Development of Middle-term Low Carbon Society Scenario of Vietnam

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Abstract

Since beginning of “Renovation” in 1986, Vietnam has been in a transition from a centrally planned economy to market-oriented one. The country has experienced one of the fastest economic growths in the world, annual average GDP growth rate of around 8% during the past several years. The Socio Economic Development Plan (SEDP) 2006-2010 envisions Vietnam as “an industrialized country by 2020” and GDP per capita is expected to increase about 636USD in 2005 to 1100USD by 2010. Along with economic development comes dramatic growth in energy demand to reach the government’s goal of modernizing and industrializing the economy and integrating into global market. Energy consumption is projected to increase fifteen-time between 2005 and 2030, with a growing reliance on coal as an energy source (PM, 2011). This trend will have significant implication for the country’s contribution to climate change through associated increase in greenhouse gases (GHG) emissions.

Climate change poses substantial challenges in Vietnam which is considered as one of the most vulnerable countries to the effects of climate change. Acknowledging the threats of climate change to Vietnam’s sustainable development, the Vietnamese government ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 16th November 1994 and the Kyoto Protocol on 25th September 2002, while pushing forward its formulation of legislation to create legal framework for climate change response. However, climate change related policies, researches and analysis in Vietnam have largely focus on effects of and adaptation to climate change. However, activities under these programs and strategies focus on primarily adaptation while mitigation activities, particularly in the energy sector are at risk of taking a back position in the face of ambitious development goals. In addition, mitigation studies in the country considered only specific aspects of low carbon study, therefore an integrated and comprehensive low carbon study on pattern of economic growth is still lacking. Moreover, Vietnamese greenhouse gases (GHG) inventory which serves for low carbon study seem to be somehow very backward with the latest information came from 2000.

With these above reasons, there is a need to develop a comprehensive study on assessment of GHG emissions and mitigations at the level of entire economy that can propose required actions towards low carbon society in Vietnam.

In order to do that, a quantification Extended Snapshot (ExSS) and an optimization AFOLU Bottom up (AFOLUB) models are used to estimated GHG emissions and mitigation potential in energy sector and AFOLU sectors, respectively. A comprehensive analysis of modeling results has been done to propose a policy package and required actions towards a low carbon society (LCS) in Vietnam.

The methodology proposed in this dissertation is very outstanding from the above point of view. For example, the ExSS model can assess the effect of consensus, trade-offs and synergy effect among the targets including low carbon target by giving future state which achieved them as socio-economic assumptions. The AFOLUB model can solve the profit maximization problem under several constraints for estimated demand of agricultural and woody products. Moreover, the AFOLUB model can help analyze effect of policies such as emission tax, energy tax and so on.

The findings show that in scenario with interference of countermeasures (2030CM), GHG emissions in Vietnam was reduced 36% compared to the business as usual scenario (2030BaU). In AFOLU sectors, midseason drainage and conservation of existing protection forests are expected the largest mitigation countermeasures in the sectors. In energy sector, about 38% of GHG emissions can be reduced in 2030CM compared to 2030BaU level. Fuel shift and energy efficiency are contributed to the largest reduction in the sector. A policy package and eleven actions towards a LCS in Vietnam are proposed as the main results of the research which has many implications because they can influence the existing energy consumption pattern and GHG emissions and mitigations in Vietnam in future. These actions have been defined with an understanding of the inherent strengths and potential of Vietnam which can be explored at this time of rapid development.

Further, the methods and results of this research would be provided to a LCS policy making process as a starting point of discussion as well as support the discussion among stakeholders. More realistic and acceptable LCS scenario for Vietnam would be defined from the discussion, evaluation and modification by various stakeholders.

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Chapter 1

Introduction

1.1 General introduction and Problem statement

With the launch of its radical reform programme "DOI MOI" in 1986, Vietnam began a transition from a centrally planned to market economy. Vietnam has experienced one of the fastest growing economies in the world, average around 8% GDP growth annually during the past several years and expanding its foreign trade by about 20% per year since the mid-1980s (Chaponnière et al., 2008). Despite the recent global economic crisis, Vietnam's economy has maintained a positive growth rate and it is expected that this trend will continue in the years to come. Among sectors in the economy, industry-construction sector grew up at the fastest speed during 2005-2007 and slowing down during the last few years (2008-2010). The services sector, on average for the period 2005-2007, is the second fastest in its growth. The economic structure of Vietnam continues to move towards an industrialized economy. In the Socio Economic Development Plan (SEDP) 2006-2010 envisions Vietnam as "an industrialized country by 2020" and increasing average GDP per capita (about 636USD in 2005) to USD 1100 by 2010. This strategy will have significant implications for the country's contribution to climate change through associated increase in greenhouse gases (GHG) emissions.

Climate change poses substantial challenges in Vietnam which is considered as one of the most vulnerable countries to the effects of climate change. Its effects include flood, drought, storms, typhoons, sea level rise and temperature increases etc., significant threat to economic and human development, and environment in Vietnam. According to PM (2008a), over the past 50 years (1958-2007), average temperature has increased about 0.5-0.7^{o}C and a 20cm sea level rise, the rainfall on average for the whole country decreased by about 2%.

Sea level rise of between 30cm and 1m over the next 100 years could cause an annual capital loss in Vietnam of up to 17 billion USD, and could cause the country to lose over 12% of its territory (World Bank, 2008). Sea level rise will inundate facilities, stations and transmission lines in coastal area in power infrastructure. Extreme weather events such as storms and floods also could damage transport infrastructure. During the period of 2001-

2005, such extreme weather events cost the transport sector VND 2571 billion in damage (MONRE, 2010). Temperatures increase the cost for ventilation and air conditioning, increase electricity consumption for living and working activities. Climate change could increase Vietnam's exposure to extreme weather events. Higher temperature increases facilitate the spread of some tropical diseases, against which Vietnamese have low immunity. Statistics from Natural Disaster Mitigation Partnership in Vietnam show that, between 1989 and 2008, there were 13097 people died and missed during natural weather disasters in Vietnam. Total loss of property for the period reached USD 4858 million averaging USD 240 million per annum (MONRE, 2010). A study from ADB (2009) stated that the impact of climate change on real Gross Domestic Product (GDP) by 2050 will be 1-3% compared with a scenario that assumes no climate change. Regarding the economics of adaptation, World Bank (2010) concluded that as a result of climate change impact on agriculture the total GDP could be reduced by 0.7%-2.4% in different scenarios and models. In forest sector, the total area of mangrove forests reduced from 400000 hectare in 1943 to less than 60000 hectare in 2008 (MARD, 2009). Impacts of sea level rise, increasing temperature, saline water intrusion and droughts etc., could put pressure on total agricultural production, local and national food security and rice exports, and is a structural upwards pressure on global food prices. This would imply an increasing pressure on the world market price of rice because Vietnam is the second rice exporter in the world (UN, 2011). "*Climate change consequences in Vietnam are severe: it is an explicit threat to the poverty alleviation and hunger eradication goals and the achievements of Millennium Development Goals and sustainable development of the country*" (cited in National Climate Change Strategy, 2011).

Acknowledging the threats of climate change to Vietnam's sustainable development, the Vietnamese government ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 16th November 1994 and the Kyoto Protocol on 25th September 2002, while pushing forward its formulation of legislation to create legal framework for climate change response. However, climate change related policies, researches and analysis in Vietnam have largely focus on effects of and adaptation to climate change. More recently, the government has started to shift some attention to mitigation aspects. For example, one of the objectives of the National Target Programme Response to Climate Change (2008) is to "take an opportunity to develop towards a low carbon economy". In addition, National Climate Change Strategy which was approved by

Vietnamese government on December 2011 aims to carry out adaptation measures and GHG emission reduction etc. However, activities under these Programme and Strategy focus on primarily adaptation while mitigation activities are at risk of taking a back position in the face of ambitious development goals.

Moreover, the GHG inventory in Vietnam is not updated regularly. To date, Vietnamese government submitted the Initial and Second National Communication to the UNFCC in 2003 and 2010, respectively. They provided information on the national GHG inventory in 1994 and 2000, respectively (Table 1.1).

Table 1.1 GHG emissions by sector, in 1994 and 2000

Unit: thousand tons of CO_2

Year	1994[1]		2000[2]	
Sector	Emissions	Percentage	Emissions	Percentage
Energy	25,637	25	52,773	35
Industrial processes	3,807	4	10,006	7
Agriculture	52,450	51	65,091	43
LULUCF	19,380	19	15,105	10
Waste	2,565	3	7,925	5
Total	**103,839**	**100**	**150,900**	**100**

Source: [1] Vietnam Initial National Communication, (MONRE, 2003); [2] Vietnam Second National Communication, (MONRE, 2010).

According to WRI (2008), GHG emissions in Vietnam are at a lower level compared to global scale (Figure 1). It can be seen in Table 1.1, total GHG emissions in 2000 were only about 150 $MtCO_2$ which was about 1.5 times over 1994 level. Although the GHG emissions in developing countries are lower compared to the developed countries, it is expected to increase sharply in the future (Kainuma et al., 2007). The anthropogenic GHG emission in Vietnam has been increasing dramatically by 7% between 1995 and 2000 and by 11% between 2000 and 2005 (Hoang et al., 2010). The per capital emissions in 2000 in Vietnam are only one third of the global average emission per person (1.9 tCO_2/year compared to global average 6.8 tCO_2/year) (MONRE, 2010 and WRI, 2008), but they are projected to grow rapidly compared with the rest of the world (Hoang et al., 2010). Figure 1 highpoints the fact that middle-income and high-income countries are responsible for about same share of GHG emissions. The Figure is particularly valuable for putting Vietnam's relative and absolute contribution of GHGs into perspective.

GHG emissions from energy sector increased more than 2 times from 25.6 $MtCO_2$ in 1994 to 52.8 $MtCO_2$ in 2000. Emissions from agriculture and land use, land use change, and forestry (LULUCF) sectors increased from 71.8 $MtCO_2$ in 1994 to 80.2 $MtCO_2$ in 2000. Emissions from energy sector are expected to sharply increase in future. This is because at present, much of Vietnam's electricity production has been generated through hydroelectric plants, but there is an rising trend towards increased use of coal, with Vietnamese government estimates that "coal will be Vietnam's leading source of energy at 34%" (Time Magazine World, HP). In addition, there are much inefficiency in household and public sector energy use, in transport sector, and in the manufacturing industry. Furthermore, with a target being an industrialized country in 2020, there will be an emerging trend of consuming energy especially fossil fuels, which lead emissions dramatically increasing.

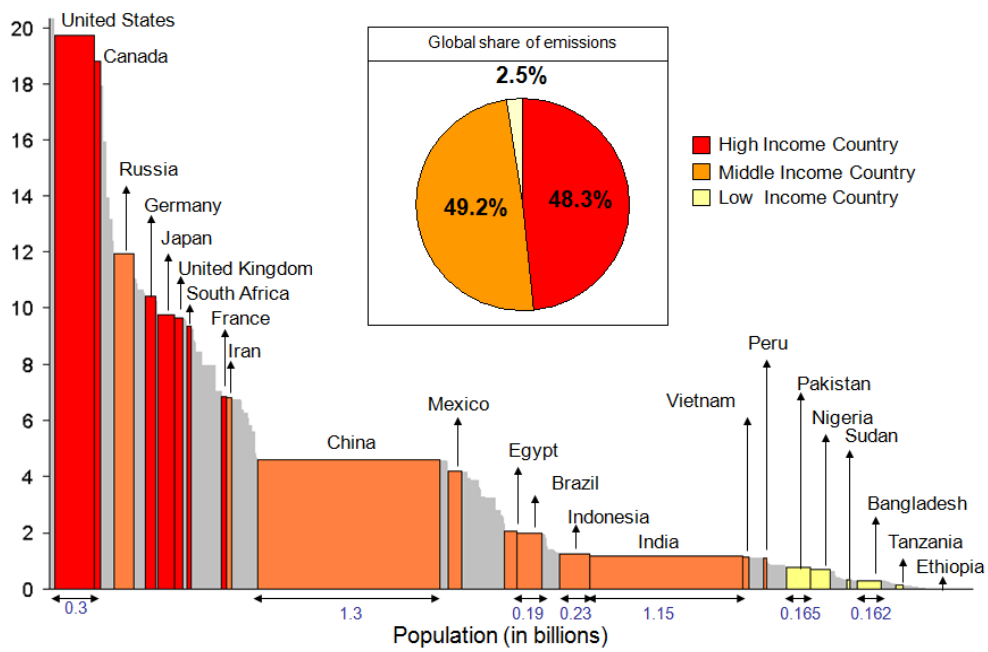


Figure 1.1 GHG emissions in Vietnam and global

Source: WDI (2008)

Agriculture, Forestry and Other Land Use (AFOLU) sectors are also one of the major GHG emissions sources, account for more than 50% of total GHG emissions in the country as shown in Table 1.1).

Therefore, looking ahead, Vietnam is likely to experience dramatic growth in consumption and associated GHG emissions. In which, energy sector is becoming primary source; agriculture remains import emitter and will increase due to intensification of wetland rice, livestock production and fertilizer use; and forestry can become a net carbon sink if Reducing Emissions from Deforestation and Forest Degradation (REDD-plus) is successful.

Recently, there are a number of studies about mitigation aspects carried out by governmental agencies, science academies, universities, institutes with international assistance at different levels and in various forms. However, they considered only specific aspects of low carbon study such as development of renewable energy, energy efficiency; development and assessment of mitigations in agriculture or forestry or energy sector separately; assessment potential for Vietnam to participate in the Clean Development Mechanism (CDM); demand-side management and energy efficiency and so on. It is therefore that an integrated and comprehensive study on pattern of economic growth that will be low carbon for the whole country is still lacking. There has not been any integrated study conducting GHG emissions and mitigation potential for both energy and AFOLU sectors that includes a portfolio of concrete countermeasures towards LCS. Moreover, the Vietnamese GHG inventory which serves for low carbon study seem to be somehow very backward with the latest information came from 2000 (MONRE, 2010).

With these above reasons, there is a need to develop a comprehensive study on assessment of GHG emissions and mitigations at the level of entire economy that can propose required actions towards LCS in Vietnam. This research will go on to study the projections of GHG emissions and mitigation potential in energy and AFOLU sectors; the proposal of the detail low carbon countermeasures and the amount of GHG reduction from each specific low carbon policy package; and provision of required actions towards LCS in Vietnam.

1.2 Objectives of Research

Against the above background, the goal of this research is to identify a package of policy as well as concrete mitigation actions to develop a LCS scenario in Vietnam. In order to achieve the goal, the following specific objectives are set:

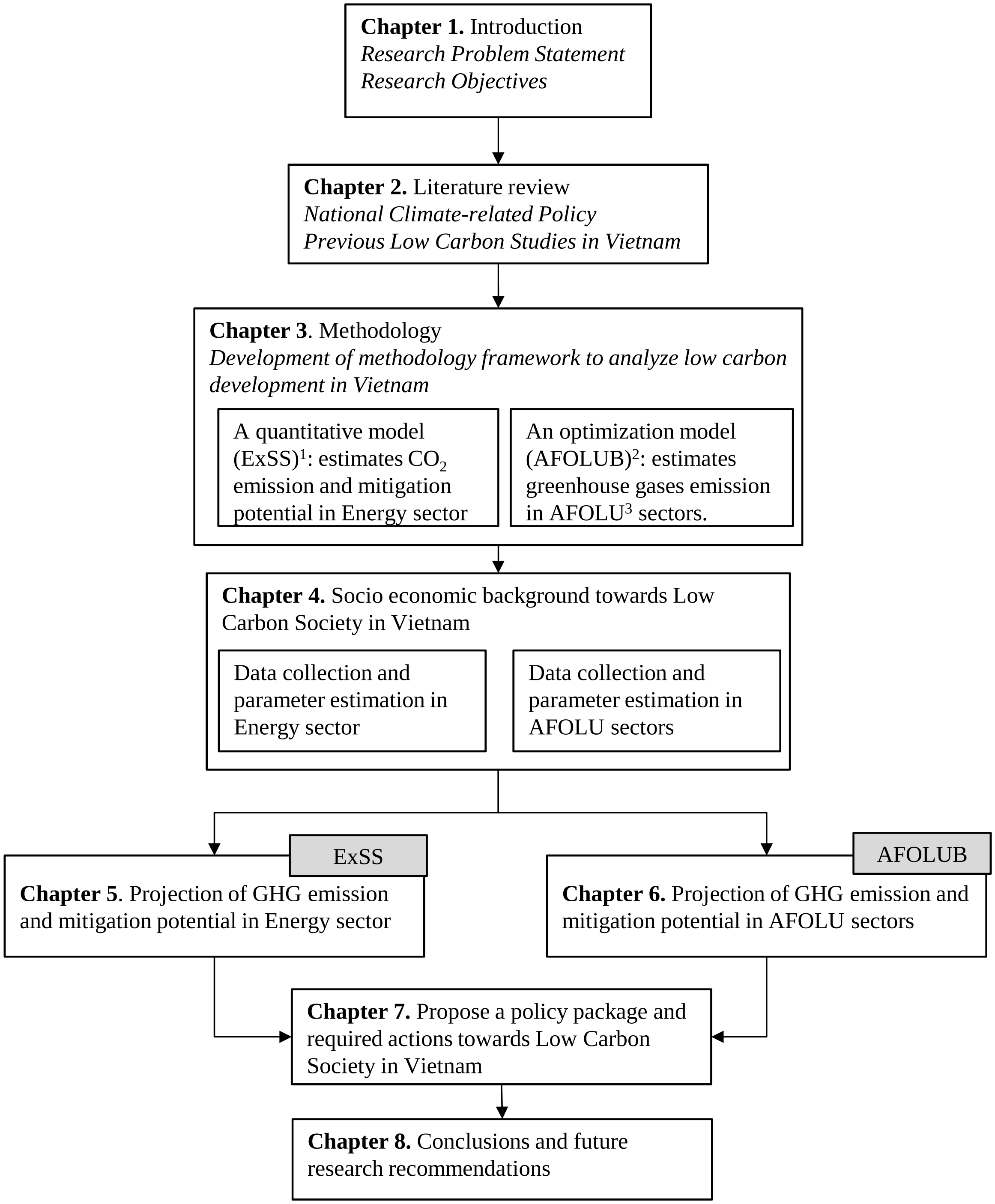
- To review the existing low carbon studies in Vietnam and review the development of energy and agriculture, forestry and other land use sectors in order to develop a database system.
- To project GHG emissions and mitigation potential in energy sector (including residential, commercial, industry and transport sectors) by using a quantitative model, namely Extended Snapshot (ExSS).
- To project GHG emissions and mitigation potential in AFOLU sectors using an optimization model, namely AFOLU Bottom-up (AFOLUB).
- To propose a policy package and mitigation actions towards LCS in Vietnam.

1.3 Scope of Research

- This research focused on the development of a LCS for Vietnam. Two scenarios, business as usual (BaU) and countermeasures (CM), are assessed in terms of GHG emissions and mitigations.
- The focus sectors are energy sectors (including residential, commercial, transport, industrial and power sectors); and AFOLU sectors (including agriculture, forestry and other land use sectors).
- The targeted GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). For energy sector, only CO_2 emission is considered. For AFOLU sectors, all of above GHG emissions are estimated.
- Base year and target year for calculation are 2005 and 2030, respectively.

1.4 Research Framework and Organization

With the target of achieving the above mentioned goal and objectives of this thesis the research framework is designed. The thesis comprised eight chapters as shown in Figure 1.2, which are structured in the following manner:



[1]ExSS: Extended Snapshot Tool
[2]AFOLUB: Agriculture, Forestry and Other Land Use Bottom up model
[3]AFOLU: Agriculture, Forestry and Other Land Use

Figure 1.2 Structure of the thesis

Chapter 1 introduces the background of this thesis research including the research problem, objectives, scope, research framework and organization.

Chapter 2 concentrates on literature review including existing major climate change policies in Vietnam and current low carbon studies in Vietnam. This chapter aims to (i) see to what extend climate change policies in Vietnam considering to mitigation aspects; (ii) understanding of strengths and weaknesses of the current low carbon studies in Vietnam. This review provides the basis establish a research framework for this research.

Chapter 3 discusses the methodology framework that consists of a socio-economic model (the ExSS model) to estimate the energy demand and the levels of CO_2 emissions/mitigations in energy sector and an optimization model (AFOLUB) to estimate the levels of GHG emissions/mitigations in AFOLU sectors. In this way, this research is able to analyze GHG emissions/mitigations and provide great detail of low carbon countermeasures in both energy and AFOLU sectors in Vietnam.

Chapter 4 describes socio economic background in Vietnam. There are collections and parameter estimations of data which will be input in the models in both energy and AFOLU sectors. These data base is also use as a foundation to develop future scenarios for GHG projections.

Chapter 5 develops two scenarios, which are business as usual (BaU) and countermeasures (CM) to project GHG emissions and mitigation potential in energy sector. The socio-economic model known as; the ExSS tool is used to estimate the energy demand and the levels of CO_2 emission in energy sector in Vietnam.

Chapter 6 develops two scenarios, which are business as usual (BaU) and countermeasures (CM) to project GHG emissions and mitigation potential in agriculture, forestry and other land use (AFOLU) sectors. The optimization model known as; AFOLUB model is used to estimate the levels of GHG (CO_2, CH_4 and N_2O) emissions and mitigation potential in AFOLU sectors in Vietnam.

Chapter 7 analyses the results of modeling (from chapter 5 and chapter 6) in order to develop a package of policy and required actions that would be taken towards LCS in Vietnam. A comprehensive analysis of GHG emissions in all sectors is investigated in the chapter. Moreover, each proposal action is described in detail in terms of GHG mitigation amount, diffusion ratio of particular countermeasure etc.

Chapter 8 presents a key conclusion of the research, and refers to the need for further extensions of this research.

Chapter 2

Literature Review

This chapter reviews the current climate change-related policies and the low carbon studies in Vietnam. The existing climate change policies are reviewed in terms of their focus and their capability of addressing GHG emissions in Vietnam. The current low carbon studies are reviewed in terms of collecting and assessing what data and studies exist that will be of use to the study and identify what work will need to be commissioned to fill key gaps. The objective of this review is to access the strengths and shortcomings of the previous related research with a view to develop for this research a comprehensive modeling framework for analyzing the low carbon development for the whole country.

Main objectives of Vietnam's environmental policy on climate change are shown in Appendix 1.

There are wide ranges of existing energy policies which have effect on GHG emissions mitigation. Summary of those energy policies are shown in Appendix 2.

2.1 Review of Climate Change - related Policy in Vietnam

Vietnam has been working with the international community to address the problem of climate change. The Vietnamese government ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 16th November 1994 and the Kyoto Protocol on 25th September 2002. Vietnam has also formulated a legal and policy framework to mitigate, respond and adapt to climate change.

2.1.1 National Target Program to Respond to Climate Change

The National Target Program to Respond to Climate Change (NTP-RCC) has been created by Vietnamese Government by decision 158/2008/QD-TTg dated December 2008 of Prime Minister (PM, 2008a). The NTP-RCC comprehensively addresses climate change effects, impacts and adaptation as well as GHG emissions mitigations which activities focused on the period 2009-2015.

The main objective is the integration of climate change actions into development strategies, programs and plans in all sectors via a unified platform to ensure sustainable development in Vietnam. The NTP-RCC outlines primarily research, analytical and capacity building activities with focus on adaption to climate change while mitigation aspect is taking a backseat. This can be seen in the main tasks of this Program which are as follows:

a. To identify climate change feature in Vietnam due to global climate change and assess climate change impacts of climate variability, sea level rise and extreme climate events;

b. To identify measures to respond to climate change;

c. To promote scientific and technological activities for climate change response measures;

d. To consolidate and enhance the organizational structure, institutional capacity and the development and implementation of policies on climate change;

e. To enhance public awareness, responsibility and participation, and develop human resources development;

f. To promote international cooperation to obtain external and joint international community's effort;

g. To mainstream climate change issues into socio-economic development strategies;

h. To develop and implement action plans of all ministries, sectors and localities to respond to climate change;

In order to support the implementation of NTP-RCC, the Vietnamese government and donors have formulated the Support Program to Respond to Climate Change (SP-RCC). The SP-RCC complements and reinforces the actions initiated under the NTP-RCC. The main objective of SP-RCC is to promote climate change adaptation activities and GHG reduction, through policy dialogues, to ensure sustainable development in Vietnam.

2.1.2 National Climate Change Strategy

Latest, following increased awareness of the climate change challenges National Climate Change Strategy (NCCS) has been formulated, which the Prime Minister approved in December 2011through decision 2139/2011/QD-TTg (PM, 2011a). The NCCS outlines the vision, objectives and priorities of government on climate change. This strategy serves as the first comprehensive assessment of Vietnam's approach to climate change. The NCCS aims to support government's efforts to strengthen the linkages between the NTP-RCC and the SP-RCC and to develop more specific priorities and targets. Therefore, the strategy has declared its intention to combine efforts on adaption and mitigation under umbrella strategy on climate change.

Besides the main objects in the strategy such as ensuring food security, energy security, water security, poverty alleviation, gender equality, social security, public health; enhancing living standards, conserving natural resources in the context of climate change, there is an objective about "consider low carbon economy and green growth as principles in achieving sustainable development; GHG emissions reduction and removal to become mandatory index in social and economic development". Priority objective in this strategy still focuses on adaptation and even though there are strategic tasks on GHG emissions reduction to global climate system such as development of new and renewable energies, energy saving and efficiency etc., they are not enough detail of countermeasures to implement towards LCS in Vietnam.

2.1.3 Environmental policies

- Vietnam is one of countries that contribute and implement Agenda 21 for national sustainable development after Global Summit on Environment and Development at Rio de Janeiro in 1992 and World Summit on Sustainable Development organized in 2002 at Johannesburg. The sustainable development strategy in Vietnam was directed at the Resolution No. 153/2004/QD-Ttg issued in August 17th , 2004 by the Vietnamese Prime Minister. This is the program of Vietnam to detail the action plan of Agenda 21, which aims to: i. ""Rationally exploit, economically and effectively use natural resources; Prevent, deal with and effective control environmental pollutions, well protect live environment; Reserve national parks, natural recourses, biosphere reserve areas and biodiversity reservation, overcome recession and improve environment" and ii. "Develop socioeconomics cemented with protection and improvement of environment; ensure harmonious development between artificial and natural environment; conserve biodiversity" (PM, 2004).
- Clean Development Mechanism (CDM): Kyoto Protocol regulates the creation and trading of emission reduction credits that are an offset against agreed emissions reductions in developing countries, from where revenue comes. Currently, there are 78

CDM projects have been approved by CDM Executive Board in Vietnam by September 2011. The CDM is functioning in Viet Nam but not yet on a large scale. Barriers to full development of the CDM in Vietnam include a lack of awareness in the business community, a lack of high-risk investment capital, a lack of appreciation among officials of the benefits of CDM projects, and limited capacities. In addition, current regulation requires that all ODA-supported credits under the CDM accrue to the Vietnam Environment Fund and not to the project owners. It is critical that Vietnam addresses these barriers and takes full advantage of the CDM. Many investments in Vietnam could benefit from the CDM. For example, there is a largely untapped potential for use of methane from waste dumps, mining and other sources that could be used as fuel for electricity generation. Vietnam has not yet started to explore carbon capture and storage (CCS) technologies, which are expensive, but capacity building related to these important technologies is needed, for example, because the location of power plants built in the near future will determine the potential application of CCS in the long term. The CDM could also ensure the financial feasibility of hydropower investments.

2.1.4 Energy polices

- National Energy Development Strategy. The strategy was approved by the Prime Minister at Decision No. 1855/QD-Ttg dated December, 2007 on Vietnam energy development up to 2010, an outlook to 2050 (PM, 2007a). The general objectives of the strategy include: ensuring national energy security in order to maintain national security and defense and to develop an independent and sovereign economy; ensuring sufficient and high quality supply of energy for socio economic development; ensuring effective exploitation and usage of domestic energy sources; ensuring investment and business diversification in the energy sector, establishing and developing a fair competitive energy market; accelerating the development of new and renewable energy, biological energy, nuclear energy market to meet the demand for socio economic development; ensuring rapid, effective and sustainable development of the energy sector together with environmental protection.

  The Vietnamese government also formulated a number of master plans on energy development for period 2011-2030. For example, the National Power Development

Master Plan for period 2011-2020 with perspective up to 2030 (PM, 2011b), Coal Exploitation Master Plan up to 2015, and orientation up to 2025 (PM, 2008b), Oil and Gas Exploitation Master Plan up to 2015, a vision towards 2025 (PM, 2009). All these Master Plans give a clear picture of the government plans for meeting estimated energy demand and supply in the country. Concrete targets of those Master Plans are presented in Appendix 2.

- Electricity savings policy. Vietnamese government has formulated a framework for energy efficiency that commenced with the approval and implementation of Electric Law in 2005. This law encourages all sectors to apply science technology in electricity activities, to improve the efficiency of energy use, to protect the environment, and to exploit and use renewable energy to generate electricity. In addition, existing legislation also provides for measures to encourage mobilizing all people to participate in saving electricity in life (offices, houses, business, services, activities and so on).
- New and renewable energy policies. The government also formulated policies to develop new and renewable energy generation such as nuclear, solar and wind power, and biofuel (IE, 2008; PM, 2007b; PM, 2010).

Prime Ministry of Vietnam has approved Master Plan on Nuclear Power Development up to 2030 through the Decision Number 906/QD-TTg, dated June 17th 2010, regarding to which targeted at gradually building and developing Nuclear power sector in Vietnam. According to this plan, the share of nuclear power in the national electricity supply is expected to increase to 7% in 2025 and 10% in 2030 (PM, 2010).

The bio-energy development plan for the period up to 2015, outlook to 202 has been approved by Prime Ministry of Vietnam through the Decision number 177/2007/QD-TTg dated November 20th 2007. In this plan, biofuel is expected to replace fossil fuels such as oil and gasoline by 0.4% in 2010 and 1% in 2015. By 2025, biofuel production technology in Vietnam is expected to be at its highest level, and biofuel will attainted 1.8 million tone and meet 5% of oil and gasoline demand (PM, 2007b).

The government of Vietnam has formulated Master Plan for Renewable Energy Development for the period up to 2015, with outlook to 2025 in 2008. This plan evaluates the potential sources of renewable energy in country. One of the specific targets is to increase the share of renewable energy in total primary 3.4% (2020) and

7% (2050). The other ones is increase the share of renewable energy in power generation 3% (2010), 5% (2025) and 10% (2050).

- Energy efficiency policy. The Prime Minister of Vietnam endorsed the Vietnam National Energy Efficiency Program (VNEEP) in 2006 for the period 2006-2015 through decision 79/2006/QD-TTg. The program targets to reduce 3% to 5% and 5 % to 8 % of the national energy consumption for 2006-2010 and 2011-2015, respectively in comparison with the business as usual (BAU) scenarios for these two periods (PM, 2007a). In this program, a number of activities were identified of which development and dissemination of high energy efficiency devices and equipment as well as formulation of sustainable energy management action plans for the industrial, building and transport sectors is recognized particularly important.

2.1.5 AFOLU policies

According to the decision 661/1998/QD-TTg dated July, 1998 of the Vietnamese Prime Minister, the main policy for forestry investment has been the Five Million Hectare Reforestation Programme, in which three million ha for protection forest and two million for production forest. This program aims to increase forest coverage to 40% of the country area, protecting existing forests and plant new ones, effectively promote the biological function, create a material area combining with the development of forest product processing. In the year 2007, under a national review, the program was amended and a new Policy on Production Forest Development was introduced to provide subsidies for growing timber and support for forest infrastructure and extension services. To date, Vietnam government has approved the Vietnam forest development and protection plan in the period 2011-2020 through decision 57/2012/QD-TTg dated January, 2012 of Prime Minister. This plan targets to increase forest coverage to 44-45% in 2020, protect the existing forest and land for forest production.

Other policies may include the Directive 85/2007/TC-BNN dated October, 2007 by Ministry of Agriculture and Rural Development on promoting reforestation and the Resolutions 26/2008/NQ/TU dated August, 2008 at the 7th Conference of the Central Committee of Vietnam Communist Party on agriculture, farmers and rural areas. The Resolution emphasized the goal of "capacity building the capacity on natural hazard prevention, mitigation and rescue; implement works for a step to reduce the harmful effects of climate change and sea level rise and so on". In addition, Vietnam government also approved National Strategy for natural hazard prevention and mitigation to 2020 through decision 172/2007/QD-TTg dated November, 2007.

Recently, Ministry of Agriculture and Rural Development has approved the Proposal to reduce GHG emissions in Agriculture and Rural up to 2020 through decision 3119/2011/QD-BNN-KHCN of the Minister. The objective of this proposal is to reduce 20% of GHG emissions (about 19 million tons of CO_2) in agriculture and rural while still ensuring development plans in this sector.

2.2 Review of Climate Change Mitigation Study in Vietnam

There are several studies on climate change mitigation in Vietnam, but they are carried out at different levels and in various forms.

- The Vietnam Initial National Communication to UNFCCC has done by Ministry of Natural Resources and Environment (MONRE) was published in 2003. The main objective of these reports is to enable the country to harmonize and update the previous studies, fill in gaps, and further enhance its scientific and technical capacity. It provided information on the national GHG inventory in 1994, analyzed and assessed impacts of climate change, and recommended a number of feasible countermeasures for the adaptation to climate change and the mitigation of GHG emission in several major economic sectors up to 2020. The limited point of this report is data use for projections of GHG emission and mitigation is too old with data in base year came from 1994.
- The Vietnam Second National Communication to UNFCCC also has conducted by MONRE and was published in 2010. This report also provided information on the national GHG inventory in 2000, analyzed and assessed impacts of climate change, and recommended a number of feasible countermeasures for the adaptation to climate change and the mitigation of GHG emission in several major economic sectors up to 2030. The main limitation is also the projection of GHG emission and mitigation based on outdated data in 2000. In addition, mitigation options in AFOLU sectors were assessed using statistical methodologies and the Comprehensive Mitigation Analysis Process (COMAP) model; and the quantifications of countermeasures in the future were determined by experts' judgments. Therefore, this report did not capture

producer's behaviors to select countermeasures in AFOLU sectors in detail and did not consider an effect on emission and mitigations caused by historical land use change and countermeasures applied in the past.

- The study on analyzing the "Economics of GHG Limitations" was conducted by Hydrometeorological Service of Vietnam in 1999, in cooperation with several organizations, for example, the Ministry of Industry, the Ministry of Transport, the Ministry of Agriculture and Rural Development, the Ministry of Health and Vietnam Scientific and Technical Association, covering the period 2000-2030. The study analyzed three main sectors of the Vietnamese economy such as industry, agriculture and forestry, taking into account the key driving force that would have significant impact on GHG emissions reduction, for example, energy efficiency, fuel shift in power generation, renewable energy, reforestation and new techniques in rice cultivation management. Significant findings in this study include: (i) projection of GHG emissions in three mention-above sectors up to 2030; (ii) proposal of an action plan for GHG emissions mitigation up to 2030. However, the study has limitation that transport sector that is one of the largest sources of GHG emissions in Vietnam was not considered in this study.
- The study on potential climate change mitigation opportunities in Vietnam of World Bank Carbon Finance Assist Program (2009) examined Vietnam's potential GHG emission reductions in energy, industry, transport, agriculture and forestry sectors in Vietnam for the period 2010-2015. The approach based on each sector potential and the relative challenges of implementing the typology in a portion of each sector, potential feasible countermeasures were evaluated based a set of criteria important to their implementation potential including estimates of potential emission reductions, in-roads institutionally, and other issues. Methodologically, calculations of the emission reduction potentials were based on the sector structure over the period 2010-2015 and used CDM methodologies and Intergovernmental Panel on Climate Change (IPCC) guidelines. One of the main limitations of this study is that the calculations of the emission reduction potentials are based on CDM methodologies of potential climate change countermeasure (CCM) projects in each sector, but some CCM projects have no approved CDM methodologies. In that case, GHG emission reductions are

calculated based on assumption of reduction. The other limitation is the study time is short, 5 years only (2010-2015).

Other studies also focused on mitigation aspect in Vietnam , for example Vietnam National Strategy Study on Clean Development Mechanism (2001-2006) with main objective of analyzing the potential for Vietnam participate in the CDM and developing a strategy for development of a CDM market in Vietnam; Promotion of Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement (2002-2004) with one of main objective focused on preparing a portfolio of renewable energy, energy efficiency and greenhouse gas abatement projects for financing by diverse sources; Energy Conservation and Efficient in Small and Medium Scale Enterprises (SME) (2005 - 2009) with objective to reduce the GHG emissions from small- and medium-sized enterprises by removing existing policy, institutional, technical, informational, and financial barriers to adoption of more energy efficient technologies and practices; Vietnam Renewable Energy Development Project (2009 - 2014) with objective to increase the supply of electricity to the national grid from renewable energy sources on a commercially, environmentally, and socially sustainable basis; System Efficiency Improvement, Equalization and Renewables Project (2002 - 2012) with objective to improve the overall efficiency of power system services, particularly to the poor in rural areas, by optimizing the transmission systems, and upgrading sub-transmissions, and medium voltage distribution lines for rural electrification; Energy Efficiency Public Lighting Project (2006 - 2010) with aimed at building both technical and policy support for transition to more energy efficient public lighting in Vietnam; Phasing out Incandescent Lamps through Lighting Market Transformation in Vietnam (2010 – 2014) with objective to phase-out of incandescent lamps production and sale through the transformation of the lighting products market as well as the promotion of high quality energy saving lamps in Vietnam; National Action Framework for Reduction of Emission from Deforestation and Degradation (REDD) (2008 - 2010) with objective to contribute to reducing emissions in Vietnam from deforestation and forest degradation nationally and regionally; Strengthening National Capacities to Respond to Climate Change in Vietnam, Reducing Vulnerability and Controlling GHG emissions (2009 - 2012) which one of objective is to analysis of GHG emissions, and formulation of investment plans and ways to change consumer behaviour for low carbon development in some selected regions; and Promoting Energy Conservation in Small and Medium Scale Enterprises (PECSME) (2005 - 2011) with goal to reduce the annual growth rate of GHG emissions from the five selected SME sectors through widespread and sustained improvement in energy utilization; and so on.

It can be seen from above review that, although the number of studies on low carbon development and GHG mitigations is not small, they are all focused on very specific aspects or sectors of low carbon development such as potential for Vietnam to participate in the CDM, promotion of new and renewable energy, energy efficiency, promoting the use of more efficient lighting, rural energy, forest sector development and reducing degradation, demand side management and energy efficiency and so on.

2.3 Summary

This chapter reviews the existing climate change-related policies and the low carbon studies in Vietnam. Followings are the main conclusions of this review:

- Vietnam's response to climate change relies on numerous existing or new sectoral policies, reviews, studies and investment projects that are related increased low carbon development. For example, Vietnam National Energy Efficiency Program, the Forest Development Strategy, National Strategy for Natural Disaster Prevention, Response and Mitigation up to 2020, the Study Report on Bottleneck Solution of Clean Development Mechanism Projects and other ministerial and provincial climate change action plans.

- Currently, Vietnam government is developing in advancing its diagnostic and analytical framework on climate change. However, there are only several activities which focus on adaption to climate change has completed, for example "Climate Change, Sea Level Rise Scenario for Vietnam" (MONRE, 2009) and its updated Climate Change Scenarios. In terms of mitigation aspect, there is no so far low carbon development methodology paving the road for a low carbon growth strategy.

Hence, the study methodology framework might help Vietnam government overcoming the drawbacks mentioned above.

- The current studies on climate change mitigation are carried out at different levels and in various forms and analyzed only specific aspects of low carbon development. Some of them used out of date data which served for projections of GHG emission and mitigation with the latest information came from 2000. Therefore, there is a need to develop a comprehensive study on assessment of GHG emissions and mitigations at the level of entire economy that can propose required actions towards LCS in Vietnam.

Chapter 3

Methodology of Research

3.1 Modeling framework for developing a LCS in Vietnam

This chapter will provide the entire of methodology of research which will be employed in this research to develop a LCS in Vietnam.

Figure 3.1 shows a methodological framework of this study where includes seven steps.

Planning of developing a LCS in Vietnam requires a consensus to be reached involving all ministries and multiple stakeholders on achievable long term development trajectory that will allow the country to maintain its growth targets while emitting less GHG than could have expected under previous development plans. In other words, LCS development involves trade-offs and agreements across the entire economy.

Modeling illustrates where a country and each sector, such as energy sector (residential, commercial, industrial, transport and power sectors) and agriculture, forestry and land use, currently stand, the direction in which they are developing, the impact of this development on the level of greenhouse gas (GHG) emissions and the resources that would be needed for mitigation.

On the basic of background and information, it can be argued that the most appropriate modeling framework to develop a LCS in Vietnam typically involves:

- Establishing a macroeconomic outlook. This entails forecasting population, GDP, industrial structure, and other macroeconomic variables for target year.
- Based-scenario development. Building a base-year scenario of the sector or economy from which it will be very useful to explore the possibility of alternative futures of Vietnam where we can assess the impact of development objectives and national strategies relating to greenhouse gas (GHG) emissions mitigation.
- Establish a scenario that takes account of current development plans, namely Business as Usual (BaU) scenario. This scenario represents a continuation of the current trend in economic policies without any GHG emissions mitigation countermeasure taking place.

- Establish a scenario that has lower greenhouse gas (GHG) emissions, namely Countermeasures (CM) scenario. This scenario is constructed to reflect a future in which there would be a lower carbon level of urgency to promote the penetration of low carbon countermeasures to limit GHG emissions.

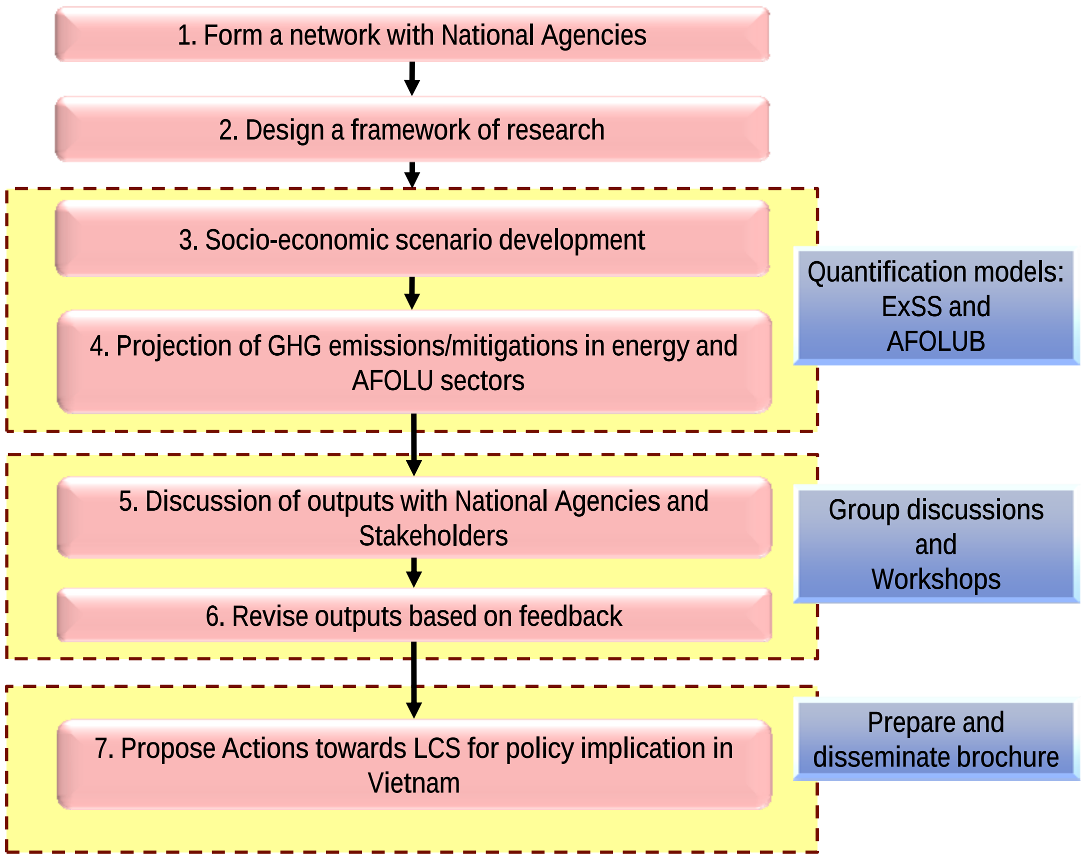


Figure 3.1 Methodological framework

In this study, we employed Extend Snapshot Model to estimate GHG emissions and mitigations in energy sector in Vietnam and AFOLU Bottom up (AFOLUB) model to estimate GHG emissions and mitigations in AFOLU sector.

The ExSS model is useful for Vietnam in order to develop long term low carbon development and action plans in energy sector. As a contribution to policy making process, the model can support the discussion among policy makers and other stakeholders by providing detailed quantitative information. For example, when a participant argued one of the countermeasures is unrealistic, one can remove the countermeasures, and discuss what kind of countermeasures can be replaced, and calculate GHG emissions immediately and evaluate the consequence. Another example is that government usually has various social or economic targets other than LCS. In many cases, the government does not assess consensus, trade-offs and synergy effect among the targets including low carbon target. The model can assess the effect of those goals to GHG emissions by giving future state which achieved them as socio-economic assumptions. Detail explanation of ExSS model is shown in section 3.2.

The AFOLUB model is useful to estimate GHG mitigation potential as a result of profit maximization choice of countermeasures and assess low carbon countermeasures in AFOLU sectors in Vietnam. The AFOLUB model have large scope for application because in the AFOLU sector, more realistic concept is that producers (i.e famers) select types of crops or livestock animals, amounts and methods of production and type of low carbon countermeasures to maximize their annual profit. From that point of view, the AFOLUB model solves the profit maximization problem under several constraints for pre-determined demand of agriculture and woody products. Therefore, the model may help analyze effect of polices such as emission tax, energy tax, subsidy, and regulation and so on. Detail explanation of AFOLUB model is shown in section 3.3.

3.2 The Extended Snapshot Model

This section provides a broad sketch of the Extended Snapshot (ExSS) model. A detailed mathematical description of the objective function is attached in Appendix 3. A more comprehensive description of ExSS tool in terms of attributes, sets, variables and equations of the system could be found in Gomi et al., (2010) and Gomi and Yoshimoto (2010).

The outline of the estimation system of a snapshot tool is shown in Figure 3.3. The main function and features of this tool is as mentioned below:

EXSS (extended snapshot tool) is a comprehensive calculation tool developed to:

- Illustrate quantitative future snapshot of a nation, especially as a low-carbon society,
- Analyze relationship of socio-economic conditions and environmental load emissions,
- Define a portfolio of the low carbon countermeasures to meet environmental target (mainly energy-oriented CO_2).

This tool estimates:

- Socio-economic activity level of the sectors in future,
- Environmental load emissions,
- Low carbon countermeasures necessary to achieve the target.

Features of this model are as follows.

- A static model formulated as a set of simultaneous equations.
- Input-output (IO) analysis is the central part in the computation system.
- IO relation is described in detail especially generation of freight and passenger transport and energy demand and supply structure.

3.2.1 Calculation flow of ExSS

The general calculation flow of ExSS system is as follows:

- Based on given final demand and input coefficient matrix, IO analysis calculates output by industry
- Transport demand including passenger and freight transport is estimated from population and output of industry.
- Energy demand is estimated from driving forces, for example, household number, and output of industry, transport demand and assumptions of applied technologies/low carbon countermeasures.
- Based on estimated final energy demand and assumptions of power generation, primary energy demand and CO_2 emissions are calculated.

The procedure to create low carbon scenario in energy sector using ExSS is shown in Figure 3.2

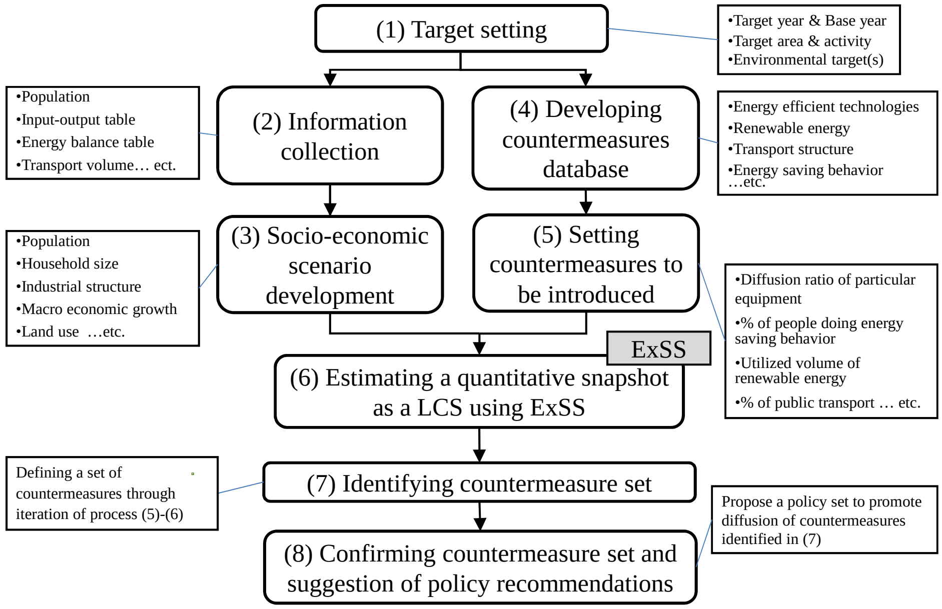


Figure 3.2 Procedure to create low carbon scenario in energy sector

The procedure to create a low carbon development in energy sector is based on the idea of "backcasting", which sets a desirable goal first in order to determine the direction of energy and environmental conservation activities and reform societies and lifestyles based on vision to the future (Gomi et al., 2011), and then seeks a way to achieve it. The backcasting method is defined as "calculating back to present from a specific target point in the future". According to Robinson (1990), the backcasting method is done to "determine the potential for future physical implementation of that target and the type of measures that will be needed to arrive at that point".

Figure 3.2 shows eight steps of this procedure, which can be explained as follows

Step 1. Setting framework

Framework of a low carbon scenario includes; target area, base year, target year, environmental target, and number of scenarios. Among them, the base year is compared with target year. The target year should be far enough to realize required change, and near enough to image the vision for the people in the region.

Step 2. Information collection

Main necessary information in base year includes demography, output of industry, input-output table, energy balance table, transport volume and so on.

Step 3. Socio-economic scenario development

Before conducting quantitative estimation, qualitative future image should be written. It is an image of lifestyle, economy and industry, transport and so on. To estimate snapshot based on that future image, values of exogenous variables and parameters are set. Using those input, ExSS calculates socio-economic indices of the target year such as population, GDP, output by industry, transport demand, and so on.

Step 4. Developing countermeasures database

Low carbon countermeasures are used which are thought to be available in the target year, for example, high energy-efficiency devices, transport structure change such as public transport, use of renewable energy, energy saving behavior and carbon sink. Technical data is required to estimate their effect to reduce GHG emissions.

Step 5. Setting countermeasures to be introduced

Since there can be various portfolios of the low carbon countermeasures such as cost minimization, ease of acceptance by stakeholders, technical achievability and so on, one must be chosen with appropriate criteria.

Step 6. Estimating a quantitative snapshot as a LCS using ExSS

Based on socio-economic indices and assumption of low carbon countermeasures' introduction, ExSS calculates energy demand and GHG emissions.

Step 7. Identify countermeasure set

This step is defining a set of low carbon countermeasures through iteration of step 5 and 6. Once, the portfolio of countermeasures is thought satisfied with national development policies as well as national development strategies. We move to next step (8). If one of stakeholders argued one of the low carbon countermeasures is unrealistic, one can remove the countermeasure, and discuss what kind of countermeasure can be introduced instead (in step 5), and calculate emissions again in step (6), and evaluate the consequence.

Step 8. Confirming countermeasures set and suggestion of policy recommendations

Once a portfolio of low carbon countermeasures is decided, policies to enhance the diffusion of the countermeasures are set. Available policies depend on the situation of the country. ExSS can calculate emission reduction of each low carbon countermeasure.

Therefore, it can show mitigation potential of countermeasures which national policy plays a particularly crucial.

3.2.2 Structure of ExSS model

Figure 3.3 shows the structure of the ExSS model

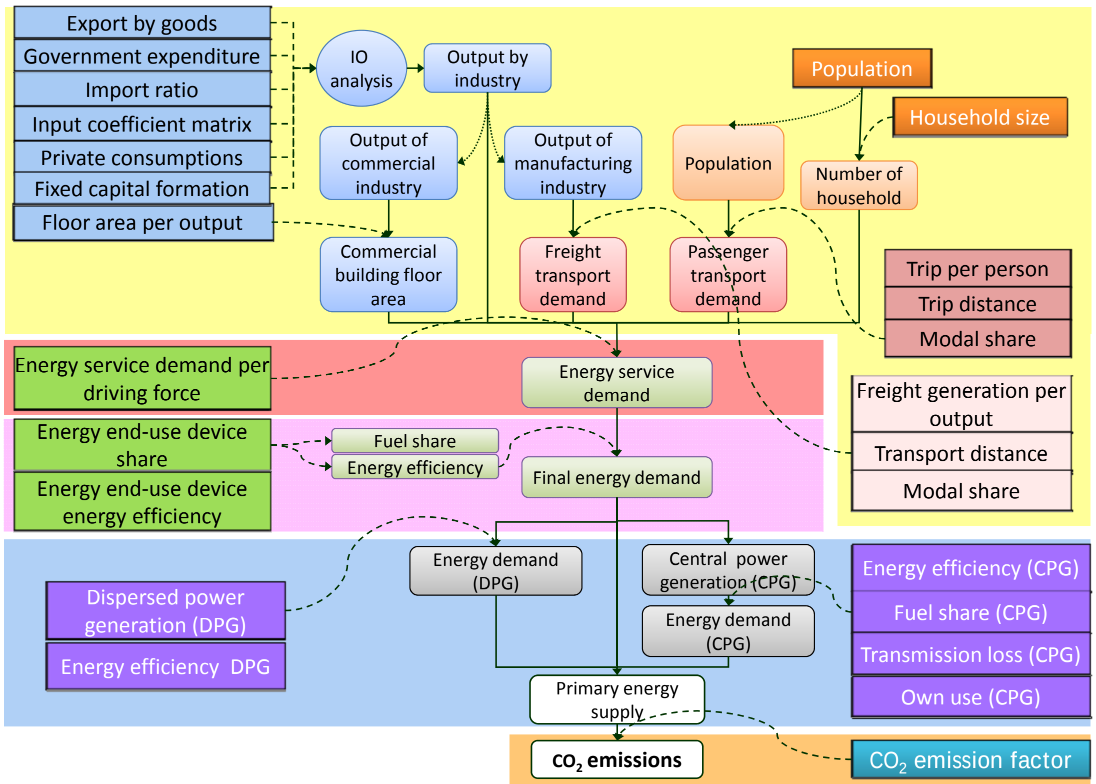


Figure 3.3 The Structure of ExSS

ExSS is a system of simultaneous equations. A set of exogenous variables and parameters is given; low carbon countermeasures are needed to define. In this simulation model, only CO_2 emission from energy consumption is used in the calculation, even though, ExSS can be used to estimate other GHG and environmental loads such as air quality. In LCS scenarios, exogenous fixed population data is used. In order to determine output of industries, input-output approach is applied. For future estimation, assumption of export value is especially important if the target region is thought to (or, desired to) develop led by particular industry, such as automotive manufacturing or sightseeing. Passenger transport demand is estimated from the population data, trip generation and modal split. However, in order to calculate the freight transport demand, it is a function of output by manufacturing industries. Floor area of commerce is determined from output of tertiary industries. Other than driving force, activity level of each sector, energy demand by fuels determined with following three parameters, for example energy service demand per driving force, energy efficiency and fuel share (Gomi, Shimada and Yuzuru, 2010). Diffusion of countermeasures changes the value of these parameters, and so changes the GHG emissions.

3.3 The Agriculture, Forestry and Other Land Use Bottom-up Model

AFOLU Bottom-up model (AFOLUB) is a bottom-up type model to estimate GHG emissions and mitigation potential in AFOLU sectors at country or regional level, dealing with quantified mitigation countermeasures. The emissions and mitigation potential are calculated using a function of Allowable Abatement Costs (AAC), which are representative parameters representing willingness of GHG reduction under several constraints for mitigation costs and mitigation potential. Moreover, the calculation is also based on future assumptions of crops harvested areas, numbers of livestock animal and area of land use change. The model illustrates selection of production countermeasures of the agricultural commodities and mitigation countermeasures by producers (i.e. farmers) based on economic rationality. The model illustrates selection of GHG mitigation options (low carbon countermeasures) based on economic rationality. Since the selection depends not only on evaluation methodologies of cost and mitigation but also dependency among countermeasures, the dependency is considered in the model. For example, for reducing fertilizer, which is one of low carbon countermeasures for croplands, the balance among decrease in output of crop due to fertilizer reduction, decrease in GHG emission tax and increase in revenue due to saving fertilizer is considered in the model. Another example is that, for improving livestock productivity, the balance among increase in mitigation costs, increase in output of livestock products and decrease in GHG emissions tax is also taken into account in the model. The AFOLUB consists of two modules: AGriculture Bottom-up module (AG/Bottom-up) and LULUCF Bottom-up module (LULUCF/Bottom-up).

3.3.1 AG/Bottom-up

The AG/Bottom-up calculates GHG emissions and mitigation potential in agricultural production; and energy consumption of agricultural machines; and combination of production and mitigation countermeasures under several AACs. (See more detail in

Hasegawa and Yuzuru, 2012)

This module is based on the assumption that producers produce commodities to supply the amount of productions given exogenously. The countermeasure application term is divided into several periods and the producers select ways of producing commodities and combinations of mitigation countermeasures in order to maximize their profit. The profit is defined by benefit – cost + benefit by bioenergy sales. Production is calculated as a multiplication of productivity (i.e. crop production per unit area and carcass weight) and quantity of activity (area of cropland and number of livestock animal).

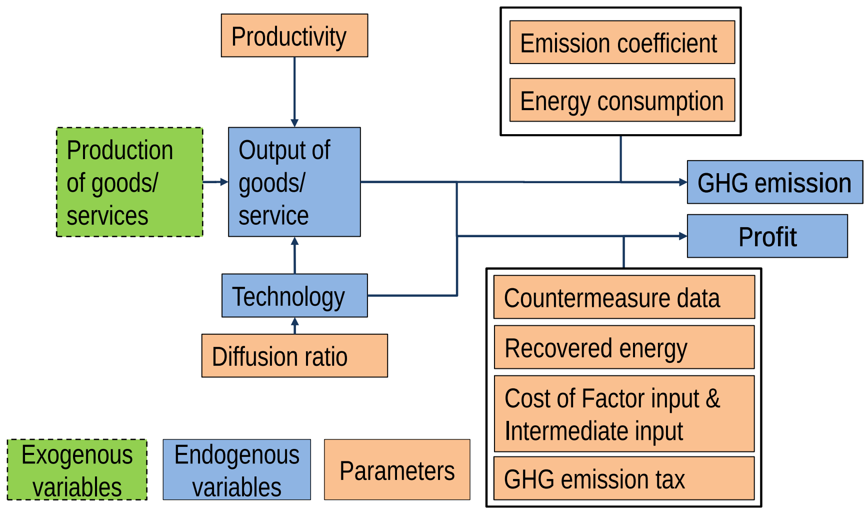


Figure 3.4 The Structure of AG/Bottom-up module

- Linkage between production and activity: yields

Yields are defined as production of commodities per unit activity. It is, for example, crop production per unit area harvested and carcass weight of livestock animals.

It is taken into account that yields may change due to application of countermeasures. For example, yield may decrease by fertilizer reduction and carcass weight of livestock animal may increase by improvement of feed systems. The model takes into account impacts of climate conditions on crop yields.

- Input and output of energy to be concerned in the model

AFOLUB takes into account emission from fossil fuel directly consumed in agriculture (i.e. energy for agricultural machinery, pumps, seeders, milking machines, tractors, combine harvesters, manure spreaders, fertilizer distributions and so on), but not from indirect energy consumption (energy for irrigation and land use change; energy for fertilizer production; energy for feed production; energy for manure management plant; and energy for agricultural transportation and so on. GHG emissions from the energy consumption are categorized into different IPCC guideline category from AFOLU sectors. GHG emission from energy is calculated separately and then the emission is aggregated to AFOLU emissions.

3.3.2 LULUCF/Bottom-up

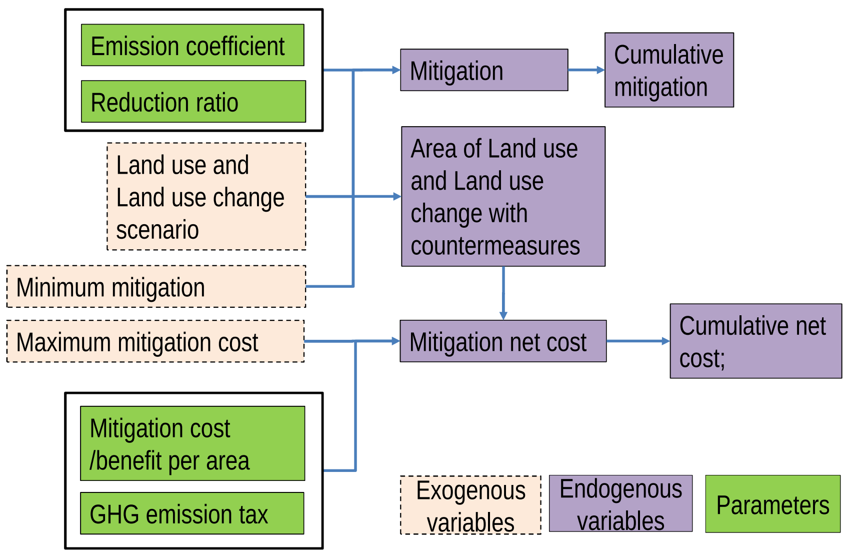


Figure 3.5 The Structure of LULUCF/Bottom-up module

The LULUCF/Bottom-up calculates GHG emissions from carbon stock change in biomass and soils on the land and those from fire, natural disturbance and peat lands and mitigations by specific countermeasures. The module does not take into account emission from wood harvesting. It is assumed that wood harvesting is not too a large factor to make great impacts on change in land use and change in emission and sink coefficients. Assumption of future land use change is given exogenously. The module calculates GHG emission and sink caused by historical land use change. The implementation degree of the countermeasures is calculated based on schemes assumed for mitigation countermeasure selection. The schemes can be set as conditions of allowable minimum mitigation potential or total maximum cost in a certain countermeasure application period. The module does not take into account benefit from activity (i.e. improved land use and wood production). The module calculates total mitigation impacts in an assumed period since mitigation impacts of some countermeasures last in the long term after application.

3.3.3 Input and output of the AFOLUB model

As shown in Figure 3.6, the data set input in AFOLUB includes: i) list of countermeasures; ii) characteristics of the countermeasure such as cost, reduction effect, life time, diffusion ratio, energy consumption and recovery; iii) scenarios of crop production, number of livestock animals and area of land use and land-use change; iv) scenarios of fertilizer input, price of commodity and energy, and production technologies; and vi) future assumption on policy such as AAC for GHG mitigation, energy tax rate, subsidy and so on. Based on the information, countermeasures to be applied to reduce emissions are evaluated.

The module considers only extra cost which is caused by installation of mitigation technologies. The extra cost is defined to be a difference from a cost in the base year.

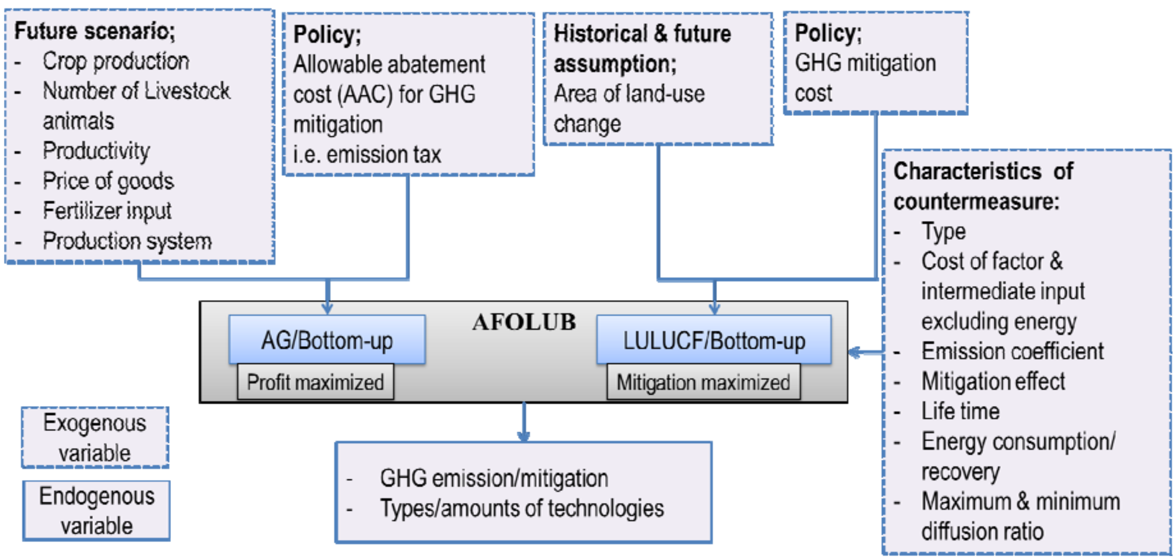


Figure 3.6 Data set used in AFOLUB model

Cost to be concerned includes i) wage for additional mitigation countermeasures, ii) cost for additional intermediate input, iii) AAC, producer subsidy, production tax etc. They are exchanged into an annual cost.

3.3.4 Agriculture commodities, GHG treated and emission sources in AFOLUB

Table 3.1 shows GHG emission sources agriculture commodities and GHG treated in AFOLUB model and emission categories defined in IPCC guideline 2006. Emission/sink sources taken into account in the study are enteric fermentation (3A1) and manure management (3A2) of livestock, LULUCF (3B), managed soils (3C4 to 3C6) and rice cultivation (3C7). Target GHG in the study are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). LULUCF sector is considered as a source of both emission and sink of carbon.

The management of livestock manure can produce both methane (CH_4) and nitrous (N_2O) emissions. CH_4 is produced by the anaerobic decomposition of livestock manure. N_2O is produced through the nitrification and denitrification of the inorganic nitrogen derived from livestock manure and urine.

Table 3.1 Emission sources and target GHG

Emission sources	Classification	Gases	IPCC category[1]
Enteric fermentation	Dairy cattle, Other cattle, Buffalo, Sheep, Goats, Camels, Horses, Mules, Asses, Swine	CH_4	3A1
Manure management	Dairy cattle, Other cattle, Buffalo, Sheep, Goats, Camels, Horses, Mules, Asses, Swine, Chickens, Ducks, Turkeys	CH_4, N_2O	3A2
Aggregate Sources and Non-CO_2 Emissions Sources on Land	Emissions from Biomass Burning[2]	CO_2, CH_4, N_2O	3C1
	Liming[2]	CO_2	3C2
	Urea Application[2]	CO_2	3C3
	Direct N_2O emission from Managed soils	N_2O	3C4
	Indirect N_2O emission from Managed soils	N_2O	3C5
	Indirect N_2O Emissions from Manure Management	N_2O	3C6
Rice cultivations		CH_4	3C7

Note: 1] Emission categories of IPCC(2006), 2] Gray part is not estimated in this study.

Normal digestive process in animals can produce CH_4. The microbial fermentation process in animal's digestive system ferment food consumed by the animal is referred to as enteric fermentation and produces CH_4 as a by-product.

Decomposition of organic material process in anaerobic condition in paddy fields can produce both CH_4 and N_2O. Anaerobic decomposition of soil organic matter by methanogenic bacteria generates CH_4.

GHG emission coefficients were referred to tier 1 and tier 2 of IPCC guideline (2006). According to the guideline, GHG emissions are calculated by multiplying quantity of activity and at least one coefficient. For the LULUCF sector, GHG emissions are calculated by multiplying land area and carbon stock change per unit area (emissions coefficients). To consider emissions and mitigation caused by land use change in the past, the coefficients for the land with conversion are assumed to change over time due to time-varying emission and sink through biomass growth. For example, quantity of emission and mitigation due to forest growth is different depending on time from plantation. In contrast, the coefficients stay constant for the remaining land.

Chapter 4
Socio-economic Background of Vietnam towards LCS

4.1 Introduction

This chapter aims on building a base-year image of the country from which it will be possible to forecast the future impact of development objectives and national strategies relating to GHG emission mitigation. Therefore, collection of the socio-economic data of a base year and energy data is performed. The use of the data list on socio-economic is shown in Appendix 4

4.2 Population and household

The source and the complement method of population related data (population by sex and age cohort, the number of households) are described in this section.

4.2.1 Population by sex and age cohort

Vietnam is the third largest populous country in Southeast Asia (after Indonesia and Philippines). According to GSO (2008), Vietnam's population reached about 83 million people in 2005. Since the data of the population by age group by sex in Vietnam was not obtained, their projection was based on Population Division - United Nations Population low variant for Vietnam (UN, HP). As a result, the value shown in Table 4.1 was acquired.

Table 4.1 Population by sex and age cohort in 2005

Unit: thousand persons

	0-14	15-64	65+	Total
Male	12,438	26,337	2,101	40,876
Female	11,823	27,407	3,000	42,230
Total	24,261	53,744	5,102	83,106

4.2.2 The number of households

The number of households in the base year 2005 was estimated based on the information in 1999 and 2009. According to the Vietnam Population and Housing Census (2009), the number of households in 1999 and 2009 were 16.6 and 22.6 million households, respectively. Annual growth rate of household number was 3.1% in the same period.

As a result, the value shown in Table 4.2 was acquired.

Table 4.2 Number of households in 2005

Year	Households (million households)
2005	20.0

4.2.3 Number of persons in a household

Based on the information of population and number of households, the average persons in a household shown in Table 4.3 was obtained

Table 4.3 Average person in a household in 2005

Year	Persons
2005	4.2

4.3 Input-output table

We referred Vietnam input-output table in 2005 (competitive-import type, 16 sectors) (Trinh, 2009). 16 industrial sectors were aggregated from 52 industrial sectors (Table 4.4). The table currently exhibited is 16-by-16 sector; it is aggregated in to 8-by-8 sector. The sector classification and its correspondence before and after aggregation are shown in Table 4.5. Input-output table was used to estimate economic data such as value added, export, import, private consumption and government consumption in the base year 2005. Details of Vietnam's input-output tables are shown in Appendix 5.

4.4 Passenger transport

The structure of the passenger transport model and the parameter estimation of the base year of the model are explained in this section.

4.4.1 Formulation of the passenger transport model

The estimation formula of the passenger transport model is shown below. The annual passenger transport volume (passenger-km) is estimated by multiplying residential population (person) by the trip generation per person per day (trip/person/day), modal share, average trip distance (km/trip), and the days for one year (365 days).

$$PTD_{ptm} = \sum_{sex} \sum_{age} Pop_{sex,age} \cdot PTG_{sex,age} \cdot PTS_{ptm} \cdot PTAD_{ptm} \cdot 365 \quad (4.1)$$

where,

PTD_{ptm}: passenger transport volume by type of transport (passenger-km)

$Pop_{age,sex}$: population by sex and age cohort (person)

$PTG_{sex,age}$: trip generation per person per day (trip/person/day)

PTS_{ptm}: modal share (passenger)

$PTAD_{ptm}$: average trip distance by type of transport (passenger) (km/trip)

sex: sexuality (male, female)

age: age cohort (a0014, a1564, a6500)

4.4.2 Data complement

Since the statically information about the passenger transport in Vietnam had not fully been obtained, the data about passenger transport volume which runs short was complemented with the following ways using some assumptions

i) Trip generation per person per day

Trip generation per person per day of the passenger transport ($PTG_{sex,age}$) in 2005 was assumed 2 trip/person/day. In this study, we considered only domestic travel was included and trip generation per person per day was same for different age groups.

Table 4.4 Industrial classification, aggregate from 52 sectors to 16 sectors

16-sector classification		52-sector classification	
Code	Description	Code	Description
1	Agricultural crops, livestock & poultry, agricl services	1	Growing of all kinds
		2	Farming of animals
2	Fishery	3	Fishing and aquaculture
3	Forestry	4	Forestry
4	Mining and quarrying	5	Mining of coal
		6	Mining of metal ores
		7	Mining of crude oil, natural gas and other mining
5	Food, beverage & tobacco manufactures	8	Processing and preserving of meat, Manufacture of vegetable and animal oils and fats, dairy products, sugar confectionary, cocoa, chocolate
		9	Processing and preserving of fruit and vegetables
		10	Manufacture of beverages
		11	Manufacture of sugar
		12	Manufacture of tea, coffee
		13	Manufacture of tobacco products
		14	Processing and preserving of fish, crustaceans and molluscs
		15	Manufacture of grain mill products, starches and starch products, Manufacture of other food products
6	Other consumer goods	16	Paper pulp and paper products and by-products
		17	Processed wood and wood products
		18	Weaving of cloths (all kinds)
		19	Carpets
		20	Leather goods
		21	Other manufacture
		22	Products of publishing house
7	Industrial materials	23	Manufacture of porcelain, terracotta, glass
		24	Manufacture of brick and tile
		25	Cement
		26	Other construction materials
		27	Manufacture of chemicals
		28	Fertilizer, pesticides and veterinary medicine
		29	Health medicine
		30	Processed rubber and by-products
		31	Soap, detergents, perfumes and other toilet preparations
		32	Plastic, plastic products
		33	Other chemical products
		34	Non-ferrous metals and products (except machinery equipment)
		35	Ferrous matals and products (except machinery equipment)
		36	Gasoline, lubricants (already refined)
8	Capital goods	37	Other metallic products
		38	Machinery, equipment
		39	Electrical and electronic products
9	Electricity, gas & water	40	Electricity, gas
		41	Water
10	Construction	42	Construction
11	Wholesale and retail trade	43	Trade
12	Transport services	44	Transportation
13	Post and telecommunication	45	Communication services
14	Finance, insurance, real estate & business services	46	Finance, credit, banking, insurance
		47	Science and technology
15	Other private services	48	Repair of small transport means, motorbikes and personal household appliances
		49	Hotels, restaurants
		50	Other services
16	Government services	51	State management, defence and compulsory social security
		52	Culture, health, education, sport

Table 4.5 Industrial classification, aggregate from 16 sectors to 8 sectors

8-sector classification		16-sector classification	
Code	Description	Code	Description
1	Agriculture-Fishery-Forestry	1	Agricultural crops, livestock & poultry, agricutural services
		2	Fishery
		3	Forestry
2	Mining and quarrying	4	Mining and quarrying
3	Food, beverage & tobacco manufactures	5	Food, beverage & tobacco manufactures
4	Other consumer goods	6	Other consumer goods
5	Industrial materials	7	Industrial materials
6	Capital goods	8	Capital goods
7	Construction	10	Construction
8	Private & government services and others	9	Electricity, gas & water
		11	Wholesale and retail trade
		12	Transport services
		13	Post and telecommunication
		14	Finance, insurance, real estate & business services
		15	Other private services
		16	Government services

ii) Modal share

Share of motorization and non-motorized transport in some cities in Asia including Vietnam is 96% and 4%, respectively (Walter and Michael, 1995). This share was applied for Vietnam case in 2005. MS1 was defined as modal share of motorization and non-motorized transport.

- Modal share of transport including road, rail, inland waterway and aviation was referred to GSO (2009). Walk and bicycle are not included in this statistic data. Road transports here are motorcycle, bus, car and truck. MS2 was defined as modal share of road, rail, inland waterway and aviation.

Table 4.6 Modal share of transport (MS2) in 2005

Transport mode	Road	Train	Ship	Aviation	Total
Share	87%	1%	12%	0%	100%

- Estimation of modal share in road transport including walk, bike, motorbike, bus, car and truck for Hanoi in 2005 was done by Schipper et, al. (2008). These numbers were used for Vietnam case in this study. MS3 was defined as the share of road transport including walk, bicycle, motorcycle, bus, car and truck.

Table 4.7 Modal share of transport (MS3) in 2005

Transport mode	Walk	Bike	Motorbike	Bus	Car	Total
Share	28%	20%	44%	5%	3%	100%

Based on Table 4.7, modal share of road transport without walk and bike (MS4) was estimated and shown in Table 4.8

Table 4.8 Modal share of transport (MS4) in 2005

Transport mode	Motorbike	Bus	Car	Total
Share	85%	10%	5%	100%

4.4.3 Parameter estimation

i) Total volume of passenger carried

$$\mathrm{VPC} = PTG_{sex,age} \times \mathrm{POP} \times 365 \qquad (4.2)$$

Where,

VPC: Volume of passenger carried (million persons.trip)

$PTG_{sex,age}$: trip generation per person per day (trip/person/day)

POP: Population (million persons)

The population (POP) data in the year 2005 was referred to General Statistics Office - Statistical Yearbook of Vietnam (2008). The result of calculation is showed below

VCP = 60668 (million persons.trip)

ii) Volume of passenger carried by non-motorized and motorized transport

Volume of passenger carried by non-motorized and motorized transport was calculated as follow:

[Volume of passenger carried by non-motorized transport]

= [Total volume of passenger carried] * [share of non-motorized transport]

[Volume of passenger carried by motorized transport]

= [Total volume of passenger carried]* [share of motorized transport]

Table 4.9 Volume of passenger carried by non-motorized and motorized transport

	Non-motorization	Motorization	Total
Share	96%	4%	100%
Volume (million persons.trip)	58241	2427	60668

Non-motorized transport was defined including walk and bicycle.

iii) Volume of passenger carried by road, rail, inland waterway and aviation

Volume of passenger carried by road, rail, inland waterway and aviation was estimated based on Table 4.6 and Table 4.9 and formula below

[Volume of passenger carried by type of transport]

= [Volume of passenger carried by motorization] * [MS2]

Table 4.10 Volume of passenger carried by road, rail, inland waterway and aviation

Transport mode	Road	Train	Ship	Aviation	Total
Share	87%	1%	12%	0%	100%
Volume (million persons.trip)	2114	23	283	7	2427

iv) Volume of passenger carried by road transport (without walk and bike)

Volume of passenger carried by road transport (without walk and bike) was estimated based on Table 4.8 and Table 4.10 and formula below

[Volume of passenger carried by type of transport]

= [Volume of passenger carried by road transport (without walk and bike)] * [MS4]

Table 4.11 Volume of passenger carried by road transport (without walk and bicycle)

Transport mode	Motorbike	Bus	Car	Total
Share	85%	10%	5%	100%
Volume (million persons.trip)	1797	211	106	2114

v) Volume of passenger carried by all type of transport in 2005

Volume of passenger carried by all type of transport in 2005 was shown in table

Table 4.12 Volume of passenger carried by all type of transport in 2005

Transport mode	Train	Bus	Car	Motorbike	Walk & Bike	Ship	Aviation	Total
Volume (million persons.trip)	23	203	122	1790	58241	283	7	60668

vi) Modal share of all types of transport in Vietnam in 2005

Modal share of all types of transport in Vietnam in 2005 was estimated based on volume of passenger carried by all type of transport in 2005 and shown in table

vii) Average trip distance

The average trip distance by transport mode was estimated based on GSO (2009), Schipper et. al, (2008) and JICA/MoT (2009) and shown in the Table 2.14:

Table 4.13 Modal share of all passenger transport type in 2005

Transport mode	Train	Bus	Car	Motorbike	Walk & Bike	Ship	Aviation
Modal share (trip,%)	0.04%	0.33%	0.20%	2.95%	96.00%	0.47%	0.01%

Table 4.14 Average trip distance by transport mode in 2005

Transport mode	km	Reference
Walk	1	Schipper et. al, 2008
Bicycle	3	Schipper et. al, 2008
Car	92	JICA/MoT, 2009
Bus	181	JICA/MoT, 2009
Rail	365	GSO, 2009
Ship	22	GSO, 2009
Aviation	811	GSO, 2009
Motorbike	6	Schipper et. al, 2008

4.4.4 Discussion

The detailed data about the passenger transport in Vietnam can be found in Statistical Yearbook of Vietnam, 2008. However, numeral statistics of road transport is too general and there is no information about non-motorized transport. Therefore, calculations must be based on some international papers and reports.

4.5 Freight transport volume

The structure of the freight transport model and the parameter estimation of the base year of the model are explained in this section.

4.5.1 Formulation of the freight transport model

The estimation formula of freight transport volume is shown below. Freight transport volume (t-km) is estimated by multiplying output of industry (VND) by freight transport generation per output (t/VND), modal share, and average trip distance (km).

$$FTD_{ftm} = FTPD_{pss} \cdot FTG_{pss} \cdot FTS_{pss,ftm} \cdot FTAD_{ftm} \tag{4.3}$$

where,

FTD_{ftm}: freight transport volume by mode (t-km)

$FTPD_{pss}$: output of industry (primary and secondary industry) (VND)

FTG_{pss}: freight transport generation per output (t/VND)

$FTS_{pss,ftm}$: modal share (freight)

$FTAD_{ftm}$: average trip distance by mode (freight) (km)

pss: primary and secondary industry

4.5.2 Parameter estimation

i) Modal share

The modal share in a freight transport was computed from the rate (t-km base) of each mode occupied to the sum total of freight transport volume (Statistical Yearbook of Vietnam, 2008). As a result, the value shown in Table 4.15 was acquired.

Table 4.15 Modal share of freight transport in 2005

Transport mode	Train	Truck	Ship	Aviation
Share	2%	71%	27%	0%

ii) Freight transport generation per output

In this study, we considered there is the same freight transport generation per output in all industry sectors and domestic transport only. Freight transport generation per output was computed by dividing the sum total value of freight transport volume (tonnage) with the sum total value of output of primary industry and secondary industry. As a result, the value 0.3 (t/billion VND) was obtained.

Table 4.16 Freight transport generation per output in 2005

Unit: ton/billion VND

	Domestic	Overseas
pd1-Agriculture-Fishery-Forestry	0.3	0.0
pd2-Mining and quarrying	0.3	0.0
pd3-Food, beverage & tobacco manufactures	0.3	0.0
pd4-Other consumer goods	0.3	0.0
pd5-Industrial materials	0.3	0.0
pd6-Capital goods	0.3	0.0
pd8-Private & government services and others	0.3	0.0

iii) Average trip distance by mode

The average trip distance by mode was computed using the freight transport volume (t-km) which was computed by complement estimation based on the formula (4.2), modal share, freight transport generation per output, and output of industry (primary and secondary). As a result, the value shown in Table 4.17 was acquired.

Table 4.17 Average trip distance by mode in 2005

Unit: km/trip

	Railways	Road	Waterway	Aviation
Average trip distance	336	60	162	2,156

4.5.3 Discussion

The detailed data about the freight transport in Vietnam was achieved from Statistical Yearbook of Vietnam (GSO, 2008).

4.6 Parameter estimation of energy demand

The parameter about energy demand is estimated from the active mass of an energy balance table and a base year. The parameter about energy demand is estimated from the amount of activities of the base year and the energy balance table.

4.6.1 Formulization of the energy demand model

The estimation formula of energy demand is shown below. Energy demanded is estimated by multiplying amount of activities by energy service demand per driving force, fuel share, and the reciprocal of energy efficiency.

$$ED_{eds,esc,e} = ESDF_{eds,esc} \cdot ESVG_{eds,esc} \cdot ES_{eds,esc} \cdot EE_{eds,esc,e} \tag{4.5}$$

where,

$ED_{eds,esc,e}$: energy demand by energy demand sector, by energy service type, and by fuel type (toe)

$ESDF_{eds,esc}$: the amount of activities by energy demand sector, by energy service type, and by sector (activity)

$ESVG_{eds,esc}$: energy service demand per driving force by energy service demand sector and energy service type (toe/activity)

$ES_{eds,esc}$: fuel share by energy demand sector and energy service type (-)

$EE_{eds,esc,e}$: the reciprocal of energy efficiency by energy demand sector, by energy service type, and by fuel type (-)

eds: energy demand sector

esc: energy service type

e: fuel type

The amounts of activities (ESDF) are socioeconomic indicators which show the level of activity of an energy demand sector; residential sector: the number of households, industry sector: output; transport sector: transport volume. Energy service means the utility acquired by using energy, and it defines as follows:

$$ESVD_{eds,esv,e} = ED_{eds,esv,e} \times EF_{eds,esv,e} \tag{4.6}$$

$ESVD_{eds,esc:}$ energy service demand by energy service demand type and energy service type (toe)

In this study, energy efficiency of the base year (2005) is set to 1.

4.6.2 Residential and commercial sectors

The energy balance table shows energy demand by fuel type of residential sector and commercial sector, respectively. The energy demand by fuel type per household was obtained by dividing energy demand by the number of households. The energy service types of residential sector and commercial sector are cooling, heating, hot water supply, cooking, lighting and others (household appliances and power).

Since the items of the energy service demand by energy service type cannot be grasped, SAGE (2003) was used to split energy service demand by energy service type. Tables used to split energy service demand by energy service type were shown in Appendix 6.

The energy demand by fuel type of residential sector and commercial sector is shown in Table 4.18

Table 4.18 Energy demand by energy service type of residential and commercial sector.

Unit: ktoe

Sector	Energy service	Coal	Petroleum	Gas	Biomass	Electricity	Total
Residential	Cooling	-	-	-	-	268	268
	Heating	861	20	-	231	17	1,129
	Hot water	-	237	-	4,857	33	5,128
	Kitchen	-	440	-	18,041	33	18,514
	Lighting	-	29	-	-	352	380
	Refrigerator	-	-	-	-	419	419
	Other electric equipment	-	-	-	-	552	552
	Total	861	726	-	23,129	1,674	26,390
Commercial	Cooling	-	-	-	-	44	44
	Heating	200	534	-	-	10	743
	Hot water	100	392	-	-	20	513
	Kitchen	33	32	-	-	3	69
	Lighting	-	-	-	-	118	118
	Refrigerator	-	-	-	-	68	68
	Other electric equipment	-	-	-	-	74	74
	Total	333	958	-	-	338	1,629

4.6.3 Industrial sector

Since it is difficult to grasp the items of energy service type in industry sector, energy service types are not divided in each industry. Energy service demand per driving force (it is the same as the energy demanded per output since energy efficiency of the base year is set to 1) and fuel share are estimated from the energy demand obtained from an energy balance table by fuel type and industry and input-output table.

We referred from SAGE (2003) in order to split energy service demand by energy service type. Tables used to split energy service demand by energy service type were shown in Appendix 6.

The energy service types of industrial sector are direct heat (furnace), steam boiler, motor and other industrial energy service.

Table 4.19 Energy demand by fuel type of industrial sector in 2005

Unit: ktoe

Sector	Sub-sector	Coal	Petroleum	Gas	Renewable	Electricity	Total
Industrial	Agriculture-Fishery-Forestry	22	473	-	-	49	544
	Mining and quarrying	582	304	12	-	228	1,126
	Food, beverage & tobaco manufactures	1,052	550	22	-	412	2,037
	Other consumer goods	1,157	605	24	-	453	2,240
	Industrial materials	739	387	15	-	289	1,431
	Capital goods	517	271	11	-	203	1,001
	Construction	729	381	15	-	285	1,410
	Total	4,799	2,971	100	-	1,919	9,789

The energy demand by energy service type of industrial sector is shown in Table 4.20

Table 4.20 Energy demand by energy service type of industrial sector in 2005

Unit: ktoe

Sector	Energy service	Coal	Petroleum	Gas	Biomass	Electricity
Industrial	Direct heat (furnace)	2,352	631	38	-	173
	Steam boiler	1,968	1,623	49	-	-
	Motor	-	-	-	-	1,497
	Other industrial energy service	480	717	13	-	249
	Total	4,799	2,971	100	-	1,919

4.6.4 Transport sector

The energy services of passenger transport sector and freight transport sector are transport modes. Energy service demand is obtained by dividing the energy demand of the energy balance table by the estimated passenger transport volume and freight transport volume in 2005. SAGE, (2003) was used to split energy service demand by energy service type.

Table 4.21 Energy demand by energy service type of transport sector in 2005.

Unit: ktoe

Sector	Transport mode	Coal	Petroleum	Gas	Renewable	Electricity
Passenger transport	Motorbike	-	1,100	-	-	-
	Car	-	952	-	-	-
	Bus	-	846	-	-	-
	Train	-	-	-	-	33
	Ship	-	8	-	-	-
	Aviation	-	169	-	-	-
	Total	-	3,075	-	-	33
Freight transport	Truck	-	3,386	-	-	-
	Train	-	-	-	-	2
	Ship	-	146	-	-	-
	Aviation	-	3	-	-	-
	Total	-	3,535	-	-	2

4.7 Energy balance table

In this study, total volume of energy supply and demand was taken from Vietnam's energy balance table 2005 (IEA, 2007). The energy balance table was disaggregated by AIM team (2009). See more in Appendix 7.

4.8 Power supply

Electricity consumption in Vietnam grew at 15% annually between 1996 and 2000, and at 15.5% over 2000-2005, faster than the GDP, which grew at 7.2% between 1996-2005 (Nhan and Duong, 2009). The elasticity of GDP to electricity was above 1.0 although at a downward trend, amounted at 1.4 during the period 2005-2010.

There was a decrease trend in total electricity consumption by household sector from 49% in 2000 to 44% in 2005, while the industrial sector's share increased from 41% to 46%. According to EVN (2006), the electricity consumption per capita was 538 kWh/year.

Fuels input, power generation, own-use, transmission loss and power supply and was identified from energy balance table 2005 (IEA, 2007) and shown in Table 4.22. Characteristics of power generation were estimated from Table 4.23.

Table 4.22 Power generation in 2005

Unit: ktoe

	Coal	Oil	Gas	Hydro power	Total
Fuel	2,132	679	4,812	1,845	9,467
Generation	769	213	1,770	1,845	4,597
Own-use	21	6	49	51	126
Transmission loss	84	23	194	203	505
Supply	663	184	1,527	1,592	3,966

Table 4.23 Characteristics of power generation in 2005

	Coal	Oil	Gas	Hydro power
Efficiency	36%	31%	37%	100%
Onw-use	3%	3%	3%	3%
Transmission loss	11%	11%	11%	11%
Generation	17%	5%	39%	40%

4.9 Collection of low carbon countermeasures in energy sector

In order to collect low carbon countermeasures which are thought to be available for Vietnam in the target year, it is necessary to take into account the technical and administrative information.

4.9.1 Technical information

To use quantitative estimation, gather technical data of low carbon countermeasures including:

Energy efficient end-use device. Household equipment, industrial equipment, vehicles, etc.

Building. Better insulation of buildings, passive heating & cooling, etc.

Power supply. Reduce transmission and distribution lost, lower CO_2 intensity of power generation, etc.

Transport structure. Public transport, transport demand management, etc.

Renewable energy. PV, solar water heater, wind power, etc.

Others: energy saving behavior by general public, carbon sinks etc.

4.9.2 Administrative information

Other than technical data, following information is also required to determine the measures portfolio, however it does not used in the calculation directly.

Cost. Direct investment cost, net cost considering profit of energy saving, required expense of government to implement the measure, etc.

Commercial year. The year when each measures will be commercially available in the area of the research. Especially for technologies being developed. Some measures are, off course, already available.

Required period. Years needed to implement fully. This information shows availability of the measure in the target year(s).

Ancillary benefit. Some measures have positive effect to economy and society, other than GHG emission reduction and energy saving. Including: improvement of transport convenience, improvement of air and water quality, reduction of waste disposal, conservation of resource, etc. Some measures will be implement even if GHG emission reduction is out of concern.

Preference of stakeholders. General preference of stakeholders in the region to each of the measures. Some measures are not preferred because of cultural, religious, ethical or administrative viewpoint, and *vice versa*.

List of low carbon countermeasures, which were collected from previous study and referred to national policies are shown in Table 4.24

National policies are shown in Appendix 1 and Appendix 2.

Table 4.24 List of low carbon countermeasures in energy sector

Sector	Low-carbon countermeasure	Data		Source	Category (*)
Residential	Energy efficiency home appliances				
	High energy efficiency air condition (cooling dedicated)	COP	8.00	*2	E
	High energy efficiency cooking stove				
	Coal-cooking stove	Thermal efficiency (base year =1)	0.45	*1	E
	LPG cooking stove	Thermal efficiency (base year =1)	0.55	*1	E
	Biomass cooking stove	Thermal efficiency (base year =1)	0.55	*1	E
	Electricity cooking stove	Thermal efficiency (base year =1)	0.85	*1	E
	High energy efficiency lighting (Compact fluorescent lamps substitute incandescent light)	Electricity consumption (conventional type = 1)	2.00	*1	E
	High energy efficiency refrigerator	Electricity consumption (conventional type = 1)	1.50	*1	E
	High energy efficiency water heating				
	Coal - water heating	COP	0.60	*1	E
	Oil - water heating	COP	0.95	*1	E
	Biomass - water heating	COP	0.95	*1	E
	Solar water heating	COP	1.00	*1	E
	Energy efficiency improvement of electric appliances	Electricity consumption (base year = 1)	1.50	*1	E
	Energy saving behavior			*5	B
	Cooling	Energy service demand reduction ratio	17%		
	Heating	Energy service demand reduction ratio	17%		
	Hot water	Energy service demand reduction ratio	17%		
	Cooking	Energy service demand reduction ratio	17%		
	Other home electric appliances	Energy service demand reduction ratio	17%		
Commercial	High energy efficiency air condition (cooling only)	COP	8.00	*2	E
	High energy efficiency lighting (Compact fluorescent lamps substitute incandescent light)	Electricity consumption (conventional type = 1)	2.00	*1	E
	High energy efficiency refrigerator	Electricity consumption (conventional type = 1)	1.50	*1	E
	High energy efficiency water heating				
	Coal - water heating	COP	0.60	*1	E
	Oil - water heating	COP	0.95	*1	E
	Solar water heating	COP	1.00	*1	E
	Energy efficiency improvement of electric appliances	Electricity consumption (base year = 1)	1.50	*1	E
	High energy efficiency cooking stove				
	Coal-cooking stove	Thermal efficiency (base year =1)	0.45	*1	E
	LPG cooking stove	Thermal efficiency (base year =1)	0.55	*1	E
	Electricity cooking stove	Thermal efficiency (base year =1)	0.85	*1	E
	Energy saving behavior			*5	B
	Cooling	Energy service demand reduction ratio	20%		
	Heating	Energy service demand reduction ratio	20%		
	Hot water	Energy service demand reduction ratio	20%		
	Cooking	Energy service demand reduction ratio	20%		
	Other home electric appliances	Energy service demand reduction ratio	20%		
Industry	Energy efficiency equipments				
	High energy efficiency boiler	Thermal efficiency (base year = 1)	1.1	*3	E
	High energy efficiency furnace	Thermal efficiency (base year = 1)	1.4	*4	E
	High energy efficiency motor	Electricity consumption (base year = 1)	0.8	*3	E
	Energy saving	Energy service demand reduction ratio	20%	*5	B
Passenger transport	Energy effciency in transport mode			*1	E
	Bio fuel (from oil to bio fuel)	Diffusion ratio	3%	*6	S
	Modal shift				B
		From vehicle to train			
		From vehicle to bus			
Freight transport	Energy effciency in transport mode			*1	E
	Bio fuel (from oil to bio fuel)	Diffusion ratio	7%	*6	S
	Modal shift				B
		From large vehicle to trai			
		From large vehicle to ship/boat/ferry			
Power generation	Improvement of CO_2 intensity of power generation				
	Generation efficiency improvement			*7	
	Coal	Generation efficiency = 45% (base year = 36%)			
	Oil	Generation efficiency = 38% (base year = 31%)			
	Gas	Generation efficiency = 42% (base year = 37%)			
	Transmission lost reduction	Transmission lost = 7% (base year = 11%)		*8	
	Fuel shifting				
	From fossil fuel to nuclear	Shifting ratio	10	*9	
	From fossil fuel to renewable energy	Shifting ratio	7	*10	

(*) Classification of low carbon countermeasures: B…Energy Saving Behaviors, E…Improvement of Energy Efficiency, S…Fuel Switch

Table 4.25 Countermeasure collection sources

*1 Mizuho Information & Research Institute, Inc. (2005): Report on investigation for scenario making and simulation program "Chapter 4 Scenario of measures"

*2 The Energy Conservation Center, Japan (2007): Catalog of energy-saving performance 2007 winter

*3 Koji SHIMADA, Yoshitaka TANAKA, Kei GOMI and Yuzuru MATSUOKA(2006): A Method Development for Long-term Local Scenario Formulation towards a LCS and its Pioneering Application to Shiga Prefecture Environmental Systems Research, Vol. 34, pp. 143-154.

*4 New Energy and Industrial Technology Development Organization, Japan (2005): Working paper of the field test to introduce high performance industrial furnace

*5 Vietnam National Energy Efficiency Program in the period 2006-2015 (VNEEP); Decision on Vietnam National Energy Efficiency Program (No. 79/2006/QD-TTg)

*6 Bio-energy development for the period up to 2015, outlook to 2025.(BIED); Decision number 177/2007/QD-TTg dated November 20th 2007

*7 Nhan T. N., M. H. Duong, 2009. The potential for Mitigation of CO_2 Emission in Vietnam's Power Sector. DEPOCEN Working paper Series No. 2009/22.

*8 National Power Development Plan for period 2011-2020 with perspective up to 2030. (PDP VII); Decision number 1208/QD-TTg dated July 21st 2011

*9 Master Plan on Nuclear Power Development up to 2030. (MPNP); Decision number 906/QD-TTg dated June 17th 2010

*10 Master Plan for Renewable Energy Development for the period up to 2015, with outlook to 2025. (MPRE); Institute of Energy Vietnam (2008)

4.10 Data collection and parameter estimation in AFOLU sectors

We estimated GHG emissions and mitigation potential in AFOLU sectors in 2030 in Vietnam based on two scenarios: (1) Scenario without low carbon countermeasures (hereinafter referred to as 2030BaU); (2) Scenario with introduction of low carbon countermeasures (hereinafter referred to as 2030CM).

Table 4.26 shows the main setting indicators for Vietnam in the base year 2005. We set a wide range of Allowable Abatement Costs (AAC): 0, 10, 100 and 10000 USD/tCO_2 for GHG emission mitigation. We defined that GHG mitigation potential in 2030 is a difference of GHG emissions between 2030BaU and 2030CM.

Table 4.26 Main setting indicators for Vietnam in 2005

Settings		2005	Reference
Population[thousand people]		83,106.3	GSO, 2008
Energy price[USD per toe]	coal	940.0	Fujimori et al, 2012
	oil	192.0	Fujimori et al, 2012
	natural gas	262.0	Fujimori et al, 2012
Irrigation area of paddy rice[%]		83.0	MONRE, 2010
Wetland of paddy rice[%]		95.0	IRRI, 2012
Total nitrogen fertilize[million tons]		1.3	FAOSTAT, 2012

4.10.1 Cost

For the AG/Bottom-up module, only extra cost caused by installation of the countermeasures is considered. The extra cost is defined as a difference from a cost in the base year. The cost is exchanged into an annual cost. Combination of countermeasures is determined in order to minimize total extra cost.

For the LULUCF/Bottom-up module, the per-area costs and indirect benefits from countermeasure application (i.e. sale of bioenergy) were converted to a per-annum basis. The module calculates: i) The total present-valued costs of mitigation countermeasures implemented from the present to the future and ii) total cost in the whole application period. A 5% discount rate was applied to the calculation. Cost and benefit for land conversion is not taken into account in this study.

4.10.2 Fertilizer input

The most common nitrogen fertilizer used in Vietnam is urea, and more than 2 million tons of urea was consumed every year (World Bank, 2010). The remainder of urea applying for crops is volatized or disposed into water, which cause N_2O emission. In this study, nitrogen fertilizer per area by country and crop was estimated by cross-entropy methodology (Golan et al., 1996) using total fertilizer consumption (FAOSTAT, 2012) and fertilizer input per harvested area by crop in 2001 (IFA/FAO/IFDC, 1999, 2002). We assumed that in the future, nitrogen fertilizer will increase in proportion to yields.

Table 4.27 Amount of synthetic fertilizer N applied to soils by types of crop in 2001

	N_fertilizer [kgN/ha/yr]
Rice	103.6
Other coarse grains	94.5
Vegetable, fuites and nuts	43.6
Oil crops	35.9
Sugar crops	89.2
Other crops	35.9
Total	402.7

4.10.3 Yields

Yields of agricultural crops was referred to MARD (2011) and Hasegawa (2009) and shown in Table 4.27.

Table 4.27 Yields of crop by year

Unit: ton/ha

	2000[*]	2005[*]	2010[*]	2015	2020	2030
Rice	4.3	4.9	5.3	5.3	5.5	5.8
Other coarse grains	3.6	3.6	4.0	4.6	5.3	7.0
Vegetable, fuites and nuts	9.3	9.3	9.7	10.1	10.6	11.6
Oil crops	1.9	1.9	2.0	2.1	2.1	2.2
Sugar crops	49.8	56.1	59.9	72.9	78.0	89.1
Other crops	1.3	1.3	1.5	1.9	2.5	3.8

[*] Yields of rice and sugar crop in 2000, 2005 and 2010 is refered to MARD (2011)

4.10.4 Price of commodity and energy

Price of commodity were referred to Hasegawa et al., (2009) and shown in Table 4.28

Table 4.28 Price of crop products

Unit: USD/ton

Type of crop	Price of product (USD/ton)					
	2000	2005	2010	2015	2020	2030
Rice	54	54	420	332	346	298
Other coarse grains	33	33	33	33	33	33
Vegetable, fuites and nuts	30	30	30	30	30	30
Oil crops	45	45	75	214	107	76
Sugar crops	5	5	5	5	5	5
Other crops	3755	3755	3146	3624	3529	3755

Fossil fuels such as oil, coal and natural gas are used in agricultural actives. There is a need of energy for agricultural machinery, pumps, seeders, milking machines, tractors, combine harvesters, manure spreaders, fertilizer distributions and so on. Information of energy price used in the AFOLUB model for Vietnam in the period 2005-2030 was referred to Fujimori et al., (2012) and shown in Table 4.29.

Table 4.29 Energy price

Unit: USD per toe

	2005	2010	2015	2020	2025	2030
Energy price [USD per toe]						
Oil	225	212	221	244	296	369
Coal	22	39	58	79	102	127
Natutal Gas	46	55	67	79	91	104

4.10.5 Annual average nitrogen excretion rates

Annual nitrogen (N) excretion rates should be determined for each livestock category defined by the livestock population characterization. Vietnam has not data on annual average N excretion rates; hence we used the IPCC default N excretion rates and typical animal mass for livestock category for Asian region to estimate annual N excretion rates by the formula 4.1 (IPCC, 2006)

$$Nex_{(T)} = N_{rate(T)} \bullet \frac{TAM}{1000} \bullet 365$$

Where $Nex_{(T)}$ = annual N excretion for livestock category T, kg N animal^{-1} yr^{-1} ; $N_{rate(T)}$ = default N excretion rate, kg N (1000 kg animal mass)$^{-1}$ day^{-1}; $TAM_{(T)}$ = typical animal mass for livestock category T, kg animal^{-1} . Then, the annual average nitrogen excretion rates for different type of animal were estimated and are shown in Table 4.30.

Table 4.30 The annual average N excretion rates in Vietnam

Unit: kg N animal^{-1}yr^{-1}

Type of animal	Annual Nitorgen excretion rates [kg N animal^{-1} yr^{-1}]
Dairy cattle	60
Other cattle	40
Buffaloes	44
Sheep	12
Goats	15
Camels	36
Horses	40
Mules	22
Asses	22
Swines	5
Chikens	0
Ducks	1
Turkeys	2

4.10.6 Production technologies

(1) Feeding system of livestock

Feeding system of livestock was referred to IPCC (2006).

Table 4.31 Ratio of feeding system of livestock

Type of animal	Grazing (%)	Feeding (%)
Dairy cattle	20	80
Other cattle	50	50
Buffaloes	50	50
Sheep	100	0
Goats	100	0
Camels	100	0
Hourses	100	0
Mules	100	0
Asses	100	0
Swines	0	100
Chikens	0	100
Ducks	0	100
Turkeys	0	100

(2) Manure management system

The manure from pasture, range and paddock grazing animals in Vietnam is allowed to lie as deposited, and is not managed.

The manure management system of feeding animals such as sheep, goats, camels, horses, mules, asses, chickens, ducks and turkeys is MS4 (Dry lot). This is a paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically.

The manure of feeding dairy cattle is treated through various type of manure management system on which 4% is treated in MS1 (lagoon), 38% in MS2 (Liquid/Slurry), 20% in MS5 (Passture/Range/Paddok), 29% in MS6 (Daily Spread), 2% in MS7 (Anaerobic Digester) and 7% in MS8 (Burned for Fuel).

The manure of feeding buffaloes and feeding other cattle is treated by MS4 (Dry lot), MS5 (Passture/Range/Paddok), MS6 (Daily Spread), and MS8 (Burned for Fuel).

Feeding swines manure is mainly treated in MS2 (Liquid/Slurry) of 40%, and MS4 (Dry lot) of 54%; and only 6% is treated in MS7 (Anaerobic Digester).

Table 4.32 Manure management system

Type of animal	Type of cattle breeding	Type of manure management system							
		MS1 (%)	MS2 (%)	MS3 (%)	MS4 (%)	MS5 (%)	MS6 (%)	MS7 (%)	MS8 (%)
Dairy cattle	Grazing					100			
Other cattle	Grazing					100			
Buffaloes	Grazing					100			
Sheep	Grazing					100			
Goats	Grazing					100			
Camels	Grazing					100			
Hourses	Grazing					100			
Mules	Grazing					100			
Asses	Grazing					100			
Swines	Grazing					100			
Dairy cattle	Feeding	4	38			20	29	2	7
Other cattle	Feeding				46	50	2		2
Buffaloes	Feeding				41	50	4		5
Sheep	Feeding				100				
Goats	Feeding				100				
Camels	Feeding				100				
Hourses	Feeding				100				
Mules	Feeding				100				
Asses	Feeding				100				
Swines	Feeding		40		54			6	
Chikens	Feeding				100				
Ducks	Feeding				100				
Turkeys	Feeding				100				

Explanation of each type of manure management system is shown in Appendix 8

(3) Share ratio of irrigation area

A proportion of irrigated and rain-fed area was estimated based on the information from Department of Water Resources (MONRE, 2010). According to that, in 2000, more than 83% of paddy rice area was irrigated and the rest was accounted for rain-fed area.

Table 4.33 Irrigated and rained land area in 2000

	Rice cultivation land	Irrigated land	Rainfed
Area (thousand ha)	7666	6395	1271
Share	100%	83%	17%

(4) Share ratio of wet-cultivated rice field

The share ratio of wet-cultivated rice field was referred to IRRI (2011). The data was during the period of 2004 to 2006.

Table 4.34 Share ratio of wet-cultivated rice field and upland rice file

	Rice cultivation land	Wet-cultivated rice field	Upland rice field
Area (thousand ha/year)	7366	6998	368
Share	100%	95%	5%

4.10.7 Collection of low carbon countermeasures in AFOLU sectors

To develop a database of countermeasures in the study, mitigation countermeasures were collected from not only domestic literature, but also from international literatures. We considered characteristic of countermeasures such as cost, mitigation potential, application terms etc. A list of countermeasures input in the model is shown in Table 4.35 and Table 4.36. Costs of countermeasures in the reported country are exchanged into costs in Vietnam by using cost of construction, wage, energy price (World Bank, 2006, IEA, 2007 and Davis Langdon & Seah International, 2010).

Table 4.35 List of mitigation countermeasures in agricultural sector

Emission sources	Code	Countermeasures	Code	Cost [USD/activity/yr]*	Mitigation [tCO_2eq/activity/yr]*	Reference
Enteric fermentation	3A1	Replacement of roughage with concentrates	RRC	-23	0.45	Bates(1998a), Shibata et al.(2010), Graus et al.(2004)
		High genetic merit	HGM	0	0.32	Bates(1998a)
Manure management	3A2	Dome digester, cooking fuel and light	CFL	44	0.62	USEPA(2006)
		Daily spread of manure	DSM	2.2	0.33	Bates(1998a)
Rice cultivations	3C7	Midseason drainage	MD	0	0.89	USEPA(2006)
		Fall incorporation of rice straw	FIR	0	0.68	USEPA(2006)
		Replace Urea with Ammonium Sulphate	RAS	20	0.24	USEPA(2006), Graus et al. (2004)
Managed soils	3C4~3C6	High efficiency fertilizer application	HEF	2.2	0.65	USEPA(2006), Hendriks et al. (1998), Amann et al. (2005)
		Slow-release fertilizer application	SRF	2150	0.76	USEPA(2006), Akiyama et al.(2010)
		Tillage and residue management	TRM	5	0.08	IPCC(2007), Smith et al.(2007)

* Activity is area of cropland for crop cultivation and animal numbers for livestocks.

Table 4.36 List of mitigation countermeasures in LULUCF sector

Mitigation countermeasures	Code	Period [years]*	Cost [USD/ha/yr]	Mitigation [tCO_2eq/ha/yr]
Protection and sustainable management of existing production forest areas	PEF	40	15.4	11.3
Conservation of existing protection forests	CEF	40	8.9	11.5
Reforestation of large timber forests in conjunction with national regeneration	RLF	40	7.6	20.0
Planting long-rotation large timber trees	LLT	40	9.3	16.9
Planting fast-growing tress for lumber	FTL	15	26.6	32.9
Planting short-rotation pulpwood forest	SRF	15	27.0	19.6
Growing long-rotation non-timber product forest	GLF	40	7.0	14.6

*) Time over which sequestration may occur before saturating (assuming no disturbance, harvest, or interruption of practice)

Source: MONRE (2010)

Chapter 5

Projection of GHG emissions and mitigations in energy sector

5.1 Socioeconomic assumption

The socioeconomic assumption in 2030, which is the requisite for the estimation of energy demand and CO_2 emissions, was described. Vietnam socio-economic development strategies (GWP, HP) are used for description of the qualitative scenario. The values of the exogenous variables and coefficients of ExSS are determined based on the qualitative scenario.

5.1.1 Setting the scenarios

In this study, there are two scenarios, the 2030BaU (business as usual) and 2030CM (countermeasures), are estimated. The 2030BaU scenario, where countermeasures for GHG emissions reduction are not introduced, reflects the situation in which both, the levels of commitments to climate-friendly-energy production and technological breakthroughs are relatively low. This scenario illustrates a continuation of the current trend in economic and energy policies without any significant change taking place.

On the other hand, the 2030CM scenario, which low carbon countermeasures are introduced in order to assess the mitigation potential of CO_2 emissions, represents the situation in which there are commitments to low carbon production and technological breakthroughs.

In addition, the socioeconomic assumption about population, industrial structure, economic growth, etc., are common to both scenarios.

5.1.2 Socio-economic assumption and its quantification

(1) Demographic composition

The population growth has been decreasing during the last decades and is expected to further decease substantially to below 1% by 2030 (Hai, et al., 2011). In this study we assumed Vietnam's population growth rate is 0.9% in 2030 and the Vietnam population is expected to reach 104 million people.

Demographic composition by sex and age cohort in 2030 is estimated based on UN Population low variant (UN, HP). The population composition by sex and age cohort in 2005 and 2030 is shown in Table 5.1.

Table 5.1 Demographic composition by sex and age cohort

Age cohort	2005 (%)			2030 (%)		
	Male	Female	Total	Male	Female	Total
0-14	15.0	14.2	29.2	8.0	7.7	15.7
15-64	31.7	33.0	64.7	35.9	35.3	71.2
65+	2.5	3.6	6.1	5.8	7.3	13.1
Total	49.2	50.8	100	49.7	50.3	100

(2) Average number of family occupants

Increasing of population and urbanization rate, life style changes and average household size becomes small. We assumed an average number of family occupants will be reduced to 3.5 persons per household (4.2 persons in 2005). The average number of household members is shown in Table 5.2. The number of households in 2030, therefore, is estimated to be 29.7 million households.

Table 5.2 Average number of household members

	2005	2030
No. of household members	4.2	3.5

(3) GDP growth rate

Although Vietnam's economy has undergone relatively high growth during the last decades, with average GDP growth rate of 7.5%, the country is still categorized as undeveloped, with GDP per capita of around 800 USD. Moreover, the country's economic growth has shown signs of slowing down due to domestic macroeconomic instabilities and partly negative indirect impacts of the global financial crisis. Therefore, promoting economic growth has become an issue of highest priority in the country's development strategies. The general development orientation of Vietnam presented in the 2011-2020 Socio-economic Development Strategy (2011-2020 SEDS) is that of sustainable development which is considered as a "through road" in the future time (cited in Hai et al., 2011). We assumed that the average GDP growth for the period 2021-2030 is equal to that of the period 2001-2010 (2011-2020 SEDS) of 7.5% pa. However, the country has been experienced the slow economic growth last several years. Therefore, in this study, we assumed annual average GDP growth rate from 2005 to 2030 is 6.5%.

(4) Structure of industry

The economic structure of Vietnam continues to move toward a more industrialized economy as experiencing during the last decades (GSO, 2011). According to the 2011-2020 Socio-economic Development Strategy, Vietnam will be an industrialized country in 2020. The share of agriculture-forestry-fishery sector is assumed declining as a proportion of GDP, in contrast to the service sector and the industry-manufacture-construction in 2030.

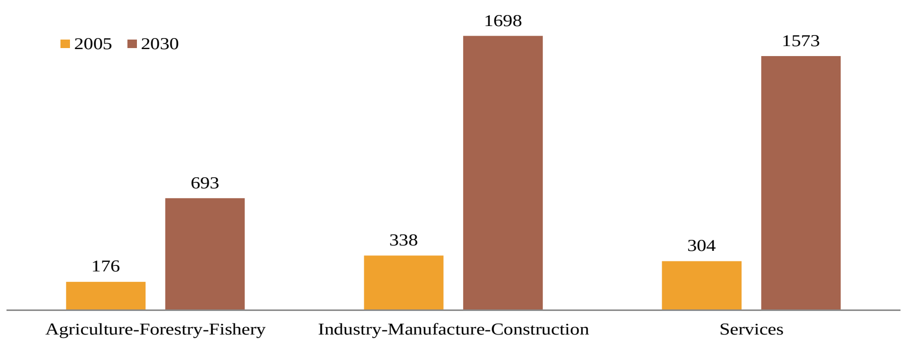


Figure 5.1 Contribution of industries to GDP in 2030 (trillion VND)

(5) Other final demand

Other final demands (consumption expenditure, gross fixed capital formation and export) set to the increasing in 6.5% (the same as GDP growth rate) of an annual average. Table 5.3 shows the setting of the other final demand in 2030.

Table 5.3 Final demand of other final demand sector

Unit: trillion VND

Final demand sector	2005	2030	2030/2005	Annual growth rate
Consumption expenditure	594	2,868	4.8	6.5%
Gross fixed capital formation	307	1,481	4.8	6.5%
Export	562	2,713	4.8	6.5%

(6) Details of final demand

The percentage distribution of private consumption expenditure and the final demand converter are shown in Table 5.4 and Table 5.5. The percentage distribution of primary industry decreases almost by half, and the percentage distribution of secondary industry and tertiary industry increases from the assumption that the demand of service industries increases.

Specifically, it is assumed that the consumption of Agriculture, Food, Beverage and Tabaco manufactures decrease, and the consumption of tertiary industry such as Electricity, Transport related, Telecommunication, Water and Other Services increases. The percentage distribution of government consumption expenditure and gross fixed capital formation of the target year is the same as that of the base year.

Table 5.4 Percentage distribution of private consumption expenditure

	2005	2025
Primary industry	14%	9%
Secondary industry	42%	39%
Tertiary industry	43%	52%

Table 5.5 The final demand converter

Sector	Sub-sector	2005	2030
Primary industry	Agriculture-Fishery-Forestry	14%	9%
	Mining and quarrying	0%	0%
Sencondary industry	Food, beverage & tobaco manufactures	24%	22%
	Other consumer goods	6%	6%
	Industrial materials	6%	5%
	Capital goods	6%	6%
	Construction	0%	0%
Tertiary industry	Electric, gas, water, transport, telecommunication, finacial, insurance, private and government services	43%	52%

(7) Transport

In this study, the target gas is restricted to only carbon dioxide (CO_2) that is the most significant GHG emitted by the transport sector, resulting from burning petrol, diesel oil, and kerosene in international combustion engines. However, we either did not include international aviation or maritime because there is a difficulty to decide which region is responsible to their emissions.

i) Passenger transport

Due to both economic growth and large expanding in population in future, development of transport sector is projected to progress significantly. Per capita passenger transport demand is assumed to increases from 2 trip/capita/day in 2005 to 2.7 in 2030. Therefore, passenger transport volume is estimated to be 103438 million trip/year.

Regardless of walk and bike, passenger transport in Vietnam is dominated by motorbike, which is projected to account for 8.3% in 2030 (only 2.95% in 2005) of total number of passengers carried (in unit of million trip/year). Share of passenger carried of other transport modes (bus, train, car, ship and aviation) are assumed to increase in 2030, on the contrary share of pedestrian and bicyclist is supposed to decrease to about 90% (96% in 2005).

Average trip distances of bus, car, train and aviation are assumed based on a transport demand forecast for 2030BaU case in VITRANSS 2 (JICA and MoT, 2009), those of motorbike, walk and bike, and ship are assumed the same in 2005. Table shows passenger transport volume, share and average trip distance by transport mode in 2030BaU.

Table 5.6 Passenger transport in 2030BaU

Transport mode	Train	Bus	Car	Motorbike	Walk & Bike	Ship	Aviation	Total
Volume (million persons.trip)	48	608	305	8,590	93,185	594	107	103,438
Modal share (trip,%)	0.0%	0.6%	0.3%	8.3%	90.1%	0.6%	0.1%	100%
Average trip distance (km)	206	145	150	6	3	22	955	-

In the CM case, since the modal shift from private vehicle (motorbikes) to public transport is promoted as a low carbon countermeasure, the modal share of train and bus increases greatly. Moreover, promoting people walk and use bicycles replacing cars is also a choice to reduce CO_2 emissions. Furthermore, since urban structure is advanced to a compact city, it is supposed that the average trip distances of trains, buses, cars, and motorcycles are short.

Table 5.7 Passenger transport in 2030CM

Transport mode	Train	Bus	Car	Motorbike	Walk & Bike	Ship	Aviation	Total
Volume (million persons.trip)	48	608	305	8,590	93,185	594	107	103,438
Modal share (trip,%)	0.1%	2.3%	0.2%	4.0%	93.0%	0.3%	0.1%	100%
Average trip distance (km)	176	41	150	6	3	22	955	-

ii) Freight transport

In the 2030BaU case, freight transport demand per output by industry is projected to increase 1.2 times of the base year, accounts for 0.35 tonne/output/day. Freight transport also relies predominantly on roads as and this transport mode is projected to keep its role in future the same as the base year 2005, which carries almost 71% of the total freight volume. Following by domestic waterway transport mode accounting for 27% and only 2% accounts for freight volume carried by train. Freight volume carried by aviation is negligible. Average trip distance is assumed to be same as those in 2005.

Table 5.8 Freight transport in 2030BaU

Transport mode	Train	Truck	Ship	Aviation
Share (%)	2%	71%	27%	0%
Average trip distance (km)	336	59	162	2,156

In the 2030CM case, since the modal shift from freight vehicles to trains and ships for freight transport is promoted as low-carbon countermeasure, the modal share of those transport mode volumes increase, account for 5% (trains) and 30% (ships). Conversely, share of freight vehicles volume (trucks) is projected to decrease to 65%. We considered only domestic aviation; however, share of freight transport volume by aviation is negligible. Furthermore, by improvement in efficiency of logistics, it is supposed that the average trip distance of freight vehicle is short.

Table 5.9 Freight transport in 2030CM

Transport mode	Train	Truck	Ship	Aviation
Share (%)	5%	65%	30%	0%
Average trip distance (km)	170	59	152	215,6

(8) Primary energy composition for national power supply

The fuel generation mix is expected to experience a significant change and still mainly relies on fossil fuels. Coal and natural gas, which have relatively greater flexibility, are expected to share high portions over the total power generation and always exceeds 50% in aggregate. Fossil fuels are expected to account for 62% of total cumulative electricity production, in which coal, natural gas and oil account for 38%, 21% and 3% of this production, respectively. Hydro power and renewable energy (nuclear, solar and wind, and biomass) account for 28% and 10%, respectively.

We supposed transmission and distribution loss reducing at 8% in 2030BaU (over 11% in 2005) and 7% in 2030CM. Owned electricity use of power plants is expected to be same as in 2005.

However, in order to limit CO_2 emissions and fossil fuel savings, the share of coal in total generation mix is expected to decrease from 38% (2030BaU) to 33% (2030CM). Nuclear and renewable energy are substituted for coal, accounting for 10% and 7% of total generation mix by 2030CM.

The primary energy composition of national electricity supply is shown in Table 5.10.

Table 5.10 Primary energy composition of national power supply

	Coal	Oil	Gas	Hydro	Nuclear	Renewables	Biomass	Total
2005	17%	5%	39%	40%	0	0	0	100%
2030BaU	38%	3%	21%	28%	4%	3%	3%	100%
2030CM	33%	3%	21%	26%	10%	6%	1%	100%

(9) Energy demand

In order to estimate end-use energy demand, one of indicators is needed to identify is energy service demands by driving forces. End-use energy sectors in Vietnam included residential, commercial, industrial, and transport sectors. The energy consumption and CO_2 emissions patterns in each sector are dependent on its structure and technologies employed.

Energy consumptions in 2030BaU case are characterized by backward and inefficient technologies and less promotion of renewable energy and energy efficiency.

Residential sector

Energy consumption in residential sector depends on living standard and life style. We supposed that the energy service demand per household of this sector increases 1.2% per year during the period 2005 to 2030 by the diffusion of electric appliances for improvement in living standards. In addition, the residential sector is expected to remain a big energy consumer which is driven by the growth of per capita income and the improvement of energy access through urbanization and rural electrification.

Major energy sources in residential sector are coal, gas, oil, electricity and traditional fuels (biomass, wood, and charcoal etc.,). We supposed that the significant issue is very high growth of electricity and oil products. This is because of increasing of GDP per capita and life style; demands for electricity (mainly for refrigerator and air conditioner) and LPG (mainly for cooking) are expected to increase rapidly. Adversely, traditional fuels are projected to decline as the rural population decreases and kitchen style in municipal residences are changed.

In 2030CM case, savings energy consumption is chosen as a low carbon countermeasure; therefore, we supposed that energy service demand per household of this sector reduces to 1% per year during the period 2005 to 2030.

Commercial sector

The commercial sector is expected to grow at a high rate, in parallel with economic growth. Coal, oil and electricity are still the main energy resources in this sector but the growth rate of electricity consumption is expected to increase dramatically. We supposed that the energy service demand per driving force of this sector increases 1.0% per year during the period 2005 to 2030.

In 2030CM case, savings energy consumption is chosen as a low carbon countermeasure; therefore, we supposed that energy service demand per driving force of commercial sector reduces to 0.8% per year during the period 2005 to 2030.

Industrial sector

The industrial sector accounts for biggest contribution to the country’s GDP characterizes by high energy intensity technologies such as manufacture materials, metal, paper, etc. Regarding to Government’s ambitious target of industrialization by the year 2020, energy consumption in this sector is expected to increase and its share in total final energy consumption is still high compared with other sectors. Energy service demand per driving force of this sector is assumed to increase at annual 1%.

For light industrial sector such as food, beverage and tobacco manufactures, and consumer good etc., we assumed that there is a sharp increasing trend in consuming of electricity and natural gas compare to those of 2005. On the other hand, in heavy industrial sector such as mining, industrial materials and construction etc., coal is expected the primarily energy sources compare to electricity and other sources.

In 2030CM case, savings energy consumption is chosen as a low carbon countermeasure; therefore, we supposed that energy service demand per driving force of industrial sector reduces to 0.8% per year during the period 2005 to 2030.

Transport sector

Road transport accounts for a major portion of Vietnam's gasoline and diesel oil consumption in the transport sector. It is supposed that those fuels are still main energy sources for transport sector in 2030. Both either are electricity vehicles expected to be used or are subways constructed in future; therefore, we assumed there is a rapid growth of electricity in transport sector. However, in 2030BaU scenario, all transport vehicles are supposed to have low fuel efficiency due to mainly to vehicle age and low average travel speeds. In 2030CM scenario, bio-fuel vehicles and high energy efficiency vehicles are introduced to cut down CO_2 emissions in this sector.

Due to high transport demand in the future in Vietnam, energy service demand per driving force in transport sector is expected to increase at annual 3% and 2% for passenger and freight transports, respectively.

Power sector

Due to increased economic activities and population growth, the demand for electricity is supposed to increase significantly in the future. The industrial sector, which is identified as a key dynamic for industrialization and modernization of the country's economy, is primarily responsible for increased electricity demand. The residential and commercial sectors are projected to consume huge amount of electricity because of the improvement in people's income and access to national electricity network. As a result, electricity generation is expected to grow at high rate. The fuel generation mix is assumed to experience a significant change in future with 38% contributed by coal, 28% by hydro power, 21% by gas, 3% by oil and 10% by renewable energy in 2030BaU scenario. Coal is contributed to the large share due to the availably of copious coal reserves and the introduction of clean coal generation technologies. Transmission loss is expected to reduce from over 11% in 2005 to 8% in 2030BaU scenario.

5.2 Estimation results

5.2.1 Socioeconomic indicators

The main results of the socio-economic indices and macro-economic indicators are shown in Table 5.11. With annual growth rate of 0.9%, population in 2030 increased 1.3 times compared to 2005, whereas increasing of household number was slightly larger because of smaller size of household. With annual growth rate of 6.5%, GDP increased almost 5 times in 2030 compared to 2005. In which, GDP contributed by secondary and tertiary sectors increased much higher than one contributed by primary sector. Passenger and freight transport increased 2.4 and 6.1 times in 2030 compared to 2005, respectively. Freight transport would increase faster than passenger transport because of rapid development of secondary industry sector.

Table 5.11 Estimation results of the main socioeconomic indicators

	2005	2030 BaU	2030 CM	2030BaU/2005	2030CM/2005
Population (million people)	83	104	104	1.3	1.3
No. of households (million)	20	30	30	1.5	1.5
GDP (trillion VND)	818	3,963	3,963	4.8	4.8
Gross output (trillion VND)	1,934	9,750	9,750	5.0	5.0
Agricuture-Fishery-Forestry (trillion VND)	261	1,026	1,026	3.9	3.9
Manufacturre-Construction (trillion VND)	1,176	6,155	6,155	5.2	5.2
Services (trillion VND)	497	2,569	2,569	5.2	5.2
Passenger transport demand (million people-km)	223,981	542,687	518,028	2.4	2.3
Freight transport demand (million ton-km)	38,856	235,212	235,124	6.1	6.1

The estimation results of passenger transport volume and freight transport volume are shown in Table 5.12 and Table 5.13.

Table 5.12 Passenger transport volume

Unit: mil p-km

	2005		2030				Transport volume change ratio		
			BaU		CM		BaU/	CM/	CM/
	Transport volume	Share	Transport volume	Share	Transport volume	Share	2005	2005	BaU
Train	8	4%	10	2%	18	4%	1.2	2.2	1.8
Bus	37	16%	88	16%	99	19%	2.4	2.7	1.1
Ship	6	3%	13	2%	7	1%	2.1	1.1	0.5
Motorbike	10	5%	50	9%	24	5%	4.8	2.3	0.5
Car	11	5%	46	8%	31	6%	4.1	2.8	0.7
Walk&bike	146	65%	233	43%	240	46%	1.6	1.7	1.0
Aviation	5	2%	103	19%	99	19%	19.1	18.4	1.0
Total	224	100%	543	100%	518	100%	2.4	2.3	1.0

Table 5.13 Freight transport volume

Unit: mil t-km

	2005		2030				Transport volume change ratio		
			BaU		CM		BaU/	CM/	CM/
	Transport volume	Share	Transport volume	Share	Transport volume	Share	2005	2005	BaU
Train	3	8%	17	7%	21	9%	5.7	7.2	1.3
Truck	18	45%	106	45%	97	41%	6.0	5.5	0.9
Ship	18	46%	110	47%	114	49%	6.1	6.3	1.0
Aviation	0	1%	3	1%	3	1%	13.6	13.6	1.0
Total	39	100%	235	100%	235	100%	6.1	6.1	1.0

The output by industry is shown in Table 5.14.

Table 5.14 Output by industry

	Output (trillion VND)			Composition ratio (%)	
	2005	2030	2030/2005	2005	2030
Primary industry	**404**	**1,684**	**4**	**21**	**17**
Agriculture-Fishery-Forestry	261	1,026	4	14	10
Mining and quarrying	143	658	5	7	7
Sencondary industry	**1,033**	**5,497**	**5**	**53**	**56**
Food, beverage & tobaco manufactures	259	1,213	5	13	12
Other consumer goods	285	1,908	7	15	20
Industrial materials	182	888	5	9	9
Capital goods	127	622	5	7	6
Construction	179	866	5	9	9
Tertiary industry	**497**	**2,569**	**5**	**26**	**26**
Total	**1,934**	**9,750**	**5**	**100**	**100**

5.2.2 Energy demand and CO_2 emissions

Estimation of energy demand and corresponding CO_2 emissions in 2030 is based on ExSS model.

(1) Final energy demand

The estimation result of final energy demands for the base year 2005, 2030BaU and 2030CM scenarios are summarized in Table 5.15 below.

Results show that the annual total final energy requirement of residential, commercial, industrial and transport sectors is expected to increase annually at 5.1% (2030BaU) and 4.0% (2030CM) over the outlook period, from 44 Mtoe in 2005 to 154 Mtoe in 2030BaU scenario and 120 Mtoe in 2030CM scenario. The projected final energy demand growth in 2030BaU scenario is higher than the past decade of 4.4% between 1995 and 2005.

Table 5.15 Final energy demand

Unit: ktoe

	Coal	Oil	Gas	Solar&wind	Biomass	Electricity	Total
2005							
Residential	861	726	-	-	23,129	1,674	26,390
Commercial	333	958	-	-	-	338	1,629
Industry	4,799	2,971	100	-	-	1,919	9,789
Passenger Transport	-	3,074	-	-	-	33	3,108
Freight Transport	-	3,535	-	-	-	2	3,537
Total	**5,993**	**11,265**	**100**	**-**	**23,129**	**3,966**	**44,453**
Share	**13%**	**25%**	**0%**	**0%**	**52%**	**9%**	**100%**
2030BaU							
Residential	2,618	9,169	-	-	21,764	12,655	46,207
Commercial	2,508	3,674	-	-	-	3,554	9,736
Industry	22,443	14,143	6,111	-	-	19,658	62,355
Passenger Transport	-	14,190	-	-	-	239	14,429
Freight Transport	-	20,954	-	-	-	101	21,055
Total	**27,569**	**62,131**	**6,111**	**-**	**21,764**	**36,207**	**153,782**
Share	**18%**	**40%**	**4%**	**0%**	**14%**	**24%**	**100%**
2030CM							
Residential	1,700	6,693	-	2,998	18,492	9,224	39,107
Commercial	1,890	3,239	-	627	-	2,343	8,099
Industry	15,341	12,991	6,562	-	2,283	15,814	52,991
Passenger Transport	-	7,027	-	-	75	165	7,267
Freight Transport	-	11,668	-	-	317	148	12,132
Total	**18,930**	**41,618**	**6,562**	**3,625**	**21,166**	**27,694**	**119,596**
Share	**16%**	**35%**	**5%**	**3%**	**18%**	**23%**	**100%**

The share of oil in final energy demand is projected to increase rapidly, accounting for 40% and 35% of total energy demand in 2030Bau and 2030CM scenarios, respectively, as a result of increased travel activities in transport sector. It is followed by electricity and coal which account for 24% and 23% of total energy demand in 2030BaU and 2030CM scenarios, respectively. The demand for electricity and coal is driven by increased economic activity, urbanization and rural electrification program. Although, there is a promotion of renewable energy in electricity generation (nuclear, solar and wind powers) in both 2030BaU and 2030CM scenarios, the share of renewable energy in total final energy still decrease as more population has access to modern energy, resulting in a reduction of the demand for traditional fuels for cooking. The share of traditional fuels (biomass, rice husk and charcoal etc.,) in total final energy consumption would reduce from 52% in the base year 2005, to 14% in 2030BaU scenario and 18% in 2030CM scenario (see Table 5.15).

Regarding to the target of being the industrialization country, energy demand in industrial sector is expected to increase dramatically and being the largest consumer of final energy – almost 41% and 45% in 2030BaU and 2030CM scenarios, respectively (see Figure 5.2).

The share of energy demand consumed by residential sector is projected to reduce substantially from 59% in 2005 to 30% in 2030BaU scenario and to 32% in 2030CM scenario, as a result of biomass being replaced by commercial energy sources. It is followed by transport sector, accounting for 23% and 16% in 2030BaU and 2030CM scenarios, respectively.

The finding shows that the shares of industrial and transport sectors are expected to increase in future, while the share of residential sector decreases. This is because of continued trends of industrialization and increasing population and travel demand. It can be said that energy consumption of industrial and transport sectors highlight the important role of these sectors in Vietnam's energy sector in future.

Compared to other sectors, the share of final energy consumption of commercial sector is smaller, which account for only 6% in 2030BaU scenario and 7% in 2030CM scenario.

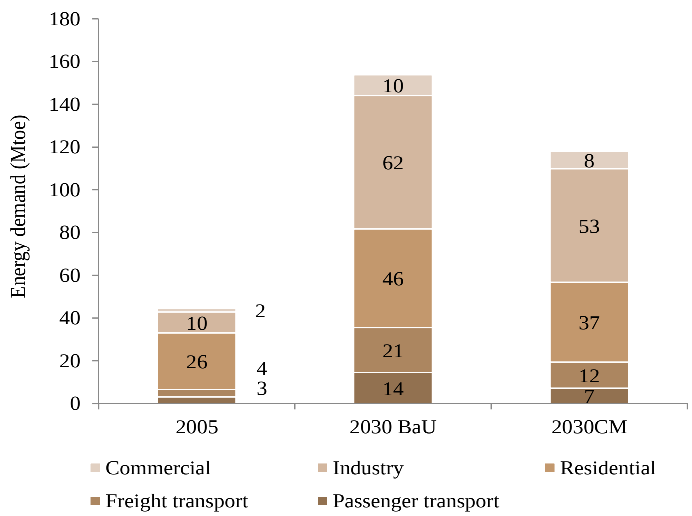


Figure 5.1 Final energy demand by sector

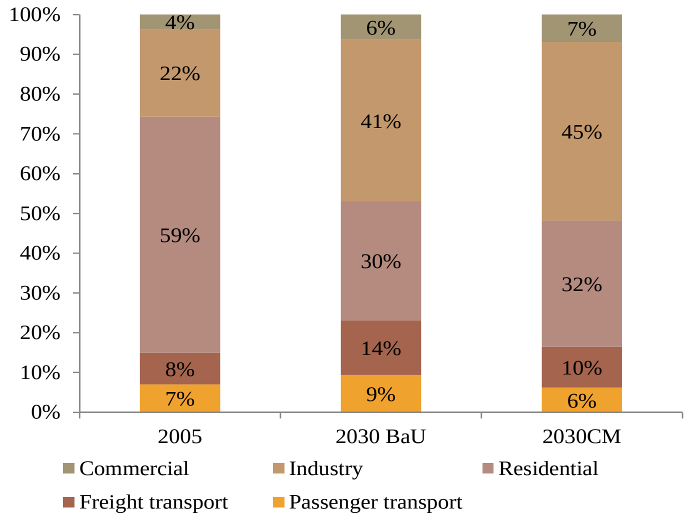


Figure 5.2 Share of energy demand by sector

(2) Primary energy demand

The estimation result of primary energy demand is shown in Table 5.16.

The primary energy demand is projected to increase 3.8 times from 52 Mtoe in 2005 to about 197 Mtoe in 2030BaU scenario, increasing annually at 5.5% over the outlook period. Commercial energy sources are expected to increase rapidly and surpass traditional energy sources in 2005, account for more than 80% of the primary energy mix. Consequently, the share of biomass is decrease substantially from 45% in 2005 to 13 and 16% in 2030BaU and 2030CM scenarios, respectively. This could be explained by the fact that due to improved living standards and rural electrification, a huge amount of population will have access to modern energy, resulting in a reduction in biomass demand.

Table 5.16 Primary energy demand

Unit: ktoe

	Coal	Oil	Gas	Hydro power	Nuclear	Solar wind	Biomass	Total
Energy demand								
2005	8,125	11,943	4,912	1,845	-	-	23,129	49,954
2030BaU	64,180	65,599	27,355	11,330	1,619	1,214	25,811	197,107
2030CM	40,023	43,229	21,142	8,573	3,062	5,462	23,463	144,953
2030BaU/2005	7.9	5.5	5.6	6.1	-	-	1.1	3.9
2030CM/2005	4.9	3.6	4.3	4.6	-	-	1.0	2.9
2030CM/2030BaU	0.6	0.7	0.8	0.8	1.9	4.5	0.9	0.7
Percentage distribution								
2005	16%	24%	10%	4%	0%	0%	46%	100%
2030BaU	33%	33%	14%	6%	1%	1%	13%	100%
2030CM	28%	30%	15%	6%	2%	4%	16%	100%

Among the fossil fuels, petroleum products are expected to continue to account for the largest share in total primary energy demand, mainly utilized in the transportation and industrial sectors. Coal and natural gas demand are projected to be major driven by sharp increase of the electricity and industrial sectors, accounting for almost 33% and 14% of total primary energy demand, respectively in 2030BaU scenario. The shares of nuclear and solar & wind are projected to account for 2% and 6% in 2030BaU and 2030CM scenarios, respectively.

(3) Electricity generation mix

The estimation result of electricity generation is shown in Table 5.17.

Table 5.17 Electric generation mix

Unit: ktoe

	Coal	Oil	Gas	Hydropower	Nuclear	Solar wind	Biomass	Total
2005	2,132	679	4,812	1,845	-	-	-	9,467
2030 BaU	36,611	3,468	21,244	11,330	1,619	1,214	4,046	79,532
2030 CM	21,092	1,611	14,580	8,573	3,062	1,837	2,296	53,052
2030BaU/2005	17.2	5.1	4.4	6.1	-	-	-	8.4
2030CM/2005	9.9	2.4	3.0	4.6	-	-	-	5.6
2030CM/2030BaU	0.6	0.5	0.7	0.8	1.9	1.5	0.6	0.7

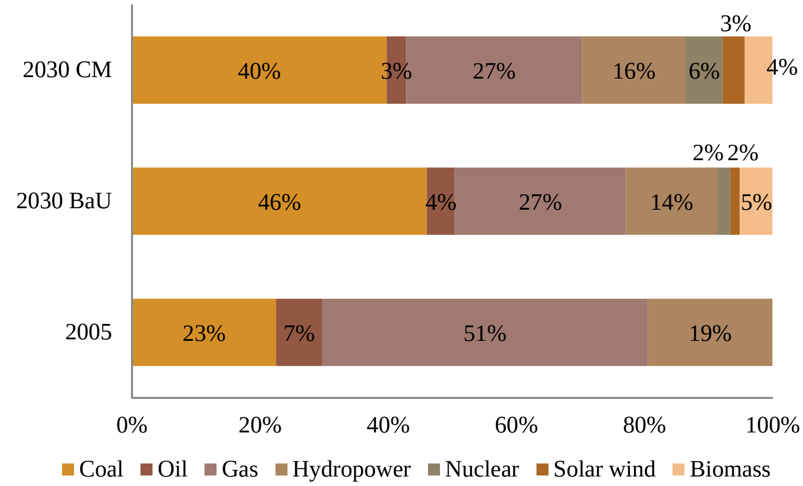


Figure 5.3 Electric generation mix

The demand for electricity is expected to increase significantly in the future, from 9% in 2005, to approximately 24% and 23% of total final energy requirements in 2030BaU and 2030CM scenarios by the year 2030, respectively (see Table 5.15). The increasing electricity demand is attributed to increased economic activities, population growth and urbanization. As identified a key dynamic for industrialization of the country's economy, the industrial sector is primarily responsible for increased electricity demand, accounting for more than 50% of total electricity consumption in both 2030 scenarios (see Figure 5.4). Moreover, residential sector is ranked as the second largest electricity consumer because of the population grow, high income lead to high energy service demand as well as improvement in access to national electricity grid, accounting for 35% (2030BaU) and 33% (2030CM) of total electricity consumption.

From 2005 to 2030, the share of hydro is expected to decrease from 19% to 14 and 15% in 2030BaU and 2030CM scenarios, respectively. By contrast, coal-fired electricity generation is expected to increase considerably and take a biggest share at 46% and 40% in 2030BaU and 2030CM scenarios, respectively, an almost two-fold increase over 2005. The share of gas-fired electricity generation is projected to decrease to nearly 27% in both 2030 scenarios. Meanwhile, the share of nuclear power is expected to increase to 2% in 2030BaU scenario and 6% in 2030CM scenario. The increase of nuclear and renewable energy, which are substituted for coal, are considered as an important role to play in ensuring the security of energy supply, through a diversification of fuel mix and in making energy activities towards low carbon economy. In addition, other renewable energy such biomass, solar and wind are expected to produce electricity in 2030 and the share of them accounts for 7% in both 2030BaU and 2030CM scenarios.

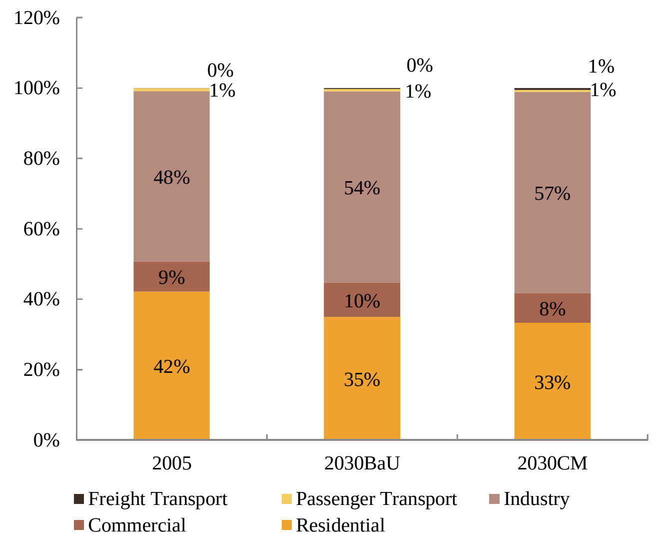


Figure 5.4 Share of electricity consumption by end-use sector

(4) Energy-related CO_2 emissions

The estimation result of CO_2 emissions is shown in Table 5.18. CO_2 emissions increase 6.4 of that of 2005 in the 2030BaU scenario, and 4.2 times of that of 2005 in the 2030CM scenario. In the 2030CM scenario, it is 0.7 times of that in the 2030BaU scenario.

CO_2 emissions are expected to increase rapidly as a result of increasing use of energy resources, especially fossil fuels. The total emissions in the base year 2005 were about 81 $MtCO_2$. This figure is expected to increase to 522 and 342 $MtCO_2$ by 2030BaU and 2030CM scenarios, respectively.

The major contributors to CO_2 emission include industrial sector, which account for 49% of total CO_2 emission in energy sector, followed by transport (22%) and residential sectors (21%) in the 2030BaU scenario, respectively (see Figure 5.5).

Per capita CO_2 emissions increase from almost 1.0 tCO_2 (in 2005) to 5.0 tCO_2 in the 2030BaU scenario, and 3.3 tCO_2 in the 2030CM scenario shown in Figure 5.6.

Table 5.18 CO_2 emissions

Unit: $ktCO_2$

Sector	2005	2030BaU	2030CM	2030BaU /2005	2030CM/ 2005	2030CM/ 2030BaU
Residential	14,803	110,234	68,232	7.4	4.6	0.6
Commercial	6,191	41,338	27,890	6.7	4.5	0.7
Industry	38,810	256,517	185,370	6.6	4.8	0.7
Passenger transport	9,972	46,525	23,101	4.7	2.3	0.5
Freight transport	11,267	67,290	37,800	6.0	3.4	0.6
Total	81,042	521,904	342,392	6.4	4.2	0.7

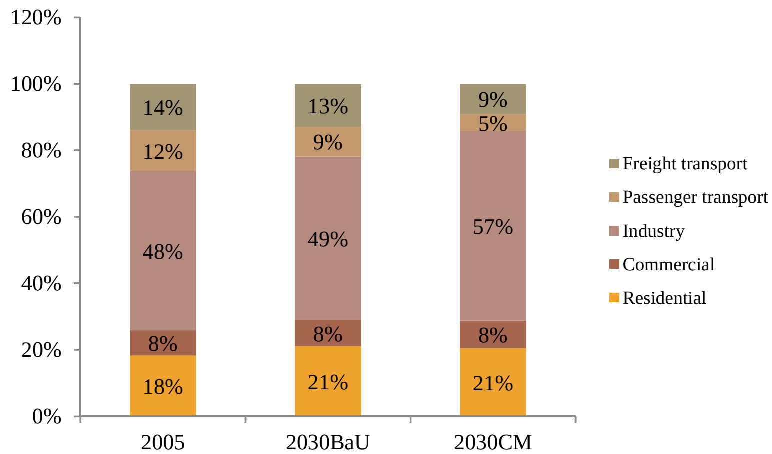


Figure 5.5 Share of CO_2 emissions by sector

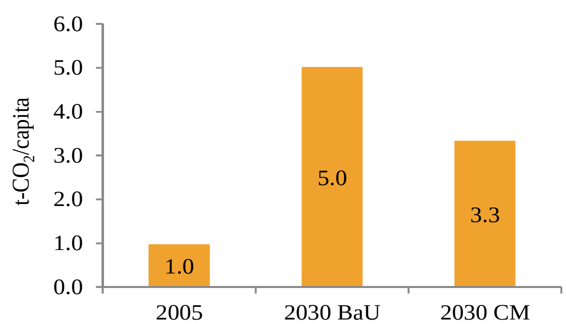


Figure 5.6 Per capita CO_2 emissions in energy sector

5.2.3 Potential mitigation of CO_2 emissions in energy sector in 2030

A list of low-carbon countermeasures is introduced to reduce CO_2 emission as shown in Table 6. The total mitigation value of 180 $MtCO_2$ in 2030CM corresponds to 34%

reduction from the emissions level in 2005. In which, 50 $MtCO_2$ (28%) reduction from industry, 23.4 $MtCO_2$ (13%) from passenger transport, 29.0 $MtCO_2$ (16%) from freight transport, 38.7 $MtCO_2$ (22%) from center power supply, 28.5 $MtCO_2$ (16%) from residential sector and 10.0 $MtCO_2$ (6%) in commercial sector (Figure 5.7).

Improvement of carbon intensity in both energy supply and demand and improvement of energy efficiency on the demand side is projected to be especially effective.

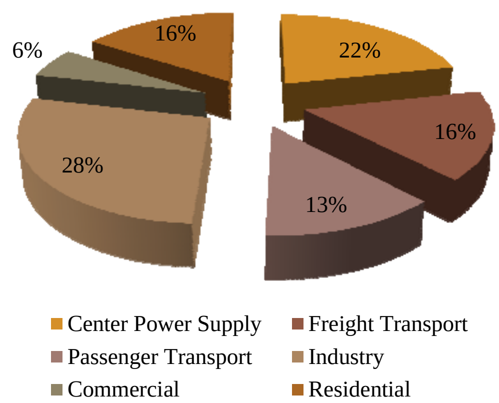


Figure 5.7 CO_2 reduction contributed by sectors

(1) Countermeasures for residential and commercial sectors

Countermeasures comprise: (i) energy efficiency improvement such as replacing existing coal-cooking stoves and existing LPG (Liquefied petroleum gases) -cooking stoves to BAT (Best available technology)-cooking stoves, replacing incandescent light bulbs by compact fluorescent lamps, replacing almost of existing energy efficiency air conditioners and refrigerators to higher energy efficiency ones, (ii) fuel shift and natural energy and (iii) energy saving behavior. Breakdown of emission mitigation by countermeasures in residential and commercial sectors is shown in Figure 5.8.

Countermeasures on electricity saving and energy efficiency in these two sectors are referred to Electricity Law (Law Number 28/2004/QH11), National Energy Development Strategy (Decision number 1855/2007/QD-TTg) and Law on Energy Efficiency and Conservation 2010 (Law Number 50/2010/QH12). However, in order to promote countermeasures in these sectors, it would 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.

Potential mitigation from each countermeasure in the residential and commercial sectors is shown in Figure 5.8.

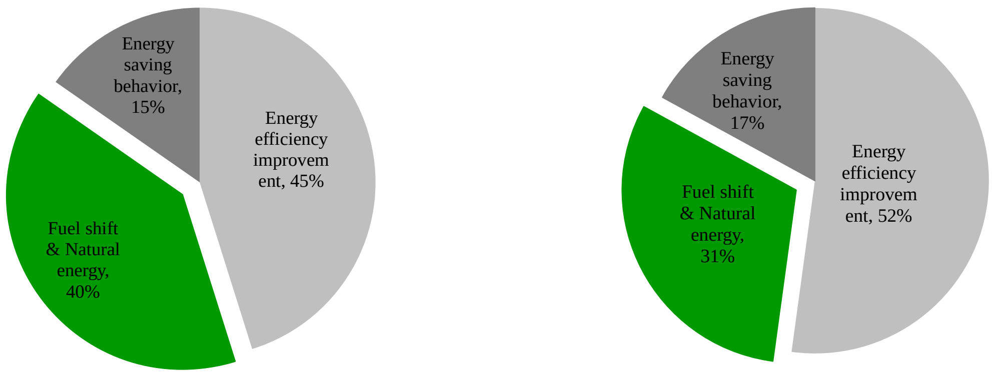


Figure 5.8 Breakdown of emission mitigation by countermeasures in residential (left) and commercial (right)

(2) Countermeasures for transport sector:

Countermeasures in transport sector is expected to account for the largest reduction, account for 29% of total CO_2 reductions in energy sector, on which 13% accounts for passenger transport and 16% from freight transport.

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. Based on the Law on Environmental Protection "transport planning should be in accordance with environmental standards and requirements", countermeasures such as modal shift, energy efficiency vehicle, bio fuel and compact city should be implemented. Concrete amount of CO_2 emission reduction from those countermeasures are shown in Table 5.21.

(3) Countermeasures for industrial sector:

Potential mitigation from industrial sector accounts for second large reduction (28%). The low carbon countermeasures in this sector includes: (i) energy efficiency improvement such as improvement of low-efficiency coal-fired boilers to higher efficiency ones, improvement of low-efficiency oil-fired boilers to higher efficiency ones, and more efficiency industrial equipment, devices and motors; (ii) shifting of fuel from high carbon intensity to lower carbon intensity such as from coal, oil to natural gas and biomass; and energy saving from industrial activities. In which, energy efficiency improvement is expected to reduce CO_2 emission by 23.5 $MtCO_2$, fuel shift by 15.7 $MtCO_2$ and energy saving by 10.9 $MtCO_2$. (Figure 5.9)

To promote low carbon countermeasures of industry sector, incentive to investment in energy efficiency improvement as well as fuel shift is essentially important. Policies for this sector should be focus on tax, subsidy and low interest loans.

(4) Countermeasures for power sector:

In power sector, low carbon countermeasures such as utilizing economically efficient domestic energy resources, promoting the use of renewable energies, reducing transmission and distribution loss, and developing nuclear power plant would decrease very large amount of CO_2 emission, accounting for 38.7 $MtCO_2$ (22%) reduction of total reduction in 2030CM.

Table 5.19 Energy demand by services by fuel in industry

Unit: ktoe

	Coal	Oil	Gas	Biomass	Electricity	Total
2005						
Furnace	2,352	631	38	-	173	3,194
Boiler	1,968	1,623	49	-		1,672
Motor	-	-		-	1,497	1,497
Others	480	717	13	-	249	979
Total	4,799	2,971	100	-	1,919	9,789
Share	49%	30%	1%	0%	20%	100%
2030 BaU						
Furnace	11,921	3,961	2,896	-	2,260	21,039
Boiler	7,932	7,163	2,352	-	5,261	22,708
Motor	-	-	-	-	9,432	9,432
Others	2,590	3,019	863	-	2,704	9,177
Total	22,443	14,143	6,111	-	19,658	62,355
Share	36%	23%	10%	0%	32%	100%
2030 CM						
Furnace	7,804	2,495	2,437	1,396	1,724	15,856
Boiler	5,587	7,783	3,133	490	3,387	20,380
Motor	-	-	-	-	8,786	8,786
Others	1,950	2,714	991	397	1,918	7,970
Total	15,341	12,991	6,562	2,283	15,814	52,991
Share	25%	21%	11%	4%	25%	100%

Table 5.20 Power supply indicators

	Coal	Oil	Gas	Hydropower	Nuclear	Solar wind	Biomass	Total
2005								
Fuel (ktoe)	2,132	679	4,812	1,845	-	-	-	9,467
Efficiency (%)	36	31	37	100				
Generation (ktoe)	769	213	1,770	1,845	-	-	-	4,597
Own-use (ktoe)	21	6	49	51	-	-	-	126
Transmission loss (ktoe)	84	23	194	203	-	-	-	505
Distribution (ktoe)	663	184	1,527	1,592	-	-	-	3,966
2030BaU								
Fuel (ktoe)	36,611	3,468	21,244	11,330	1,619	1,214	4,046	79,532
Efficiency (%)	42	35	40	100	100	100	30	
Generation (ktoe)	15,377	1,214	8,498	11,330	1,619	1,214	1,214	40,465
Own-use (ktoe)	421	33	233	310	44	33	33	1,109
Transmission loss (ktoe)	1,196	94	661	882	126	94	94	3,148
Distribution (ktoe)	13,759	1,086	7,604	10,138	1,448	1,086	1,086	36,207
2030CM								
Fuel (ktoe)	21,092	1,611	14,580	8,573	3,062	1,837	2,296	53,052
Efficiency (%)	45	38	42	100	100	100	40	
Generation (ktoe)	9,492	612	6,124	8,573	3,062	1,837	919	30,618
Own-use (ktoe)	260	17	168	235	84	50	25	839
Transmission loss (ktoe)	646	42	417	584	208	125	63	2,085
Distribution (ktoe)	8,585	554	5,539	7,754	2,769	1,662	831	27,694

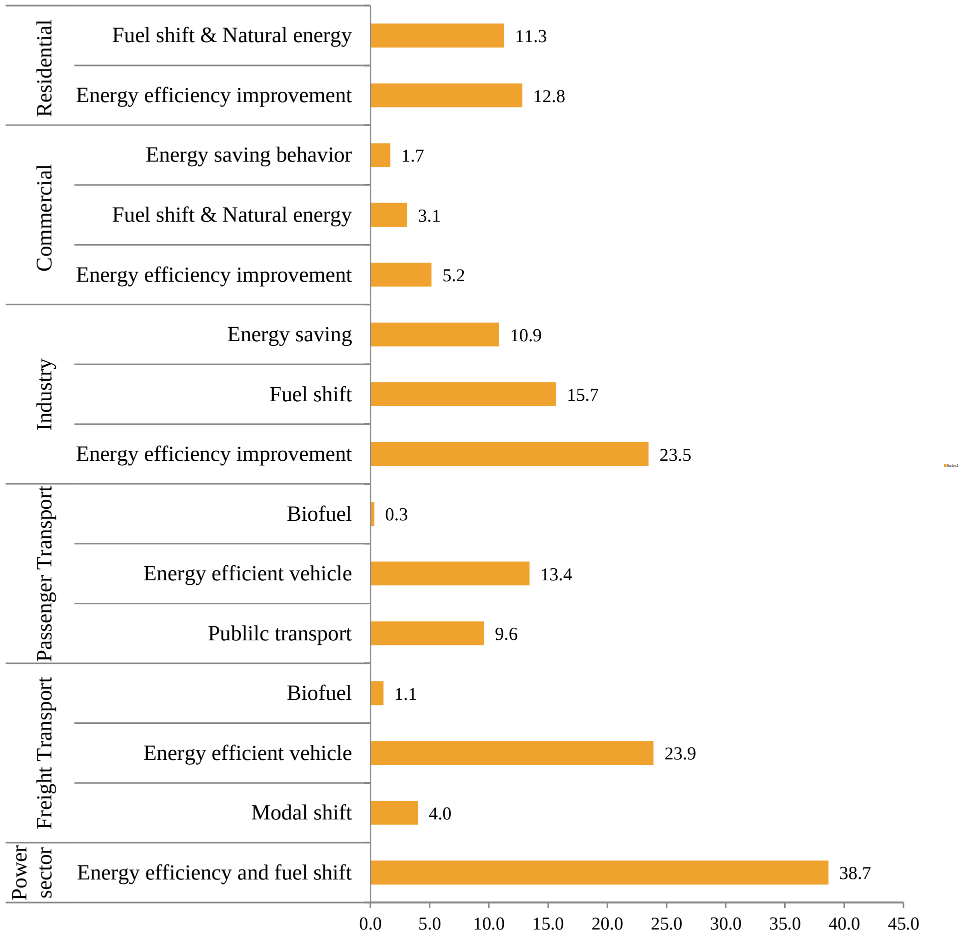


Figure 5.9 Contribution of each sector to reduce CO_2 emission ($MtCO_2eq$)

Table 5.21 List of low carbon countermeasures in energy sector

Sector	Low-carbon countermeasure	Identidied implementtation intensity (%)		Emission reduction ($Mt-CO_2$)	Related National Policy[(*)]
Residential sector	Energy efficiency home appliances				Law on Energy Efficiency and Conservation (National Assembly, 2010)
	High energy efficiency air condition	Diffusion ratio	70	1.6	
	High energy efficiency cooking stove			5.9	
	Coal-cooking stove	Diffusion ratio	25		
	LPG cooking stove	Diffusion ratio	40		Law on Energy Efficiency and Conservation (National Assembly, 2010)
	Biomass cooking stove	Diffusion ratio	55		
	Electricity cooking stove	Diffusion ratio	40		
	High energy efficiency lighting (Compact fluorescent lamps substitute incandescent light)	Diffusion ratio	60	2.3	
	High energy efficiency refrigerator	Diffusion ratio	60	0.9	Law on Energy Efficiency and Conservation (National Assembly, 2010)
	High energy efficiency water heating			0.9	
	Coal - water heating	Diffusion ratio	25		
	Oil - water heating	Diffusion ratio	67		
	Biomass - water heating	Diffusion ratio	55		Law on Energy Efficiency and Conservation (National Assembly, 2010)
	Solar water heating	Diffusion ratio	10		
	Energy efficiency improvement of electric appliances	Diffusion ratio	60	1.2	
	Energy saving behavior			4.3	Energy consumption: saving 3% to 5% (2006-2010) and 5% to 8% (2011-2015) (PM, 2006)
	Cooling (Energy service demand reduction ratio 17%)	Diffusion ratio	100		
	Heating (Energy service demand reduction ratio 17%)	Diffusion ratio	100		
	Hot water (Energy service demand reduction ratio 17%)	Diffusion ratio	100		Energy consumption saving 15% (2020) and 30% (2030) (PM, 2011a)
	Cooking (Energy service demand reduction ratio 17%)	Diffusion ratio	100		
	Other home electric appliances	Diffusion ratio	100		
	Other fuel shifting			11.3	Share of household using renewable energy in cooking 50% (2010), 80% (2020) (IE, 2008)
	Total			**28.5**	
Commercial sector	High energy efficiency air condition	Diffusion ratio	70	1.2	Law on Energy Efficiency and Conservation (National Assembly, 2010)
	High energy efficiency lighting	Diffusion ratio	40	0.3	
	High energy efficiency refrigerator	Diffusion ratio	80	1.1	
	High energy efficiency water heating			1.0	
	Coal - water heating	Diffusion ratio	50		
	Oil - water heating	Diffusion ratio	57		
	Solar water heating	Diffusion ratio	15		
	Energy efficiency improvement of electric appliances	Diffusion ratio	60	0.6	Law on Energy Efficiency and Conservation (National Assembly, 2010)
	High energy efficiency cooking stove	Diffusion ratio		0.8	
	Coal-cooking stove	Diffusion ratio	50		
	LPG cooking stove	Diffusion ratio	57		
	Electricity cooking stove	Diffusion ratio	50		
	Energy saving behavior			1.8	Energy consumption: saving 3% to 5% (2006-2010) and 5% to 8% (2011-2015) (PM, 2006)
	Cooling (Energy service demand reduction ratio 20%)	Diffusion ratio	100		
	Heating (Energy service demand reduction ratio 20%)	Diffusion ratio	100		
	Hot water (Energy service demand reduction ratio 20%)	Diffusion ratio	100		Energy consumption saving 15% (2020) and 30% (2030) (PM, 2011a)
	Cooking (Energy service demand reduction ratio 20%)	Diffusion ratio	100		
	Other electric appliances	Diffusion ratio	100		
	Other fuel shifting			3.2	
	Total			**10.0**	
Industrial sector	Energy efficiency equipments			23.5	In dustry 50% cleaner production technology will be applied and energy saving 8-13% (2020); almost cleaner production technology will be applied (2050) (PM, 2011a)
	High energy efficiency boiler		40-50		
	High energy efficiency furnace	Diffusion ratio	35-65		
	High energy efficiency motor	Diffusion ratio	60		
	Energy saving (Energy service demand reduction ratio 20%)			10.9	
	Other fuel shifting			15.7	
	Total			**50.0**	
Passenger transport sector	Energy effciency in transport mode	Diffusion ratio	30-50	13.4	
	Bio fuel (from oil to bio fuel)	Diffusion ratio	3	0.3	Using bio-energy, meeting 0.4% (2010), 1% (2015) and 5% (2025) of oil and gasoline demand in country (PM, 2007b)
	Modal shift			9.6	Shift from high intensity energy to lower intensity in transportation 40% (2020) and 80% (2050) (PM, 2011a)
	From vehicle to train	Share of train = 0.1% (base year = 0.04%)			Inceasing public transport 5-7% in medium and large cities: 35-35% (2020) and 50% (2050) (PM, 2011a)
	From vehicle to bus	Share of bus = 2.3% (base year = 0.33%)			
	From vehicle and ship to walk and bike	Share of walk & bike = 93% (base year = 90%)			
	Total			**23.4**	
Freight transport setor	Energy effciency in transport mode	Diffusion ratio	30-50	23.9	shift from high intensity energy to lower intensity in transportation 40% (2020) and 80% (2050) (PM, 2011a)
	Bio fuel (from oil to bio fuel)	Diffusion ratio	5	1.1	
	Modal shift			4.0	
	From large vehicle to train	Share of train = 5% (base year = 2%)			
	From large vehicle to ship/boat/ferry	Share of ship = 30% (base year = 27%)			
	Total			**29.0**	
Power generation sector	Improvement of CO_2 intensity of power generation			**38.7**	(Nhan and Duong, 2009)
	Generation efficiency improvement				
	Coal	Generation efficiency = 45% (base year = 36%)			
	Oil	Generation efficiency = 38% (base year = 31%)			
	Gas	Generation efficiency = 42% (base year = 37%)			
	Transmission lost reduction	Transmission lost = 7% (base year = 11%)			Tranmission lost complies to N1- criterion (PM, 2011b)
	Fuel shifting				
	From fossil fuel to nuclear				In 2030: total capacity of nuclear power plant will be 15000 MW (10% of total power generation) (PM, 2010)
	From fossil fuel to renewable energy				Share of renewable energy in power generation: 0.6% at present to 3.5% (2010), 4.5% (2020) and 6% (2030) (IE, 2008)
Total				**179.5**	

Chapter 6

Projection of GHG emissions and mitigations in AFOLU sector

6.1 Future assumptions up to 2030

As inputs to the AFOLUB, we prepared assumptions of activities, namely crop harvested area (Figure 6.1), number of livestock animals (Figure 6.2 and Figure 6.3) and area of land use change (Figure 6.4), which cause GHG emissions. They were treated as exogenous variables in the model. Domestic data sources, such as GSO (2009), MARD (2011b) and MONRE (2010), have a high priority to be used to develop future assumptions. International data sources, such as FAOSTAT (2012), IRRI (2011) and other reports were used in the cases that domestic data is not available.

6.1.1 Crop harvested area

All harvested areas of crops such as paddy rice, maize, tree nuts, oil crops, sugar cane, tea, coffee, rubber etc. were considered in this study. Historical harvested areas of crops except paddy rice were referred to FAOSTAT (2012). Paddy rice areas in 2000, 2005 and 2010 were collected from MARD (2011b). Maize area in 2000 was taken from GSO (2009) and those in 2005 and 2010 was get from FAOSTAT (2012). Sugar cane areas in 2000 and 2005 were based on GSO (2009) and those in 2010 were from FAOSTAT (2012). Areas of industrial crops (tea, coffee, rubber etc.) were from MONRE (2010) for 2000 and 2005 and from FAOSTAT (2012) for 2010. Areas of oil and other crops (vegetables, fruits, etc.) from 2000 to 2010 were referred to FAOSTAT (2012).

In Vietnam, rice is the biggest harvested area, which accounted for 75% and 66% of total harvested areas of crops in 1970 and 1990, respectively (FAOSTAT, 2012). In 2000, Vietnam had 7.7 million hectare of paddy rice, which comprised of 39% of spring paddy, 30% of autumn paddy and 31 % of winter paddy (GSO, 2010). However, due to urbanization and industrialization, harvested paddy rice area declined from 7.7 million hectare in 2000 to 7.4 million hectare in 2005. According to MARD (2011b), harvested paddy rice area in Vietnam is expected to further decrease in the future by 7.3 and 7.2 million hectare respectively in 2020 and 2030.

Regarding to maize, which is the second large crops in Vietnam, the harvested area increased gradually from 0.7 million hectare in 2000 to more than 1.1 million hectare in

2010. It will reach to 1.4 million hectare in 2020 and keep stable until 2030 (MARD, 2011b). Between 2000 and 2010, sugar cane and oil crop areas were almost 0.9 million hectare, accounted for about 7% of total harvested areas. This proportion was assumed to be remained almost the same in future years, of which 5% (0.6 million hectare) was oil crop area and 2% (3 million hectare) was sugar cane area. Harvested areas of industrial crops (tea, coffee, rubber etc.) increased gradually from 1.0 million hectare and reached 1.1 million hectare in 2010. They were assumed to be constant in the future. Harvested areas of other crops (vegetables, fruits, tree nuts and so on) increased from 2.0 million hectare in 2000 to 2.6 million hectare in 2010 and were assumed to be unchanged in 2020 and 2030.

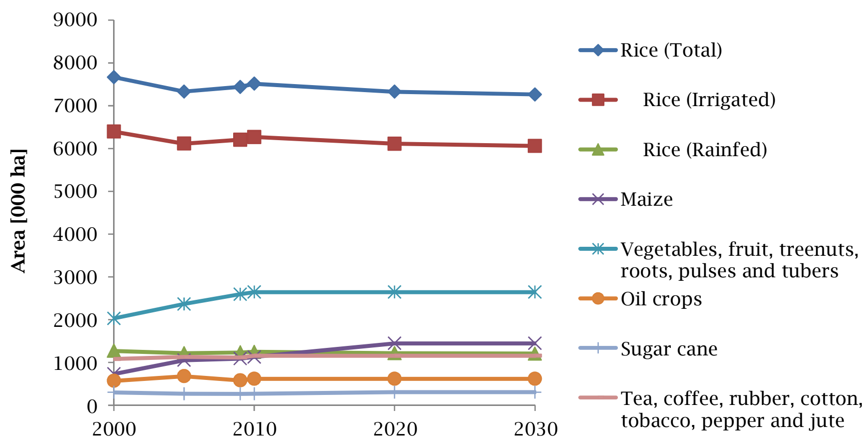


Figure 6.1 Scenarios of harvested area of crop production

6.1.2 Numbers of livestock animal

Historical trends of all types of livestock from 2000 to 2010 were set based on FAOSTAT (2012), MONRE (2010) and MARD (2011b). Cattle (buffalo and cow) and poultry (chicken and duck) are the main type of livestock in Vietnam. Between 2000 and 2010, cattle increased from 4.1 million heads to 8.0 million heads, of which dairy cattle accounted for more than 97% of total number of cattle. Cattle were disaggregated into dairy and beef cattle using its ratio in 2000 (GSO, 2002). Number of poultry increased steadily from 2000 to 2010 up to 300 million heads in which chicken accounted for 212 million heads and duck did for 91 million heads. A proportion of chicken and duck was based on the data in 2000 (FAOSTAT, 2012). While the number of sheep was 4000 heads in 2000 (MONRE, 2010), the number of horses declined gradually from 120 in 2000 to 100 thousand heads in 2010. Number of goats and swines increased sharply from 540 to 1370 thousand heads of goats and 20 to 230 million heads of swines in the period of 2000 to 2010.

Regarding to future assumption of livestock, we referred to MARD (2011b). In order to satisfy for domestic supply, amount of cattle will increase more than 1.7 times between 2010 and 2030 and reach 14 million heads in 2030, of which 1 million heads are dairy cattle and 13 million heads are beef cattle. Number of buffaloes is still expected to remain at 2.9 million heads from 2010 until 2030 (MARD, 2011). Pork is one of the main sources for meat supply in the country; therefore, number of swine is expected to increase sharply in the future. MARD (2011b) planed that there will have 35 and 49 million heads of swine in 2020 and 2030, respectively.

There is no plan to increase the number of sheep, goats and horses in the future, hence amount of those livestock animals in 2030 was assumed to be remained unchanged as that in 2010.

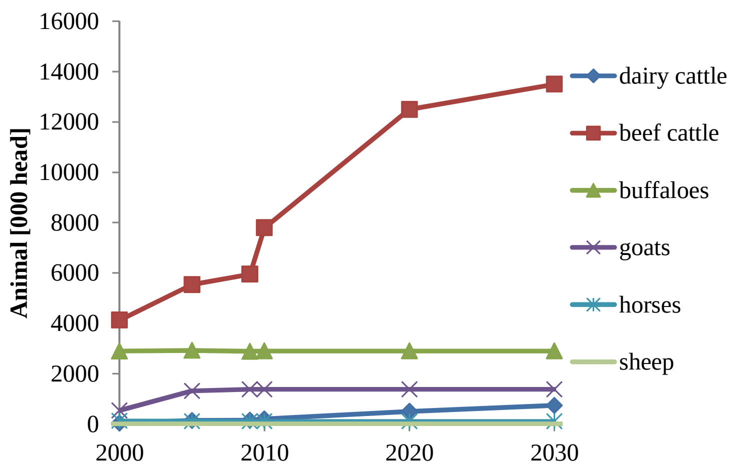


Figure 6.2 Scenarios of livestock animal (1)

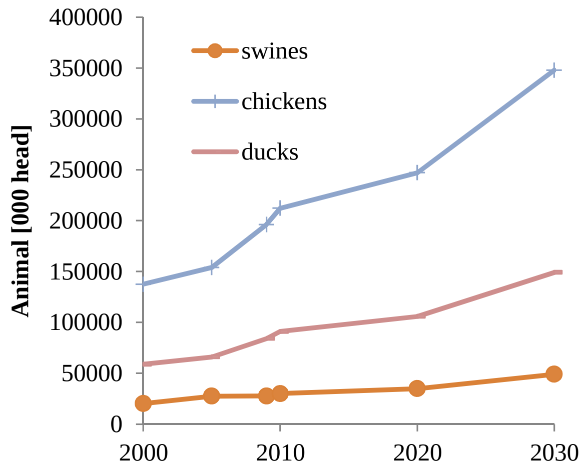


Figure 6.4 Scenarios of livestock animal (2)

6.1.3 Area of Land use change

Regarding to historical trends in land use change, we referred to FAOSTAT (2012) and other domestic documents. For instance, according to Quy and Can (1994), the patterns of land use have changed considerably, particularly Vietnam's forest cover was removed dramatically during the period of 1943 to 1993 and decreased from at least 43% to 20%. Since then Vietnam has made considerable efforts to increase its overall forest cover, some farmers have shifted from crop cultivation to reforestation. The reforestation had been conducted alongside national encouraged-reforestation policies (PM, 1998 and PM, 2012). Forestland increased from 9.3 million hectare in 1990, which equates to 39% of total land area, to 12.6 and 13.6 million hectare in 2005 and 2009, respectively (FAOSTAT, 2012). Forestland category was divided into natural forest and plantation using a 2005 ratio (GIZ, 2007). Grassland was referred to FAOSTAT (2012) for 2000, 2005 and 2009. Cropland areas were increased from 6.1 to 8.1 million hectare between 1970 and 1990 (FAOSTAT, 2012). Settlements in 2000 were referred to "land use from residential sector" in GSO (2002). Areas of settlements from 1970 to 1990 and from 1990 to 2000 were extrapolated using a growth ratio of population the period.

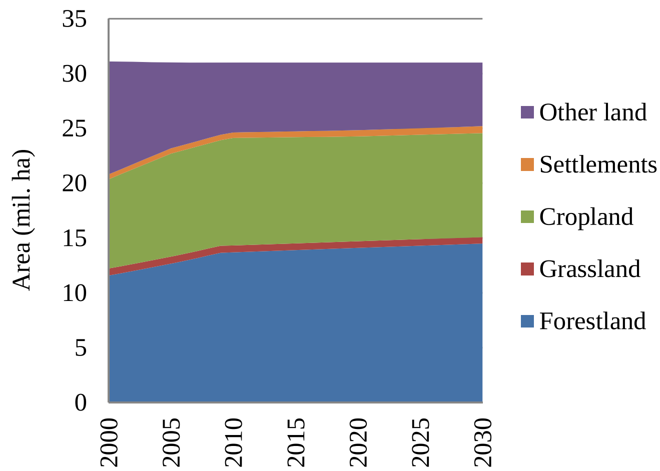


Figure 6.4 Scenarios of land use and land use change

For future land use change, we basically referred to MONRE (2010). Total country areas from 2010 up to 2030 were assumed at the 2009 level (FAOSTAT, 2012). According to PM (2012), the forest area in the country will further increase between 2010 and 2020. Forest areas will reach 14.1 and 14.5 million hectare in 2020 and 2030, respectively (MONRE, 2010). This area in 2010 was estimated based on a growth rate between 2009 (FAOSTAT, 2012) and 2020 (MONRE, 2010). Cropland areas from 2010 to 2030 are extrapolated using a growth ratio of total harvested areas of crops. Cropland area will slight decrease from 9.9 to 9.8 million hectare between 2020 and 2030 due to the decline of rice field area. Settlement area from 2005 to 2030 was extrapolated using an annual growth ration of population between 2005 and 2008 (GSO, 2009).

Other land was defined as the land not classified as the other categories. It includes built-up and related land, barren land and other wooded land etc. Other land is calculated as subtracting total of area of forestland, grassland, cropland, settlements and inland water from country area. In this study, we did not take into account emission from fires and natural disturbance.

6.2 Results and discussions

6.2.1 GHG emissions change in the future in BaU case

Breakdown of GHG emissions in AFOLU sectors from 2000 to 2030 in Vietnam are shown in Figure 6.5.

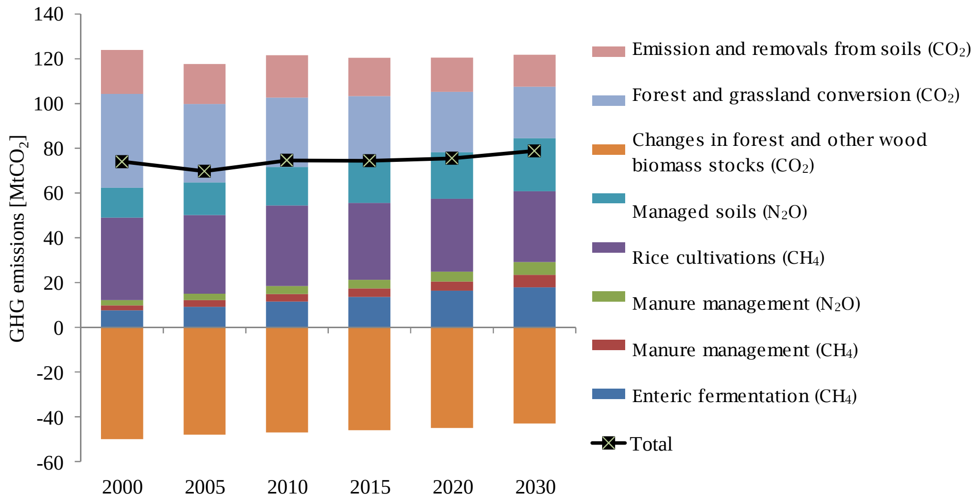


Figure 6.5 Breakdown of GHG emissions from AFOLU sectors in BaU case

In agricultural sector, CH_4 contributed to the largest GHG emission, followed by N_2O. The major sources are rice cultivation (3C7) (CH_4), livestock (3A1, 3A2) (CH_4 and N_2O) and then managed soil (3C4 to 3C6) (N_2O). The finding shows that total GHG emission in 2000 was 62 $MtCO_2$/year, and they gradually increased to 65 and 72 $MtCO_2$/year in 2005 and 2010, respectively. After that, the emission is expected to increase gradually to 85 $MtCO_2$/year in 2030. As shown in Figure 6.5, after 2010, CH_4 emission is projected to be less than those in the past due to decreasing in land under rice cultivation (3C7), however, the emission amount still would very high accounting for about 37% of total emission in 2030. This is because not only there is the large area of irrigated paddy rice cultivation but also 83% of the paddy rice would constantly subjected to CH_4 intensive flooded irrigation. N_2O emission from managed soils (3C4 to 3C6) is expected to increase significantly between 2010 and 2030 by 7 $MtCO_2$, because of both increasing amounts of nitrogen fertilizer for higher crop yields and high and inefficient fertilizer application rates. Moreover, due to increasing sharply amount of livestock population, GHG emissions from livestock (3A1, 3A2) are expected to increase to 24 and 30 $MtCO_2$ in 2020 and 2030, respectively. Emission sources from livestock comprise enteric fermentation (3A1) and manure management (3A2), which account for 18 and 12 $MtCO_2$ in 2030, respectively. While there would be a steady decline in emissions from paddy rice cultivation (3C7), emissions from livestock (3A1, 3A2) and managed soil (3C4 to 3C6) is expected to rapid increase. Therefore, total emission in agriculture sector is expected to continue further increasing in the future. In 2030, the largest share 37% of total GHG emission of agriculture sector comes from rice cultivation (3C7), following by managed soil (3C4 to 3C6) (28%), enteric fermentation (3A1) (21%) and livestock manure management (3A2) (14%).

As for LULUCF sector, main source of CO_2 is from forest and grassland conversion, followed by emission and removal from soils. In 2000, net GHG emission from the sector was 12 $MtCO_2$, which accounted for forest and grassland conversion (42 $MtCO_2$), emission and removals from soils (20 $MtCO_2$) and changes in forest and other woody biomass stocks (-50 $MtCO_2$).

Due to government programs such as PM (1998 and 2012), plantation forest and regeneration of natural forests have increased forest areas significantly. Therefore, total GHG emission from forestry and land use change declined gradually from 5 $MtCO_2$ in 2005 to 3 $MtCO_2$ in 2010, respectively. After 2015, LULUCF is expected to be a net sequestration of CO_2, which amount to -3 and -6 $MtCO_2$, respectively in 2020 and 2030.

6.2.2 Mitigation potential in AFOLU sector in Vietnam

(1) Mitigation potential under different AACs in 2030

We estimated GHG mitigation potential by countermeasures under wide range of AACs for GHG emission mitigation in 2030. Mitigation potential in AFOLU in 2030 would reduce 48.4 $MtCO_2$ in the case of full application of countermeasures or 62% below the 2030BaU emission level (Table 6.1).

Table 6.1 Mitigation from different of AACs in 2030

Mitigation in 2030 [$MtCO_2$]		Code	Allowable abatement cost [USD/tCO_2]			
			0	10	100	10000
Agriculture	Enteric fermentation: High genetic merit	HGM	0.1	0.1	1.6	1.8
	Enteric fermentation: Replacement of roughage with concentrates	RRC	3.2	3.2	2.6	2.5
	Manure management: Daily spread of manure	DSM	0.0	0.0	0.0	4.9
	Manure management: Dome digester, cooking fuel and light	CFL	2.8	2.8	2.8	0.1
	Rice cultivations: Replace urea with ammonium sulphate	RAS	0.0	1.8	1.8	1.8
	Rice cultivations: Midseason drainage	MD	4.7	6.7	6.7	6.7
	Rice cultivations: Fall incorporation of rice straw	FIR	0.0	3.4	3.4	3.4
	Managed soils: High efficiency fertilizer application	HEF	0.0	2.9	2.7	2.4
	Managed soils: Slow-release fertilizer	SRF	0.0	0.0	0.8	2.8
	Total		**10.8**	**20.8**	**22.7**	**26.6**
LULUCF	Protection and sustainable management of existing production forest areas	PEF	0.0	3.1	3.1	3.1
	Conservation of existing protection forests	CEF	0.0	16.5	16.5	16.5
	Planting fast-growing trees for lumber	FTL	0.0	1.3	1.3	1.3
	Total		**0.0**	**20.9**	**20.9**	**20.9**
Total			**10.8**	**41.7**	**43.5**	**47.5**

For agricultural sector, about 13% of the additional mitigation potential is expected at available at below 0 USD/tCO_2 of AAC (Table 6.1). At below 10 USD/tCO_2, the emission is expected to be reduced extensively by 25% from that in the 2030BaU. In this case, mitigation countermeasures for rice cultivation (3C7) such as replace urea in fertilizer with ammonium sulphate (RAS), midseason drainage (MD) and fall incorporation of rice straw (FIR) are expected to reduce 11.9 $MtCO_2$, corresponding approximately 60% of total mitigation potential in agricultural sector. Therefore, GHG mitigation from rice cultivation (3C7) is expected to greatly contribute to reduce a large amount of GHG emission in agriculture sector in Vietnam. In livestock sector, replacement of roughage with concentrates (RRC) for enteric fermentation (3A1), and dome digester, cooking fuel and light (CFL) for livestock manure management (3A2) have high economic effects. These mitigation countermeasures at below 10USD/tCO_2 of AAC could reduce altogether 6.1 $MtCO_2$, which account for halving 10% for each of total mitigation potential in agricultural sector in 2030.

At AAC below 100 USD/tCO_2, the additional mitigation countermeasures such as high genetic merit (HGM) of livestock (3A1) and slow-release fertilizer (SRF) in managed soils (3C4 to 3C6) are expected to be installed. Although their additional costs are quite high, the addition mitigation potential from these two countermeasures are very small, 2.4 $MtCO_2$ in total. At over 100USD/tCO_2 of AAC, application of expensive countermeasures such as daily spread of manure (DSM) in livestock (3A2) and slow-release fertilizer application (SRF) in managed soil (3C4 to 3C6) are expected to additionally reduce emissions by 7.7 $MtCO_2$. The additional mitigation potential in this case is expected to be 32% (Table 6.2).

Table 6.2 Mitigation relative 2030BaU

	GHG emission in 2030 BaU [$MtCO_2$]	AAC [USD/tCO_2eq] 0	10	100	10000
		GHG emission in 2030 CM [$MtCO_2$]			
Agriculture	85	74	64	62	58
Mitigation relative 2030 BaU		13%	25%	27%	32%
LULUCF	-6	-6	-28	-28	-28
Mitigation relative 2030 BaU		0%	-367%	-367%	-367%
Total	79	68	36	34	30
Mitigation relative 2030 BaU		14%	54%	57%	62%

For LULUCF sector, as shown in Table 6.1, reductions in CO_2 emission do not take place at below 0USD/tCO_2 of ACC. In all other rest cases of AACs, mitigation potential by adopting of countermeasures such as protection and sustainable management of existing production forest areas (PEF), conservation of existing protection forests (CEF) and plantation of fast-growing trees for lumber (FTL) would be the same, amounted at 20.9 $MtCO_2$. Conservation of existing protection forests (CEF) is expected to reduce the largest amounts of emissions (16.5 $MtCO_2$/year), and the countermeasure is considered as a key technology for GHG mitigations in the sector in Vietnam.

(2) Mitigation potential change in the future at below 10USD/tCO_2 of AAC

Table 6.3 illustrates the mitigation potential in the period of 2000 to 2030 at the AAC below 10USD/tCO_2.

Table 6.3 Mitigation at below 10USD/tCO_2 of AAC

Mitigation at below 10USD/tCO_2 [MtCO_2]		Code	2000	2005	2010	2015	2020	2030
Agriculture	Enteric fermentation: High genetic merit	HGM	0.0	0.0	0.0	0.1	0.1	0.1
	Enteric fermentation: Replacement of roughage with concentrates	RRC	1.3	1.6	2.0	2.4	2.9	3.2
	Manure management: Dome digester, cooking fuel and light	CFL	1.1	1.5	1.7	1.8	2.0	2.8
	Rice cultivations: Replace urea with ammonium sulphate	RAS	2.1	2.0	2.0	1.9	1.9	1.8
	Rice cultivations: Midseason drainage	MD	7.8	7.4	7.6	7.2	6.9	6.7
	Rice cultivations: Fall incorporation of rice straw	FIR	3.9	3.8	3.9	3.7	3.5	3.4
	Managed soils: High efficiency fertilizer application	HEF	1.7	1.8	2.1	2.2	2.5	2.9
	Total		**17.9**	**18.1**	**19.3**	**19.4**	**19.7**	**20.8**
LULUCF	Protection and sustainable management of existing production forest areas	PEF	0.6	0.7	1.2	1.7	2.2	3.1
	Conservation of existing protection forests	CEF	0.7	3.2	6.1	8.9	11.6	16.5
	Reforestation of large timber forests in conjunction with national regneration	RLF	1.1	0.3	0.0	0.0	0.0	0.0
	Planting long-rotation large timber trees	LLT	0.9	0.0	0.0	0.0	0.0	0.0
	Planting fast-growing trees for lumber	FTL	1.8	4.0	1.1	0.4	0.1	1.3
	Planting short-rotation pulpwood forest	SRF	1.1	0.0	0.0	0.0	0.0	0.0
	Growing long-rotation non-timber product forest	GLF	0.8	0.0	0.0	0.0	0.0	0.0
	Total		**6.9**	**8.2**	**8.4**	**11.0**	**14.0**	**20.9**
Total			**24.8**	**26.2**	**27.7**	**30.4**	**33.6**	**41.7**

For agricultural sector, there is an increase trend of mitigation potential from 17.9 MtCO_2 in 2000 to 20.8 MtCO_2 in 2030. Mitigation countermeasures from rice cultivations (3C7) such as MD (7.8 MtCO_2), FIR (3.9 MtCO_2) and RAS (2.1 MtCO_2) contributed to the largest mitigation, accounting for about 75% of total mitigation in the period of 2000 to 2010. Mitigation potential from those, however, is expected to be about 60% in the period of 2015 to 2030. In livestock enteric fermentation (3A1), comparing RRC and HGM, it can be seen that mitigation potential from RRC is much higher than this from HGM in the period of 2000 to 2030. Mitigation potential of CFL from livestock manure management (3A2) is expected to increase almost 3 times in 2030 compared to 2000. As shown in Table 6 that HEF is expected to have significant effectiveness in 2030, accounts for 2.9 MtCO_2 (14% of total mitigation potential). Although mitigation potential from rice cultivations (3C7) are expected to reduce during the 2000 to 2030 period, MD and FIR contribute as the largest mitigation potential in agricultural sector in Vietnam. We can conclude that mitigation countermeasures, which play the most important role in agricultural sector in Vietnam are MD and FIR from rice cultivation (3C7); RRC and CFL from livestock management (3A1, 3A2); HEF from managed soil (3C4 to 3C6).

For LULUCF sector, in 2030 CEF is expected to have the largest mitigation potential (16.5 MtCO_2), while FTL would be an insignificant mitigation countermeasure with only

1.3 $MtCO_2$. Therefore, CEF was identified as one of the most cost effective methods to abate GHG emission in the sector (79% of total mitigation potential), followed by PEF (15%). Although, other mitigation countermeasures such as reforestation of large timber forests in conjunction with national regeneration (RLF), planting long-rotation large timber trees (LLT), planting short-rotation pulpwood forest (SRF) and growing long-rotation non-timber product forest (GLF), could mitigate significant amount of CO_2 emission in period of 2000 to 2005, after that period they are expected to have no more mitigation potential.

Chapter 7

Required Actions towards LCS in Vietnam

7.1 Comprehensive analysis of GHG emissions and mitigations

Total GHG emissions in Vietnam was 151 $MtCO_2$ in 2005, on which, 70 and 81 $MtCO_2$ come from AFOLU and energy sectors, respectively. Under 2030BaU scenario, total GHG emission increases to 601 $MtCO_2$ or about 4 times higher than 2005.

The models estimate that total GHG emission is to be reduced to 379 $MtCO_2$ in 2030CM scenario through the adoption of low carbon countermeasures for mitigating GHG. Total GHG reduction is 222 $MtCO_2$ which accounts for 42 and 180 $MtCO_2$ from AFOLU and energy sectors, respectively.

GHG emissions from agriculture sector is estimated to be at 85$MtCO_2$ and Land Use, Land Use Change and Forestry (LULUCF) sector is expected to be a sink source of GHG emission, accounts for 6$MtCO_2$. GHG emission sources of agriculture sector comprises managed soil (N_2O), rice paddy (CH_4), livestock manure (N_2O), livestock manure (CH_4) and enteric fermentation (CH_4).

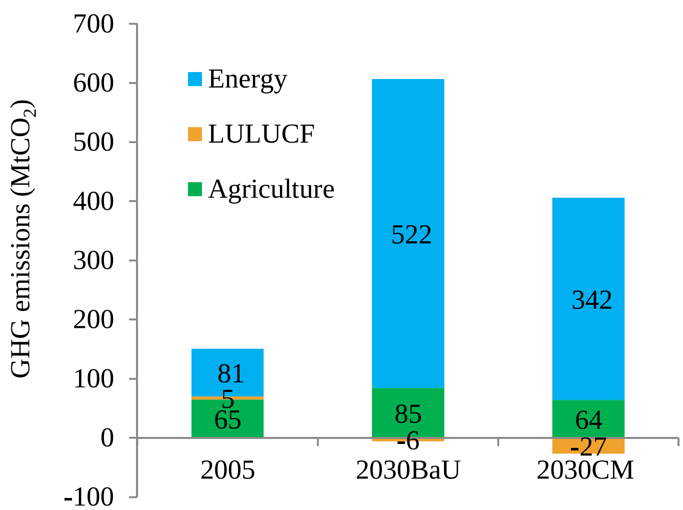


Figure 7.1 Total GHG emissions in Vietnam in 2030

GHG emissions (CO_2) from energy sector are calculated at amount of 522 $MtCO_2$.

In 2005, per capita GHG emissions in Vietnam were at 1.8 tCO_2. In 2030, this number is projected to increases to 5.8 tCO_2 in 2030BaU scenario. It is expected to reduce to 3.7

tCO_2 in 2030CM scenario (Figure 7.2).

GHG emission intensity is 0.18 tCO_2/billion-VND in 2005. The GHG emission intensity is further reduced to 0.15 tCO_2/billion-VND in 2030BaU scenario. In 2030CM scenario records a reduction of more than 50% from base year to achieve 0.10 tCO_2/billion-VND (Figure 7.3).

The per capita GHG emission shows an increase from 2005 to 2030BaU, but the GHG emission intensity shows a reduction. This is because when GHG emission is estimated against the GDP, a reduction is identified.

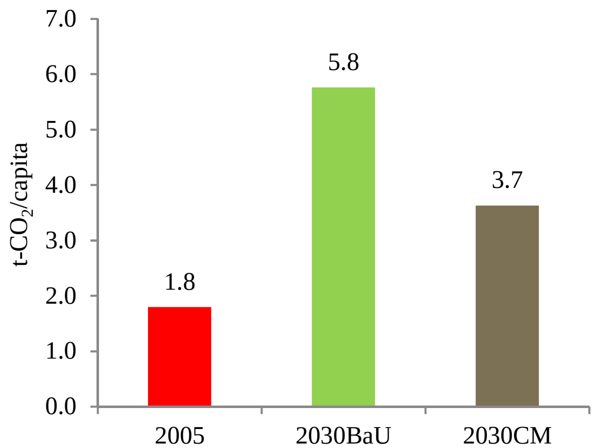


Figure 7.2 Per capita CO_2 emissions in Vietnam

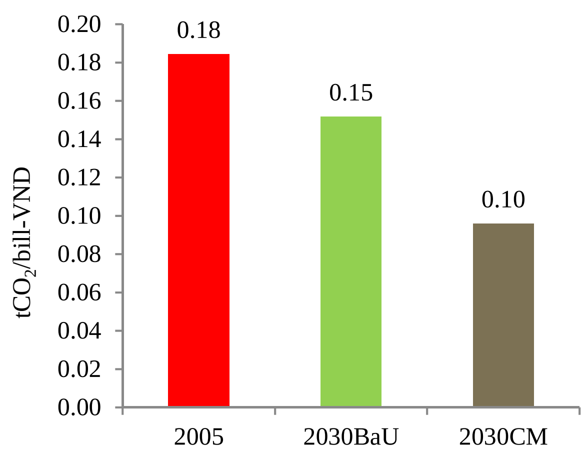


Figure 7.3 GHG intensity in Vietnam

7.1.1 GHG emissions in Energy sectors

CO_2 emissions in energy sector increase 6.4 times of that of 2005 in the 2030BaU scenario, and 4.2 times of that of 2005 in the 2030CM scenario. CO_2 emissions are expected to increase rapidly as a result of increasing use of fossil fuels. The total emissions in the base year 2005 were about 81 $MtCO_2$. This figure is expected to increase to 522 and 342 $MtCO_2$ by 2030 for BaU and CM scenarios, respectively. The major contributors to CO_2 emission include industrial sector (49% of total CO_2 emissions in 2030BaU scenario), followed by transport and residential sectors which account for 21% and 22% of total CO_2 emission in the 2030BaU scenario, respectively.

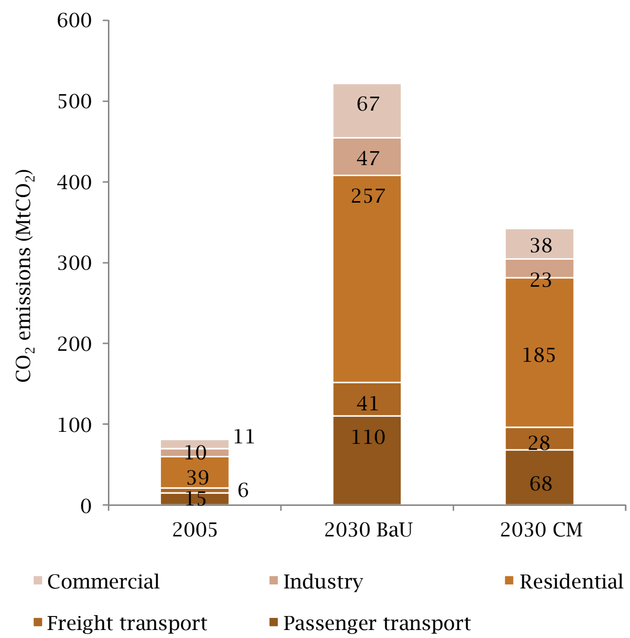


Figure 7.4 CO_2 emissions by sector in energy sectors

7.1.2 GHG emissions in AFOLU sectors

Total GHG emissions in AFOLU sectors in 2030 are expected to reach amount at 79 $MtCO_2$.

In agricultural sector, CH_4 contributed to the largest GHG emission, followed by N_2O. The major sources are rice cultivation (CH_4), livestock (CH_4 and N_2O) and then managed soil (N_2O). GHG emissions in agricultural sector in 2000 were 62 $MtCO_2$, and they gradually increased to 65 and 72 $MtCO_2$ in 2005 and 2010, respectively. After that, the emission is expected to increase gradually to 85 $MtCO_2$ in 2030.

For LULUCF sector, main source of GHG is from forest and grassland conversion, followed by emission and removal from soils. Total GHG emissions from LULUCF are expected to decline gradually from 5 $MtCO_2$ in 2005 to 3 $MtCO_2$ in 2010, respectively. After 2015, LULUCF is expected to be a net sequestration of CO_2, with amounts of -3 and -6 $MtCO_2$, respectively in 2020 and 2030.

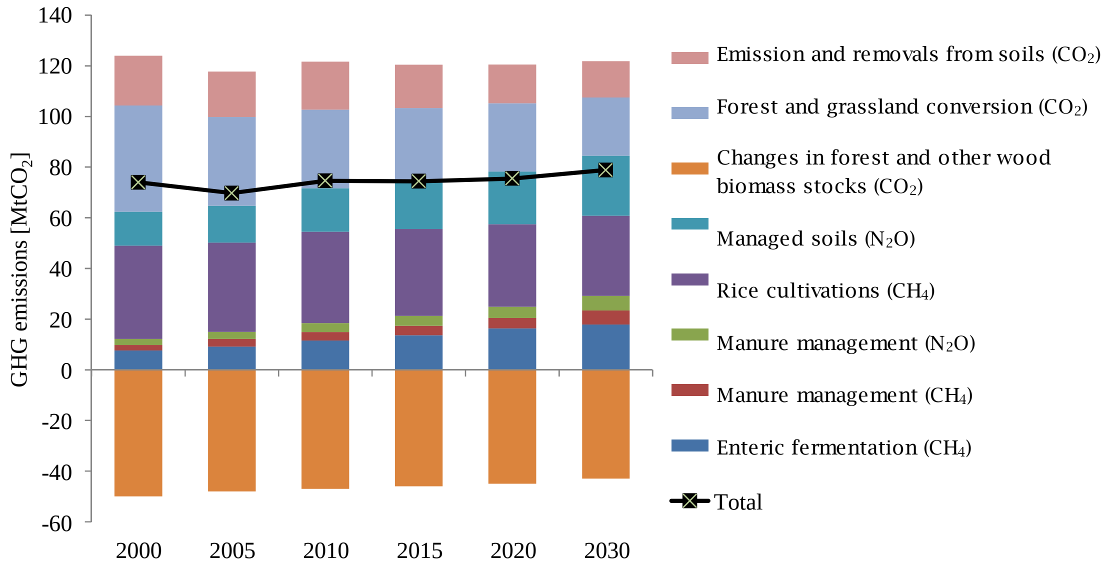


Figure 7.5 GHG emissions in AFOLU in 2030BaU

7.1.3 Mitigation Potential in 2030

Total GHG emissions in Vietnam is calculated to reduce from 601 $MtCO_2$ in the 2030BaU scenario to 379 $MtCO_2$ in the 2030CM scenario by adoption of low carbon countermeasures for mitigating GHG emissions in 2030 (Figure 7.6). Based on the model simulation, the reductions of GHG emissions by types of countermeasures consist of relevant countermeasures (Figure 7.7).

In energy sectors, among the countermeasures, energy efficiency improvement and fuel shift in power sectors account for the largest proportion which amount at 38.7 $MtCO_2$, followed by efficient vehicles in freight transport sector (23.9 $MtCO_2$), energy efficiency improvement in industry (23.5 $MtCO_2$).

Table 7.1 GHG emissions/mitigations in 2030BaU and 2030CM

Sector	GHG emissions ($MtCO_2$)		GHG emissions mitigation ($MtCO_2$)
	2030BaU	2030CM	
AFOLU sectors	79	37	42
Agriculture	85	64	21
LULUCF	-6	-27	21
Energy sectors	522	342	180
Residential sector	110	68	42
Commercial sector	41	28	13
Insudtry	257	185	71
Transport	114	61	53
Total	**601**	**379**	**221**

In AFOLU sector, we have estimated mitigation potential by several AAC for mitigation. Under 10USD/tCO_2 of AAC, both agriculture and LULUCF are expected to reduce GHG emissions altogether 42 $MtCO_2$ which account for halving 21 $MtCO_2$ for each sector.

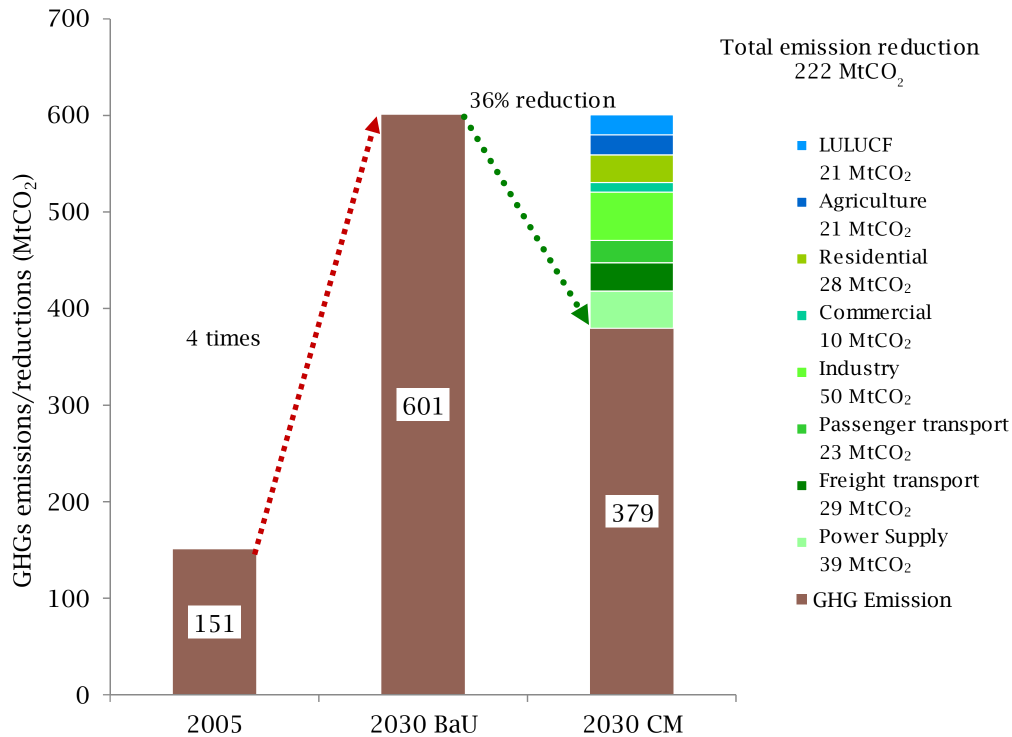


Figure 7.6 GHG emission and mitigations by sector

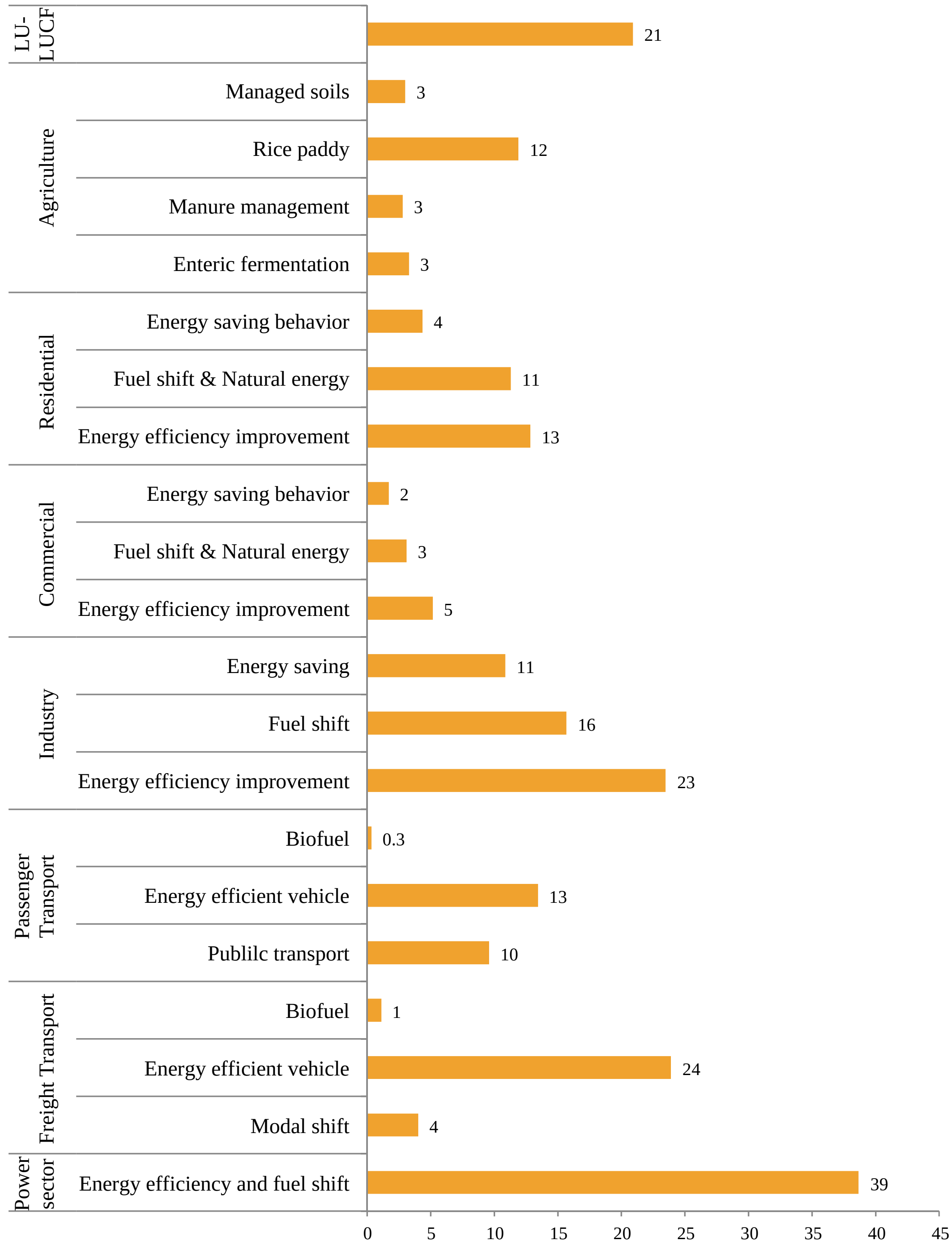


Figure 7.7 GHG mitigation potential in Vietnam in 2030 ($MtCO_2eq$)

In order to realize a LCS, Vietnam needs to have new set of strong policies to encourage and promote these low carbon countermeasures.

7.2 Required actions in energy sector

Six "Actions" derived from different sectors where the low carbon countermeasures are proposed.

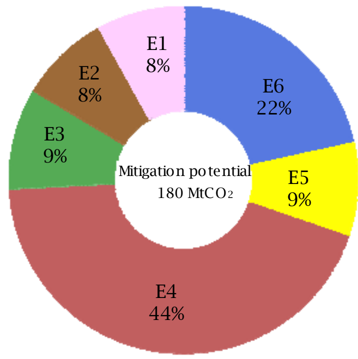


Figure 7.8 Contribution to CO_2 emission reduction from six actions

Table 7.2 Breakdown countermeasures of each action in energy sector

Action	Low carbon countermeasure	$ktCO_2$	%
Action 1	Green Building	**14,401**	**8.0%**
	Residential	11,302	6.3%
	Commercial	3,099	1.7%
Action 2	Convienient Transport	**15,049**	**8%**
	Bio diesel vehicle	1,442	1%
	Modal shift	5,101	3%
	Compact city	8,507	5%
Action 3	Energy Saving Behavior	**16,917**	**9%**
	Residential	4,349	2%
	Commercial	1,697	1%
	Industry	10,871	6%
Action 4	Energy Efficiency Improvement	**78,812**	**44%**
	Residential	12,838	7%
	Commercial	5,159	3%
	Industry	23,484	13%
	Passenger transport	13,431	7%
	Frieght transport	23,901	13%
Action 5	Fuel Shift in Industrial sector	**15,670**	**9%**
Action 6	Smart Power Plant	**38,662**	**22%**
	Energy efficiency improvement and fuel switch	38,662	22%
Total	Total	**179,512**	**100%**

7.2.1 Action E1. Green Building

The "Green Building" action focuses on countermeasures of fuel shifting and natural energy utilization of two sectors (residential and commercial). This action is expected to reduce 14.4 $MtCO_2$, account for 8% of total CO_2 emission reduction in energy sector (Figure 7.9); on which residential sector can reduce 11.3 $MtCO_2$ and commercial sector can reduce 3.1 $MtCO_2$.

Fuel shifting and natural energy utilization comprise following countermeasures such as biomass cooking, solar heating, and solar water heater etc.

In this action, CO_2 emission reduction from residential sector accounts for 78% and commercial sector 22%.

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.

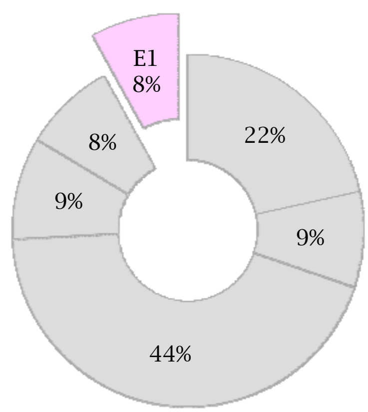


Figure 7.9 Mitigation potential by Action E1

Table 7.3 Breakdown of emission reduction in Action E1

	CO_2 emission reduction [$ktCO_2$]	Contribution in the Action [%]	Contribution in total reduction in energy sector [%]	Contribution in total reduction in Vietnam [%]
Residential	**11,302**	78%	6%	5%
Heating	369			
Hot water	2,040			
Cooking	8,893			
Commercial	**3,099**	22%	2%	1%
Heating	456			
Hot water	2,306			
Cooking	338			
Total	**14,401**	100%	8%	7%

7.2.2 Action E2. Convenient Transport

The action on "Convenient Transport" primarily comprises of a shift from private vehicles to public transportation (such as from motorbike and car to bus and train) by traffic management system and increased penetration of fuel switch (fuel switch from gasoline and diesel to electricity and bio-diesel).

This action is contributed to reduce 15.0 $MtCO_2$, on which GHG reductions from modal shift (freight transport) is 4.0 $MtCO_2$, public transport (passenger transport) is 9.6 $MtCO_2$, from promoting of fuel switch (bio-diesel) in both passenger and freight transport is 1.4 $MtCO_2$. Total CO_2 reductions from this action are expected to contribute to 8% of total CO_2 emission reduction in energy sector in Vietnam.

Policies to encourage this action can be: environmental standards & requirements of vehicles, upgrading transport infrastructure and encouraging environmental & economical-fuel vehicle such as natural gas and hybrid cars, investment to public vehicles, and bold policy to control and reduce the use of motorbikes.

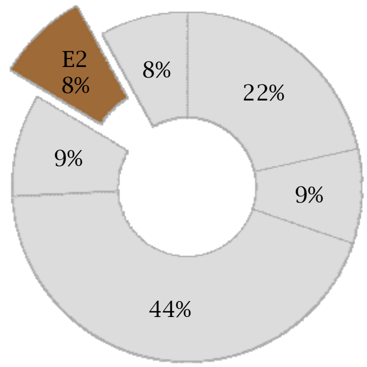


Figure 7.10 Mitigation potential by Action E2

Table 7.4 Breakdown of emission reduction in Action E2

	CO_2 emission reduction [$ktCO_2$]	Contribution in the Action [%]	Contribution in total reduction in energy sector [%]	Contribution in total reduction in Vietnam [%]
Passenger transport	**9,932**	66%	6%	4%
Bio diesel vehicle	335			
Public transport	9,596			
Freight transport	**5,117**	34%	3%	2%
Bio diesel vehicle	1,107			
Modal shift	4,011			
Total	**15,049**	100%	8%	7%

7.2.3 Action E3. Energy Saving Behavior

The action “Energy Saving Behavior” is projected to reduce 16.9 $MtCO_2$ or 9% of total CO_2 emission reduction in energy sector. Energy saving activities focus on energy services such as cooling, heating, hot water, cooking in commercial and residential sectors, direct heating, steam and motor in industrial sector.

Understanding the importance of energy efficiency in socio-economic development and environmental protection, Vietnam has developed a national program to enhance effective use of energy with emphasize on both, supply and demand sides. Based on the program, we assumed energy service demand reduction ration in residential sector is 17% and those in both commercial and industrial sectors are 20%.

Table 7.5 Breakdown of emission reduction in Action E3

	CO_2 emission reduction [$ktCO_2$]	Contribution in the Action [%]	Contribution in total reduction in energy sector [%]	Contribution in total reduction in Vietnam [%]
Residential	**4,349**	26%	2%	2%
Cooling	94			
Heating	109			
Hot water	525			
Cooking	2,961			
Lighting	245			
Refrigerator	179			
Other electric equipment	236			
Commercial	**1,697**	10%	1%	1%
Cooling	51			
Heating	594			
Hot water	581			
Cooking	108			
Lighting	163			
Refrigerator	93			
Other electric equipment	106			
Industry	**10,871**		6%	5%
Furnace	3,182			
Boiler	3,872			
Motor	2,250			
Other	1,567			
Total	**16,917**	36%	9%	8%

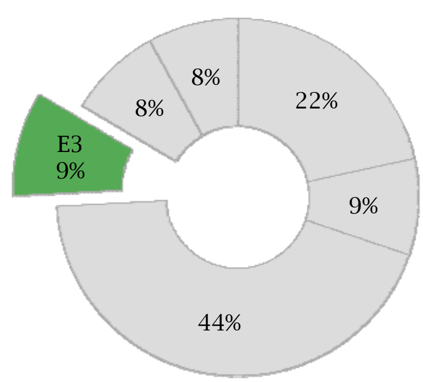


Figure 7.11 Mitigation potential by Action E3

Energy savings in industrial sector is expected to contribute to the highest amount of CO_2 reduction, accounts for 11.0 $MtCO_2$. It is followed by residential and commercial sectors with respectively amount of CO_2 reductions are 4349 and 1697 $ktCO_2$.

7.2.4 Action E4. Energy Efficiency Improvement

The "Energy Efficiency Improvement" action is able to reduce CO_2 emissions in all sectors in 2030 by 78.8 $MtCO_2$ or 44% of total CO_2 emission reduction in energy sector. The highest amount of CO_2 emission reduction accounts for transport sector by 37.3 $MtCO_2$. It is followed by industry, residential and commercial sectors with respectively amount of CO_2 reductions are 23.5, 12.8 and 5.2 $MtCO_2$.

This action is used to turn the existing or low-efficiency device, equipment, motors or vehicles into "best available technology" models in all sectors.

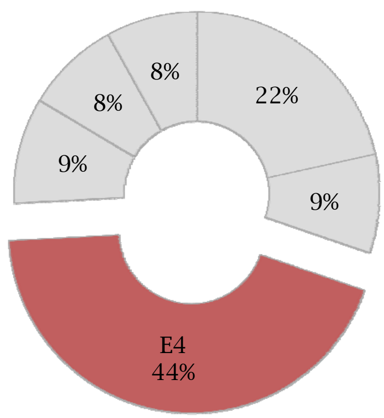


Figure 7.12 Mitigation potential by Action E4

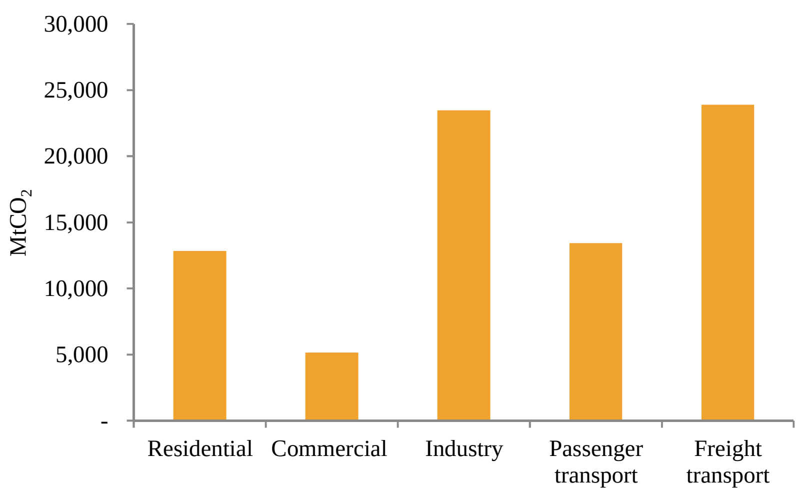


Figure 7.13 Mitigation potential of energy efficiency improvements by sector

Table 7.6 Breakdown of emission reduction in Action E4

	CO_2 emission reduction [$ktCO_2$]	Contribution in the Action [%]	Contribution in total reduction in energy sector [%]	Contribution in total reduction in Vietnam [%]
Residential	**12,838**	16%	7%	6%
Cooling	1,460			
Heating	127			
Hot water	857			
Cooking	5,937			
Lighting	2,275			
Refrigerator	940			
Other electric equipment	1,241			
Commercial	**5,159**	7%	3%	2%
Cooling	795			
Heating	969			
Hot water	822			
Cooking	303			
Lighting	1,092			
Refrigerator	624			
Other electric equipment	555			
Industry	**23,484**	30%	13%	11%
Furnace	14,861			
Boiler	4,757			
Motor	974			
Other	2,892			
Passenger transport	**13,431**	17%	7%	6%
Motorbike	4,033			
Car	3,355			
Bus	3,772			
Train	31			
Ship	18			
Aviation	2,221			
Freight transport	**23,901**	30%	13%	11%
Truck	23,698			
Train	10			
Ship	179			
Aviation	13			
Total	**78,812**	100%	44%	36%

7.2.5 Action E5. Fuel Shift in Industry

The action “Fuel Shift in Industry” is projected to reduce CO_2 emission in 2030 by 15.7 $MtCO_2$ or 9% of total CO_2 emission in energy sector.

Fuel uses in industry sector will be able to shift from high carbon intensity to lower carbon intensive. 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.

Breakdown of emission reduction in Action E5 is shown in Table 7.7.

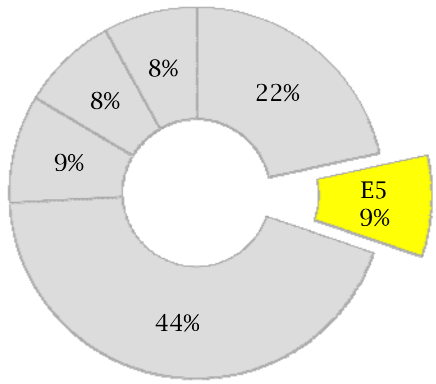


Figure 7.14 Mitigation potential by Action E5

Table 7.7 Breakdown of emission reduction in Action E5

Sector	CO_2 emission reduction [$ktCO_2$]	Contribution in the Action [%]	Contribution in total reduction in energy sector [%]	Contribution in total reduction in Vietnam [%]
Agriculture-Fishery-Forestry	1,335	9%	1%	1%
Mining and quarrying	2,253	14%	1%	1%
Food, beverage & tobaco manufactures	2,067	13%	1%	1%
Other consumer goods	3,251	21%	2%	1%
Industrial materials	3,037	19%	2%	1%
Capital goods	1,060	7%	1%	0%
Construction	2,667	17%	1%	1%
Total	**15,670**	100%	9%	7%

7.2.6 Action E6. Smart Power Plants

The action "Smart Power Plants" is calculated to reduce CO_2 emission in 2030 by 26.6 $MtCO_2$ or 16% of total CO_2 emission reduction in energy sector. This action comprises of 4 main countermeasures; namely, utilizing economically efficient domestic energy resources, promoting the use of renewable energies, reducing transmission and distribution loss, and developing nuclear power plant.

Table 7.8 Breakdown of emission reduction in Action E6

	CO_2 emission reduction [$ktCO_2$]	Contribution in the Action [%]	Contribution in total reduction in energy sector [%]	Contribution in total reduction in Vietnam [%]
Residential	**13,514**	35%	8%	6%
Cooling	464			
Heating	136			
Hot water	994			
Cooking	9,115			
Lighting	742			
Refrigerator	889			
Other electric equipment	1,173			
Commercial	**3,493**	9%	2%	2%
Cooling	253			
Heating	484			
Hot water	722			
Cooking	241			
Lighting	808			
Refrigerator	462			
Other electric equipment	524			
Industry	**21,122**	55%	12%	10%
Furnace	2,548			
Boiler	4,709			
Motor	11,194			
Other	2,672			
Passenger transport	**284**	1%	0%	0%
Motorbike	98			
Car	81			
Bus	40			
Train	66			
Freight transport	**251**	1%	0%	0%
Truck	237			
Train	14			
Total	**38,662**	100%	22%	17%

The share of high carbon intensity fuel 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 is expected to reduce to 9% in 2030BaU scenario and 7% in 2030CM scenario.

Share of nuclear is projected to contribute 10% to generate power in 2030CM scenario.

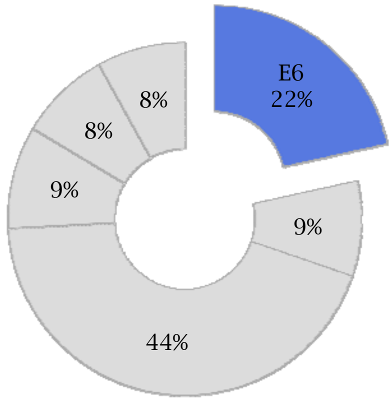


Figure 7.15 Mitigation potential by Action E6

7.3 Required actions in AFOLU sectors

7.3.1 Action A1. Livestock manure management

The action "Livestock Manure Management" is expected to reduce 2.8 $MtCO_2$ at AAC of 10 USD/tCO_2, accounts for 7% of total GHG emissions in AFOLU sectors (see Figure 7.16). The low carbon countermeasures in this action are "daily spread of manure" and "dome digester, cooking fuel and light".

In the former one, anaerobic digestion would reduce GHG emissions if applied to beef and dairy manures currently sorted as liquids/slurries and pig manure kept in pits for longer than a month. The daily spread of manure would bring about GHG emissions reduction in all of these cases, and a small reduction for dairy and pig manures kept in solid storage. In latter countermeasure, dome digesters are designed for small-scale and unheated ones. Biogas generated is typically used by the household for cooking and other household energy needs.

Mitigation in different AAC in Action A1 is shown in Table 7.9.

Total mitigation is no change in deferent AAC of 0, 10 and 100 USD/tCO_2. However, it can get more mitigation in the case 100 USD/tCO_2 of AAC.

There is a completion between low carbon countermeasures in terms of cost, the cheaper countermeasures are expected to be employed more compare to other.

In the case at 100000 USD/tCO_2 of AAC, total cost of “dome digester, cooking and light” is higher than that of “daily spread of manure”. Therefore, “daily spread of manure” is chosen instead of “dome digester, cooking fuel and light” in that case.

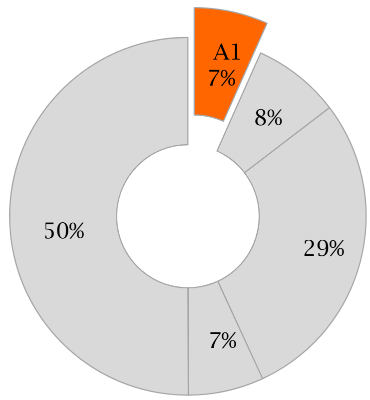


Figure 7.16 Mitigation potential of Action A1

Table 7.9 Breakdown of emission mitigation in action A1 in different AAC

Mitigation in 2030 [$MtCO_2$]	Allowable abatement cost [USD/tCO_2]			
	0	10	100	100000
Daily spread of manure	0.0	0.0	0.0	4.9
Dome digester, cooking fuel and light	2.8	2.8	2.8	0.1
Total	**2.8**	**2.8**	**2.8**	**5.0**

7.3.2 Action A2. Livestock enteric fermentation

The action “Livestock Enteric Fermentation” is contributed to reduce 3.3 $MtCO_2$ at AAC of 10 USD/tCO_2 in 2030. This action comprises of 2 main countermeasures; namely, high genetic merit and replacement of roughage with concentrates, account for 8% of total GHG emissions in AFOLU sectors (Figure 7.17).

The “high genetic merit” countermeasure is to improve the genetic merit of dairy cows. As a result, average national yields have increased. One of the major improvements is the ability of the cow to partition nutrients into milk preferentially to maintenance and/or growth. This has undoubtedly resulted in increased efficiency. However, high genetic merit cows can have increased problems with fertility, lameness, mastitis and metabolic disorders, and all these issues will have to be addressed if genetic progress is to be successfully continued. This countermeasure contributes to reduce 0.1 $MtCO_2$ at AAC of 10 USD/tCO_2.

The “replacement of roughage with concentrates” is to increase conversion efficiency. This countermeasure contains high portions of structural carbohydrates with concentrates to improve propionate generation in rumen, contributes to reduce 3.2 $MtCO_2$at AAC of 10 USD/tCO_2.

Mitigation in different AAC in Action A2 is shown in Table 7.10.

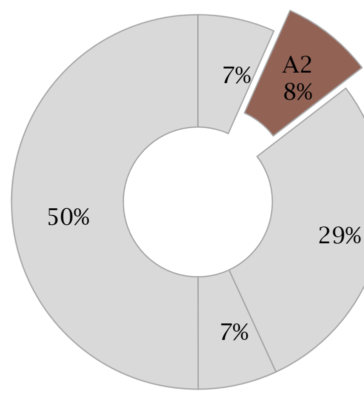


Figure 7.17 Mitigation potential of Action A2

Table 7.10 Breakdown of emission mitigation in action A2 in different AAC

Mitigation in 2030 [$MtCO_2$]	Allowable abatement cost [USD/tCO_2]			
	0	10	100	100000
High genetic merit	0.1	0.1	1.6	1.8
Replacement of roughage with concentrates	3.2	3.2	2.6	2.5
Total	**3.3**	**3.3**	**4.2**	**4.3**

7.3.3 Action A3. Rice cultivation management

The action “Rice Cultivation Management” is contributed to the largest potential mitigation in agricultural sector, account for 29% of total GHG emission reduction in AFOLU sectors (Figure 7.18). This action will contribute to reduce about 11.9 $MtCO_2$, on which “midseason drainage” can reduce the biggest amount of GHG emissions in this action about 6.7 $MtCO_2$, “fall incorporation of rice straw” accounts for 3.4 $MtCO_2$ and “replace urea with ammonium sulphate” accounts for 1.8 $MtCO_2$.

CH_4 emits from rice fields can be substantially reduced through modified water management technologies, such as midseason drainage or alternate wetting and drying. In this technology, rice fields are three times within a growing season and surface water layer is 5 to 10 cm for remaining, flooded period. This countermeasure is possible to combine the aims of reducing CH_4 emission and saving irrigation water.

The “fall incorporation of rice straw” is aimed to shift straw amendment from in-season to off-season; as a result this process can reduce availability of dissolved organic carbon and thus reducing CH_4 emissions.

For countermeasure “replace urea with ammonium sulphate”, sulfate additions to soil can increase mitigation potential, which suppresses CH_4 production

Mitigation in different AAC in Action A3 is shown in Table 7.11.

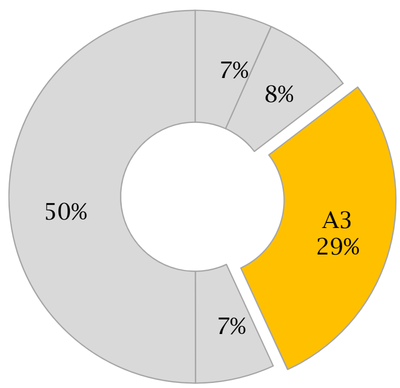


Figure 7.18 Mitigation potential of Action A3

Table 7.11 Breakdown of emission mitigation in action A3 in different AAC

Mitigation in 2030 [$MtCO_2$]	Allowable abatement cost [USD/tCO_2]			
	0	10	100	100000
Replace urea with ammonium sulphate	0.0	1.8	1.8	1.8
Midseason drainage	4.7	6.7	6.7	6.7
Fall incorporation of rice straw	0.0	3.4	3.4	3.4
Total	**4.7**	**11.9**	**11.9**	**11.9**

7.3.4 Action A4. Soil management

The action “Soil Management” is contributed to reduce 2.9 $MtCO_2$, account for 7% of total GHG emission in AFOLU sectors (Figure 7.19). This action comprises of 2 main countermeasures; namely, high efficiency fertilizer application and slow-release fertilizer.

In which:

High efficiency fertilizer application is expected to reduce 2.9 $MtCO_2$. In Vietnam, fertilizer is excessed use, lead to emit of CO_2 and N_2O. Therefore, reducing the redundant fertilizers or improving the efficiency of fertilizer use will decrease GHG emissions.

Mitigation in different AAC in Action A4 is shown in Table 7.12.

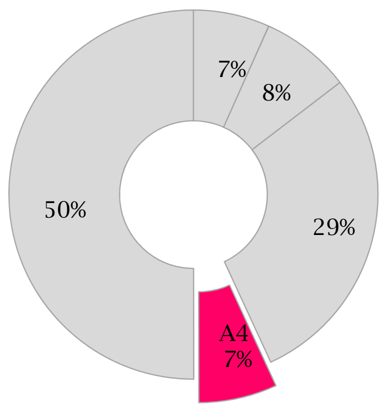


Figure 7.19 Mitigation potential of Action A4

Table 7.12 Breakdown of emission mitigation in action A4 in different AAC

Mitigation in 2030 [$MtCO_2$]	Allowable abatement cost [USD/tCO_2]			
	0	10	100	100000
High efficiency fertilizer application	0.0	2.9	2.7	2.4
Slow-release fertilizer	0.0	0.0	0.8	2.8
Total	**0.0**	**2.9**	**3.5**	**5.1**

Slow-release fertilizer is more expensive countermeasure; therefore it is expected to apply in the case that higher cost willing to be paid. When applying this countermeasure, nitrogen is slowly released from coated or tablet fertilizer over a 30-day period following application. This countermeasure will increase fertilizer-use efficiency.

7.3.5 Action F. Forest and land use management

The action "Forest and Land Use Management" is a biggest reduction contributor, account for 50% of GHG emissions reduction in AFOLU sectors, which numbers to about 20.9 $MtCO_2$ main low carbon countermeasures such as "protection and sustainable management of existing production forest areas", "conservation of existing protection forests" and "planting fast-growing trees for lumber".

Mitigation in different AAC in Action F is shown in Table 7.13.

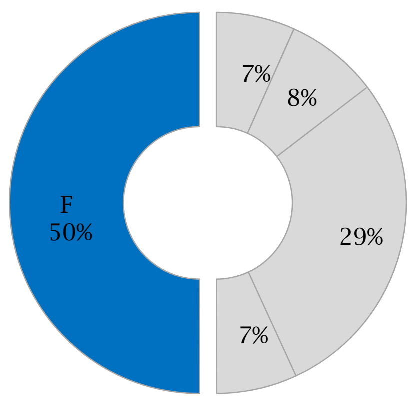


Figure 7.20 Mitigation potential of Action F

Table 7.13 Breakdown of emission mitigation in action F in different AAC

Mitigation in 2030 [$MtCO_2$]	Allowable abatement cost [USD/tCO_2]			
	0	10	100	100000
Protection and sustainable management of existing production forest areas	0.0	3.1	3.1	3.1
Conservation of existing protection forests	0.0	16.5	16.5	16.5
Planting fast-growing trees for lumber	0.0	1.3	1.3	1.3
Total	**0.0**	**20.9**	**20.9**	**20.9**

Currently, Vietnam has been taking steps to reduce emissions from deforestation and forest degradation (REDD). Vietnam is one of the countries to obtain approval for a small scale forestation project under United Nation's Clean Development Mechanism

(CDM). Planting fast-growing trees for lumber can potentially be developed as CDM project while "protection and sustainable management of existing production forest areas" and "conservation of existing protection forests" are potential REDD projects.

7.4 LCS policy packages in Vietnam

To develop a LCS for Vietnam, a package of low carbon policies is formulated based on the results of modeling (Figure 7.21). This policy package encompasses several solutions such as fuel switch (e.g. from high carbon intensity fuels to lower carbon intensity fuels), promotion of renewable energy, improvement of energy efficiency of energy using equipment and building, promotion of public transport, development of traffic management system, improvement of power supply sector, management of manure and enteric fermentation of livestock, management of paddy cultivations and soil management.

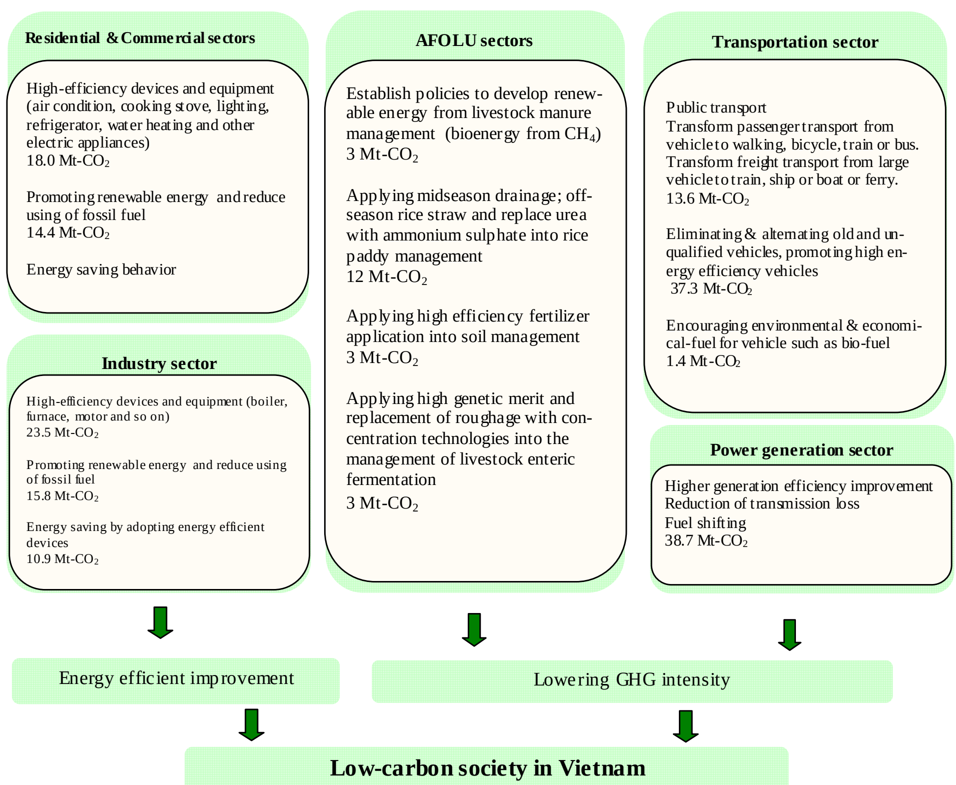


Figure 7.21 LCS policy packages in Vietnam

Chapter 8

Conclusions and Recommendation for Future Works

8.1 Conclusions of the research

This chapter aims to summarize the thesis' conclusions and provide recommendations for policy implications. Furthermore, the contributions and limitations of this research also provided and along with their commendations for further research are proposed.

In Vietnam, LCS is relatively new concept. Currently, there is no official document containing roadmaps towards LCS, except for several government's initiatives that are in line with and supportive to the LCS concept. This thesis presents the results of an academic research assessing scenarios of LCS visions 2030 in Vietnam with associated mitigation actions and policies to achieve the LCS.

As conclusion, the goal of the research focused on the development of a LCS for Vietnam. Two scenarios, BaU and CM, are conducted to assess GHG emissions and mitigations in Vietnam. The focus sectors are energy sectors and AFOLU sectors. The targeted GHGs are CO_2, CH_4 and N_2O. For energy sector, only CO_2 emission is considered. For AFOLU (agriculture, forestry and other land use) sectors, all of above GHG emissions are estimated. The scenario of visions includes socio-economic development paths and the associated emissions. The discussion of mitigation actions to achieve LCS visions covers technology and policy options. It is very positively that, after completing the research, the knowledge of this research will contribute to some extend as follows:

While Vietnam's emissions are relatively low in a global context, they are growing rapidly and will likely four folds (601 $MtCO_2$) by 2030 unless significant mitigation actions are under taken. In the past, AFOLU sectors contribute most to GHG emissions in Vietnam, but the sectors are expected soon to be outpaced by emission increase in the energy sector (MONRE, 2003 and MONRE, 2010). In this study, findings show that GHG emissions in energy sector are projected at 522 $MtCO_2$ which accounts for more than six folds of those in AFOLU sectors in 2030BaU.

In 2030CM scenario, overall GHG emission is expected to reduce 36% from 2030BaU. Emission intensity was reduced 20%.

Agriculture has an important role to play in mitigating GHG emissions. We find that GHG emissions in the sector are contributed to decrease by 57% by 2030CM compared to 2030BaU level. Midseason drainage and conservation of existing protection forests are expected the largest mitigation countermeasures in the sector.

In energy sector, about 38% of GHG emissions can be reduced in 2030CM compared to 2030BaU level. Fuel shift and energy efficiency are projected the largest countermeasures in the sector.

Eleven Actions (six Actions for energy sectors and five Actions for AFOLU sectors) are the key steps that can influence the existing energy consumption pattern and GHG emissions in future. These actions have been defined with an understanding of the inherent strengths and potential of Vietnam which can be explored at this time of rapid development.

8.2 Recommendation for Future Works

In spite of every effort to pursue the objectives of this research, there are some limitations of the study. It focused on energy sector and AFOLU sector while other aspects such as waste and industrial processes are also one of the sources of CO_2 emission are therefore not within the scope of the study. The scope of the study would be extended to broader area including other sectors that cause GHG emission.

In terms of development of modeling, for ExSS model, it should be considered the issue of transportation model especially international transportation problems. For the AFOLU model, it considers only emission part in one certain society. As for further study, it should be developed model for example AFOLU Activities model (AFOLUA) which is top-down model to estimate amounts of human activities in AFOLU sector based on population and socio-economic indicators. The AFOLUA model aims to discuss mitigation potential in AFOLU sectors in different socio-economic scenarios including different GDP and population.

Last but not least, in order to attain required actions which introduced in the target year, a roadmap that specified what kind of policy must be done is required in future study. A roadmap is a schedule of actions/countermeasures spread and introduction of the policies.

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Appendixes

Appendix 1 Vietnam’s environmental policy on climate change

No	National program, policiy and law	Main ojectives
1	*National Climate Change Strategy (NCCS, 2011); Decision number 2139/QD-TTg dated 05 December 2011*	(1) Ensure food security, energy security, water security, and so on in the context of climate change; (2) Consider low-carbon economy and green growth as principles in achieving sustainable development; GHG emission reduction and removal to become a mandatory index in social and economic development. (3) Take advantage of climate change opportunities for social and economic development; promote climate-friendly behaviours. (4) Join forces with international communities in addressing climate change; increase international cooperation to address climate change effectively.
2	*National Target Program to Respond to Climate Change (NTP-RCC); Decision number 158/2008/QD-TTg dated on December 2008*	This program comprehensively addresses climate change effects, impacts and adaptation responding to sea level rise and GHG emission mitigation (1) To assess climate change impacts on sectors and regions in specific periods; (2) To develop feasible actions plans to effectively respond to climate change in the short-term and long-term to ensure sustainable development of Vietnam; (3) To take opportunities to develop towards a low-carbon economy; (4) To join the international community’s effort in mitigating climate change and protecting the climatic system
3	*Vietnam Agenda 21 policies; Decision number 153/2004/QD-TTg dated August 17th 2004*	To strengthening the legal basis for environmental protection, supporting research and development into, and transfer of, environmentally friendly technologies, and stipulating Vietnam’s active participation in international activities related to the 1992 UNFCCC.
4	*Law on Environmental Protection; Decision number 52/2005/QH11 dated November 29th 2005*	This Law provides for activities of environmental protection; policies, measures and resources for environmental protection; rights and obligations of organizations, households and individuals in environmental protection
5	*Clean Development Mechanism (CDM)*	Kyoto Protocol regulates the creation and trading of emission reduction credits. Currently, there have been 78 CDM projects have been approved by CDM Executive Board in Vietnam up to now. (December 2011)

- Ministry of Natural Resources and Environment (MoNRE) was assigned as a National Focal Agency for participating and implementing UNFCCC and Kyoto Protocol.
- Department of Meteorology Hydrology and Climate Change (DMHCC), which belongs to MoNRE, is the Designed National Authority for CDM in Vietnam.

Appendix 2 Energy National Policies and Strategies in Vietnam

No	Energy Policy and Strategies	Concrete targets	
1	*National Energy Development Strategy in the period up to 2020, perspective up to 2050. (NEDS, 2007); Decision number 1855/2007/QD-TTg dated December 27th 2007*	Energy conservation and energy efficiency	Energy elasticity: from 1.46 at present to 1.0 (2015) and 0.8 (after 2020) Energy consumption: saving 3% to 5% during 2006-2010 and 5% to 8% during 2011-2015
		Primary energy supply	47.5 to 49.5 Mtoe (2010) 100 to 110 Mtoe (2020) 110 to 120 Mtoe (2025)
		Renewable energy	Share of household using renewable energy in cooking 50% (2010), 80% (2020)
		Energy trade	Connect regional power grid (2010-2015) Connect gas pipeline network (2015-2020) Capacity of refinery: 25-30 million tonnes crude oil (2020)
2	*National Power Development Plan for period 2011-2020 with perspective up to 2030. (PDP VII); Decision number 1208/QD-TTg dated July 21st 2011*	Power supply plan	Electricity demand growth rate: 14% per annum (2011-2015); 11% (2016-2020). Electrical production 695-834 billion kWh (2030); In which: renewable eneergy (6%), nuclear (10.1%), hydro power (9.3%), coal (56.4%), gas (14.4%) and imported electricity (3.8%) Electrical generation from small hydro and renewable energy will be 3,100MW (2020) and 4800MW (2030) Electrical generational from wind power 1000MW (2020) and 6200MW (2030); from biomass 500MW (2020) and 2000MW (2030) Tranmission lost complies to N1- criterion Enrgy elasticity ratio from 2.0 (current) to 1.5 (2015) and 1.0 (2020)
3	*Master Plan for Coal Development up to 2015, and orientation up to 2025. (MPCD); Decision number 89/2008/QD-TTg dated July*	Coal explration Coal production and processing	Coal reserves in 300m-1000m in depth 61-65 million tonnes (2020-2025) Coal demand growth rate 11.2% per annum (2005-2025)
4	*Master Plan on Vietnam Oil and Gas Sector Development up to 2015, a vision towards 2025.(MPOG); Decision number 233/QD-TTg dated February 18th 2009.*	Oil & gas exploration	Reserve 30-50 million cubic meter a year Reserve in 400m water depth
		Oil & gas supply	25-30 million tonnes (2006-2010) 60-65 million tonnes (2011-2015) 30-35 million tonnes (after 2016) Domestic refineries will satisfy petroleum product demands by 2014 Oil demand will grow by 8.3% per annum (2005-2025); reaching 19.5 million tonnes in 2025 Gas demand will grow by 8.1% per annum (2005-2025); reaching 18.9 billion cubic meters in 2025
5	*Master Plan for Renewable Energy Development for the period up to 2015, with outlook to 2025. (MPRE); Institute of Energy Vietnam (2008)*	Renewable energy sources	Small hydro (2500 MW); solar (3.25MW); wind (500 MW); biomass (400MW); geothermail (240 MW)
		Renewable energy share in primary energy and power generation	(2050) In power generation: 0.6% at present to 3.5% (2010), 4.5% (2020) and 6% (2030)
6	*Bio-energy development for the period up to 2015, outlook to 2025.(BIED); Decision number 177/2007/QD-TTg dated November 20th 2007.*	Using bio-energy, meeting 0.4% (2010), 1% (2015) and 5% (2025) of oil and gasoline demand in country	
7	*Master Plan on Nuclear Power Development up to 2030. (MPNP); Decision number 906/QD-TTg dated June 17th 2010*	First nuclear power plant wii be built in 2015 and operate in 2020 In 2025: total capacity of nuclear power plant will be 8000 MW (7% of total power generation) In 2030: total capacity of nuclear power plant will be 15000 MW (10% of total power	
8	*Law on Energy Efficiency and Conservation No. 50/2010/QH12*	The Law includes policies and measures to promote energy efficiency and conservation (EE&C); prescribing EE&C; and the rights, obligations and responsibilities of organizations, households and individuals in EE&C. Subjects of application are focus on organizations, households and individuals using energy in Vietnam.	
9	*Vietnam National Energy Efficiency Program in the period 2006-2015(VNEEP); Decision on Vietnam National Energy Efficiency Program (No. 79/2006/QD-TTg)*	Overall objective: to reduce the investment on the power sector through promoting nation-wide energy efficiency (EE) technologies and management for a sustainable socio-economic development • Specific objectives: to reduce 3-5% and 5-8% of the total national energy consumption compared to the BAU (2006-2010) and (2011-2015), respectively; • Contents: 6 pillars – Pillar 1 - Strengthening the national governance of energy efficiency and conservation – Pillar 2 – Education, raising awareness on EE – Pillar 3 – Development and dissemination of high EE devices and equipments – Pillar 4 – Promoting EE in industrial enterprises – Pillar 5 – Promoting EE in buildings – Pillar 6 – Promoting EE in transport sector	

Appendix 3 Formulation of the ExSS model

Number of household

$$HHD_{hht} = \sum_{age} \underline{Pop}_{age,hht} \Big/ \underline{Pphhd}_{hht}$$

HHD_{hht} : Number of household of household type *hht* [number]

$\underline{Pop}_{age,hht}$: Population by age cohort *age* by household type *hht* [number]

$\underline{Pphhd}_{hht}$: Person per household by household type *hht* [number]

hht : Household type ($\in eds$)

age : Age cohort

Inverse matrix of Leontief

$$\sum_j (\underline{Imat}_{i,j} - (1 - \underline{IMR}_i) \times \underline{Amat}_{i,j} \times Ainv_{j,k}) = \underline{Imat}_{i,k}$$

$\underline{Imat}_{i,j}$: Unit matrix

$\underline{Mr}_i$: Import ratio of industry *i* (= import / regional demand) [ratio ≦1]

$\underline{Amat}_{i,j}$: Input coefficient matrix (input coefficient to industry *i* from industry *j*) [share, $\sum_j \underline{Amat}_{i,j} = 1$]

$Ainv_{i,j}$: Inverse matrix of Leontief (Here, $(I-(I-\overline{M})A)^{-1}$ type is applied.) [number]

i,j,k : industry (=*pds*)

Domestic final demand

$$FD_{pds} = \sum_{dfds} (\underline{FD\_ttl}_{dfds} \times \underline{FD\_cvm}_{pds,dfds})$$

FD_{pds} : Domestic final demand to industry *pds* [monetary]

$\underline{FD\_ttl}_{dfds}$: Total final demand of domestic final demand sector *dfds* [monetary]

$\underline{FD\_cvm}_{pds,dfds}$: Converter matrix of final demand (share of industry *pds* in final demand sector *dfds*) [share, $\sum_j \underline{FD\_cvm}_{i,j} = 1$]

dfds : Domestic final demand sector ($\in fds$)

fds : Final demand sector (including *dfds*, export and import)

Industrial output

$$EX_j = \underline{FD\_ttl}_{ex} \times \underline{FD\_cvm}_{j,ex}$$

$$PD_i = \sum_j (Ainv_{i,j} \times (((1-\underline{Mr}_j) \times FD_j) + EX_j))$$

PD_i : Gross output of industry *i* [monetary]

$\underline{EX}_j$: Export of insutry *j* [monetary]

$\underline{FD\_ttl}_{ex}$: Total export [monetary]

$\underline{FD\_cvm}_{ex,j}$: Share of industry *j* in export [share, $\sum_j \underline{FD\_cvm}_{ex,j} = 1$]

ex: export ($\in fds$)

Intermediate input

$$SAM_{sams,pds} = PD_{pds} \times \underline{Amat}_{sams,pds}$$

$\underline{SAM}_{sams,pds}$: Intermediate input from sector *sams* to industry *pds*

sams :Elements of IO table (industry *pds*, value added sector *vas*)

Import

$$IM_{pds} = (FD_{pds} + \sum_j SAM_{pds,j}) \times \underline{Mr}_{pds}$$

IM_{pds} : Import of goods or services produced by industry *pds* [monetary]

Passenger transport demand

$$PTD_{ptm} = \sum_{td} \sum_{age} \sum_{hht} \underline{Pop}_{age,hht} \times \underline{Ptg}_{age,td} \times \underline{Pts}_{td,ptm} \times \underline{Ptad}_{td,ptm} \times 365 \times (1/10^6)$$

PTD_{ptm}: Pssenger transport demand [million passenger-km]

$\underline{Pop}_{age,hht}$: Population by age cohort and household type [number]

$\underline{Ptg}_{age,td}$: Trip per person per day by age cohort and transport destination [passenger-trip/population/day]

$\underline{Pts}_{td,ptm}$: Modal share of passenger transport [share, trip/trip, $\sum_{ptm} Pts_{td,ptm} = 1$]

$\underline{Ptad}_{td,ptm}$: Average trip distance of passenger transport [km]

ptm : passenger transport mode ($\in eds, \in esc$)

td : transport destination

Freight transport demand

$$FTD_{ftm} = \sum_{pss}\sum_{td} PD_{pss} \times \underline{Ftg}_{pss,td} \times \underline{Fts}_{td,ftm} \times \underline{Ftad}_{td,ftm} \times (1/10^6)$$

FTD_{ftm}: Freight transport demand [mill. ton-km]

PD_{pss}: Output of primary and secondary industry [monetary]

$\underline{Ftg}_{pss,td}$: Freight generation per industrial output [ton/ monetary]

$\underline{Fts}_{td,ftm}$: Modal share of freight transport [share, ton/ton, $\sum_{ftm} Fts_{td,ftm} = 1$]

$\underline{Ftad}_{td,ftm}$: Average distance of freight transport [km].

pss: primary and secondary industry ($\in pds$)

ftm : freight transport mode ($\in eds, \in esc$)

Energy service demand

$$ESDF_{eds,esc} = \begin{cases} HHD_{hht} & (for \quad hht) \\ FA_{svs} & (for \quad svs) \\ PD_{pss} & (for \quad pss) \\ \sum_{td}\sum_{age}\sum_{hht} \underline{Pop}_{age,hht} \times \underline{Ptg}_{age,td} \times \underline{Pts}_{td,ptm} \times 365 \times (1/10^6) & (for \quad ptm) \\ \sum_{pss}\sum_{td} PD_{pss} \times \underline{Ftg}_{pss,td} \times \underline{Fts}_{td,ftm} \times (1/10^6) & (for \quad ftm) \end{cases}$$

$$ESVD_{eds,esc} = ESDF_{eds,esc} \times \underline{Esvg}_{eds,esc}$$

$ESDF_{eds,esc}$: Driving force of energy demand sector *eds*, energy service *esc* [*unit depends on the sector*]

$ESVD_{eds,esc}$: Energy service demand of energy demand sector *eds*, energy service *esc* [*unit depends on the sector and service*]

$\underline{Esvg}_{eds,esc}$: Energy service demand per driving force of energy demand sector *eds*, energy service *esc* [*unit depends on the sector and service*]

eds : Energy demand sector

esc : Energy service

Final energy demand

$$TCef_{eds,esv,e,device} = \underline{TCsv}_{eds,esv,e,device} / \underline{TCed}_{eds,esv,e,device}$$

$$ES_{eds,esv,e} = \sum_{tc} \underline{TCsh}_{eds,esv,e,device}$$

$$EF_{eds,esv,e} = \frac{\sum_{tc}\left(TCef_{eds,esv,e,device} \times \underline{TCsh}_{eds,esv,e,device}\right)}{ES_{eds,esv,e}}$$

$$ED_{eds,esv,e} = ESVD_{eds,esv} \times ES_{eds,esv,e} \times EF_{eds,esv,e}$$

$TCef_{eds,esv,e,device}$: Energy efficiency of energy demand sector *eds*, energy service *esv*, fuel *e*, energy endues device *device*

$\underline{TCsh}_{eds,esv,e,device}$: Device share energy demand sector *eds*, energy service *esv*, fuel *e*, energy endues device *device* ($\sum_{e}\sum_{tc} TCSH_{eds,esc,e,device} = 1$**)**

$\underline{TCsv}_{eds,esv,e,device}$: Energy service supplied by energy endues device *device* of energy demand sector *eds*, energy service *esv*, fuel *e*. (service supplied by $\underline{TCed}_{eds,esv,e,\ device}$*)*[*unit depends on the service*]

$\underline{TCed}_{eds,esv,e,device}$: Energy required for energy endues device *device* of energy demand sector *eds*, energy service *esv*, fuel *e*. (energy required by $\underline{TCsv}_{eds,esv,e,\ device}$*)* [ktoe/service]

$ED_{eds,esv,e}$: Final energy demand of energy demand sector *eds*, energy service *esv*, fuel *e*

[ktoe]

$\underline{ES}_{eds,esv,e}$: Fuel share of energy demand sector *eds*, energy service *esv*, fuel *e*

$\underline{EF}_{eds,esv,e}$: Fuel share of energy demand sector *eds*, energy service *esv*, fuel *e* [share]

device: Energy enduse device

Central power generation

$$ELD\_cps_{eds} = \sum_{esv} ED_{eds,esv,ele} - \sum_{e} \underline{DPG}_{eds,e}$$

$$CPG_e = \sum_{eds} ELD\_cps_{eds} \times \underline{CPGsh}_e$$

Where,

ELD_cps_{eds}: Electricity demand to central power generation from energy demand sector *eds*

$ED_{eds,\,esv,\,ele}$: Final electricity demand of energy demand sector *eds*, energy service *esv*

$\underline{DPG}_{eds}$: dispersed power generation in energy demand sector *eds*.

CPG_e: Power supply by central power generation by fuel *e*

$\underline{CPGsh}_e$: Share of power supply in central power generation by fuel *e* [share, ktoe/ktoe, $\sum_e \underline{CPGsh}_e = 1$]

ele: Electricty ($\in e$)

Primary energy demand of power generation

$$DPG\_ed_{eds,e} = \left[\frac{\underline{DPG}_{eds,e}}{\underline{DPGef}_{eds,es} \times (1 - \underline{DPGown}_{eds,e})} \right]$$

$$CPG\_ed_e = \frac{CPG_e}{\underline{CPGef}_e \times (1 - \underline{CPGown}_e) \times (1 - \underline{CPGtl}_e)}$$

$DPG\_ed_{eds,e}$: Energy demand of fuel *e*, dispersed power generation at energy demand sector *eds* [ktoe]

$\underline{DPGef}_{eds,e}$: Energy efficiency of fuel *e*, dispersed power generation at energy demand sector *eds* [generation/ input fuel, ktoe/ktoe]

$\underline{DPGown}_{,e}$: Own use ratio of fuel *e*, dispersed power generation at energy demand sector *eds* [ratio, ktoe/ktoe]

CPG_ed_e: Energy demand of fuel *e*, central power generation [ktoe]

$\underline{CPGef}_e$: Energy efficiency of fuel *e*, central power generation [generation/fuel input, ktoe/ktoe]

$\underline{CPGown}_e$: Own use ratio of fuel *e*, central power generation [own use/generation, ktoe/ktoe]

$\underline{CPGgl}_e$: Transmission loss rate of fuel *e*, central power generation [rate, ktoe/ktoe]

CO_2 emission factor (power generation)

$$DPG\_Co2ef_{eds} = \sum_e (DPGed_{eds,e} \times \underline{Co2ef}_e) / \sum_e \underline{DPG}_{eds,e}$$

$$Co2ef_{ele} = \sum_e (CPGed_e \times \underline{Co2ef}_e) / \sum_e CPG_e$$

$$Ttl\_Co2ef_{eds} = \left(\frac{Eld\_cps_{eds}}{\sum_{esv} ED_{eds,esv,ele}} \right) \times Co2ef_{ele} + \left(1 - \frac{Eld\_cps_{eds}}{\sum_{esv} ED_{eds,esv,ele}} \right) \times DPG\_Co2ef_{eds}$$

DPG_Co2ef_{eds}: CO_2 emission factor of dispersed power generation in energy demand sector *eds* [tC/toe]

CO_2ef_{eds}: CO_2 emission factor of central power generation [tC/toe]

$\underline{CO_2ef}_e$: CO_2 emission factor of fuel *e* [tC/toe]

Ttl_Co2ef_{eds}: CO_2 emission factor of electricity demanded by energy demand sector *eds* [tC/toe]

CO_2 emissions

$$CO2_{eds} = \sum_{esv} \left(\sum_{nele} ED_{eds,esv,nele} \times CO_2ef_{nele} + \sum_{esv} ED_{eds,esv,ele} \times Ttl\_CO_2ef_{eds} \right) \quad (0\text{-}1)$$

CO_{2eds} : CO_2 emissions of energy demand sector *eds* [ktC]

$ED_{eds,esv,nele}$: Energy demand (except of electricity) of energy demand sector *eds*, energy service *esv* [ktoe]

$nele$: Fuel except of electricity ($\in e$)

Primary energy demand

$$PED_e = \sum_{eds}\sum_{esv} ED_{eds,esv,nele} + \sum_{eds} DPG\_ed_{eds,nele} + CPG\_ed_{nele}$$

PED_e : Primary energy demand of fuel *e*

Appendix 4 List of socio-economic indicators and its value 2005

Code in Ex	Name	Value in 2005	Unit	Source
POP	Population by age and sex		person	Population Division - United Nations Population low variant, 2030 for Vietnam
	Male			http://esa.un.org/unpp/p2k0data.asp
	0-14	12,437,523		General Statistic Office of Vietnam (2008)
	15-64	26,337,179		
	65+	2,101,755		
	Female			
	0-14	11,822,616		
	15-64	27,406,839		
	65+	3,000,388		
HH	Number of households	20,020,187	household	Vietnam Population and Housing Census (2009)
PD	Output by industry		trillion VND	Input-output table 2005, General Statistic Office of Vietnam
	Agriculture-Fishery-Forestry	261		
	Mining and quarrying	143		
	Food, beverage & tobaco manufactures	259		
	Other consumer goods	285		
	Industrial materials	182		
	Capital goods	127		
	Construction	179		
	Electric, gas, water, transport, telecommunication, finacial, insurance, private and government services	497		
PTG	Passenger transport generation per person per day	2	trip/capita/day	Assumption
	Passenger transport generation in 2005	60,668	mil.trips/year	
PTS	Modal share		%	
	Train	0.04		Walter and Michael, 1995
	Bus	0.33		Schipper et. al, 2008
	Car	0.2		JICA/MoT, 2009
	Ship	0.47		General Statistic Office of Vietnam (2009)
	Motorbike	2.95		
	Walk & bicycle	96		
	Domestic aviation	0.01		
PTAD	Average trip distance		km/trip	
	Train	356		Schipper et. al, 2008
	Bus	181		JICA/MoT, 2009
	Ship	22		General Statistic Office of Vietnam (2009)
	Motorbike	6		
	Walk	1		
	Bike	3		
	Car	92		
	Domestic aviation	811		
PTD	Passenger transport demand		mil p-km	
	Train	8418		
	Bus	36681		
	Ship	6220		
	Motorbike	10451		
	Walk & bicycle	145602		
	Car	11230		
	Domestic aviation	5378		
FTG	Frieght transport generation per output	0.29	t-output/day	Calculated by total freight transport volume and output of industry
FTS	Modal share		%	Calculated by freight transport volume by type of transport
	Railways	2.1		
	Road	71.3		
	Inland waterway	26.6		
	Domestic aviation	0		
FTAD	Average trip distance		km/trip	Estimated by freight transport volume, modal share, freight transport generation per output per day, and population
	Railways	336		
	Road	60		
	Inland waterway	162		
	Domestic aviation	2156		
FTD	Frieght transport volume		mil-t/km	General Statistic Office of Vietnam (2008)
	Railways	2949		
	Road	17668		
	Inland waterway	17999		
	Domestic aviation	239		

Appendix 5a Vietnam Input-output table in 2005, 16 sectors

Unit: thousand billion VND

Code	Description	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	**Total Intermediate Consumption**	Final Consumption Expenditure	Gross Domestic Capital Formation	Export	(Less) Imports	Total Final Demand	**Total Gross Output**
01	Agricultural crops, livestock & poultry, agricl	22	0	0	0	90	3	1	0	0	0	0	0	0	0	2	0	**118**	56	4	28	16	**72**	**191**
02	Fishery	0	6	0	0	22	0	0	0	0	0	0	0	0	0	1	0	**29**	26	0	3,651	1	**29**	**58**
03	Forestry	0	1	1	0	0	8	0	0	0	0	0	0	0	0	0	0	**12**	0	0	0	0	**0**	**12**
04	Mining and quarrying	0	0	0	3	3	1	10	0	0	5	0	0	0	1	1	0	**26**	1	0	127	11	**118**	**143**
05	Food, beverage & tobacco manufactures	8	0	0	0	44	0	0	0	0	0	1	1	0	0	7	1	**62**	143	13	72	30	**197**	**259**
06	Other consumer goods	1	1	0	1	10	160	7	5	1	8	3	0	1	3	2	6	**209**	35	-4	160	115	**75**	**285**
07	Industrial materials	19	10	1	9	15	38	97	28	7	78	8	10	1	6	11	11	**348**	37	36	42	282	**- 166**	**182**
08	Capital goods	0	2	0	5	3	4	5	58	3	26	18	2	3	2	3	6	**141**	33	41	48	135	**- 14**	**127**
09	Electricity, gas & water	2	2	0	6	4	6	7	2	3	2	1	0	0	1	2	2	**39**	4	0	0	0	**4**	**43**
10	Construction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	179	0	0	**179**	**16**
11	Wholesale and retail trade	2	0	0	1	3	4	5	2	0	2	0	1	0	1	2	1	**24**	28	29	30	0	**87**	**110**
12	Transport services	1	1	0	1	3	4	2	1	0	2	1	0	0	1	1	2	**20**	15	8	3	8	**18**	**37**
13	Post and telecommunication	1	0	0	5	0	1	1	0	0	1	0	0	0	2	2	2	**15**	10	0	3	4	**9**	**25**
14	Finance, insurance, real estate & business	0	2	0	10	2	3	1	1	0	2	10	4	1	8	3	5	**52**	37	0	5	13	**30**	**82**
15	Other private services	0	0	0	1	0	1	0	0	0	1	1	0	0	1	1	3	**12**	67	0	20	12	**75**	**87**
16	Government services	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6	**9**	101	0	20	17	**103**	**112**
	TOTAL INTERMEDIATE INPUT	**57**	**26**	**2**	**42**	**200**	**235**	**137**	**99**	**14**	**126**	**44**	**18**	**7**	**28**	**37**	**45**	**1,115**	**594**	**307**	**562**	**644**	**818**	**1,934**
17	Compensation of employees	105	21	5	43	21	18	19	15	14	24	29	9	8	25	30	56	**441**						
18	Indirect Taxes	10	2	3	6	16	10	6	3	2	7	13	2	2	10	4	1	**97**						
19	Depreciation	8	2	0	12	4	8	8	3	1	7	6	3	4	5	4	7	**83**						
20	Operating surplus	10	7	2	41	19	14	12	7	12	15	19	5	4	14	12	3	**197**						
	GROSS VALUE ADDED	**134**	**32**	**10**	**101**	**59**	**50**	**45**	**29**	**29**	**53**	**67**	**19**	**18**	**54**	**50**	**68**	**818**						
	GROSSS LINPUT (=OUTPUT)	**191**	**58**	**12**	**143**	**259**	**285**	**182**	**127**	**43**	**179**	**110**	**37**	**25**	**82**	**87**	**112**	**1,934**						

Appendix 5b Vietnam Input-output table in 2005, 8 sectors

Unit: thousand billion VND

No.	Description	01	02	03	04	05	06	07	08	**Total intermediate consumption**	Private consumption	Government consumption	Fixed capital formation	Export	Import	**Total gross output**
01	Agriculture-Fishery-Forestry	30	0	112	11	1	0	0	4	**159**	83	0	4	32	-17	**261**
02	Mining and quarrying	0	3	3	1	10	0	5	3	**26**	1	0	0	127	-11	**143**
03	Food, beverage & tobaco manufactures	9	0	44	0	0	0	0	9	**62**	143	0	13	72	-30	**259**
04	Other consumer goods	3	1	10	160	7	5	8	16	**209**	35	0	-4	160	-115	**285**
05	Industrial materials	29	9	15	38	97	28	78	53	**348**	37	0	36	42	-282	**182**
06	Capital goods	3	5	3	4	5	58	26	37	**141**	33	0	41	48	-135	**127**
07	Construction	0	0	0	0	0	0	0	0	**0**	0	0	179	0	0	**179**
08	Private & government services and others	11	24	12	20	16	7	9	71	**170**	254	9	37	81	-54	**497**
	Total intermediate input	**85**	**42**	**200**	**235**	**137**	**99**	**126**	**193**	**1115**	**585**	**9**	**307**	**562**	**- 644**	**1934**
	Gross value added	176	101	59	50	45	29	53	304	**818**						
	Total gross output	**261**	**143**	**259**	**285**	**182**	**127**	**179**	**497**	**1934**						

Appendix 5c Vietnam Input-output table in 2030, 8 sectors

Unit: thousand billion VND

No.	Description	01	02	03	04	05	06	07	08	**Total intermediate consumption**	Consumption	Fixed capital formation	Export	Import	**Total gross output**
01	Agriculture-Fishery-Forestry	119	1	526	73	6	0	1	19	**745**	254	20	156	-150	**281**
02	Mining and quarrying	0	15	14	9	49	1	25	13	**126**	4	2	615	-89	**532**
03	Food, beverage & tobaco manufactures	34	0	204	2	2	0	1	46	**289**	622	62	346	-105	**924**
04	Other consumer goods	10	3	49	1074	32	25	37	82	**1313**	170	-19	771	-328	**595**
05	Industrial materials	115	43	69	256	475	137	375	275	**1745**	141	175	204	-1377	**-857**
06	Capital goods	11	23	16	24	25	284	124	194	**701**	158	197	230	-664	**-79**
07	Construction	0	0	0	0	0	0	0	0	**0**	0	866	0	0	**866**
08	Private & government services and others	43	108	57	134	78	33	46	368	**868**	1512	178	389	-378	**1702**
	Total intermediate input	**333**	**193**	**935**	**1573**	**667**	**482**	**609**	**997**	**5787**	**2861**	**1481**	**2713**	**-3092**	**9750**
	Gross value added	693	466	278	335	221	140	257	1573	**3963**					
	Total gross output	**1026**	**27**	**75**	**69**	**29**	**16**	**33**	**174**	**9750**					

Appendix 6a Table use to split energy service type – Industrial sector

Industry		Other industries						
		Boilers	Boilers	Process Heat	Machine Drive	Electro-chemical	Others	
		ISOI	ISOI	IPOI	IMOI	IEOI	IOOI	Total
Electricity	INDELC			9%	78%	3%	10%	100%
Natural Gas	INDNGA	49%		38%	1%		12%	100%
LPG	INDLPG	6%		65%	1%		28%	100%
NGL	INDNGL							100%
Coal	INDCOA	41%		49%			10%	100%
Ovencoke	INDCOK						100%	100%
Coke Oven Gas	INDCOG							
Blast Furnace Gas	INDBFG	100%						100%
Oxygen Steel Furnace Gas	]INDOXY	100%						100%
Heavy Fuel Oil	INDHFO	70%		29%	0%		1%	100%
Refined Petroleum Products	INDOIL	47%		13%	8%		32%	100%
Ethane	INDETH							100%
Naphta	INDNAP							100%
Petroleum Coke	INDPTC	100%						100%
Biofuels	INDBIO	100%						100%
Geothermal	INDGEO	100%						100%
Heat	INDHET			63%	1%		35%	100%

Appendix 6b Table use to split energy service type – Commercial sector

Commeciral		Space heating	Space cooling	Hot water heating	Lighting	Cooking	Refrigerators and freezers	Electric Equipment	Other Energy Use	Other energy uses
		CH1	CC1	CHW	CLA	CCK	CRF	COE	COT	Total
Natural gas	COMNGA	15%		40%		40%			5%	100%
Diesel	COMDST	50%		50%						100%
Heavy fuel oil	COMHFO	70%		30%						100%
Kerosene	COMKER	50%		40%		10%				100%
Coal	COMCOA	60%		30%		10%				100%
LPG	COMLPG	60%		35%		5%				100%
Biofuels	COMBIO	30%		30%		40%				100%
Electiricity	COMELC	3%	13%	6%	35%	1%	20%	22%		100%
Heat	COMHET	100%								100%
Geothermal	COMGEO	100%								100%
Solar	COMSOL			100%						100%

Appendix 6c Table use to split energy service type – Residential sector

Residential		Space heating	Space cooling	Hot water heating	Refrigerators and freezers	Cloth dryer	Cooking	Cloth washers	Dish washers	Other energy uses	Miscellaneous electric energy	Lighting	
		RH1	RC1	RHW	RRF	RCD	RK1	RCW	RDW	ROT	REA	RL1	Total
Natural gas	RESNGA	10%		35%			40%			15%			100%
Diesel	RESDST	20%		50%						30%			100%
Heavy fuel oil	RESHFO	100%											100%
Kerosene	RESKER	15%		30%			40%					15%	100%
Coal	RESCOA	50%		40%			10%						100%
LPG	RESLPG	25%		40%			35%						100%
Biofuels	RESBIO	20%		30%			50%						100%
Electiricity	RESELC	2%	8%	8%	10%	1%	5%	3%	1%		20%	42%	100%
Heat	RESHET	100%											100%
Geothermal	RESGEO	100%											100%
Solar	RESSOL			100%									100%

Appendix 6d Table use to split energy service type – Transport sector

Transportation		ROAD										RAIL		
		Light Vehicle					Other Vehicle					Total		
			Autos	Light trucks	Three wheels	Two wheels		Buses	Heavy trucks	Medium trucks	Commercial trucks		Freight rail	Passenger rail
			TRT	TRL	TRE	TRW		TRB	TRH	TRM	TRC		TTF	TTP
Coal	TRACOA											100%	80%	20%
Methanol	TRAMET	90%	80%	20%			10%	50%		50%				
Ethanol	TRAETH	90%	80%	20%			10%	50%		50%				
Natural gas	TRANGA	90%	80%	20%			10%	70%			30%			
LPG	TRALPG	70%	67%	33%			30%	70%			30%			
Gasoline	TRAGSL	70%	57%	40%	1%	3%	30%	20%	10%	35%	35%			
Aviation Gasoline	TRAAVG													
Jet Kerosene	TRAJTK													
Diesel	TRADST	5%	35%	65%			95%	20%	50%	25%	5%	100%	80%	20%
Heavy Fuel Oil	TRAHFO											100%	90%	10%
Electiricity	TRAELC	100%	90%	10%			0%					100%	5%	95%

Appendix 6e Table use to split energy service type – Transport sector

Transportation		SHIP*			AIR*		
		Total			Total		
			Freight ship	Passenger ship		Freight air	Passenger air
Coal	TRACOA	100%	95%	5%	100%	2%	98%
Methanol	TRAMET	100%	95%	5%	100%	2%	98%
Ethanol	TRAETH	100%	95%	5%	100%	2%	98%
Natural gas	TRANGA	100%	95%	5%	100%	2%	98%
LPG	TRALPG	100%	95%	5%	100%	2%	98%
Gasoline	TRAGSL	100%	95%	5%	100%	2%	98%
Aviation Gasoline	TRAAVG	100%	95%	5%	100%	2%	98%
Jet Kerosene	TRAJTK	100%	95%	5%	100%	2%	98%
Diesel	TRADST	100%	95%	5%	100%	2%	98%
Heavy Fuel Oil	TRAHFO	100%	95%	5%	100%	2%	98%
Electiricity	TRAELC	100%	95%	5%	100%	2%	98%

(*) fuel mix in navigation and aviation are not desbribed in SAGE (2003), assumed in this study

Appendix 7a Vietnam energy balance table (disaggregated type)

Extended EnergyBalanceTable
COUNTRY: Vietnam
Unit: ktoe
TIME: 2005

	Anthracite	Other Bituminous Coal	Primary Solid Biomass	Charcoal	Natural Gas	Crude Oil	Natural Gas Liquids	Liquefied Petroleum Gases (LPG)	Motor Gasoline	Kerosene Type Jet Fuel	Kerosene	Gas/Diesel Oil	Residual Fuel Oil	Non-specified Petroleum Products	Hydro	Electricity	Total of All Energy Sources
Production	1359	16783	23951	0	6199	18935	465	0	0	0	0	0	0	0	1845	0	69537
Imports	0	57	0	0	0	0	0	572	2763	438	344	5980	2179	0	0	0	12332
Exports	-1359	-8714	0	0	-1286	-18291	0	0	0	0	0	-284	0	0	0	0	-29933
International Marine Bunkers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stock Changes	0	0	0	0	0	-644	0	0	0	0	0	0	0	0	0	0	-644
Total Primary Energy Supply	0	8126	23951	0	4914	0	465	572	2763	438	344	5696	2179	0	1845	0	51292
Transfers	0	0	0	0	0	0	-465	373	0	0	0	0	0	300	0	0	208
Statistical Differences	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transformation Sector	0	-2132	-1228	405	-4814	0	0	0	0	0	0	-124	-555	0	-1845	4598	-5694
Main Activity Producer Electricity Plants	0	-1962	0	0	-4657	0	0	0	0	0	0	-118	-191	0	-1845	4361	-4412
Autoproducer Electricity Plants	0	-170	0	0	-156	0	0	0	0	0	0	-6	-364	0	0	237	-459
Charcoal Production Plants	0	0	-1228	405	0	0	0	0	0	0	0	0	0	0	0	0	-822
Non-specified (Transformation)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Energy Sector	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-126	-126
Own Use in Electricity, CHP and Heat Plants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-126	-126
Used for Pumped Storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nuclear Industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Charcoal Production Plants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-specified (Energy)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distribution Losses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-505	-505
Total Final Consumption	0	5994	22724	405	100	0	0	945	2763	438	344	5572	1624	300	0	3967	45176
Industry Sector	0	4777	0	0	100	0	0	109	0	0	12	1218	1159	0	0	1870	9246
Non-specified (Industry)	0	4777	0	0	100	0	0	109	0	0	12	1218	1159	0	0	1870	9246
Transport Sector	0	0	0	0	0	0	0	0	2673	438	0	3611	307	0	0	35	7065
International Aviation	0	0	0	0	0	0	0	0	0	265	0	0	0	0	0	0	265
Domestic Aviation	0	0	0	0	0	0	0	0	0	172	0	0	0	0	0	0	172
Road	0	0	0	0	0	0	0	0	2673	0	0	3611	0	0	0	0	6285
Rail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	35
Domestic Navigation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-specified (Transport)	0	0	0	0	0	0	0	0	0	0	0	0	307	0	0	0	307
Other Sectors	0	1216	22724	405	0	0	0	837	89	0	331	743	158	0	0	2062	28565
Residential	0	861	22724	405	0	0	0	570	0	0	144	12	0	0	0	1674	26391
Commercial and Public Services	0	333	0	0	0	0	0	267	0	0	187	365	139	0	0	338	1629
Agriculture/Forestry	0	22	0	0	0	0	0	0	89	0	0	365	19	0	0	49	545
Fishing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-specified (Other)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-Energy Use	0	0	0	0	0	0	0	0	0	0	0	0	0	300	0	0	300
Non-Energy Use Industry/Transformation/Energy	0	0	0	0	0	0	0	0	0	0	0	0	0	300	0	0	300
Memo: Feedstock Use in Petchemical Industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-Energy Use in Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-Energy Use in Other Sectors	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elect.Output in GWh	0	8941	0	0	20586	0	0	0	0	0	0	0	0	2482	21454	0	53463
Elec Output-main activity producer ele plants	0	8227	0	0	19918	0	0	0	0	0	0	0	0	1109	21454	0	50708
Elec Output-autoproducer electricity plants	0	714	0	0	668	0	0	0	0	0	0	0	0	1373	0	0	2755
Elec Output-main activity producer CHP plants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elec Output-autoproducer CHP plants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: AIM team, 2009

Appendix 7b Vietnam energy balance table (aggregated type)

Thousand tonnes of oil equivalent / *Milliers de tonnes d'équivalent pétrole*

SUPPLY AND CONSUMPTION 2004 / 2005	Coal	Crude Oil	Petroleum Products	Gas	Nuclear	Hydro	Geotherm. Solar etc.	Combust. Renew. & Waste	Electricity	Heat	Total
Indigenous Production	18142	19400	-	6199	-	1845	-	23955	-	-	69541
Imports	57	-	12276	-	-	-	-	-	-	-	12332
Exports	-10073	-18290	-284	-1286	-	-	-	-	-	-	-29933
Intl. Marine Bunkers	-	-	-	-	-	-	-	-	-	-	-
Stock changes	-	-644	-	-	-	-	-	-	-	-	-644
TPES	**8126**	**465**	**11991**	**4914**	**-**	**1845**	**-**	**23955**	**-**	**-**	**51296**
Electricity and CHP Plants	-2132	-	-679	-4814	-	-1845	-	-	4598	-	-4872
Petroleum Refineries	-	-	-	-	-	-	-	-	-	-	-
Other Transformation *	-	-465	675	-	-	-	-	-764	-631	-	-1185
TFC	**5994**	**-**	**11987**	**100**	**-**	**-**	**-**	**23192**	**3967**	**-**	**45240**
INDUSTRY SECTOR	**4777**	**-**	**2499**	**100**	**-**	**-**	**-**	**-**	**1870**	**-**	**9246**
Iron and Steel	-	-	-	-	-	-	-	-	-	-	-
Chemical and Petrochemical	-	-	-	-	-	-	-	-	-	-	-
Non-Metallic Minerals	-	-	-	-	-	-	-	-	-	-	-
Non-specified	4777	-	2499	100	-	-	-	-	1870	-	9246
TRANSPORT SECTOR	**-**	**-**	**7029**	**-**	**-**	**-**	**-**	**-**	**35**	**-**	**7065**
Aviation	-	-	437	-	-	-	-	-	-	-	437
Road	-	-	6285	-	-	-	-	-	-	-	6285
Non-specified	-	-	307	-	-	-	-	-	35	-	343
OTHER SECTORS	**1216**	**-**	**2158**	**-**	**-**	**-**	**-**	**23192**	**2062**	**-**	**28628**
Residential	861	-	727	-	-	-	-	23192	1674	-	26453
Comm. and Publ. Services	333	-	957	-	-	-	-	-	338	-	1629
Agriculture/Forestry	22	-	473	-	-	-	-	-	49	-	545
Non-specified **	-	-	-	-	-	-	-	-	-	-	-
NON-ENERGY USE	**-**	**-**	**301**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**301**
Electricity Generated - GWh	*8941*	-	*2482*	*20586*	-	*21454*	-	-	-	-	*53463*
Heat Generated - TJ	-	-	-	-	-	-	-	-	-	-	-

* Includes Transfers, Statistical Differences, Own Use and Distribution Losses.
** Includes Fishing.

Source: IEA, 2007

Appendix 8 Explanation of manure management system

Abbreviation	Type of manure management system	Explanation (IPCC guideline, 2006)
MS1	Lagoon	A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilise fields.
MS2	Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods less than one year
MS3	Solid Storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.
MS4	Drylot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically.
MS5	Pasture/Range/ Paddock	The manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed.
MS6	Daily Spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.
MS7	Anaerobic Digester	Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel or covered lagoon. Digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CO2 and CH4 , which is captured and flared or used as a fuel.
MS8	Burned for Fuel	The dung and urine are excreted on fields. The sun dried dung cakes are burned for fuel.

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