Study on Urban Energy Consumption in Padang City of Indonesia: System Dynamics Modeling Approach

(インドネシア・パダン市における都市エネルギー消費に関する研究)

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Abstract

Indonesia with a population of more than 241 million, or the fourth largest country in the world, challenges to achieve energy sustainability. Furthermore, as a developing country, Indonesia faces rapid economic growth. With real gross domestic product (GDP) reached at the average of 6.5% per year during the last 5 years, Indonesia has to address the increasing energy demands for growing economies, as well as address the potential impact of emissions and climate change. To fight against climate change and increases of energy consumption, particularly fossil fuels, urban sectors should be put on the priority.

The main objective of this research is to analyze the urban energy consumption and emission in the city of Indonesia. This objective further follows to several investigations, which are thus (a) based on the case study of Padang, to investigate the residential energy consumption, (b) based on best practice from other countries, to investigate the opportunities to reduce electricity consumption that can be applied in Indonesia, (c) based on existing condition of energy consumption and emission trends in Indonesia, to develop a model to investigate the fuel consumption and emission impact in the road transportation of local city of Indonesia, and (d) based on best practice from other countries, to investigate the opportunities to reduce fuel consumption and emissions that can be applied in Indonesia.

From the study on residential energy consumption under Chapter 2, it was found that lifestyles and daily life activities of household members will have a positive impact on energy consumption and emissions level. Although this topic has been widely discussed, most studies focus on developed countries. As one of the developing countries, very few studies were found discussing the residential energy consumption in Indonesia.

Despite that there are many of energy saving technologies being widely used; the problem is in the “bad habits” of household members in the use of technology. Therefore, this study used cross-section analysis and on-site measurement methods that were focused on each household’s lifestyle using life schedule data. This study stressed the investigation of lifestyle and residential energy consumption based on the ownership of home appliances, income levels, occupations, family patterns and different residential areas

In view of finding from Chapter 2 and the fact that currently Indonesia still facing the energy crisis, the purposes of this Chapter 3 is to investigate the opportunities to reduce electricity consumption. The study emphasizes the cities` action around the world that has approached the challenge of controlling and reducing the residential electricity consumption.

In Chapter 3, we explore the “unwisely habits” of household`s lifestyle that unconsciously wasting electrical energy. Leaving the lights on during the daytime, leaving the “appliances on” while not used, low awareness of environmental impacts still being “unwisely habits” that should be changed.

In chapter 4, a practical and reliable method to predict fuel consumption and emission level by using System Dynamics was developed in line with limited availability and supporting data. The model was estimated the fuel consumption and emissions data for the case of Padang city, one of the fastest growing cities in Indonesia. Results show that Padang, with the existing vehicles` growth rate, the total fuel consumption and emissions only from road transportation is predicted to be 65 times higher than that of 2013. From the above test scenarios, it is concluded that the main driving forces of road fuel consumption and emissions is the private vehicles which include passenger cars and motorcycles. Hence, these results should be prioritized in the future context to reduce private vehicle usage and encourage people to move to public transportation. Nevertheless, an integrated public transportation system is one of the key points to reduce fuel consumption and emissions from road transport.

Every country has taken differences action towards controlling fuel consumption and emissions. The Government of Indonesia commits to reduce a greenhouse gas emissions by 26% by own efforts and reach 41% if received international assistance in 2020 from the condition without an action plan. Increasing of energy consumption, particularly energy from fossil fuel has responsible for the increased concentration of air pollution in urban areas. Hence, in the Chapter 5, several strategies that have been taken by government around the world to reduce fuel consumption and emission from road transport were observed. Clean fuels, tighter emission standard for vehicles, tax incentive and other emission regulation were executed in order to achieve the reduction goals. Indonesia and local city can gain from the existing international experience of taking potential actions to reduce fuel consumption and emissions level in the future.

As a growing city, Padang will certainly face the same problems with the big cities, so with these studies expected to be input for making long term sustainable planning programs. Effort only local government is not enough, but regardless of all cities, society, center government, and also other countries must work together to change our lifestyle to save energy and to reduce emissions for future generation.

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Studies on Urban Energy Consumption in Padang City of Indonesia: System Dynamics Modeling Approaches

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Abbreviation

BTU	British Thermal Unit
BOE	Barrel Oil Equivalent
GDP	Gross Domestic Product
p.a	Per annum
TFR	Total Fertility Rate
LPG	Liquefied Petroleum Gas
VA	Volt Ampere
kWh	Kilowatt-hours
TJ	Tetra Joule
GHG	Greenhouse gases
CO2	Carbon dioxide
CH4	Nitrous oxide
CO	Carbon oxide
HC	Hydrocarbon
PM	Particulate matter
SO2	Sulfur dioxide
BOE	Barrel of oil equivalent
ADO	Automotive diesel oil
IDO	Industrial diesel oil
FO	Fuel oil
BRT	Bus rapid transit
UNFCCC	United Nations framework convention on climate change
RAN-GRK	Rencana aksi nasional-Gas rumah kaca (In Indonesia) or National action plan for reduction emissions of greenhouses gases
TIC	Traffic impact control
MEMR	Ministry of energy and mineral resource
MoE	Ministry of environment
MoT	Ministry of transportation

List Publications and Conferences Papers

Journals:

1. Iwan Sukarno, Hiroshi Matsumoto, Lusi Suanti, Ryushi Kimura. Urban Energy Consumption in City of Indonesia: General Overview, International Journal of Energy Economics and Policy, Vol. 1, pp.360-373, 2015.
2. Iwan Sukarno, Hiroshi Matsumoto, Lusi Susanti. Transportation Energy Consumption and Emissions - A View from City of Indonesia, Future Cities and Environment, Vol. 2, No. 6, 2016. DOI 10.1186/s40984-016-0019-x

International Conferences:

1. Iwan Sukarno, Hiroshi Matsumoto, Lusi Suanti, Ryushi Kimura. Residential energy consumption in a local city of Indonesia, Proceedings of the 23rd Pacific Conference of the Regional Science Association International (PRSCO) and the 4th Indonesian Regional Science Association (IRSA), Bandung, Indonesia, 2-4 July 2013.
2. Iwan Sukarno, Hiroshi Matsumoto, Lusi Susanti: Urban energy consumption based on cohort model in a local city of Indonesia, Proceedings of The 12th International Conference on Sustainable Energy Technologies (SET2013), Hong Kong, China, 26-29 August 2013)
3. Iwan Sukarno, Hiroshi Matsumoto, Lusi Susanti. The impact of household lifestyle on electricity consumption in Indonesia: Statistic perspective analysis. The Irago Conference 2014. AIST, Tsukuba-city, Ibaraki, Japan, 6-7 November 2014.
4. Iwan Sukarno, Hiroshi Matsumoto, Ryushi Kimura, Lusi Susanti. Factors Affecting Residential Energy Consumption In Regional Cities of Indonesia, Indoor Air 2014:

The 13th International Conference on Indoor Air Quality and Climate, Hong Kong, China, 7-12 July 2014.

5. Iwan Sukarno, Hiroshi Matsumoto, Lusi Susanti. Transportation Energy Consumption and Emissions - A View from City of Indonesia. Proceedings of The 14th International Conference on Sustainable Energy Technologies (SET2015), Nottingham, United Kingdom, 25-27 August 2015)

Chapter 1

Introduction

1.1 Energy Consumption and Climate Change

Climate changes as one of environments issues has been became serious concern in the last few decades and affecting every country around the world. This phenomenon take seriously harm the economies, people`s live, societies and eco-systems worldwide. Climate change as the impact of greenhouse gas (GHG) emissions is a result of fast growing fossil use. Among fossil fuels, oil is the main contributor of emissions. Data under Asia/World Energy Outlook 2014 shows that world energy consumption of fossil fuels increase from 13,371 Million tons of oil equivalent (Mtoe) in 2012 to 19,276 Mtoe in 2040 (AWEO, 2014). In the "end user" sectors, International Energy Outlook 2011 shows that energy consumption predicted growth from 2010 to 2035 (cf. Figure 1.1). Increase of energy consumption, especially in the residential, industrial and commercial sectors. A significant increase is predicted to occur in Non-OECD countries such as Malaysia, Singapore, Brunei, and 40 other countries, including Indonesia. As developing country, Indonesia has to address the increasing energy demands for growing economies, as well as address the potential impact of emissions and climate change.

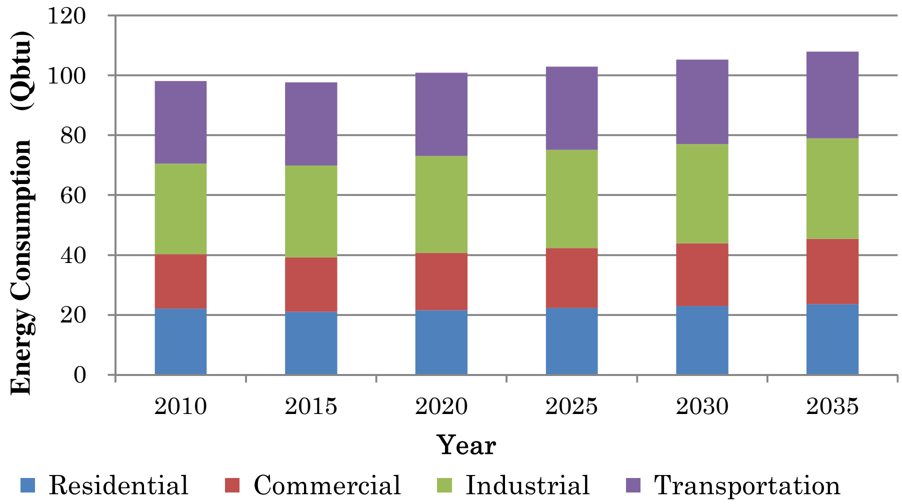

Figure 1.1. World energy consumption, 1990-2035 (U.S EIO, 2011)

Intergovernmental Panel on Climate Change (IPCC) predicted that the global average surface temperature was increased about 2^{o}C between 2000-2100, and the average sea level is also predicted to increase about 50 cm over the same period (IPCC, 2014). The global warming phenomenon impacts are strongest and most comprehensive to natural system (IPCC, 2014; ESDM, 2012; Ratanavaraha, 2015). It is no doubt that the climate change is linked to change of precipitation pattern, snow and ice melting, increasing of coastal flooding, a longer wildfire seasons, etc. Climate change also has a significant effect on human health. Extremely hot seasons are expected to result in longer and increase of heat waves that create serious health risks, increased of air pollution, an intense allergy season, the migration of insect diseases, etc.

The burning of fossil fuels to provide energy is the major contributor to produce carbon in the atmosphere which is main driver of global warming (IPCC, 2014; ICLEI, 2009). United States Environmental Protection Agency was counted that in the year of 2013 the largest source of greenhouse gas emissions (GHG) from human activities is from burning fossil fuels for electricity (31%), transportation (27%), industry (21%), commercial and residential (12%), Agriculture (9%), and land use (13%) (EPA, 2013).

1.2 Energy and Emission Problems in Indonesia

According to the BP Energy Outlook 2011, Since 1900 world population has more than quadrupled, real income has grown by a factor of 25, and primary energy consumption by a factor of 22.5 (cf. Figure 1.2). Over the last 20 years, world population has increased by 1.6 billion people, and it is projected to rise by 1.4 billion over the next 20 years. The world's real income has risen by 87% over the past 20 years, and it is likely to rise by 100% over the next 20 years [BP, 2011].

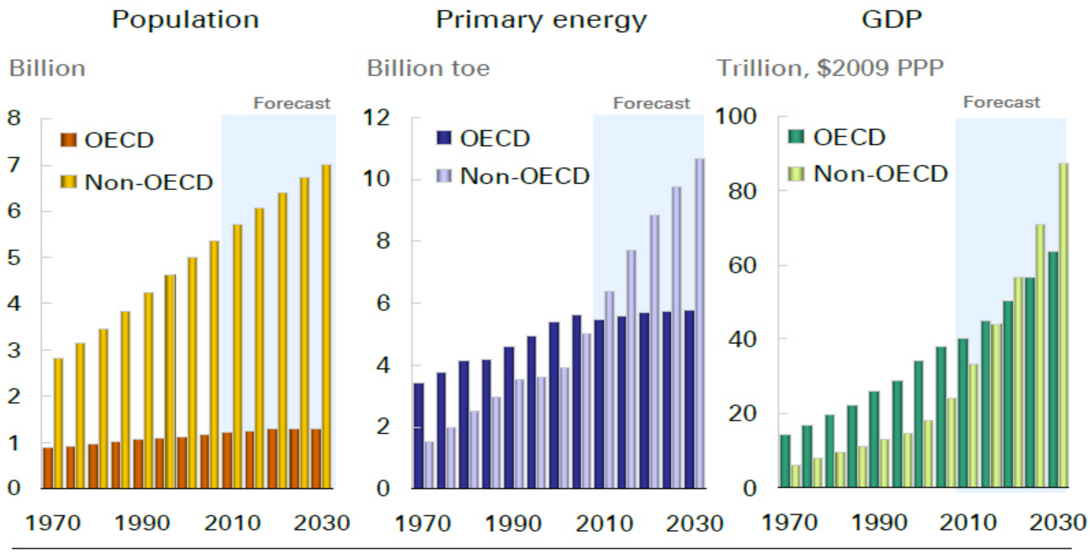

Figure 1.2. Global energy trends (BP, 2011)

United Nation (UN) estimates that 60% of the world's population now lives in the urban area and expected continue rising (UN, 2008; ICLEI, 2009). Hence, over 60 per cent of world energy demand is consumed in cities (Maria, 2012). Cannot be denied, particularly in developing country are experience rapid change from rural to urban-based economies as they are transformed by their urbanizing populations (ICLEI, 2009).

According to BP statistical review of world energy 2015, the amount of primary energy consumption in 2015 was 174.8 million tons of oil equivalents (TOE). Worldwide, Indonesia`s energy was consumed about 1.4% of the world total energy consumption. In fact, from the total amount of energy consumption, 58% still comes from fossil sources. For Indonesia, it is quite alarming because fossil-based energy reserve of Indonesia is estimated to last only for the next 18-30 years (cf. Figure 1.3) (ESDM, 2014).

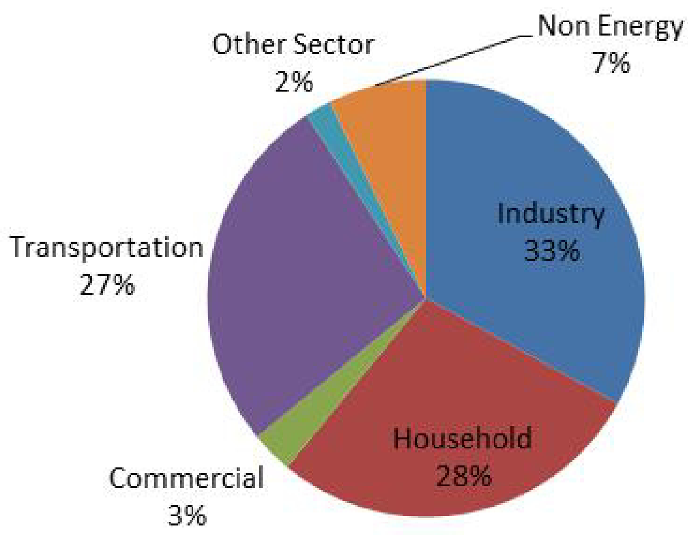

Figure 1.3. Share of energy consumption (ESDM, 2014)

As mentioned in the earlier, Indonesia as one of the developing countries still depends on energy to drive the economy. Energy and economy will increase simultaneously with population growth, particularly in the industrial sector. Figure 1.4 shows the economic growth of Indonesia has decreased over the past 5 years. Generally, decreasing the economy growth of Indonesia is influenced by the global economic condition such as decreased of oil price, China`s economic condition, and so on. Furthermore, decreasing export and increasing of commodities also influenced Indonesia`s economy.

According to the Handbook of Energy and Economic Statistics of Indonesia published by Ministry of Energy and Mineral Resources 2010, in the energy sector, Indonesia`s energy supply and energy consumption are continuously increased over the past 11 years by 3.7% and 3.4%.

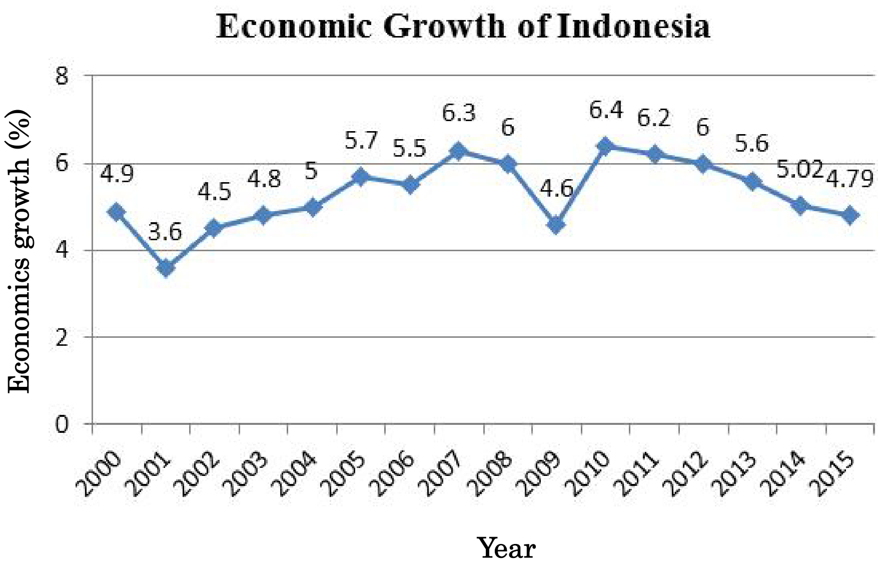

Figure 1.4. Economic Growth of Indonesia (BPS, 2015)

Indonesia energy outlook BPPT 2011, also gives an overview of Indonesian energy condition that final energy demand will have developed with an average growth rate of 4% per year and dominated by three important sectors: household, transportation and industry (Figure 1.5) (OEI, 2011).

Residential energy use is defined as energy consumed by household (IB, 2012). By 2030, it is estimated that electricity use will be important in the household sector (OEI, 2011). Electricity consumption will rise by more than 5 times or share of electricity with respect to total final energy demand in this sector will reach 49.2% from 11.2% in the 2009. By 2030, the role of LPG is expected to increase until 24.4%, and on the contrary the use of firewood will decline to 26.4%. The role of kerosene as fuel will largely be replaced by LPG so that in 2014, the share of LPG to match the role of electricity in this sector.

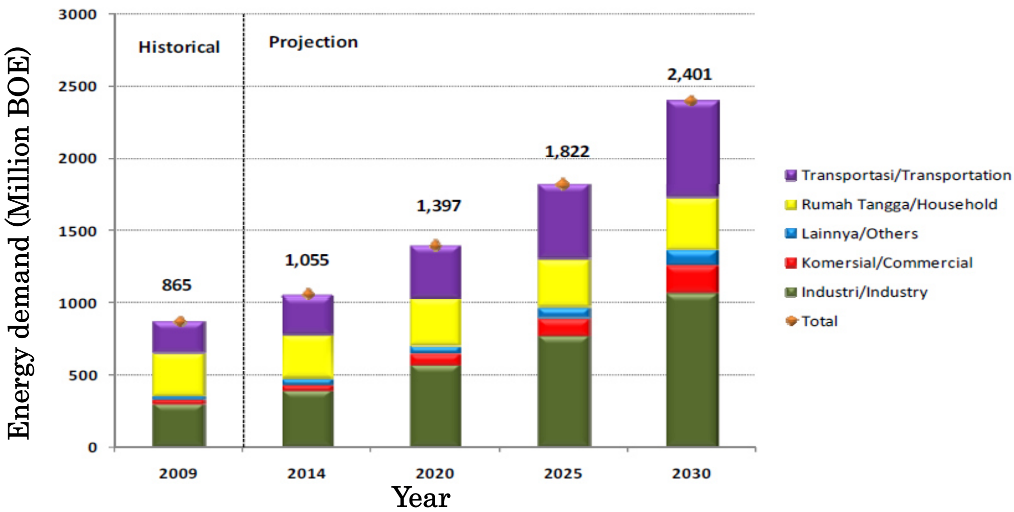

Figure 1.5. Projection of total final energy demand by end user (OEI, 2011)

For the final energy demand in the industrial sector, BPPT also noted that from 2014 to 2030 will undergo a slight increase with an average growth rate of 6.5% per year. By 2030, the total final energy demand in this sector will increase almost 4 times to that of 2009. The share of biofuels in 2030 will reach 5.6% of total final energy demand in this sector.

In the commercial sector, BPPT also predict that all the fuel is expected to decline unless the electricity and LPG. The electricity use rise with a growth rate 10.1%, subsequently in 2030 the share of electricity will reach 80.6%. The requirement of LPG is expected to rise in the presence of kerosene to LPG conversion except in the area outside of Java Island that has not been reached by kerosene to LPG conversion program.

Increasing energy consumption, particularly fossil fuels usually imposed a heavy environmental burden. GHG and other air pollutants become undesired effects of energy used. World Bank in 2014 was noted that Indonesia's CO_2 emissions increased from 24.7 million metric tons in 1965 to 434 million metric tons in 2014 or increased on average by 2.1% per year. The largest share of GHG emissions in 2012 came from the electricity sector (32%), followed by industry (29%), transportation sector (28%), household (7%), commercial (3%) and others (1%) (KIGS, 2013).

Besides disrupts the sustainability of an ecosystem, in the long term, pollution will reduce the quality of human life. Varian air pollutants have ability to be transported in short or long distance and have impact on human health (Kampa and Kastanas, 2008). In long term exposure of sulphur dioxide (SO_2) and nitrogen oxides (NOx) are experienced affect to nose and throat irritation, followed by bronchoconstriction and dyspnea, lung inflammation, respiratory infections (Kagawa, 1985; Balmes et al., 1987; Chauhan et al., 1998). Disorders of the brain and heart function also can occur as a result of inhaling the carbon monoxide (CO) (Badman and jaffe, 1996).

In fact that the most significant increase of energy consumption and emissions are expected to take place in cities, where rapidly urbanization and economics activities (Oshita et al., 2015; Fong, 2007; IGES, 2004). Thus, dealing with these issues, cities can play a big role on reducing fuel consumption and emissions.

1.3 Study objectives

To fight against climate change and increases of energy consumption, particularly fossil fuels, urban sectors should be put on the priority. Past studies are revealed it is important to investigate the energy consumption and emissions from cities, especially in the developing countries. In view of these, the main objective of this research is to analyze the urban energy consumption and emission in the city of Indonesia. This objective is further followed to several investigations, which are;

(a) To investigate the residential energy consumption in the city of Indonesia.

(b) To investigate the opportunities to reduce electricity consumption

(c) To understand the existing condition of energy consumption and emission trends in Indonesia and the present effort in controlling urban energy consumption and emissions.

(d) To develop a model to investigate the fuel consumption and emission impact in the road transportation in the local city of Indonesia

1.4 Case study

This study was based on the cases of Padang City of West Sumatra Province, Indonesia (Figure 1.6). Indonesia is one of the fastest growing developing countries in Asia with a population of more than 241 million, or the fourth largest population country in the world. The real Gross Domestic Product (GDP) reached at the average of 6.5% per year during last five years. According to Monetary Policy of Indonesian Bank, this growth was driven by household expenditure and infestation. Related to the household expenditure, this increase comes from sales of non-food index, household appliances, information technology device, and spare parts [8]. In terms of the population, with normal growth 2.6% per years, Indonesian population can be predicted over 300 million in 2025.

Padang city was chosen for the case study as it is a typical medium size city that faced rapid economic growth. The city covers an area of 694.96 km^2 and has a population of 902,413 in 2015 (Padang yearbook, 2015). Padang consists of 11 districts, Bungus, East Padang, Koto Tangah, Kuranji, Lubuk Begalung, Lubuk Kilangan, Nanggalo, North Padang, Pauh, South Padang, and West Padang.

Figure 1.6. Case Studies (Padang, Indonesia)

Similar to other city in developing countries, Padang faces a rapid transformation, an increase in population and a significant economic growth.

In view of rapid growth of urbanization and economy in Sumatera islands, it is necessary for this city to have a comprehensive study on fuel consumption and emissions, so that this study can be integrated into long term planning of the city, particularly for city development after the big earth quake in 2009.

No doubt that growing populations consume more energy. With population growth reaching 1.5% per years, Padang becomes one of fastest growing cities in Indonesia. By using cohort model with the population is projected to continue rising until 2050 (Figure 1.7).

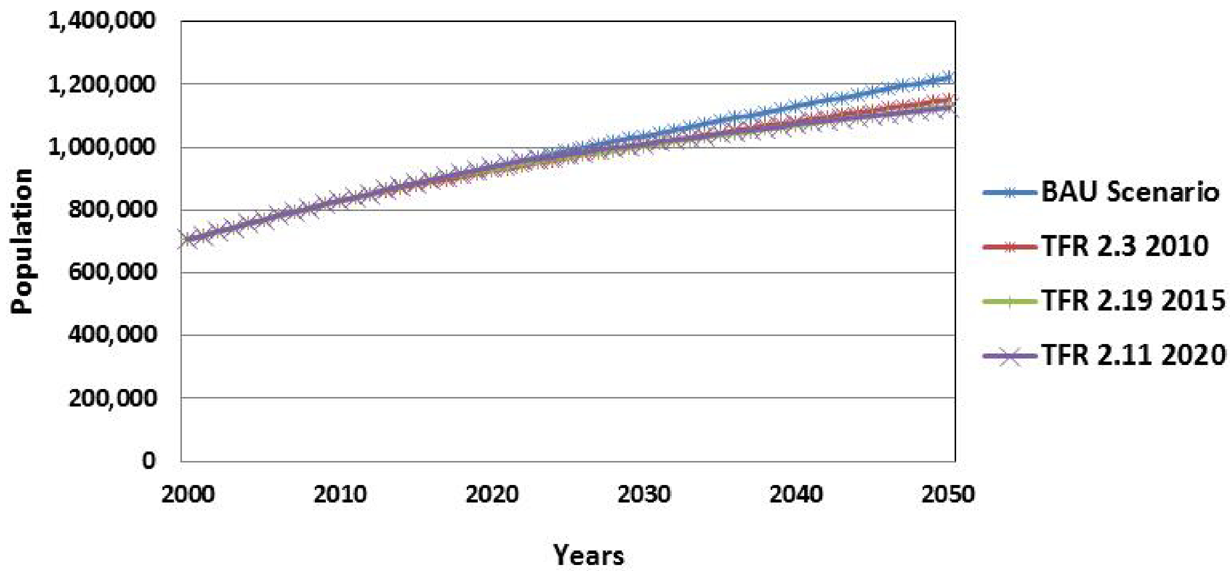

Figure 1.7 Estimated populations by cohort method under Population scenarios

Under TFR scenarios, by reducing fertility rate up to 2.11 by 2025, The Padang City Population were successfully suppressed an annual 7%. This decline is still worrying if seen from the structure of population. According to the 2011 Padang City populations' structure, the majority of population is a young age and productive age (Figure 1.8) and the average age of marriage is 21.3 for women and 25.4 for men.

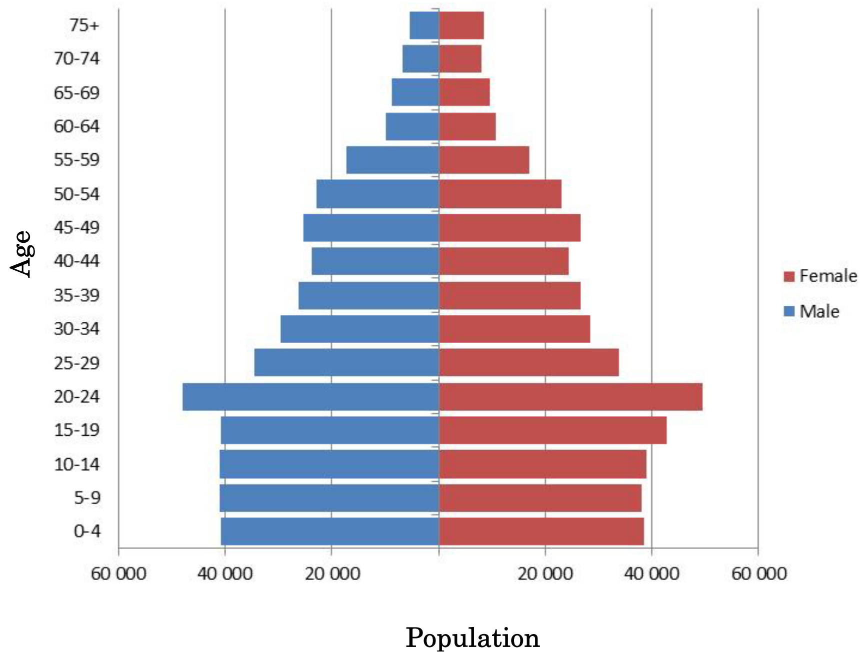

Figure 1.8. The Padang City population structure

Related to the energy consumption in residential sector, the Statistical data of Padang in 2012 showed the share of electricity consumption. Almost 92 percent of electricity consumed by the residential sector, only 5.32 percent by the commercial sector, 1.92 percent of public sector, 1.28 percent by government, and only 0.04 percent by industrial sector (Figure 1.9).

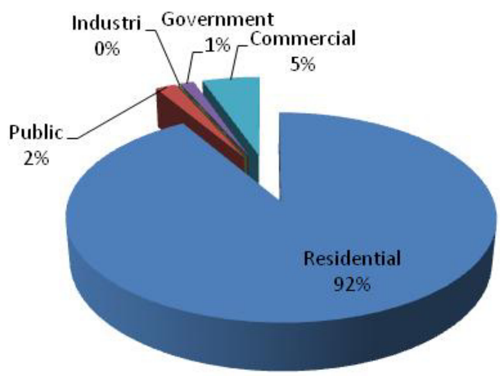

Figure 1.9. Electricity consumption by sector

In the transportation sector, figure 1.10 and 1.11 illustrate the increases of the number of public and private vehicles last 10 years.

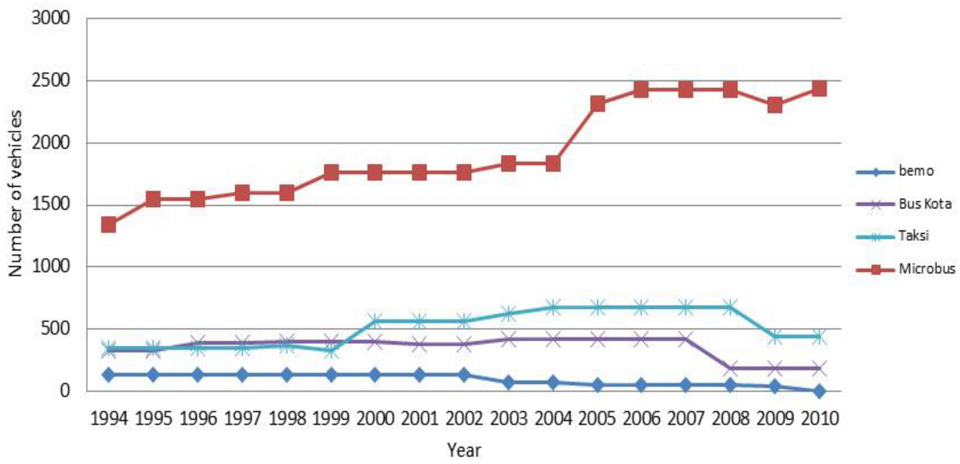

Figure 1.10 Number of public vehicles from 1994 to 2010

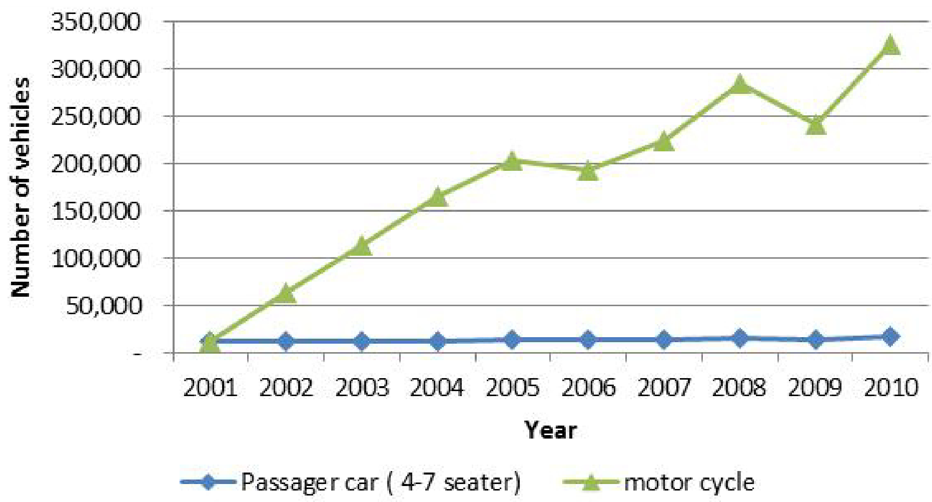

Figure 1.11 Number of private vehicles from 2001 to 2010

1.5 Structure of this thesis

This thesis is organized into six chapters (cf. Figure 1.7), in line with the objectives explained above. The thesis starts with a general introduction under Chapter 1 that explains the background and objectives of this study.

Chapter 2 focuses on residential energy consumption in the local city of Indonesia. This section describes the present state of household energy consumption in relation to the household characteristics (household pattern, employment status, employment sector, and household lifestyle). From the founding of Chapter 2, Chapter 3 explores the opportunities to reduce residential energy consumption, particularly in electricity consumption. In this chapter, several best practice and policies around the world have been described.

In the next Chapter 4, describe the fuel consumption and emission trends in road transport. In this chapter, under the present state of fuel consumption and emission trends in Indonesia and the case study area, a system dynamics model for road transportation was developed to mimic the fuel consumption and road emission trends. Based on results of Chapter 4, Chapter 5 explores the opportunities to reduce fuel consumption and emission from road transport. In this chapter, several best practice and policies around the world have been described.

Chapter 6 presents the overall conclusions and recommendations of this doctoral research project.

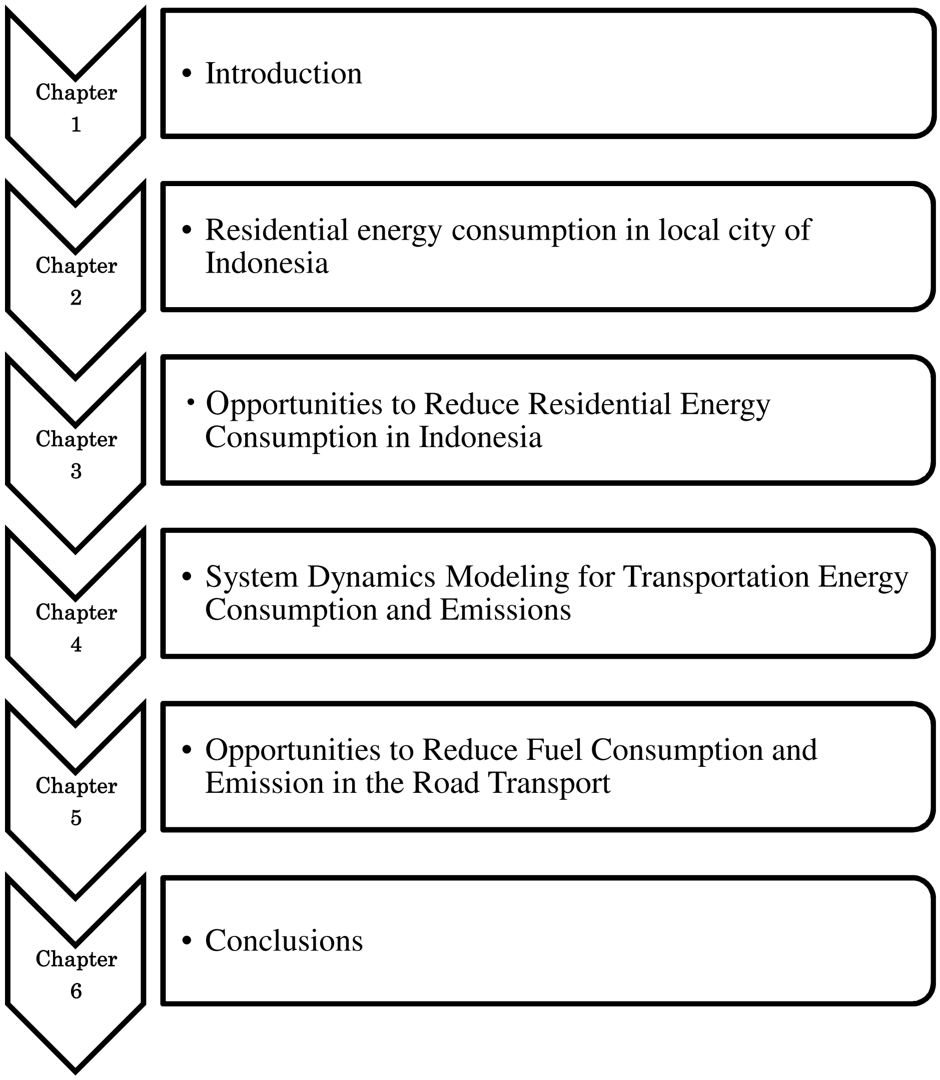

Figure 1.12 Structure of thesis

Chapter 2

Residential energy consumption in local city of Indonesia

2.1 Introduction

It has been widely recognized that the residential sector is one of the key contributors to total energy consumption and greenhouse emission in most countries. A report was released in 2008 by International Energy Agency that energy consumption in the residential sector was 29% of total global energy demand, and it was even higher in non-OECD countries with a 36% share (IEA 2008). The increase of residential energy was estimated to be 1.1% per year, from 52 quadrillion Btu in 2008 to the estimated 69 quadrillion Btu in 2035 (IEO, 2011). Energy consumption in residential sectors was investigated by many researchers across the world. The researchers have identified several factors affecting residential energy consumption, such as a household behavior (Mohammad et al. 2013, Chen et al. 2011, Ouyang and Hokao 2009, Green and Ellegard 2008), occupancy and household income level (Fong at al. 2007), pattern of household

(Permana et al. 2008), electric appliance ownership (Genjo et al. 2004, Chen et al. 2013, and Wijaya et al. 2012, Sugiura et al. 2013), and the selection of energy source (Nakagami et al. 2008). Wijaya et al. analyzed the potential electricity saving in households in terms of technology use, social and economic characteristics in two different cities of Indonesia; Bandung and Yogyakarta. Nuryanti et al. also analyzed the accessibility of energy consumption in the household sector. In addition, Pranadji et al., conducted a survey to analyze the household behavior regarding the use of household fuel in Bogor, Indonesia. From an urban context, authors also carried out a further study to investigate the urban energy consumption in Padang, a local city of Indonesia (Sukarno et al. 2013). In the residential sector, the findings showed that electricity consumption was spread to the residential sector (92%), followed by commercial sectors (5.32%), public sectors (1.92%), the government (1.28%), and only 0.04% in the industrial sector. Even though many researchers put through studied energy consumption in the residential sector, most of the studies focused on the developed countries and only a few carried out studies in developing countries especially in Indonesia. From these findings, it is clear that the largest amount of electricity is consumed in housing. Furthermore lifestyle is one of the important aspects that dictate the residential energy consumption pattern (Fong et al., 2007). However, only a few of these studies took into consideration aspects of household lifestyle, such as family pattern, income level, ownership of home appliances, and residential location.

With an average growth 2.6% per year, the Indonesian population could be predicted to reach over 300 million by the year 2025. The large population and recent economic growth have resulted in an improvement of the overall living standard in Indonesia. Besides, lifestyles in the modern cities of developing countries are becoming energy intensive and people have been conspicuous and overly consumptive (Gupta. M.D, 2011). According to Monetary Policy of Indonesian Bank, this growth was driven by household expenditure and infestation. Related to the household expenditure, this increase comes from sales of non-food index, household appliances, information technology devices, and spare parts [IB, 2013]. Hence, lifestyle aspects should be made a priority to understand residential energy consumption, particularly in developing countries.

2.2 Purpose of Study under this Chapter

The purpose of this chapter is to investigate the household lifestyle aspects of the residential energy consumption. Lifestyle aspects include the family patterns, occupations, home appliance ownership, and housing area. The energy consumption is investigated based on the life schedules of each family member. To limit the scope of discussion, Padang, the capital city of West Sumatera province, was selected for the case study.

2.3 Research Methodology

2.3.1 Survey and Data Collection

Since there is no data set related to household energy consumption in the urban context, the authors had to conduct an independent survey to collect data for this study. Padang was selected as the case study. The total population of Padang is about 844,316 with an averaged family size of about 6 (Padang in Figure 2012). The sample size was determined to be 97 considering 95% confident level 10% margin of error.

Table 2.1. District of Padang 2012

No	Sub district	Area Size (km^2)	Population (person)	Number of households	Number of households surveyed
1	Bungus Teluk Kabung	7	23,142	5,181	10
2	Lubuk Kilangan	8.15	49,750	11,783	17
3	Lubuk Begalung	8.08	108,008	26,001	24
4	South Padang	10.03	57,386	13,991	16
5	East Padang	232.25	77,952	19,312	20
6	West Padang	8.07	46,060	12,134	13
7	North Padang	57.41	69,275	19,325	13
8	Nanggalo	146.29	57,731	13,849	14
9	Kuranji	85.99	128,835	30,346	31
10	Pauh	30.91	60,553	15,100	16
11	Koto Tangah	100.78	165,633	39,336	36
Total					210

Sources: Author calculation; Padang in Figure 2012

Hence, in this research a sample of 210 households covering each district were collected, and the responses were obtained through a door to door survey. The sample sizes in each district were proportional to the total number of household each district of Padang. However, the selected households surveyed in each district depended on the readiness of the respondents to participate. Random sampling was used in this survey to ensure each household had equal chance to be selected. Table 2.1 shows the characteristics of each district and the number of households surveyed for the study.

Generally, the questionnaire consisted of three parts; part one was an interview regarding the general characteristics of the respondent, the household lifestyle and energy consumption. Part two consisted of household appliances, and the respondent`s average monthly electricity consumption of each home appliance. The last part of the questionnaire was about household daily life activities (Table 2.2).

Table 2.2. Description of questionnaire

Primary items	Descriptions
Household characteristics	Number of family members, education level, occupation, household income, floor area, characteristic of energy consumption (type of energy sources for cooking, electricity consumption)
Household appliances	Number of household appliances and average usage time per day
Daily life activities	Daily life activities of household related to household appliance use

2.3.2 Data Analysis

Figure 2.1 illustrates the study methodology of the current research. In order to investigate the impact of household lifestyle on electricity consumption trends, related historical data, i.e., population, socioeconomic and other supporting data were obtained from the Indonesia Statistics Agency and Ministry of Energy and Mineral Resources.

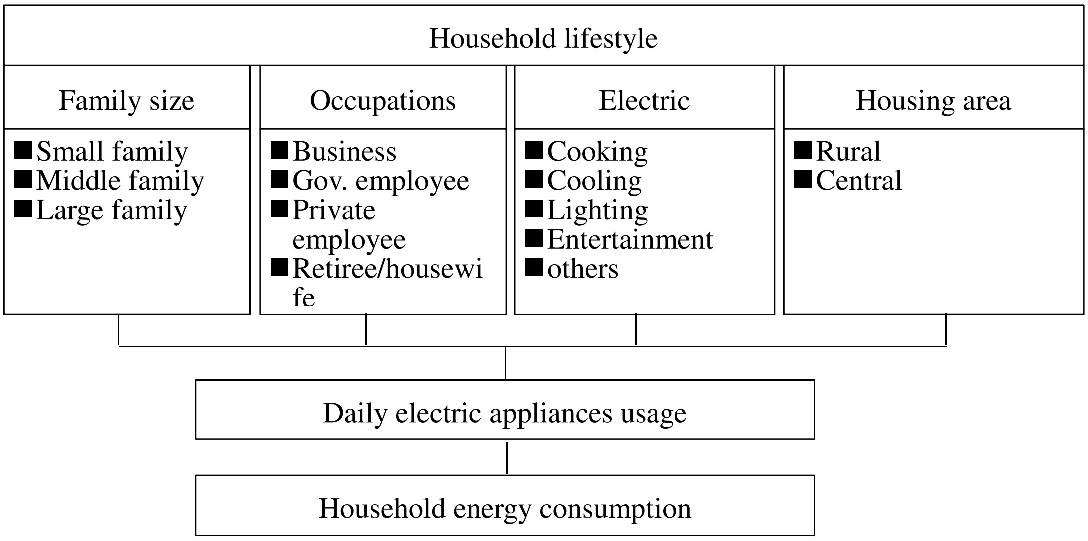

Figure 2.1. Methodology of study

In the home appliances survey, the participants were asked to fill out the number, type and duration of each home appliance used per day. The home appliances were divided into 5 categories of home daily activities which were cooking, cooling, lighting, entertaining and other uses. By considering the life schedules of different household groups and the use of electricity, the energy consumptions were calculated. Results were divided according to household status in term of family size, occupation, electric appliances ownership and housing area.

2.4 Characteristics of households

The characteristics of households in Padang could be divided by two types of household structure: a single household with one core family, and multiple households with more than one family residing in the same building. As shown in Fig. 2 and Table 3, 45.7% of the households were average-sized families with 5-6 persons per household, 37.1%

were small families with 2-4 persons per household, and 17.1% were large families with more than 7 persons per household. Families living in rural areas generally had a larger number of children than those in urban areas.

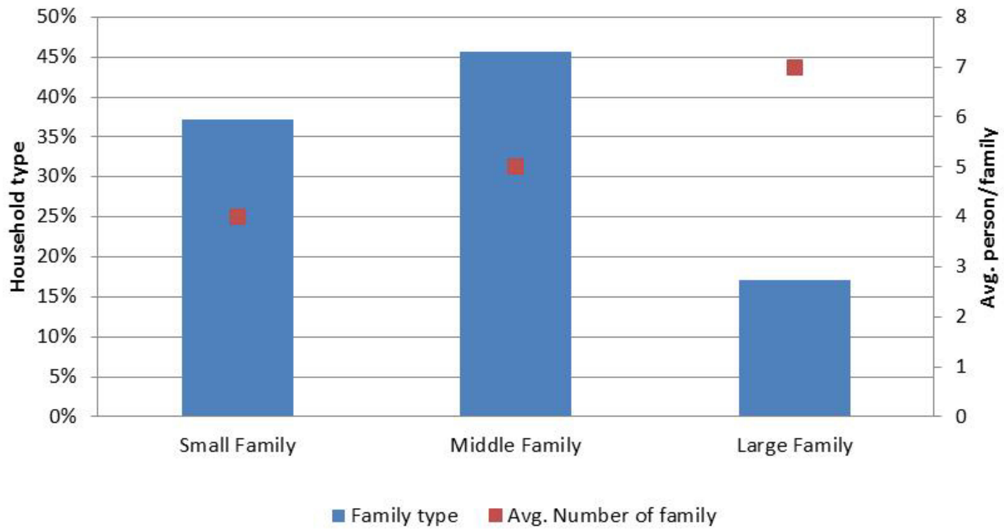

Figure 2.2. Household types and family size

Related to the household income, 62.9% of the respondents were categorized as the middle income group with an average income of $ 150 USD to $ 500 USD, 15.7% were in the high income group with an average income above $ 500 USD, and the rest, approximately 21%, were in the low income group with an average income of less than $ 150 USD (Figure 2.3). The findings also showed that the majority of the population work as private employees (32%), business professionals (15%), government employees (29%), and others or retirees (13%).

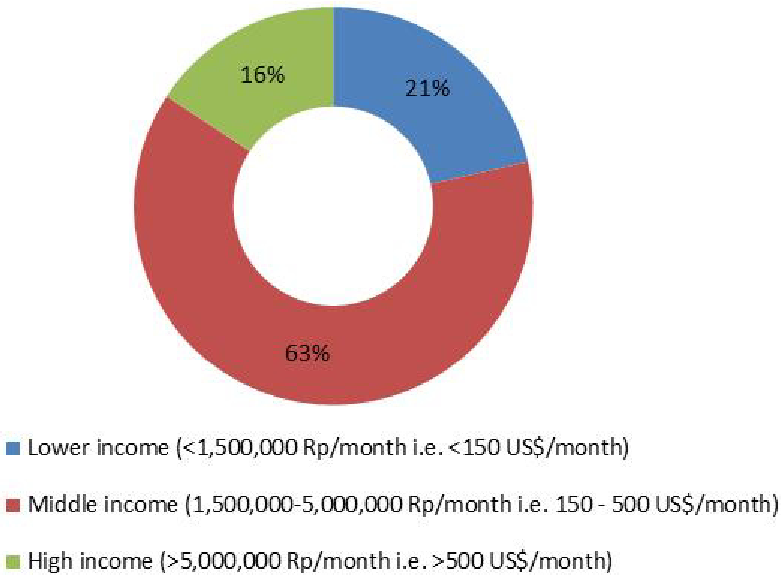

Figure 2.3. Household incomes

Table 2.3. Characteristics of Houses investigated

Family type	Number of respondents	House type		House structure		Floor area (m^2)
		1 story	>1 story	Wooden	Non-wooden	
Small family	78	76	2	10	68	21-36
Middle family	96	90	6	15	81	37-74
Large family	36	29	7	8	28	>85

2.5 Ownership of Home Appliances

Ownership of electrical devices can be an indicator of electricity consumption in the residential sector. Identification and mapping of electrical appliance usage in households would be helpful for determining and understanding the energy consumption characteristics in a household.

Figure 2.4 shows the ownership of major home appliances in the urban area of Padang; they are classified into cooking, cooling, entertainment and other devices. The cooking devices include a rice cooker with warmer, refrigerator, dispenser with hot and cool mode, juice blender, electric stove, mixer, coffee maker, toaster, and food processor. Toasters, microwaves and electric stoves were mostly owned by middle to high income level residents. In terms of cooling devices, the survey showed that electric fan was more widely used than air conditioners. The number of electric fan possessed by respondent was over 160% compared to the AC that was only 15%, meaning more than 50% of respondents have two or more electric fans.

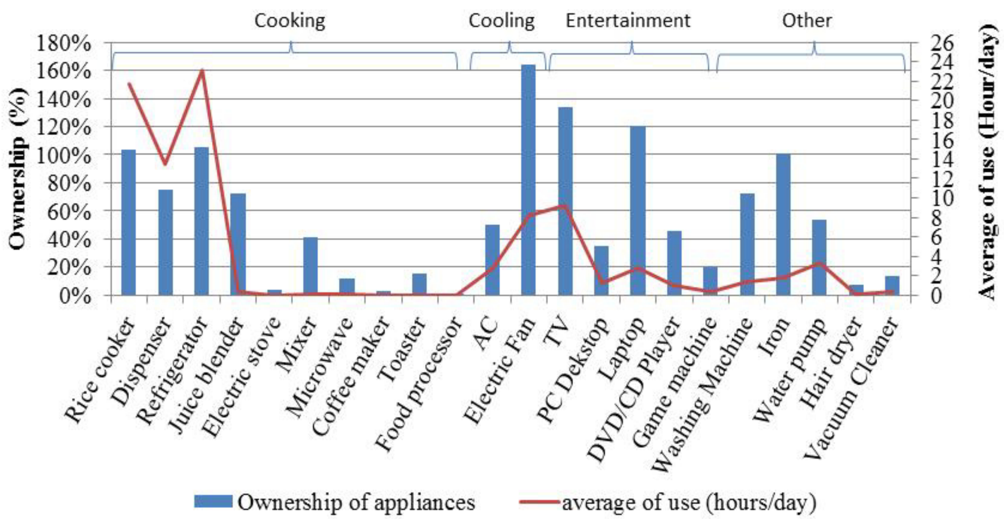

Figure 2.4. Household appliance ownerships

In the entertainment category, TVs, PC desktop, DVD/CD players, and game machines were the commonly used devices in Padang. “Others” were categorized into supporting appliances such as washing machine, irons, water pump, hair dryer, and vacuum cleaner. Almost 100% of respondents have iron and more than 65% of respondents have washing machine.

An interesting point might be seen in Figure 2.4 and Table 2.4. Several home appliances such as rice cooker, refrigerator, electric fan and laptop were shown over 100% even electric fan reaches over 160%. This percentage shows the number of equipment unit compared to the total respondents. It is indicated that respondents have two or more similar items. On the other hand, the higher ownerships of home appliances such as refrigerator, rice cooker, TV, slightly indicated the increase of household income and also indicated high electricity consumption in the surveyed population.

Figure 2.4 also gives an overview about the average usage of home appliances. This information can be attributed to the energy consumption of each device. Cooking appliances such as refrigerators, rice cookers and dispensers have the longest usage time compare to the other home appliances. Rice cookers were used for about 22 h/day, refrigerators were used for about 22 h/day and water dispensers were used for about 10 h/day. In cooling devices, electric fans were operated much longer than air conditioners with almost 8 h/day on average, as much as a TV in the entertaining devices. This duration included standby time when the devices are no longer used but still plugged into the electric source. In line with these findings, the Indonesia Statistics Agency released their behavioral indicators of the environmental report in 2012. In the 33 provinces of Indonesia, the results showed that more than 23% of households on average often allowed the electronic device to stay on or in standby mode (ISA, 2012). It is should be noted that even in the standby mode, electric device still consumes electricity (Raj et al., 2009; Solanki et al., 2013). The amount of power consumption during standby mode could be up to 20 watts, depending on the model and type of appliance (Alan. M, 2003; SA. GOV, 2016).

Table 2.4. Ownership of common electric appliances

Appliances	Household appliances ownership		
	Padang city (2014)	**Kandahar city (Mohammad et al.,2013)**	**Hongkong (Wan and Yik, 2004)**
Rice cooker	104%	0%	93%
Dispenser	75%	46%	19%
Refrigerator	106%	41%	94%
Juice blender	72%	-	-
Electric stove	4%	-	-
Mixer	41%	-	-
Microwave	11%	0%	56%
Coffee maker	3%	-	-
Toaster	15%	-	-
Food processor	1%	-	-
AC	50%	4%	93%
Electric Fan	164%	92%	84%
TV	133%	57%	98%
PC Dekstop	35%	12%	79%
Laptop	120%	-	-
DVD/CD Player	46%	-	-
Game machine	20%	-	-
Washing Machine	72%	70%	93%
Iron	100%	75%	80%

Appliances	Household appliances ownership		
	Padang city (2014)	Kandahar city (Mohammad et al.,2013)	Hongkong (Wan and Yik, 2004)
Water pump	53%	78%	-
Hair dryer	8%	-	-
Vacuum Cleaner	14%	4%	27%

Sources: Author calculation

2.6 Energy consumption by home appliances

Figure 2.5 illustrates the calculation results of energy consumption by home appliance in the cooking, cooling, lighting, entertainment and other household activities. It should be understood that the calculations are based on the quantity of electric devices for each activity category (regardless of type, size, capacity, brand, and technical detail of devices). Generally, the results indicated that cooking activities consumed more energy compared to the other four activities. On average, per household consumption is about 300 kWh/year. As shown in Figure 2.6, refrigerators, rice cookers and dispensers are consuming much more energy than the other cooking appliances.

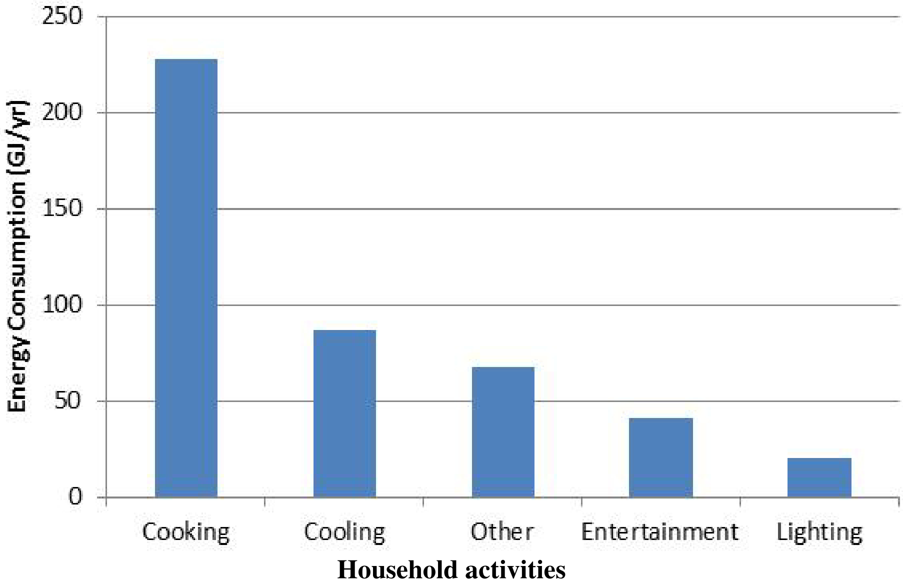

Figure 2.5. Energy consumption by household activities

In cooling appliances, as mentioned before, electric fans were more widely used than ACs, thus the annual energy consumption due to electric fans was greater than ACs. The high energy consumption of electric fans might be caused by usage time and the number of electric fans. On the other hand, TV was the largest energy consumer among the entertainment devices. TV is the favorite device for entertainment at any time and could be used alone or shared by family members. As shown in Figure 2.4, based on the surveyed population TV was the entertainment device owned by every household. Moreover, about 26% of respondents had more than one TV; on average the TV is lit for 9.3 hours per day. Lastly, in the "other" devices, water pumps were the largest energy consumers compared to washing machines, irons and hair dryers. The water pump was used as a backup to suck water from the wells or other sources when there was no water supply from the water supply company.

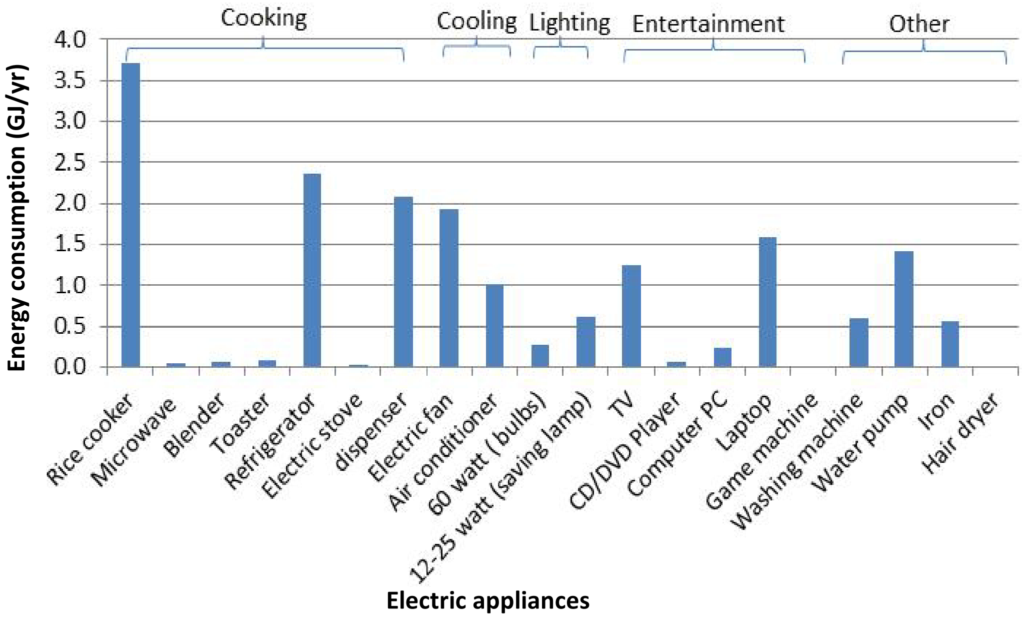

Figure 2.6. Energy consumption by appliances

Regarding of the ownership of electric appliances, Nielsen (1993), Wijaya M.E., Tezuka T (2013) and Chen et al. (2013) determined that increase in the number of home appliances resulted in increase of electric consumption. Comparing with previous research by Wijaya et al. 2012, it can be concluded that a majority of electricity consumption is from cooking and cooling device (Figure 2.7).

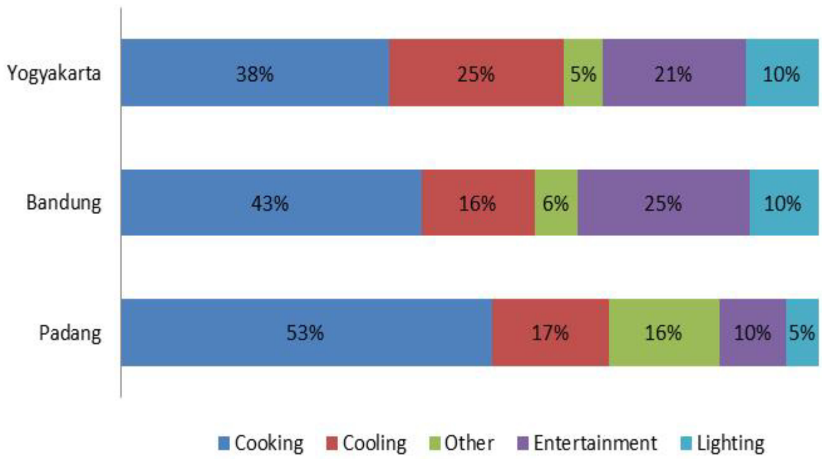

Figure 2.7. Comparison electricity consumption

Other activities that contribute to the electricity consumption are entertainment activities. From the figure above shows, the entertainment activities in the Yogyakarta and Bandung cities contributed 21% and 25% of energy consumption

2.7 Energy consumption by household occupation and income level

The results in Figure 2.8 show that government employees and retirees generally consumed more energy compared to businessmen and private employees. As a government employee, the working time is between 7.30 am and 4.30 pm from Monday to Friday. Therefore, they have more time to stay at home and consume more energy as associated with use of electric home appliance. On the other side, businessmen and private employees have longer working hours depending on the type of business and/or company.

Figure 2.8. Energy consumption (per household) by family occupation

In terms of income level, the increase of income encourages people to change their lifestyle and the desire to have more appliances becomes larger (Tewathia, 2014., Manjunath et al.,2014). The result study (Figure 2.8) shows that high income group generally consumes more household energy than the other income groups. High power equipment such as microwave, air conditioners, electric stove, washing machines, etc. are the commonly use in this group. As is show in Figure 2.6, even few in number, that equipment can raise electricity consumption.

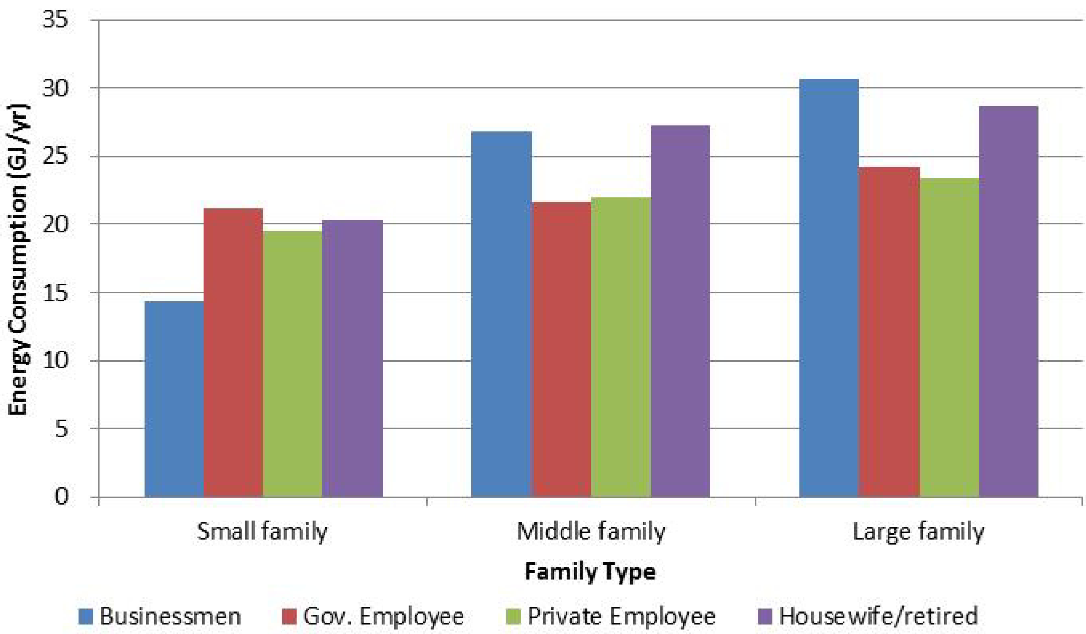

Figure 2.9. Energy consumption (per household) by family type

2.8 Energy Consumption by Family Pattern

As explained earlier in the methodology (see Figure 2.1), annual energy consumption for cooking, cooling, lighting, entertainment and other home device were calculated based on several types of family patterns. As mentioned in the Figure 2.9, energy consumption has positive relationship with household size. The bigger the family, the higher their energy consumption was. It is also determined by Genjo et al. (2005), Fong et al. (2007), Wijaya M.E., Tezuka T (2013) that the family size significantly influences the energy consumption particularly on the electricity consumption. However, as shown in the Figure 2.10, the average energy consumption per person is smaller due to the sharing of equipment. In particularly, Filippini and Pachauri (2004) conclude that household with a large size family (greater than 6 person) had lower energy consumption that those with smaller member.

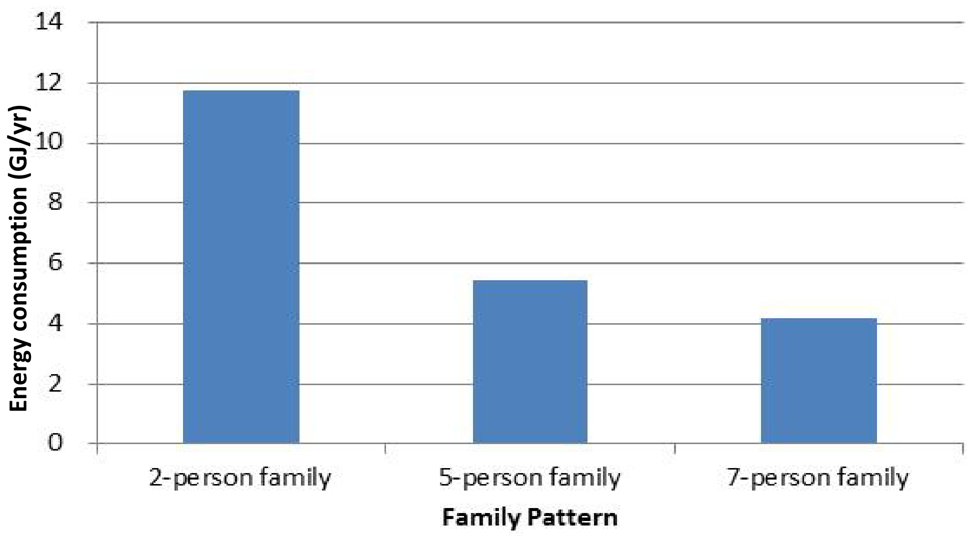

Figure 2.10. Average per person energy consumption

2.9 Energy Consumption by Different Area

This section describes the relationship between energy consumption and residential areas. Figure 2.11 describes the energy consumption related to household lifestyle of different residential areas, regardless of income level, family pattern and electric appliance types. As shown in the graph, the per household consumption rates range from 0.7 GJ/year to 2.1 GJ/year. Generally, slight variations of energy consumption are seen among different residential areas. It should be underlined that the calculation is only based on the usage of commonly used household appliances and generalize in terms of the power, types, and sizes of electrical appliances. Unavailability of detailed data is one of the problems with this research. It is believed more distinctive results could be produced if the details of electrical appliance ownership, including the power used, the type and the size of each category of equipment were included in the calculation. From the figure, several high population areas such as Koto Tangah, Lubuk Begalung and Kuranji showed the same results. Areas having high populations consume less energy per household than other areas of lower population as well as rural areas. This could be attributed to several reasons such as occupations with longer hours, social activities or interactions which make the period spent at home short.

Regarding this section, the investigation shall be improved in further research, to involve several details of electrical appliances and housing size in the calculation.

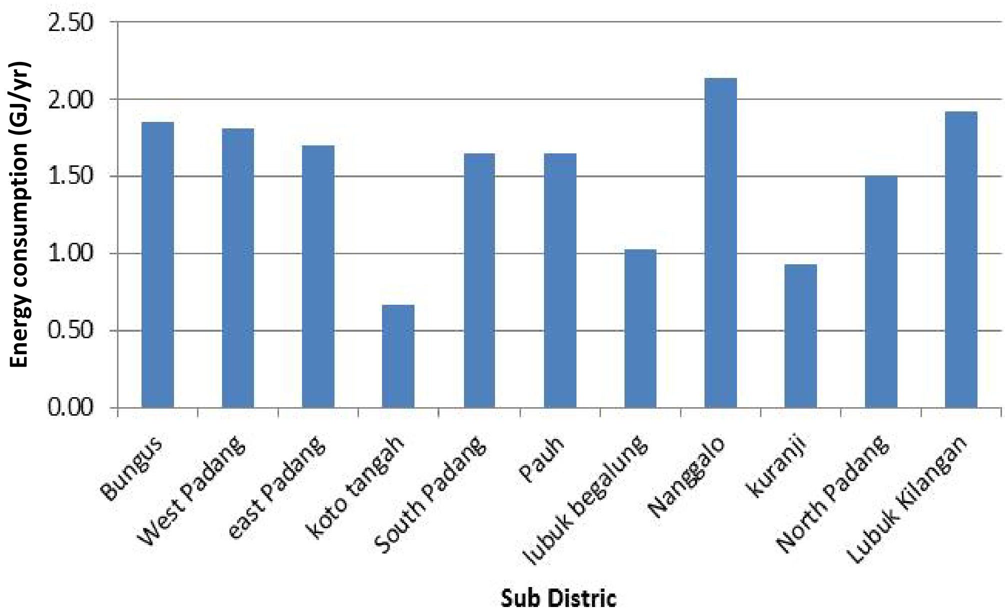

Figure 2.11. Energy consumption per district

2.10 Discussion

The current study has investigated the impact of household lifestyle on energy consumption trends in different locations and social economic conditions. Most existing studies have described the energy consumption in the residential sector, but most of them consider the energy consumption of the developed countries with subtropical climates such as China, Japan, USA, UK and others. Very few of the studies took on developing countries with tropical climate like Indonesia (Mohammad et al. 2013, Wijaya et al. 2012 and Pranadji et al. 2010). The fundamental difference (in term of household energy consumption) is the use of heating and/or cooling devices. However, in the tropical country such as Indonesia, cooling devices are widely used rather than heating devices.

Padang is a typical "hot city" where the monthly average temperature in the dry season is around 31 ^{0}C with a maximum of 35 ^{0}C. In rainy season, the monthly average temperature is around 28 ^{0}C with a minimum of 22 ^{0}C. With these temperatures throughout the year, and the humidity between 75% - 90%, almost all households use either AC or a fan as cooling devices.

As presented in the research, that less than 50% of households have AC as a cooling device, a similar pattern of results was shown by previous studies in two other cities (Bandung and Jogjakarta) of Indonesia (Wijaya et al. 2012 and Pranadji et al. 2010). Affordable prices and low electricity consumption, encourage people to use electric fans rather than AC. Technically, electric fan only requires 15 - 60 watts, while AC requires between 300 - 2500 watts of electricity power. Hence, for continued usage, using a fan becomes an efficient option for the lower to middle class households.

With respect to daily life activities, different family patterns, and employment status-in line with the result of Fong et al., these factors were closely related to energy consumption trends. Although these studies did not report energy consumption for differences in employment status, they revealed similar results in as much as housewives and retirees consume more household energy than the other work groups.

2.11 Conclusion

In this study, we analyzed the impact of household lifestyle on energy consumption. Although this topic has been widely discussed, most studies focus on developed countries. As one of the developing countries, very few studies were found discussing the residential energy consumption in Indonesia. A common problem which occurs in developing countries is the availability of official data. Therefore, this study used cross-section analysis and on-site measurement methods that were focused on each household's lifestyle using life schedule data.

This study stressed the investigation of lifestyle and residential energy consumption based on the ownership of home appliances, income levels, occupations, family patterns and different residential areas. Generally, the findings of this study are as follows:

(a) Household lifestyle in term of family patterns, income levels, electric appliance usage and residential areas are closely related to energy consumption.

(b) Cooking activities consumed more energy compared to the other four activities due to number of electric appliances usage, included permanently used appliances and intermittently used appliances.

(c) In terms of family patterns, households with big families are expected to have, higher the energy consumption, but the average energy consumption per person is smaller due to the sharing of equipment.

(d) Household with retired or housewife and government employee generally consumed more energy due to longer hours spent at home.

(e) Power consumption (operation and standby mode), number of appliances and operating hours are the three aspect that will plays an important role to decrease residential energy consumption in the future

Although this study can be used to determine the level of energy consumption in the residential sector, it should be noted that there are some limitations in this study. The energy consumption was calculated based on the quantity of electric devices for each activity category (regardless of type, size, capacity, brand, and technical details of devices). Thus, in this study, the main purpose was to understand energy consumption trends rather than to calculate the exact energy consumption rates. Besides, the result of this study is also considered to show the effect of the household lifestyle in terms of family patterns, income levels, occupations and also residential areas on energy consumption.

Nevertheless, it is believed that developing countries will experience social change such as increasing population, income level and also changing in the average person's lifestyle which will affect household energy consumption trends.

Chapter 3

Opportunities to Reduce Residential Energy Consumption in Indonesia

3.1 Introduction

Over past of a few years, the residential energy consumption has been widely investigated in the many countries, as a critical aspect for a large share of the total energy consumption. As an effect of an increasing urban population, energy consumption in the residential sector will drastically increase. Besides, no doubt that increasing of household income giving effect to the increasing of living standard, and giving incentives to purchase more electric appliances and consuming more electricity.

As mentioned in the Chapter 2, with an average growth 2.6% per year, the Indonesian population could be predicted to reach over 300 million by the year 2025. The large population and recent economic growth have resulted in an improvement of the overall living standard in Indonesia. Besides, lifestyles in the modern cities of developing countries are becoming energy intensive and people have been conspicuous and overly consumptive (Gupta. M.D, 2011).

From the results of Chapter 2, it reveals that household lifestyle in term of family patterns, income levels, electric appliance usage and residential areas are closely related to energy consumption. As Figure 3.1 shows, cooking appliances (refrigerator, rice cooker, dispenser) consumed the most energy, followed by cooling system (electric fan and air conditioner), entertainment (electronic and computer). Government of Indonesia under Presidential Decree No. 13 of 2013 has planned for saving energy, one of which is electricity. In 2012, the Ministry of Energy also issued Ministri Regulation No. 13/2012 about Electricity Consumption Savings. It is mentioned several ways to save electricity, such as the use of natural light (sunlight) as sources of illumination in the house during the day and turn off the electronic devices (TV, radio, air conditioning, water pump) when not in use or use as needed.

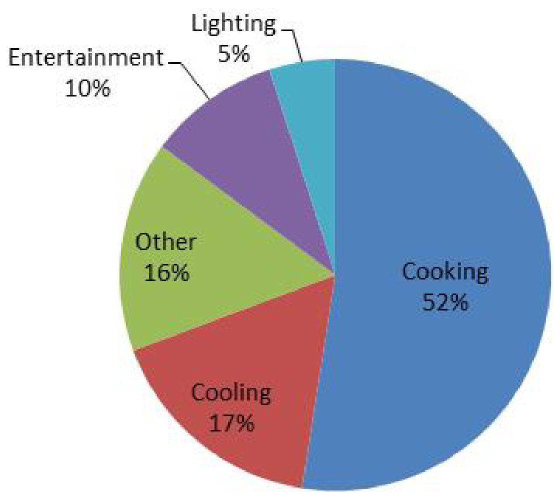

Figure 3.1. Energy use by end-use, 2015

Indonesia as developing country has an opportunity to lead the way toward better electricity reduction. In this Chapter, presents examples of cities around the world, taking action to reduce electricity consumption. Such policy and action can be taken as consideration to reduce electricity consumption in the residential sector.

3.2 Purpose of study under this Chapter

With the increasing concern on the depletion of fossil fuels and awareness of energy conservation, numerous cities around the world take an aggressive action to reduce energy consumption, particularly in the residential sector.

In view of finding from Chapter 2 and the fact that currently Indonesia still facing the energy crisis, the purposes of this Chapter 3 is to investigate the opportunities to reduce electricity consumption, also to identifying the possible policy option for Indonesia.

3.3 Current State of Electricity in Indonesia

As a large middle-income country with a growing economy, a critical component of Indonesia's future strength will be its ability to harness and manage sustainable sources of energy. If the Indonesian economy continues to grow at its current rate, Indonesia's Ministry of Energy and Mineral Resources (MEMR) estimates that domestic demand for energy will also raise by around 7% per year, with electricity demand alone projected to nearly triple between 2010 and 2030.

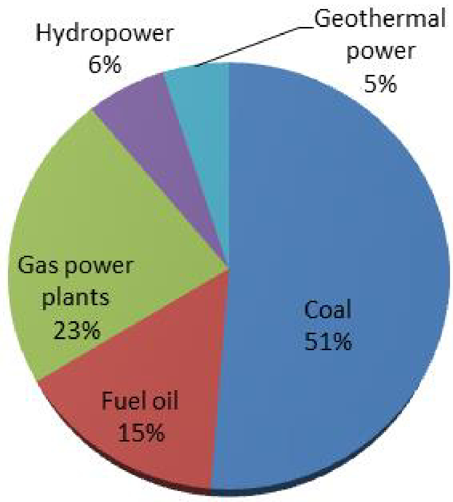

Figure 3.2. Electricity production sources (MEMR, 2013)

Figure 3.2 shows that most of Indonesia`s electricity production still come from fossil fuels. Coal was dominated about 51%, an increase of 7% from the previous period. Gas power plants are the second largest use of electricity produced with 23%, followed by fuel oil (15%), hydropower (6%), and geothermal power (5%).

Table 3.1. Electricity demand

User group	2011 (GWh)	2011 (GWh)	Growth (%)
Residential	65,110.00	72,132.54	10.8%
Industry	54,725.17	60,175.96	10.0%
Commercials	28,309.45	30,988.64	9.5%
Socials	3,993.82	4,495.57	12.6%
Government building	2,790.27	3,057.21	9.6%
Public street lighting	3,063.97	3,140.83	2.5%
Total	157,992.66	173,990.75	10.1%

Sources: MEMR, 2013 (Author calculation)

The Indonesia`s electricity demand continues to increase every year. At 2012, the total demand for electricity in Indonesia reached 174 TWh, an increase of 10.1% compared to the electricity needs in the year of 2011 (MEMR, 2013).

Electricity demand was dominated by residential sector (41.5%), followed by industry (34.5%) and commercials sector (17.8%).

3.4 Household`s Behavior on Electricity Consumption in Indonesia

3.4.1 Use of Electricity Appliance

Generally, a high use of home appliances is correlated with the increase of household electricity consumption. Survey results that have been described previously in Chapter 2 seen that households have two or more electrical devices for the same purposes, such as rice cookers, refrigerators, TV, electric fan, and laptop. The ownership more than one of these devices per households is due to a higher living standard.

Related to the appliance`s performance, the home appliances can be divided into two groups: (Green et al., 2007)

- *Permanently used appliances* which are active all time, e.g. the refrigerator, freezer, and alarm clock.
- *Intermittently used appliances* which are used to varying degree, at different times, they can be active or not used at all depending on the household`s needs, e.g. toaster, just blender, and electric fan.

Statistical survey results show that most of the permanently used appliances were placed in the kitchen for cooking purposes such as refrigerator, rice cooker with warmer, water dispenser (including hot and cool mode). While, other home appliances were placed for other purposes included cooling, lighting and supporting purpose.

In terms of the way to use home appliances, it's influenced by family size, economic level, education, and interests. The results also show that increasing family size and floor area also followed by increasing of home appliance ownership (Figure 3.4). However, from group of appliances categorized, most of them are the number of intermittently used appliances such as TV, DVD/CD player, game machine, and electric fan.

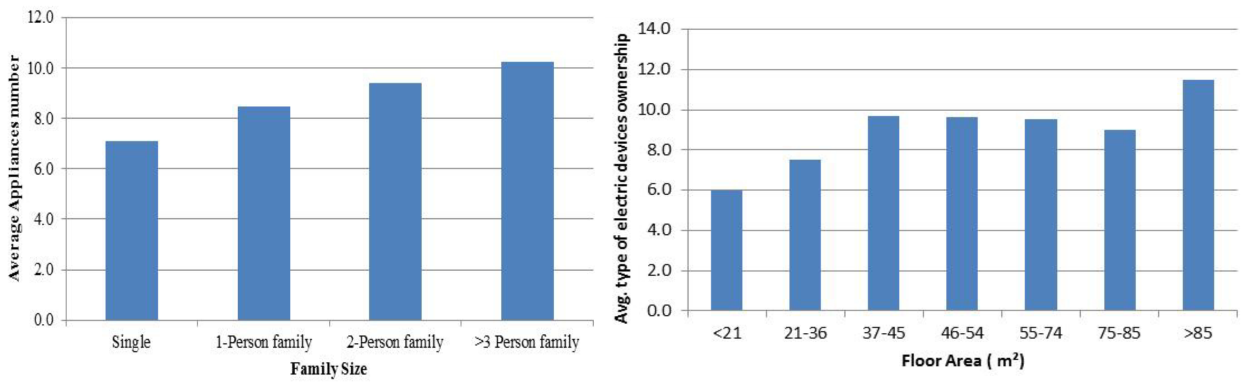

Figure 3.3. Average appliance number

Currently, on a National level, electrification ration reached 87% in 2015, an increase from the previous year`s 83%. However, this ratio is still below the average of other countries in Asia, which was 99% (Malaysia, Thailand and Vietnam) or even 100% electrification ratio of Singapore and Brunei (EY, 2015). With the electricity demand growth almost 8.7% per years, the PT Perusahaan Listrik Negara (PLN), a state-owned enterprise on behalf of the Government of Indonesia (GoI) as the only permitted legal entity in supplying electricity for public needs should increase the electrification ratio to meet the demand needs.

3.4.2 Household's behavior challenges

Considering the behavior of electricity uses, the Indonesia Statistics Agency (ISA) was published the Behavior Indicators, Environmental Concern that provide an overview of the household`s behavior on electricity usage. The household behavior challenges to be faced in relation to electricity are as follows:

(a) The electric appliances ownerships

As mentioned before that one of the indicators to demonstrate electricity consumption is through the information on electric appliances as shown in Table 3.2.

Table 3.2. Ownerships of electric appliances

Appliances	Household appliance ownership		
	Indonesia (2013)	Padang city (2014)	Kandahar city (Mohammad et al.,2013)
Rice cooker	64.06%	104%	0%
Dispenser	27.70%	75%	46%
Refrigerator	43.51	106%	41%
Juice blender	-	72%	-
Electric stove	-	4%	-
Mixer	-	41%	-
Microwave	-	11%	0%
Coffee maker		3%	-
Toaster	-	15%	-
Food processor	-	1%	-
AC	5.56%	50%	4%
Electric Fan	53.63%	164%	92%
TV	88%	133%	57%
PC Dekstop	17,52%	35%	12%
Laptop		120%	-
DVD/CD Player	46.08%	46%	-
Game machine	-	20%	-
Washing Machine	11%	72%	70%
Iron	68.72%	100%	75%
Water pump	42.85%	53%	78%
Hair dryer	-	8%	-
Vacuum Cleaner	-	14%	4%

Sources: Author calculation

The most commonly electric appliances are rice cooker, dispenser, refrigerator, TV, iron and water pump. The higher ownerships of home appliances slightly indicated the increase of household income and also indicated high electricity consumption in the surveyed population. Sugiura et al. 2013, Chen et al. 2013 also determined that increasing of the ownership of home appliances, particularly electric appliances caused by the higher household income.

(b) Leaving the lights on during the daytime.

According to data released by the ISA in 2013, there are 20% of households in Indonesia that left the lights on when not in use, especially during the daytime. Whereas, on the National data more than 38% (Padang about 40%) of households still use the traditional incandescent bulbs. These bulbs produce more heat than effective light and consumed more electricity.

(c) Leaving the "appliances on" while not used

Table 3.3 Household behavior related to letting the appliances on

Appliances	Electricity consumption (Watt)	National data (2013)	Padang (2014)
TV	80-400	51%	56%
AC	350-750	41%	30%
Electric fans	110-300	47%	70%
PC Desktop/Laptop	170-500	33%	55%
Radio/Tape/DVD	50-150	40%	65%
Water Pump	100-500	30%	53%

Source: ISA, 2013 and author calculation

From Table 3.3 above, it can be seen that almost 50% of households still leaving the electronic “appliances on” even not used. Besides consuming electricity, leaving “appliances on” also generates CO_2 emission (Table 3.4).

Table 3.4 CO_2 emissions from electric appliance usage per hours

Appliance	CO_2 emission (gr)
Lamp 10 Watt	8.9
Radio/Tape/DVD player	53.4
TV LCD 32”	111.4
PC Desktop/ Laptop	223.0
Rice cooker	267.3
Iron	445.5
AC	668.3

Sources: http://www.iesr.or.id/category/kampanye-2/low-carbon-society

Another side of electric appliances is standby power. Standby power is the energy that still consumed when the electric appliances are not performing their principal function (Solanki et al, 2012, Raj et al, 2009). The amount of power consumption during standby mode could be up to 20 watts, depending on the model and type of appliance (Alan. M, 2003; SA. GOV, 2016). Either permanently used appliances such as refrigerator, air conditioning or intermittently used appliances such as TVs, electric fan, and juice blender consumed energy on the standby mode. It accounts 5-10% of total residential energy use (Solanki et al, 2013). Indonesia Statistics Agency (ISA) in 2012 published that more than 51% of households not unplug the appliances which are rarely used such as TVs, electric fan, microwave, rice cooker, washing machine, and other intermittently used appliances.

(d) Awareness of environmental impact

No doubt that rapid growth in population and income are causing change in electrical energy demand from time to time (Kamaludin, 2013 and Jones et al., 2014). As mentioned above, about 66% of Indonesia electricity is still generated from fossil fuel.

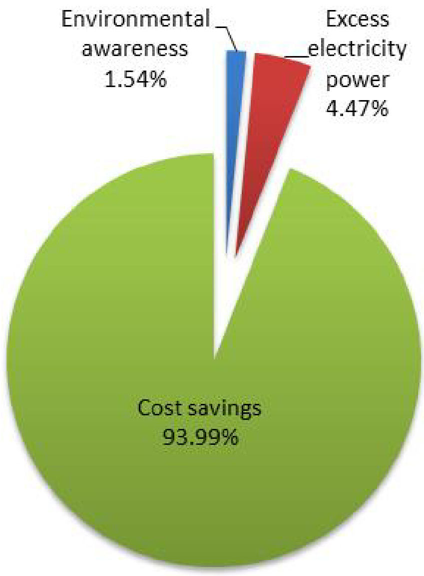

Figure 3.4. Household`s reason for electricity saving

Besides, Indonesia CO2 emissions will increase from 201 million tons in 2015 to 383 tons in 2024 of which 87% came from coal (PLN, 2014). However, public awareness of environmental impact still low, particularly with respect to electricity energy saving. ISA (2012) gives an overview of the public reason of home`s electricity saving. As shown in Figure 3.4, almost 94% of household in Indonesia were saving electrical energy for cost reasons. Otherwise, less than 2% of households were saving electrical energy for environmental reasons.

3.5 Strategies to consider

This section presents the examples cities action around the world that has approached the challenge of controlling and reducing the residential electricity consumption. Indonesia and local city in particular can gain from the existing international experience of taking potential action to lower residential electricity consumption. There are several strategies which complement each other to control and reduce electricity consumption:

(a) Hong Kong

Hong Kong, as one of the world`s major financial and commercial centers where many of the activities take place in the building. In 2012 from a total of 155,079 TJ of electricity consumption, about 26% or the 2nd biggest were consumed by the residential sectors. Air conditioning accounts for 30%, lighting 13%, refrigerator 6%, hot water 3% and cooking 8% respectively of the total electricity end-uses.

Table 3.5. Hong Kong energy saving policy (2015-2025)

Aspects	**Action**
Public education and social mobilization	● EMSD runs educational programs on an on-going basis that includes school visits and roving exhibitions to introduce energy issues to students. ● EMSD initiated the Energy Efficiency Centre at the Hong Kong Science Museum with sponsorship from CLP and HEC; and its interactive Energy Label Net provides information on energy labelling and encourages people to select more energy efficient products. ● EMSD works with relevant service providers to help them better understand energy saving methods, such as organizing annual gatherings.

Aspects	Action
	● Good efforts need to be recognized. In 2004, EMSD first launched the Hong Kong Energy Efficiency Awards to encourage the private sector to save energy.
Financial support /incentive to trigger action	● Providing public funds in the right places can help to trigger community adoption of improved energy practices. ● Promotion of energy saving by Power Company. ● Encourage the energy saving project.
Government leadership and target setting	● Since 1994, EEO of EMSD created an expert unit within the Government to focus on achieving energy efficiency. ● Hong Kong adopted three electricity reduction targets relating to government buildings and two targets relating to energy intensity across the territory: ➢ 2003 and 2009 set targets for government buildings – to reduce 6% and 5% energy consumption under comparable operating. ➢ 2015 adopted a new target of 5% electricity reduction for government buildings for 2015-2020. ➢ 2007 and 2011 adopted APEC's Energy Intensity Target – to reduce energy intensity respectively by at least 25% by 2030 (base 2005) and 45% by 2035 (base 2005)
Public housing	● Energy saving systems. ➢ Optimizing the illumination levels in public areas by adopting energy efficient lighting, maximizing daylight by using photo sensor and timer control, and implementing two level lighting control systems. ➢ Using various means to save energy with respect to lifts and water pump systems.

Aspects	Action
	➢ Implementing grid-connected PV systems in new public housing developments. ● Energy awareness rising. ➢ Developed and rolled-out an Energy Management System in December 2011 for new developments using the ISO 50001 best practice energy framework. ● Good management and inhabitants' behavior. ➢ Installed small meters and display panels at ground level lobbies of new housing blocks. ● Tightening the energy efficient grading standards of home electric appliances to give buyers easily understandable information about energy saving.

Sources: EB, 2015

Hong Kong energy saving policy is to drive saving through a combination of educational, social, economic and regulatory means, especially for buildings and inhabitants to become highly energy efficient by 2025 (EB, 2015). The summary of the energy saving policy can be seen on the Table 3.5.

(b) Japan

Japan is one of the countries where the energy consumption by residential sectors growth 10% in the past of 10 years. The major of energy use in residential sectors can be grouped in to space heating and cooling, cooking appliances, hot water supply, and also lighting. Since the oil crises, Japan has achieved the highest level of energy efficiency in the world through the efforts of the public and the government (SEE, 2012) In general, a number of initiatives and policies have been taken to encourage improvements in electrical energy efficiency.

Table 3.6. Japan energy policy

Policies	Examples Actions
Tax incentives and financing	● The Japanese government provides tax incentives and financing to accelerate the introduction of energy efficient technologies and equipment in the industrial and commercial sector ● The Japanese Government operates several subsidy systems for CO_2 reduction and energy conservation projects
Minimum efficiency standards and labeling	● The Government's Kyoto implementation plan for the residential and commercial/ institutional sectors focus on the following major elements: ➢ Energy efficiency of machinery and equipment: 45% of goal ➢ Energy efficiency in housing and office buildings: 43% of goal ➢ Home and Building Energy Management Systems: 12% of goal
Education and training	● The Energy Saving Label affixed to most household appliances and the ENERGY STAR label on commercial and residential products
Research & Development	● Next-generation energy efficient plasma display panels (PDPs); highly efficient white LED; triple-effect high-performance absorption-type hot water systems.
Top Runner Target Product Standards	● Improve the energy efficiency of specific technologies ● Various kinds of machinery and equipment ➢ Air conditioner, TV, VTR, Light, Copying machine, Computer, Magnetic disk, Refrigerator, Heater, Gas cooking product, hot water supply system, Electric toilet seat, vending machine, and transformer

Source: SEE, 2012

(c) Brunei Darussalam

According to Statistical Yearbook for Asia and the Pacific (UNESCAP) 2013 Brunei has the highest average electricity consumption per capita in Asia, reached to 2948 kWh per capita. From the total electricity consumption, the houses and residential areas account for 38% or represent 63% of all customers (ACE, 2006). To promote and to secure the future of Brunei energy sectors, Energy Department, Prime Minister Office (EDPMO) has set 3 strategic goals;

1. Strengthen and grow oil and gas upstream and downstream activities
2. Ensure safe, secure, reliable and efficient supply and use of energy
3. Maximizes economic spin-off from energy industry – boost local content and secure high participation of the local workforce

Related to reduce electricity energy consumption in residential sectors, Measures include applying "smart" tariffs, application of high-energy efficient technologies in buildings, installation of smart meters and evaluation of the feasibility of altering tariff structure that promotes efficient consumption behavior.

Implementation of the initiatives set out in the residential sector would reduce energy consumption to 36 percent from the Business-As-Usual (BAU) scenario which is about 16.2 percent of the total targeted energy intensity reduction by 2035. Similar measures in commercial sector could result up to 41 percent reduction which is about 18.5 percent of the total targeted energy intensity reduction by 2035. To realizing all strategic goals to reduce energy, particularly electricity energy in residential sectors, in 2009, the Centre for Strategic and Policy Studies (CSPS) has as conducted a Brunei Energy Efficiency and Conservation Study on the Roadmap Formulation and Policy Advice with the following recommendations: (BERW, 2014)

1. Policy 1: Appliance Energy Efficiency Standards and Labeling

- Establishing legal framework for energy efficiency standards.
- Setting up minimum energy efficiency standards for air conditioners in the first phase, followed by refrigerators, lightings and other appliances in the subsequent phases.
- Designing the types of energy efficiency indicators and rating scale to be adopted for each appliance.
- Introducing energy labeling for selected electrical appliances.

2. Policy 2: Building Regulation

- Establishing legal framework for Building Energy Efficiency.
- Introducing energy efficient or green building labels or certificates.
- Demonstrating green buildings

3. Policy 3: Energy Management

- Introducing the energy management process that is compatible with International standards such as ISO 50001.
- Introducing energy audit policy for buildings and industries
- Promoting Energy Service Company (ESCO)

4. Policy 4: Fuel Economy Regulation

- Evaluate the possibility of implementing fuel economy regulations.
- Promoting the utilization of hybrid and electric vehicles.

5. Policy 5: Electricity Tariff Reform

   - Expanding the current progressive electricity tariff for residential sector to other sectors when appropriate.
   - Evaluating feasibility of altering tariff structure to promote desired consumption behavior.
   - Conducting regular surveys to understand the optimum tariff schedule through understanding the relationships between household income and electricity usage.

6. Policy 6: Financial Incentives

   - Introducing appropriate incentives for energy efficient appliances and vehicles.

7. Policy 7: Awareness Raising

   - Setting up EEC curriculum in national education system to increase awareness at the grassroots level.
   - Introducing annual awards to incentivize individual and corporation to practice energy management.
   - Conducting energy exhibitions, roadshows, workshops and seminars for general public to demonstrate the potential for EEC.
   - Educate young generation through the establishment of Energy Clubs in secondary schools and sixth form centers.
   - Regularly publishing energy consumption of major energy users to inform end users and induce their behavioral change.
   - Conducting regular survey on energy consumption pattern in different sector to spur an informed-based decision making process.

3.6 Policy options for Indonesia

By taking steps now to reduce electricity consumption in residential sectors and based on the case studies from other cities worldwide the following are some policy steps and options can be taken as consider to promote electricity reduction. The actions can be divided into short- term opportunities and long-term options.

3.6.1 Short-term opportunities

(a) Campaign the "saving action" in the daily life activities

The campaign aims to have individuals, households and society work together to reduce electricity consumption. In particular, it calls people to:

- Changing the traditional incandescent bulbs (40 watt) with the "energy saving lamps" (8 watt). In order to promote this action, PLN has started to hand out three pieces of "energy saving lamps" to every household. These initiatives will save electricity energy of 2.4 MWh per year or equivalent to 811.38 million liters of fuel per year (MEMR, 2013)
- Reducing electricity consumption of at least 50 Watt during peak hours between 17:00 - 22:00.

At 17:00 to 22:00 pm is the peak load where all customers lit electricity simultaneously for lighting, cooking, cooling and using electric appliances. Through this program is expected to reduce the number of maximum load.

(b) Promote a good practice in the electric appliances usage

Promoting a good practice in the electric appliances usage is a challenge task. The difficulty is to make people aware of how to use electric appliances wisely so they can recognize the responsibility for their own contribution for electricity consumption. Some real actions that can be done are:

- Unplug socket of electric appliances when they are not being used, not only turn off the device by remote control
- Set air conditioners temperature minimum at 25 degree Celsius (MERM regulation No.13/2012)
- Changing the bulb lamps with compact florescent lamps (CFL) or other energy saving lamps.
- Choose and buy energy efficiency and eco- friendly products
- Reduce usage time of cooling system (electric fan/AC) by natural ventilation
- In the peak load time (17:00-22:00) turn off the lamps when they not being used.
- Eliminate needless lighting in the day time by using natural lighting

3.6.2 Long-term planning options

(a) Promote Appliances energy standard and eco-labelling

In 2008, Indonesia launched an energy labeling program. According to the roadmap of the energy labeling program, CFLs is the first labeled product. The aim of this energy labeling is to identify energy saving level for electrical household appliances and it kinds. The standard includes; form, size, color and symbol significant of the energy saving level, location for the energy saving, criteria of energy saving label, and energy saving level score and the amount of star. The energy labeling is important as consideration when choosing and purchasing electric appliances.

(b) Public education and social mobilization

Public awareness campaigns play an important role in raising awareness of the public and in drawing public attention to the risks and advantages of certain behavior in the energy saving. Energy saving campaign in school is one of an investment in long term behavior change. Socialization of energy saving regulation and current status of energy problem is one way to increase public awareness of energy saving for a better future. Besides, the government should conduct energy exhibitions, roadshows, workshops and seminars for the general public to demonstrate the potential of energy reduction.

(c) Building regulation standard

Building account one-third of total energy consumption and important sources of carbon dioxide (CO2). Achieving energy reduction in the building sector is challenging for developing country in the future. The building sector, including residential and service sub-sectors, plays an important role in decreasing the electricity energy consumption. They are used all technologies in the building envelope and its insulation, in space heating and cooling systems, in water heating, in lighting, in appliances and consumer products, and in business equipment. The building regulation includes the building energy efficiency and green building label or certificate.

3.7 Conclusions

This chapter has attempted to synthesize information on policy option that can help to reduce the electricity consumption in the residential sector. The study finds that several options can be taken as consideration for more comprehensive energy reduction plan and implemented over time. By changing in the household`s behavior in the electricity use and promote a good practice in the electric appliances usage, in the short term option is believed to be effective for reducing electricity energy consumption in the monthly bill. In the long term option, government role is essential for implementing energy standard and eco-labelling of electric appliances and promote public education and social mobilization to change people's mind set about energy.

Chapter 4

System Dynamics Modeling for Transportation Energy Consumption and Emissions

4.1 Introduction

In the last few decades, fuel consumption and emission became a serious concern of researchers and policy maker. Global warming, climate change and side effect to human health are problems that face human kind (Sozen et al., 2007; Fong et al., 2008; Ratanavaraha and Jomnonkwo, 2015; Colvile et al. 2001). Strategic options have to be taken to face this situation. According to the data published by the International Energy Outlook 2011 the consumption of fossil fuels, in the global scale, will increase from 354 quadrillion Btu in 1990 to 770 quadrillion Btu in 2035 (EIA, 2011). A significant increase is predicted to occur in Non-OECD countries such as Malaysia (Kasipillai and

Chan, 2008; Shahid et al., 2014), Singapore (GFEI, 2010), Brunei (Ali, 2013), and 40 other countries, including Indonesia. Previous studies showed that the most significant increase fuel consumption and emissions is taking place in cities, where rapidly increase in urbanization and concentrated economic activities (Fong et al., 2008; Ho et al., 2007; Ramachandra and Shwetmala, 2009).

Furthermore, on a global scale, using the year of 2008 as a reference, transportation sector is predicted to have a contribution of 82 percent to the total increase in the usage of liquid fuels in 2035 (IEA, 2011). In the last three years, the sector experienced the largest annual growth rate, reaching 6.45% per year compared to the other sectors (IEO, 2013). From the total energy consumption, 30% of the consumption came from the transportation sector. Moreover, the highest portion of energy source used in the transportation sector is the fuel oil (ESDM, 2012). According to Indonesian transport department`s official report, the total number of vehicles continuously increased almost 90 million in 2012. Moreover, motorcycles population grew from 13 million in 2000 to 77 million in 2012 while the number of passenger cars jumped from 3 million in 2000 to 10 million in 2012 (ESDM, 2012).

Generally, the growth of the transportation sector is mainly driven by road transportation which depends on the availability of oil. In fact that from the total amount of energy consumption, 58% still comes from fossil sources. For Indonesia, it is quite alarming because fossil-based energy reserve of Indonesia is estimated to last only for the next 18-30 years (ESDM, 2012). However, road transport has gradually become an essential part of the transportation system in Indonesia. As result, road transport contributes more than 90% to the total oil consumption and is responsible the increase in the concentration of Greenhouse gases (GHG) and other pollutants. Air pollutants from transportation sources include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), carbon monoxide (CO), hydrocarbon (HC) and particulate matter (PM) (Azhaginiyal, 2014).

The increase in the concentration of GHG in the atmosphere has proven to be harmful to human health and is responsible for global warming and climate change (Fong et al., 2008; Colvile et al., 2001). For Indonesia, Official data published by the Ministry of Mineral Resources showed that the total amount of GHG emissions in 2010 from the transportation sector was 105.1 million tons CO_2-eq. (CO_2 = 104.4 million tons CO_2-eq., CH_4 = 0.4 million tons CO_2-eq., and N_2O = 0.3 million tons CO_2-eq.) (ESDM, 2012). Furthermore, about 91% of the total GHG emissions were produced by road transportation, only about 1% and 8% of the total of GHG emission were produced by marine and air transport, respectively (ESDM, 2012). Hence, fuels (gasoline and diesel fuel) consumed by road transportation activities should be put as the priority action in order to reduce road emissions in the future. Through this study, a system dynamics model is developed to estimate and predict the transportation and emissions trends. In light of these study goals, the model was designed consists of two sub models, i.e., transportation model and emission model. Later on, three scenarios (a normal growth, a partial effort scenario and an integrated transportation scenario) are designed to illustrate the road transportation and emission trends.

4.2 Purpose of Study under this Chapter

Through this study, a system dynamics model is developed to estimate and predict the transportation and emissions trends. In light of these study goals, the model was designed consists of two sub models, i.e., transportation model and emission model.

Later on, three scenarios (a normal growth, a partial effort scenario and an integrated transportation scenario) are designed to illustrate the road transportation and emission trends.

4.3 Overview of the Study Site

In this study, a transportation model has been developed to estimate the fuel consumption and emission in a city of Indonesia. The system dynamics based on the computer simulation model was used to mimic the transportation and emissions system. Padang, the capital city of West Sumatera was chosen as boundary study. Three categories of vehicles such as motorcycles, cars, buses, are used in this model as representing the common transportation in the study area, including private vehicles (cars and motorcycles) and public vehicles (microbuses, buses, and taxi). However, since this is a local level study, shipping, air and long distance fright transportation were omitted in this model.

Related to the transportation sector, according to the Indonesian Transportation Department, the ratio of the population of private vehicles and public vehicles is 98% : 2%. During the period of 2000-2013, the growth of private vehicles reached 12% per year, while the growth of vehicles used in public transportation sector was only 2% per year and shows a downward trend. The population of motorcycles had the highest increase. It reached 250 motorcycles per 1000 people respectively.

4.4 Concept of System Dynamics

The model is a simplified representation of the real - world phenomenon to make it easier to understand. With a model building, our understanding of characteristic of real system would be more effective rather than direct observing the real system (Forrester. J.

W., 1999). Furthermore, Hannon et al, 2001 also stated that a model help to understand a complex real system by mimicking the system and simplified with several assumption of system behavior. Moreover, each element of the model have unique relation and follow the system`s responses when a model a simulated with a computer. When a feedback process among each element of the system is captured trough time, a model become "dynamic". However, not only through of time, a computer modeling becomes "dynamic" also because a dynamic exchange of data and information among the stakeholders (Hannon et al. 2001). In the urban context, system dynamic modeling can help the policy maker to meet challenges of decision making to support the urban development process (Sanjaykumar. S., 2008). Therefore, to develop the transportation and emission models, a commercial simulation program called STELLA is used.

In order to understand the relationship among various variables in the transportation sector and road emission, a causal loop diagram is developed (Figure 4.1).

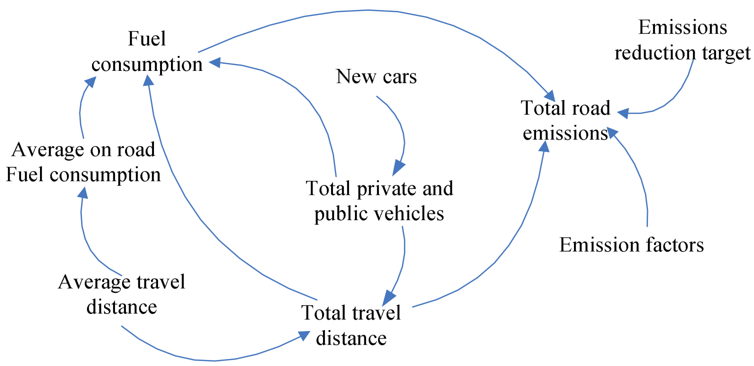

Figure 4.1. Basic causal loop of road transportation

The two main drivers of fuel consumption are the total kilometers travelled by the vehicles and vehicle population. Increasing of fuel consumption, this in turn positively affects to the total of road emissions. The strong link between road emission and fuel consumption provides an important insight into the growth of the transportation demand.

As described above, Padang is a capital city as well as an area with high population density, if compared to other regions. One problem which is quite alarming today is the issue of transportation. The number of vehicles on the road is not comparable to the growth of road infrastructure. Fuel consumption and air pollution become critical issues needing an immediate solution. In this study, the number of private and public vehicles is estimated from the historical data of Padang City from 1994 to 2013. Travel distance of public transportation is estimated by multiplying the average distance of the average trip per day. Table 4.1 shows an assumption that is used in the calculation of fuel consumption.

Table 4.1. Average Fuel Consumption

Type of vehicle	**Average Travel Distance (km/day)**	**Fuel Consumption (km/l)**	**Fuel Consumption (l/vehicles/year)**
Car	18	12	548
Motorcycle	18	43.85	150
Microbus (petrol)	100	12	3,042
Buses (diesel)	126	10	4,599
Taxi	24	12	730

Source: Author calculation

With respect to the emissions model, data related to emissions and other urban pollutants produced by fuel combustion were calculated based on fuel consumption and the distance travelled by different transportation modes. Emission factors to trace GHG emissions and other air pollutants of various types of vehicle are estimated according to EURO emissions standard, as shown in Table 4.2.

Table 4.2. Emission Factors (g/km)

Pollutant/ vehicle	Car	Motorcycle	Auto Rickshaw	Microbus	Bus	Taxi
CO_2	223.6	26.6	26.6[a]	515.2	515.2	208.3
CO	2.2[a]	2.2[a]	5.5[a]	4[a]	3.6	0.9
NOx	0.2	0.19	0.3[a]	12	12	0.5
CH_4	0.17	0.18	0.18	0.09	0.09	0.01
SO_2	0.053	0.013	0.029	1.42	1.42	10.3
PM	0.03	0.05	0.2	0.56	0.56	0.07
HC	0.25	1.42	1[a]	0.87	0.87	0.13

Source: Ramachandra and Shetmala, 2009

[a] Ministry of environment regulation, No.04/2009

4.5 Transportation Model Development

A system dynamic model for transportation and emissions is developed based on a causal loop diagram (Figure 4.1). Total vehicles from road transportation are quantified based on the number of vehicles and average growth rate of vehicles in a year per different vehicle type, which is given by:

$$TV_i(t) = TV_i(t - dt) + (V_i \times GRV_i) \times dt \quad (1)$$

Where, TV_i = total vehicles per type (i); V_i = vehicles per type (i); GRV_i = growth rate of vehicles per type (i).

Fuel consumption is calculated based on the multiplication of vehicles mileage and fuel economy of each type of vehicles, and is given by:

$$\mathrm{TFC} = \sum(V_i \times AD_i) \times FE_{i,km} \quad (2)$$

Where, TFC = fuel consumption; V_i = vehicles per type (i); AD_i = average distance of vehicle per type (i); $FC_{i,km}$ = fuel economy from vehicles type (i) per driven kilometer.

Furthermore, emissions from road transportation is estimated based on the number of vehicles and total travel distance per different vehicle type, and is given by:

$$E_i = \sum(V_j \times TD_j) \times EF_{i,j,} \quad (3)$$

Where, E_i = emission (i); V_j = vehicles per type (j); $EF_{i,j}$ = emission factor of emission (i) from vehicles type (j).

In this transportation and emissions model, it is assumed that future fuel consumption and air emissions trends are mainly affected by vehicle growth rate, emissions standard, and split mode between private and public uses as shown in Table 4.3. Three test scenarios are carried out using this model in order to investigate and predict future fuel consumption and air emissions trends.

Scenario 1 is called a reference scenario whereby it is assumed that the simulation runs based on the existing trend of vehicles growth rate and transportation split mode. In scenarios 2 and 3, it is assumed that, starting from year of 2020 it has major change in several conditions. Prior to 2020, the trends are assumed to be the same as scenario 1, and based on the implementation of Transport Master Plan of Padang 2030 some major improvements on public transportation system will be taking place on/after the year of 2020. Detailed overview of the test scenarios and the stock - flow diagram of the transportation and emissions produced are shown in Table 4.3 and Figure 4.2.

Table 4.3. Detail of simulation scenarios

Variables	**Scenario 1** ***Normal Growth (reference scenario)***	**Scenario 2** ***Partial effort***	**Scenario 3** ***Integrated transportation***
Private vehicles growth	Continue to increase: 12% p.a	Continue to increase: 12% p.a	Starting in 2020, level gradually decrease by 8%
Public Transport growth	Gradually decrease by 1% p.a (bus type) and gradually increase by 2% p.a (microbus type)	From 2020, gradually increase by 1% (Bus rapid transit)	From 2020, gradually increase by 3% p.a (integrated transportation (Bus rapid transit, rail transport)
Emissions standard	Euro II	Euro III	Euro III
Split mode between private and public transportation	53:47 (based on 2010 condition)	Starting 2020, the level of public transportation gradual increases by 50%	from 2020, gradually increase by 70%

1. The above assumptions of future trends are adapted from Transport Master Plan of Padang 2030, and the authors` own rationales.
2. Emission standard is adopted from Ministry of Environment Regulation.

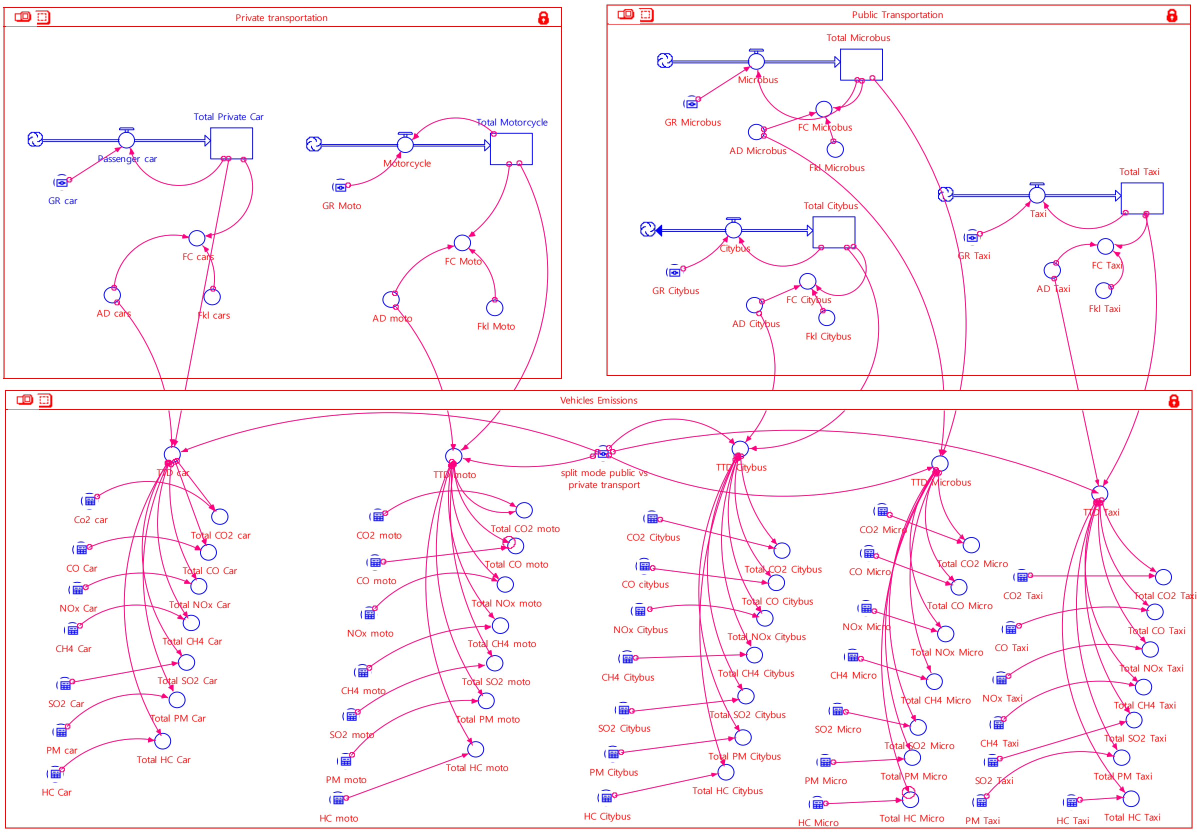

Figure 4.2. The stock - flow diagram of transportation and emissions model

4.6 Results and Discussions

4.6.1 Current Status

Table 4.4 shows the historical fuel consumption level of road vehicles in Indonesia from 2006 to 2013. From the tale, it can be inferred that the fuel consumption level increased from 170 to 323 thousand BOE per year, equivalent to an annual growth rates of 8.1%. It is also can be seen that premium and ADO had the highest growth rate. This was due to the high intensity in motor vehicles usage.

Table 4.4. Energy consumption in transportation sector (Thousand BOE)

	2006	2007	2008	2009	2010	2011	2012	2013
Gas	42	49	124	191	195	181	154	185
Fuel types								
Avgas	19	12	11	9	12	13	14	16
Avtur	14,303	14,845	15,526	16,262	20,779	20,983	22,967	24,499
premium	92,901	98,847	111,377	121,226	130,486	144,330	160,910	166,800
Bio premium	9	326	257	617	0	0	0	0
Pertamax	2,947	2,752	1,736	3,478	3,985	3,643	3,884	4,934
Bio pertamax	0	58	95	118	0	0	0	0
Pertamax plus	748	921	669	829	971	1,717	870	931
Bio solar	1,408	5,692	6,041	15,558	28,503	46,583	60,132	70,932
Kerosene	22	22	18	11	6	4	3	3
ADO	57,268	55,241	60,812	67,328	70,655	59,672	61,092	54,940
IDO	105	57	34	29	35	26	20	15
FO	314	269	194	163	244	158	215	124
Total Fuel	**170,044**	**179,042**	**196,770**	**225,628**	**255,676**	**277,129**	**310,107**	**323,194**
Electricity	41	52	50	68	54	54	66	79

Source : CIDEMR, 2014

ADO : Automotive Diesel Oil

IDO : Industrial Diesel Oil

FO : Fuel Oil

BOE : Barrel Oil Equivalent

The Indonesian National Police reported that from over 86 million vehicles in 2011, 80% were motorcycles, 11% were passenger cars, 6% were trucks, and 3% were buses (BPS, 2011). Over the past 5 years, the Indonesia's vehicles market was grew over 20% and continue increase (Bandivadekar, 2013).

4.6.2 Reference Scenario

In the reference scenario, the current growth rate of various type vehicles (private and public) will continues to happen until the year of 2050 without any major interruption from the present policy. A part of public transportation, the growth rate of city bus gradually decrease by 1% per year, while microbus continuously increase by 2 % per year. The decrease in the growth rate of city buses was assumed due to the shift, from city buses to other vehicle types (microbuses or motorcycles), made by passengers. This phenomenon can be seen from General Plan for Road Transport Network (RUJTJ) of Padang City for the year of 2004-2013 (Figure 4.3). When scenario 1 was applied to the model and setting the split mode ratio between private and public vehicles equals to 53:47, the model predicted that population of vehicles, the amount of fuel consumed will increase, as depicted in Figure 4.4.

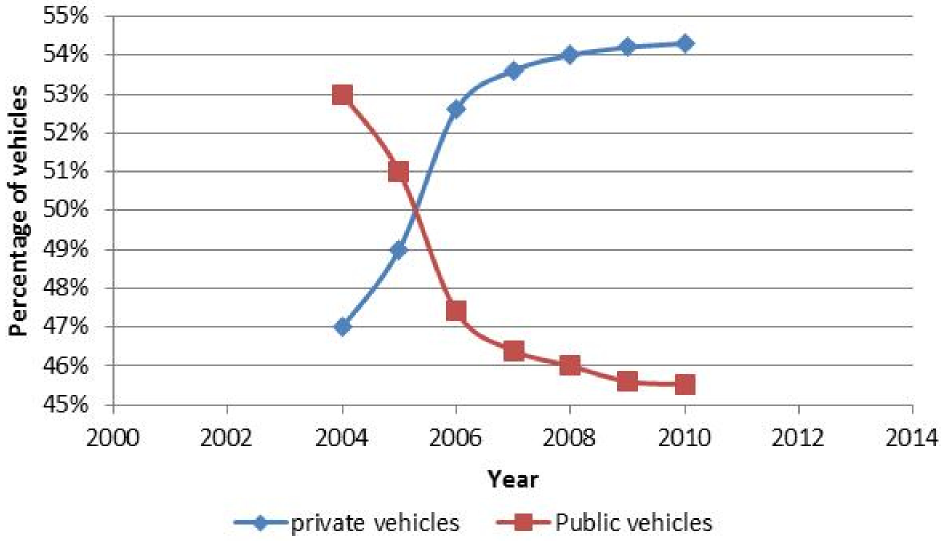

Figure 4.3. Trend of transportation modes

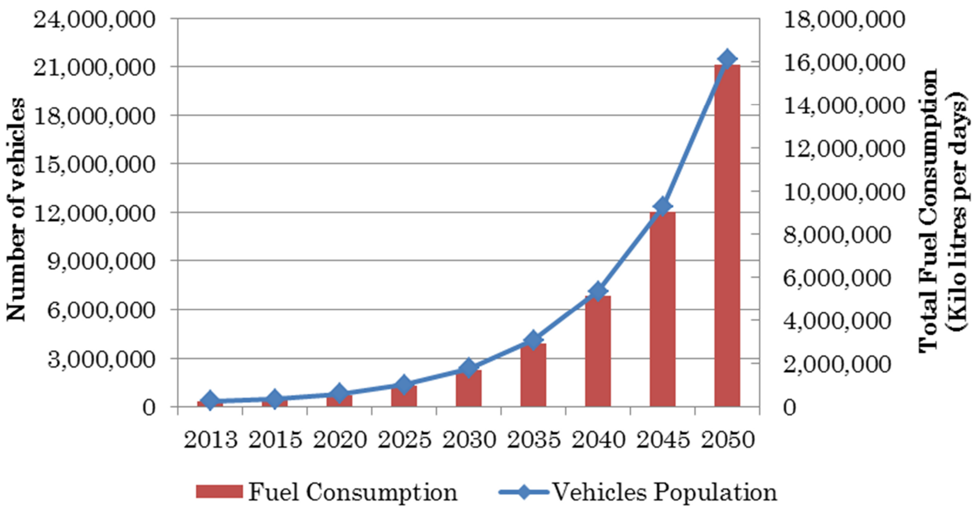

Figure 4.4. Scenario 1- vehicles population and fuel consumption

Moreover, from Table 4.5, it also can be seen that the predicted emission level in 2050 is 65 times higher than the emission level in the year of 2013. Emission analysis based on the vehicles type reveal that motorcycles contribute higher CO2 and other pollutant compounds in year of 2050 (CO_2: 53.8%, CH4: 91.4%, CO: 90.8%, HC: 98.7%, Nox: 85%, PM: 93.3%, SO2: 65%) compared to other road vehicles such as buses, microbuses, taxi and cars.

Table 4.5. Scenario 1- Total emissions from road transport (Kg/km)

Vehicles type	2013 CO_2	2013 CH_4	2013 CO	2013 HC	2013 Nox	2013 PM	2013 SO_2	2050 CO_2	2050 CH_4	2050 CO	2050 HC	2050 Nox	2050 PM	2050 SO_2
Citybus	4,424	0.8	30.9	7.5	103	4.8	12.2	3,050	0.5	21.3	5.2	71	3.3	8.4
Microbus	50,850	8.9	395	85.9	1,184	55.3	140.2	105,803	18.5	821	178.7	2,464	115.0	291.6
Taxi	1,115	0.8	11.0	1.2	1.0	0.1	0.3	1,611	1.2	15.9	1.8	1.4	0.2	0.4
Car	170,652	130	1,679	191	153	22.9	40.4	4,138,954	3,147	40,723	4,628	3,702	555.3	981.1
Motorcycle	74,860	507	6,191	5,403	535	141	37	4,958,141	33,551	410,072	357,881	35,415	9,320	2,423

Source: Author calculation

4.6.3 Overall Simulation

Figures 4.5 and 4.6 present the predicted population of private and public vehicles in Padang. In scenarios 2 and 3, it was assumed that major changes will be made by government in the year of 2020. As a consequence, the model predicted that the population of the vehicles for each scenario is equal from the year of 2013 to 2020 as shown in the figure above.

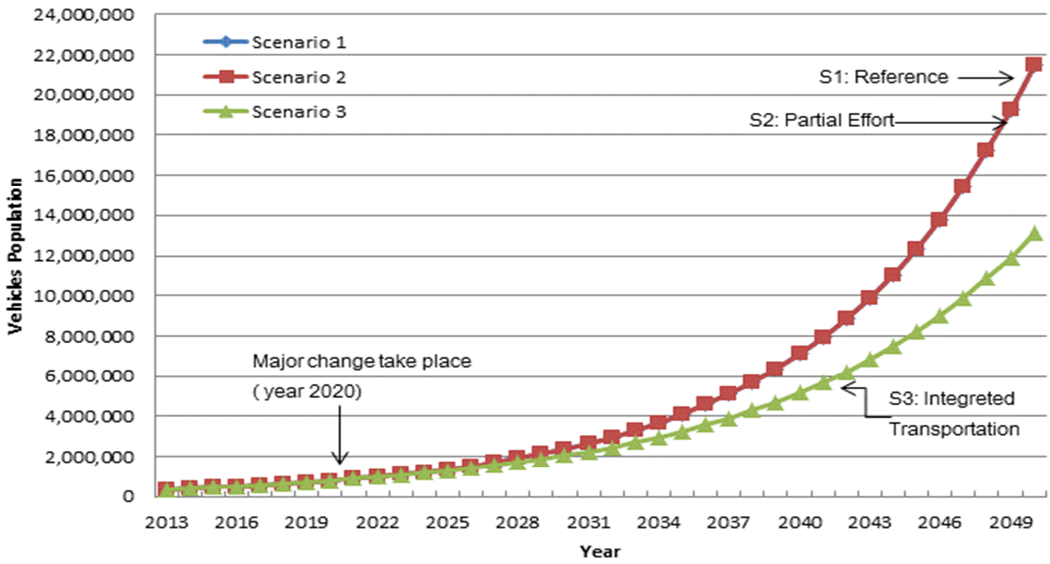

Figure 4.5. Private vehicle populations

Due to the various changes starting from the year 2020 such as vehicle growth rate, implemented of rail transport and split mode transportation, several results of scenarios were seen after year 2020. Under the reference scenario (S1), both of vehicles population (private and public) experience a steady increase until year 2050. A part of private vehicles, the model predicted that the number of motorcycles in 2050 will be 66 times higher than the number in 2013 and the population of passenger cars in 2050 will be 24 times larger than their population in 2013.

Even though with partial effort by implementation of bus rapid transit (BRT), the number of private vehicles was predicted to be same as their population in the reference scenario. In this scenario, a slight increase in the number of vehicles used as means of public transportation was due to the increase in the population of city buses.

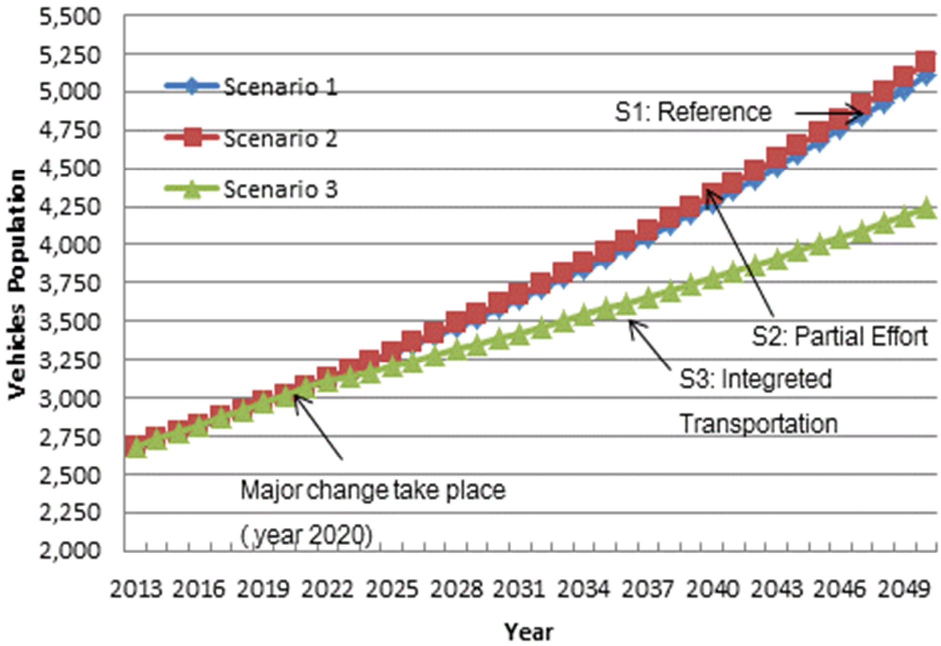

Figure 4.6. Public vehicle populations

According to the master plan of Padang transportation 2010-2030, the implementation of BRT is one of the alternative solutions to decrease the usage of privately owned vehicles. When scenario 3 was applied to the model, it was predicted that, with the implementation of an integrated transportation system consisting of BRT and rail transport, the total number of vehicles used as a means of public transportation will be decreased. This is due to the decrease in the number of microbuses (7 passengers). Furthermore, the model also predicted that the implementation of an integrated mass transportation system will lead to the reduction in the number of microbuses and private vehicles. Under scenario 3, the population of microbuses will be reduced to 30%.

In terms of fuel consumption, the simulation result is shown in Figure 4.7. For scenarios 1 and 2, the total fuel consumption almost has the same pattern. This is due to the partial effort applied to both scenarios. A better result is shown in scenario 3. The total fuel consumption in 2050 is successfully suppressed 36 times lower than the consumption in

2013. The reason for this is the implementation of an integrated public transportation system.

With the implementation of an integrated public transportation system, which was set to

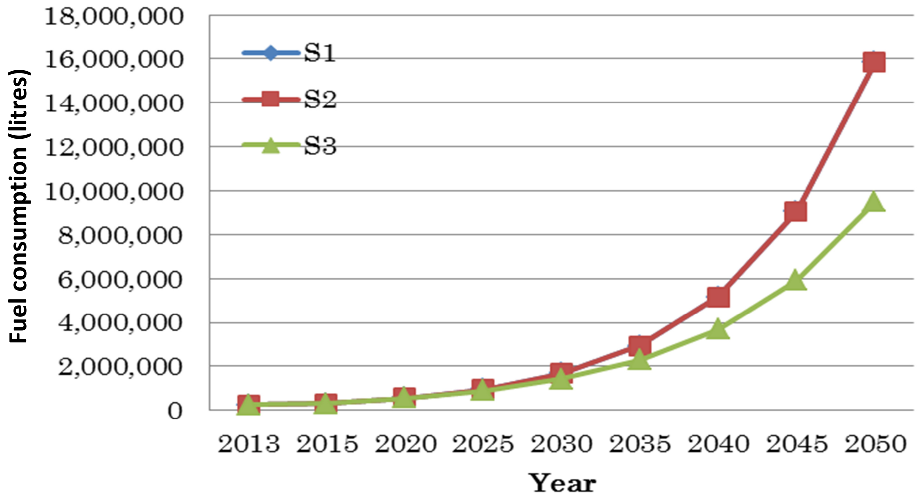

Figure 4.7. Total fuel consumption

happen in 2020 in the simulation, the decrease in road emissions level produced by road vehicles can be observed in Table 4.6. It was found that the emission level of scenario 3 was 34% lower than the emission level of scenario 1 and 17% lower than the emission level of scenario 2. The important point presented by of these results is the emissions produced by motorcycles. From the simulation, it was found that the reduction in the population of private vehicles and the implementation of an integrated public transportation system played a significant role in decreasing emission from road transport. Presently, about 70% of the total amount of emission is caused by motorcycle.

Table 4.6. Total emissions of scenario 3- year 2050 (kg/day)

Vehicles type	CO_2	CH_4	CO	HC	Nox	PM	SO_2
City bus	6,140	1.1	43	10	143	7	17
Microbus	50,750	9	394	86	1,182	55	140
Taxi	1,028	0.8	10	1.1	0.9	0.1	0.2
Car	4,223,145	3,211	37,774	4,722	3,777	567	1,001
Motorcycle	3,883,347	26,278	291,981	43,797	21,899	7,300	1,898

Source: Author calculation

Thus, from the overall results it was found that having a split mode of 70:30 between private and public transportation provided a good result in terms of fuel consumption and emissions. However, to implement this scenario in the real world is not easy. Hence, this element must be a priority for urban energy studies in the future and integrated with the long-term urban planning toward sustainable development.

4.7 Conclusion

In order to project fuel consumption and emission from the road sector in Padang from 2013 to 2050, an integrated system dynamics model was developed under three different scenarios. Although it is a basic model with various limitations as mentioned above, it provides to capture the energy consumption and emission trends. The results show that Padang, in the small scope, will be confronted with a heavy burden of fuel consumption and emissions, which will need serious attention in the future. Particularly, with the existing vehicles growth rate, the total fuel consumption and emissions only from road transportation is predicted to be 65 times higher than that of 2013. From the above test scenarios, it is concluded that the main driving forces of road fuel consumption and emissions is the private vehicles which include passenger cars and motorcycles. Hence, these results should be prioritized in the future context to reduce private vehicle usage and encourage people move to public transportation. Nevertheless, an integrated public transportation system is one of the key points to reduce fuel consumption and emissions from road transport.

Chapter 5

Opportunities to Reduce Fuel consumption and Emission in the Road Transport

5.1 Introduction

Since the last few decades, fuel consumption and emission became a serious concern of researchers and policy maker. Every country has taken differences action towards controlling fuel consumption and emissions. The Government of Indonesia commits to reduce a greenhouse gas emissions by 26% by own efforts and reach 41% if received international assistance in 2020 from the condition without an action plan. Thus, in the transportation sector, the emission reduction target is about 0.038 Giga tons CO_2-eq. (ESDM, 2011).

According to the data published by the International Energy Outlook 2011 the consumption of fossil fuels, in the global scale, will increase from 354 quadrillion Btu in 1990 to 770 quadrillion Btu in 2035 (EIA, 2011). A significant increase is predicted to occur in Non-OECD countries such as Malaysia, Singapore, Brunei, and 40 other countries, including Indonesia. Worldwide, using the year of 2008 as a reference, the transportation sector is predicted to have a contribution of 82 percent to the total increase in the usage of liquid fuels in 2035 (IEA, 2011). In the last three years, the sector experienced the largest annual growth rate, reaching 6.45% per year compared to the other sectors (IEO, 2013). From the total energy consumption, 30% of the consumption came from the transportation sector. Moreover, the highest portion of energy source used in the transportation sector is the fuel oil (ESDM, 2012).

This chapter investigates the potential improvement in the road transportation in urban areas. Besides, this chapter also describes the examples of several urban areas that have implemented policies to reduce fuel consumption and emission in road transport.

5.2 Present State of Fuel Consumption and Vehicles Emission

The transportation sector has grown along with the increase of national economy. Over the past 5 years, the Indonesia's vehicle markets were growing over 20% and continue increasing (Bandivadekar, 2013). According to Indonesian transport department`s official report, the total number of vehicles continuously increased almost 90 million in 2012. Moreover, motorcycles population grew from 13 million in 2000 to 77 million in 2012 while the number of passenger cars jumped from 3 million in 2000 to 10 million in 2012 (ESDM, 2012).

Table 5.1 presents the historical fuel consumption level of road vehicles in Indonesia from 2006 to 2013. The fuel consumption level increased from 170 to 323 thousand BOE per year, equivalent to an annual growth rate of 8.1%. It is also can be seen that premium and ADO had the highest growth rate. This was due to the high intensity in motor vehicle usage.

Table 5.1: Fuel consumption in transportation sector (Thousand BOE)

	2006	2007	2008	2009	2010	2011	2012	2013
Gas	42	49	124	191	195	181	154	185
Fuel types								
Avgas	19	12	11	9	12	13	14	16
Avtur	14,303	14,845	15,526	16,262	20,779	20,983	22,967	24,499
premium	92,901	98,847	111,377	121,226	130,486	144,330	160,910	166,800
Bio premium	9	326	257	617	0	0	0	0
Pertamax	2,947	2,752	1,736	3,478	3,985	3,643	3,884	4,934
Bio pertamax	0	58	95	118	0	0	0	0
Pertamax plus	748	921	669	829	971	1,717	870	931
Bio solar	1,408	5,692	6,041	15,558	28,503	46,583	60,132	70,932
Kerosene	22	22	18	11	6	4	3	3
ADO	57,268	55,241	60,812	67,328	70,655	59,672	61,092	54,940
IDO	105	57	34	29	35	26	20	15
FO	314	269	194	163	244	158	215	124
Total Fuel	**170,044**	**179,042**	**196,770**	**225,628**	**255,676**	**277,129**	**310,107**	**323,194**
Electricity	41	52	50	68	54	54	66	79

Source: CIDEMR, 2014

ADO : Automotive Diesel Oil

IDO : Industrial Diesel Oil

FO : Fuel Oil

BOE : Barrel Oil Equivalent

Increasing of energy consumption, particularly energy from fossil fuel has responsible for the increased concentration of air pollution in urban areas. The increase in the concentration of air pollution has proven to be harmful to human health and is responsible for global warming and climate change (Fong et al., 2008; Colvile et al., 2001). For Indonesia, Official data published by the Ministry of Mineral Resources showed that the total amount of GHG emissions in 2010 from the transportation sector was 105.1 million tons CO_2-eq. (CO_2 = 104.4 million tons CO_2-eq., CH_4 = 0.4 million tons CO_2-eq., and N_2O = 0.3 million tons CO_2-eq.) (ESDM, 2012). Furthermore, about 91% of the total GHG emissions were produced by road transportation, only about 1% and 8% of the total of GHG emission were produced by marine and air transport, respectively (ESDM, 2012). World Bank in 2013 also released the world development indicators (WDI) on September 2015. In terms of the CO2 Emission, Figure 6.1 shows the Indonesia CO2 emission from fuel combustion. In the past 5 years, CO2 emission was gradually increased. Increasing trend of CO2 emissions is observed for all fuel types.

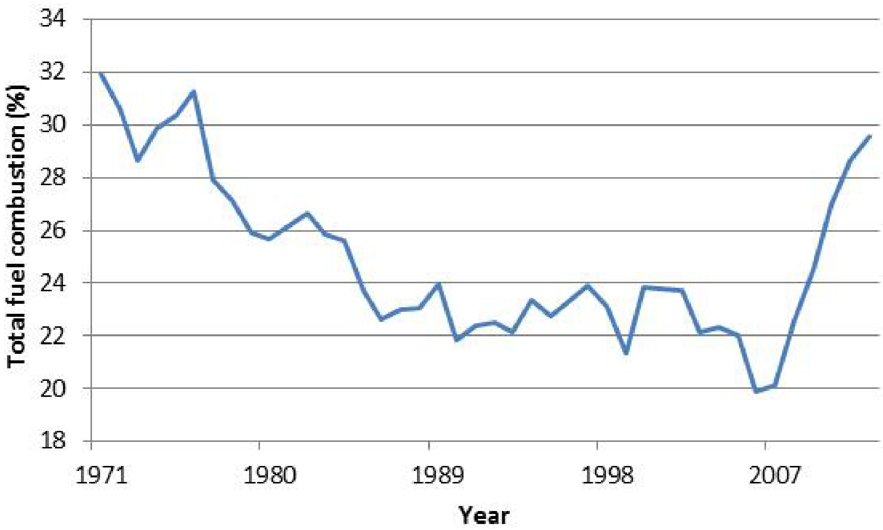

Figure 5.1. CO2 emissions from transport (% of total fuel combustion)
Source: World Bank, 2013

Besides, in the last decade, the monitoring data show annual PM10 concentrations over twice the WHO guideline. Air pollutants are associated with a wide variety of health problems, including heart disease, asthma, stroke, lung cancer, and other respiratory disorders (WHO, 2006).

5.3 Policy Mitigation and Opportunities to Reduce Road Transport Emissions

5.3.1 Best Practice Strategies to Consider

There are several strategies that have been taken by government around the world to reduce fuel consumption and emission from road transport. Clean fuels, tighter emission standard for vehicles, tax incentive and other emission regulation were executed in order to achieve the reduction goals.

1) Clean fuel strategy

Motor vehicle emissions are associated with fuel quality. Recently, gasoline and diesel fuel were the most familiar transportation fuels in Indonesia. The use of subsidized premium gasoline, which has high sulfur content, is currently made up of almost 97 percent of the total gasoline consumption. Unfortunately, the fuel quality is the lowest in ASEAN. The sulfur content of diesel oil ranges from 2,000 to 3,000 ppm. Meanwhile, the fuel that has met the standard of Euro 4 is between 50 and 500 ppm. Compared with other Asian countries, the sulfur content of fuel in Singapore is only 10 ppm, China 50 ppm, Thailand 50 ppm, and Japan and South Korea 10 ppm. Beijing has already reduced sulfur level to 10 ppm and implemented Euro 5/V-equivalent standard. Recently, Indonesian Government launched to use of compressed natural gas (CNG) for public transport. Three-wheeled taxis have already been identified as a target for replacement with CNG vehicles.

Related to the clean fuel strategies, further several cities around the world those have implemented the clean fuel program such as New Delhi, Bogota and Beijing.

(a) CNG in INDIA

Started on July 1998, the Supreme Court of India orders the CNG program in New Delhi, particularly for entire fleet of buses, three wheelers, taxis, diesel buses, and small commercial vehicles. The Central Pollution Control Board the apex air quality monitoring agency in Delhi based on the air quality trends has stated that after the implementation of the CNG program the particulate levels dropped by about 24 per cent from the 1996 levels (Roychowdhury, 2010).

(b) Low sulfur fuel in Bogota, Colombia

The decline in the city's air quality and correlation between diesel-vehicle particulate matter emissions and the sulfur content of the fuel is widely documented. The current sulfur content of the diesel fuel sold in Bogota (1,200 ppm) is higher than that found in major Latin American cities. Face this challenge, in 2010 with a promotion of bus rapid transit in Bogota that called as the TransMilenio BRT system, Bogota also adopts 50ppm sulfur fuel for the city`s diesel bus fleet with Euro IV standard (JR, 2010). Further, starting January 2013, the low sulfur fuel program also implemented in the heavy-duty vehicles.

(c) Clean fuels in Beijing

The percentage of light vehicles has increased from 74 percent in 2001 to 93 percent in 2013 (Yang et al., 2015). As a result, Beijing confronted the issue of vehicle emissions not only from light-duty gasoline vehicles but also from heavy-duty diesel vehicles. Starting 2008, the government successfully secured supply of 50ppm sulfur gasoline and diesel parallel with a program of the EURO 4 standard for local registered vehicles. Recently, to reduce air pollution and alleviate dependence on foreign oil, the Chinese government instituted a plan to boost the market penetration of new energy vehicles (NEVs), including battery-powered vehicles, plug-in hybrid electric vehicles, and fuel-cell vehicles..

2) Improve the tailpipe emission standard

Most countries around the world have chosen to adopt European tailpipe emissions standard. The EURO emission standard has progressed from EURO 1 in 1990 to EURO 6 in 2015. Each emission standard is matched by a fuel quality standard that progressively reduces the sulfur content of the fuel in both diesel and gasoline. Figure 5.2 shows the dramatic effect that each successive Euro vehicle emissions standard has had on particulate matter. As the arrows on the right indicate, the current standard, Euro 6/VI, lowers actual emissions of PM2.5 (measured in grams per kilometer) from both light- and heavy-duty vehicles by 99% from the historical uncontrolled levels.

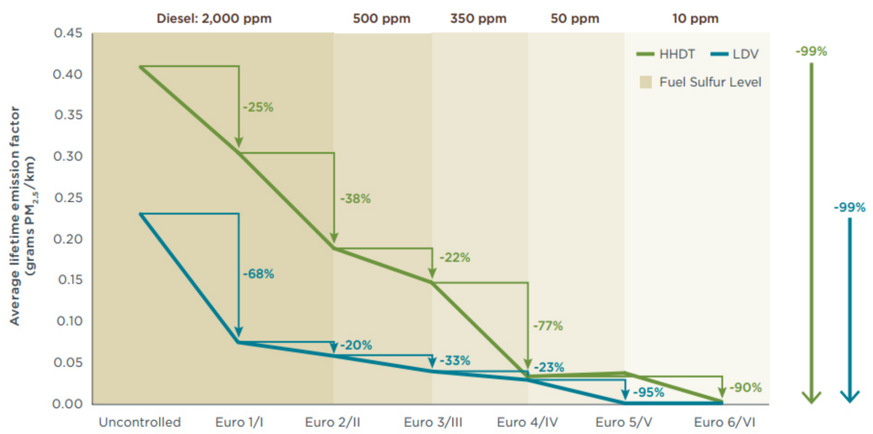

Figure 5.2. European tailpipe emission standards (Chamblish et al., 2013)

Recently, most of Asian countries, including Indonesia have adopted EURO standard. In 2013 Indonesia started implements EURO III for motorcycles (Table 5.2).

Further, through the new policy by MoEF Regulation No.23/2012, upgraded the emission standard for new and current production motorcycle (2-wheeler vehicles with engine displacement >50cm3) types to Euro 3, implemented 1 August 2013 for new types and 1 August 2015 for current production vehicles. This strategy must be followed by the tighter national fuel standard. Moreover, Indonesian government starts to supply fuels with appropriate quality to support implementation Euro 4 Standard in the big cities on October 2016.

Table 5.2 Motorcycles and three wheeler vehicles

Category	Reference Standard	CO	HC	NOx
		(g/km)		
L1	Euro 2	1.0	1.2[1]	
L2	Euro 2	3.5	1.2[1]	
L3 < 150cm^3	Euro 3	2.0	0.8	0.15
L3 ≥ 150cm^3	Euro 3	2.0	0.3	0.15
L4 and L5 gasoline	Euro 2	7.0	1.5	0.4
L4 and L5 diesel	Euro 2	2.0	1.0	0.65

Notes:

[1] Total HC + NOx.

L1: Two-wheeled vehicle with engine displacement ≤50cm^3 and design maximum speed ≤50km/hr

L2: Three-wheeled vehicle with engine displacement ≤50cm^3 and design maximum speed ≤50km/hr

L3: Two-wheeled vehicle with engine displacement >50cm^3 or design maximum speed >50km/hr

L4: Three-wheeled vehicle with asymmetric wheel configuration and engine displacement >50cm^3 or design maximum speed >50km/h (motorcycle + trolley)

L5: Three-wheeled vehicle with symmetric wheel configuration and engine displacement >50cm^3 or design maximum speed >50km/h

Source: summarize from MoEF Regulation No.10/2012

(a) Implementing of EURO 4/IV in Philippine

Based on a report from the Department of Transportation and Communications (DOTC) shows that motor vehicles have been increasing "rapidly" with an average growth rate of 6% over the past decade and identified to have seriously caused the environmental damages particularly in urban areas in the Philippines.

The Philippine government set January 1, 2016, for the implementation of Euro 4, at which time all fuel sold nationally was required to have sulfur limits not exceeding 50 parts per million and all vehicles sold was to be Euro 4 compliant. Prior to 2016, the Philippines adhered to the Euro 2 standard, in which the sulfur limit in fuel was 10 times higher and hindered the government's ability to adopt improved vehicle emission-control technologies (CAA, 2016).

(b) New vehicle emission standard in Beijing

As mentioned in the previous section, the government successfully secured supply of 50ppm sulfur gasoline and diesel parallel with a program of the EURO 4 standard for local registered vehicles. In 2008, Beijing became the first region to implement EURO IV/4 and EURO V/5. Furthermore, in 2013 Beijing`s government launched of implementation of EURO VI/6.

(c) Control of vehicle emissions in Thailand

For over a decade, the road transports (motorcycles, cars, vans and pickups) were the major type at about 90% of registered vehicles. With an increase rate of 22% per annual, the demand of the transport sector is expected to reach 64.7 MTOE, at nearly 2.5 times increase from the year 1995.

Emission standard for new vehicles in Thailand had been established since 1993. Controls of CO and NOX from gasoline vehicles are performed through the use of catalytic converters. After January 1, 1993, all cars having engine sized greater than 1600 cc must be installed catalytic converters. The cars with engine sized smaller than

1600 cc are required to install catalytic converters after June 1, 1993 (TAAPCS, 2000). Recently, vehicle emission standards in Thailand are developed by the Thai Industrial Standards Institute (TISI), collaborated with the Ministry of Industry, the Pollution Control Department (PCD) and agency of the Ministry of Natural Resources and Environment.

5.3.2 Policy Options of Road Transportation

In order to follow up the Bali Action Plan at the Conferences of Parties (COP 13) to the United Nations Frameworks Convention on Climate Change (UNFCCC) and results COP-15 in Copenhagen and COP-16 in Cancun, the Government of Indonesia commits to reduce a greenhouse gas emissions by 26% by own efforts and reach 41% if received international assistance in 2020 from the condition without an action plan. To comply with this commitment, the President of the Republic of Indonesia issued the Presidential Decree No. 61 in 2011 regarding the National Action Plan for Reducing Emissions of Greenhouse Gases (RAN-GRK). It is a working document containing measures to reduce greenhouse gas emissions in Indonesia. Hence, the Ministry of Transportation proposed 9 main strategies for energy conservation in the transportation sector (ESDM, 2012), as listed in Table 5.4.

Based on the RAN-GRK, there are 7 action plans proposed in Padang, Indonesia, including (1) the reformation of Bus Rapid Transit (BRT) system; (2) the renewal of public transportation vehicles; (3) socialization and training of smart driving; (4) non-motorized transport development; (5) intelligent transport system development; (6) the implementation of Traffic Impact Control (TIC); and (7) parking Management Application. The plan adopts a new paradigm of enhancing sustainable transportation development to reduce energy consumption and GHG emissions from the transportation sector, called the *avoid-shift-improve* approach (Ratanavahara et al. 2015). "*Avoid*" or "*reduce*" can be achieved by reducing the need to travel through infrastructure planning and trip management. The "*shift*" means switching from private vehicles to the environmentally friendly public transport. "*Improve*" means increasing the energy efficiency of vehicle technology.

Furthermore, the Indonesian government has realized the importance of reducing the GHG emissions. As shown in the simulation results in the Chapter 4, the growth of GHG emissions can be reduced by reducing of private vehicle ownership. One of the options is the integration of transportation systems such as train and bus modes. Furthermore, light-rail transit system, Bus Rapid Transit, non-motorized transport should be integrated with land-use and urban planning. In details, the strategies options that can be applied are described in Table 5.3.

Table 5.3. Strategies to Reduce fuel consumption and GHG emission

Srategy	Measure	Opportunities/Challenges	Stakeholder
Clean Fuel Strategy	Improvement of fuel quality	- Adopted low sulfur fuel for diesel vehicles - Changing regular fuel (premium RON 88) with more clean fuel type such as Pertalite (RON 90) or Pertamax (RON 92)	National government, MEMR, MoT
	Use of alternative fuels (CNG/biofuel)	- Promote the CNG/biofuel for public transport - A significant political will is necessary	National government, MEMR, MoT, Local government, Automotive industry
Improvement of tailpipe emission	Improvement of emission standard	- Adopted EURO 3 and preparing for EURO 4	National government,

Srategy	Measure	Opportunities/Challenges	Stakeholder
standard	for new vehicles	- Integrated with Bus Rapid transit	MEMR, MoT, Local government
	Implemented of standard emission inspection for private vehicles	- Requires enforcement policy - Massive campaign to promote emission benefits	National government, MEMR, MoT, vehicle owners,
Improvement of transportation infrastructure	Mass rapid transit option	- Integration of transport planning and land use - Encourage people to move from private vehicles to public transport	National government, MEMR, MoT, Local Government, policy makers,
	Non-motorized transport	- Changing the behavior of society - Significant regulation is necessary	National government, MEMR, MoT, Local Government, urban planner, policy makers
Improvement of society awareness	- Educational programs - Energy conservation and energy efficiency campaigns - Use of media and communication	- Educate the young generation how to save energy - Changing the mind set of young generation about energy conservation - Integrated approach is required - Complex and multi sectoral activities	National government, MEMR, MoT, MoE, local Government, policy makers

MEMR : Ministry of Energy and Mineral Resource

MoE : Ministry of Environment

MoI : Ministry of Industry

MoT : Ministry of Transportation

Table 5.4. National Action Plan for Reducing Emissions of Greenhouse Gases (RAN-GRK)

No	Action Plans	Key point (s)	Location
1	Reformation of Bus Rapid Transit (BRT) system	● Implementation of mass transit ● Road based using Buses which uses a special line.	12 cities of Indonesia: Medan, **Padang**, Pekanbaru, palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
2	Renew of public transportation vehicles	● Evaluating of public transportation vehicles ✓ Emission inspection ✓ Vehicles life time ● Change with the new vehicles	12 cities of Indonesia: Medan, **Padang,** Pekanbaru, palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
3	Installation of “converter kit” for public vehicles	● Installation of “converter kit” for public vehicles to replace oil fuel use to natural gas. ● Reduce CO2 emission to 20%	9 cities of Indonesia: Medan, Palembang, Jabodetabek, Cilegon, Cirebon, Surabaya, Denpasar, Balikpapan and Sengkang
4	Socialization and training of	● Teaching and training the environmentally friendly	12 cities of Indonesia:

No	Action Plans	Key point (s)	Location
	smart driving	driving to save fuel and to reduce air pollution.	Medan, **<u>Padang,</u>** Pekanbaru, palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
5	Non-motorized transport development	● Increasing pedestrian and bicycle paths ● Integrated with public transport planning and air quality planning	12 cities of Indonesia: Medan, **<u>Padang,</u>** Pekanbaru, palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
6	Intelligent transport system development	● Improving the communication and information system in the public transport ➢ Travel routes ➢ Cut the travel time ● Decrease the GHG emissions	13 cities of Indonesia: Medan, **<u>Padang,</u>** Pekanbaru, palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan, Banjarmasin and Jabodetabek (Jakarta, Bogor, Depok, Tanggerang and Bekasi)
7	Implementation of Traffic	● Land use and transport planning	12 cities of Indonesia:

No	Action Plans	Key point (s)	Location
	Impact Control (TIC)	● Travel demand management ● Integrated public transport	Medan, **<u>Padang,</u>** Pekanbaru, palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
8	Parking Management Application	● Anti-idling regulation ● Transport demand management (TDM)	12 cities of Indonesia: Medan, **<u>Padang,</u>** Pekanbaru, palembang, Bandung, Semarang, Yogyakarta, Surabaya, Denpasar, Makasar, Balikpapan and Banjarmasin
9	Implementation of Congestion Charging and Road Pricing	● Decrease the private vehicles on the road ● Integrated with mass transportation	2 cities of Indonesia: Jakarta and Surabaya

Chapter 6

Concluding Remarks

In the last few decades, the world was still seeking to address the impact of global warming due to human activities. The global warming phenomenon impacts are strongest and most comprehensive to natural system. Extremely hot seasons are expected to result in longer and increase of heat waves that create serious health risks, increased of air pollution, an intense allergy season, the migration of insect diseases, etc.

Global warming and climate change will not only felt by the developed countries, but the impact will be felt by all humankind of any hemisphere. The global warming phenomenon should be put on global issues, crossing of region, ethnicity, and nationalities. Dealing with these issues requires close cooperation from all nations, and at all levels of society.

The effect of global warming and climate change will be felt by all sectors, including residential, transportation, business and industry. Therefore, dealing with these issues requires aggressive action to solve it. From the study on residential energy consumption under Chapter 2, it was found that lifestyles and daily life activities of household members will have a positive impact on energy consumption and emissions level. Although this topic has been widely discussed, most studies focus on developed countries. As one of the developing countries, very few studies were found discussing the residential energy consumption in Indonesia.

Despite that there are many of energy saving technologies being widely used; the problem is in the "bad habits" of household members in the use of technology. Therefore, this study used cross-section analysis and on-site measurement methods that were focused on each household's lifestyle using life schedule data. This study stressed the investigation of lifestyle and residential energy consumption based on the ownership of home appliances, income levels, occupations, family patterns and different residential areas

Now days, many developed countries took intensive study and investigation to minimize the non-renewable energy resources. Cannot be denied, particularly in developing country are experiencing rapid change from rural to urban-based economies as they are transformed by their urbanizing populations and still depends on energy to drive the economy. In view of finding from Chapter 2 and the fact that currently Indonesia still facing the energy crisis, the purposes of this Chapter 3 is to investigate the opportunities to reduce electricity consumption. The study emphasizes the cities` action around the world that has approached the challenge of controlling and reduces the residential electricity consumption.

Indonesia is among developing countries that still use non-renewable energy resources to produce electricity. The demand electricity was dominated by residential sectors; where the electricity usage was dominated for operate the electric appliances. Most of electricity consumption was majority to meet secondary needs. In Chapter 3, we explore the "unwisely habits" of household`s lifestyle that unconsciously wasting electrical energy. Leaving the lights on during the daytime, leaving the "appliances on" while not used, low awareness of environmental impacts still being "unwisely habits" that should be changed. On whole, we can learn and adopt from the city`s action around the world that has approached the challenge of controlling and reduce the residential electricity consumption. Indonesia and local city in particular can gain from the existing international experience of taking potentials` action to lower residential electricity consumption.

Another aspect that also played a role in global warming is the transportation sector. The growth of the transportation sector is mainly driven by road transportation, which depends on the availability of oil. In fact that from the total amount of energy consumption, a majority still comes from fossil sources. On the other hand, it has been mentioned for several times that the main sources of energy consumption and emissions are from the cities. However, while most of the developed countries have an important action to reduce energy consumption and emissions, In Indonesia, to date still faces the issue of controlling the number of vehicles. In order to deal with these issues, in chapter 4, we develop a practical and reliable method to predict fuel consumption and emission level using System Dynamics in line with limited availability and supporting data. The model was estimated the fuel consumption and emissions data for the case of Padang city, one of the fastest growing cities in Indonesia. The model also can be applied for the major city in Indonesia.

From Chapter 4, results show that Padang, in the small scope, will be confronted with a heavy burden of fuel consumption and emissions, which will need serious attention in the future. Particularly, with the existing vehicles` growth rate, the total fuel consumption and emissions only from road transportation is predicted to be 65 times higher than that of 2013. From the above test scenarios, it is concluded that the main driving forces of road fuel consumption and emissions is the private vehicles which include passenger cars and motorcycles. Hence, these results should be prioritized in the future context to reduce private vehicle usage and encourage people to move to public transportation. Nevertheless, an integrated public transportation system is one of the key points to reduce fuel consumption and emissions from road transport.

Every country has taken differences action towards controlling fuel consumption and emissions. The Government of Indonesia commits to reduce a greenhouse gas emissions by 26% by own efforts and reach 41% if received international assistance in 2020 from the condition without an action plan. Increasing of energy consumption, particularly energy from fossil fuel has responsible for the increased concentration of air pollution in urban areas. Hence, in the Chapter 5, we explore several strategies that have been taken by government around the world to reduce fuel consumption and emission from road transport. Clean fuels, tighter emission standard for vehicles, tax incentive and other emission regulation were executed in order to achieve the reduction goals. Indonesia and local city can gain from the existing international experience of taking potential actions to reduce fuel consumption and emissions level in the future.

Nonetheless, the important key point that must be looked is the commitment of the government. Not only public policy and regulation, but also policy support for research and development for technology breakthrough. In fact, Indonesia is still lagging behind other developing countries such as Malaysia, Thailand, Singapore and Philippine in research and development for technology breakthrough. It is believed that the findings and recommendations in this thesis will serve as a guide for cities in Indonesia, particularly for Padang in the long term sustainable development program.

Last, but not the least, as a growing city, Padang will certainly face the same problems with the big cities, so with these studies expected to be input for making long term sustainable planning programs. Effort only local government is not enough, but regardless of all cities, society, center government, and also other countries must work together to change our lifestyle to save energy and to reduce emissions for future generation.

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