment (IMRE), Technische Universität Bergakademie Freiberg, Germany and King Mongkut's Institute of Technology Ladkrabang, Thailand.

- Bachelor of Engineering (2001-2006):
  Bachelor of Engineering (B.Eng) in Civil Engineering, Brawijaya University Malang, Indonesia.

Work Experience

- PT. Bank Mandiri (Persero) Tbk (2011- present)

LIST OF PUBLICATIONS

Publications

Using the QUERI Model- AirPacts Program to Assess the External Costs of Three Power Plants in Indonesia with Three Different Energy Sources.