

The phenomenon of climate change in the last few decades has become one of the strategic issues for all over the world, including Indonesia. At the G20 Summit in Pittsburgh and COP15 in Copenhagen, Indonesia is committed to taking part in reducing greenhouse gases (GHG) by 26% with domestic resources and 41% with international assistance in 2020. The commitments are then followed up by the formulation of Presidential Regulation No. 61/2011 and No. 71/2011 on national action plans for GHG reduction. This regulation provides the basis for ministries, institutions and local governments to implement programs/activities aimed at reducing GHG emissions from key development sectors. The Presidential Regulation has mandated local governments to develop Local Action Plans for Greenhouse Gas Emission Reduction. Moreover, Indonesia has set unconditional reduction target of 29% and conditional reduction target up to 41 % of the business as usual scenario by 2030 in Intended Nationally Determined Contribution (INDC) in 2015.

Following up the Presidential Regulation 61/2011 and 71/2011, Semarang City as one of the cities in Indonesia has a liability in the GHG reduction activities. This research on the low carbon society (LCS) scenario for Semarang City are carried out aiming to contribution to promoting climate change actions and policies in the city. This study is one of the outcomes of the collaboration among Municipality of Semarang, Diponegoro University and Asia-Pacific Integrated Model (AIM) team in Japan.

The research are begun with collecting data and information related to socioeconomic parameters and energy consumption. A lot of domestic and international sources are used to estimate both current and future status of Semarang City. The entire data is processed with the help of Extended Snapshot (ExSS) tool. ExSS is applied for the projection of carbon dioxide (CO₂) emission and design of LCS scenario. This preliminary research focuses on energy-related CO_2 emission.

Semarang City's CO₂ emission is estimated to be 5,282 ktCO₂e in 2015 based on collected data. The industry sector is a sector emitting the largest CO₂ in Semarang City. This sector accounts for nearly half of the total emission.

Two kinds of scenarios, namely Business as Usual (BaU) scenario and Countermeasure (CM) scenario, are prepared to analyze reduction potential of CO2 emission in future. In BaU scenario, it is assumed that there is no policy or technology intervention to reduce carbon emission, while attempt to reduce carbon emission is assumed in CM scenario. In the CM scenario, Semarang City Government will promote five LCS actions and implement various LCS projects belonged to the actions. One of the action named "Sustainable Transport", which promotes energy efficient vehicle and modal shift, will contribute to the reduction of 4,220 ktCO2e. These actions and projects help Semarang City to reduce total CO₂ emission in 2030 by 29% compared to BaU scenario. CO2 emission per GDP, which is 39.4 tCO2e/bil. Rp in 2015, will be decreased to 26.9 tCO2e/bil. Rp in BaU scenario and to 19.2 tCO₂e/bil. Rp in CM scenario by 2030. Besides, CO2 emission per capita is 3.3 tCO2e/person in 2015 and will be increased by more than 3 times from 2015 to 2030 in BaU scenario. On the other hand, it will be reduced to 7.8 tCO2e/person from BaU scenario in CM scenario.

In conclusion, Semarang City has a potential to reduce CO_2 emission corresponding to INDC of Indonesia. The city can be developed more effectively and efficiently with contribution to the mitigation of world climate change.

Table 1. CO ₂ emission by sector								
2015 2030BaU 2030CM 2030BaU/2015 2030CM/2030BaU								
CO ₂ emission (ktCO ₂ e)	5,282	22,409	16,009	4.24	0.71			
Industry	2,524	14,577	10,826	5.77	0.74			
Commercial	571	4,042	2,665	7.08	0.66			
Residential	748	1,174	862	1.57	0.73			
Passenger transport	1,351	2,093	1,246	1.55	0.60			
Freight transport	87	523	410	5.99	0,78			
CO ₂ emission per GDP (tCO ₂ e/bil. Rp)	39.4	26.9	19.2	0.68	0.71			
CO ₂ emission per capita (tCO ₂ e/person)	3.3	10.9	7.8	3.29	0.71			













SOCIOECONOMIC VISION

Based on collected data of Semarang City in 2015 and information such as the national economic vision, "Masterplan for Acceleration and Expansion of Indonesia's Economic Development 2011-2025", socioeconomic indicators for 2030 has been projected as shown in Table 2. There will have been an increase in the number of each socioeconomic factor by 2030.

Population and Household

Population of Semarang City will grow by 464,733 people from 2015 to 2030 or 1.29 times as much as population in 2015. This situation is similar to the number of households in Semarang City. The number of households will also increase by 1.46 times compared to the number in 2015. Growth of the number of households is a little bit faster than population growth because household size will become smaller from the present to 2030.

Macro Economy

As described in Table 2, the increase of macroeconomic indicators occurred by 2030 is about 6 times as much as the value in 2015. There are three aspects underlying the macroeconomic conditions which are gross regional domestic product (GRDP), GRDP per capita and final consumption expenditure.

First, the value of GRDP in 2015, which amounted to 134,207 bil. Rp, will have increased to as big as 834,197 bil. Rp by 2030. Manufacturing of food, textile and transport equipment and Information and communication technology (ICT) industry will lead the economic growth of this area as written in the masterplan. The largest contributor to GRDP in Semarang City is the secondary sector. Table 3 and Figure 1 indicate the change of economic structure in Semarang City. GRDP of Semarang City in 2030 will still be dominated by the secondary sector, especially the construction industry, followed by the tertiary sector, and the last is the primary sector. Nevertheless, the

Table 3. GRDP by economic activity

	2015	2030	2030 /2015
Primary industry	1,373	3,590	2.61
Secondary industry	73,340	440,906	6.01
Mining and quarrying	261	1,414	5.41
Foods, beverage and tobacco	17,885	110,507	6.18
Paper, paper products and printing	408	2,165	5.30
Chemicals and pharmaceuticals	6,785	35,783	5.27
Non-metal mineral products	459	1,490	3.24
Basic metals	2,840	17,264	6.08
Metal products, machinery and equipment	2,804	17,162	6.12
Other manufacturing	5,695	32,959	5.79
Construction	36,201	222,162	6.14
Tertiary industry	59,493	389,701	6.55
Electricity, gas, water and waste	250	1,658	6.62
Wholesale and retail trade	18,966	124,395	6.56
Transport and communications	14,669	99,352	6.77
Financial, real estate and company services	10,452	67,700	6.48
Other services	15,157	96,597	6.37
Total	134,207	834,197	6.22

Transportation

In connection with the increasing socioeconomic aspects of Semarang City, transport demand will also grow by 2030. Freight transport volume will increase by 5.99 times from 2015, while growth rate of passenger transport volume between 2015 and 2030 is 1.55. Freight transport demand will change rapidly leaded by the growing manufacturing output.

Figure 2 describes modal share in passenger transport . In BaU scenario, modal share is assumed not to be changed from 2015. On the other hand, modal shift from motorbikes and private cars to public transportation such us buses, bus rapid transits (BRTs) and railways are expected in CM scenario. Modal share of public transportation will have reached to 25% by 2030 in CM scenario.

Table 2. Main socioeconomic indicators in Semarang City

	Unit	2015	2030	2030/2015
Population	persons	1,595,267	2,060,000	1.29
No. of households	households	471,327	686,667	1.46
GRDP per capita	mil. Rp	84	405	4.81
GRDP	bil. Rp	134,207	834,197	6.22
Primary industry		1,373	3,590	2.61
Secondary industry		73,340	440,906	6.01
Tertiary industry		59,493	389,701	6.55
Final consumption	bil. Rp	79,822	486,134	6.09
Gross capital formation	bil. Rp	99,697	607,179	6.09
Export	bil. Rp	37,563	228,772	6.09
Import	bil. Rp	114,672	690,811	6.02
Commercial floor area	thous. m ²	50,252	330,043	6.57
Transport demand				
Passenger transport	mil. pass-km	18,342	28,422	1.55
Freight transport	mil. ton-km	3,391	20,307	5.99

increase in GRDP in the secondary sector is not greater than that of the tertiary sector. Growth rates of the primary, secondary and tertiary sectors between 2015 and 2030 are 2.61 times, 6.01 times and 6.55 times.

Second is GRDP per capita. GRDP per capita in 2015 was 84 mil. Rp and will have reached to 405 mil. Rp by 2030. GRDP per capita will increase by 4.81 times compared with that in 2015.

As a result of population growth and income increase caused by economic growth, final consumption expenditure in the year 2030 will also have increased rapidly. The increase in the year 2030 equals to 6.09 times as large as that in 2015. There is a connection between consumption expenditure and GRDP, especially in the high increase in tertiary sectors, namely Transport and communications; Electricity, gas, water and waste; Wholesale and retail trade; and Financial, real estate and company services.







ENERGY DEMAND AND SUPPLY

Under BaU scenario, final energy consumption will increase by 2,22 times in 2030 compared to 2015. The amount of energy consumed, which was 1,682.8 ktoe in 2015, will have increased to 6,149.6 ktoe in 2030. Table 4 describes that the industry sector will still be the highest energy consumer with the increase in 2030. However, the most rapid growth of energy consumption does not occur in the industry sector, but in the commercial sector instead. Energy consumption of the commercial sector in 2030 will be 7.08 times as much as that in 2015.

In contrast, energy consumption in CM scenario will be 27% lower than that in BaU scenario owing to implementation of LCS projects. Energy consumption will be reduced significantly in the passenger transport sector. The reduction rate compared with BaU scenario is 41%. According to Figure 3, oil will still dominate share of energy source in 2030, but it will have begun to switch from coal and oil to natural gas and electricity as a source of energy especially in CM scenario. Furthermore, use of solar energy will increase for heat-



CO₂ EMISSION

Table 5 and Figure 5 describe estimated CO_2 emission. In BaU scenario, total CO_2 emission will increase by 4.24 times from 2015 and will have reached to 22,409 ktCO₂e in 2030. On the other hand, CO_2 emission in CM scenario will become 16,009 ktCO₂e, which is equivalent to 29% reduction compared with BaU scenario.

The industry sector will still be the largest CO_2 emitter in both BaU and CM scenario. The biggest increase in CO_2 emission in BaU scenario will occur in the commercial sector, where CO_2 emission will

	Total Industry	2,738.9 1,905.2	6,029.5 2,140.8	3,363.7 3,137.6	10,276.8 3,642.7	22,408.9 10,826.3
	Freight transport Total	0.0 2,738.9	522.8 6,029.5	0.0 3,363.7	0.0 10,276.8	522.8 22,408.9
2030 BaU	Residential Passenger transport	0.0 0.0	272.4 2,093.0	0.4 0.0	901.5 0.0	1,174.4 2,093.0
	Industry Commercial	2,738.9 0.0	2,820.5 320.8	3,322.9 40.3	5,694.5 3,680.7	14,576.9 4,041.7
	Total	497.0	2,149.3	592.7	2,042.5	5,281.5
	Freight transport	0.0	87.3	0.0	0.0	87.3
2015	Residential	0.0	173.5	0.3	574.2	748.0
	Industry Commercial	497.0 0.0	492.5 45.3	586.8 5.7	948.2 520.0	2,524.5 571.0
	Sector	Coal	Oil	Gas	Electricity	Total
	Table 5. CO ₂ emission by sector and fuel (ktCO ₂ e)					

ing water in the residential and commercial sector in CM scenario though the share in total energy demand is still small.

Regarding energy mix in power generation, share of renewable source such as solar, wind, geothermal and biomass energy will have increased to 17% in CM scenario as the national power development plan is implemented (Figure 4). CO₂ emission factor will be improved from 10.07 tCO₂/toe in 2015 to 7.74 tCO₂/toe in 2030 CM scenario.

Table 4. Fina	l energy	consumption	by se	ector (ktoe)
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Total	1,682.8	6,149.6	5,091.0	3.65	0.83
Freight transport	29.6	177.2	138.8	5.99	0.78
Passenger transport	457.7	709.2	421.0	1.55	0.59
Residential	392.2	615.8	605.1	1.57	0.98
Commercial	71.7	507.6	442.5	7.08	0.87
Industry	731.6	4,139.9	3,483.6	5.66	0.84
Sector	2015	2030BaU	2030CM	BaU/2015	CM/BaU
		-	-		



have increased by 7.08 times compared to 2015, followed by the freight transport sector (5.99 times) and the industry sector (5.77 times).

In CM scenario, the passenger transport sector and the commercial sector will lead emission reduction. The passenger transport sector will have achieved 40% reduction of CO₂ emission compared with BaU scenario, while CO₂ emission will be reduced by 34% in the commercial sector.



CO2 EMISSION REDUCTION BY LCS ACTIONS/PROJECTS

A variety of LCS projects shown in Table 8 are assumed to be implemented to achieve CO_2 emission reduction in CM scenario. These projects are aggregated into five LCS actions from the perspective of fields and similarities. The actions are "Green Industry", "Smart Building", "Smart Device", Sustainable Transport" and "Green Energy". These actions can help to reduce CO_2 emission by 4,220.3 ktCO₂e. In addition, 2,179.3 ktCO₂e of CO₂ emission are reduced by improvement of CO_2 emission factor of electricity due to the national power policy to promote switching from coal to renewable energy.

Action 1: Green Industry

Action 1 covers LCS projects for reducing energy consumption or CO_2 emission especially factories in industries. CO_2 emission reduction equivalent to 2,552.0 kt CO_2e by this action is largest among all actions, because the industry sector emit more CO_2 than any other sectors and has large room to reduce emission. Energy saving support scheme such as energy service company (ESCO) projects is a dominant project in this action. This project contributes to reduce 964.6 kt CO_2e of CO_2 emission.

Action 2: Smart Building

LCS projects related with housing and building are categorized in Action2. Reduction of CO_2 emission reaches 248.4 ktCO₂e in Action 2. Not only energy saving technology like insulated materials applied to buildings but also installation of infrastructure for natural gas and solar water heater are main projects in the action. For instance, Introduction of solar water heater to houses and buildings can reduce CO_2 emission by 76.2 kt CO_2e .

Action 3: Smart Device

Action 3 is a group of LCS projects promoting energy efficient devices and equipment used in houses and offices. Total GHG emission reduction by projects of the action is 434.1 ktCO₂e. Projects for the commercial sector has a large potential to reduce CO₂ emission reduction. Energy saving support scheme is a project that reduce energy consumption and 150.6 ktCO₂e of CO₂ emission.

Action 4: Sustainable Transport

LCS projects regarding transportation are included in Action 4. CO_2 emission reduction by the action amounts to 950.1 ktCO₂e. Modal shift to public transportation as well as promotion of fuel efficient vehicles are listed in this action. promoting high efficient motor bike is a project which have the largest potential to reduce CO_2 emission (452.3 ktCO₂e) in the action.

Action 5: Green Energy

Action 5 is a category for projects regarding electric power generation from renewable energy. 35.7 ktCO₂e of emission can be reduced by photovoltaic power generation systems and small-scale hydropower generation facilities are introduced in Semarang City.

Table 6. Contribution to CO ₂ emission reduction b	by action and sector (ktCO ₂ e)
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Table 0. Contribution to CO ₂ emission reduction by detion and sector (kteO ₂ c)						
	Industry	Commercial	Residential	Passenger Transport	Freight Transport	Total
Action 1: Green Industry Promotion of energy efficient equipment and fuel shift	2,552					2,552
Action 2: Smart Building Diffusion of low-energy building (Insulation, fuel shift)		215	33			248
Action 3: Smart Device Promotion of energy efficient device/appliance		357	77			434
Action 4: Sustainable Transport Energy efficient vehicle and modal shift				837	113	950
Action 5: Green Energy deployment of renewable electricity		26	10			36
Total	2,552	598	120	837	113	4,220

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Source

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PROJECTS TO ACHIEVE LOW CARBON SOCIETY

Table 8. CO_2 emission reduction by project

Action		Project	Sector	Emission reduction (ktCO ₂ e)
1 Green Industry	1-01	Energy saving support scheme such as ESCO (Energy Saving Company) project for industries	Industry	964.6
	1-02	Installation high energy efficiency facilities	Industry	346.6
	1-03	Regional energy supply system	Industry	489.7
	1-04	Improvement of kiln and furnace technology	Industry	692.3
	1-05	Promotion of fuel shift of furnaces and boilers from coal to natural gas	Industry	58.8
		Total		2,552.0
2 Smart Building	2-01	Installation of insulated glasses to commercial buildings	Commercial	84.1
	2-02	Installation of insulated glasses to houses	Residential	12.2
	2-03	Introduction of incentive to low energy buildings	Commercial	15.9
	2-04	Introduction of insulating material to houses	Residential	7.0
	2-05	Energy efficiency technology applied to buildings	Commercial	35.8
	2-06	Shift to natural gas in buildings	Commercial	17.1
	2-07	Introduction of solar water heater to commercial buildings	Commercial	52.3
	2-08	Introduction of solar water heater to households	Residential	23.9
		Total		248.4
3 Smart Device	3-01	Energy saving support scheme such as ESCO (Energy Saving Company) project for commercial buildings	Commercial	150.6
	3-02	High efficiency lighting in commercial buildings	Commercial	66.5
	3-03	High efficiency lighting in households	Residential	22.8
	3-04	High efficiency air conditioners (such as air conditioners with inverter controllers) in commercial buildings	Commercial	137.3
	3-05	High efficiency air conditioners (such as air conditioners with inverter controllers) in households	Residential	33.7
	3-06	Promotion of energy-efficient appliances	Residential	23.1
		Total		434.1
4 Sustainable Transport	4-01	Promotion of eco-driving with digital tachographs	Transport	7.2
	4-02	Wide-range traffic control	Transport	28.8
	4-03	Expansion of frequencies and routes of bus and BRT	Transport	96.2
	4-04	Development of public transportation like railway and MRT	Transport	98.6
	4-05	Shift to CNG bus	Transport	6.1
	4-06	Introduction of electric motorbikes	Transport	61.5
	4-07	Promotion of energy-efficient vehicles (cars for passenger)	Transport	452.3
	4-08	Promotion of energy-efficient vehicles (motorbikes)	Transport	86.7
	4-09	Promotion of energy-efficient vehicles (trucks)	Transport	112.8
		Total		950.1
5 Green Energy	5-01	Introduction of photovoltaic power generation to commercial buildings	Commercial	24.3
	5-02	Introduction of photovoltaic power generation to households	Residential	9.7
	5-03	Introduction of small-scale hydropower generation (at water distribution stations)	Commercial	1.7
		Total		35.7
Improvement of CO ₂ emi	ssion fa	ctor of electricity		2,179.1
Total				6,399.5

METHODOLOGY

1. Start of the Story

First, we authorize a task force to develop LCS scenario and allocate human resource and budget for the research. We also make a schedule based on needs and situation of a local government.

2. Framework Setting

Background research is important to set an effective framework suited with the target region. We determine framework of the scenario (the target year, the base year, types of greenhouse gases, the target activities and the number of scenarios) by reference to the background. The base year should be decided with consideration for data availability. More than one scenarios such as BaU scenario and CM scenario should be set to analyze effects of LCS actions to reduce GHG emissions.

3. Data Preparation

Two kinds of data are needed. One is for the current status and the other is for the future vision. We collect data and information about population, No. of household, economic accounts, inputoutput tables, transport volume, energy balance tables and GHG emission. If some data are unavailable in the target region, it can be estimated based on other available regional and national data.

4. Design of LCS Projects and Projection of Future Scenario

Based on the collected information, GHG emission for the base year and BaU scenario are estimated by the quantification tool, ExSS. This model was developed by Kyoto University. We adopt both bottom-up approach and top-down to estimate CM scenario. First, we list LCS projects that can be implemented in the target region by the

ACRONYMS AND ABBREVIATIONS

AIM	Asia-Pacific Integrated Model	GHG	Greenhouse Gasses
Bappeda	Development Planning Agency	GRDP	Gross Regional Domestic Product
BaU	Business as Usual	LCS	Low Carbon Society
BRT	Bus Rapid Transit	IEA	International Energy Agency
СМ	Countermeasure	IGES	Institute for Global Environmental Strategies
CNG	Compressed Natural Gas	INDC	Intended Nationally Determined Contribution
СОР	Conference of the Parties	MRT	Mass Rapid Transit
CPG	Central Power Generation	NIES	National Institute for Environmental Studies, Japan
DPG	Dispersed Power Generation	pass-km	Passenger-km
ESCO	Energy Service Company	Rp	Rupiah
ExSS	Extended Snapshot Tool	tCO ₂ e	Tons of Carbon Dioxide Equivalent
G20	Group of Twenty	toe	Tons of Oil Equivalent

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Acknowledgement

This research is supported by the Ministry of the Environment, Japan and the Ministry of Research, Technology and Higher Education of the Republic of Indonesia.

target year, and calculate GHG emission reduction by each project from bottom up based on assumption of degree of implementation. Then, ExSS is used again to estimate GHG emission and reduction from a macro perspective in CM scenario to remove duplication of GHG reduction among projects and to keep consistency.

5. Bridging the Output to Real World

We formulate actions by grouping projects according to themes and fields for implementation. The whole outputs are summarized to a brochure/report and reported to policy makers.



Figure 6. Structure of ExSS