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Title: Benefits of Green Space for Air Quality Improvement and GHG Emissions Reduction in Jakarta

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Benefits of Green Space for Air Quality Improvement and GHG Emissions Reduction in Jakarta

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Summary

Jakarta as the capital city of Indonesia, since 2012 have enacted Jakarta Spatial Plan 2030. Jakarta 2030 is a statutory long term plan that can be categorized as comprehensive spatial plan that provide the vision and goals of the city development for the next 20 years. One of the main and interesting issue in the Jakarta 2030, is they will increase the area of green space up to 30% of all Jakarta area. The current green space only covers around 12.2% from total Jakarta area. In order to achieve their goals of providing adequate green space, in the next 20 years, the municipality along with the society and private entity must provide additional 17.8% of the total Jakarta to green space.

Even though the needs, importance and awareness of green space in Jakarta have aroused and even put as an integral part of Jakarta Spatial Plan 2030 towards promoting sustainable development and mainstreaming the importance of environmental aspects to be considered in the development plan of the city, Jakarta have not provide adequate guidelines to measure, value and quantify the level of benefits of the provisioning of green space to the city and its local residents in air quality context and to the reduction of carbon emissions. Contribution of this study is to become more apparent about the importance of protecting and promoting green space as part of city's development, especially by making the benefit quantified, measured, and in the end, visible, in particular with regard to health and economic benefit as impact of GHG emissions reduction and air quality improvement.

Main findings of this study is the provisioning of green space in Jakarta for 30% in 2030 will reduce GHG emissions reduction by up to 1.67 million tonnes of CO_2e, and will reduce the PM_{10} concentration in Jakarta up to 33.27 µg/m^3, SO_2 up to 6.39 µg/m^3, NO_2 up to 16.92 µg/m^3, and O_3 up to 44.83 µg/m^3. These numbers of reductions give a significant health and economic impact to Jakarta. For health impacts, some of the important impacts are mortality will be reduced to 319 cases, hospital admission related to air pollution will be reduced to 346 cases, emergency room visit related to air pollution will be reduced to 5,807 cases, asthma attacks related to air pollution will be reduced to 87,343 cases, chronic bronchitis related to air pollution will be reduced to 1,510 cases, and respiratory symptoms among adults related to air pollution will be reduced to 266,384 cases.

In total, the potential economic benefit of the provisioning of green space in Jakarta for 30% in 2030 is estimated between 4.2 trillion rupiah to 6.7 trillion rupiah, or about 435.2 to 697.1 million US dollar. By forecasting the local budget of Jakarta in 2030, the potential economic benefit of the provisioning of green space in Jakarta for 30% in 2030 is estimated around 2.8% to 4.6% of the local budget.

Keywords

Green space, GHG emissions, air pollutants, health benefit, economic benefit.

Abbreviations

AQGs	=	WHO Air Quality Guidelines
API	=	Air Pollutant Index
BAU	=	Business as Usual
BOD	=	Biochemical Oxygen Demand
CAI-Asia	=	Clean Air Initiative for Asian Cities Center
CB	=	Chronic Bronchitis
CBD	=	Convention on Biological Diversity
CD	=	Chest Discomfort
CFCs	=	Chlorofluorocarbons
CH_4	=	Methane
CO	=	Carbon Monoxide
CO_2	=	Carbon Dioxide
CO_2e	=	Carbon Dioxide equivalent
COD	=	Chemical Oxygen Demand
ERP	=	Electronic Road Pricing
ERV	=	Emergency Room Visit
GHG	=	Green House Gas
HC	=	Hydrocarbon
HFCs	=	Hydrofluorocarbons
IDR	=	Indonesian Rupiah
IHS	=	Institute for Housing and Urban Management
IPCC	=	Intergovernmental Panel on Climate Change
IRAP	=	International Road Assessment Program
LAI	=	Leaf Area Index
LRI	=	Lower Respiratory Illness
MPI	=	Multi-Pollutant Index
NAAQS	=	National Ambient Air Quality Standards
NO_2	=	Nitrous Dioxide
O_3	=	Ozone
PAN	=	Para Acrylo-Nitrit
PFCs	=	Perfluorocarbons
PJ	=	Peta Joule
PM_{10}	=	Concentrations of particulate matter less than 10µm in aerodynamic diameter
PSI	=	Pollutant Standard Index
RAD	=	Restricted Activity Days
RAN GRK	=	*Rencana Aksi Nasional terhadap Gas Rumah Kaca* (National Action Plan for Green House Gases)
RHA	=	Respiratory Hospital Admission
RSD	=	Respiratory Symptom Days
SF_6	=	Sulfur Hexafluoride
SO_2	=	Sulfur Dioxide
TEEB	=	The Economics of Ecosystems and Biodiversity
THC	=	Total Hydro Carbon
TOD	=	Transit Oriented Development
UHI	=	Urban Heat Island

UN	=	United Nations
UN-DESA	=	United Nations Department of Economic and Social Affairs
UNEP	=	United Nations Environment Program
US-EPA	=	United States Environmental Protection Agency
VOC	=	Volatile Organic Compounds
VSL	=	Value of a Statistical Life
WHO	=	World Health Organization
WTP	=	Waste Treatment Plant
WWTP	=	Waste Water Treatment Plant

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Chapter 1: Introduction

1.1 Background

“The world is increasingly urban, interconnected, and changing. If current trends continue, by 2050 the global urban population is estimated to be 6.3 billion, nearly doubling the 3.5 billion urban dwellers worldwide in 2010” (Secretariat of the Convention on Biological Diversity, 2012). The outcome of the continuing fraction between growing urbanization and the protection of nature may result on depletion of natural resources, including water, on a global scale, and will often consume prime agricultural land, with knock-on effects on biodiversity and ecosystem services elsewhere.

Cities and Biodiversity Outlook (Secretariat of the Convention on Biological Diversity, 2012) highlighted four challenges facing urban areas all over the world, they are:

i. Shortages of natural resources (including water) and environmental degradation;
ii. Climate change, as manifested by rising sea level, higher temperatures, variation in precipitation, and more frequent and severe floods, droughts, storms, and heat waves;
iii. Demographic and social changes associated with urbanization and population growth, such as the contradictory tendencies of increased wealth and the absolute increase in the numbers of poor; and
iv. Management of the transition to a more technologically sustainable future that will reduce ecological impacts, including minimizing carbon footprints.

To tackle the issue and to foster a more sustainable approach of city and urban development, cities and urban areas must not neglect the importance of incorporating environmental development into spatial planning schemes and regimes that the city conduct. One of the major components of incorporating the environmental paradigm is to protect and promote green spaces as urban ecosystem.

Jakarta as the capital city of Indonesia, since 2012 have enacted Jakarta Spatial Plan 2030—hereinafter referred to as Jakarta 2030. Jakarta 2030 is a statutory long term plan that can be categorized as comprehensive spatial plan that provide the vision and goals of the city development for the next 20 years. One of the main and interesting issue in the Jakarta 2030, is they will increase the area of green space up to 30% of whole Jakarta. The current green space only covers around 12,2% from total Jakarta area (Regulation of Jakarta Special Capital Region Number 1 year 2012 concerning Jakarta Spatial Plan 2030, 2012). In order to achieve their goals of providing adequate green space, in the next 20 years, the municipality along with the society and private entity must provide additional 17,8% of the total Jakarta to green space, through land use conversion from other uses, such as inefficient land use like sprawling residential areas, abandoned land, river basin greening, pedestrian greening, road sides, and other land uses that is not in line with the vision of creating Jakarta as a productive, safe, convenience and sustainable living area; and through private sector participation.

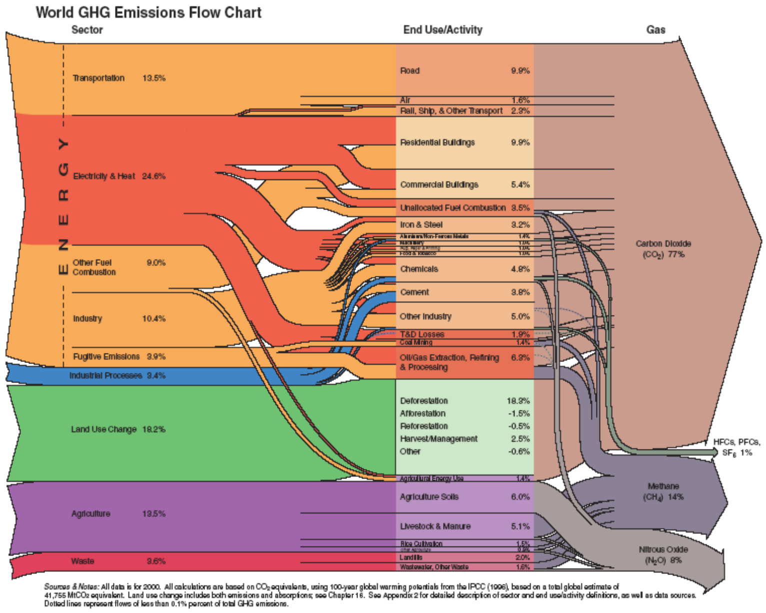
The objective behind this plan is to create a more sustainable development that not only emphasize in economic and social development but also emphasize in maintaning and increasing the importance of environmental development to be incorporated in a city development as a whole. This objective is also made in order to foster the effort in mainstreaming the climate change mitigation agenda—by the reduction of carbon emission—into the city development plan.

Many empirical evidence especially in cities and urban areas have shown that green areas are shrinking, environment quality are degrading, and problems related to environmental quality degradation such as health problems, pollution, congestion, loss of social cohesion and interaction, crime; are increasing in cities and urban areas. City development often ignores and neglects environmental aspects because the benefits and value of urban ecosystem services, especially green open space, are not calculated. This study aims to bring out and make visible the benefits of urban green open space as urban ecosystem by identifying the local and global benefits of urban green open space and investigating and quantifying particular benefits that is highly important and related to Jakarta, especially in the context of air quality improvement and carbon dioxide emissions reduction. The dominant global benefit of urban green space is GHG (Green House Gases) reduction (sustainablecitiesinstitute.org,). This study also would like to investigate and calculate the carbon dioxide emission reduction if the additional green space as in Jakarta Spatial Plan 2030 is implemented today.

Climate change now threatens to undermine the progress achieved by low- and middle-income countries, and the poorest populations are most vulnerable (World Bank, 2010). There are two major types of activities than can be carried out related to climate change, they are mitigation and adaptation. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Meanwhile mitigation refers to an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, Intergovernmental Panel on Climate Change, 2001).

Greenhouse Gases (GHG) are gases which allow direct sunlight (relative shortwave energy) to reach the Earth's surface unimpeded. Many GHG occur naturally in the atmosphere, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), while others are synthetic. Those that are man-made include the chlorofluorocarbons (CFC_s), hydrofluorocarbons (HFC_s) and Perfluorocarbons (PFC_s), as well as sulfur hexafluoride (SF_6). Based on IPCC report on 1996 (IPCC, Intergovernmental Panel on Climate Change, 1996), using 100 year global warming potentials, Carbon Dioxide (CO_2) is the major gas contributor of Green House Gases (GHG) (77%), as can be seen on the graph below. Indonesia have set up a policy guidelines in mitigation and adaptation of climate change called National Action Plan for Greenhouse Gas Emission (RAN GRK), and Jakarta is also conducting an effort of mainstreaming the climate change mitigation agenda.

Figure 1: World GHG Emission Flow Chart



Source: IPCC (1996).

1.2 Problem Statement

The plan for public green space provision must be seen as beneficial acts towards sustainable development in Jakarta, thus, any local, regional and global benefits from it should be investigated and measured.

The conversion of land use, especially in highly urbanized megacity such as Jakarta is a complex issue. It's related to land ownership, public financing, and the settlements and the people living in the area and its surroundings. While the mainstreaming the environmental and climate change issue must remain important in city development, the effectiveness of the effort of achieving it, particularly by the provisioning of green space, must be accountable and feasible to conduct.

In some respect, the plan (Jakarta 2030) have not provide adequate guidelines to measure, value and quantify the level of benefits of the provisioning of green space to the city and its local residents in air quality context and to the reduction of GHG emissions.

GHG emissions level in Jakarta are concerning for its level that is higher than the national average and its similarity to the level of other more industrious and developed city. Based on data on fuel consumption, landfill, sewage and wastewater treatment, analysis conducted by the Jakarta Environmental Management Agency on 2005 baseline year (Regulation of Jakarta Special Capital Region Number 131 year 2012 concerning Local Action Plan of Green House Gases Reduction, 2012), total GHG emissions of Jakarta in 2005 was 34.67 million tonnes CO_2e (without AFOLU sector / excluding plant absorption) or 3.84 tonnes CO_2e per capita, higher than the national GHG emissions reached 2.52 tonnes CO_2e per capita, and about per capita emissions of Seoul, South Korea (2006) with 4.10 tonnes CO_2e per capita.

Air pollutants are posing significant challenge to developing world since its nature of impact that pose a significant threat to human health. World Health Organization (World Health Organization, 2005) stated that clean air is considered to be a basic requirement of human health and well-being. According to a WHO assessment of the burden of disease due to air pollution, more than 2 million premature deaths each year can be attributed to the effects of urban outdoor air pollution and indoor air pollution (caused by the burning of solid fuels). More than half of this disease burden is borne by the populations of developing countries.

Poor air quality and air pollution in the city has proven not only damaged the health of the people but also has impacts on economy due to the costs incurred. Studies by Shah (1997) in World Bank technical paper and Syahril, Resosudarmo and Tomo (2002) showed the substantial economic cost incurred by Indonesia from air pollution. A 1994 study by the World Bank estimated that the economic cost due to air pollution in Jakarta was IDR 500 billion from 1,200 premature deaths, 32 million respiratory problem cases, and 464,000 cases of asthma (Shah and Nangpal, 1997). A 2002 study in Jakarta funded by the ADB estimated the economic cost due to PM_{10} pollution in Jakarta at IDR 1.7 trillion in 1998 and expected the cost to increase to around IDR 4.2 trillion in 2015 if no action is taken (Syahril, Resosudarmo, et al., 2002).

1.3 Research Objective

There are three main objectives of this research:

1. The identification and assessment of urban ecosystem services of green space in Jakarta.
2. To measure air pollution reduction and GHG emissions reduction due to urban green space in Jakarta. For this purpose, the specific objectives are:
   - Identify the current level (2012) of air pollutants and GHG emissions (business as usual scenario);
   - Identify the level of air pollutant and GHG emissions in 2030 with the Business as Usual (BAU) scenario; and
   - Identify the level of air pollutant and GHG emissions in 2030 with the additional green space for 30% of total Jakarta area (2030 additional green space scenario).
3. To investigate to what extend the health and economic benefits of urban green space in Jakarta in 2030, in the context of air quality improvement and GHG emissions reduction. For this purpose, the specific objectives are:
   - Measure the health benefits of the additional green space in Jakarta based on Jakarta 2030 Plan; and
   - Measure the economic benefits of the additional green space in Jakarta based on Jakarta 2030 Plan.

1.4 Research Questions

In order to achieve the research objectives, research questions were formulated. The main research question is:

"What are the benefits of the provisioning of green space with the additional green space of Jakarta 2030 Spatial Plan?"

To answer the main question, the specific research questions are:

1. What kind of ecosystem services provided by different types of green space in Jakarta?

2. What is the current level of air pollutants and GHG emissions in Jakarta?

3. How much the air pollutants and GHG emissions will be reduced with the additional greening in 2030?

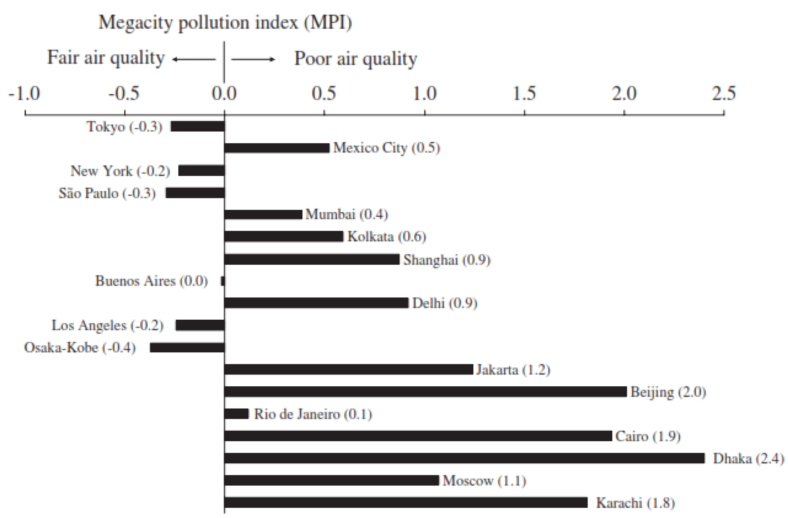
4. What are the health and economic benefits (of the air quality improvement) to the city?

1.5 Significance of the Study

The research work is a combination of case study research and scientific desk study. It is aimed at formulating, assess, measuring methods, and quantify the value and benefits of specific ecosystem services of green open space. This research is significant due to the following reasons:

- Poor air quality has been major environmental issues in Jakarta. Studies showed that Jakarta ranked number five of major megacities that has the highest level of poor air quality based on Megacity Pollutant Index (MPI) analysis (Gurjar, Butler, et al., 2008).

Figure 2: MPI-based total Pollutant Level in Megacities



Source: Gurjar, Butler, et al., 2008.

- Jakarta GHG emissions per capita are among the highest compare to other major cities in the world, as shown by table below, therefore efforts to reduce GHG emissions in Jakarta—one of which is by promoting urban green space—are imperatives.

Table 1: GHG Emissions per capita of World's Major Cities

City	GHG Emissions per capita (tonnes of CO_2 eq) (year in brackets)
Washington DC (US)	19,7 (2005)

City	GHG Emissions per capita (tonnes of CO_2 eq) (year in brackets)
Glasgow (UK)	8,4 (2004)
Toronta (Canada)	8,2 (2001)
Shanghai (China)	8,1 (1998)
New York (US)	7,1 (2005)
Beijing (China)	6,9 (1998)
London (UK)	6,2 (2006)
Tokyo (Japan)	4,8 (1998)
Jakarta (Indonesia)	3,8 (2005)
Seoul (Rep. Korea)	3,8 (1998)
Barcelona (Spain)	3,4 (1996)
Rio de Janeiro (Brasil)	2,3 (1998)
Sao Paulo (Brasil)	1,5 (2003)

Source: Author, adapted from Dodman (2009) in (UN-HABITAT, 2011); and (Sugar, Kennedy, et al., 2013).

- The values of ecosystem services particularly in urban areas in mega-city like Jakarta have not been measured. The impact of the absence of such measurements and valuation result to a degradation of environmental quality in urban areas due to change in land use from green open space to a developed area, which in the end may result to environmental-related problems, such as health problems, floods, soil erosion, increase of temperature, social problems, and other significant problems. It is significant for such study like this one to be conducted in order to bring out the true value of ecosystem services can bring to human well-being, the residents, society, and the city; and
- Identification of the health and economic benefits of green space provision in Jakarta have not been measured before.

1.6 Scope and Limitations

The research will be conducted with following scope and limitations:

- There are various types of benefits of urban greening, this research identify all types of benefits but only investigate and measure health and economic impacts of air pollutant reduction and GHG emission reduction (global benefit).
- Due to the limitation of available data and comparability with the results of previous studies, this study will focus only on measuring four air pollutant parameters or indicators, which are the dominant air pollutants, they are fine particulate matter (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ground-level ozone (O_3).
- The reduction factor of air pollutants only measured by certain types of green space in Jakarta, such as green spaces that are categorised as urban parks and road side green space or street with trees.
- The area of the study will be limited to Jakarta provincial border, not the span of urbanized area in the Greater Jakarta or Jakarta Metropolitan Area (The Greater Jakarta consists of 5 autonomous municipality (Jabodetabek: Jakarta, Bogor, Tangerang, Bekasi, Depok)).

Chapter 2: Literature Review

2.1 Introduction

In this chapter, theories and concepts related to green space, green open space, urban greening, urban forest and trees, and urban ecosystem services, particularly related to its benefits and assessment. Constructing additional green space in Jakarta 2030 plan that include area, percentage and map, scenario building which include data, variables and indicators that will be used in this research are identified and explored in order to provide a base to this research. The categorization of benefits will follow the sustainability approach, which comprise of three major types; they are environmental benefits, economic benefits, and social benefits. After the benefits have been identified, theories and concepts will be cited. As explained on chapter one, this study identifies all benefits and quantification methods to assess the benefits, but focuses on air pollution as one critical local benefit that is highly relevant to Jakarta to be measured in this study, and also GHG emissions reduction. To conclude this literature review, the conceptual framework will be formulated and discussed.

2.2 Open Space and Green Space General Concepts and Theories

2.2.1 Definition of Green Open Space

Many definitions, concepts and theories have tried to conclude, summarize and describe the broad understanding of green space and open space. There is no single explanation can act as principle definition of what green space is all about. One of the most comprehensive explanations of a green space and its system comes from the Council of Europe (Council of Europe Committee of Ministers Recommendation No. R (86) 11 of the Committee of Ministers to Member States on Urban Open Space, 1986):

> "Urban parks and green spaces are an essential part of the urban heritage and infrastructure, being a strong element in the architectural and landscape character of towns and cities, providing a sense of place and engendering civic pride. They are important for enabling social interaction and fostering community development, as well as providing an outdoor classroom for biological and ecological studies. Public green spaces help to conserve natural systems, including carbon, water and other natural cycles, within the urban environment, supporting ecosystems and providing the contrast of living elements in both designed landscapes and conserved wildlife habitats within our urban settlements. Parks and green spaces are supportive of social and economic objectives and activities. In particular the provision of public parks helps to reduce the inequalities, poor health and social exclusion in deprived areas and reduces the inherent tension between the many social and ethnic groups who form the wider community. Providing for the recreational and leisure needs of a community assists the economic revival of cities, increasing their attractiveness as a place for business investment, to live, work and take our leisure."

Sustainability, which comprise of and interact between environmental, economic and social aspects have made into a point that we should re-think and re-evaluate development paradigm to lead the existence and interactions between the three aspects should be included into considerations that in the end might contribute to sustainable urban environments. Green space provides a role of joining those aspects to make a balance of a traditional development that emphasize more on "grey space". Increasingly, urban green space is seen as an "integral part of cities providing a range of services to both the people and the wildlife living in urban areas" (James, Tzoulas, et al., 2009).

The terms green space and open space are often used interchangeably (Swanwick, Dunnett, et al., 2003) that makes it hard to distinguish clearly between the two and might lead to confusion of giving a clear definition. James (2009) synthesize the definition based on the key terms that were suggested by Swanwick et al. (2003). Swanwick et al. (2003) suggested that "urban areas are made up of the built environment and the external environment between buildings. The external environment, in their model, is composed of two distinct spaces: 'grey space' and 'green space'. Grey space is land that consists of predominantly sealed, impermeable, 'hard' surfaces such as concrete or tarmac. Green space land, whether publicly or privately owned, consists of predominantly unsealed, permeable, 'soft' surfaces such as soil, grass, shrubs, trees and water".

2.2.2 Legal Formal Definition of Green Open Space in Indonesia

Based on Law of the Republic of Indonesia number 26 year 2007 concerning Spatial Planning (Government of Indonesia, 2007), Green Open Space (*Ruang Terbuka Hijau / RTH*) is a lengthwise, line, and/or grouping area, with a characteristics of open utilization, publicly or privately owned, act as a place to grow plants and vegetations, either naturally or artificially.

Ministry of Public Works, Government of Indonesia (Government of Indonesia, 2008) on their Ministerial Decree of Public Works No. 05/PRT/M/2008 concerning Guidelines for Provisioning and Utilization Green Open Space in Urban Areas explains more about classification and types of Green Open Space. The classification of green open space can be seen in graph below.

Figure 3: Classification of Green Open Space in Indonesia

Green Open Space	Physical	Function	Structure	Ownership
	Natural	Ecology	Ecological Pattern	Public
		Aesthetic		
	Artificial	Socio-Cultural	Planned Pattern	Private
		Economy		

Source: Ministerial Decree of Public Works No. 05/PRT/M/2008 concerning Guidelines for Provisioning and Utilization Green Open Space in Urban Areas

Meanwhile, the types of green open spaces (Ministerial Decree of Public Works No. 05/PRT/M/2008 concerning Guidelines for Provisioning and Utilization Green Open Space in Urban Areas) are:

1. Green Spaces in Offices, Commercials, Services, Tourism, Public and Social Services and Facilities, Mixed-used Areas, and Green Roofs;
2. Urban Parks;
3. Urban Forests;
4. Green Belts;
5. Green Streets or Road Sides Green Space;
6. Pedestrian Ways;
7. Train Lines;
8. Electrical Transmission Networks Green Space;
9. River Basin;
10. Coastal Area Green Space;
11. Spring Water Green Space; and
12. Cemetery.

2.3 Environmental Benefits of Green Open Space

2.3.1 Climate Change and Green House Gases

Climate change is the biggest challenge that human has ever faced in history. "The IPCC (Intergovernmental Panel on Climate Change) warns that at current greenhouse gas emission rates, average global temperatures will likely increase by 4°C by 2030, the catastrophic effects of which are beyond our ability to predict" (Secretariat of the Convention on Biological Diversity, 2012). There are two principal efforts to react the climate change phenomena, they are adaptation and mitigation. GHG is part of mitigation effort. Mitigation is defined as "Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to Climate Change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks" (IPCC, Intergovernmental Panel on Climate Change, 2007).

Cities play a major role in climate change mitigation, since we live in an urbanized world and more than half of population currently living in cities; cities contribute about 60-70 % of global green house gas emissions (IPCC, Intergovernmental Panel on Climate Change, 2007). One of the efforts in mitigation to climate change is to promote green spaces in urban areas. Many scholars have proven that green spaces offer massive ecosystem services.

From Cities and Biodiversity Outlook (2012) report, is it stated that "Green spaces can increase carbon storage and uptake. Although there is considerable variation in green space across cities, there is overwhelming consensus that urban green spaces offer numerous ecosystem services, among them shade provision, rainwater interception and infiltration, and pollution reduction. Forests can contribute indirectly to climate-change mitigation by providing more shade and cooling, thereby reducing overall energy consumption. Finally, green spaces can significantly reduce the urban heat island (UHI) effect, where urban areas are warmer than surrounding regions."

Benefits of green spaces in carbon emission reduction are provided by services from trees. Trees can act as carbon sinks. Most trees use photosynthesis to convert Carbon Dioxide (CO_2) into nutrients (sustainablecitiesinstitute.org,). Urban trees act as a sinks of CO_2 by storing excess carbon as biomass during photosynthesis. The amount of CO_2 stored is proportional to the biomass of the trees (Chaparro and Terradas, 2009).

2.3.2 Removal of Air Pollutants

One of the major environmental and health problems in cities and urban areas is air pollution. It is caused by many sources; among them are transportation, dust and debris from soils, roads, and surfaced areas, waste incinerators, and also from heating of buildings. Air pollution is also responsible for increases in respiratory and cardiovascular diseases in cities (Sunyer, Basagana, et al., 2002).

Trees remove gaseous air pollution primarily by uptake through leaf stomata, though some gases are removed by the plant surface. Factors that affect pollution removal by trees include the amount of healthy leafsurface area, concentrations of local pollutants, and local meteorology (Smith, 1990: in (Nowak and Dwyer, 2007)). It is clear that vegetation reduces air pollution, but to what level seems to depend on the local situation (Svensson and Eliasson, 1997: in (Bolund and Humhammar, 1999)). In general, vegetation is much better than water or open spaces for filtering the air (Bolund and Humhammar, 1999).

Bolund and Humhammar in their article Ecosystem Services in Urban Areas (1999), added that “the location and structure of vegetation is important for the ability to filter the air. Bernatzky (1983) reports that 85% of air pollution in a park can be filtered out, and in a street with trees, 70%. Thick vegetation may simply cause turbulence in the air while a thinner cover may let the air through and filter it”.

The measuring methods for air removal was described by Gómez-Baggenthun and Barton, (2013): “Vegetation in urban areas improves air quality by removing pollutants from the atmosphere, including ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter less than 10 µm (PM_{10}) (Nowak, 1994a; (Escobedo and Nowak, 2009)). Removal of pollutants operates through filtration of particulates through the leaves of trees and shrubs (Nowak, Rowntree, et al., 1996)”.

Jim and Chen (2009) based on their article “Ecosystem services and valuation of urban forests in China” clearly examined the quantification methods applied in China to measure the monetary value of air pollutant impact to the city. “To quantify the monetary value of air pollutant removal by urban forests, two methods have been adopted in Chinese studies. The first is the marginal cost, which estimates the additional cost of producing a unit of air pollutant. The second is the replacement cost, which estimates the approximate cost of reducing pollutant emission using extant control techniques in industries, such as desulphurization and particulate precipitation” (Jim and Chen, 2009).

2.3.3 Temperature and Microclimatic Reduction, and Reduction of Urban Heat Island (UHI) Effect.

Local climate and even weather are affected by the city. In studies of US cities, some of these differences have been quantified, and expressed as changes compared with surrounding country-side: air temperature is 0.7°C higher measured as the annual mean, solar radiation is reduced by up to 20%, and wind speed is lowered by 10–30% (Haughton and Hunter, 1994:

in (Bolund and Humhammar, 1999)). The phenomenon, sometimes called the urban heat island effect, is caused by the large area of heat absorbing surfaces, in combination with high amounts of energy use in cities (Bolund and Humhammar, 1999).

Example of cause of UHI effect is large areas of asphalt and concrete trap the heat of the sun and reflects it back into the environment, thereby raising the temperature in surrounding areas. The process contributes to smog, global warming and higher energy costs associated with increased air conditioning in buildings (sustainablecitiesinstitute.org,). The UHI effect consists of local rises in the temperature of city areas caused by greenhouse gas emission from heating and traffic in combination with heat absorption by built surfaces (Moreno García, 1994: in (Gómez-Baggethun and Barton, 2013)). Shades and humidity provided by trees in urban areas can lower and moderate local temperatures.

Some of the key strategies for using urban green space to mitigate the UHI include green roofs, shade trees, and urban landscape design. For example, green roofs can significantly reduce both peak flow rates and total runoff volume of rainwater by storing it in plants and substrate and releasing it back to the atmosphere through evapo-transpiration. Such roofs can retain 70–80 percent of rainfall in summer and 10–35 percent in winter, depending on their build-up, thus supporting an improved microclimate (Secretariat of the Convention on Biological Diversity, 2012).

2.3.4 Reduction of Storm Water Run-Off, Flooding Damage, Storm Water Treatment, Drainage, and Improve Water Quality

Ecosystems play a fundamental role in providing cities with fresh water for drinking and other human uses and by securing storage and controlled release of water flows. Vegetation cover and forests in the city catchment influences the quantity of available water (Higgens et al., 1997: in (Gómez-Baggethun and Barton, 2013)). Increasing the impermeable surface area in cities reduces the capacity of water to percolate in soils, increasing the volume of surface water runoff and thus increasing the vulnerability to water flooding (Villareal and Bengtsson, 2005). Interception of rainfall by tree canopies slows down flooding effects and green pavements/soft lanes reduce the pressure on urban drainage systems by percolating water (Bolund and Humhammar, 1999).

2.3.5 Urban Noise

Traffic, construction and other human activities make noise a major pollution problem in cities, affecting health through physiological and psychological damages. Urban soil and plants and trees can attenuate noise pollution through absorption, deviation, reflection, and refraction of sound waves (Aylor, 1972; Kragh, 1981; Ishii, 1994; Fang and Ling, 2003: in (Gómez-Baggethun and Barton, 2013)). In belt trees, for example, the sound waves are reflected and refracted, dispersing the sound energy through the branches and trees (Chaparro and Terradas, 2009). An indicator of measuring urban noise is by calculated by weighting leaf area (m2) and distance to roads (m) (Nowak, 2000).

Vegetation can also mask sounds by generating its own noise as wind moves tree leaves or as birds sing in the tree canopy. These sounds may make individuals less aware of offensive noises because people are able to filter unwanted noise while concentrating on more desirable sounds (Robinette, 1972: in (Nowak and Dwyer, 2007)).

2.3.6 Urban Wildlife and Biodiversity

There are many additional benefits associated with urban vegetation that contribute to the long-term functioning of urban ecosystems and the well-being of urban residents. These include wildlife habitat and enhanced biodiversity (Nowak and Dwyer, 2007). Urban wildlife can serve as biological indicators of changes in the health of the environment (e.g., the decline of certain bird populations was traced to pesticides), and can provide economic benefit to individuals and society (Van Druff et al., 1995: in (Nowak and Dwyer, 2007)).

"Urbanization can sometimes lead to the creation and enhancement of animal and plant habitats, which, in turn, usually increases biodiversity. However, the introduction of new plant species into urban areas can lead to problems for managers in maintaining native plant structure, as exotic plants can invade and displace native species in forest stands" (Nowak and Dwyer, 2007).

Ways of measuring the biodiversity is by using Shannon diversity and evenness index (Dobbs, Escobedo, et al., 2011). Calculated using the formula:

$$SD = -\sum_{i=1}^{s} p_i \ln p_i,$$

where p is the amount of tree species on the plot in relation to the total tree species in the city. A value of 1 means that existing tree species are equally abundant in the sampling unit; a value of zero implies that individuals are concentrated among few tree species.

Another indicator of measuring the biodiversity is by using "ratio of native trees" (Dobbs, Escobedo, et al., 2011), by calculating percent native trees in the plot. A high percent was assumed to be optimal.

2.3.7 Waste Treatment

Ecosystems filter out, retain and decompose nutrients and organic wastes for urban effluents through dilution, assimilation and chemical re-composition (TEEB, The Economics of Ecosystems and Biodiversity, 2010). Ponds, for example, filter wastes from human activities reducing the level of pollution in urban waste water (Karathanasis et al., 2003: in (Gómez-Baggethun and Barton, 2013)), and urban streams retain and fix nutrients from organic waste. Plant communities in urban soils can play an important role in the decomposition of many labile and recalcitrant litter types (Vauramo and Setälä, 2011: in (Gómez-Baggethun and Barton, 2013)).

2.3.8 Pollination and Seed Dispersal

Green spaces as urban ecosystems are places where habitats and biodiversity can be surpisingly high. This also reflects in number of species that transmitting and dispersing pollen and seeds of various plants, such as birds and bees. For example, urban systems host important populations of birds and bees (Saure, 1996; Tommasi et al., 2004, Melles et al., 2003,: in (Gómez-Baggethun and Barton, 2013)). Research has shown that management practices of biodiversity in allotment gardens, cemeteries, and city parks promote functional groups of insects and birds, also enhancing pollination and seed dispersal (Andersson et al., 2007: in (Gómez-Baggethun and Barton, 2013)).

2.3.9 Moderation of Environmental Extreme

Another additional benefit of urban ecosystem was expressed by Gómez-Baggenthun and Barton (2013) as moderation of environmental extreme: “Ecosystems such as mangroves act as natural barriers that buffer cities from extreme climate events and hazards, including storms, waves, floods, hurricanes, and tsunamis (Farber, 1987; Danielsen et al., 2005; Costanza et al., 2006a; Kerr and Baird, 2007). Vegetation stabilizes the ground reducing the likelihood of landslides. Likewise, as discussed above, cooling effects by urban vegetation can buffer the impact of heat waves in cities (Hardin and Jensen, 2007)”.

2.4 Economic Benefits of Green Open Space

2.4.1 Increase of Property Value

One of the main economic benefits that can be directly monetized and compared is the increase of property value in relation to proximity to green space in urban areas. There are at least three benefits as explained by Nowak and Dwyer (2007):

- “The sales value of real estate reflects the benefits that buyers attach to attributes of the property, including vegetation on and near the property;
- Parks and greenways have been associated with increases in nearby residential property values; and
- Increased real estate values generated by green space also produce direct economic gains to the local community through property taxes.”

2.4.2 Energy Saving

Another economic benefit from urban green space as urban ecosystem service is energy saving. “Trees can reduce building heating and cooling energy needs, as well as consequent emissions of air pollutants and CO_2 by power plants, by shading buildings and reducing air temperatures in the summer, and by blocking winds in winter” (Nowak and Dwyer, 2007). Geographical, topographical and regional climate variability is also the factors of the effectiveness of trees to conserve and save energy-use. Along with those macro factors, there also local factor that has to be taken into consideration, that is the location of trees around buildings. “Tree arrangements that save energy provide shade primarily on east and west walls and roofs, and wind protection from the direction of prevailing winter winds” (Nowak and Dwyer, 2007).

Sustainable Cities Institute on their Report on Benefits of Trees and The Urban Forest added that “trees can reduce heating and cooling costs for building. When placed strategically around buildings, trees can reduce cooling costs by 30%, and heating costs by 20-50%. By providing shade and a barrier to wind, trees cool buildings during hot weather, and limit snow accumulation during cold weather. Economically this is beneficial as it can reduce the fuel costs associated with heating and cooling.”

2.5 Social Benefits of Green Open Space

2.5.1 Recreation and Cognitive Development

Many scholars conclude that green spaces can provide a sense of recreation and encourage community interaction. People tend to gather more when green spaces are available. Gómez-Baggenthun and Barton (2013) in their article "Classifying and valuing ecosystem services for urban planning", synthesize the benefit of recreation and cognitive development provided by green space:

> "People often choose where to spend their leisure time based on the characteristics of the natural landscapes in a particular area (Chiesura, 2004; Kaplan, 1983; Kaplan and Kaplan, 1989). Green spaces in urban areas provide multiple opportunities for physical exercise, improved mental health, and cognitive development. For example, allotment gardens are often used for environmental education (Groening, 1995; Tyrväinen et al., 2005), and important bodies of local ecological knowledge have been documented in cities (Andersson et al., 2007; Barthel et al., 2010). Because urban inhabitants develop affective links to the ecological sites of their cities, urban ecosystems also play an important role in sense of place (Altman and Low, 1992)."

Green spaces in urban areas also provide multiple opportunities for cognitive development. For example, urban forests and allotment gardens are often used for environmental education purposes, and important bodies of local ecological knowledge have been documented in cities (Groening 1995; Tyrväinen et al. 2005; Barthel et al. 2010: in Gómez-Baggenthun and Barton, 2013). High visibility, variability, and complexity of urban forest ecosystems also make an outstanding laboratory for environmental education (Nowak and Dwyer, 2007).

2.5.2 Animal Sighting

Some urban ecosystems include large numbers of birds, butterflies, amphibians, and other species that many urban inhabitants like to see in streets, parks, and gardens. Diversity may peak at intermediate levels of urbanization, at which many native and nonnative species thrive, but it typically declines as urbanization intensifies (Beebee, 1979, Melles et al., 2003, Blair, 1996, Blair and Launer, 1997: in (Gómez-Baggethun and Barton, 2013)).

2.5.3 Improve Human Health

Many community managed green spaces exist primarily to create therapeutic opportunities for disadvantaged or excluded groups such as adults with learning difficulties, the elderly and ethnic minority communities. Living near parks, woodland or other open spaces helps to reduce health inequalities, regardless of social class (Mitchell and Popham, 2008).

Ulrich in his three articles describes the relationship between stress reduction and green space:

- "Clinical evidence suggests that exposure to an outdoor green environment reduces stress faster than anything else. Simply viewing nature can produce significant recovery or restoration from stress within three to five minutes" (Ulrich, 1999).
- "For people experiencing anxiety or stress, studies indicate that certain types of nature scenes quickly foster more positive feelings and promote beneficial changes in physiological systems for instance, blood pressure" (Ulrich, Simons, et al., 1991).

- “Patients recovering from surgery, recover faster, need fewer strong drugs for pain, and have fewer minor complications if they have a room with a window that overlooks green environments such as trees, grass and water” (Ulrich, 1984).

2.5.4 Aesthetic and Safety

Gómez-Baggenthun and Barton (2013) in their article “Classifying and valuing ecosystem services for urban planning”, synthesize the aesthetic benefit: “The information function relates to aesthetics-based opportunities for recreation and pleasure. Ecosystems provide unlimited opportunities, inspirational and educational fulfillment, reflection and spiritual enrichment (De Groot et al., 2002; Kim and Kaplan, 2004; Tzoulas et al., 2007) and are one of the highest valued ecosystem functions in cities (Konijnendijk et al., 2005; (MA, 2003)). Aesthetics in this study refers to the preference of people to live in pleasant environments and is revealed in real estate prices (Tyrväinen and Miettinen, 2000). The presence of a tree is also valued by people, so if a tree is lost, monetary compensation is necessary (Nowak et al., 2002)”. Trees lined streets also promote safer driving by giving the impression of narrowing streets. They also provide a buffer between vehicles and pedestrians.

2.6 Synthesis of Benefits

Synthesis of all the benefits mentioned on the previous subchapter, including the ecosystem services approach of valuation and indicators can be seen on a table below.

Table 2: Synthesize of Urban Ecosystem Benefits and its Measuring Indicators

	Types of Benefits			Examples	Indicators	Reference(s):
	Benefits		Ecosystem Services			
GREEN SPACE	Global	Environmental	Green House Gases Reduction	Carbon sequestration and storage by the biomass of urban shrubs and threes	Carbon is multiplied by 3.67 to convert to CO_2	Dobbs (2011); Gómez-Baggenthun and Barton (2013); Nowak and Dwyer (2007); Nowak (2013).
	Local	Environmental	Removal of Air Pollutants	Removal and fixation of pollutants by urban vegetation in leaves, stems and roots	O_3, SO_2, NO_2, CO, and PM_{10} µm pollutant flux ($g/cm^2/s$) multiplied by tree cover (m^2)	Dobbs (2011); Gómez-Baggenthun and Barton (2013); Jim and Chen (2009); Chaparro and Teradas (2009); Nowak (2000).
			Temperature and Microclimatic Reduction, and Reduction of Urban Heat Island (UHI) Effect	Trees and other urban vegetation provide shade, create humidity and block wind	Leaf Area Index; Temperature decrease by tree cover x m^2 of plot trees cover (°C)	Dobbs (2011); Bolund and Humhammar (2009).
			Reduce Stormwater Run off, flooding damage, stormwater treatment and improve water quality	Soil and vegetation percolate water during heavy and/or prolonged precipitation events	Soil infiltration capacity; % sealed relative to permeable surface (ha)	Villarreal and Bengtsson (2005); Gómez-Baggenthun and Barton (2013)
			Urban Noise	(storm protection) Tree structure	Plot tree density and % cover. High tree densities and less than 30% of tree cover produce lower amounts of debris	(Escobedo et al., 2009); Dobbs (2011)
				(storm protection) Crown dieback	Average percent individual tree crown dieback for trees on plot	Dobbs (2011)
				(Drainage) Curve number	Curve number based on soil hydrologic group and land use	(Engel et al., 2004); Dobbs (2011)
				(Drainage) Soil infiltration	Infiltration curve using Friedman et al. (2001) methods for urban areas using plot soil bulk densities in cm/h	Friedman et al. (2001); Dobbs (2011)

	Types of Benefits			Examples	Indicators	Reference(s):
	Benefits		Ecosystem Services			
				Absorption of sound waves by vegetation barriers, specially thick vegetation	Leaf area (m2) and distance to roads (m); noise reduction dB(A)/vegetation unit (m) calculated by weighting distance to roads by leaf area	Aylor (1972); Ishii (1994); Kragh (1981); Nowak (2000); Dobbs (2011); Gómez-Baggenthun and Barton (2013)
			Urban Wildlife and Biodiversity	Urban wildlife can serve as biological indicators of changes in the health of the environment	Type of foliage. Percent evergreen species in the sampling unit	Aylor (1972); Dobbs (2011).
					Shannon diversity and evenness index.	Dobbs (2011)
			Waste treatment	Effluent filtering and nutrient fixation by urban wetlands	Ratio of native trees. Percent native trees in the plot, a high percent was assumed to be optimal	Dobbs (2011)
					P, K, Mg and Ca in mgkg−1 compared to given soil/water quality standards	Vauramo and Setälä (2010); Gómez-Baggenthun and Barton (2013)
			Pollination and Seed Dispersal	Urban ecosystem provide habitat for birds, insects, and pollinators	Species diversity and abundance of birds and bumble bees	Hougner et al. (2006); Andersson et al. (2007); Gómez-Baggenthun and Barton (2013)
			Moderation of environmental extremes	Storm, floods, and wave buffering by vegetation barriers; heat absorption during severe heat waves	Cover density of vegetation barriers separating built areas from the sea	Danielsen et al., (2005); Costanza et al. (2006); Gómez-Baggenthun and Barton (2013)
			Increase of property values	The sales value of real estate reflects the benefits that buyers attach to attributes of the property, including vegetation on and near the property.	Monetary property values	Tyrväinen (1997); Cho et al. (2008); Troy and Grove (2008); Gómez-Baggenthun and Barton (2013); Nowak and Dwyer (2007)
GREEN SPACE	Local	Economic	Energy Conservation	Parks and greenways have been associated with increases in nearby residential property values		Nowak and Dwyer (2007).
				Increased real estate values generated by green space also produce direct economic gains to the local community through		

	Types of Benefits			Examples	Indicators	Reference(s):
	Benefits		Ecosystem Services			
				property taxes.		
				Trees can reduce building heating and cooling energy needs, as well as consequent emissions of air pollutants and CO_2 by power plants, by shading buildings and reducing air temperatures		
			Recreation and Cognitive Development	Urban parks provide multiple opportunities for recreation, meditation, and pedagogy	Surface of green public spaces (ha)/inhabitant (or every 1000 inhabitants)	Chiesura (2004); Gómez-Baggenthun and Barton (2013)
	Local	Social (and cultural)	Improve human health	providing environments that encourage exercise	Percent tree and maintained grass cover in forest, residential and institutional and recreation land uses	Bjerke et al. (2006); Kuo et al. (1998); Parsons (1995); Dobbs (2011)
						Nowak and Dwyer (2007)
			Aesthetics and safety	Reduce the cost of health services due to the increase of air quality provided by urban greening		Ulrich (1999); Ulrich et al. (1991); Ulrich (1984)
				Stress relieve		
				Trees lined streets promote safer driving by giving the impression of narrowing streets. They also provide a buffer between vehicles and pedestrians	Replacement value includes tree species, condition, size and location per plot	Nowak et al., (2002); Dobbs (2011).
			Animal Sighting	Urban green space provide habitat for birds and other animals people like watching	Abundance of birds, butterflies and other animals valued for their aesthetic attributes	Blair (1996); Blair and Launer (1997); Gómez-Baggenthun and Barton (2013)

Source: Author, based on literature review.

2.7 Importance of Air Quality

As mentioned on Chapter one, this study investigates the services provided by green space by selecting the most dominant benefit that has high correlation and significance to be measured. This section will analyse the benefit that will be investigated in this study that has a high urgency, relation and significant benefit to Jakarta, by analysing it from various sources about Jakarta environmental issues and its pollution.

Air pollution

Yusuf and Resosudarmo (2007) in their article “Does clean air matter in developing countries' megacities? A hedonic price analysis of the Jakarta housing market, Indonesia” mentioned that “Since the early 1990s, urban air pollution, particularly in megacities of developing countries, has been recognised as one of the world's major environmental concerns. After a decade, nevertheless, environmental quality indicators still indicate that cases of severe urban air quality in developing countries continue to occur.”

Poor air quality and air pollution in the city has proven not only damaged the health of the people but also has impacts on economy due to the costs incurred. Clean Air Initiative for Asian Cities (CAI-Asia) Center (CAI-Asia, Clean Air Initiative for Asian Cities Center, 2010) on their report on Indonesia air quality profile described that there are significant and substantial health problems and economic cost incurred by Indonesia from air pollution. Studies by Shah (1997) in World Bank technical paper and Syahril, Resosudarmo and Tomo (2002) showed the substantial economic cost incurred by Indonesia from air pollution. A 1994 study by the World Bank estimated that the economic cost due to air pollution in Jakarta was IDR 500 billion from 1,200 premature deaths, 32 million respiratory problem cases, and 464,000 cases of asthma (Shah and Nangpal, 1997). A 2002 study in Jakarta funded by the ADB estimated the economic cost due to PM_{10} pollution in Jakarta at IDR 1.7 trillion in 1998 and expected the cost to increase to around IDR 4.2 trillion in 2015 if no action is taken (Syahril, Resosudarmo, et al., 2002).

Another reason why air pollution is considered one of the most important aspects in environmental problem assessment in Jakarta is not only it posed a significant negative health and economic impact, but also in outward-looking perspective, Jakarta ranked very high compare to other world’s mega cities in terms of air quality. Gurjar, Butler, et al. (2008) conducted a study on evaluation of emissions and air quality in megacities using ambient air quality measures and Multi-Pollutant Index (MPI), from 18 world’s mega-cities that Gurjar analysed, Jakarta always ranked above 10 highest level of each air pollution matter, such as Total Suspended Particles (TSP), Sulfur Dioxide (SO_2), and Nitrous Dioxide (NO_2), where in overall Jakarta rank worst 5 of 18 mega-cities based on MPI. Details of numbers and comparisons can be seen as follow.

Table 3: Ranking of mega-cities based on ambient air quality measures and MPI

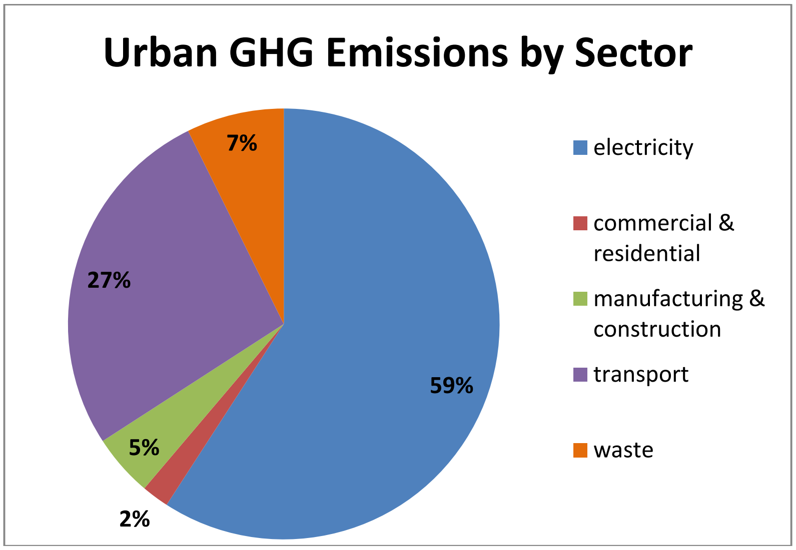
Megacities in 2000	TSP ($\mu g\, m^{-3}$) [Rank]	SO_2 ($\mu g\, m^{-3}$) [Rank]	NO_2 ($\mu g\, m^{-3}$) [Rank]	MPI [Rank]
Tokyo	40 [15]	19 [9]	55 [11]	−0.27 [16]
Mexico City	201 [10]	47 [4]	56 [10]	0.52 [10]
New York-Newark	27 [18]	22 [7]	63 [7]	−0.23 [14]
São Paulo	53 [14]	18 [10]	47 [12]	−0.29 [17]
Mumbai (Bombay)	243 [9]	19 [9]	43 [14]	0.39 [11]
Kolkata (Calcutta)	312 [6]	19 [9]	37 [15]	0.59 [9]
Shanghai	246 [8]	53 [3]	73 [5]	0.87 [8]
Buenos Aires	185 [11]	20 [8]	20 [18]	−0.01 [13]
Delhi	405 [4]	18 [10]	36 [16]	0.92 [7]
Los Angeles-Long Beach-Santa Ana	39 [16]	9 [13]	66 [6]	−0.25 [15]
Osaka-Kobe	34 [17]	19 [9]	45 [13]	−0.37 [18]
Jakarta	271 [7]	35 [6]	120 [3]	1.24 [5]
Beijing	377 [5]	90 [2]	122 [2]	2.01 [2]
Rio de Janeiro	139 [13]	15 [11]	60 [8]	0.11 [12]
Cairo	593 [2]	37 [5]	59 [9]	1.93 [3]
Dhaka	516 [3]	120 [1]	83 [4]	2.40 [1]
Moscow	150 [12]	15 [11]	170 [1]	1.07 [6]
Karachi	668 [1]	13 [12]	30 [17]	1.81 [4]

Note: 1. Out of 54 (i.e. 18 × 3) observations, sample sizes for different years were as follows: 1990 ($n = 1$), 1992–1994 ($n = 3$), 1995 ($n = 7$), 1998–1999 ($n = 13$), 2000–2001 ($n = 30$). 2. GC_i values for different pollutants used in computing the MPI in this table are as follows: TSP = $90\,\mu g\, m^{-3}$ (WHO, 1987), $SO_2 = 50\,\mu g\, m^{-3}$ (WHO, 1987, 2000), and $NO_2 = \mu g\, m^{-3}$ (WHO, 1997, 2000).

GHG Emissions

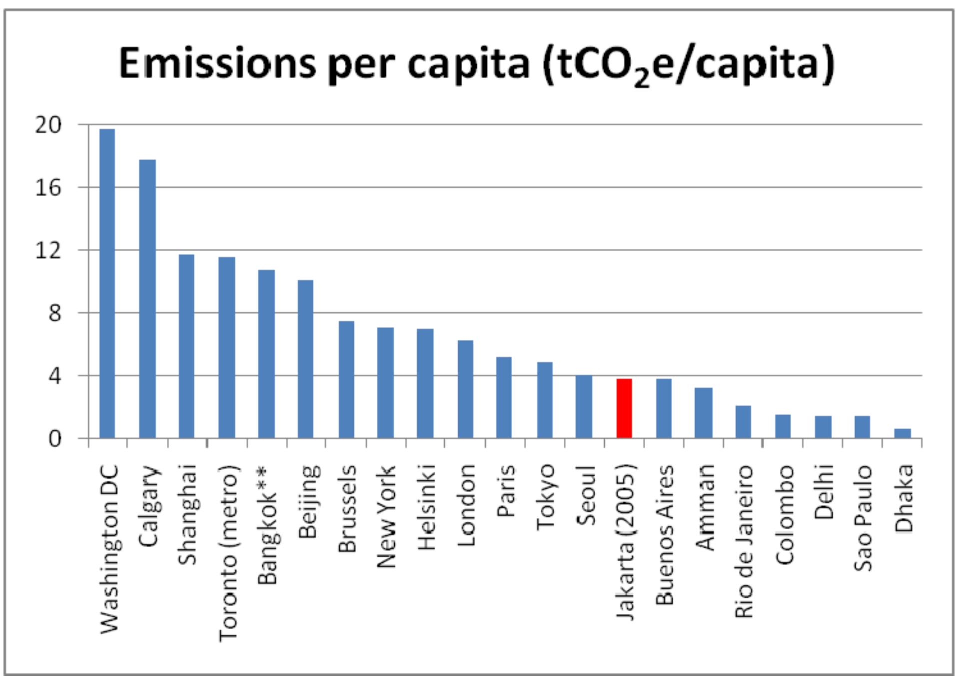
United Nations Human Settlement Program, or UN-HABITAT, on their report Cities and Climate Change: Global Report on Human Settlements 2011 stated that "World's cities responsible for up to 70 per cent of harmful greenhouse gases while occupying just 2 per cent of its land". It is undeniably clear that city is the main source of harmful GHG. Jakarta as one of mega-cities is also part of the major contributors of GHG. New findings done by Sugar, Kennedy, et al. (2013) provided a shocking fact that the recent total urban GHG emissions in Jakarta already at the same level as total urban GHG emissions in London in 2006. The study showed that total urban GHG emissions in Jakarta is 44,562 ktCO_2e or 44,5 million tonnes CO_2e, while total urban GHG emissions in London as stated in Global Report on Human Settlements 2011, UN-HABITAT is 44,3 million tonnes CO_2e. For GHG emissions per capita, Jakarta also has a significant number compare to other world cities. Based on (Regulation of Jakarta Special Capital Region Number 131 year 2012 concerning Local Action Plan of Green House Gases Reduction, 2012), GHG emissions per capita in Jakarta is 3.84 tonnes CO_2 equivalent per capita. Jakarta GHG emissions come from two major categories of sectors; they are stationary combustion, which include electricity, commercial and residential, and manufacturing and construction; and mobile combustion, which include transport and waste. Electricity is the main emitter sector with 59%, follows by transport with 27%. Percentage of urban GHG emissions in Jakarta per sector can be seen on the graph below.

Figure 4: Percentage of Urban GHG Emissions by Sector for Jakarta in 2013 based on Literature



Source: Sugar, Kennedy, et al., 2013

Figure 5: Comparison of Cities' GHG Emissions (w/o AFOLU)



Source: Dodman (2009) in UN-HABITAT (2011); and (Regulation of Jakarta Special Capital Region Number 131 year 2012 concerning Local Action Plan of Green House Gases Reduction, 2012)
**incl. Air (Airport) and Ocean (shipping) transport
Note: Table see Annex 3

2.8 Health and Economic Impacts

This study focuses on air pollutant removal and carbon dioxide emissions reduction as a result of additional green space in Jakarta in 2030. Further, this study will investigate the health and economic benefits related to those contexts. Indicators that are used for operationalizing the air quality variable are Particulate Matter (PM_{10}), Sulphur Dioxide (SO_2), Ozone (O_3), and Nitrous Dioxide (NO_2). "PM, SO_2, O_3, and NO_2 are considered classical/traditional air pollutants, and commonly used as indicator pollutants" (Chen and Kan, 2008). They are the most common ambient air pollutants encountered in our daily lives.

2.8.1 Health Impacts

Health impacts due to air pollutants:

- PM_{10}
  World Health Organization (WHO) on its Air Quality Guidelines (AQGs) stated that (World Health Organization, 2005) the evidence on airborne particulate matter (PM) and its public health impact is consistent in showing adverse health effects at exposures that are currently experienced by urban populations in both developed and developing countries. There are ranges of effects from adverse effect such as mortality (cardiovascular and respiratory mortality), asthma attack, respiratory symptoms, chronic bronchitis, lower respiratory illness in children, which lead to morbidity (hospital admission and emergency room visit), and school and work absenteeism ((Ostro, 1994); (World Health Organization, 2005); (Chen and Kan, 2008); (Both, Westerdahl, et al., 2013)).
  For this study, health impacts that act as indicators from PM_{10} are:
  1. Premature mortality (PM);
  2. Respiratory hospital admission (RHA);
  3. Emergency room visit (ERV);
  4. Restricted activity days (RAD);
  5. Lower respiratory illness among children (LRI/c);
  6. Asthma Attacks (AA);
  7. Respiratory symptom/person (RS); and
  8. Chronic Bronchitis.
- SO_2
  The United States Environmental Protection Agency (US-EPA) describes that Sulfur dioxide (SO_2) is one of a group of highly reactive gasses known as "oxides of sulfur." The largest sources of SO_2 emissions are from fossil fuel combustion at power plants and other industrial facilities. SO_2 is linked with a number of adverse effects on the respiratory system. The ranges of health effects are mortality associated to cardiovascular cause and predominantly respiratory symptoms for children and adult ((Ostro, 1994); (World Health Organization, 2005); (Chen and Kan, 2008)).
  For this study, health impacts that act as indicators from SO_2 are:
  1. Premature mortality (PM);
  2. Respiratory symptoms/children (RS/C); and
  3. Respiratory sumptoms/adults (RS/A).
- Ozone
  The United States Environmental Protection Agency (US-EPA) describes that Ozone is found in two regions of the Earth's atmosphere – at ground level and in the upper regions of the atmosphere. Both types of ozone have the same chemical composition (O_3). While upper atmospheric ozone protects the earth from the sun's harmful rays, ground level ozone is the main component of smog. Health effects of ozone predominantly attack the lung systems which lead to asthma symptoms and respiratory symptoms (Chen and Kan, 2008).

For this study, health impacts that act as indicators from O_3 are:

1. Respiratory hospital admission (RHA);
2. Asthma Attacks (AA);
3. Respiratory symptom/person (RS); and
4. Minor Restricted Activity Days (MRAD).

- NO_2

  NO_2 forms quickly from emissions from cars, trucks and buses, power plants, and off-road equipment. NO_2 is associated with adverse effects to human health, dominantly associated to the respiratory system.

  For this study, health impacts that act as indicators from NO_2 is:

  1. Respiratory symptom/adults (RSA).

Study conducted by Ostro (1994) as a World Bank technical working paper, has measured and estimated increment in annual health effects associated with unit change in pollutants in Jakarta. He used dose-response functions to calculate the health effect. It is a formula to calculate the number of people in a certain area who contact a particular health problem, since these people are exposed to air pollutant concentrations above the air quality standard. This study also uses the dose-response function which will be explained on chapter 3.

2.8.2 Economic Impacts of Air Pollution

A 1994 study by the World Bank estimated that the economic cost due to air pollution in Jakarta was IDR 500 billion (Shah and Nangpal, 1997). A 2002 study in Jakarta funded by the ADB estimated the economic cost due to air pollution in Jakarta at IDR 1.7 trillion in 1998 and expected the cost to increase to around IDR 4.2 trillion in 2015 if no action is taken (Syahril, Resosudarmo, et al., 2002).

Resosudarmo and Napitupulu (2004) on their research on health and economic impact of air pollution in Jakarta (Resosudarmo and Napitupulu, 2004), measured the Economic Value per Unit Air Pollution Health Problem. They implemented the methodology in estimating the health impacts of air pollutants used by Ostro (2004), and used general formula to measure the economic value. This study also uses Resosudarmo methodology to measure the economic impacts of air pollution in Jakarta which formula will be explained in chapter 3.

2.8.3 Economic Impacts of GHG Emissions

To measure economic impacts on carbon dioxide reduction, this study uses the social cost of carbon (SCC). This methodology is used to assume the economic benefits of carbon dioxide emissions reduction. Chae and Park (2011) defined the SCC as the "net present value of climate change impacts over the next 100 years (or longer) from one additional ton of carbon emitted to the atmosphere today," i.e. the marginal global damage cost of carbon emissions.

The purpose of the "social cost of carbon" (SCC) is to incorporate the social benefits of reducing carbon dioxide (CO_2) emissions into cost-benefit analyses of regulatory actions that impact cumulative global emissions. The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change. The factors use for SCC in this study will be explained on chapter 3.

2.9 Scenario Building

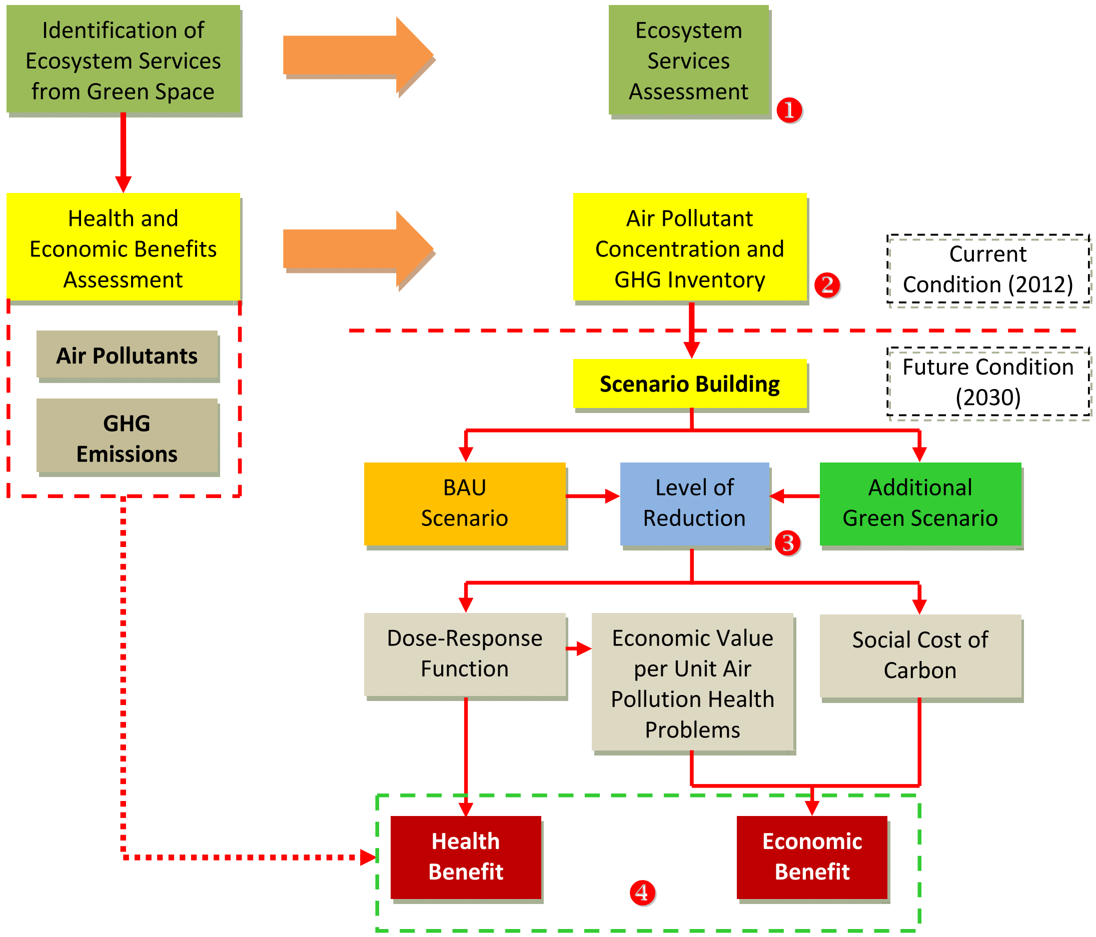
One of the mainly used approaches for estimating, forecasting and calculating emissions is by establishing multiple scenarios that can picture a comparison between the results to provide alternatives to policy maker. Example of using scenarios is on Resosudarmo and Napitupulu (2004) on their article “Health and Economic Impact of Air Pollution in Jakarta” which is also treated as one of the main reference in this study. On their article which the emphasis was on vehicle emissions, they established five simulation scenarios; they are base case; vehicle emissions standard; catalytic converter for taxis; public transportation management; and combined policy (Resosudarmo and Napitupulu, 2004).

This study also uses scenario building to approximate the health and economic benefits of urban green space in Jakarta. There are two scenarios to be built, (1) Business as Usual (BAU) Scenario; and (2) Additional Green Scenario. BAU scenario is a scenario to portray the current air quality indicators with the current area of green space. The Additional Green space scenario is a scenario to portray the level of each indicator in Jakarta in 2030 with the additional green space that up to 30% as stated in Jakarta 2030 Spatial Plan.

2.10 Conceptual Framework

The link and relationship between the theories and concepts about green space, benefits of it from sustainability perspective (environment, economic, and social), and benefits specific related to health and economic, in the context of air quality and GHG emissions, and development of scenario is formulated to build the conceptual framework of this study as follow.

Figure 6: Conceptual Framework



Source: Author

Notes: ❶ indicates answer of research question

Chapter 3: Methodology

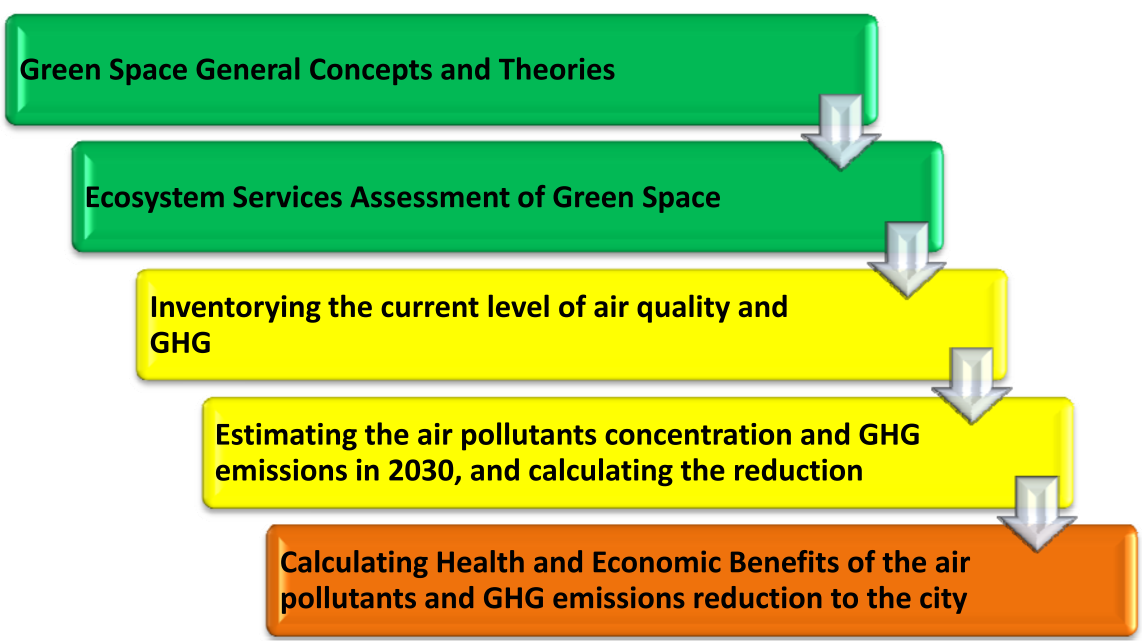
Research approach and methods are explained in this chapter. Further on this chapter, variables and indicators to answer the research objectives and research questions, and also the operationalisation of those variables and indicators, data collection methods, list of targeted institutions, data analysis, validity and reliability are explained.

The characteristic of this research is exploratory. It is exploratory because it looks for understanding and identification of the meaning of urban green space then measuring the health and economic benefits due to air pollutants and GHG emissions reduction if the plan of additional greening for up to 30% of total Jakarta area in 2030 will be taken place based on a specific framework.

3.1 Research Approach

The Research type is exploratory: what are the health and economic benefits of the improvement of air quality and reduction of carbon emissions to the city. The approach mostly using quantitative data collection analysis such as: calculating the current level of air quality and carbon dioxide, and by updating findings and data from literature to the current condition on field, estimating the air quality and GHG emissions if the plan of additional greening for up to 30% of total Jakarta area will be taken place in 2030 whilst calculating the level of reduction of its indicators, and finally quantifying the health and economic benefits of the improvement of air quality and carbon dioxide emissions reduction. Design and steps of the research can be seen in figure as follows.

Figure 7: Steps of the research



Source: Aurthor

3.2 Research Questions, Variables and Indicators

To operationalize the research question, variables and indicators are developed. For research sub-question one "What is the current level of air pollutants and carbon dioxide in Jakarta?" and two "How much the air pollutants and carbon dioxide will be reduced if the greening is introduced today?", the variables are air quality and carbon factors. For research sub-question three "What are the health and economic benefits (of the air quality improvement) to the city?" the variables are health benefit and economic benefit. The Operationalisation of the research question, variables and indicators are shown below.

Table 4: Operationalisation: Variables and Indicators

Research Question	Sub-Questions	Variables	Indicators	Methodology	Analysis
What are the benefits of the provisioning of green space as the impact of the implementation of Jakarta 2030 Plan?	What kind of ecosystem services provided by different types of green space in Jakarta?	Types of ecosystem services	Types of green space in Jakarta	• Primary data (interview)	Scenario Building: 1. Baseline 2. Addition -al green 2030
	What is the current level of air pollutants and GHG emissions in Jakarta?	Air Pollutants	PM_{10}	• Primary data • Secondary data • Scientific calculation	
			SO_2		
			NO_2		
			O_3		
		GHG	CO_2e		
	How much the air pollutants and GHG emissions will be reduced with the additional greening in 2030?	Air pollutants	• Absorption factor • Emission shares coefficient by source of emission		
		GHG	• Population Growth • Economic Growth • Energy Sector • Waste Sector • Carbon conversion factor	• Secondary data	
	What are the health and economic benefits (of the air quality improvement) to the city?	Health	• Dose-response function	• Primary data • Secondary data • Scientific calculation	
		Economic	• Economic Value per Unit Air	• Primary data • Secondary data	

Research Question	Sub-Questions	Variables	Indicators	Methodology	Analysis
			Pollution Health Problems • SCC (Social Cost of Carbon emissions reduction)	• Scientific calculation	

Source: Author.

3.3 Research Methodology

3.3.1 Data Collection Methods

There are three types of methods used in this study; they are primary data collection, secondary data, and scientific calculation.

Primary data:

Primary data that will be collected in this study can be categorised as follow:

1. Assessments of ecosystem services are obtained from in-depth interview with air quality and green space experts, and public official.
2. Indicators for air quality; are obtained from Local Environmental Management Agency-Jakarta, Air Quality Monitoring Unit, and Jakarta Planning and Development Office.
3. Indicators for GHG emissions are obtained from Jakarta Planning and Development Office.
4. Updating the health costs indicators are obtained from eight hospitals as representatives of public and private hospital.
5. For almost all quantitative indicators, the data are updated and obtained from Indonesian Statistic Agency.

Secondary data:

Secondary data used in this study are based on the literature related to Jakarta condition, which partially already described in Chapter two. Factors used in this study are also based on the literature.

3.3.2 List of Targeted Institutions

Data and information required in this study that focus on the certain variables including air quality, carbon factors, health and economics, to answer the research questions. It would be based on several key institutions as mentioned in the following table.

Table 5: List of Targeted Institutions

Variables	Institutions
Ecosystem Services	• Dir. Gen. Of Spatial Planning-Ministry of Public Works • Green Space and Air Quality Experts • *Bappeda DKI Jakarta* (Jakarta Planning and Development Office) • *Dinas Pertamanan DKI Jakarta* (Jakarta Parks/Green Space Office)
Air Pollutants	• *BPLHD DKI Jakarta* (Local Environmental Management Agency-

Variables	Institutions
	Jakarta) • *Bappeda DKI Jakarta* (Jakarta Planning and Development Office) • *Dinas Pertamanan DKI Jakarta* (Jakarta Parks/Green Space Office)
GHG Emissions	• Green Space Experts • *Dinas Pertamanan DKI Jakarta* (Jakarta Parks/Green Space Office)
Health	• Statistics Indonesia • Ministry of Health • *Dinas Kesehatan DKI Jakarta* (Jakarta Health Office) • Eight hospitals in Jakarta representing public and private hospitals
Economics	• Statistics Indonesia

Source: Author

3.3.3 Validity and Reliability

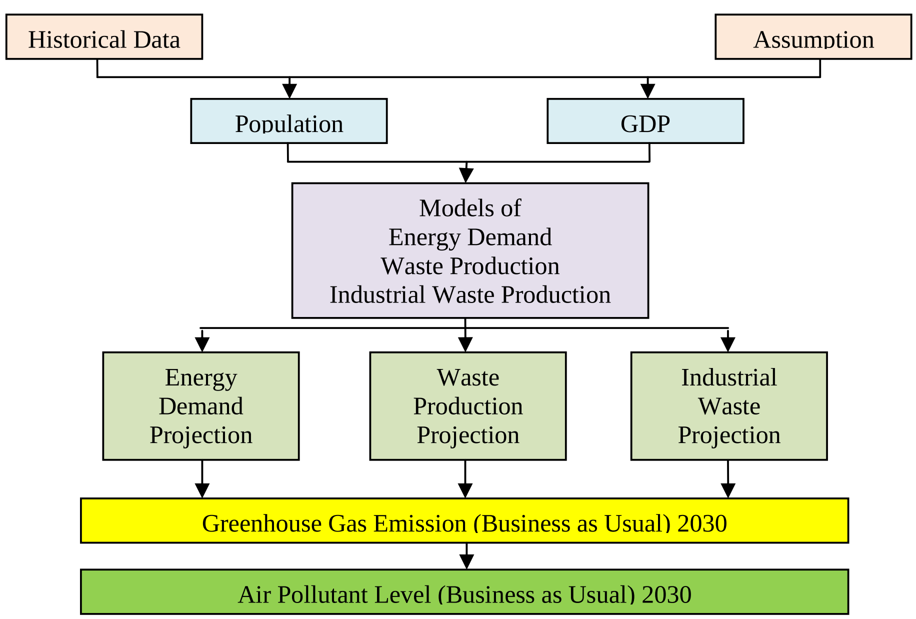
For validity and reliability, this study uses triangulation method by validating the data obtained from literature through field data collection, especially to five air quality monitoring units in Jakarta, and data collection from eight hospitals, representing public and private hospital to update the health cost which previous study have made (Resosudarmo and Napitupulu, 2004), and interview with experts.

3.3.4 Data Analysis Methods

This research emphasize on scientific estimations and calculations by using scenario analysis: (1) Baseline Scenario, and (2) Additional green space scenario. Steps of data analysis that will be conducted on this research are as follows:

1. Build baseline scenario:
    - Identify the current condition of indicators: PM_{10}, SO_2, NO_2, O_3, CO_2
    - Identify benefit factors: health factors and economic factors
    - Methodology for establishing baseline scenario can be seen on graph below.

Figure 8: Methods of BAU Scenario



Source: Author, adapted from Local Action Plan for GHG Emissions Reduction 2012

2. Build additional green space scenario:
    - Identify the GHG and air pollutants reduction factors.
    - Identify the reduction of the air quality's indicator after the additional green space scenario
3. Measure the benefits:
    - Calculate the reduction of air quality's indicator to benefit factors:
        - Health benefits
        - Economic benefits:
            - Economic Value per Unit Air Pollution Health Problems
            - SCC (Social Cost of Carbon)

3.3.5 Calculation Methodologies

GHG reduction

Regulation of Jakarta Special Capital Region Number 131 year 2012 on Local Action Plan of Green House Gases in 2012 adopting the methodology used by IPCC on their fourth assessment report (IPCC, Intergovernmental Panel on Climate Change, 2007) working group II on mitigation of climate change, mentioned that methodology to calculate the Carbon Dioxide (CO_2) emission sinks by the AFOLU sector, which in Jakarta case is categorized as green space is as follow:

Equation (1)

$$CO2\ emission\ sink = Biomass\ x\ Carbon\ Conversion\ Factor\ x\ \frac{44}{12}$$

Air pollutant reduction

Bolund and Humhammar in their article Ecosystem Services in Urban Areas (Bolund and Humhammar, 1999), stated that 85% of air pollution in a park can be filtered out, and in a street with trees 70%. From the detailed type of green space in Jakarta, protected green space; parks/ urban forests; government area green space; green spaces in offices, commercials, services, TODs, tourism, public and social services and facilities, and mixed-used areas; green spaces in industrial estates and industrial areas; and green spaces in residential areas are grouped for its capacity to reduce 85% of air pollution, while road sides and street with trees are group for its capacity to reduce 70% of air pollution.

Dose-response function

Dose-response function as a way for measuring the health impact of air pollutants in Jakarta firstly introduced by Ostro (1994), as a World Bank technical working paper. It measured and estimated increment in annual health effects associated with unit change in air pollutants in Jakarta. It is a formula to calculate the number of people in a certain area who contact a particular health problem, since these people are exposed to air pollutant concentrations above the air quality standard. The generic function can be seen as follows:

Equation (2)

$$H_{i.p} = b_{i.p}.\ POP\ .\ dA_p$$

Where:

i index for type of health problems related to air pollution

p index for type of air pollutants
$H_{i.p}$ number of cases of health problem $_i$ caused by air pollutant $_p$
$B_{i.p}$ slope of the dose-response function
POP Population within the polluted area under consideration
dA_p ambient level of a certain type of air pollution in the area under consideration above the air pollution standard

Based on various literatures mentioned in Chapter 2, air pollutants affect a significant impact to human health. This study is aimed to quantify the health benefit by calculating potential health problems can be avoided if additional green scenario is applied, as in Jakarta Spatial Plan 2030. There are several health indicators that are observed in this study according to the case of particular air pollutants. The methodology in estimating health impacts are using dose-response functions developed by Ostro (Ostro, 1994) and Resosudarmo (Resosudarmo and Napitupulu, 2004) for Jakarta for specific air pollutants are as follows.

For the case of PM_{10}, dose-response functions utilised in this study are as follows:

Equation (3)

1. (Premature) mortality:
   Number of deaths = 0.096 * (PM_{10} – Low PM_{10}) * POP * CM
   Where: PM_{10} is the level of PM_{10} in BAU scenario; Low PM_{10} is the new level of PM_{10} after the reduction caused by Additional Green (AG) scenario; POP is the population of Jakarta; and CM is the crude mortality rate for Jakarta (approximately 0.007).
2. Respiratory Hospital Admission (RHA):
   Number of RHA cases = 0.000012 * (PM_{10} – Low PM_{10}) * POP
3. Emergency Room Visit (ERV):
   Number of ERV cases = 0.0002354 * (PM_{10} – Low PM_{10}) * POP
4. Restricted Activity Days (RAD):
   Number of RAD cases = 0.0575 * (PM_{10} – Low PM_{10}) * PropA * POP
   Where: PropA is proportion of adults in Jakarta
5. Lower Respiratory Illness among Children (LRI/c):
   Number of LRI cases = 0.00169 * (PM_{10} – Low PM_{10}) * (1 – PropA) * POP
6. Ashtma Attack (AA):
   Number of AA cases = 0.0326 * (PM_{10} – Low PM_{10}) * POP * AP
   Where: AP is the percentage of asthmatic people in the population (approximately 0.07)
7. Respiratory Symptom/person (RS):
   Number of RS cases = 0.183 * (PM_{10} – Low PM_{10}) * POP
8. Chronic Bronchitis (CB):
   Number of CB cases = 0.0000612 * (PM_{10} – Low PM_{10}) * POP

For the case of SO_2, dose-response functions utilised in this study are as follows:

Equation (4)

1. (Premature) mortality:
   Number of deaths = 0.048 * (SO_2 – Low SO_2) * POP * CM
   Where: SO_2 is the level of SO_2 in BAU scenario; Low SO_2 is the new level of SO_2 after the reduction caused by additional green scenario.
2. Respiratory Symptom/children (RS/C):
   Number of RS/C cases = 0.00000181 * (SO_2 – Low SO_2) * (1 – PropA) * POP

3. Respiratory Symptom/adults (RS/A):
   Number of CDA cases = 0.010 * (SO_2 – Low SO_2) * PropA * POP

For the case of NO_2, dose-response function utilised in this study is only for Respiratory Symptoms/person (RS) in adults. The function is as follows:

Number of RS = 0. 1022 * (NO_2 – Low NO_2) * 0.01882 * PropA* POP
Where: NO_2 is the level of NO_2 in BAU scenario; Low NO_2 is the new level of NO_2 after the reduction caused by additional green scenario; and 0.01882 is the conversion factor from pphm to $\mu g/m^3$ for NO_2.

For the case of O_3, dose-response functions utilised in this study are as follows:

Equation (5)

1. Respiratory Hospital Admission (RHA):
   Number of RHA cases = 0.000077 * (O_3 – Low O_3) * POP * 0.01963
   Where: O_3 is the level of O_3 in BAU scenario; Low O_3 is the new level of O_3 after the reduction caused by additional green scenario; and 0.01963 is the conversion factor from pphm to $\mu g/m^3$ for O_3.
2. Ashtma Attack (AA):
   Number of AA cases = 0.68 * (O_3 – Low O_3) * POP * AP * 0.01963
   Where: AP is the percentage of asthmatic people in the population (approximately 0.07); and 0.01963 is the conversion factor from pphm to $\mu g/m^3$ for O_3.
3. Respiratory Symptom Days (RSD):
   Number of RSD cases = 0. 55 * (O_3 – Low O_3) * POP * 0.01963
4. Minor Restricted Activity Days (MRAD):
   Number of MRAD cases = 0.34 * (O_3 – Low O_3) * PropA * POP * 0.01963

Data of Population are obtained from analysis as mentioned on previous chapter; meanwhile, proportion of adults in Jakarta is obtained from Jakarta Statistics 2012 (BPS-Statistics of Jakarta, 2013).

POP: Population in Jakarta in 2030 is estimated 13,658,828 lives.

PropA: Proportion of Adult which by the Jakarta Statistics Agency is categorised as people above the age of 15 in Jakarta is 76%.

Conversion from pphm to $\mu g/m^3$ (National Institute of Standard and Technology Periodic Table):

Equation (6)

1 $\mu g/m^3$ = (ppm) * (molecular weight) * 24.45

24.45 is a conversion factor that represents the volume of one mole of gas.
For NO_2, molecular weight is 46.01
1 ppm NO_2 = 1.882 $\mu g/m^3$ → 1 pphm NO_2 = 0.01882 $\mu g/m^3$
For O_3, molecular weight is 48
1 ppm O_3 = 1.963 $\mu g/m^3$ → 1 pphm NO_3 = 0.01963 $\mu g/m^3$

The synthesis of estimated increment in annual health effects associated with unit change in air pollutants can be seen on table as follows.

Table 6: Estimated Increment in Annual Health Effects Associated with Unit Change in Pollutants in Jakarta

Outcome	Pollutants (units)			
	PM_{10} (10 µg/m^3)	SO_2 (10 µg/m^3)	Ozone (pphm)	NO_2 (pphm)
Premature Mortality (% change)	0.96	0.48		
Premature Mortality/100,000	6.72			
RHA/100,000	12.0		7.70	
ERV/100,000	235.4			
RAD	0.575			
LRI/c	0.016			
AA	0.326		0.68	
RS	1.83		0.55	
CB/100,000	61.2			
MRAD/person			0.34	
RS/C		0.18		
RS/A		0.10		0.10

Note: RHA = Respiratory Hospital Admissions
ERV = Emergency Room Visit
RAD = Restricted Activity Days
LRI/c = Lower Respiratory Illness among children
AA = Ashtma Attacks
RS = Respiratory Symptom/person
CB = Chronic Bronchitis
MRAD = Minor Restricted Activity Days
RS/C = Respiratory Symptom/children
RS/A = Respiratory Symptom/adults
pphm = Parts per hundred millions

Source: Ostro, 1994

Economic value per unit air pollution health problems

The generic function of economic value of health problems associated with air pollutants are calculated using a formula as follows:

Equation (7)

$$TC_{i.p} = V_i \ . H_{i.p}$$

Where:

$TC_{i.p}$ total economic value of health problem $_i$ caused by pollutant $_p$

V_i Value of health

$H_{i.p}$ number of cases of health problem $_i$ caused by air pollutant $_p$

Methods for specific health problems are described as follows (Resosudarmo and Napitupulu, 2004):

1. Mortality
   The value of a mortality case in this study uses the value of statistical life (VSL) approach. VSL is estimated as the discounted value of expected future income at the average age. A study conducted by International Road Assessment Program (IRAP) about "The True Cost of Road Crashes: valuing life and the cost of serious injury"

(Dahdah and McMahon, 2008) stated that based on 2004 research, with the human cost (HC) methodology, VSL in Indonesia is 30 times the GDP per capita. Thus, this study uses the ratio of VSL to GDP per capita of 30 times. GDP per capita in Jakarta in 2011 (Jakarta in Figure 2012) at 2000 constant price is 43.4 million Rupiah. With the figure, it is calculated that VSL in Jakarta in 2011 is 1.303 million Rupiah. With the latest Indonesian discount rate of 5.75%, VSL in Jakarta in 2030 is estimated Rp. 3,766,501,365.

2. Respiratory Hospital Admission (RHA)
   The value of an RHA case is estimated as the average cost of medical treatment per RHA case. This cost covers medical doctor's treatment, medicine and approximately 2 days in hospital.
3. Emergency Room Visit (ERV)
   The value of an ERV case is estimated as the average cost of using emergency room service. This cost includes the costs of a medical doctor, medicine, and one day in the emergency room.
4. Restricted Activity Days (RAD).
   The value of an RAD case is assumed to be equal to the average daily individual income of minimum wage in Jakarta. Regional minimum wage of Jakarta in 2013 is Rp. 2,216,243 per month, or Rp. 26,594,916 per year, or Rp. 72,863 daily. In 2030 with the discount rate of 5.75%, Regional minimum wage that will be used to value RAD is estimated Rp. 188,483.
5. Lower Respiratory Illnesses among Children (LRI/c).
   The value of an LRI case is calculated as the average cost of medical treatment per LRI case, which equals the costs of the medical doctor and medicine needed.
6. Ashtma Attack (AA).
   The value of an AA case is approximately the average cost of medical treatment per AA case, which equals the cost of medical doctor and medicine needed.
7. Respiratory Symptom/person (RS).
   The value of an RS is assumed to be equal to the average cost of medical treatment per RS case.
8. Chronic Bronchitis (CB).
   The value of a CB case is estimated as the average cost of medical treatment per case.

The economic value for each health problems are based on the survey from eight hospitals representing the public and private hospitals.

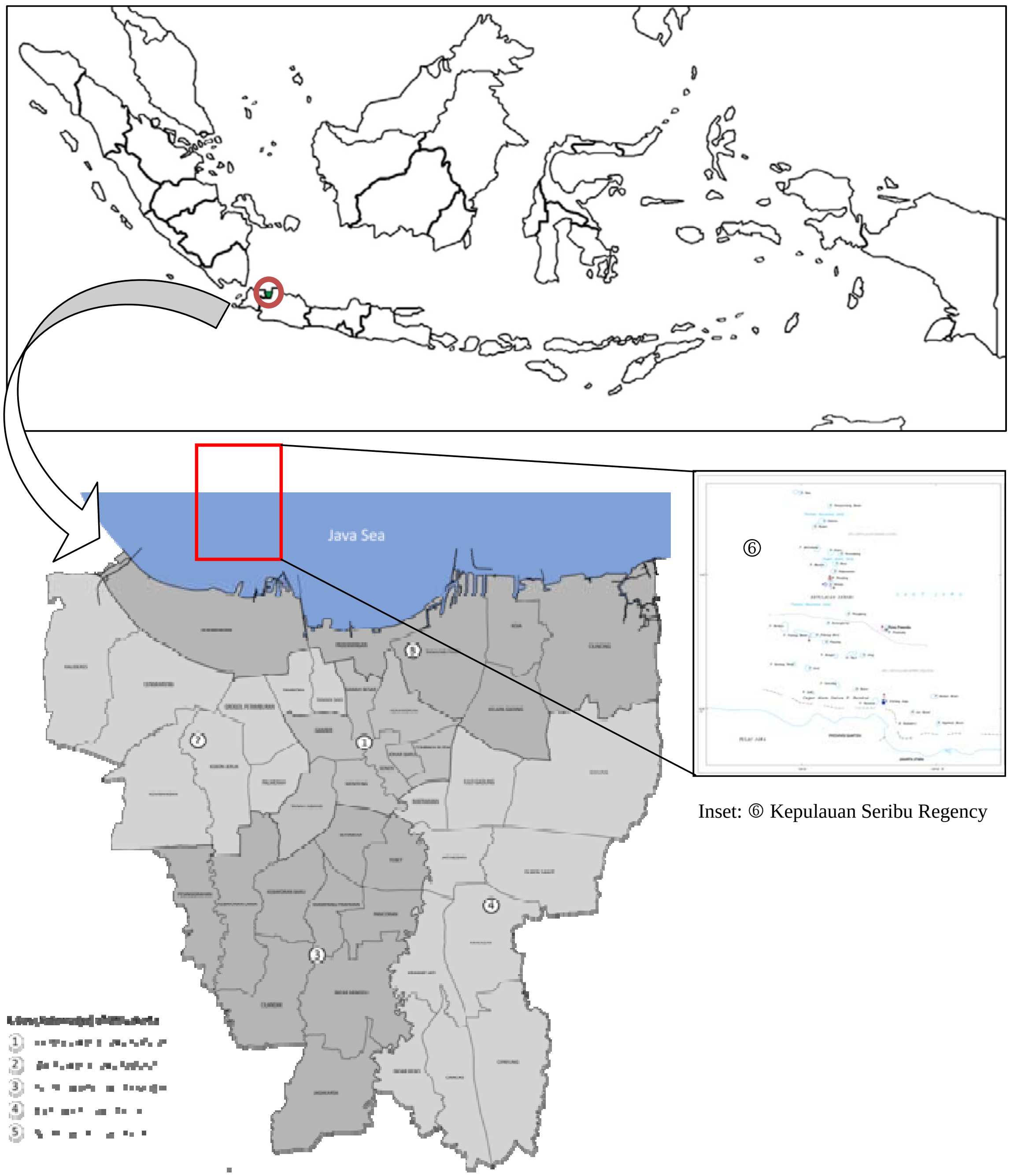
Social Cost of Carbon (SCC)

To measure economic impacts on carbon dioxide reduction, this study uses the social cost of carbon (SCC). This methodology is used to assume the economic benefits of carbon dioxide emissions reduction. Chae and Park (2011) defined the SCC as the "net present value of climate change impacts over the next 100 years (or longer) from one additional ton of carbon emitted to the atmosphere today," i.e. the marginal global damage cost of carbon emissions. There were several studies and reports that used to assume the economic benefits of carbon dioxide emissions reduction. IPCC in 1996 published a result between the range of \$6–160 tC in year 2000 prices. A small number of studies following the report by IPCC presented the SCC as \$9–\$197/tC in 2000 prices (Defra, 2005, in (Chae and Park, 2011)). The 4th IPPC (IPCC, 2007, in (Chae and Park, 2011)) reviewed the range of SCC from available studies and reported a range of \$4–\$95/tCO_2, assuming a 2.4% per year increase. This study uses SSC value from from the 4th IPCC report, with a range of \$4–\$95/tCO_2, assuming a 2.4% per year increase, as a minimum and maximum range, and use value of SCC from (Chae and Park, 2011) of US$12 /t$CO_2$ as the central value and using national discount rate of 5.75%.

Chapter 4: Results and Analysis

4.1 Geography and Climate

Figure 9: Geographic Location of Jakarta



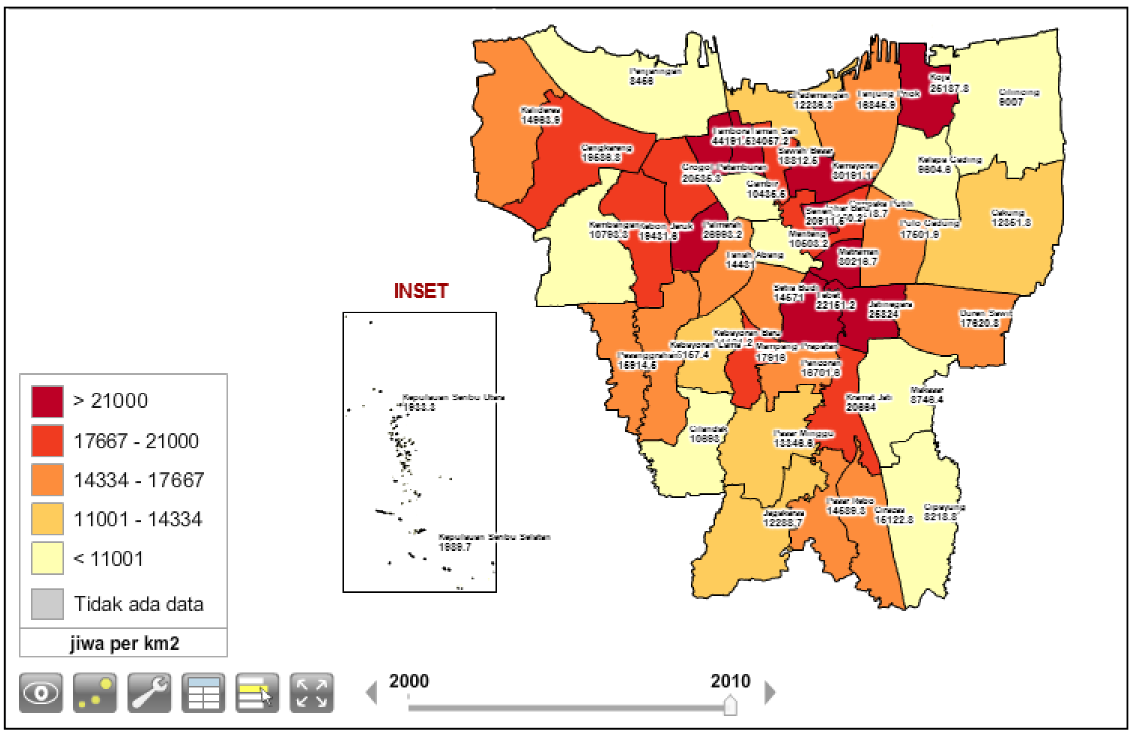
Inset: ⑥ Kepulauan Seribu Regency

Source: Author, adapted from Jakarta Spatial Plan 2030

Located in the northwest of Java Island, Jakarta is the Capitol of Indonesia, as well as the country's economic and political center, and with total population based 2010 census of 9,607,787 and on temporary population projection in 2012 is 9,932,063 (BPS-Statistics of Jakarta, 2013), Jakarta also the most populous city in Indonesia. Geographically Jakarta lies between $5^0$19'12" to $6^0$23'54" South Latitude and $106^0$22'42" to $106^0$58'18" East Longitude, with the total land area of 662.3 km^2 and sea area of 6,977.5 km^2 includes 110 islands scattered in Kepulauan Seribu Regency (Governor of Jakarta Special Capital Region Decree Number 171 year 2007 concerning Establishment of Area Limits and Village in Jakarta Special Capital Region, 2007).

Mainland Jakarta is bounded on the north with the Java Sea by the total length of coastline of 32 km. On the East, Jakarta is bordered by Bekasi, West Java Province; on the west by Tangerang, Banten Province; and on the south by Depok and Bogor, West Java Province. Administrative region within Jakarta is divided into five municipalities and one regency, namely administrative municipality of Jakarta Utara (142.20 km^2), Jakarta Pusat (47.90 km^2), Jakarta Timur (187.73 km^2), Jakarta Barat (126.15 km^2), and Jakarta Selatan (145.73 km^2), and Kepulauan Seribu Regency (11.81 km^2), with total of 44 districts (Regulation of Jakarta Special Capital Region Number 1 year 2012 concerning Jakarta Spatial Plan 2030, 2012). Jakarta is a lowland area with an average altitude of +7 meter above sea level. Population distribution in Jakarta can be seen in figure below.

Figure 10: Population Distribution by District in Jakarta



Source: Statistics of Jakarta Special Capital Region, using STATPLANET software, 2013.

As in Indonesia in general, Jakarta has a tropical climate with rainy season between October to March and dry season between April to September. The weather in Jakarta is affected by the breeze from the sea and land alternately between day and night. The average temperature in Jakarta is around 27^0 to 28^0 Celsius. The temperature difference between rainy season and dry season is relatively small. This is understandable because of changes in air temperature in the area of Jakarta as well as other regions in Indonesia are not influenced by season, but by the difference in height of the region.

Table 7: Climate Condition in Jakarta

Description	Jakarta
Temperature (^0C)	
Max	32.5
Min	25.5
Average	28.4
Relative Humidity (%)	
Max	90.5
Min	60.0
Average	74.3
Atmospheric pressure (mbs)	1,009.5
Wind direction (point)	270
Wind velocity (M/SE)	5.2
Rainfall (mm^2)	1,274.1
Sunlight (%)	63

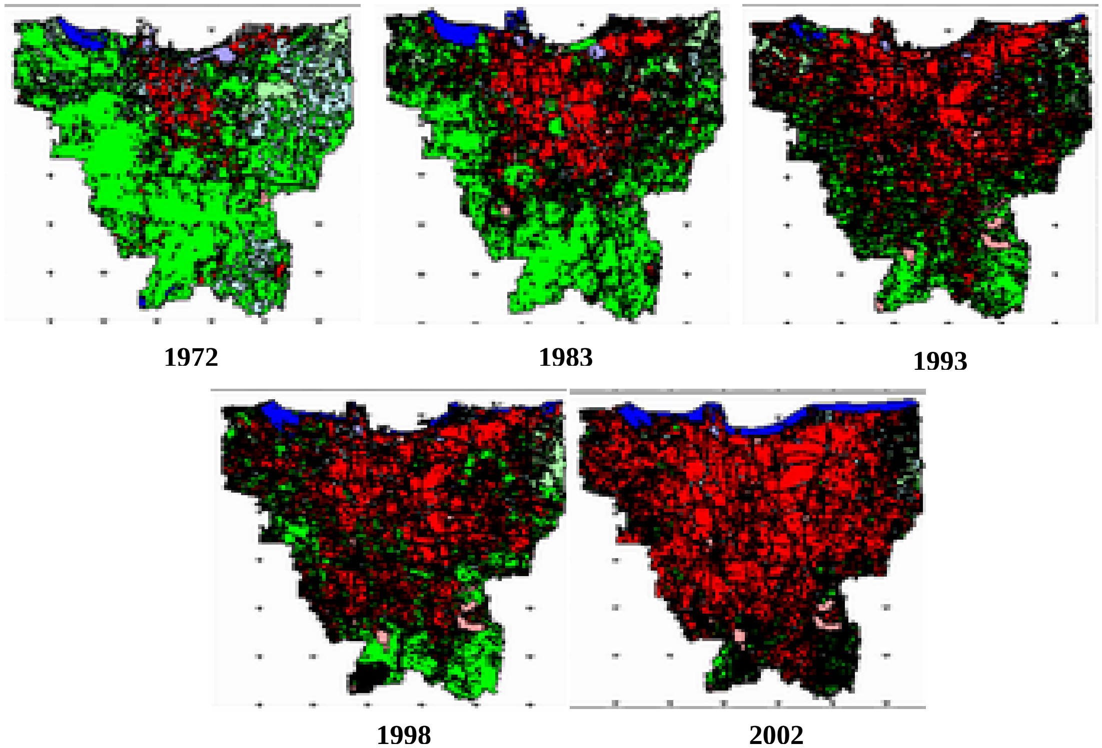
Source: Jakarta in Figures, 2012.

Jakarta climatological conditions in line with the global warming have moderate but gradually changed. Global warming has caused the uneven pattern of temperature and air pressure spatially. As a result, Jakarta has evidenced extreme weather phenomena, more frequent tropical storms, and shifting seasons. BMKG analysis results of data processing for 50 years showed that the more high intensity of tropical cyclones, especially in the Indian Ocean, changes in season length, and the beginning of the rainy season / dry season, rising sea temperatures and sea level rise. For Jakarta, it is estimated the likelihood of getting earlier early rainy season and delay the dry season. This led to the rainy season in Jakarta increasingly elongated and shortened the dry season, although the levels are not too high (0.1 – 0.3 days per year) (Government of Jakarta Special Capital Region, 2011).

4.2 Land Use Pattern

Physical and land use development in Jakarta since the last four decades marked by vast growing of built-up area and the diminishing and decreasing of green spaces and open spaces. The rapid growing of the development of built-up areas is in line with the increase of population growth and its economic activities. These trends indicate than land and the availability of green space and open space has become a crucial problem that needs to be addressed accordingly by the Jakarta government. The following images show the rapid development of built-up area in Jakarta for the last four decades.

Figure 11: The Development of Built-up Area in Jakarta from 1972

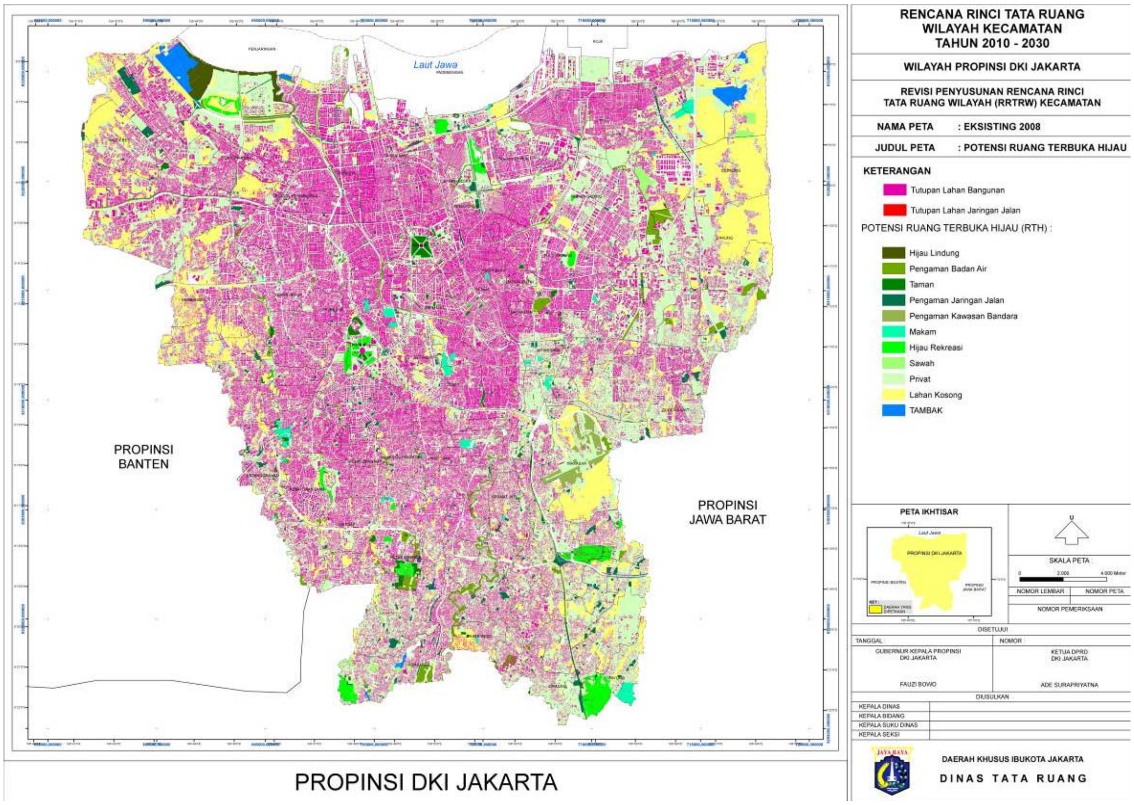


Source: Final Report of Jakarta Spatial Plan 2030.

More recent conditions are interpreted from satellite imagery in 2008 confirms that Jakarta is dominated by built-up area represented by buildings, roads, and other infrastructure. Interpretation of satellite images provide information that approximately 66.62% of Jakarta mainland territory is built land, being 33.38% can be interpreted as land which has not been or is not built, such as urban forests, green space, green belt, cemetery, land agriculture, parks, water bodies, lakes, marshland, vacant land, and others.

The image, when confirmed with records of land use in 2008 by Jakarta administrative, made the non-built up area in Jakarta in 2008 is 18.84% of all total Jakarta mainland, and 7.36% of which are green spaces owned and managed by the public (Jakarta administrative). From all total land use, housing has the biggest proportion of 48.41%, followed by industry, office, and commerce with 15.68%.

Figure 12: Interpretation of Satellite Image in 2008 of Jakarta Land Use



Source: Final Report of Jakarta Spatial Plan 2030

4.3 Ecosystem Services Identification and Assessment of Urban Green Space

In chapter two, literature study has shown various benefit from services derived from urban green space as urban ecosystem. This study explored more detail about quantification and assessment of health and economic benefits from services provided by green space in Jakarta, particularly in GHG emissions reduction, and removal of air pollution or air quality improvement. It has to be viewed that these are not the only benefits that can be obtained by protecting and promoting green space in urban areas particularly in Jakarta. Other benefits have been explained and synthesized. But those explanations are obtained from literature, that in some extent present a general benefit of green space. To identify what are the actual ecosystem services that are provided by green space in Jakarta, and to what extent the degree of influence or relevance from particular types of green space in Jakarta to particular services it provides, this study also tried to analyse qualitatively the ecosystem services provided by specific types of green space in Jakarta, as an additional findings of this study.

Based on Ministerial Decree of Public Works No. 05/PRT/M/2008 concerning Guidelines for Provisioning and Utilization Green Open Space in Urban Areas, green space can be categorised into 12 types. In adjustment to the types of green space available in Jakarta, the author categorised the types of green space into eight:

1. Office, commercial and residential area green space;
2. Urban parks;
3. Urban forests;

4. Pedestrian ways;
5. Network green space (road sides/trees on street, train lines, electrical transmission, green belt);
6. River Basin;
7. Coastal Area, mangrove, wetlands; and
8. Cemetery.

These types then put into matrix with 15 types of services potentially provided by green space based on literatures on Chapter 2 as follows.

Table 8: Ecosystem Services Provided by Green Space

No.	Ecosystem Services	No.	Ecosystem Services
1	Green house gas reduction	9	Moderation of environmental extremes
2	Temperature and microclimatic reduction, and reduction of urban heat island (UHI) effect	10	Increase of property values
3	Removal of air pollutants	11	Energy conservation
4	Reduce storm water runoff, flooding damage, storm water treatment and improve water quality	12	Recreation and cognitive development
5	Urban noise	13	Improve human health
6	Urban wildlife and biodiversity	14	Aesthetics and safety
7	Waste treatment	15	Animal sighting
8	Pollination and seed dispersal		

Source: Author.

The ecosystem services assessment is a result from in-depth interview from five experts from environmental engineer, air quality, and public official, with four points scale:

1. +++ positive relation with high relation and influence;
2. ++ positive relation with medium relation and influence;
3. + positive relation with low relation and influence; and
4. Blank cell means no or negative relation and influence.

The result can be seen on the following table.

Table 9: Ecosystem Services Assessment of Green Space in Jakarta

	Types of Benefits			types of green space in jakarta							
	Benefits		Ecosystem Services	Office, Residencial and Commercial green space	urban parks	urban forest	pedestrian ways	network greenspace (road sides, train lines, electrical transmission, green belt)	river basin	coastal area, mangrove, wetlands	cemetery
GREEN SPACE	Global	Environmental	Green House Gases Reduction	+	++	+++	+	+	+	+	+
	Local	Environmental	Temperature and Microclimatic Reduction, and Reduction of Urban Heat Island (UHI) Effect	++	+++	++	+	+	+	+	+
			Removal of Air Pollutants	++	++	++	++	++	+	+	+
			Reduce Stormwater Run off, flooding damage, stormwater treatment and improve water quality	++	+++	+++	+	+	+++	++	+
			Urban Noise	++	+	+	+++	+++			
			Urban Wildlife and Biodiversity		++	+++			+	++	
			Waste treatment							+	
			Pollination and Seed Dispersal		+	+++			+	+	+
			Moderation of environmental extremes	+	++	+++	+		++	+++	+
GREEN SPACE	Local	Economic	Increase of property values	+++	+++	+	+++	++	+	++	
			Energy Conservation	+++	+	+	+	+	+		
	Local	Social (and cultural)	Recreation and Cognitive Development	+	+++	+++	+		++	+	

	Types of Benefits			types of green space in jakarta							
	Benefits		Ecosystem Services	Office, Residencial and Commercial green space	urban parks	urban forest	pedestrian ways	network greenspace (road sides, train lines, electrical transmission, green belt)	river basin	coastal area, mangrove, wetlands	cemetery
			Improve human health	+	+++	+++	+	+	++	+	+
			Aesthetics and safety	++	+++	+	++	+	+	+	
			Animal Sighting		+	+++			+	+	+

Source: Author

Note : +++ high relation/influence

++ medium relation/influence

+ low relation/influence

Blank no or negative influence

From the result above, it is identified that every type of green space in Jakarta has benefit and provide ecosystem services. Ecosystem service of waste or sewage treatment is the type of service that has the fewest benefit from all types of green space in Jakarta. The service can only be provided by wetlands. This result is similar to the findings from Bolund and Humhammer (1999) on their article Ecosystem Services in Urban Areas in Stockholm.

Not all types of green space provide positive and significant ecosystem service. For example, cemetery does not increase property value. On the other hand, proximity to cemetery might influence property value in negative way. The issue of proximity also influence the degree of relation between type of green space and ecosystem service. Dr. Asep Sofyan, an air quality expert and lecturer at Bandung Institute of Technology (ITB – Air and Waste Management Research Group) stated “urban forests, even though have a high density of trees and canopy cover with high leaf area index, only have medium influence—instead of high—in air pollutant removal because urban forests in Jakarta do not have a high proximity to the source of emissions, such as industry, residential, and mobile source”.

For GHG reduction, urban forests provide high influence and benefits, because forests have the ability to sequester and storage carbon dioxide. Dr. Yuwono, lecturer at Bogor Agricultural Institute (IPB – Department of Civil and Environmental Engineering) added “the ability for carbon to be absorbed by trees depends on the type of trees and the age of trees. The younger the age of trees, the higher the ability to absorb carbon, until reach the saturate level where trees cannot grow anymore. The characteristics of urban forests in Jakarta are categorised as young forest.”

For removal of air pollutants service, all types of green space in Jakarta have some level of influence as ecosystem service. It is also very dependant to the exposed population, the least dense the population in the surrounding green space, the lower the influence, such as cemetery, river basin, and wetlands.

For office, commercial and residential green space, these types of green space provide ecosystem services such as GHG reduction, temperature reduction, removal of air pollutants, reduce stormwater run-off, reduce urban noise, increase property value, energy conservation, improve human health, and aesthetics and safety.

4.4 Current Level of GHG Emissions (2012)

The results of this subchapter mostly based on the secondary data from the Local Action Plan for GHG Emissions Reduction in Jakarta, 2012. The results from the document are essential to build the Business as Usual (BAU) scenarios.

The approach used to inventory GHG emissions in Jakarta is referred to the 'International Standard for Determining Greenhouse Gas Emissions for Cities' organized by UNEP, the World Bank, and the UN Habitat in 2010 (UNEP-United Nations Environment Program, 2010). This inventory is using the principles and methods of calculation established by the Intergovernmental Panel on Climate Change (IPCC). Sector GHG emissions considered are energy, waste, and forest (green space) (which in part of AFOLU (Agricultural, Forestry, and Other Land Use) sector base on the standard), while the type of GHG emissions are considered include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

The standard mentioned above adopts the principle that the vitality of the city led to the production of GHG emissions outside the city for the purpose of consumption of the citizen in the city. Thus, emissions generated outside of the city (due to the consumption of energy and goods in the city and / or the production of waste thrown or deposited outside the city) should be counted as city emission. However, estimating the emissions associated with the consumption of all goods and services in the town would be difficult and impractical. To that end, which can be taken into account and should be incorporated into the city emissions inventories are:

- Emissions from the generation of electricity consumed in the city (including the loss in transmission and distribution);
- Emissions from aircraft and ships carrying passengers and goods out of the town;
- Emissions from waste produced in the city (but are thrown out of town).

GHG inventory in Jakarta is divided into three major sector groups as follow:

1. Energy:
   - Electric Consumption
   - Combustion from industry, household, and commercial
   - Energy consumption for land, air, and water transportation
2. Waste:
   - Solid waste
   - Liquid waste
3. AFOLU (Agriculture, Forest, and Other Land Use) (in urban is categorised as green space).

In general, GHG emissions are calculated with the following equation:

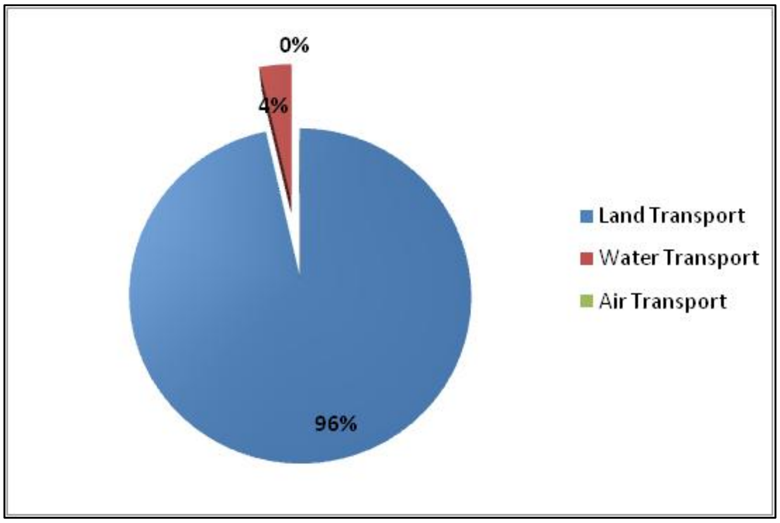
GHG emissions = Activity data x GHG intensity

Activity data are varied following inventory components, such as energy consumption (including energy in the transport sector) or the production of waste. GHG intensities are taken from IPCC reference values are also used in the national inventory. Activity data and GHG intensity used are obtained from Local Action Plan of GHG Emissions Reduction in Jakarta.

4.4.1 Energy Sector

The biggest fossil fuel consumption found in transport sector. Coal and natural gas dominantly used by the industry sector, while LPG (Liquid Petroleum Gas) and electricity are mostly used by the household sector. Based on final energy consumption from all sectors, industry and transport consumed the largest energies (36% and 34% respectively), followed by household (22%) and commerce (7%). From the transport sector, land transportation played a dominant role in energy consumption with total 96% of all types of transport, followed by water and marine transport (almost 4%), and air transport (less than 1%). Final energy consumption by sector in year 2005 can be seen on annex 3.

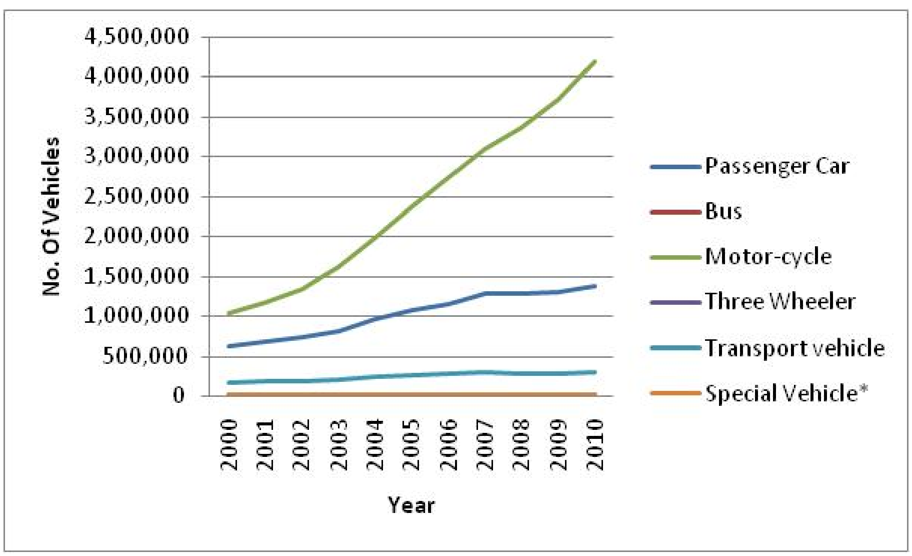
Figure 13: Energy Consumption Sub-Sector Transportation, year 2005



Source: (Regulation of Jakarta Special Capital Region Number 131 year 2012 concerning Local Action Plan of Green House Gases Reduction, 2012)
Note: table see Annex 3

Number of vehicles in Jakarta over the last 10 years (2000-2010) are shown in the following table. This data is used in addition to projecting the number of vehicles up to 2030 and taking into account estimates of future economic growth, as well as to calculate the GHG emissions and mitigation potential per category of vehicle (bottom-up approach).

Figure 14: Number of Vehicles in Jakarta from 2000-2010



Source: Tax Service Office Jakarta, 2013.
*Ambulance, Fire Brigade, Hearse, Tow car, forklift, and others.
Note: table see on Annex 3

4.4.2 Waste Sector

Source of solid waste in Jakarta comes from residential, schools, offices, industries, markets, and others. The trash were transported to temporary shelters to be forwarded to the Sunter Intermediary Station and Cakung Recycling and Composting Centre to be sent to the Integrated Waste Sites Bantar Gebang. Moreover, waste from temporary shelters also directly transported to Integrated Waste Sites Bantar Gebang. Amount of domestic waste transported by the Jakarta Sanitation Office and third parties to Integrated Waste Sites Bantar Gebang reached 2.34 million tons in 2005. The domestic waste came from about 12 million Jakarta residents (including commuter) (Regulation of Jakarta Special Capital Region Number 131 year 2012 concerning Local Action Plan of Green House Gases Reduction, 2012) (see Annex 3 for characteristics of Waste Water Treatment Plant (WWTP)).

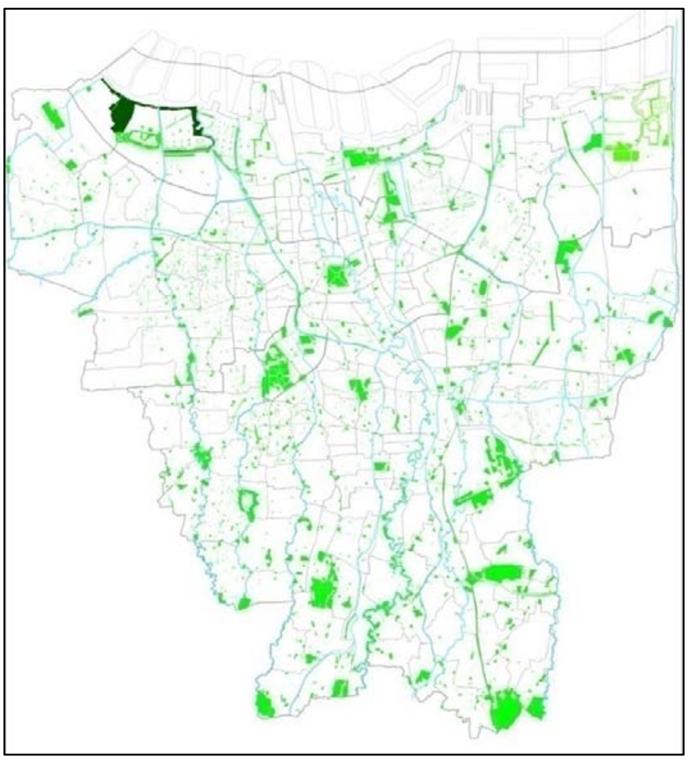
GHG emissions are also generated from domestic wastewater, waste water reservoirs in On-site Waste Water Treatment Plant (WWTP) at Pulogebang and Duri Kosambi, off-site WWTP Water Reclamation Plant Setiabudi West and East.

4.4.3 AFOLU Sector (Green Space)

Green space has function as CO_2 absorbent. That is, green space is GHG mitigation efforts (not increase emissions but reduce emissions). Green space provision efforts in Jakarta are mainly from greening in urban parks, urban forests, mangrove forests, cemeteries, and the green line. The CO_2 absorption capacity depends on the type of plants of green space.

Total area of green space area in Jakarta in 2005 was 7,596 hectares, while in 2010 total area of green space in Jakarta was 8,090 hectares. Figure below shows the distribution of green space in Jakarta in 2010 (see Annex 3 for table of details of green space in Jakarta).

Figure 15: Green Space Distribution in Jakarta in 2010



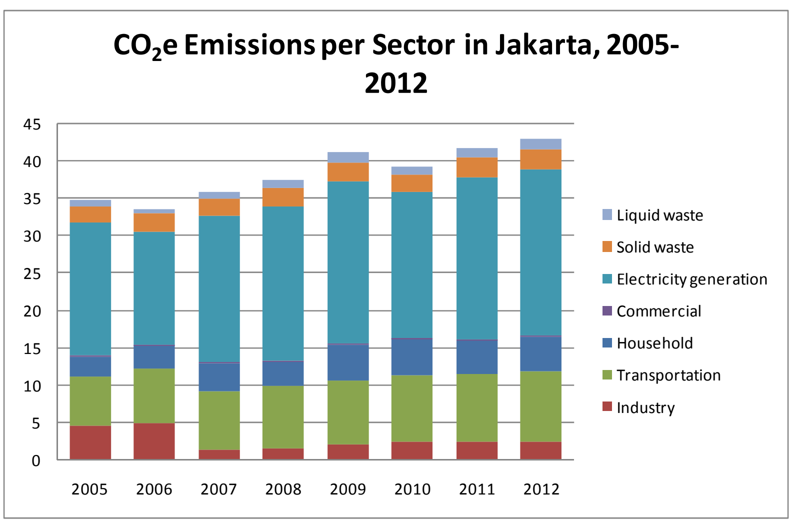
Source: Jakarta Parks Office, 2013

4.4.4 Total Emissions Profile

Based on data on fuel consumption, landfill, sewage and wastewater treatment, analysis conducted by the Jakarta Environmental Management Agency on 2005 baseline year (Regulation of Jakarta Special Capital Region Number 131 year 2012 concerning Local Action Plan of Green House Gases Reduction, 2012), total GHG emissions of Jakarta in 2005 was 34.67 million tonnes CO_2e (without AFOLU sector / excluding plant absorption) or 3.84 tonnes CO_2e per capita, higher than the national GHG emissions reached 2.52 tonnes CO_2e per capita, and about per capita emissions of Buenos Aires, Argentina (2000) with 3,83 tonnes CO_2e per capita. The biggest sector that contributes to GHG emissions is electricity generation sector, with 17.79 million tonnes of CO_2 equivalent, or about 51%, followed by 6.57 million tonnes of CO_2 equivalent, or about 19%. In 2012, total GHG emissions of Jakarta was 42.80 million tonnes CO_2e (without AFOLU sector / excluding plant absorption) or 4.31 tonnes CO_2e per capita, or about per capita emissions of Seoul (2006) with 4.10 tonnes CO_2e per capita.

Since 2005 to 2012, it is recorded that GHG emissions have an increasing trends in general, even though there are some sectors that experienced decreasing trends, such as industry. It is understandable that emissions from industry have a slightly decrease in emissions, since Jakarta have established as a service city and many industries were moved out of Jakarta administrative boundaries, mainly to the east (Karawang, Jawa Barat) and and some to the west (Tangerang, Banten). The trends of GHG emissions from 2005 to 2012 can be seen at the graph below.

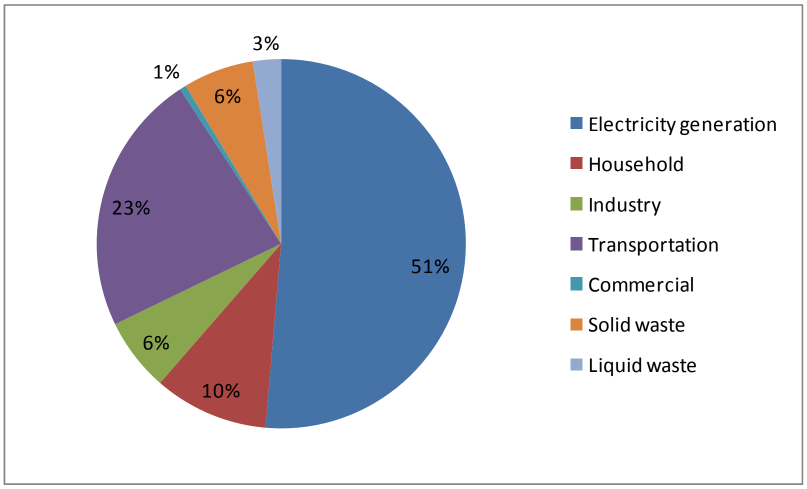
Figure 16: GHG Emissions in Jakarta, 2005-2012 (million tonnes CO_2e)



Source: Local Action Plan for GHG Reduction

In 2012, the distribution of GHG emissions per sector has slightly different changes, especially in industry where industry in 2005 produced 4.66 million tonnes of CO_2e or 14%, in 2012, GHG emissions from industry has decreased to 2.75 million tonnes of CO_2e or about 6%, half of the distribution in 2005. On the contrary, the GHG emissions from the household sector have increased from 2005 to 2012. In 2005 the household sector produced 2.60 million tonnes of CO_2e or about 8%, while in 2012 GHG emissions from household sector have increased to 4.3 million tonnes of CO_2e, or around 10%. Distribution of GHG emissions per sector in 2012 can be seen on figure below.

Figure 17: Distribution of GHG Emissions per Sector in 2012



Source: Local Action Plan for GHG Reduction.

4.5 Current Air Pollutants Emissions and Concentration (2012)

Air quality plays a significance importance in managing urban environments, since it will directly affect people's health and comfort in the city. Sources which produce pollutant and harmful gaseous are classified into two types of sources, they are stationary sources (industrial activities and burning of household waste) and mobile sources (transport activity).

From the stationary sources, industry and processes are the biggest polluter of dust with total of 4,617.01 tonnes in 2012. Solid waste incineration produced the biggest Sulfur Dioxide (SO_2) with 118.63 tonnes, as well as Nitrogen Dioxide (NO_2) with 711.50 tonnes, and Carbon Monoxide (CO) with 9,964.50 tonnes, while Hydrocarbon (HC) dominantly polluted by industry and processes, with 15,355.81 tonnes.

The biggest air pollutant contributor in Jakarta apparently comes from mobile sources (transportation). It applies to all types of pollutants. Transportation in Jakarta produced dust of total 4,486,991 tonnes in 2012, SO_2 with total 9,844,545.90 tonnes, NO_2 with 22,468,261.80 tonnes, HC with 25,568,333.30 tonnes, CO 653,427,253.80 tonnes, and Carbon Dioxide (CO_2) with 6,770,572,809.00 tonnes.

Table 10: Air Pollutants Emissions in Jakarta, 2012

Sources	Dust tonnes/yr	SO_2 tonnes/yr	NO_2 tonnes/yr	HC tonnes/yr	CO tonnes/yr	CO_2 tonnes/yr
Stationary Sources:						
Industry and Processes	4,617.01	66.86	156.84	15,355.81	0.00	
Solid Waste Incineration	1,898.00	118.63	711.50	3,558.75	9,964.50	
Sub-Total Stationary	6,515.01	185.49	868.34	18,914.56	9,964.50	0.00
Mobile Sources:						
Transportation	4,486,991.00	9,844,545.90	22,468,261.80	25,568,333.30	653,427,253.80	6,770,572,809.00
Total	4,493,506.01	9,844,731.39	22,469,130.14	25,587,247.86	653,437,218.30	6,770,572,809.00

Source: State of Jakarta Environment, 2012
Note: Detail of each sources see Annex 3

Parameter HC dan NO_2 on air with the assistance or addition of sun light (ultraviolet) will form new pollutant parameter, they are Para Acrylo-Nitrit (PAN), namely in the form of smog, and Ozone (O_3), which is more dangerous to human health.

Under these conditions, it is necessary to monitor ambient air quality to describe the condition of the air quality in Jakarta, where the results of such monitoring can be used as a basis for determining the Jakarta government policies relating to environmental management. In terms of air quality concentration, Jakarta conducted ambient air quality monitoring with continuum method from five different spots, they are in (1) Hotel Indonesia interchange, (2) Kelapa Gading, (3) Jagakarsa, (4) Lubang Buaya, and (5) JAF 4. Location of these stations can be seen on Annex 3.

As mentioned on the previous chapter, this study will use four air pollutants indicators, they are particulate matter (PM_{10}), Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), and Ozone (O_3). Jakarta administrative with the Governor Decree Number 551 year 2001 have set up Ambient Air Quality Standards of all air pollutants. These standards however have differences in terms of level of standards compare to a newer guidelines set by WHO in 2006 under WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide, and sulfur dioxide, and since then Jakarta administrative have not renewed or ratified the guidelines. For that reason, this study will try to look at both standards. The differences found in PM_{10}, where for 24-hour mean measuring time, the Jakarta Standard is 150 µg/m^3, while WHO guideline is 50 µg/m^3. Difference also found in SO_2, where for 24-hour mean measuring time, the Jakarta Standard is 260 µg/m^3, while WHO guideline is 20 µg/m^3. For NO_2, the measurement that are applied in Jakarta is for 24-hour mean with the standard of 92.5 µg/m^3, whilst guideline from WHO AQGs is 40 µg/m^3 for annual mean and 200 µg/m^3 for 1-hour mean.

Table 11: Air Quality Standards in Jakarta and WHO Standards

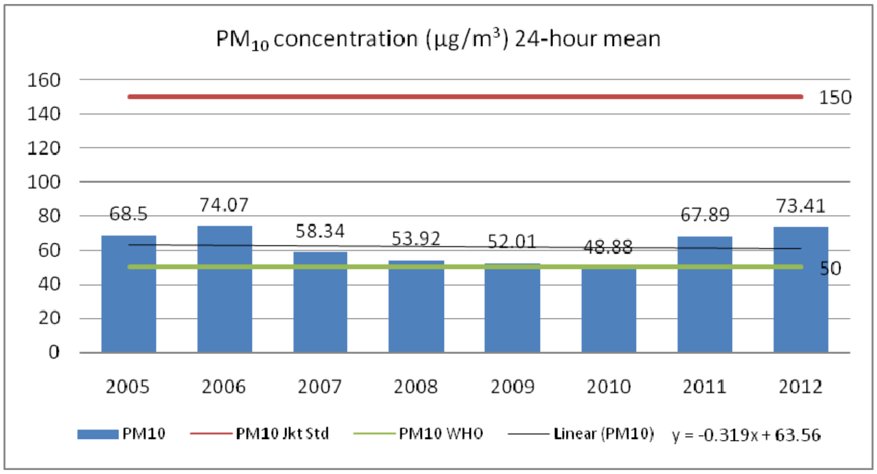
measuring time	µg/m^3							
	PM_{10}		NO_2		SO_2		O_3	
	Jkt	WHO	Jkt	WHO	Jkt	WHO	Jkt	WHO
24-hour	150	50	92.5	-	260	20		
8-hour								100
annual				40			30	-

Source: (Governor of Jakarta Special Capital Region Decree Number 551 year 2001 concerning Standard of Ambient Air Quality and Noise Level in Jakarta, 2001) and (World Health Organization, 2005).

4.5.1 PM_{10}

The main source of PM_{10} pollution comes from motorized vehicle. From the monitoring results in Jakarta from average annual 2005 to 2012 measured in 24-hour mean, PM_{10} concentration had not exceed the Jakarta standards of 150 µg/m^3, but exceed the international standards set by the WHO which is more recent, of 50 µg/m^3. The concentration had gradually decreased since 2006 to 2010, but increased again from 2010 to 2012. From the 8 year data obtained, it showed a decreasing trend as seen on figure below.

Figure 18: Average Annual PM_{10} Concentration in Jakarta (24-hour mean), 2005-2012

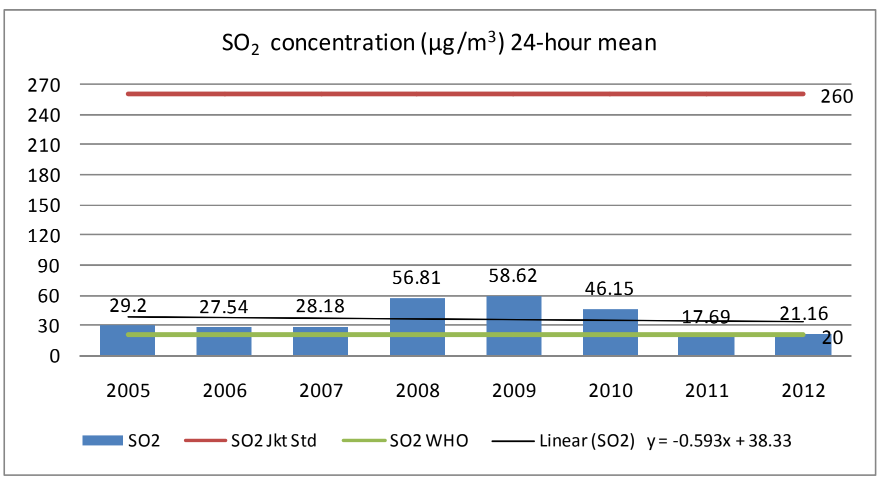


Source: Author, adapted from State of Jakarta Environment, 2012.

4.5.2 SO_2

From the monitoring results in Jakarta for SO_2 from average annual 2005 to 2012 measured in 24-hour mean, SO_2 concentration had not exceed the Jakarta standards of 260 µg/m^3, but exceed the international standards set by the WHO which is more recent, of 20 µg/m^3. The concentration had significant increase in 2008 and 2009 but then gradually decreased again to 2012. From the 8 year data obtained from 2005 to 2012, it showed a decreasing trend as seen on figure below.

Figure 19: Average Annual SO_2 Concentration in Jakarta (24-hour mean), 2005-2012

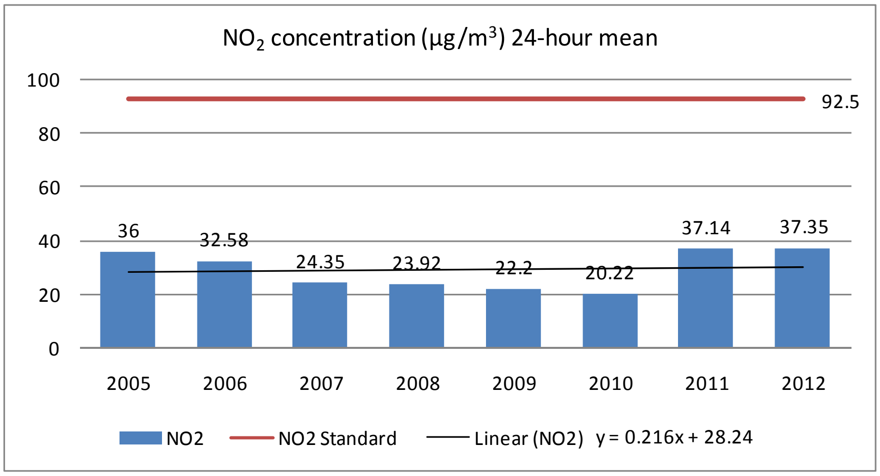


Source: Author, adapted from State of Jakarta Environment, 2012.

4.5.3 NO_2

As well as PM_{10} and SO_2, NO_2 concentration in Jakarta from 2005 to 2012 is also below the air quality standard set by the Jakarta administrative, of 92.5 µg/m^3. But unlike PM_{10} and SO_2, NO_2 has an increasing trend of concentration based the 8 year data from 2005-2012. In 2012, NO_2 recorded the highest concentration of 37.35 µg/m^3 measured in 24-hour mean. Trends and data of NO_2 can be seen on figure as follow.

Figure 20: Average Annual NO_2 Concentration (24-hour mean) in Jakarta, 2005-2012

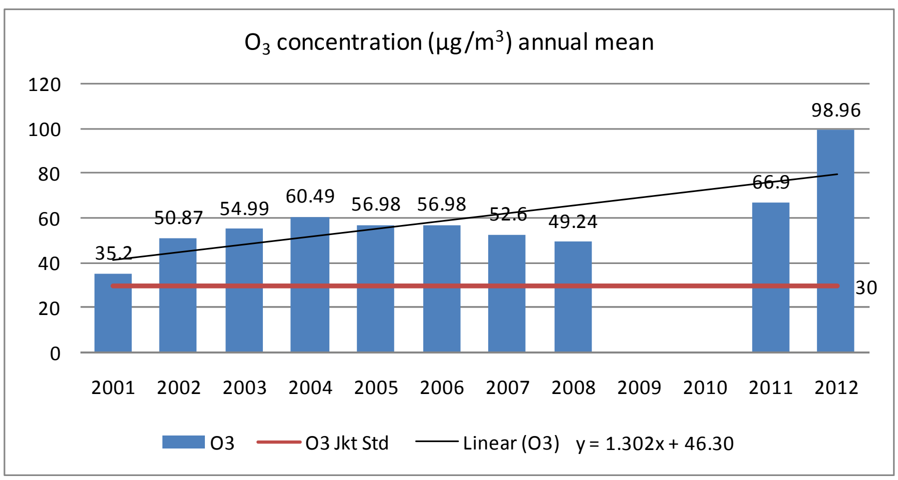


Source: Author, adapted from State of Jakarta Environment, 2012.

4.5.4 O_3

Different from PM_{10}, SO_2 and NO_2, Ozone (O_3) concentration in Jakarta had exceed the standard set by the Jakarta administrative from 2001 to 2012 (annual mean) of 30 µg/m^3. The linear trend also showed that O_3 have increasing trend, and in 2012, the O_3 ground concentration annual mean in Jakarta have exceeded more than triple the standard set by the government, with 98.96 µg/m^3.

Figure 21: Average Annual O_3 Concentration (annual mean) in Jakarta, 2001-2012



Source: Author, adapted from State of Jakarta Environment, 2012; CAI-Asia 2010.

Note: 2009 and 2010 data not available.

4.5.5 Conclusion of Air Quality Condition in Jakarta

From all the four air pollutant indicators mentioned above and from Jakarta Air Pollutant Index in 2012, it can be concluded:

1. The level of PM_{10}, SO_2 and NO_2 concentration in Jakarta from 2005 to 2012 still under the standard that has been set by the Jakarta administrative by Governor of Jakarta Decree Number 551 year 2001 concerning Establishment of Ambient Air Quality Standard and Level of Noise Standard in Jakarta Special Capital Region (Kep gub 551/2001), but must

be noted that the standard was set in 2001. In 2006, World Health Organization (WHO) released the WHO Air Quality Guidelines for Particulate Matter, Sulfur Dioxide, Nitrogen Dioxide, and Ozone (World Health Organization, 2005)(WHO AQGs), which have not ratified by the Jakarta administrative, which if refer to the latter, PM_{10} and SO_2 concentrations in Jakarta are above the standard level.

2. The level of PM_{10} and SO_2 concentration in Jakarta based on the last 8 years of monitoring, have a slight decreasing trends.
3. Meanwhile, the level of NO_2 and O_3 concentration in Jakarta based have an increasing trends, even the level of O_3 in year 2012 has more than triple above the standard.

4.6 Business As Usual (BAU) Forecast Scenario

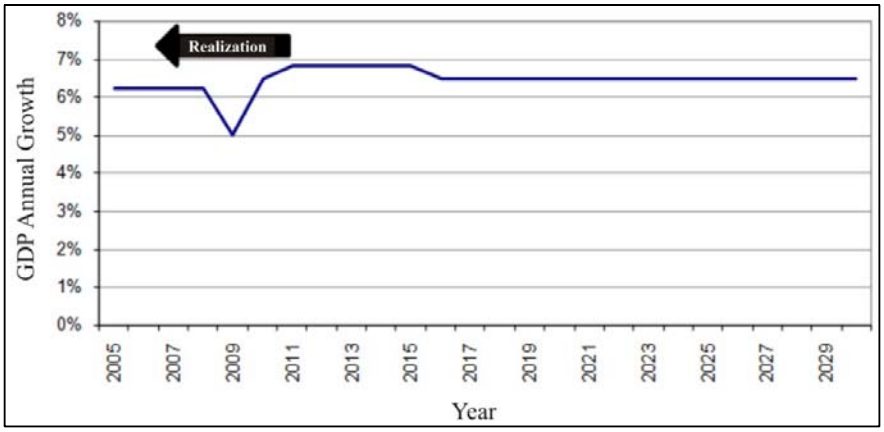
For scenario analysis to estimate the forecast in 2030, methodology was developed adopting methodology used in Local Action Plan for GHG Emissions Reduction (Regulation of Jakarta Special Capital Region Number 131 year 2012 concerning Local Action Plan of Green House Gases Reduction, 2012). In this case, the estimated amount of GHG emissions that occurred in Jakarta in 2005 and 2030 is highly dependent on two main parameters, namely economic growth and population projections Jakarta.

Historical data and projection of Jakarta Regional GDP growth and population growth used as input in developing model of energy demand and waste production (Regulation of Jakarta Special Capital Region Number 131 year 2012 concerning Local Action Plan of Green House Gases Reduction, 2012). Results of the model are projection of final energy demand, which includes industry, transport, household, commercial, and others; and solid and liquid waste. With that projection, GHG emissions from every sector can be generated. This GHG emissions projection is called Business as Usual forecast scenario. The result which covers every possible emitting and polluting sectors can also acted as projection of air pollutants to 2030.

4.6.1 Regional Growth Domestic Product

One of the main parameters of the activity that causes GHG emissions in Jakarta is economic growth, reflected in Jakarta Regional Gross Domestic Product (GDP). During 2005 to 2010, GDP Jakarta in 2000 constant prices increased significantly by an average of 6.03% per year and is assumed to increase gradually to reach 6.83% in 2011 and constant until 2015, and decreased to 6.5% at a constant rate until 2030. Jakarta GDP declined in 2009 was the impact of the world’s economy and energy crisis that was also affected the GDP. Below is the graph that shows the trend of annual growth of Jakarta Regional GDP.

Figure 22: GDP Annual Growth of Jakarta

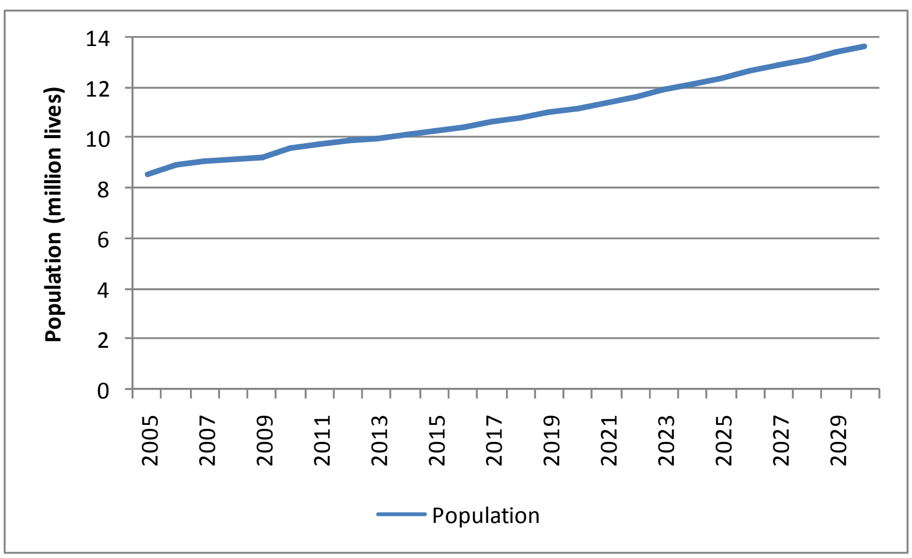


Source: Local Action Plan of GHG Emissions Reduction in Jakarta, 2012

4.6.2 Population

Total population in Jakarta based on Intercensal Population Survey in 2005 was 8.54 million lives, and increased to 9,61 million lives based on census in 2010. Based on data from United Nations, Department of Economic and Social Affairs (UN-DESA), Population Division, the Average Annual Rate of Population Growth of Jakarta from 2011 to 2015 is 1.67%, it will be increased for the duration between 2016 to 2020 to 2.11%, then it will be decreased to 1.94% for the duration between 2021 to 2025, then it will be steady at the same rate in 2026 to 2030. These trends were analysed using historical data of population from 1950. In 2030, the population of Jakarta is estimated around 13.66 million lives.

Figure 23: Population Growth of Jakarta



Source: Author

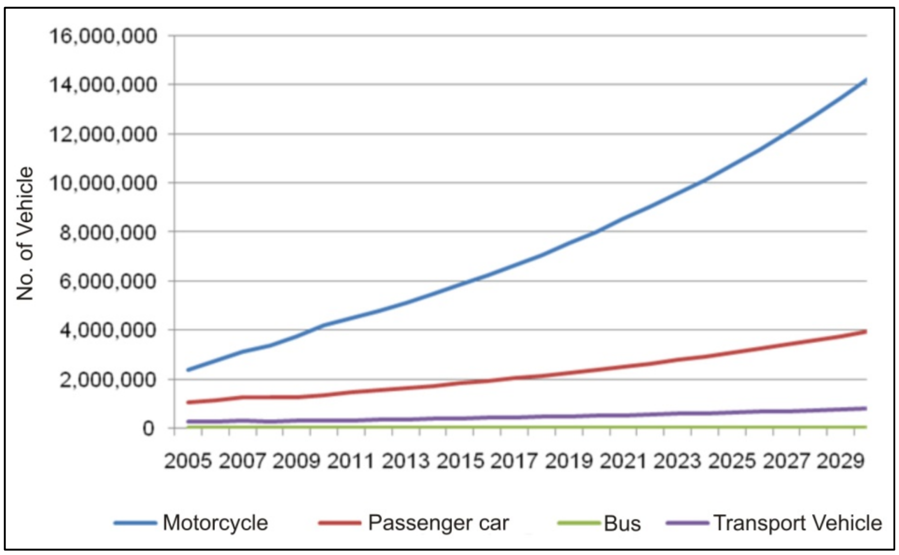
4.6.3 Energy

In formulating the final energy demand projections, in addition to considering the main parameters of population and economic growth, final energy demand projections are also done by considering the Indonesia energy indicator in 2030. The considered energy indicators are—among others—final energy consumption per capita, electricity consumption per capita, share of final energy consumption by sector, and the share of electricity consumption of final energy consumption in each sector.

The consideration of Indonesia energy indicator in estimating Jakarta energy demand in 2030 is needed because Jakarta is national economic barometer, so the direction of Jakarta energy demand in 2030 is related to the pattern of Indonesia energy demand in 2030.

Especially for land transportation, energy demand projections also take into consideration the projected growth of motorized vehicles per category. In these projections, economic growth projection factors affect the growth of passenger vehicles (minibuses and jeeps), transport (goods) vehicles, and motorcycles. Meanwhile, the projected growth in other categories (buses, trucks, taxis, public transport) is assumed to follow a linear growth trend of motorized vehicle for the last 10 years. Based on these assumptions, the number of motorized vehicles in 2030 is estimated at 19 million, with around 75% of them are motorcycles, 21% are passenger cars, and less than four percent are buses and trucks. Share of motorcycles in 2030 was greater than in 2005 (63%) and in 2010 (71%).

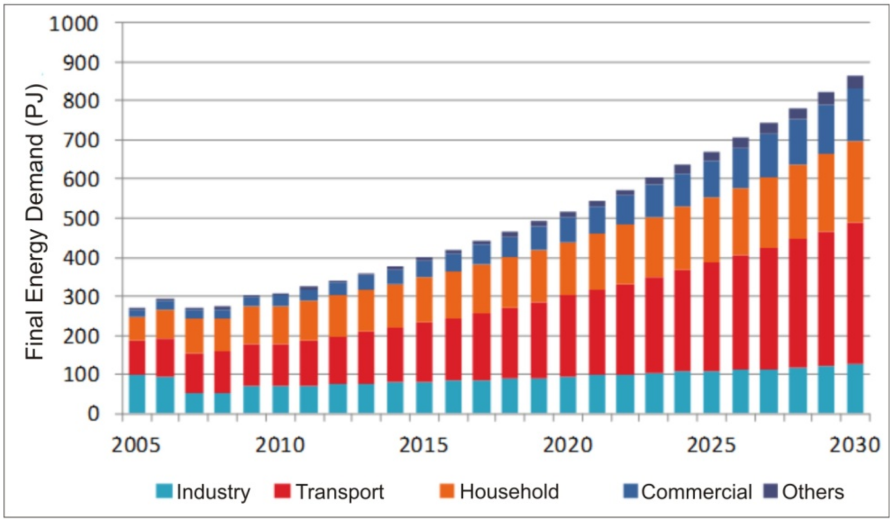
Figure 24: Number of Vehicles in 2030



Source: Local Action Plan for GHG Emissions Reduction

Based on the assumption of economic growth, population, transportation, Indonesia energy indicators, and historical data of final energy consumption during 2005 to 2010, projection of final energy demand by sector is obtained. Consumption and final energy demand during 2005 to 2030 are increased by an average of 4.75% per annum from 271.50 Peta Joule (PJ) in 2005 to 916.74 PJ in 2030.

Figure 25: Final Energy Demand in 2030

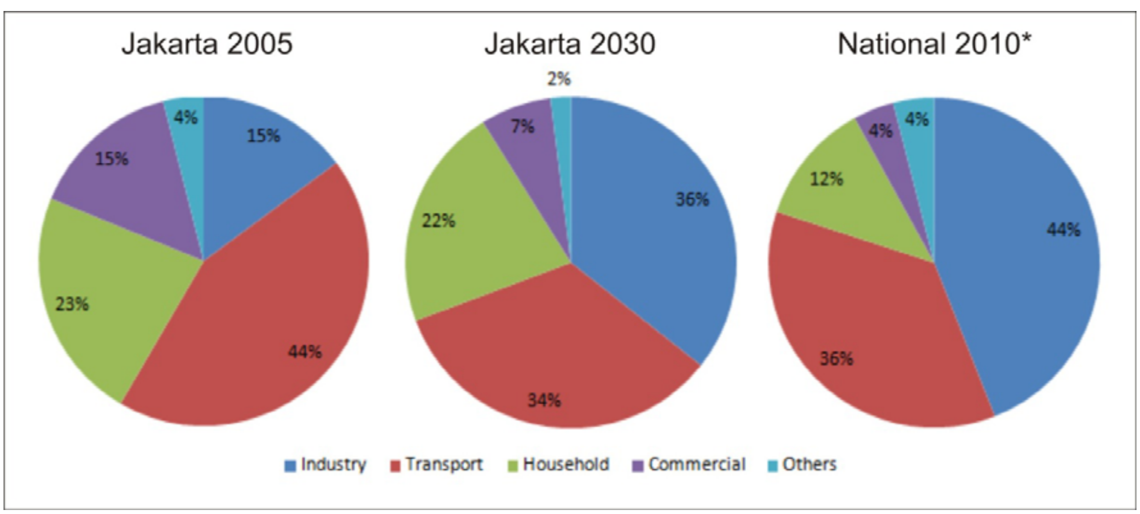


Source: Local Action Plan for GHG Emissions Reduction

By 2030, transportation sector is expected to be the sector with the highest final energy demand following the trend of the growth of motorized vehicles that are affected by the unavailability of public transport mass (BAU scenario) in Jakarta. Based on data from the Jakarta Tax Office in 2010, there were increase on average of 1,776 vehicles per day which includes 1,522 increase of motorcycle, and 286 increase of passenger car. In addition, the area for the industrial park in Jakarta is relatively limited because Jakarta has become service-based city than industrial and manufacturing-based city, resulting in a decline in the share of final energy demand of the industrial sector.

Another significant sector to be underlined is the large share of final energy demand for the household sector in Jakarta, compare to national final energy demand for the household sector. This is occured because electrification ratio in Jakarta has reached 100% and Jakarta has higher income per capita than the average national income per capita.

Figure 26: Distribution of Consumption and Final Energy Demand in Indonesia and In Jakarta by Sector



Source :Local Action Plan for GHG Emissions Reduction; and Handbook of Economics and Energy Statistic of Indonesia, 2011

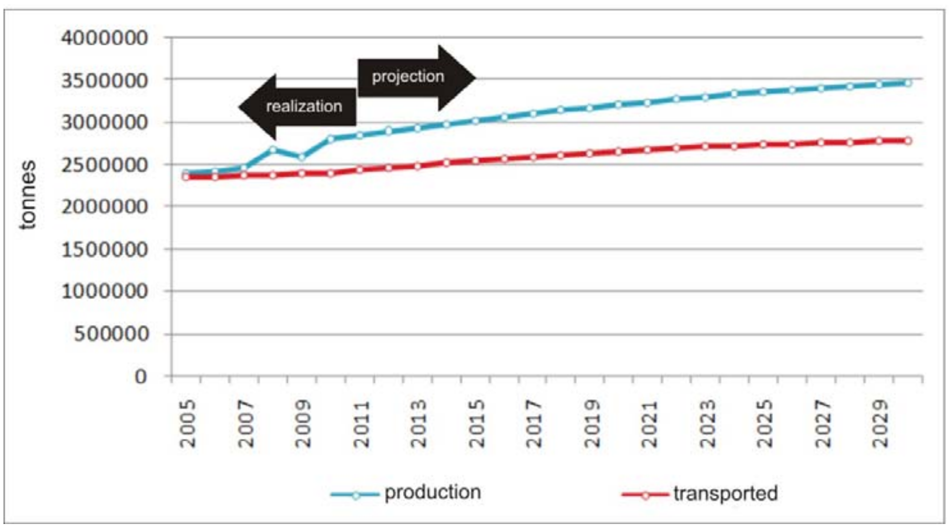
Note: Industry, household and commercial sectors in National exclude biomass

4.6.4 Waste

Based on the experience of the Jakarta Sanitation Office in waste management, solid waste generation per day is expected to increase an average of 1.01% per year from 7,691 tons / day in 2010 to 9,461 tons / day in 2030. The increase of the amount of waste occurs due to the increase of population and inhabitants activities. The amount of waste transported to WTP Bantar Gebang until the end of 2009 is estimated at 17,937,073 tons. Not all waste produced can be transported to the WWTP. In 2010, the amount of waste transported to reach 14.8% and increased gradually to 19.8% in 2030. Thus, the cumulative amount of waste transported in 2030 was 72,993,795 tons.

The non-transported waste occurred due to the activity of 3R (reduce, reuse and recycle) in the community, burned, and thrown into water bodies. Any non-transported waste that are not managed through the 3R shows that waste management in Jakarta is not optimal. Currently, regulations on waste management are not yet available, although the Law No. 18 year 2008 concerning Waste Management has been established and regulated. People behaviour that are still ignorance on managing their own waste by self burning and thrown into the water bodies for example, reflects that the public and private sector participation in the management of municipal waste is still low. Data and projection of waste management in Jakarta can be seen on graph as follows.

Figure 27: Data and Projection of Waste Management



Source: Local Action Plan for GHG Emissions Reduction

Production of domestic wastewater is a function of the total population. Assuming effluent Biological Oxygen Demand (BOD) loadings of 0.04 kg / person / day, projected BOD content of domestic wastewater in Jakarta is expected to increase from 0.13 million tons in 2005 to 0.17 million tons in 2030, as shown in below. Management of liquid waste on-site in Jakarta is currently available in Pulogebang and Duri Kosambi. The graph of projected production of BOD domestic water can be seen on Annex 3.

4.6.5 GHG Emissions

Based on the projected fuel demand by type on various sectors by 2030, losses T / D (Transmission and Distribution), and the emission factor of fossil fuels and electricity, GHG emissions are calculated. CO_2e emissions of the energy sector are expected to increase from 31.71 million tonnes in 2005 to 113.80 million tonnes in 2030, an increase of an average of 5.25% per year. The high increase in CO_2e emissions are caused by the high growth in electricity demand, and electricity is generally produced from coal-fired power plants (coal power plant).

In 2005, the sector that produced the biggest CO_2e emissions due to the final energy consumption was the electricity sector (56.1%), followed by the transport sector (20.7%), industry (14.7%), households (8.2%) and commercial (0.2%). By 2030, the share of the electricity sector role as a producer of CO_2e emissions increased dramatically to 64.5% of total CO_2e emissions, followed consecutively by transportation (25.2%), households (5.0%), industry (5, 0%), and commercial (0.3%). Total CO_2e emissions in the energy sector in 2005 accounted for 93% of total CO_2e emissions in Jakarta, while in 2030 increased to 97%.

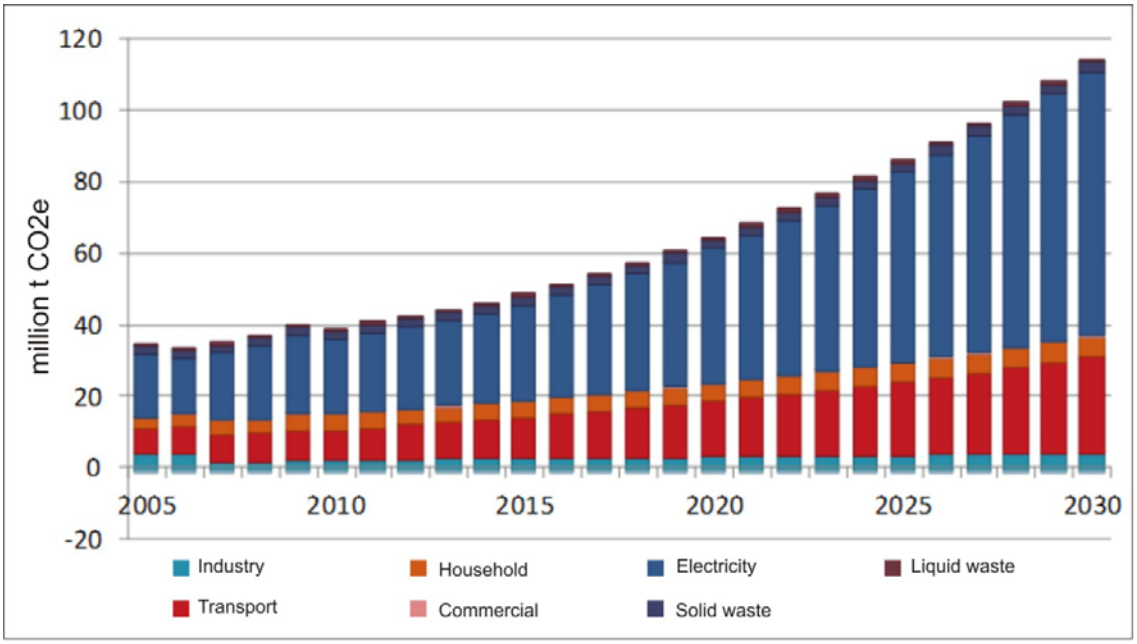
Waste sector generally emits CH_4 which is part of GHG emissions. Although the CH_4 produced by waste has much smaller amount than the CO_2 produced by energy sector, but the heat resulted from it is 21 times stronger than CO_2. Based on the data of total transported waste to WTP Bantar Gebang, waste composition, and projection of total waste in 2030, CO_2e emissions from waste in WTP Bantar Gebang increased from 2.21 million tons in 2005 to 2.62 million tons CO_2e in 2030.

Total GHG emissions of wastewater are a combination of domestic sewage, on-site (Pulogebang and Duri Kosambi) treatment domestic sewage, and off-site (West Setiabudi and East Setiabudi) treatment domestic sewage. For domestic sewage that is processed in Integrated Sewage Treatment Plant Duri Kosambi and Pulogebang, the amount of CH_4 emissions is a combination of CH_4 emissions from wastewater treatment, and sludge treatment.

Based on population projections and data on wastewater, GHG emissions from wastewaster sector have increased from 0.76 million tonnes of CO_2e in 2005 to 1.03 million tons CO_2e in 2030. Most of the GHG emissions from the production of wastewater produced by household waste (92%)

Total CO_2e emissions in 2005 from fossil fuel combustion activities, waste disposal on WTP Bantar Gebang, production of liquid waste (household, on-site, off-site) reached 34.67 million tons in 2005 and increased to 117.45 million tons in 2030, an increase of 3.4-fold in the next 25 years. This amount of emissions is the emissions for the BAU scenario.

Figure 28: Total CO_2 Emissions of BAU Scenario

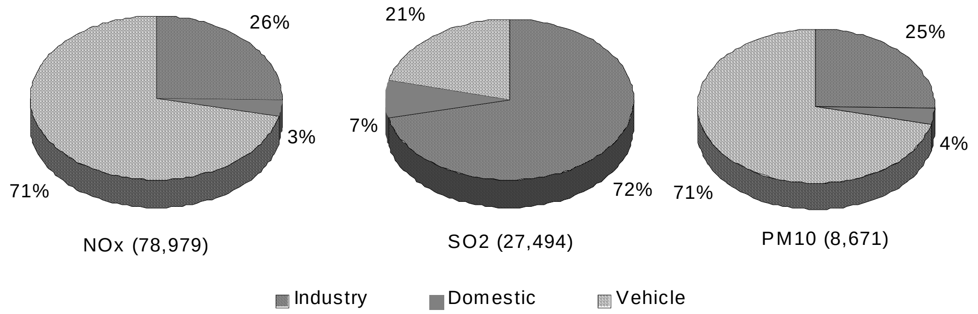


Source: Local Action Plan for GHG Emissions Reduction

4.6.6 Air Pollutants

Analysing and calculating the projection of the green house gases emissions for 2030 in Jakarta as in previous subchapter was conducted by taking into account all sectors that emitted gaseous and also produced air pollutants. From the article by Tamin and Rachmatunisa (2004) on Integrated Air Quality Management in Indonesia, it is stated that emission shares from each air pollutants are varied depends on source of type of sectors. This study were based on research by ADB in Indonesia in 1998, which the data were also used by Resosudarmo and Napitupulu on their article about Health and Economic Impacts of Air Pollutants in Jakarta, which is one of the main reference for this study. For PM_{10}, 25% were contributed by industry sector, 4% by domestic (household), while vehicle were the dominant sector by 71%. For SO_2, the most dominant sector is industry with 72%, while domestic contributed 7% and vehicle 21%. For NO_2, the characteristics were quite similar to PM_{10}, where vehicle contributed the biggest share by 71%, followed by industry by 26% and domestic 3%. As explained before on chapter 2, ground-level Ozone (O_3) is not a primary pollutant. O_3 formed when NO_2 are exposed to VOC and UV. Thus, shares of O_3 are similar to NO_2, as the base or primary pollutant. Emission shares by source of type in Jakarta can be seen on graph as follows.

Figure 29: Emission shares by source type in Jakarta



Source: (Tamin and Rachmatunisa, 2004)

Projection the air pollutant parameters used in this study, such as PM_{10}, SO_2, NO_2 and O_3 for 2030 is using the growth of each sector given from the Local Action Plan for GHG Emissions Reduction in Jakarta calculate by the shares by source type of each air pollutants as seen on graph above. For industry, the annual sectoral growth up to 2030 is 1.31%. For domestic (household), the annual sectoral growth up to 2030 is 1.62%. For transport, the annual sectoral growth up to 2030 is 6.00%. The estimated annual growth rate of air pollutant concentration based on the growth rate of each sector and its emission shares can be seen on table below.

Table 12: Annual Growth Rate of Sectors Related to Air Pollutants Parameter

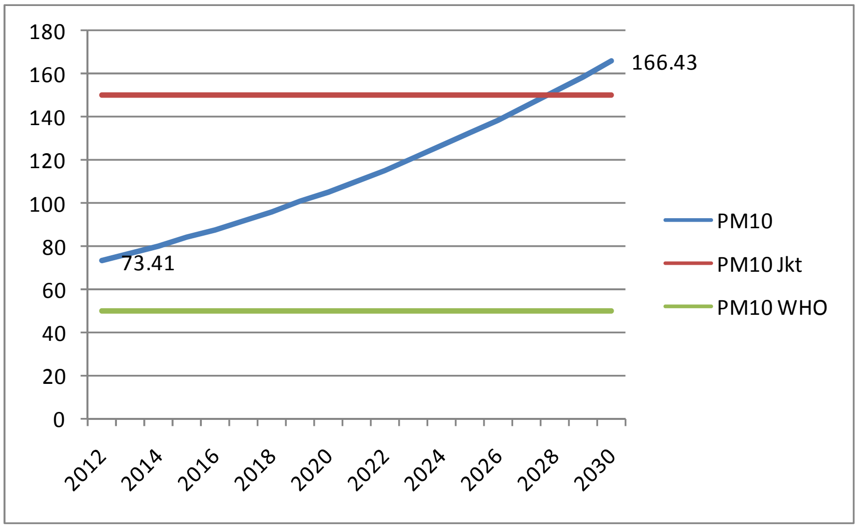
Pollutants	Sectoral Contribution	Annual growth rate to 2030	Sectoral Shares	Annual growth of air pollutants
PM_{10}	Industry	1.31%	25%	4.65%
	Domestic	1.62%	4%	
	Transport	6.00%	71%	
SO_2	Industry	1.31%	72%	2.32%
	Domestic	1.62%	7%	
	Transport	6.00%	21%	
NO_2	Industry	1.31%	26%	4.65%
	Domestic	1.62%	3%	
	Transport	6.00%	71%	
O_3	Industry	1.31%	26%	4.65%
	Domestic	1.62%	3%	
	Transport	6.00%	71%	

Source: Author, adopted from Local Action Plan for GHG Emissions Reduction (2012); and (Tamin and Rachmatunisa, 2004).

PM_{10}

In 2012, the average PM_{10} concentration in Jakarta (24-hour mean measuring time method) is recorded at 73.41 µg/m^3. With the growth rate of 4.65% per year, it is estimated that level of PM_{10} in 2030 is 166.43 µg/m^3. Up to 2027, the level of PM_{10} concentration in Jakarta is still below the standard set by Jakarta administrative in 2001, at the level of 150 µg/m^3. However, in 2028 to 2030, the level of PM_{10} concentration in Jakarta has passed the Jakarta standard. Even more, if we look at the WHO AQGs which is international guidelines of air quality and was established more current (2006), the standard of PM_{10} concentration that is harmless to human health is 50 µg/m^3. If following the WHO standard, the level of PM_{10} concentration in Jakarta since 2012 has exceeded the standard. Below is the graph that showing the projection of PM_{10} in Jakarta in 2030.

Figure 30: Projection of PM_{10} concentration (24-hour mean) in Jakarta

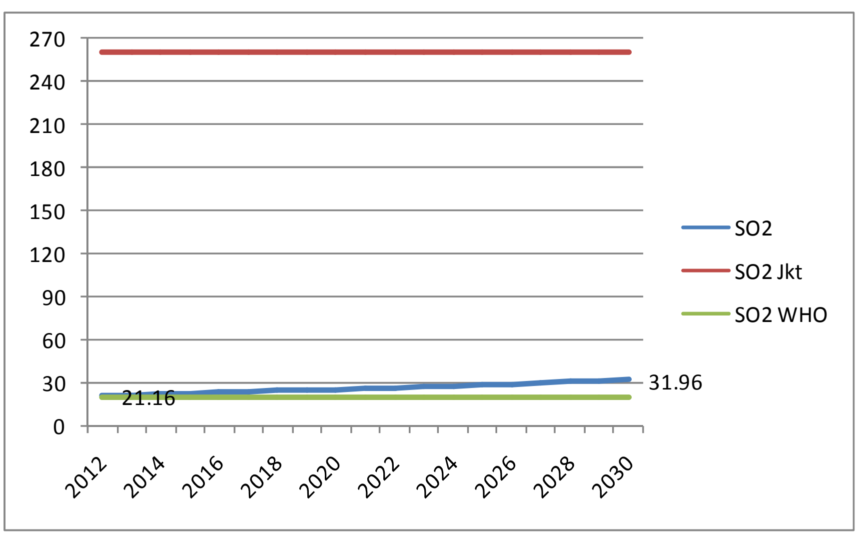


Source: Author

SO_2

In 2012, the average SO_2 concentration in Jakarta (24-hour mean measuring time method) is recorded at 21.16 µg/m^3. With the growth rate of 2.32% per year, it is estimated that level of SO_2 in 2030 is 31.96 µg/m^3. Up to 2030, the level of SO_2 concentration in Jakarta is still below the standard set by Jakarta administrative in 2001, at the level of 260 µg/m^3. However, if we look at the WHO AQGs which is international guidelines of air quality and was established more current (2006), the standard of PM_{10} concentration that is harmless to human health is 20 µg/m^3. If following the WHO standard, the projected level of SO_2 in 2030 is exceeding the standard. Below is the graph that showing the projection of SO_2 in Jakarta in 2030.

Figure 31: Projection of SO_2 concentration (24-hour mean) in Jakarta

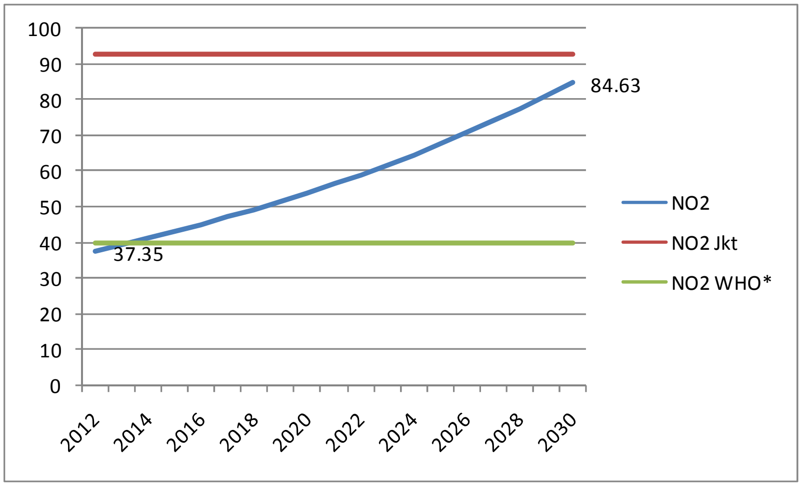


Source: Author

NO_2

In 2012, the average NO_2 concentration in Jakarta (24-hour mean measuring time method) is recorded at 37.35 µg/m^3. With the growth rate of 4.65% per year, it is estimated that level of NO_2 in 2030 is 84.63 µg/m^3. The standard NO_2 concentration level set by Jakarta administrative for 24-hour mean measuring time is 92.5 µg/m^3. The projected level of NO_2 concentration in Jakarta is still below that standard until 2030. Below is the graph that showing the projection of NO_2 Jakarta in 2030.

Figure 32: Projection of NO_2 concentration (24-hour mean) in Jakarta



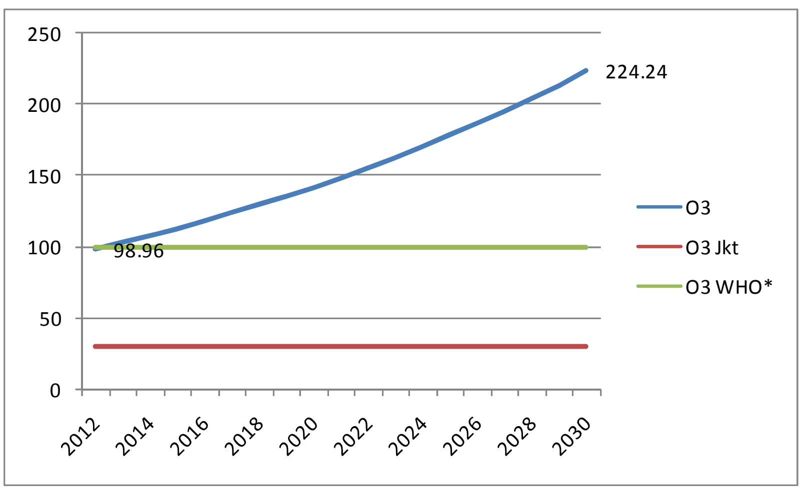
Source: Author

Note: *the 40 µg/m^3 WHO standard is not based on 24-hour mean, but annual mean

O_3

In 2012, the average O_3 concentration in Jakarta (annual mean measuring time method) is recorded at 98.96 µg/m^3. With the growth rate of 6.00% per annum, it is estimated that level of O_3 in 2030 is 224.24 µg/m^3. The standard O_3 concentration level set by Jakarta administrative for annual mean measuring time is 30 µg/m^3. The projected level of O_3 concentration in Jakarta even from 2005 is already exceeding the standard of 30 µg/m^3. Below is the graph that showing the projection of NO_2 Jakarta in 2030.

Figure 33: Projection of O_3 concentration (annual mean) in Jakarta



Source: Author

Note: *the 100 µg/m^3 WHO standard is not based on annual mean, but 8-hour mean

4.7 Additional Green (AG) Scenario

This subchapter will provide analysis on the additional green space scenario. This scenario will analyse the level of carbon emissions and air pollutants (PM_{10}, SO_2, NO_2, and O_3) in 2030 if the green space target as planned in Jakarta Spatial Plan 2030 is reached, which is 30% of total Jakarta Special Capital Region area.

4.7.1 Carbon Emissions Reduction

Based on the study of green open space in Jakarta in Gas Pollutants Reduction, stated that the total area of green space in Jakarta in 2005 is 7,696 hectares. Recent analysis by satellite imagery in 2010 validated by Jakarta Parks Office, Jakarta Marine and Fishery Office, and Jakarta Planning and Development Office, stated that total area of green space in 2010 is 8,090 hectares. In 2030, according to Jakarta Spatial Plan 2030, total area of green space is targeted at 19,860 hectares, or 30% of the total Jakarta Special Capital Region area. The area and percentage of Jakarta green space can be seen on table below.

Figure 34: Condition and Estimation of Jakarta Green Space

	2005		2010		2030	
	Hectares	Percentage	Hectares	Percentage	Hectares	Percentage
Green Space	7,596	11.5%	8,090	12.2%	19,860	30%

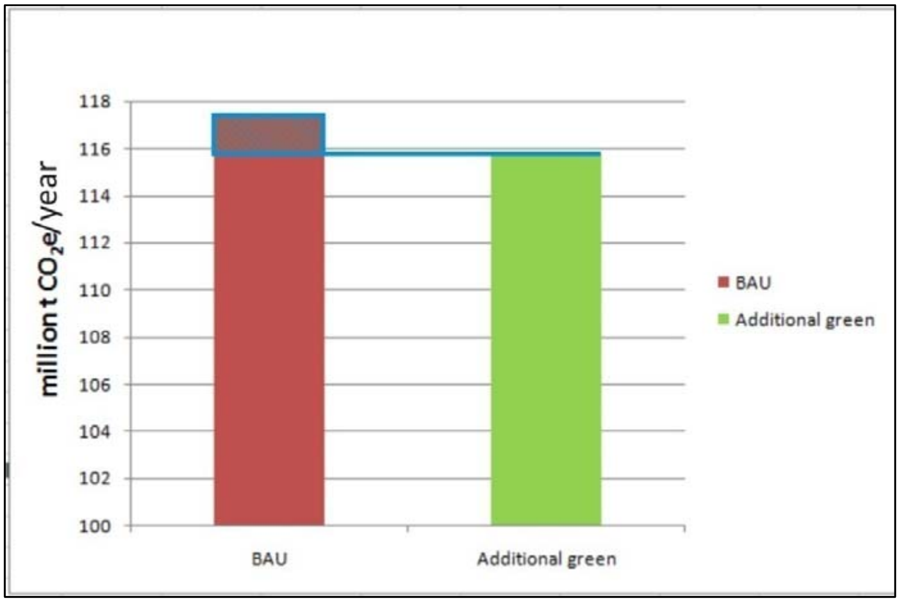
Source : Jakarta Parks Office, Jakarta Marine and Fishery Office, and Jakarta Planning and Development Office, adjusted.

Regulation of Jakarta Special Capital Region Number 131 year 2012 on Local Action Plan of Green House Gases in 2012 adopting the methodology used by IPCC on their fourth assessment report (IPCC, Intergovernmental Panel on Climate Change, 2007) working group II on mitigation of climate change, mentioned that methodology to calculate the Carbon Dioxide (CO_2) emission sinks by the AFOLU (Agriculture, Forestry and Other Land Use) sector, which in Jakarta case is categorized as green space, is referred to formula **equation (1)**.

In that document, it is analysed that in 2005, with the total green space of Jakarta of 7,596 hectares, the total absorption of CO_2 is estimated at 646,422 tonnes of CO_2e. Based on that study, the carbon conversion factor of Jakarta green space is estimated 22.91. This result is imperative to calculate the Carbon Dioxide (CO_2) emission sinks by the green space in Jakarta in 2030. Using the methodology and formula as mentioned above, it is found that the total absorption of CO_2 in Jakarta in 2030 is estimated at **1,668,132.46 tonnes CO_2e** or 1.67 million tonnes of CO_2e, with the total area of green space of 19,860 hectares.

Comparing to the result of CO_2e in 2030 under Business as Usual (BAU) scenario as in subchapter 4.5.5., the total CO_2e in Jakarta without AFOLU is 117.45 million tonnes CO_2e, the projected green space in Jakarta in 2030 will reduce the total carbon emissions of **1.4%.** As a result, by taking into account the carbon absorption from the green space in Jakarta, the final annual carbon emissions in Jakarta in 2030 under additional green scenario is **115.78 million tonnes CO_2e**, as seen on graph below.

Figure 35: Carbon Emissions Comparison of BAU and Additional Green Scenario



Source: Author

4.7.2 Air Pollutant Reduction

Using the methodology mentioned in chapter three that is derived from Bolund and Humhammar in their article Ecosystem Services in Urban Areas (Bolund and Humhammar, 1999), matched with the area of green space in 2030 with the AG scenario, the reduction of the level of air pollutant concentration are based on specific types of green space as follows.

Table 13: Factors of Air Pollutants Removal from Types of Green Spaces in Jakarta

Types of Green Space	Level of Reduction	Types of Green Space	Level of Reduction
Protected Green Space	85%	Greening for North Jakarta Reclamation Land	n/a
River Basin Green Space	n/a	Greening in Thousand Islands (Kepulauan Seribu) Regency	n/a
Coastal Green Space	n/a	Government Area Green Space	85%
Lakes and Ponds Basin Green Space	n/a	Green Spaces in Offices, Commercials, and Public Services	85%
Parks/ Urban Forests	85%	Green Spaces in Industrial Estates and Areas	85%
Cemetery	n/a	Urban Agriculture Areas	n/a
Road Sides Train Lines and Electrical Transmission Networks Green Space	70%	Green Spaces in Residential Areas	85%

Source: Author, adapted from Bolund and Humhammar, 1999.

The result can be seen from the following table.

Table 14: Air Pollutants Reduction Based on Land Use and Green Space Distribution in 2030

Types of Green Space	Area (Hectares)	Proportion (%)	PM_{10}		SO_2		NO_2		O_3	
			BAU	AG	BAU	AG	BAU	AG	BAU	AG
Protected Green Space	53,756	0.81	1.35	0.20	0.26	0.04	0.69	0.10	1.82	0.27
River Basin Green Space	1	2.09	3.48	3.48	0.67	0.67	1.77	1.77	4.69	4.69
Coastal Green Space	1,650	0.02	0.03	0.03	0.01	0.01	0.02	0.02	0.04	0.04
Lakes and Ponds Basin Green Space	37,408	0.57	0.95	0.95	0.18	0.18	0.48	0.48	1.28	1.28
Parks/ Urban Forests	5	7.04	11.72	1.76	2.25	0.34	5.96	0.89	15.79	2.37
Cemetery	76,808	1.16	1.93	1.93	0.37	0.37	0.98	0.98	2.60	2.60
Road Sides Train Lines and Electrical Transmission Networks Green Space	74,968	1.13	1.88	0.56	0.36	0.11	0.96	0.29	2.53	0.76
Greening for North Jakarta Reclamation Land	75,000	1.13	1.88	1.88	0.36	0.36	0.96	0.96	2.53	2.53
Greening in Thousand Islands (Kepulauan Seribu) Regency	2,885	0.04	0.07	0.07	0.01	0.01	0.03	0.03	0.09	0.09
Government Area Green Space	29,600	0.45	0.75	0.11	0.14	0.02	0.38	0.06	1.01	0.15
Green Spaces in Offices, Commercials, and Public Services	3	3.80	6.32	0.95	1.21	0.18	3.22	0.48	8.52	1.28
Green Spaces in Industrial Estates and Areas	1	1.76	2.93	0.44	0.56	0.08	1.49	0.22	3.95	0.59
Urban Agriculture Areas	84,391	1.27	2.11	2.11	0.41	0.41	1.07	1.07	2.85	2.85
Green Spaces in Residential Areas	6	8.73	14.53	2.18	2.79	0.42	7.39	1.11	19.58	2.94
Total Green Space	**19,860**	**30.00**	49.93	16.66	9.59	3.20	25.39	8.47	67.27	22.44
Non Green Space Land Use	66,200	70.00	116.50	116.50	22.37	22.37	59.24	59.24	156.97	156.97
Summary		100.00	166.43	133.16	31.96	25.57	84.63	67.71	224.24	179.41
Reduction				**33.27**		**6.39**		**16.92**		**44.83**

Source: Author

The synthesis of the above analysis to show the comparison of level of air pollutants concentration between Business As Usual scenario and Additional Green scenario in 2030 can be seen at table as follows.

Table 15: Comparison of Level of Air Pollutants Concentration between BAU and Additional Green Scenario in 2030

Air Pollutants	Concentration of Air Pollutants (µg/m^3)		
	BAU	Additional Green	Reduction
PM_{10}	166.43	133.16	33.27
SO_2	31.96	25.57	6.39
NO_2	84.63	67.71	16.92

O_3	224.24	179.41	44.83

Source: Author

4.8 Health Benefit Assessment

Based on various sources mentioned in Chapter 2, air pollutants have a significant impact to human health. This study aims to quantify the health benefits by calculating potential health problems can be avoided if additional green scenario is applied, as in Jakarta Spatial Plan 2030. There are several health indicators that are used in this study according to the case of particular air pollutants. The methodology in estimating health impacts are using dose-response functions developed by Bart Ostro (Ostro, 1994) and Resosudarmo (Resosudarmo and Napitupulu, 2004) for Jakarta as mentioned on chapter three, specifically from **equation (2), (3), (4), (5), (6)**. The result can be seen on table below.

Table 16: Number of Potential Reduction Air Pollution-related Health Cases in 2030

Outcome	Number of Potential Reduction Health Cases per Pollutants			
	PM_{10}	SO_2	Ozone	NO_2
Premature Mortality	166	153		
RHA	296		50	
ERV	5,807			
RAD	759,077			
LRI/child	7,013			
Asthma Attacks	56,289		31,054	
Respiratory symptoms/person	4,514,010		358,812	
Chronic bronchitis	1,510			
MRAD			221,811	
Respiratory symptoms among children		14,421		
Respiratory among adults		253,472		12,912

Source: Author

4.9 Economic Benefit Assessment

There are two types of assessment to measure the economic benefit as a result of the provisioning of green space in Jakarta in 2030 up to 30% of total area of Jakarta. To assess the economic benefit of air pollutant reduction, Economic Value per Unit Air Pollution Health Problem method is used. To assess economic benefit of carbon emissions reduction, Social Cost of Carbon is utilised as has been described in the methodology chapter.

4.9.1 Economic Benefit from Air Pollutant Reduction

On previous chapter, health benefit assessment has conducted to quantify how many air pollution-related health cases will be potentially reduced if the additional greening scenario will be executed to 2030 and target of 30% green space in Jakarta will be achieved. After the number of potential health cases has been found, to see how the air quality improvement will be beneficial to the city, the Economic Value per Unit Air Pollution Health Problem method is used.

The health costs data for estimating the above indicators were obtained by survey from eight public owned and private owned hospitals in Jakarta in 2013. Using assumption from (Resosudarmo and Napitupulu, 2004), 90 percent of patients seek medical treatment at public hospitals, and the remaining 10 percent seek medical treatment at private hospitals or individual medical practices. Below is the table that shows the economic value per of each air pollution health problems, with the comparison values from previous studies are also presented. To calculate the cost for 2030, this study uses the national discount rate of 5.75% per year.

Table 17: Comparison of Economic Value per Unit Air Pollution Health Problems in Jakarta

Outcome	In rupiah for 1990		In rupiah for 2001	In rupiah for 2013	In rupiah for 2030
	URBAIR (Indonesia)	URBAIR (US-derived)	Resosudarmo (2004)	Author's Analysis	Author's Analysis
Premature Mortality	23,450,000	650,000,000	92,157,163	1,302,000,000	3,766,501,365
RHA	335,000	6,000,000	823,050	960,650	2,485,030
ERV	11,165	55,300	135,170	212,807	550,494
RAD	4,466	12,400	17,050	188,483	487,572
LRI in children	n/a	n/a	11,900	175,464	453,895
Asthma Attacks	11,165	21,400	24,650	175,464	453,895
RS/C	n/a	n/a	11,900	176,036	455,373
RS/A	4,466	3,200	11,900	176,036	455,373
Chronic bronchitis	22,300	70,000	57,260	215,679	557,922

Source: Author

The table above shows the economic value per unit of air pollution health problems then utilised as a factor to obtain the total economic value related to health problems of improving air quality as a result of the provision of green space in Jakarta for up to 30% in 2030, by multiplying the economic value per unit to particular case of health problems (**equation (7)**) as in previous table. The result can be seen on table as follows.

Table 18: Total Economic Benefit of Potential Reduction Health Cases in 2030

Outcome	Economic Benefit of Potential Reduction Health Cases in Million Rupiah in 2030			
	PM_{10}	SO_2	Ozone	NO_2
Premature Mortality	624,337	577,694		
RHA	736		125	

Outcome	Economic Benefit of Potential Reduction Health Cases in Million Rupiah in 2030			
	PM_{10}	SO_2	Ozone	NO_2
ERV	3,196			
RAD	370,104			
LRI/child	3,183			
Asthma Attacks	25,549		14,095	
Respiratory symptoms Days	2,048,885		162,863	
Chronic bronchitis	842			
MRAD			108,149	
Respiratory symptoms for children		6,567		
Respiratory symptoms for adults		115,424		5,880
Total	3,076,833	699,685	285,232	5,880
Grand Total	4,067,630			
Grand Total in US$	423,711,472			

Source: Author

*Note: Dollar exchange value used in this study is based on the latest national budget assumption of Rp. 9,600 per US$

From the result above, it is apparent that the provisioning of green space in Jakarta for up to 30% of total Jakarta area has a significant impact in reducing air pollutants concentration thus improving human health and the city also might gain potential economic benefit of **4.1 trillion rupiah, or about 423.7 million US dollar in 2030**, only from measuring the air quality improvement benefit.

4.9.2 Economic Benefit from Carbon Emissions Reduction

As mentioned on the methodology chapter, this study uses Social Cost of Carbon (SCC) to assume the economic benefit of carbon dioxide reduction. This study uses SSC value from the 4th IPCC report (IPCC, Intergovernmental Panel on Climate Change, 2007), with a range of \$4–\$95/tCO_2 in 2007, assuming a 2.4% per year increase, as a minimum and maximum range, and use value of SCC from (Chae and Park, 2011) of US\$12 /tCO_2 as the central value and using national discount rate of 5.75%. The value of SCC per ton CO_2 in 2030 can be seen on table as follows.

Table 19: The Value of SCC in 2030

SCC	US\$ / tCO_2
Minimum	6.90
Central	34.71
Maximum	163.92

Source: Author

In the previous section, it has been analysed that the additional green scenario will contribute to the reduction of carbon emissions in Jakarta in 2030 for up to **1,668,132.46 tonnes CO_2e** or 1.67 million tonnes of CO_2e, with the total area of green space of 19,860 hectares. By using the factor from Social Cost of Carbon, the economic benefit from carbon emissions reduction under the additional green scenario is between the range of **US\$ 11,513,027** and **US\$ 273,434,394** with the central value **US\$ 57,908,048 or US\$ 57.9 million**.

4.9.3 Total Economic Benefit

Total economic benefit gained from the provisioning of urban green space in Jakarta for up to 30% in 2030 is calculated by adding economic benefit from air pollutant removal in relation to health problems and economic benefit from carbon emissions reduction with the additional green scenario. The result can be seen on the following table.

Table 20: Economic Benefit for the City on Air Quality Improvement and Carbon Emissions Reduction

Economic Benefit		In billion Rupiah	In million US Dollar
Air pollutant removal in relation to health problems		4,067.63	423.71
Carbon emissions reduction	Min	110.53	11.51
	Central	555.92	57.91
	Max	2,624.97	273.43
Total	Min	**4,178.16**	**435.22**
	Central	**4,623.55**	**481.62**
	Max	**6,692.60**	**697.15**

Source: Author

From table above it can be concluded that The provisioning of green space in Jakarta for up to 30% in 2030 will reduce 1.7 million tonnes CO_2e and will improve the air quality, and will be beneficial to the health of the inhabitants and economy of the city of estimated between **Rp. 4.2 Trillion** to **Rp. 6.7 Trillion;** or about **US$ 435.2 Million** to **US$ 697.1 Million,** with the central value of **Rp. 4.6 Trilion** or about **US$ 481.6 Million.**

Chapter 5: Conclusions and Recommendations

The conclusions of this study are presented in this final chapter. The conclusion will be drawn based on data, findings and analysis exhibited on chapter four. In this chapter, descriptions and explanations to respond the research questions are also displayed. Finally, recommendations and further research directions are offered.

In the beginning of this study, it was expressed that even though the needs, importance and awareness of green space in Jakarta have aroused even put as an integral part of Jakarta Spatial Plan 2030 towards promoting sustainable development and mainstreaming the importance of environmental aspects to be considered in the development plan of the city, Jakarta have not provide adequate guidelines to measure, value and quantify the level of benefits of the provisioning of green space to the city and its local residents in air quality context and to the reduction of carbon emissions. Contribution of this study is to become more apparent about the importance of protecting and promoting green space as part of city's development, especially by making the benefit quantified, measured, and in the end, visible.

5.1 Conclusions

In order to answer the main research question of what are the benefits of the provisioning of green space with the additional green space of Jakarta 2030 Spatial Plan, this study was followed through based on three specific sub-questions. This subchapter presents the conclusion regarding the answer of each question.

Assessment of Ecosystem Services.

From the result, it is identified that every type of green space in Jakarta has benefit and provide ecosystem services, but the influence and significance are varied depending on types of green space. Not all types of green space provide positive and significant ecosystem service. For example, cemetery does not increase property value. On the other hand, proximity to cemetery might influence property value in negative way. The issue of proximity also influence the degree of relation between type of green space and ecosystem service. Urban forests, even though have a high density of trees and canopy cover with high leaf area index, only have medium influence—instead of high—in air pollutant removal because urban forests in Jakarta do not have a high proximity to the source of emissions, such as industry, residential, and mobile source.

For GHG reduction, urban forests provide high influence and benefits, because forests have the ability to sequester and storage carbon dioxide. The ability for carbon to be absorbed by trees depends on the type of trees and the age of trees. The younger the age of trees, the higher the ability to absorb carbon, until reach the saturate level where trees cannot grow anymore. The characteristics of urban forests in Jakarta are categorised as young forest.

Current level of green house gases emissions and air pollutants.

The level of GHG emissions in current or the latest condition in 2012 is 42.80 million tonnes CO_2e (without AFOLU sector / excluding plant absorption) or **4.31 tonnes CO_2e per capita**. This level of emissions is about per capita emissions of Tokyo (2006) with 4.89 tonnes CO_2e and Seoul (2006) with 4.10 tonnes CO_2e per capita, and almost double the national emissions in 2005 of 2.52 tonnes CO_2e. This condition should be responded to a minor alarming state from the Jakarta administrative that the development of Jakarta is not going to a sustainable direction that they are beginning to intend to, for its similarity of the emissions per capita from a more developed and industrious city like Tokyo and Seoul. Measures should be taken to address this issue.

In the case of air pollutants, there are four main air pollutants that are analysed in this study, they are fine particulate matter (PM_{10}), Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), and ground Ozone (O_3). The concentration level of each level of air pollutants are as follow: PM_{10} concentration is **73.41 µg/m^3**, SO_2 concentration is **21.46 µg/m^3**, NO_2 concentration is **37.35 µg/m^3**, and O_3 concentration is **98.96 µg/m^3**. This level means that PM_{10}, SO_2 and NO_2 concentration in Jakarta are still under the standard that has been set by the Jakarta administrative by Governor of Jakarta Decree Number 551 year 2001 concerning Establishment of Air Quality Standard and Level of Noise Standard in Jakarta Special Capital Region (PM_{10} standard is 150 µg/m^3, SO_2 standard is 260 µg/m^3, and NO_2 standard is 92.5 µg/m^3). This conclusion did not come without critical remarks. It must be noted that the standard was set in 2001. In 2006, World Health Organization (WHO) released the WHO Air Quality Guidelines for Particulate Matter, Sulfur Dioxide, Nitrogen Dioxide, and Ozone (WHO AQGs), which have not ratified by the Jakarta administrative, which if refer to the latter, PM_{10} and SO_2 concentrations in Jakarta are above the standard level (PM_{10} standard is 50 µg/m^3, SO_2 standard is 20 µg/m^3). Meanwhile for O_3, the current level is way above the standard level set by Jakarta administrative of 30 µg/m^3.

Level of green house gases emissions and air pollutants in 2030 after the additional greening is introduced.

To investigate the result of the level of green house gases emissions and air pollutants in 2030, this study established and conducted two scenarios. First scenario is Business as Usual (BAU) Scenario. This scenario was designed to forecast the level of green house gases emissions and air pollutants in 2030 with the condition of the current green space, meaning that there is no additional provisioning of green space. Second scenario is the Additional Green Scenario This scenario was designed to forecast the level of green house gases emissions and air pollutants in 2030 with the additional green of up to 30% of total Jakarta area as in Jakarta 2030 Spatial Plan.

For the forecasting methodology, all sectors related to the emissions of carbon and air pollutants were considered, such as population growth, economic growth, energy demand and consumption, vehicle growth, and waste production and transportation growth. For the reduction as the effect of additional green space, carbon conversion factor and air pollutant reduction factor were used. The result can be seen on the following table.

Table 21: Comparison of the level of GHG emissions and air pollutants between two scenarios in 2030

GHG/Pollutants	BAU	Additional Green	Reduction
GHG Emissions (mtCO_2e)	117.45	115.78	1.67
PM_{10} (µg/m^3)	166.43	133.16	33.27
SO_2 (µg/m^3)	31.96	25.57	6.39
NO_2 (µg/m^3)	84.63	67.71	16.92
O_3 (µg/m^3)	224.24	179.41	44.83

Source: Author

Health and economic benefit as the effect of air quality improvement to the city and comparison to the result of previous studies.

To measure the health impact of air pollutants, this study used previous study from Ostro (Ostro, 1994) and Resosudarmo and Napitupulu (Resosudarmo and Napitupulu, 2004) to capture the change in mortality and particular morbidity for every level of air pollutant concentration was changed. There are several indicators to be measured; they are mortality, hospital admissions related to respiratory, lower respiratory illness among children, restricted and minor restricted activity days, asthma attack, chronic bronchitis and respiratory symptoms or chest discomfort. With the reduction of air pollutant concentration in Jakarta as effect of additional greening for up to 30% of the total Jakarta area, the results are as follows:

Table 22: Number of Health Cases Reduced

Health problems	No. of cases	Health problems	No. of cases
Mortality	319	Respiratory symptom	4,872,822
Hospital admission	346	Chronic bronchitis	1,510
Emergency room visit	5,807	Minor restricted activity days	221,811
Restricted activity days	759,077	Respiratory symptoms among children	14,421
Lower respiratory illness among children	7,013	Respiratory symptoms among adults	266,384
Asthma attacks	87,343		

Source: Author

To measure the economic impacts, there are two ways of measuring. To measure the economic impact of air pollution, the Economic Value per Unit Air Pollution Health Problem method was used. It means that each health cases were converted into monetary unit to value its cost. The result was the provisioning of green space in Jakarta for up to 30% of total Jakarta area had potential economic benefit of **4.1 trillion rupiah, or about 423.7 million US dollar in 2030.**

To measure the economic impact of GHG emissions reduction, the Social Cost of Carbon (SCC) was used. This study uses SSC value from from the 4th IPCC report, with a range of \$4–\$95/tCO_2 in 2007, assuming a 2.4% per year increase, as a minimum and maximum range, and use value of SCC from (Chae and Park, 2011) of US\$12 /tCO_2 as the central value and using national discount rate of 5.75%. After calculating the SCC future value to 2030, for every ton of CO_2 was valued between the range US\$ of 6.9 to US\$ 163.92 per ton of CO_2 with the central value of US\$ 34.71 per ton of CO_2. With the potential reduction of emissions as the effect of additional green scenario of **1,668,132.46 tonnes CO_2e**, the potential economic benefit of additional green space in Jakarta for up to 30% of total Jakarta area is between **11.5 million dollar** to **273.4 million dollar**, or about **110 billion rupiah** to **2.6 trillion rupiah**.

Reflections from the Literature

In total, the potential economic benefit of the provisioning of green space in Jakarta for 30% in 2030 is estimated between **4.2 trillion rupiah** to **6.7 trillion rupiah,** or about **435.2** to **697.1 million US dollar**. By forecasting the local budget of Jakarta in 2030 of 146.75 trillion rupiah, the potential economic benefit of the provisioning of green space in Jakarta for 30% in 2030 is estimated between **2.8 % to 4.6 % of the local budget**. Compare to previous studies, this result had some increase in economic cost. A **1994** study by the World Bank estimated that the economic cost due to air pollution in Jakarta was **IDR 500 billion** (Shah and Nangpal, 1997). A 2002 study in Jakarta funded by the ADB estimated the economic cost due to air pollution in Jakarta at **IDR 1.7 trillion in 1998** and expected the cost to increase to around **IDR 4.2 trillion in 2015** if no action is taken (Syahril, Resosudarmo, et al., 2002).

Table 23: Economic Impacts Comparison to the Results of Previous Studies

In Billion Rupiah				
1994	1998	2015	2030	
World Bank	ADB	Resosudarmo	Author	
			Minimum	Maximum
500	1,700	4,200	4,200	6,700

5.2 Limitations and Further Research

Even though this study brought extensive findings, data, and calculation, and served comprehensive result for making the benefit of green space quantifiable and visible from GHG emissions reduction and air pollutant removal in particular, and other ecosystem benefits in general, this study came not without limitations. Some of the limitations that can be explored are this study use the aggregate of total Jakarta area. Some of the variables for example in air pollutant and air quality level are best explained in more specific location with measured range and boundaries. This study uses aggregate of total Jakarta area because the conclusions that are wanted to be drawn are for the city in total. The reason is that it will have more value and benefit to the Jakarta administrative and to other people that want to use this study to measure all the parameters, indicators, and benefit for a city as a whole. The result can also be compared to previous studies that have been done with Jakarta case (Ostro, 1994; Shah and Nangpal; 1997, Resosudarmo and Napitupulu, 2004). Other limitation is that the results in air pollutants reduction provided by this study is at the minimum level because it only measures the reduction from particular types of green space, due to the limitation of data and factors that were used. Last, even though extensive usage of data from various sources have been taken into account, the scenarios generated in this study did not estimate probability of policy change during the course to 2030, which may lead to differ the results.

Complimentary further research about breaking down the air pollution by grid geographically, taking into account all types of green space to measure the reduction, and policy assessment to propose as another scenario building, if conducted properly, can improve the result which can later be given to the Local and National Government as a basis of policy making in terms of air quality and green space.

This study focused on measuring and quantifying the benefits of green space with regard to air quality improvement and carbon emissions. Other benefits or ecosystem services provided by green space had also briefly explored in this study in general. Complementary research to measure and quantify the benefits of green space in general and in local context in Jakarta is of significant importance to portray a full and complete benefit of urban greening and green space as urban ecosystem.

Other research and studies on policies to reduce the air pollution and GHG emissions problems are also required. Green space is only one example and sector that can slightly reduce those problems. Other policies especially on dealing with the abatement of emissions from the sources are of significant importance. Policy assessment on transportation such as promoting integrated multi-modal public transport (public bus with dedicated bus line, commuter train, Transit Oriented Development (TOD), park-and-ride, and other possible policies), bicycle lane, Electronic Road Pricing (ERP), rejuvenation of public transport's vehicles would be valuable addition. Other policies such as promoting green building, gradual conversion from fossil fuel to gas or renewable energies would also made an important addition.

Two types of additional further researches mentioned above—from measuring and quantifying other ecosystem services provided by the green space, and from investigating possible policies that can help reduce the emissions—if conducted properly, and communicate and integrate the results to the local and national government as the policy maker, can be the answer to construct a roadmap towards sustainable development in Jakarta, as one of dominant target and paradigm as mentioned on Jakarta 2030 Spatial Plan.

5.3 Discussions

Despite those limitations, this study has provided valuable results and findings which can be drawn to fruitful conclusions and discussions. First, it is evident that green space has contributed to provide valuable ecosystem services, two of which (GHG emissions reduction, removal of air pollutant and improve human health), among others, have been comprehensively explored and quantified in this study. Second, air pollution reduction gives a significant health benefits. Therefore air quality improvement policies should be put in high priority. Third, most of the emissions especially for air pollutions are coming from mobile sources or vehicles and industry. In the future, policy that is designed to control from the emission sources is more appropriate. Last, this study can contribute to mainstreaming the sustainable development paradigm in Jakarta by putting environment as a centre of consideration in executing any urban development policies and programs.

This study can also act as discussion for policy formulation related to green space. It is evident that green space provides various benefits and ecosystem services. From quantifying only the air pollutants reduction and GHG emissions reduction, the city might reduce the economic cost for up 4.8% of their budget. Methodology to value and quantify the benefits of green space must be introduced and promoted to be seen as a basis of spatial planning. Make the invisible value of green space become visible, is a way to promote environment as one of the pillars of sustainable development.

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Annex 1: Interview Guidelines

Guiding questions of interviews to experts

1. What is the current level of air quality in Jakarta?
2. How is the trend of air quality in Jakarta?
3. What is the most dominant type of vegetations that were planted in Jakarta green space?
4. What are the average types of vegetations that were planted and will be planted in Jakarta green space?
5. What is the average factor of absorption of air pollutants with urban trees and shrubs in Jakarta green space?
6. What is the average factor of absorption of carbon dioxide with urban trees and shrubs in Jakarta green space?
7. What is the trend of green space area in Jakarta?
8. What are the efforts of green space provisioning in Jakarta since the Jakarta 2030 Plan was enacted?
9. Do you think the Jakarta Provincial Government can meet their target of achieving 20% green space in 2030?
10. What are the restraining factors of implementing the additional green space as in Jakarta 2030 Spatial Plan?
11. Is there any plan for Indonesia to enter the carbon market?
12. What do you think the factors that Indonesia have not entered the carbon market?

Guiding questions of interviews to health agency officer and hospital administrator

1. What is the current price of respiratory hospital admission?
2. What is the trend of price of respiratory hospital admission for the last five years?
3. What is the current price of emergency room visit?
4. What is the trend of price of emergency room visit for the last five years?
5. What is the current price of lower respiratory illness treatment for children (outpatient care)?
6. What is the trend of price of lower respiratory illness treatment for for children (outpatient care) for the last five years?
7. What is the current price of asthma symptoms treatment?
8. What is the trend of price of asthma symptoms treatment for the last five years?
9. What is the current price of respiratory symptoms treatment for adults?
10. What is the trend of price of respiratory symptoms treatment for adults for the last five years?
11. What is the current price of respiratory symptoms treatment for children?
12. What is the trend of price of respiratory symptoms treatment for children for the last five years?
13. What is the current price of chronic bronchitis treatment for children?
14. What is the trend of price of chronic bronchitis treatment for children for the last five years?

Annex 2: Thesis Workplan

No	Activities	Time Frame																																		
		February				March					April				May				June					July				August					September			
		1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	5	1	2	3	4
I	Preparation																																			
1	Thesis Proposal		■																																	
2	Supervisors assigned					■																														
3	Initial literature review						■	■																												
4	Discussion of Chapter 1 and initial review								■			■																								
5	Review of literature												■	■	■																					
6	Development of conceptual framework													■	■																					
7	Colloqium 2														■																					
8	Submission of Chapter 2															■																				
9	Discussion of Chapter 1 and 2															■	■																			
10	Preparation of thesis methodology																■	■																		
11	Submission of Chapter 3																	■																		
12	Submission of second research proposal																	■																		
13	Final research proposal																		■																	
II	Pre-Survey																																			
1	Finalizing the methodologies																		■	■																
2	Preparation, testing, and finalization of survey																			■																
III	Data Collection, Processing and Analysis																																			
1	Survey																			■	■	■														
2	Data cleaning and checking of survey's results																					■	■													
3	Data input and processing																							■	■											
4	Analysis																							■	■	■										
IV	Thesis Writing																																			
1	Preparation of draft thesis																										■	■	■	■	■					
2	Submission of draft thesis																														■	■	■			
3	Submission of final thesis																																■	■		

Annex 3: Data and Tables

Final energy consumption by sector in year 2005

Types of Energy	Unit	Sector				
		Household	Industry	Transport	Commerce	Others
Avtur	kL	0	0	8.508	0	0
Avgas	kL	0	0	10.889	0	0
Petrol	kL	0	3.341	1.845.268	0	0
Biopremium	kL	0	0	0	0	0
Kerosene	kL	776.337	11.903	0	0	0
Diesel	kL	0	139.791	755.170	28.752	0
Biodiesel	kL	0	0	0	0	0
Diesel Oil	kL	0	17.286	2.960	0	0
Burning Oil	kL	0	81.792	82.858	0	0
Coal	kg	0	2.216.810	0	0	0
LPG	ton	226.487 [c)]	95.276 [b)]	183	0	0
Natural Gas	MMCF	365 [e)]	61.997 [e)]	194 [f)]	0	0
Electricity	GWh	5.918	5.677	81	5.052	1.197

Source: (Regulation of Jakarta Special Capital Region Number 131 year 2012 concerning Local Action Plan of Green House Gases Reduction, 2012)

Total Energy Consumption Sub-sector Transportation, year 2005

Energy sources	Unit	Total	Energi (PJ)	Transport Sub-sector
Avtur	kL	8.508	0,3792	Air
Avgas	kL	10.889	0,2775	Air
Gasoline	kL	1.845.268	60,1943	Land
Diesel	kL	755.170	27,1866	Land
Diesel	kL	2.960	0.1094	Water
Kerosene	kL	82.858	3,2029	Water
LPG	kg	183	0,0085	Land
Natural Gas	MMCF	194	0,2003	Land
Listrik	GWh	81	0,2917	Land

Source: Local Action Plan for GHG Emissions Reduction

Number of Vehicles in Jakarta, year 2000 – 2010

Year	Passenger Car	Bus	Motor-cycle	Three Wheeler	Transport vehicle	Special Vehicle*	Total
2000	633,002	15,121	1,044,669	14,543	167,923	12,424	1,887,682
2001	690,841	15,837	1,173,151	14,544	181,008	12,831	2,088,212
2002	740,019	16,413	1,354,113	14,563	194,344	13,225	2,332,677
2003	813,871	16,987	1,623,331	14,762	211,120	13,749	2,693,820
2004	967,539	17,819	1,990,393	14,851	236,006	14,245	3,240,853
2005	1,074,739	18,511	2,378,209	14,853	258,043	15,247	3,759,602
2006	1,152,566	19,598	2,740,452	15,235	272,038	15,898	4,215,787
2007	1,275,284	20,407	3,109,395	15,680	287,619	16,856	4,725,241
2008	1,273,498	19,088	3,370,100	15,489	276,895	16,879	4,971,949
2009	1,295,739	19,644	3,724,816	15,570	280,595	18,008	5,354,372
2010	1,373,287	20,257	4,196,587	15,580	295,250	19,893	5,920,854

Source: Local Action Plan for GHG Emissions Reduction

Characteristics of WWTP Pulogebang and Duri Kosambi

Characteristics	Unit	Amount	
		Pulogebang	Duri Kosambi
Waste water volume	m^3/month	9.000	9.000
COD inlet	Ton/m^3	4,69 x 10^{-3}	4,285 x 10^{-3}
COD outlet	Ton/m^3	6,80 x 10^{-5}	5,66 x 10^{-5}
Volume of treated waste water	m^3	7.850	7.857
Volume of dry material in the sludge to be processed	Ton	1725*	1714,5*
Volume of dry material in the sludge treated	Ton	820	873

Source: Local Action Plan for GHG Emissions Reduction

Characteristics of WWTP Setiabudi Barat and Setiabudi Timur

Description	Setiabudi Barat	Setiabudi Timur
Surface area (m^2)	26.100	17.400
Highest level of waste water (m)	4.5	4.7
Lowest level of waste water (m)	1.5	1.5
Depth (m)	3	3.2
Ground elevation of reservoir (m)	-0.5	-0.5
Storage capacity (m^3)	78.300	55.680
Waste water volume (m^3/tahun)	11,9 Juta	7,7 Juta
COD inlet (kg COD/m^3)	2,812	
COD outlet (kg Cod/m^3)	0,941	

Source: Local Action Plan for GHG Emissions Reduction

Green Space in Jakarta, 2010

No	Green Space	2010 (hectares)
A	**Parks and Fields**	
1	Urban parks/neighbourhood parks	924.38
2	Toll Road (median)	1,317.27
3	Sports field	498.55
4	Cemetery	679.68
5	green space in residential area	837.62
6	Cultural heritage site	1,083.98
	Sub total	**5,341.48**
B	**Agriculture**	
1	Garden	97.82
2	Agricultural area	308.00
3	Horticulture	393.58
	Sub total	**799.40**
C	**Forest**	
1	Land conservation area	25.25
2	Island conservation area	170.87
3	Protected forest	44.76
4	Eco-tourism forest	99.82
5	Electrical Transmission Networks Green Space	47.40
6	Urban forest	400.00
7	river basin and coastal green space	856.02

No	Green Space	2010 (hectares)
8	Special-use green space	115.00
9	Island green space	190.00
	Sub total	**1,949.12**
	Total	**8,090.00**

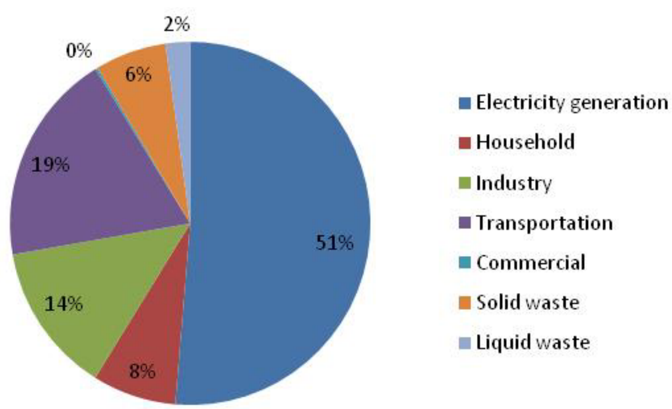
Source: Jakarta Planning and Development Office; Jakarta Environmental Management Agency; Jakarta Parks Office; Jakarta Marine and Fishery Office

GHG Emissions in Jakarta, 2005 baseline year

Sector	GHG Emission (m tCO_2 eq.)	Per capita (tCO_2 eq./cap)
Electricity generation	17.79	1.97
Household	2.6	0.52
Industry	4.66	0.29
Transportation	6.57	0.73
Commercial	0.08	0.01
Solid waste	2.21	0.24
Liquid waste	0.76	0.08
Total	**34.67**	**3.84**

Source: (Regulation of Jakarta Special Capital Region Number 131 year 2012 concerning Local Action Plan of Green House Gases Reduction, 2012)

Distribution of GHG Emissions per Sector in 2005



Source: (Regulation of Jakarta Special Capital Region Number 131 year 2012 concerning Local Action Plan of Green House Gases Reduction, 2012)

Emissions per capita Jakarta and Indonesia in 2005

Sector	Emissions per capita (tCO_2e/kapita)	
	Jakarta	National
Energy	3.51	1.81
Waste	0.33	0.71
Total (without AFOLU)	3.84	2.52

Source: Local Action Plan for GHG Emissions Reduction

World Cities' GHG Emissions (without AFOLU)

City	Emissions per capita (tCO_2e/capita)	Base Year
Washington DC	19.70	2005
Calgary	17.70	2003
Shanghai	11.70	2006
Toronto (metro)	11.60	2005
Bangkok**	10.70	2005
Beijing	10.10	2006
Brussels	7.50	2005
New York	7.10	2005
Helsinki	7.00	2005
London	6.20	2006
Paris	5.20	2005
Tokyo	4.89	2006
Seoul	4.10	2006
Jakarta (2005)	**3.84**	2005
Buenos Aires	3.83	2000
Amman	3.25	2008
Rio de Janeiro	2.10	1998
Colombo	1.54	1995
Delhi	1.50	2000
Sao Paulo	1.50	2003
Dhaka	0.63	1994

Source: Author, adapted from Dodman (2009) in UN-HABITAT (2011); and Local Action Plan for GHG Emissions Reduction

Air Pollution from Stationary Source (1), Industry and Processes

Industry and Processes	Unit	Production	Dust		SO_2		NO_2		HC		CO		Others		
		(.000 unit/yr)	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit		tonnes/yr
(01)	(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Food Industry															
3114 Fish Cannery	ton	4.16	0.05	0.21										H_2S	
3115 Animal and Plant Oil Extraction	ton	136.18													
3116 Grain Processing	ton		8.80												
3116a Sugar Cane Factory	ton		20.00												
3121a Cane and Glucose Factory	ton	17.50	4.00	69.98											
Beverage Industry															
3133c Total Beer Production	ton		4.00												
Textile Industry															
3211c Cotton	ton	47.63	14.00	666.78											
Wood Industry															
3311a Plywood Industry	sheet	16.78					1.20	128.14							
Paper Industry															
3411a Pulp Sulfit Kraft															
(i) Without Pollution Control	ton		123.00		25.00				35.00				7.20	H_2S	
(ii) With Scrubber	ton		27.00		25.00				35.00				7.20	H_2S	
3411b Pulp Sufit															
(i) Without Pollution Control	ton														
(ii) With Scrubber	ton														
3411c Semi-Chemical Pulp															
(i) Without Pollution Control	ton														
(ii) With Scrubber	ton														

Industry and Processes		Unit	Production	Dust		SO_2		NO_2		HC		CO		Others		
			(.000 unit/yr)	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit		tonnes/yr
(01)		(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Basic Chemical Industry															
3511	Anorganic Chemical	ton	199.76													
3511a	Acid Chloride															
(i)	Without Pollution Control	ton												3.00	HCl	
(ii)	With Pollution Control	ton												2.00	HCl	
3511b	Sulfit Acid	ton	61.80				20.00	1,236.02								
3511c	Nitric Acid															
(i)	Without Pollution Control	ton							26.20							
(ii)	With Pollution Control	ton							2.50							
3511d	Phosphate Acid (wet process)	ton												20.10	Fluoride	
3511f	Phosphate Acid (thermal process)	ton		5.10												
3511g	Amonia	ton								45.00				101.00	NH_3	
3511h	Sodium Hidroxide (mercury cell)															
(i)	Without Control	ton Cl_2												306.00	Cl_2	
(ii)	With Water Absorbent	ton Cl_2												8.50	Cl_2	
3511i	Sodium Hidroxide (diaphragm cell)															
(i)	Without Control	ton Cl_2												60.00	Cl_2	
(ii)	With Water Absorbent	ton Cl_2												11.00	Cl_2	
3512	Fertilizer															
3512a	Normal Superphosphate	ton		4.50										0.08	Fluoride	
3512b	Triple Superphosphate	ton												0.02	Fluoride	
3512c	Amonium/Diamonium Phosphate	ton		41.00										0.02	Fluoride	

Industry and Processes		Unit	Production	Dust		SO_2		NO_2		HC		CO		Others		
			(.000 unit/yr)	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit		tonnes/yr
(01)		(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
3512e	Nitric Fertilizer (NH_3 + HNO_3)	ton		5.00				2.00						1.50	NH_3	
3512f	Urea	ton		10.00		0.70		2.00						5.00	NH_3	
3513	Synthetic Resin, Plastic, Fibre															
3513a	Rayon Fibre	ton												27.50	CS_2	
														3.00	H_2S	
3513b	Synthetic Rubber															
(i)	Butadium	ton								20.00						
(ii)	Others	ton								5.00						
3513e	Resin Vynil (PVC)	ton	88.04	17.00	1,496.71					3.50	308.15					
3521	Paint, Varnish, Lacquer															
3521a	Paint															
(i)	Paint Manufacturing	ton	24.74	1.00	24.74					15.00	371.10					
(ii)	Surface Coating	ton	2.42							560.00	1,354.91					
3521b	Varnish															
(i)	Paint Manufacturing	ton	1.25							40.00	50.20					
(ii)	Surface Coating	ton	0.30							500.00	150.00					
3521c	Lacquer, Surface coating	ton								770.00						
3523	Soap and Cleaning Material															
3523c	Detergent															
(i)	Without Control	ton		45.00												
(ii)	With "Dry Cyclone"	ton	452.24	4.00	1,808.96											
3530	Oil Refinery (desulfurization unit production) (a)	kg S that are separated														

Industry and Processes		Unit	Production	Dust		SO_2		NO_2		HC		CO		Others		
			(.000 unit/yr)	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit		tonnes/yr
(01)		(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Additional emission process from old refinery	m | raw material								2.50						
	Additional emission process from new refinery	m | raw material								1.54						
	Container Tank Emission:															
	Gasoline refining	m | capacity								12.10						
	Jet fuel refining	m | capacity								4.40						
	Kerosene refining	m | capacity								1.90						
	Distillation of petroleum	m | capacity								1.90						
	Crude oil refining	m | capacity								10.60						
3540	Asphalt Production															
3540a	Road Asphalt	ton		22.00												
3540b	Roof Asphalt	ton		2.30						0.80		0.50				
	Non-Metalic Minerals Industry															
3610	Ceramics and Earthenware	ton		65.00												
3620	Glass and Processed Glass	ton	20.15	1.00	20.15											
3691	Building materials from clay	ton	3.85	65.00	250.02									10.00	F_2	38.46
3710c	BOF Steel Furnace															
(i)	Without Control	ton		25.50								69.50		0.10	CaF_2	
(ii)	With Spraying Chamber	ton		7.65										0.03	CaF_2	
(iii)	With Venturi	ton		0.26										0.01	CaF_2	
3710d	Open Steel Furnace															
(i)	Without Control	ton		8.70										0.02	CaF_2	
(ii)	With Electrostatic Precipitator	ton		0.18										0.01	CaF_2	

Industry and Processes		Unit	Production	Dust		SO_2		NO_2		HC		CO		Others		
			(.000 unit/yr)	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit		tonnes/yr
(01)		(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(iii)	With Venturi	ton		0.09										0.01	CaF_2	
3710e	Steel furnaces with electric arc furnace															
(i)	Without Control	ton		5.50								9.00		0.12	CaF_2	
(ii)	With Electrostatic Precipitator	ton		0.30								9.00		0.01	CaF_2	
(iii)	With Venturi	ton		0.11								9.00		0.01	CaF_2	
3710f	Iron and Steel Foundry	ton	21.77	8.50	185.05							72.50				
3720	Non-ferrous metal basic industries															
3720a	Aluminium (from bauxite)															
(i)	Without Control	ton		295.00										26.10	HF	
(ii)	With spraying tower	ton		83.30										14.10	HF	
3720c	Secondary aluminum smelting	ton	37.97	2.15	81.63											
3720d	Refining of copper from sulfide ores	ton		270.00												
3720g	Brass and bronze foundry	ton		30.00												
3720h	Lead ore smelting	ton		300.00		297.00										
3720i	Secondary zinc smelting															
(i)	Without Control	ton		65.00		43.00										
(ii)	With Control	ton		1.60		43.00										
3720j	Primary lead smelting and refining															
3720k	Primary zinc smelting	ton	0.04	300.00	12.78	1,100.00	46.86									
3720l	Secondary zinc processing	ton		50.00												
	Metal processing products															
3840a	Household appliances	ton steel plate	9.70							16.20	157.10					
3843b	Car indsutry	ton steel plate	800.27							16.20	12,964.35					

Industry and Processes	Unit	Production	Dust		SO_2		NO_2		HC		CO		Others		
		(.000 unit/yr)	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit		tonnes/yr
(01)	(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Electricity and Gas															
4101 Energy generator															
4102 Manufacturing of coke gas	ton coals		1.75		2.01		0.20		2.10		0.63		0.09	NH_3	
4102 Manufacturing of coke gas	ton coke		2.50		2.90		0.30		3.00		0.90		0.12	NH_3	
4102 Manufacturing of coke gas	thousand m | gas		3.75		3.41		0.40		4.50		1.35		0.19	NH_3	
TOTAL		1,946.55		4,617.01		66.86		156.84		15,355.81		0.00			38.46

Source: State of Jakarta Environment 2012

Air Pollution from Stationary Source (2), Waste Incineration

Incinerating Process	Unit	Solid waste	Dust		SO_2		NO_2		HC		CO		CO_2	
		(.000 unit/yr)	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr
(01)	(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	(13)	(12)	(13)
Municipal waste incineration														
(i) without control	ton		15.00		1.25		1.50		0.75		17.50			
(ii) with water spraying system	ton		7.00		1.25		1.50		0.75		17.50			
Industrial/commercial waste incineration	ton		7.50		1.25		1.00		7.50		10.00			
Open incineration of municipal waste	ton	237.25	8.00	1,898.00	0.50	118.63	3.00	711.75	15.00	3,556.75	42.00	9,964.50		
TOTAL		237.25		1,898.00		118.63		711.75		3,556.75		9,964.50		0.00

Source: State of Jakarta Environment 2012

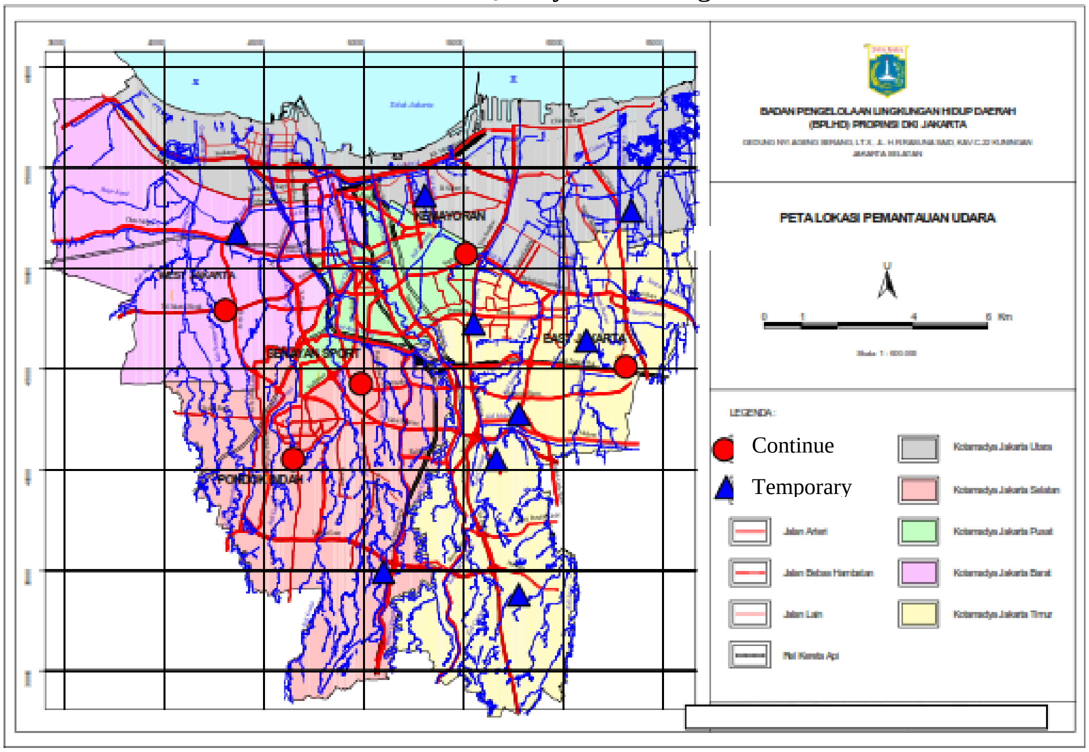
Air Pollution from Mobile Source (Transportation)

Types of Vehicle	Fuel	Unit	Consumption	Dust		SO_2		NO_2		HC		CO		CO_2	
			(.000 unit/yr)	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr
(01)	(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	(13)	(14)	(15)	(16)

Types of Vehicle	Fuel	Unit	Consumption	Dust		SO_2		NO_2		HC		CO		CO_2	
			(.000 unit/yr)	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr	kg/unit	tonnes/yr
(01)	(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Cars and Truck	Gasoline	ton	1,678,946.40	2.00	3,357,892.80	0.50	906,631.10	10.30	17,293,147.90	14.50	24,344,722.80	377.00	632,962,792.80	3,150.00	5,288,681,160.00
	Diesel	ton	470,412.80	2.40	1,128,990.70	19.00	8,937,843.20	11.00	5,174,540.80	2.60	1,223,073.30	43.50	20,462,956.80	3,150.00	1,481,800,320.00
Wide Body Jetplane				2.00		3.00		50.00		19.00		74.00		4,485.00	
Other long range jet				2.00		3.00		14.00		75.00		86.00		5,210.00	
Medium range jet		(number of take-off and landing)		0.50		1.00		11.00		5.00		18.00		1,150.00	
Turbo plane				1.50		0.50		3.00		4.00		9.00		546.00	
Business Jet			358.15	0.30	107.40	0.20	71.60	1.60	573.00	1.50		4.20	1,504.20	255.00	91,329.00
Aviation Piston				0.01		0.00		0.00		0.20		5.50		330.00	
Steam-powered ship on port		days		6.80		136.00		90.70		4.10		0.00		20.00	
Motor-powered ship on port		days		7.50		19.50		22.70		14.90		20.80		726.00	
Petroleum turbine	Petroleum	ton		0.77		20.10		9.70		0.80		2.20		2,950.00	
Gas turbine	Natural Gas	.000 m^3		0.27		15.50		6.60		0.70		1.80		2,750.00	
TOTAL			2,149,717.35		4,486,990.90		9,844,545.90		22,468,261.70		25,567,796.10		653,427,253.80		6,770,572,809.00

Source: State of Jakarta Environment 2012

Location of Air Quality Monitoring Station



Source: State of Jakarta Environment, 2012

PM_{10} concentration ($\mu g/m^3$) 24-hour mean

Year	PM_{10}	PM_{10} Jkt Std	PM_{10} WHO Std
2005	68.5	150	50
2006	74.07	150	50
2007	58.34	150	50
2008	53.92	150	50
2009	52.01	150	50
2010	48.88	150	50
2011	67.89	150	50
2012	73.41	150	50

Source: State of Jakarta Environment, 2012

NO_2 concentration ($\mu g/m^3$) 24-hour mean

Year	NO_2	NO_2 Jkt Std
2005	36	92.5
2006	32.58	92.5
2007	24.35	92.5
2008	23.92	92.5
2009	22.2	92.5
2010	20.22	92.5
2011	37.14	92.5
2012	37.35	92.5

Source: State of Jakarta Environment, 2012

SO_2 concentration (μg/m^3) 24-hour mean

Year	SO_2	SO_2 Jkt Std	SO_2 WHO Std
2005	29.2	260	20
2006	27.54	260	20
2007	28.18	260	20
2008	56.81	260	20
2009	58.62	260	20
2010	46.15	260	20
2011	17.69	260	20
2012	21.16	260	20

Source: State of Jakarta Environment, 2012

O_3 concentration (μg/m^3) annual mean

Year	O_3	O_3 Jkt Std
2001	35.2	30
2002	50.87	30
2003	54.99	30
2004	60.49	30
2005	56.98	30
2006	56.98	30
2007	52.6	30
2008	49.24	30
2009	dna	30
2010	dna	30
2011	66.90	30
2012	98.96	30

Source: State of Jakarta Environment, 2012; State of Jakarta Environment, 2011; CAI-Asia, 2010
Note: 2009 and 2010 data not available

Air Pollutant Index (API) Description in Jakarta

Range	**Description**
0-50	Level of air quality that does not give effect to human's health or animals and no effect on plants, buildings, or aesthetic value
51-100	Level of air quality that does not give effect to human's health or animals but gives effect on sensitive plants and aesthetic value
101-199	Level of air quality that is detrimental to the health of sensitive people or groups of animal, or may cause damage to plants or aesthetic value
200-299	Level of air quality that is harmful to human's health for a certain exposed population
>300	Level of air quality that in general is dangerous and may cause serious health problems to all exposed population

Source: Minister of Environment Decree Number: KEP-45/MENLH/10/1997 concerning Standard of Air Quality Index

Average Annual Population Growth Rate

Year	Growth Rate (%)
2005-2010	1.38
2011-2015	1.67
2016-2020	2.11
2021-2025	1.94
2026-2030	1.94

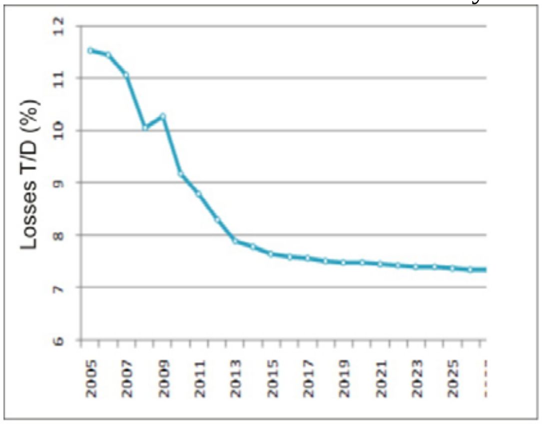
Source: UN-DESA

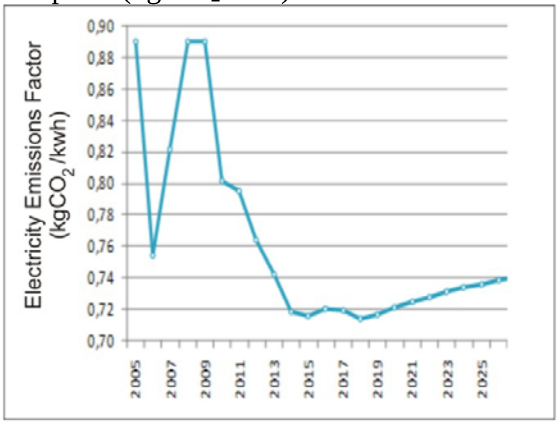
Population Projection in Jakarta

Year	Population	Year	Population	Year	Population
2005	8,540,306	2014	10,149,216	2023	11,900,186
2006	8,961,680	2015	10,289,276	2024	12,151,280
2007	9,064,591	2016	10,461,107	2025	12,407,672
2008	9,146,111	2017	10,635,807	2026	12,648,381
2009	9,223,000	2018	10,813,425	2027	12,893,759
2010	9,607,787	2019	10,994,009	2028	13,143,898
2011	9,740,374	2020	11,177,609	2029	13,398,890
2012	9,874,792	2021	11,413,457	2030	13,658,828
2013	10,011,064	2022	11,654,281		

Source: Author

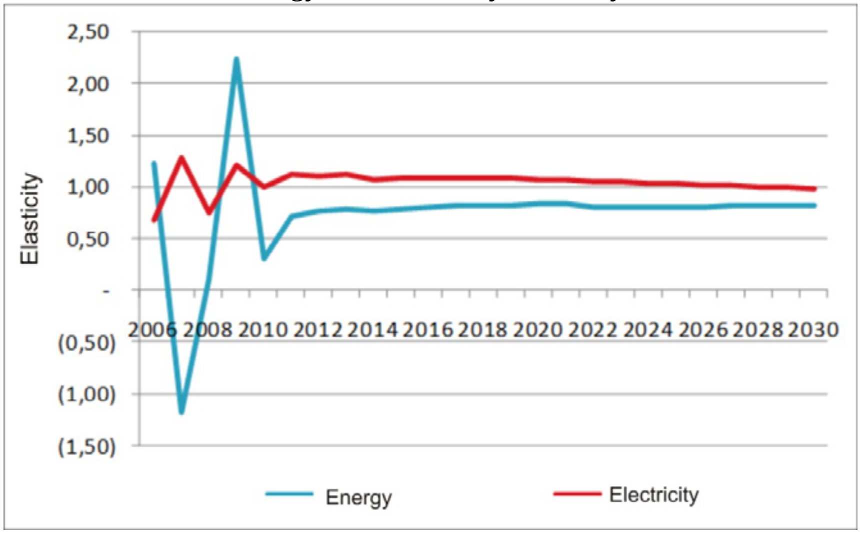
Projection of Losses T/D Electricity System Java-Bali (%) and Emissions Factor of Electricity Consumption (kg CO_2/kwh)





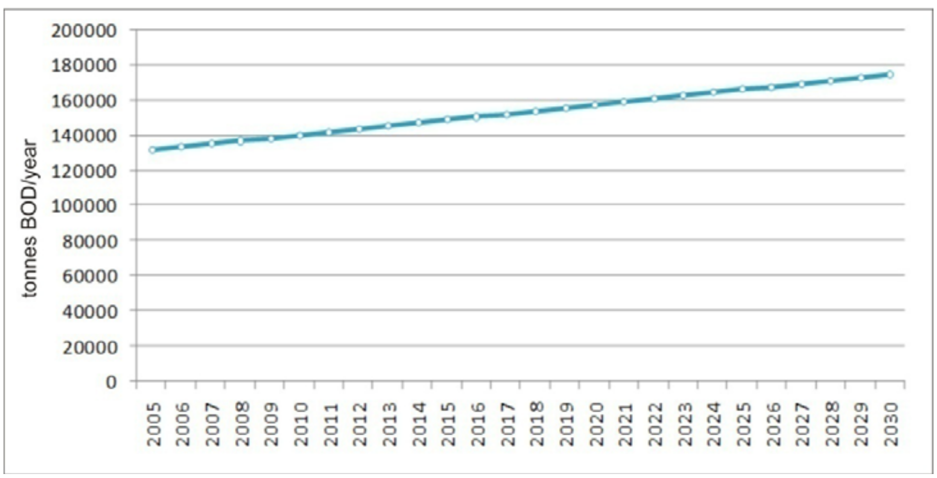
Source: Local Action Plan for GHG Emissions Reduction

Energy and Electricity Elasticity



Source: Local Action Plan for GHG Emissions Reduction

Projected Production of BOD Domestic Wastewater



Source: Local Action Plan for GHG Emissions Reduction

Projection of Air Pollutants to 2030

Year	PM10	PM10 Jkt	PM10 WHO	SO2	SO2 Jkt	SO2 WHO	NO2	NO2 Jkt	NO2 WHO*	O3	O3 Jkt	O3 WHO*
2001	-	-	-	-	-	-	-	-		35.2	30	100
2002	-	-	-	-	-	-	-	-		50.87	30	100
2003	-	-	-	-	-	-	-	-		54.99	30	100
2004	-	-	-	-	-	-	-	-		60.49	30	100
2005	68.50	150	50	29.20	260	20	36.00	92.5	40.0	56.98	30	100
2006	74.07	150	50	27.54	260	20	32.58	92.5	40.0	56.98	30	100
2007	58.34	150	50	28.18	260	20	24.35	92.5	40.0	52.6	30	100
2008	53.92	150	50	56.81	260	20	23.92	92.5	40.0	49.24	30	100
2009	52.01	150	50	58.62	260	20	22.20	92.5	40.0		30	100
2010	48.88	150	50	46.15	260	20	20.22	92.5	40.0		30	100
2011	67.89	150	50	17.69	260	20	37.14	92.5	40.0	66.90	30	100

Year	PM10	PM10 Jkt	PM10 WHO	SO2	SO2 Jkt	SO2 WHO	NO2	NO2 Jkt	NO2 WHO*	O3	O3 Jkt	O3 WHO*
2012	73.41	150	50	21.16	260	20	37.35	92.5	40.0	98.96	30	100
2013	76.83	150	50	21.65	260	20	39.09	92.5	40.0	103.56	30	100
2014	80.40	150	50	22.15	260	20	40.90	92.5	40.0	108.38	30	100
2015	84.14	150	50	22.66	260	20	42.81	92.5	40.0	113.41	30	100
2016	88.05	150	50	23.19	260	20	44.80	92.5	40.0	118.69	30	100
2017	92.15	150	50	23.73	260	20	46.88	92.5	40.0	124.21	30	100
2018	96.44	150	50	24.28	260	20	49.06	92.5	40.0	129.98	30	100
2019	100.92	150	50	24.84	260	20	51.34	92.5	40.0	136.02	30	100
2020	105.62	150	50	25.41	260	20	53.73	92.5	40.0	142.35	30	100
2021	110.53	150	50	26.00	260	20	56.22	92.5	40.0	148.96	30	100
2022	115.68	150	50	26.61	260	20	58.84	92.5	40.0	155.89	30	100
2023	121.06	150	50	27.22	260	20	61.57	92.5	40.0	163.14	30	100
2024	126.69	150	50	27.85	260	20	64.43	92.5	40.0	170.72	30	100
2025	132.58	150	50	28.50	260	20	67.43	92.5	40.0	178.66	30	100
2026	138.75	150	50	29.16	260	20	70.57	92.5	40.0	186.97	30	100
2027	145.21	150	50	29.83	260	20	73.85	92.5	40.0	195.66	30	100
2028	151.96	150	50	30.52	260	20	77.28	92.5	40.0	204.75	30	100
2029	159.03	150	50	31.23	260	20	80.87	92.5	40.0	214.27	30	100
2030	166.43	150	50	31.96	260	20	84.63	92.5	40.0	224.24	30	100

Source: Author

Cost of Hospitals and Medical Treatment

No.	Hospital	In Rupiah													
		Lung Specialist	Type of Hospital	Emergency Fee (doctor only)	Cost					Average room cost	Types and Cost of Treatment			
					SVIP	VIP	Class I	Class II	Class III		Bronchitis	Respiratory	Lower Respiratory	Ashtma
1	RS. Harapan Bunda	125,000	Private	60,000	825,000	725,000	400,000	305,000	140,000	412,330	Nebulizer+Diametri: 130,000	Nebulizer: 90.000	Nebulizer: 90.000	Nebulizer: 90.000
2	RS. Marinir Cilandak	80,000	State-Owned	60,000	425,000	300,000	225,000	150,000	90,000	155,101	Nebulizer+Heat: 120,000	Nebulizer: 80.000	Nebulizer: 80.000	Nebulizer: 80.000
3	RS. Siaga Raya	200,000	Private	99,000	1,000,000	750,000	350,000	200,000	100,000	525,000	Nebulizer: 60.000	MWD: 100,000	Nebulizer: 60.000	Nebulizer: 60.000
4	RS. ASRI	200,000	Private	100,000	2,000,000	1,300,000	600,000	400,000	200,000	857,143	Nebulizer+Heat: 130,000	Steam: 130,000	Steam: 130,000	Steam: 130,000
5	RS. Tria Dipa	140,000	Private	60,000	-	750,000	500,000	350,000	150,000	413,441	Nebulizer+Diametri +Rontgen+Therapy: 340,000	Steam: 85,000	Steam: 85,000	Steam: 85,000
6	RS. Jakarta Medical Center	187,500	Private	87,500	775,000	725,000	300,000	200,000	100,000	269,737	Nebulizer+Heat: 95,000	Nebulizer+Heat: 95,000	Nebulizer+Heat: 95,000	Nebulizer+Heat: 95,000
7	RS. Medistra	400,000	Private	100,000	4,300,000	1,350,000	700,000	400,000	180,000	959,612	Nebulizer: 200.000	Nebulizer: 200.000	Nebulizer: 200.000	Nebulizer: 200.000
8	RS. Tebet	240,000	Private	110,000	1,050,000	760,000	400,000	300,000	130,000	436,602	Nebulizer: 50.000	Nebulizer: 50.000	Nebulizer: 50.000	Nebulizer: 50.000

Source: Survey

Number used in Cost of Health Problems

No.	Hospital	In Rupiah															
		Cost of Health Problems															
		RHA	**Number used**	**ERV**	**Number used**	**AA**	**Number used**	**LRI**	**Number used**	**RS**	**Number used**	**CB**	**Number used**	**CD**	**Number used**	**PM**	**RAD**
1	RS. Harapan Bunda	1,464,660		210,000		215,000		215,000		215,000		255,000		340,000			
2	RS. Marinir Cilandak	850,203		210,000		160,000		160,000		160,000		200,000		240,000			
3	RS. Siaga Raya	1,850,000		249,000		260,000		260,000		300,000		260,000		500,000			
4	RS. ASRI	2,644,286	960,650	250,000	212,807	330,000	175,464	330,000	175,464	330,000	176,036	330,000	215,679	530,000	269,357	1,302,000,000	188,483
5	RS. Tria Dipa	1,491,882		210,000		225,000		225,000		225,000		480,000		365,000			
6	RS. Jakarta Medical Center	1,309,474		237,500		282,500		282,500		282,500		282,500		470,000			
7	RS. Medistra	3,219,223		250,000		600,000		600,000		600,000		600,000		1,000,000			
8	RS. Tebet	1,703,204		260,000		290,000		290,000		290,000		290,000		530,000			

Source: Survey