A proposal of Sustainable Low-carbon Society in Vietnam towards 2030

NGUYEN Thai Hoa[1], Kei GOMI[2] and Yuzuru MATSUOKA[3]

[1]PhD candidate, E-mail:nguyenthai.hoa@hx5.ecs.kyoto-u.ac.jp; envi_koneko@yahoo.com
[2]Post doctoral research fellow, E-mail: g.kei@iwyh.mbox.media.kyoto-u.ac.jp
[3]Professor, E-mail: matsuoka@env.kyoto-u.ac.jp
Department of Urban Environmental Engineering, Graduate School of Engineering, Kyoto University
(C cluster, Kyoto-Daigaku-Katsura, Nishikyoku, Kyoto 615-8540, Japan)

In conventional growth pathway, developed countries have been emitting a large amount of green house gases in the process of economic growth. To avoid it, a developing country like Vietnam should leap-frog this process and creates low-carbon society (LCS) directly. One of the strategic objectives of Vietnam government is "development towards a low-carbon economy". In order to contribute discussion on LCS, we created a national sustainable LCS scenario in Vietnam in 2030. We applied an estimation model, Extend Snapshot Tool (ExSS) which estimates quantitative and consistent future snapshot consists of socio-economic indicators, CO_2 emissions, and low-carbon measures. Socio-economic assumption in 2030 was determined based on Vietnam Socio-economic development strategies. Referring the latest strategies to mitigate climate change in Vietnam, a quantitative and concrete portfolio of low-carbon measures was identified. The findings show that (1) with annual GDP growth of 7% and population of 99.3 million persons, per capita emission will increase to 4.5t-CO_2 in 2030 business-as-usual (BaU) or 4.6 times higher than base year 2005. (2) The potential of CO_2 mitigation in 2030 is 45% reduction from BaU. (3) Among the measures, energy efficiency improvement was found to have the largest potential (38% of total reductions). (4) The reduction potential of power generation sector and greater share of public transport, in which the investment's policies play a very important role, was 18% and 16%, respectively. This scenario will be proposed to policy makers and stimulate discussion among stakeholders. Through the discussion, evaluation and modification by various stakeholders, more realistic and acceptable scenario would be defined. Then, Vietnam government will be able to formulate policies towards LCS.

Key words: *Vietnam, low-carbon society (LCS), CO_2 emission, energy, ExSS*

1. INTRODUCTION

(1) Climate change activities in Vietnam and Government Initiatives towards a Low-Carbon Society

Responding to climate change (CC) has been identified as a key challenge to Vietnam's development progress. CC will seriously affect life, production and environment in Vietnam and its impacts are a threat to poverty reduction as well as the achievements of the Millennium Development Goals. CC had caused natural disasters; storms, floods, and droughts frequently occur all over the country and affect to the lives of millions of people. According to World Bank[1)], the sea level rise will increase by 1m at the year 2100 that could cause a yearly capital loss in Vietnam of up to 17 billion USD, and could cause the country's coastal deltas to be inundated over 12% of total territory, where 23% of the 84 million Vietnamese people reside. UNDP[2)] predicts that the Mekong River Delta will be the most severely affected region in term of saline water intrusion, with 1.77 million ha of land vulnerable salinization, accounting for 45% of the delta's surface.

Being one of non-Annex I Parties, Vietnam is not obligatorily committed to reduce greenhouse gases (GHG) emissions as defined in the Kyoto Protocol[3)], but responsible for achieving sustainable socio-economic development. In the view of long term development, if it does not have any intervention of abatement countermeasures, Vietnam will contribute a significant of GHG emission which will make global warming worsen. These changes have direct impact on environment, growth and human in Vietnam. In order to prevent this peril, socio-economic development in Vietnam must go hand in hand with low-carbon society's development. Low Carbon Society (LCS) is relatively new concept in Vietnam. There is no official document containing roadmaps to achieve LCS target. However, there are several national policies, financial instruments and strategies addressing CC and linkage to low-carbon develop-

ment that are in line with and supportive to the LCS concept. Vietnam is now developing the Second National Communication which is expected would be completed in 2010 with following main contents: estimation of the GHG in 2010, 2020, 2030; vulnerable assessment, developing CC mitigation options and adaptation measures based on scenarios in Vietnam in the period 2020-2100; public awareness raising; technology transfer. In 2008, Vietnam government also developed a National Target Program to Respond to CC[4] which its strategic objectives are to assess CC impacts on every sector, area and region in specific period and to take opportunities to develop toward a low-carbon economy, and to join the international community's efforts in mitigating CC and protecting the climatic system.

LCS scenarios have been proposed in some Asian countries such as Japan[5], Malaysia[6], Indonesia[7], India[8]. This study proposes a scenario towards sustainable low-carbon development in Vietnam in 2030. Concrete objectives are (i) deducing the inventory of socio-economic, energy and CO_2 emission in CO_2 equivalent of Vietnam in base year 2005; (ii) quantifying socio-economic activity level in 2030 according to national development objectives; and (iii) proposing five actions to achieve LCS.

(2) Background of Energy in Vietnam

In the last few years, Vietnam had rich fossil energy resource such as oil, gas and coal which are non-renewable energy and also well-endowed with renewable in the form of hydropower, biomass and solar energy which can satisfy the basic needs of energy for the internal socio-economic development as well as partially export to other countries. Electricity demand in Vietnam has the average growth rate of 15% over the last decade, and the Vietnam Institute of Energy has predicted annual growth rates of approximately 18% for the period of 2010-2030[9].

Currently, energy is explored, transformed, transported and used with low efficiency while the self-usage and losses rates are high. Investments in the energy sector can have a substantial impact on water quality, air quality and human health. It is becoming increasingly important to address the potential environmental impacts of energy use and policies.

Electricity consumption in Vietnam grew at 15.3% over 2000-2005. The electricity consumption per capita in 2005 was 538 kWh per year, and is expected to increase up to about 2350 kWh per year by 2020 and over 3096 kWh per year by 2030[10].

Total electricity generation capacity in Vietnam in 2007 was 12948 MW, of which Electricity of Vietnam (EVN) facilities accounted for about 72%, followed by local and foreign independent power producers (24%) and 4% of power was imported[11].

2. CURRENT SITUATION OF SOCIO-ECONOMIC DEVELOPMENT IN VIETNAM

(1) General information

Vietnam is located in Southeast Asia with a total land area of 331,690 km^2 consisting of thousands of islands and a coast line of approximately 3,260 km. Vietnam climate is under the influence of tropical monsoon. Vietnam is known as one of the most populous nations in Southeast Asia and one of the most densely populated nations in the world. In 2009, total population is 86.5 million people, growing at a rate of 1.1%. As economic activities become more vigorous, more people continue to flow into cities, lead to the urbanization rate is around 30.5%.

(2) Macro-economic

Vietnam stands out as having achieved the highest economic growth in recent years. In 2005, the GDP grew by over 8.4%. In which, primary sector contributed 20.7%, secondary and tertiary sector contributed 40.24% and 39.1%, respectively[11]. The service sector is becoming an important economic area for Vietnam. According to Vietnam Prime Minister Nguyen Tan Dung, in the next 20 years, Vietnam will advance by leafs and bounds in all aspects. Vietnam targets to become an industrial country in 2020. While this economic prospect offers great opportunities for development of the energy sector in Vietnam, it also raises concerns over the protection of the environment. Vietnam's GDP reached 838 trillion dong ($53 billion), bringing per capita income to $636 per year, in 2005. According to the Trade Promotion Department (under the Ministry of Trade), foreign direct investment (FDI) rose $5.72 billion, an increase of 25% compared to 2004.

(3) Transportation

Current transportation infrastructure is inadequate to meet Vietnam's rapidly growing needs. In order to meet the target of industrialization and modernization of the country, Vietnam determines that transportation is extremely important and should go ahead of other sectors.

Road transport is the most advanced in terms of privatization and handles the largest volume about 65%[12] (2005) of domestic passenger and freight transports. Road transport mainly serves the domestic market, while international road transport account for an insignificant share.

Inland waterway transport is very developed due to the natural endowment of dense river and canal network, and ranks the second which accounting for 25-30% of total domestic transported volume. Other transportations are contributed by maritime transportation, air transport and railway transport which accounting for 20% of total transport volume.

(4) Industry and Land use

Most of the industrial zones in Vietnam are concentrated in three key economic regions, the North, the Central and the South of Vietnam. By the end of 2008, these three key economic regions had 149 industrial zones with the total natural land areas of 49,232 hectares, accounting for 68 percent of the total number of industrial zones, and 81 percent of their total natural land areas

The major industries of the country are food processing, garments, machine building, fertilizer, shoes, glass, tires, oil, coal, steel, cement and paper.

Secondary industry (manufacturing and construction) makes the largest contribution (over 40%) to the GDP growth rate.

In 2005, export value reached $32.23 billion, while import value rose to $36.88 billion. Vietnam's main exports are crude oil, textiles, garments, footwear and aquatic products. Main imports are machinery, equipment, parts and petroleum products.

3. METHODOLOGY OF LCS SCENARIOS

The methodology for creating LCS scenarios[12] was applied in this research. It includes main steps as follow:

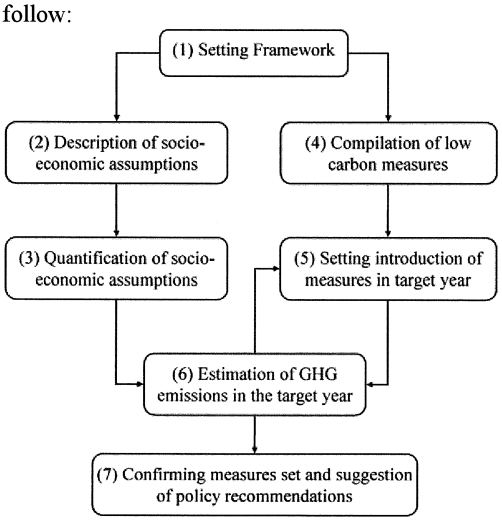

Fig. 1 Procedure of the methodology

(1) Setting framework

Framework of a LCS scenario includes; target area, base year, target year, environmental target, and number of scenarios. In order to achieve the necessary changes the target year should ideally be in the distant future, while in order to make it easy for people to imagine the future a nearer target year is preferable.

(2) Description of socio-economic assumptions

Before conducting quantitative estimation, qualitative future image should be written. It is an image of lifestyle, economy and industry, land use, etc. For LCS scenario, socio-economic assumptions are prior conditions, not the goals desired to be achieved. Therefore in this study, we do not consider how to realize a socio-economic assumption.

(3) Quantification of socio-economic assumptions

To estimate a Snapshot based on future image of (2), values of exogenous variables and parameters are set. Using those input, the tool, namely Extended Snap Shot (ExSS)[13], calculates socio-economic indices of the target year.

(4) Compilation of low-carbon measures

To collect counter measures, which are thought to be available in the target year. Technical information is required to estimate their effect to reduce GHG emissions.

(5) Setting introduction of low-carbon measures in the target year

Technological parameters related to energy demand and CO_2 emissions, in short energy efficiency, are defined. Since there can be various portfolios of the measures, one must choose appropriate criteria.

(6) Estimation of GHG emission in the target year

Based on socio-economic indices and assumption of measures' introduction, GHG emissions are calculated using ExSS. If the GHG emissions achieve the low-carbon target, proceed to (7). Otherwise return to (5), setting low carbon measures, and iterate this process until the low carbon target is achieved.

(7) Proposal of policies

Propose policy set to introduce the measures defined. Available policies depend on the situation of the country. ExSS can calculate emission reduction of each counter measure. Therefore, it can show reduction potential of measures, which especially need local policy. It can also identify measures, which have high reduction potential and therefore important.

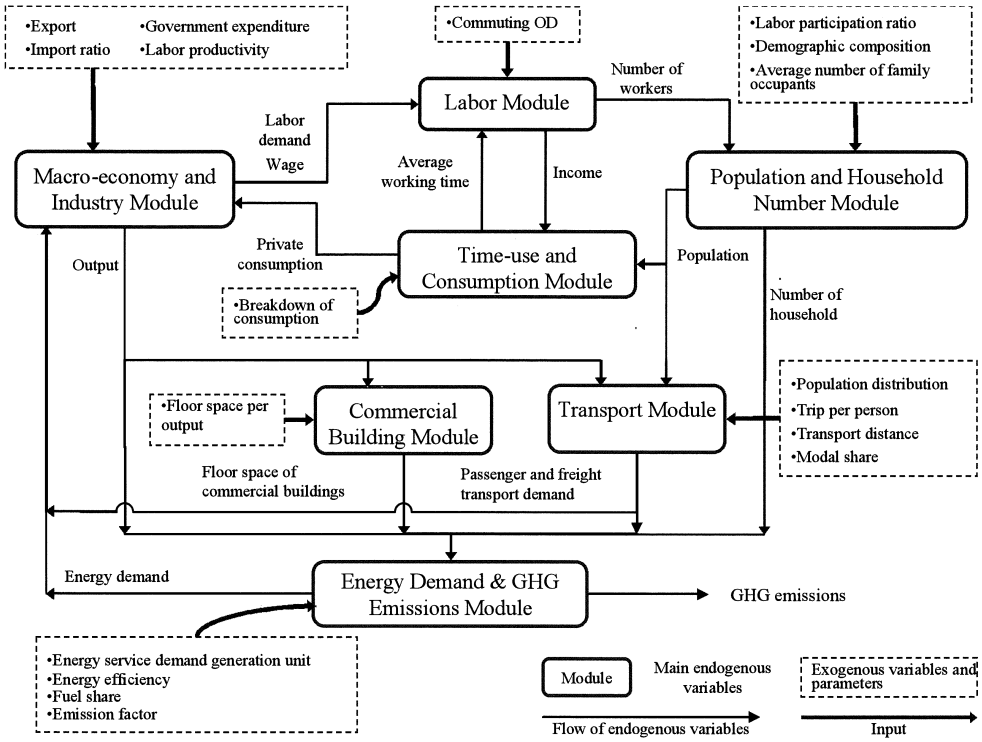

Fig. 2. Structure of the Extended Snapshot Tool

4. QUANTITATIVE ESTIMATION TOOL – EXTEND SNAPSHOT TOOL (ExSS)

Fig. 2 shows the structure of the Extended Snapshot Tool (ExSS); seven blocks with input parameters, exogenous variables and variables between modules. ExSS is a system of simultaneous equations. Given a set of exogenous variables and parameters, solution is uniquely defined. In this simulation model, only CO_2 emission from energy consumption is calculated, even though, ExSS can be used to estimate other GHG and environmental loads such as air quality. To determine output of industries, input-output analysis is applied. For future estimation, assumption of export value is especially important if the target country is thought to (or, desired to) develop led by particular industry, such as automotive manufacturing.

Passenger transport demand is estimated from the population and freight transport demand whereby it is a function of output by manufacturing industries. Other than driving force, activity level of each sector, energy demand by fuels determined with three parameters; energy service demand per driving force, energy efficiency and fuel share. Diffusion of counter measures changes the value of these parameters, and so CO_2 emissions.

5. A LCS SCENARIO FOR VIETNAM APPLYING ExSS TOOL

(1) Framework

The base year 2005 was chosen to analyze current state and is the starting point of calculation because of its available statistic information. The year 2030 was chosen as the final year of calculation and the goal of LCS, because it is also one of the target years, which adopts current national socio-economic development plan.

In this study, the target gas was restricted to only carbon dioxide emissions from fossil fuels.

The target activities are residential, commercial, industrial, transportation and power sectors. In the transportation sector, we covered only the domestic transportation in both passenger and freight transports because there is a difficulty to decide which country is responsible to emission. However, as emission from international aviation can be significant, this problem should be considered in the future work.

Currently, Vietnam has not had a concrete target to reduce GHG emissions. However, one of strategic objectives of National Target Program is to develop

feasible action plans which effectively respond to climate change to ensure sustainable development of Vietnam and to take opportunities to develop towards low-carbon economy. Therefore, in this analysis, we proposed a potential mitigation of CO_2 emissions in the target year.

We estimated two scenarios[14]: one was the case without mitigation measures, namely 2030 BaU (Business as Usual) and the other was the case to introduce countermeasure to achieve the emission target, namely 2030 CM (With Counter Mitigation measures). In 2030 BaU case, we assumed all parameters follow the national socio-economic development trend towards 2030. In 2030 CM case, we introduced low-carbon countermeasures, which will be implemented to achieve LCS in Vietnam. Low-carbon measure was referred from previous studies (such as Japan[5] and Malaysia[6]), and the information on newer measures and technologies was added.

2) Socio-economic assumption and its quantification

Estimation of socio-economic development and macro economic indicators in 2030 in Vietnam is shown in Table 1 and Table 2.

a) Demographic composition

The population growth rate has been reduced recently. However, it is projected to increase of 1% per year in the period of 2010-2030[15]. As of 2005, the population is 83.1 million people[12]. According to United Nation Population Division, Vietnam population will reach over 99.3 million people in 2030[16].

The General Office of Population and Family Planning said at that Vietnam's population has entered the "golden" stage in which the group of working-age people nearly doubles that of dependent age. The country's "golden population" stage will start next year when 67 percent of the population, or 59.5 million people, are expected to be of working age – from 15 to 59.

Table 1 Estimate socio-economic indicators

Parameter	2005	2030	2030/ 2005
Population (million people)	83	99	1.2
No. of households (million)	25	33	1.3
GDP (trillion VND)	818	4,182	5.1
Gross output (trillion VND)	1,933	10,404	5.4
Primary industry (trillion VND)	261	1,068	4.1
Secondary industry (trillion VND)	1,176	6,675	5.7
Tertiary industry (trillion VND)	496	2,660	5.4
Passenger transport demand (mil p-km)	57,696	518,785	9.0
Freight transport demand (mil t-km)	100,728	1,085,643	10.8

Table 2 Marco economic indicators (trillion VND)

Indicator	2005	2030	2030/2005
GDP	818.5	4,182.5	5.1
GDP/capita (mil VND)	9.8	42.1	4.3
Private consumption	585.3	296.9	5.1
Government consumption	8.9	44.9	5.1
Fixed capital formation	30.7	155.6	5.1
Exports	56.2	285.1	5.1
Imports	644.4	323.8	5.0

b) Average number of family occupants

Since number of household is the driving force of energy consumption in residential sector, it is calculated by household size and population.

We calculated household size in 2005 was 3.15 persons in a household and we assumed smaller size of household would be in the future. Therefore, there is an average number of family occupants of three persons every household in 2030. Base on that, number of household will be 33.1 million (2030).

c) Industrial structure

Vietnam is on an increasing economic growth trajectory and has priorities in meeting the development needs. According to Prime Minister Nguyen Tan Dung, annual average GDP growth rate will be in the range of 7-8% in the period of 2010-2030. It is projected that growth of secondary industry will be in the range of 6% and 8.5% up to 2050. Service sector trends to grow fastest, especially faster than the growth of the whole economy[17]. By 2030, economic structure has been estimated as follow: Agriculture, forestry and fisheries 9.8%, industry and construction 55% and services 35.2%.

d) Transportation

Currently, motorbike is overwhelming vehicle in passenger transport. Road and shipping have been the major transportation mode in freight sectors in the future. In the future, the share of using motorbike was assumed to shift in to public transport. Transportation development trend is increasing of public transport and more people respond to walk and use bicycle. Therefore, modal share of passenger and freight transportation sector in 2030 was proposed as follow: [Train] 10%, [Bus] 30%, [Waterway] 11.6%, [Motorcar & motorbike] 35.3%, [Walk] 7%, [Bicycle] 5%; and [Train] 4%, [Road] 61%, [Waterway] 35%, respectively.

e) Composition of private consumption expenditure

The private consumption expenditure has mainly shifted in tertiary industry and manufactures (such as food, beverage and tabaco) and other consumer goods. The composition of this expenditure in 2030 of those sectors was estimated as follow: [Tertiary industry] 50%, [Manufacture industry] 28% and [Consumer goods] 11%.

f) Input coefficient

In this analysis, we do not mention particular changes in the input structure of the industries. It is assumed to be constant in the target year.

3) Compilation of low-carbon measures

We referred some portfolios of countermeasure from the previous study in Japan[5] and other Asian countries[6,7,8]. Low-carbon measure was divided into five actions; (i) Action 1: Convenient Transport, (ii) Action 2: Green Building, (iii) Action 3: Energy Efficiency Improvement, (iv) Action 4: Fuel Switch in Industry, (v) Action 5: Smart Power Plants. Moreover, Vietnam government now supports for CDM (Clean Development Mechanism) programs which aim to mitigate CO_2 emission. Therefore, we added this program into our portfolio of countermeasure.

5. RESUTLS

(1) Energy demand and carbon dioxide emissions

The model result shows that the total energy demand of Vietnam is projected to increase about 3.3 times from 44.4 million toe (toe: tonne of oil equivalent) in 2005 to 144.7 million toe in 2030 BaU scenario. Energy demand of passenger transport and freight transport has increased by 5.7 times and 6.9 times, respectively (Fig. 3).

However, energy demand of industry is estimated to increase 5.2 times and still will maintain the largest share of 36% (52 million toe), followed by transport (42 million toe, 29%), residential (39 million toe, 27%), and commercial (11 million toe, 8%) in 2030 BaU.

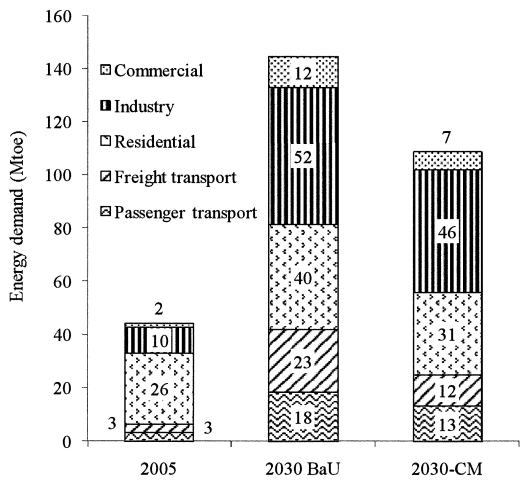

Fig. 3 Energy demand by sectors

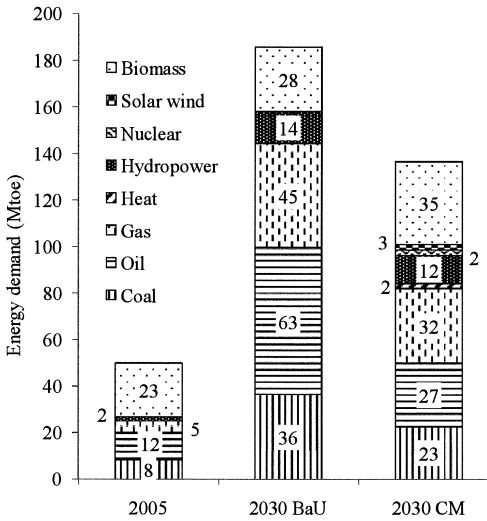

Fig. 4 Energy demand by primary energy

This study shows that by 2030 BaU the energy system of the country would rely more on oil than biomass (fuel wood) this corresponds to the increasing of oil products of supply from the domestic refinery (Fig. 4). By 2030 BaU, the share of oil in the TPES (total primary energy supply) would rise to about 34% (as compared to 24% in 2005), followed by natural gas (24%), coal (19%), renewable (15%), and hydropower (8%).

The total CO_2 emissions in Vietnam are projected to increase from approximately 80.9 million t-CO_2 (2005) to 446.3 million t-CO_2 (2030 BaU) or 5.5 times higher than 2005. It can be illustrated from CO_2 emission from industry will be about 210 million t-CO_2 and the share will be around 47% of total CO_2 emission. CO_2 emissions from passenger transport and freight transport are found to be about around 6 times greater than the amount in 2005.

CO_2 per capita will increase from 0.97 tones of CO_2 per capita in 2005 to 4.5 of CO_2 per capita in 2030 BaU scenario.

Fuel sources for power generation are dominated by natural gas, accounting for 1845 ktoe of the total capacity in 2005 which has the largest share of about 50%, followed by coal (22.5%), hydropower (19.5%) and oil (7%). This share still remain in 2030 BaU scenario.

(2) Potential mitigation in 2030

The amount of CO_2 emission in Vietnam will be reduced from 446.3 million t-CO_2 in the 2030 BaU scenario to 250 million t-CO_2 in 2030 CM by adoption of counter measure for mitigating CO_2 in 2030. Energy efficiency improvement accounts for the

largest CO_2 emission reduction of 40% of total reduction, distributed as 31.6 million t-CO_2 (16%) in transport, 20.4 million t-CO_2 (10%) in industry, 15.6 million t-CO_2 (8%) and 10.3 million t-CO_2 (5%) in commercial and residential, respectively.

Fuel switch of all sectors make up the second largest CO_2 emission reduction of 65.5 million t-CO_2 (33%). The next big potential comes from power supply sector by 36.8 million t-CO_2 emission reduction (19%). The last potential reduction is from increasing the use of public transport (8% of total CO_2 reduction).

Portfolio of energy efficiency improvement includes: (i) industry sector: improvement of low-efficiency coal-fired boilers to higher efficiency ones, improvement of low-efficiency oil-fired boilers to higher efficiency ones, and more efficient industrial equipments and motors; (ii) residential and commercial sectors: replace existing coal-cooking stoves and existing LPG (Liquefied petroleum gases) -cooking stoves to BAT (Best available technology)-cooking stoves, replace incandescent light bulbs by compact fluorescent lamps.

However, in order to realize a low carbon society, Vietnam has to have new and bold policies to encourage and promote businesses and citizens to take these countermeasures.

(3) Five Actions towards LCS

Based on the defined low carbon measures above, we proposed five actions towards LCS in Vietnam (Fig. 5).

a) Action 1: Convenient Transport

The action on convenient transport primarily comprises of a shift from private vehicles to public transportation by traffic management system and increased penetration of fuel switch.

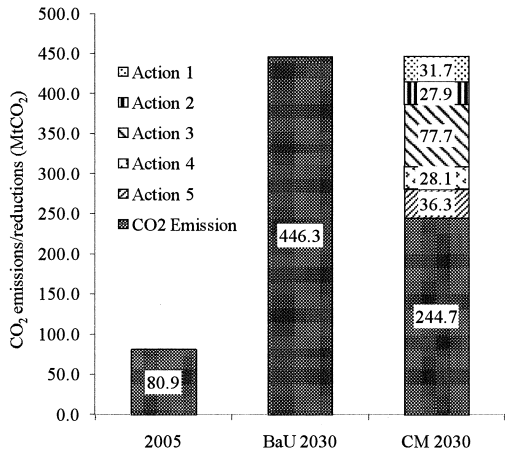

Fig. 5 Five Actions towards LCS in Vietnam

CO_2 reductions from modal shift is 22.1 million t-CO_2. Promoting fuel switch could reduce 9.6 million t-CO_2. Total CO_2 emission reduction from this action contribute to 16% of total CO_2 emission reduction.

As usual economic growth without any interference of mitigations, energy demand and CO_2 emission of this sector will increase to 18.4 million toe and 60 million t-CO_2 in 2030 BaU, respectively. However, in 2030 with countermeasure, the final energy consumption reduces to 13.2 million toe. Accordingly, CO_2 emissions decrease to 40 million t-CO_2.

Currently, Vietnam has paid due attention to transport demand management which including transport infrastructure development (focusing investment on road network development, building new and upgrading key national highways), investment to public vehicles, and bold policy to control and reduce the use of motorbikes.

b) Action 2. Green Building

The "Green Building" action focuses on measures of fuel shifting and natural energy utilization of two sectors (residential and commercial). This action is targeted to reduce CO_2 emissions in 2030 by 12.6 million t-CO_2 and 15.3 million t-CO_2 in the two sectors: commercial and residential, respectively.

Fuel shifting and natural energy utilization comprise following measures such as: biomass heating, solar heating, photovoltaic power and solar water heater.

This action contributes to 39% and 48% CO_2 emission reduction compared to total CO_2 emission reduction in commercial and residential sector, respectively.

In order to achieve this action, it should be deploying policies concerning (i) subsidy to introduce natural energy system (solar and wind energy, photovoltaic power), (ii) low interest loan in investment to building using renewable energy, (iii) environmental performance standard and evaluation of housing and buildings.

c) Action 3. Energy Efficiency Improvement

The "Energy Efficiency Improvement" action is able to reduce CO_2 emissions in all sectors in 2030 by 77.7 million t-CO_2, accounting for about 38% compared to total CO_2 emission reduction.

The highest amount of CO_2 emission reduction accounts for transport sector by 31.6 million t-CO_2, following by industry, commercial and residential sectors with respectively amount of CO_2 reductions are 20.4, 15.6 and 10.3 million t-CO_2.

This action aims to turn the existing or low-efficiency device, equipment, motors or vehicles into "best available technology" models in all sec-

tors. "National Strategic Program on Energy Saving and Effective Use" is used in order to implement this action.

d) Action 4: Fuel switch of Industry

The action "Fuel Switch in Industry" is targeted to reduce CO_2 emission in 2030 by 28.0 million t-CO_2 or 14% of total CO_2 emission. In which, largest potential reduction is accounted for steam boiler by 17.8 million t-CO_2, followed by furnace, 8549 kt-CO_2, and other activities, 1734 kt-CO_2.

Fuel uses in industry sector, will be able to shift from high carbon intensity fuel to lower ones. For instance, fuel switch from coal and oil to natural gas.

To promote mitigation measures of industry sector, incentive to investment in fuel switch is essentially important. Policies for this sector should be focus on tax, subsidy and low interest loans.

e) Action 5: Smart Power Plants

The action "Smart Power Plants" is calculated to reduce CO_2 emission in 2030 by 26.8 million t-CO_2 or 18% of total CO_2 emission. This action comprises of 4 main measures; utilizing economically efficient domestic energy resources, promoting the use of renewable energies, reducing transmission and distribution loss, and developing nuclear power plant[18].

The share of high carbon intensity fuel was decreased and replaced by lower carbon intensity fuel and renewable energies such as solar & wind and biomass.

The transmission loss in 2005 was 11.3% and this number will reduce to 9% in 2030 BaU case and 7.5% in 2030 CM. This trend is made according to EVN's goal for 2025. The model results show that nuclear is required to contribute 8% of power generation in 2030 CM case.

6. CONCLUSION

Due to the constraints of data and information availability, in this study we adopted a simple modeling method. Therefore, it is necessary to apply this model in more detail and more sophisticated in order to investigate a strategy to develop a low-carbon society in Vietnam.

Important research information required for further study includes; more detailed and disaggregated information related to energy in four sectors (resident, commercial, transportation and industry), availability of new clean energy and renewable energy resources, and CO_2 emission from agricultural sector. With this information, it will be promising to show more valid estimation of CO_2 emissions and reductions, which enables the assessment of each mitigation measures and priority of the policies being conducted.

ACKNOWLEDGEMENT

This research was sponsored by Global Environment Research Fund (GERF) - Ministry of Environment Japan (S-6-1) and Global Center of Excellence (GCOE) on Human Security Engineering for Asian Megacities – Kyoto University. It was also supported by National Institute for Environmental Studies (NIES) and Asia-Pacific Integrated Model Team. We would like to express our gratitude for their support.

REFERENCES

1) World Bank: Climate Changes Have Heavy Impact on Vietnam, 2008.
2) Ninh, N. H., Trung, V. K., Niem, N. X.: Flooding in Mekong River Delta, Vietnam, UNDP, 2007.
3) Kyoto Protocol, 1998.
4) Vietnam Government: National Target Program on Climate Change, Vietnam, 2008.
5) Japan Low-Carbon Society scenario team: Japan Scenarios and Actions towards Low-Carbon Societies (LCSs), The Japan_UK Joint Research Project on a Sustainable Low-Carbon Society (LCS), 2008.
6) Matsuoka, Y., Kuruta, G., Fujiwara, T., Shimada, K., Gomi, K., Yoshimoto. K., Janice, J. S., Ho. C. S., Supian, A., Muhammad, Z. S. M. H., Chau, L. W.: Low-carbon city 2025 sustainable Iskandar Malaysia, http://2050.nies.go.jp/LCS, January, 2009.
7) Retno, G. D., Kobashi, T., Matsuoka, Y., Gomi, K., Ehara, T., Kainuma, M., Fujino, J.: Indonesia Low Carbon Society Vision of 2050 in Energy Sector, 2010.
8) Shukla, P. R., Prasoon, A., Amir, B. B., Nidhi, A., Kainuma, M., Masui, T., Fujino, J., Matsuoka, Y., Hibino, G., Ehara, T.: India Low Carbon Society Vision 2050 http://2050.nies.go.jp/LCS, 2009.
9) Electricity of Vietnam: 2006a Planning Reports, 2006.
10) Electricity of Vietnam: EVN's Goals 2005, 2005.
11) Vietnam Institute of Energy, The Sixth Master Plan on Electric Power Sector Development, 2006b.
12) GSO (General Statistics Office): Statistical yearbook. *Statistical Publishing House, Hanoi, Vietnam*, 2009.
13) Gomi, K., Shimada, K., Matsuoka, Y.: A low-carbon scenario creation method for a local-scale economy and its application in Kyoto city, *Energy Policy*, Vol. 38, issue 9, pp. 4783-4796, 2009.
14) Hoa, N. T., Gomi, K., Matsuoka, Y., Fujino, J., Kainuma, M., Shrestha, R. M.: Sustainable Low-carbon development towards 2030 in Vietnam, http://2050.nies.go.jp/LCS, February 2010.
15) Bao, N.M.: Vietnam Energy Outlook, 2008.
16) United Nations, Population Division: World Population Prospects, The 2008 Revision Population Database, http://esa.vn.org/unpp, 2009.
17) Institute of Economics, Vietnam Economic Research Network: Vietnam Power Development Plan VI (in Vietnamese), 2005.
18) Duong, H., Nguyen, T.: The potential for mitigation of CO_2 emissions in Vietnam's power sector, Fourth GMSARN International Conference, HaLong, Viet Nam , 2009.