Khon Kaen-Towards Low Carbon Society

July, 2013

The Joint Graduate School of Energy and Environment (JGSEE),
Center of Excellence on Energy Technology and Environment (CEE-PERDO),
King Mongkut's University of Technology Thonburi (KMUTT), Thailand

Regional Environmental Office 10 (REO 10),
Ministry of Natural Resources and Environment, Thailand

Khon Kaen Province, Thailand

Khon Kaen Municipality, Thailand

Kyoto University (KU), Japan

National Institute for Environmental Studies (NIES), Japan

Asia Pacific Integrated Modeling Team (AIM), Japan

Institute for Global Environmental Strategies (IGES), Japan

Mizuho Information and Research Institute (MHRI), Japan

PREFACE

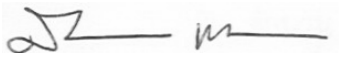
Khon Kaen province is one of the biggest provinces in the Northeast region of Thailand. With its central location of the region, Khon Kaen has planned to develop toward the East –West economic corridor aiming to link four countries, Myanmar, Thailand, Lao PDR, and Vietnam with the Indochina highway. It is interesting to look at the future development of which Khon Kaen itself has declared for the climate change abatement declaration

'Khon Kaen-Towards Low Carbon Society' aims to apply concept of Low Carbon Society (LCS) for provincial scale with an objective to support the Khon Kaen vision in becoming the role model of Low Carbon City for Great Mekong Sub-region (GMS) with the city image of 3H: happiness city, healthy city, and GMS hub.

This study is the collaboration among The Joint Graduate School of Energy and Environment (JGSEE), King Mongkut's University of Technology Thonburi (KMUTT) - Thailand, Kyoto University (KU) - Japan, National Institute for Environmental Studies (NIES) - Japan, Asia-Pacific Integrated Model Team (AIM) - Japan, Institute for Global Environmental Strategies (IGES) - Japan, and Mizuho Information and Research Institute (MHRI) - Japan.

The report contains both quantification of greenhouse gas and the countermeasures collected from the workshop, held on June 18th, 2013. We would like to express our gratitude to Khon Kaen province, Khon Kaen municipality and Khon Kaen local governments for their kind collaboration on data acquisition and their advice during 'Khon Kaen Low Carbon Society Workshop'.

We hope this report is informative and interesting to those who would like to learn more on low carbon society approach.



Sirintornthep Towprayoon

The Joint Graduate School of Energy and Environment
Center of Excellence on Energy and Environment
King Mongkut's University of Technology Thonburi, Bangkok, Thailand

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EXECUTIVE SUMMARY

The purpose of this study is to develop Khon Kaen's low carbon society (LCS) based on the participation of Khon Kaen people. This study estimates emission and removal of greenhouse gas (GHG) in the base year 2005 and projected to the target year 2050, covering 4 main activities; 1) energy consumption, 2) waste management, 3) agriculture, and 4) land use, land use change, and forestry. The emission is projected to year 2050.

Energy consumption activities included industrial sector, passenger transport sector, freight transport sector, commercial sector, and residential sector. The GHG emissions in these activities are estimated and projected by using Extended Snapshot Tool (ExSS)-energy module based on the socio-economic information.

Waste management activities consider only in 31 municipalities in Khon Kaen because of the limitation of the information of the outside of municipality. GHG emissions estimation and projection are calculated by using Extended Snapshot Tool (ExSS)-waste module based on the generated waste rate, the waste management method, and the demographic information.

Agricultural activities include fermentation, manure management, rice cultivation, open burning, and agricultural soil. The estimation of GHG emissions from agricultural activities based on 2006 IPCC guidelines. The emission projection based on relationship between economic and agricultural factors.

For land use, land use change, and forestry activities, this study focuses on the amount of GHG emissions and removal which occurs in the forest land and crop land (perennial crop). So, this study estimate amount of CO_2 removal from the forest land remains forest land and the crop land remains crop land. CO_2 removal projection is based on the current status of the land use and Khon Kaen's plan.

The mitigation options for Khon Kaen's LCS are developed based on the output from the 'Khon Kaen Low Carbon Society Workshop' which held on June 18th, 2013. The finding in the workshop is that Khon Kaen has been doing many activities which can be classified into 4 main grouped based on the strategy of the National Municipal League of Thailand including: STG1.Green City Strategies, STG2.Clean City Strategies, STG3.City of Energy Care Strategies, and STG4.Living Sustainable City Strategies. List of activities for each strategies are summarized as demonstrated in Figure 2. This study used the first three strategies as the mitigation options for Khon Kaen's LCS.

The results of this study are summarized as follow (see figure 1):

I. The net amount of GHG emissions of Khon Kaen in the base year 2005 are approximately 2,372,000 tCO_2eq which emitted 3,040,000 tCO_2eq and removed 669,000 tCO_2eq.

II. Based on socio-economic projection without mitigation plan, the net of GHG emissions in the target year 2050 will increase to 7,525,000 tCO_2eq or 3.2 times of the base year. Take into consideration on the growth rate of GHG emissions by activity; there are 190% increased of energy consumption activities, 156% increased of waste management activities, and 73% increased of agricultural activities. For the removal, it is about 3.5% decreased because of the reduction of the forest area and the reversing of carbon removal rate by the aged forest.

III. GHG emission mitigation activities have potential to reduce GHG emission to 5,870,000 tCO_2eq or 28% decrease from the target year without mitigation plan and the CO_2 removal can be increased to 697,000 tCO_2eq or 10% increment.

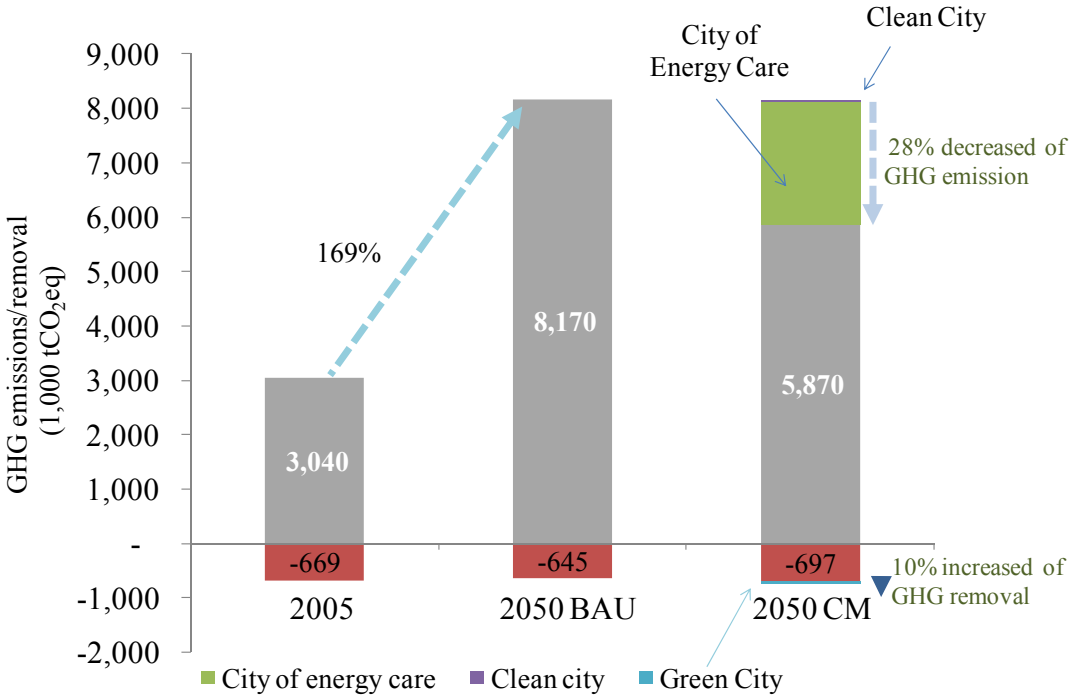


Figure 1 GHG emissions and mitigations by Khon Kaen's LCS scenario

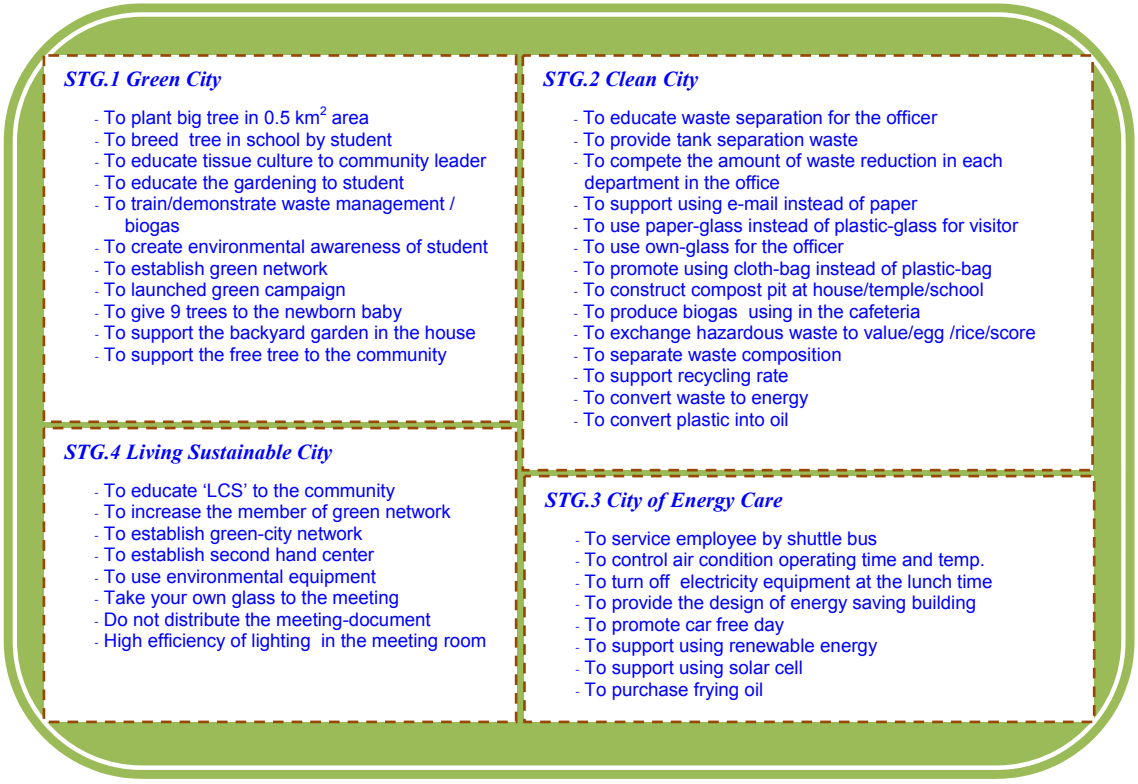


Figure 2 Khon Kaen activities related on GHG emissions mitigation, classified by strategy

ABOUT KHON KAEN

Geography

Khon Kaen is a province, situated in the North-eastern part of Thailand (as called Isaan). It is about 445 kilometers from Bangkok which covers about 10,885 square kilometers (15th of Thailand). Neighboring provinces of Khon Kaen from the north-clockwise direction are Nongbualampoo, Udornthani, Kalasin, Mahasarakam, Buriram, Nakornratchasima, Chaiyapoom and Petchchaboon provinces (as demonstrated in Figure 3). Khon Kaen is the heart of Isaan.

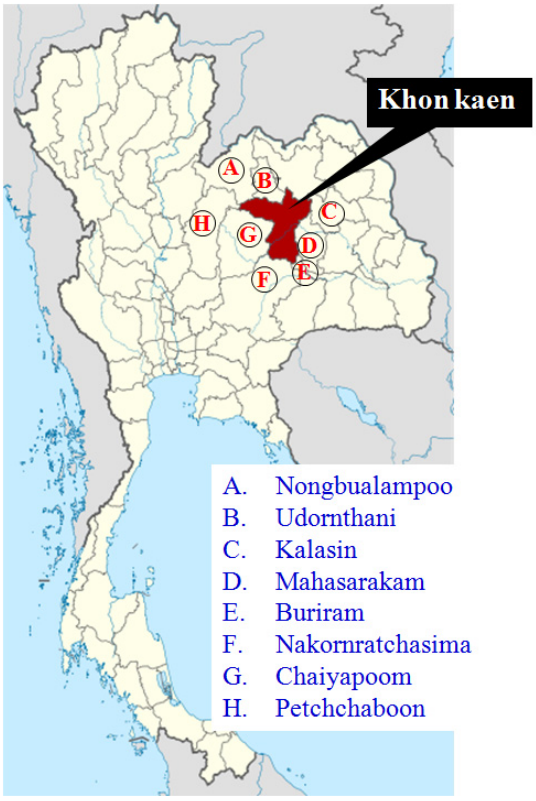


Figure 3 Khon Kaen location

Climate

Khon Kaen has a tropical savanna climate. The average temperature range is 21.8-32.5 degree Celsius. In the summer season, the weather is very hot and about 36 degree Celsius of the average maximum temperature. The average annual rainfall is about 1,214 millimeters.

Demography

Khon Kaen has 1,766,066 populations (record in 2011) which is the 4th largest in Thailand. The density of population is about 160 population/square kilometer which is the 19th in Thailand ranked.

Administrative Division

Khon Kaen is divided into 26 districts (called Amphoe) as demonstrated in Figure 4. District is subdivided into 198 sub-districts (called Tambon) and 2,139 villages.

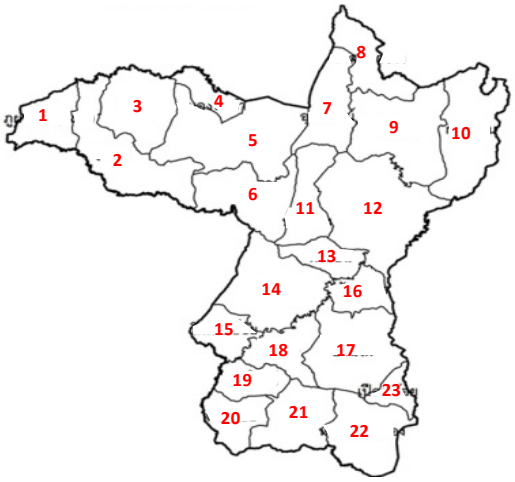


Figure 4 Khon Kaen administrative divisions

Economy

Khon Kaen economy is mainly upon the industrial, commercial, and agricultural sectors. The gross provincial product (GPP) of Khon Kaen has continuously increased since year 2001. In 2011, Khon Kaen GPP at current market price is about 5,176 million US$ (yr 2011), or 12th largest in Thailand and increased by 3% from year 2010. About 11 percent of GPP obtained from the agricultural sectors, and the rest obtained from the non-agricultural sectors. The gross provincial product per capita is 2,729 US$ or 38th in Thailand provinces. Khon Kaen is the strategic location which is the confluence between the north-south and the west-east of Greater Mekong Sub-region economic corridors (see Figure 5).

(Exchange rate: 1 US$ = 30 baht)

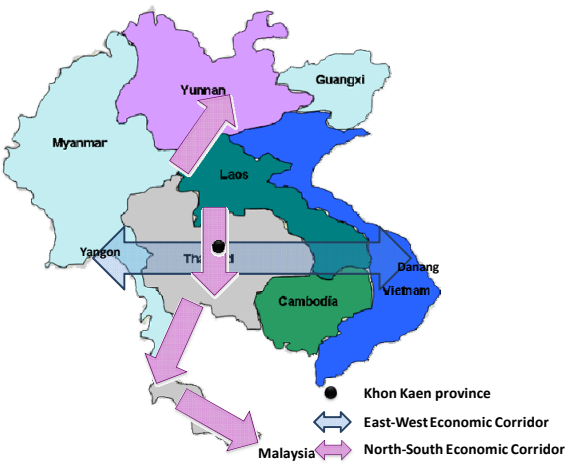


Figure 5 Greater Mekong sub-region economic corridors

Energy Situation

Energy Consumption

Khon Kaen final energy consumption in 2007 was about 955.7 kiloton of oil equivalent (ktoe), which included 70% of oil, 18% of electricity, and 12% of renewable energy. The energy consumption has continuously increased mostly in the form of oil. The energy consumption in 2007 was 45% increased greater than the year 2003 (The final energy consumption in 2003 was about 658 ktoe). Among on the energy consumption activities, 49% of the total was shared by transportation sector, followed by industrial sector (23%), residential sector (12%), agricultural sector (6%), commercial sector (5%), and other sector (4%).

Energy production

In 2007, Khon Kaen produced 234 ktoe of electricity by using 3 main sources: natural gas, hydro, and renewable (bagasse and wood residues). Their shares in power generation are about 77%, 10%, and 9% respectively.

Energy Potential

Khon Kean has an estimated annual potentail of 10,483 ktoe of renewable energy, 76% of the estimated potential from solar energy, 18% from bioenergy, 5% from natural gas, 0.3% from hydro-energy, and 0.2% from bio-gas.

CONCEPT OF LOW CARBON SOCIETY

What is a 'Low Carbon Society'?

A low carbon society (LCS) is a society that has a minimum of GHG emission; bringing the high quality of life. The basic concept of LCS is to reduce or limit the activity that emits GHG emission. The main point of LCS is how to achieve the target of GHG emission reduction. GHG emission reduction is becoming a challenge in many countries. To achieve the country's goal of GHG emission mitigation, it is very important to have supported from local plan.

Principles of LCS [1]

There are 3 basic principles of LCS comprised of

1) Reducing carbon discharge in all sectors
2) Advocating frugality, achieving high-quality life through simpler ways of life, and shifting from a high consumption society to a high-quality society
3) Harmonic coexistence with the nature and maintaining and safeguarding natural environment becoming essential pursuance the human society

Why we need to develop LCS?

The average temperature of the Earth's atmosphere and ocean has increased continuously since the late 19th century. It is caused by the increasing of green house gases (GHGs) concentration as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) by anthropogenic activities for example energy consumption activity, waste management activity, agricultural activity, land use, land use change, and forestry activity, and so on. The global warming leads the climate change such as the rise of sea level and precipitation, and drought in some area which threats the food security. A way to reduce the violent of this problem is LCS pattern. LCS is a way to decrease the amount of GHG emissions emitted to the atmosphere and also enhance the amount of carbon sink. Many nations have set the GHG emissions mitigation strategies. To achieve the national strategy, the collaboration from the local authority is very important.

1 Yang Wenyao, The impact of spatial planning, urban design and built form on urban sustainability, 46th ISOCARP Congress 2010

KHON KAEN'S SOCIO-ECONOMIC IN THE BASE YEAR (YEAR 2005)

Khon Kaen is one of 77 provinces of Thailand which has the 4th largest population in Thailand or about 2.7% of Thailand. The total area of Khon Kaen is about 2.1% of Thailand which is the second largest of the north-eastern region. The forest area is about 12.9%, mostly located in the northwest corner of province. In terms of economy, Khon Kaen's economic is the 12th of Thailand which is about 13 % of the Thailand's income. The base year situation of Khon Kaen province is summarized in Table 1

Table 1 Khon Kaen province situation

	Unit	Khon Kaen	Thailand	% Khon Kaen / Thailand
Population	Million pp	1.8	66.0	2.7%
GPP-GDP Agriculture	Million US$	421.4	28,289.6	1.5%
GPP-GDP Non Agriculture	Million US$	3,376.1	272,969.6	1.2%
Energy consumption	ktoe	955.8	64,886.0	1.5%
Area of province	km^2	10,886.0	513,115.0	2.1%
Forest area	km^2	1,407.0	183,446.0	0.8%
Agricultural area	km^2	7,562.9	288,545.0	2.6%

KHON KAEN'S SOCIO-ECONOMIC PROJECTION IN YEAR 2030 & YEAR 2050

The Khon Kaen's emissions projection in the target year (year 2030 and year 2050) is based on socio-economic assumption as shown in Table 2. Following is the information of the assumption in each indicator.

Table 2 Quantitative assumption of socio-economic in year 2030 and year 2050

Indicator	Growth rate
Demography	
Population	1.01% /year increase
Demographic composition	0-14: 0.99 %, 15-64: 1.00 %, 65+: 1.02 %
Economic	
GPP-primary sector	2.5% /year increase
GPP-secondary sector	5.0% /year increase
GPP-tertiary sector	5.0% /year increase
Transportation	
Trip generation	2.05% /year increase
Modal share of passenger transportation	walk/bike: 7.8%, small vehicle: 77.1%, large vehicle: 0.2%, bus: 14.4%, air 0.26%, train 0.24%,
Land use	
Land use	Forest area 1,406.98 km^2

Demography

Population projections are based on the average increase of population in last 14 years (year 1999-2012). The number of population will increase from 1,747,542 pp in year 2005 to 1,822,869 pp in year 2030 and 1,948,125 pp in year 2050 which increase about 1.01% per year. The average household size will reduce from 3.3 (year 2005) to 2.1 (year 2050).

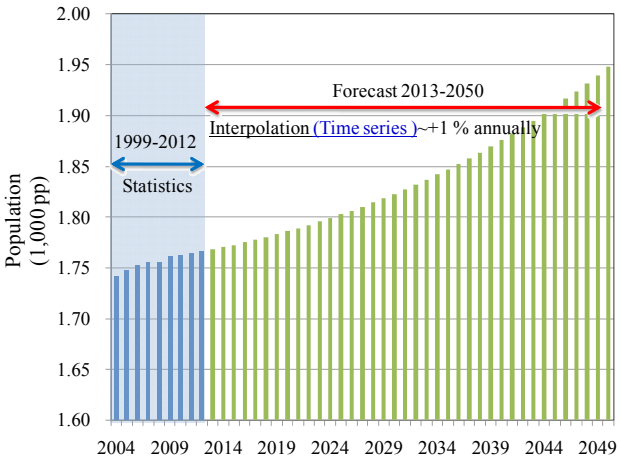


Figure 6 Number of population

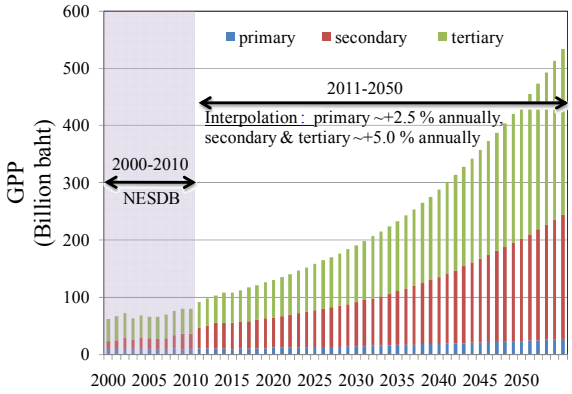


Figure 7 Gross Provincial Product by sectors

Economy

Khon Kaen's Gross Provincial Product (GPP) projections are based on the sub-regional plan of Department of Public Works and Town and Country Planning (DPT). The annual growth rate of Khon Kaen's GPP in primary, secondary, and tertiary sector is about 2.5%, 5.0%, and 5.0% respectively. The Khon Kaen's GPP has continuous increased which reached to more than 120,000 million baht and 500,000 million baht in the year 2030 and 2050 respectively.

Transportation

Khon Kaen's trip generation model was developed by the Office of Transport and Traffic Planning (OTP) and reported that the passenger transport demand will increase from 18,158 million passenger kilometers in year 2005 to 71,665 in year 2030 and 73,214 million passenger kilometers in year 2050. For freight transportation demand, it will increase about 2.1 times from 579 million tons kilometer in year 2005 to 1,143 and 1,219 million tons kilometer in the year 2030, and 2050 respectively.

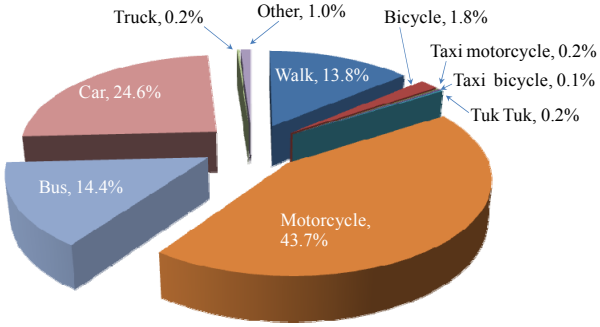


Figure 8 Share of passenger transport in Khon Kaen municipality

Land Use & Land use change

Khon Kaen has total area of 10,886 km^2 which mainly used as agricultural area (73% of total area), followed by forest area and settlement area (13% and 6% of total area respectively). During year 2002 to 2008, the land use in Khon Kaen has been changed; the agricultural area had been decreased about 0.6% while forest land increased by 3.3%.

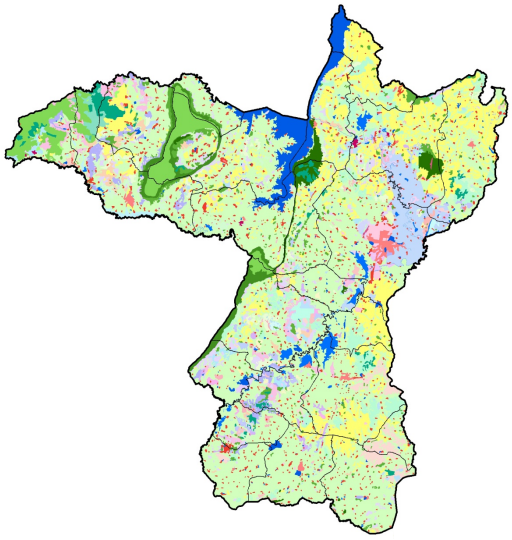


Figure 9 Khon Kaen land use, year 2008

Table 3 Socio-economic indicator for year 2030, and year 2050

	2005	2030	2050	2030/ 2005	2050/ 2005	2050/ 2030
Population *(million pp)*	1.75	1.82	1.95	1.04	1.11	1.07
No. of household *(million hh)*	0.47	0.87	0.93	1.85	1.98	1.07
GPP *(million $US)*	2,933	6,619	8,532	2.26	2.91	1.29
GPP/capita *($US/pp)*	1,678	3,631	4,379	2.16	2.61	1.21
Gross output *(million $US)*	8,830	17,106	24,036	1.94	2.72	1.41
Private consumption *(million $US)*	1,677	6,187	7,933	3.69	4.73	1.28
Government consumption *(million $US)*	340	1,142	2,231	3.36	6.56	1.95
Fixed capital formation *(million $US)*	793	2,740	4,767	3.46	6.01	1.74
Exports *(million $US)*	4,310	6,597	10,694	1.53	2.48	1.62
Imports *(million $US)*	4,188	10,046	17,093	2.40	4.08	1.70
Floor space for commercial *(km^2)*	17	396	223	13.12	17.41	1.33
Passenger transport demand *(million p-km)*	18,158	71,665	73,214	3.95	4.03	1.02
Freight transport demand *(million t-km)*	579	1,143	1,219	1.97	2.11	1.07

GHG EMISSIONS IN THE BASE YEAR & THE TARGET YEAR

This study estimates GHG emission in 4 main activities; energy consumption activities, waste management activities, agricultural activities, and land use, land use change and forestry activities. In the base year (year 2005), the amount of GHG emissions was about 3,040,000 tCO_2eq whereas about 669,000 tCO_2eq of removal. So, the net of GHG emissions in Khon Kaen province was about 2,372,000 tCO_2eq.

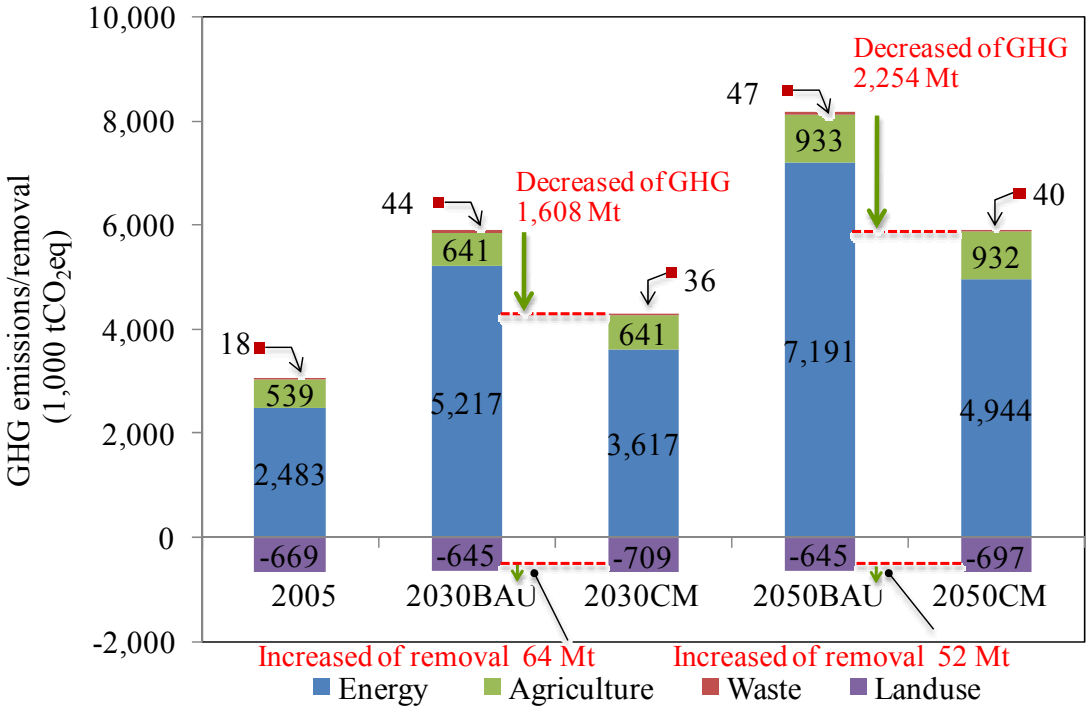


Figure 10 Projections of GHG emissions and removal classified by main activity

The emission projection is based on macro-economic model. In the business as usual (BAU) scenario, the total amount of GHG emissions will continuously increase and reach to 5,902,000 and 8,170,000 tCO_2eq in the year 2030 and 2050 respectively. The amount of removal will be about 645,000 tCO_2eq in the year 2050. The net GHG emissions were projected to increase from 2,372,000 tCO_2eq in 2005 to 5,256,000 and 7,525,000 tCO_2eq in the year 2030 and 2050 respectively. The main source of GHG emission in 2050 is energy consumption activities which takes the account 88% of GHG emissions, followed by agricultural and waste management activities (11% and 1% respectively). Projected GHG emissions and removal classified by the main activity are shown in Figure 10. The comparison of BAU scenario and the countermeasure (CM) scenario, it is expected to reduce the GHG emissions from 5,902,000 to 4,294,000 tCO_2eq in year 2030 and reduce from 8,171,000 to 5,916,000 tCO_2eq in year 2050. It is also expected to enhance the removal from 645,000 to 697,000 tCO_2eq in year 2050. The emission reduction is obtained from the using of bio-fuel in transportation activity, the planting and conservation of forest area in LULUCF activity, and the effective of waste recycle in waste management activity.

Emission from energy-consumption activities

Energy consumption activity comprises of 5 sectors; industrial sector, passenger transport sector, freight transport sector, commercial sector, and residential sector. Based on the macro-economic model, the total energy consumption was projected to increase from 665 ktoe in year 2005 to 1,505 ktoe in year 2030 and 2,462 ktoe in year 2050 and caused a rise of GHG emission from 2,483,000 tCO_2eq to 5,216,000 tCO_2eq in year 2030 and 7,191,000 tCO_2eq in year 2050. Transportation sector has the largest share of 45% of total energy consumption, followed by industrial sector (31%), commercial sector (16%), and residential (8%) as shown in Figure 11. In terms of the growth rate, commercial sector has the highest growth rate (about 6 times of the base year) followed by industry (3 times), transport (2.1 times), and residential (1.9 times). (See Figure 12)

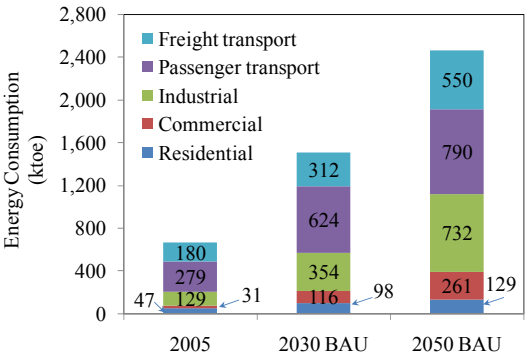


Figure 11 Energy consumption

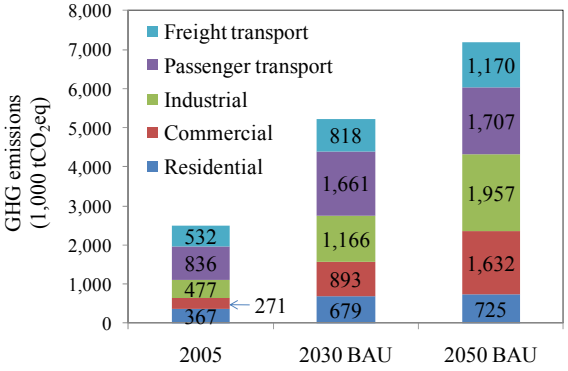


Figure 12 GHG emissions from energy consumption activities

Emission from waste management activities

In 2005, the average daily amount of waste generated in Khon Kaen was about 0.85 kilograms per person. Only 90% of generated waste was sent to landfill. In the landfill, the waste was separated and recycled by 12% (including paper, plastic, and glass). The GHG emission is projected to increase from 18,000 tCO_2eq to 43,800 tCO_2eq in year 2030 and 47,000 tCO_2eq in year 2050.

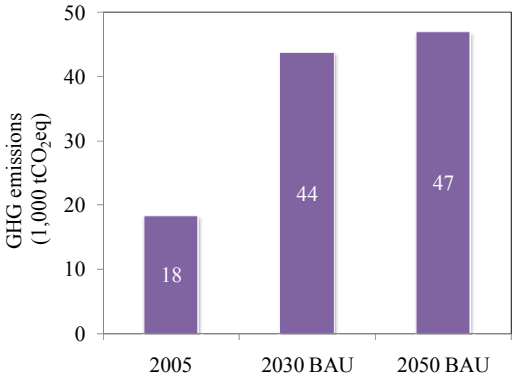


Figure 13 GHG emissions from waste management activities

Emission from agricultural activities

Agricultural activity comprises of 5 sectors; livestock sector, manure management sector, rice cultivation sector, open burning sector, and agricultural soil sector. In agricultural soil, it emits N_2O from incorporation of fertilization and crop residues into the soil. The GHG emission is projected to increase from 539,000 tCO_2eq to 641,000 tCO_2eq in year 2030 and 932,000 tCO_2eq in year 2050. Enteric fermentation has the largest share of 76% of GHG emissions from agricultural activities, followed by manure management (10%), biomass open burning (7%), and agricultural soil due to N fertilization (6%).

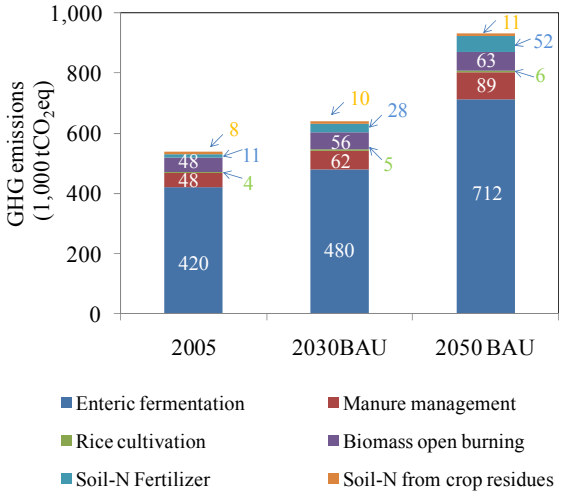


Figure 14 GHG emissions from agricultural activities

Emission from land use, land use change, and forestry (LULUCF)

Growth of tree and perennial crops absorb CO_2 from the atmosphere and store carbon in the root. In Khon Kaen, the total area of forest and perennial crop had slightly decreased until 2010, after 2010, it is assumed to be constant and removed CO_2 is about 645,000 tCO_2eq annually.

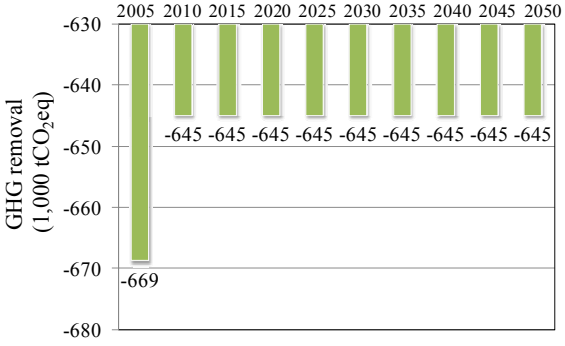


Figure 15 GHG removals from LULUCF activities

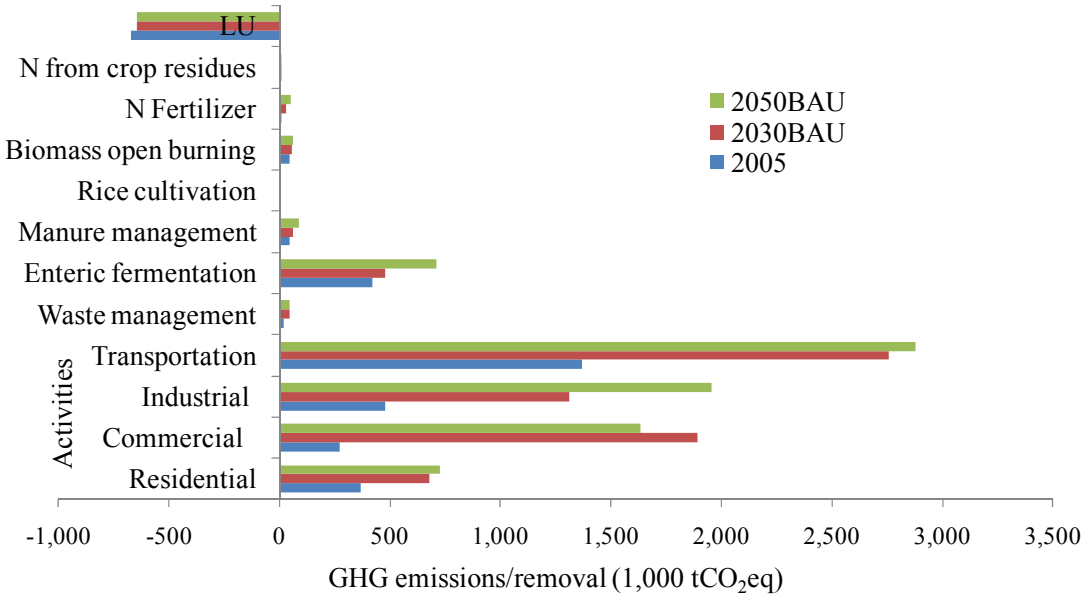


Figure 16 Projection of GHG emissions and removal classified by sector

STRATEGIES TOWARD LOW CARBON SOCIETY SCENARIOS FOR YEAR 2030 & YEAR 2050

Khon Kaen's potential to be a 'LCS'

Provinces have an important role in driving towards a national emission reduction target. Khon Kaen is one of the provinces that emphasizes global warming problem. Khon Kaen has set the 'green vision' and has the roadmap to low carbon city since 2009 to support Khon Kaen's declaration on 'Climate Change Adaptation and Mitigation 2020'. Moreover, Khon Kaen is supported to be a prototype of 'Green Eco City' by Office of Natural Resources and Environmental Policy and Planning, Ministry of Natural Resources and Environment. Khon Kaen has established the 'Khon Kaen Green City network' by collaboration of public and private section. Khon Kaen has a high potential to be a 'green eco city' because of the strong citizens participation in Khon Kaen.

Khon Kaen Vision

'To be the coolest and happiest place to live in the world within 2020 &
To be the model of low carbon city in Mekong Region'

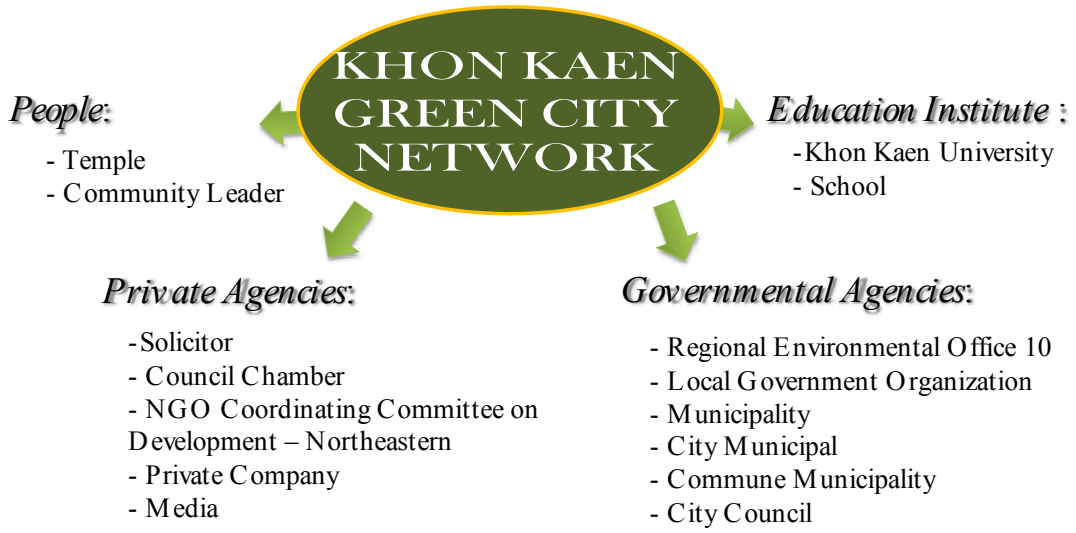
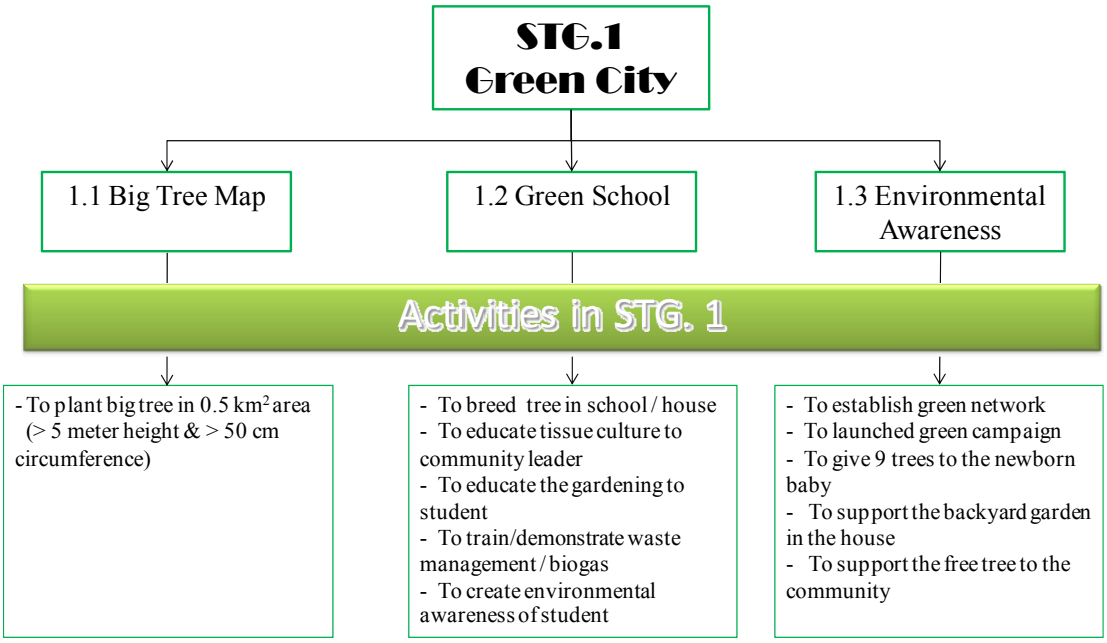


Figure 17 Members of Khon Kaen Green City Network

Local people actions to approach Khon Kaen LCS

Public and private collaboration (governmental and private offices/institution/mass media/temple/community) in Khon Kaen has been a key driver to approach '*Khon Kaen LCS'*. Khon Kaen has been doing many activities based on the 4 strategies to approch *'Low Carbon City'*of The National Municipal League of Thailand including: Strategy 1. Green City, Strategy 2. Clean City, Strategy 3. City of Energy Care, and Strategy 4. Living Sustainable City. The information of each strategy is shown in the following:

Strategy 1: Green City: To maintin the existing green land and expand the new green space

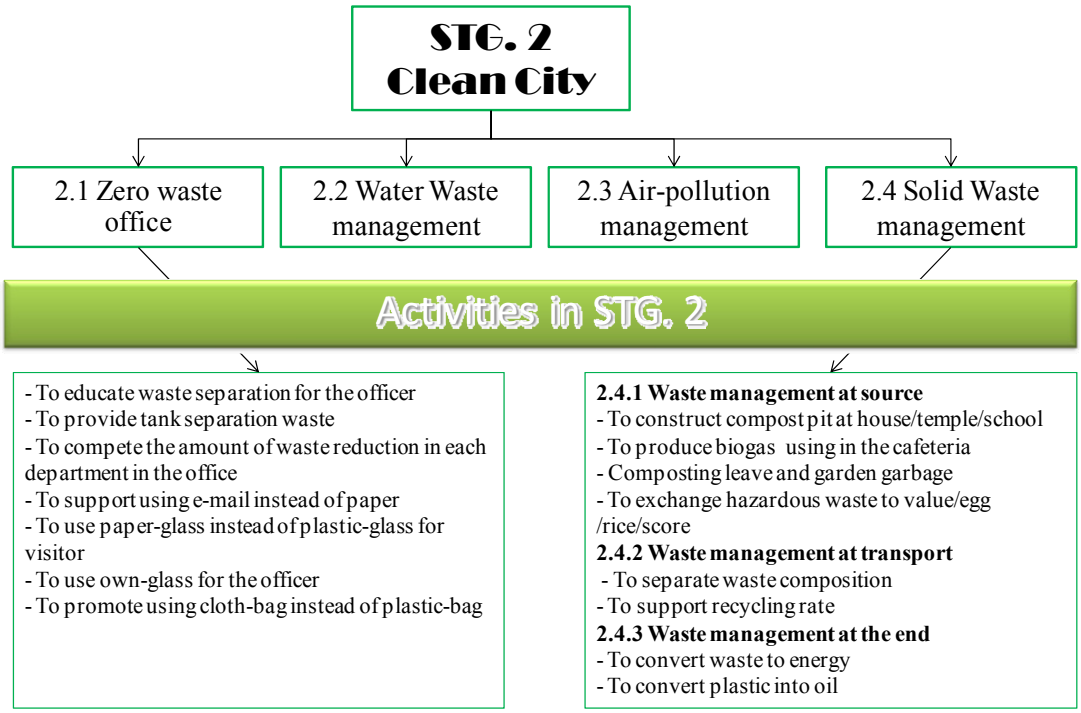


Big Tree

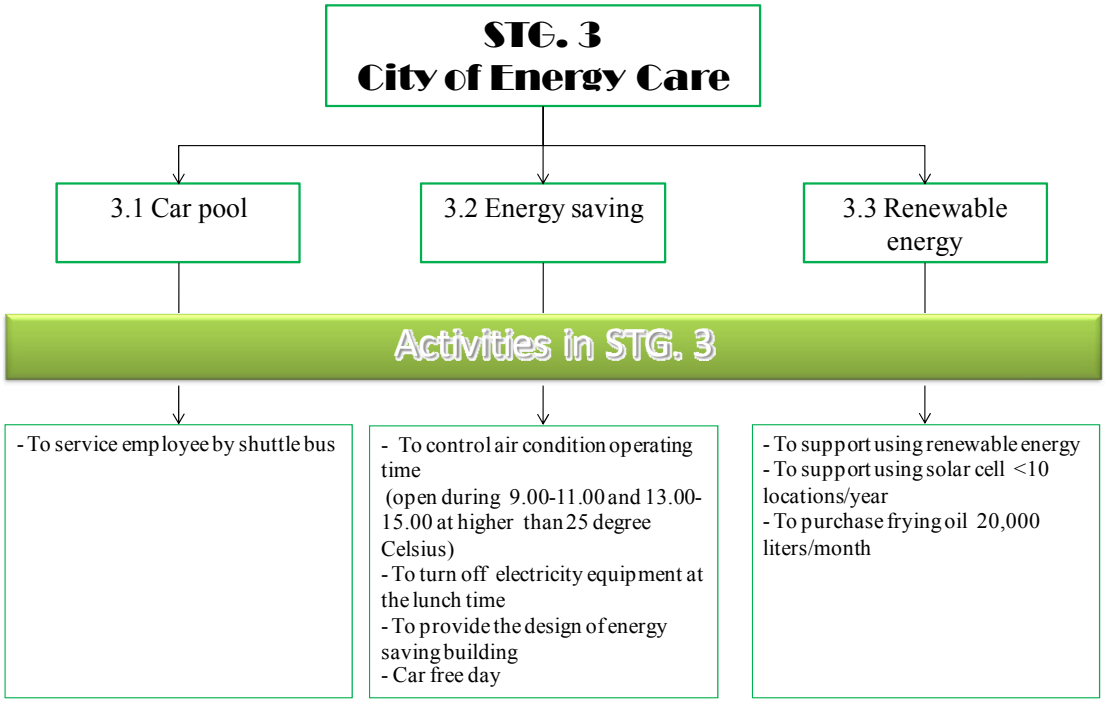
Green School

Environmental Awareness

Strategy 2: Clean City: To become the land of zero waste by integrated waste management



Strategy 3: City of Energy Care: To become the social of green power by reducing the oil consumption whereas increasing the green energy consumption



Strategy 4: Living Sustainable City: To become the city of eco-friendly

Zero Waste Office

Potential of GHG emission mitigation in year 2030 & year 2050

3 strategies toward '2050 Khon Kaen's LCS' are developed from the activities by the local people. The 3 strategies have potential to reduce the net of GHG emissions in Khon Kaen by 31% or reduce from 7,525,000 tCO_2eq to 5,173,000 tCO_2eq.

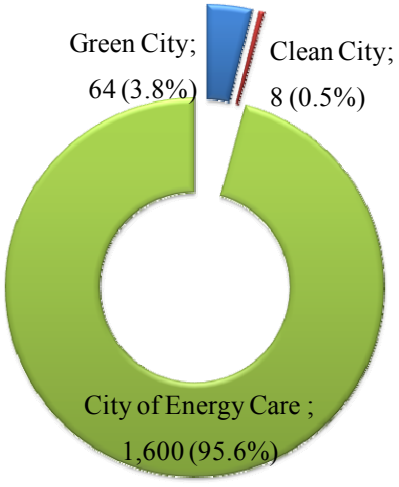


Figure 18 Percentage of GHG emissions mitigation by strategy in year 2030

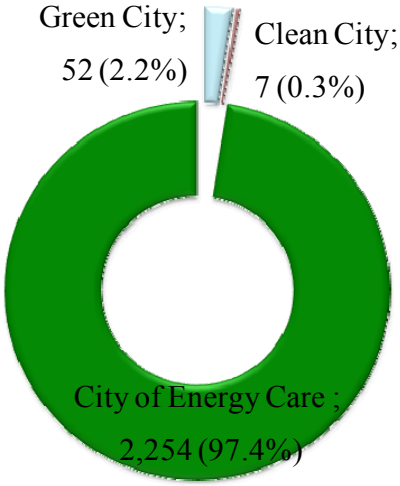


Figure 19 Percentage of GHG emissions mitigation by strategy in year 2050

Strategy 1: Green City

The activities in 'Green City' are mostly related on increasing of green space. This scenario assumes:

- ✓ Year 2015 *(Launch of Planting & Conservation Campaign)*: Planting and continuous maintenance of big trees in 50% of degraded forest land (~100 km^2)
- ✓ Year 2030 Planting & Conservation: Planting and continuous maintenance of big trees in 100% of degraded forest land (~ 200 km^2)
- ✓ Year 2030-2050 Planting & Conservation: Conservative all of forest land

The amount of removal from LULUCF activities in BAU year 2050 is estimated to be about 645,000 tCO_2eq. If Khon Kaen achieves 'Green City scenario', it is expected to increase about 52,000 tCO_2eq removal or nearly about 10% increase of sink from LULUCF activities.

Strategy 2: Clean City

The activities in 'Clean City' relate on the control of generated waste and the increase of recycled waste. This scenario assumes:

- ✓ Year 2015 *(Launch of Recycling campaign)*: increasing the recycling rate to 15% of generated waste
- ✓ Year 2030 Recycling: increasing the recycling rate to 30% of generated waste
- ✓ Year 2050 Recycling: Keeping the recycling rate at 30% of generated waste

The amount of GHG emissions from waste management activities in BAU year 2050 is estimated to be about 47,000 tCO_2eq. If Khon Kaen achieves 'Clean City Strategy', it is expected to reduce GHG emissions about 7,000 tCO_2eq or about 15% reductions of GHG emissions from waste management activities.

Strategy 3: City of Energy Care

The activities in 'City of Energy Care' relate on the reduction of energy consumption and the enhancement of renewable energy. This scenario assumes:

- ✓ Year 2015 *(Launch of campaign)*:
  - *Modal shifting*: Share of private car transportation demand in the Khon Kaen municipality is reduced by 10%.
  - *Fuel Switching*: Share of bio-fuel in passenger and freight transportations are increased by 10%
- ✓ Year 2030:
  - *Modal shifting*: Share of private car transportation demand in the Khon Kaen municipality is reduced by 50%.
  - *Fuel Switching*: Share of bio-fuel in passenger and freight transportations are increased by 50%
- ✓ Year 2050:
  - *Modal shifting*: Keeping the share of private car transportation as year 2030
  - *Fuel Switching*: Keeping the share of bio-fuel in passenger and freight transportation as year 2030

The amount of GHG emissions from energy consumption activities in BAU year 2050 is estimated to be about 7,191,000 tCO_2eq. If Khon Kaen achieves 'City of Energy Care Strategy', it is expected to reduce GHG emissions about 2,200,000 tCO_2eq or about 31% reductions of GHG emissions from energy consumption activities.

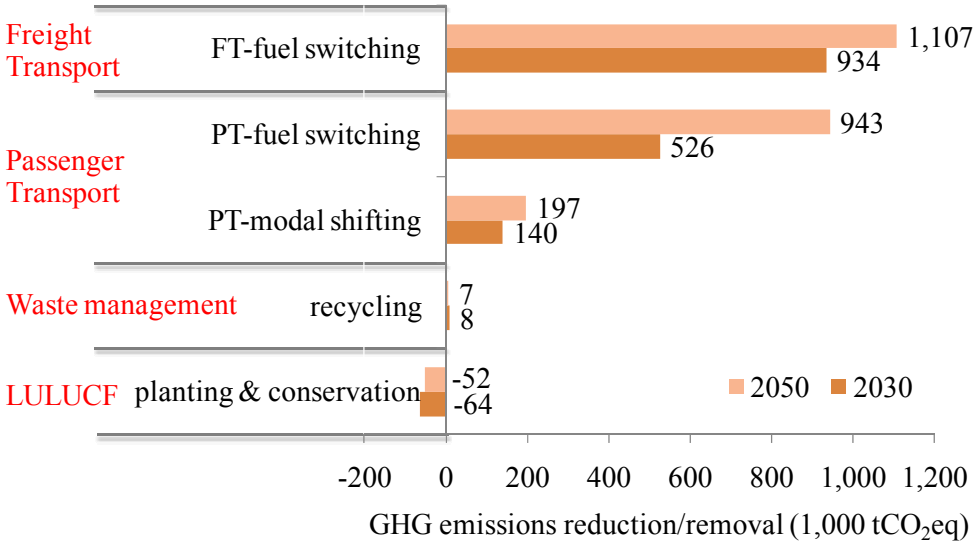


Figure 20 Potential of each mitigation option

Table 4 Summary of Khon Kaen's LCS plan, year 2050

Emission Mitigation Plan	GHG Reduction (1,000 tCO_2eq)	% GHG emission reduction/removal
1. Green City		
- Planting & Conservation	52.3 [a]	
2. Clean City		
- Recycling	7.5	
3. City of Energy Care		
- Modal shifting in passenger transport	196.7	
- Fuel switching in passenger transport	943.1	
- Fuel switching in freight transport	1,107.0	
Emission reduction from (BAU Year 2050)	**2,254.3**	**28%**
Removal increase from (BAU Year 2050)	**52.3**	**10%**
Total GHG emission (CM Year 2050)	**5,870**	
Total removal (CM Year 2050)	**697**	
Net emission (CM Year 2050)	**5,173**	

Remark: [a] the amount of removal of CO_2eq in the atmosphere

APPENDICES

METHODOLOGY

In order to create a local low-carbon society scenario, we developed a methodology based on the idea of "back casting", which sets a desirable goal first, and then seeks a way to achieve it. Figure 21 shows an overview of the method.

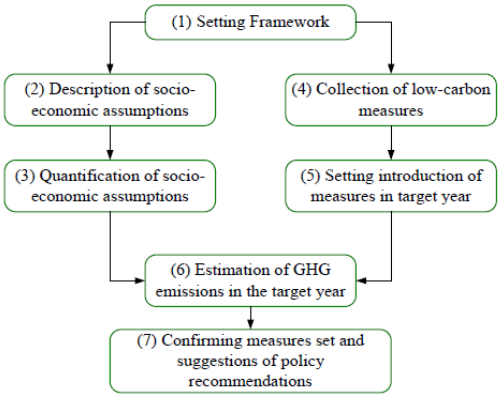


Figure 21 Procedure to create LCS scenarios

(1) Setting framework
The framework of an LCS scenario includes target area, base year, target year, environmental target, and number of scenarios. Among them, the base year is compared with the target year. The target year should be far enough to realize a required change, and near enough for the people in the region to imagine the vision.

(2) Assumptions of socio-economic situations
Before conducting quantitative estimation, a qualitative future image should be written. It is an image of lifestyle, economy and industry, land use, and so on.

(3) Quantification of socio-economic assumptions
To estimate a snapshot based on a future image of (2), values of exogenous variables and parameters are set. Using those inputs, ExSS calculates socio-economic indices of the target year such as population, GDP, output by industry, transport demand, and so on.

(4) Collection of low-carbon measures
Counter measures, which are thought to be available in the target year, for example, high energy-efficiency devices, transport structure such as public transport, use of renewable energy, energy saving behavior, and carbon sinks are used. Technical data are required to estimate the effects of the counter measures to reduce GHG emissions.

(5) Setting introduction of counter measures
Technological parameters related to energy demand and CO_2 emissions, in short energy efficiency, are defined. Since there can be various portfolios of the measures, one must choose appropriate criteria. For example, cost minimization, acceptance to the stakeholders, or probability of technological development.

(6) Estimation of GHG emission in the target year
Based on socio-economic indices and assumption of measures, GHG emissions in the target year are calculated.

(7) Proposal of policies
A policy is set to introduce the measures defined. Available policies depend on the situation of the municipality or the country in which it belongs. ExSS can calculate emission reduction from each counter measure.
Therefore, it can show reduction potential of countermeasures, which especially need a supportive local policy. It can also identify measures, which have high reduction potential and therefore are important.

Quantitative estimation tool 'extended snapshot tool'

Figure 22 shows the structure of the Extended Snapshot Tool (ExSS): seven blocks with input parameters, exogenous variables and variables between modules. ExSS is a system of simultaneous equations. Given a set of exogenous variables and parameters, solution is uniquely defined. In this simulation model, only CO_2 emission from energy consumption is calculated, even though, ExSS can be used to estimate other GHG and environmental loads such as air quality. In many LCS scenarios, exogenously fixed population data are used. However, people migrate more easily, when the target region is relatively a smaller area such as a state, district, city or town. Population is decided by demand from outside of the region, labor participation ratio, demographic composition and relationship of commuting with the outside of the region. To determine output of industries, an input-output approach with "export-base approach" is combined in line with the theory of regional economics.
Industries producing export goods are called "basic industry". Production of basic industries induces other industries i.e. non-basic industries, through demand of intermediate input and consumption of their employees. The

number of workers must fulfill labor demand of those industries. Given assumptions of where those workers live and labor participation ratio, population living in the region is computed. This model enables us to consider viewpoints of regional economic development to estimate energy demand and CO_2 emissions. For future estimation, assumption of export value is especially important if the target region is thought to (or, desired to) develop led by a particular industry, such as automotive manufacturing.

Passenger transport demand is estimated from the population and freight transport demand, whereby it is a function of output by manufacturing industries. Floor area of commerce is determined from output of tertiary industries. With driving force and activity level of each sector, energy demand by fuels is determined with three parameters. These parameters are energy service demand per driving force, energy efficiency and fuel share.

Diffusion of counter measures changes the value of these parameters, and so changes the GHG emissions.

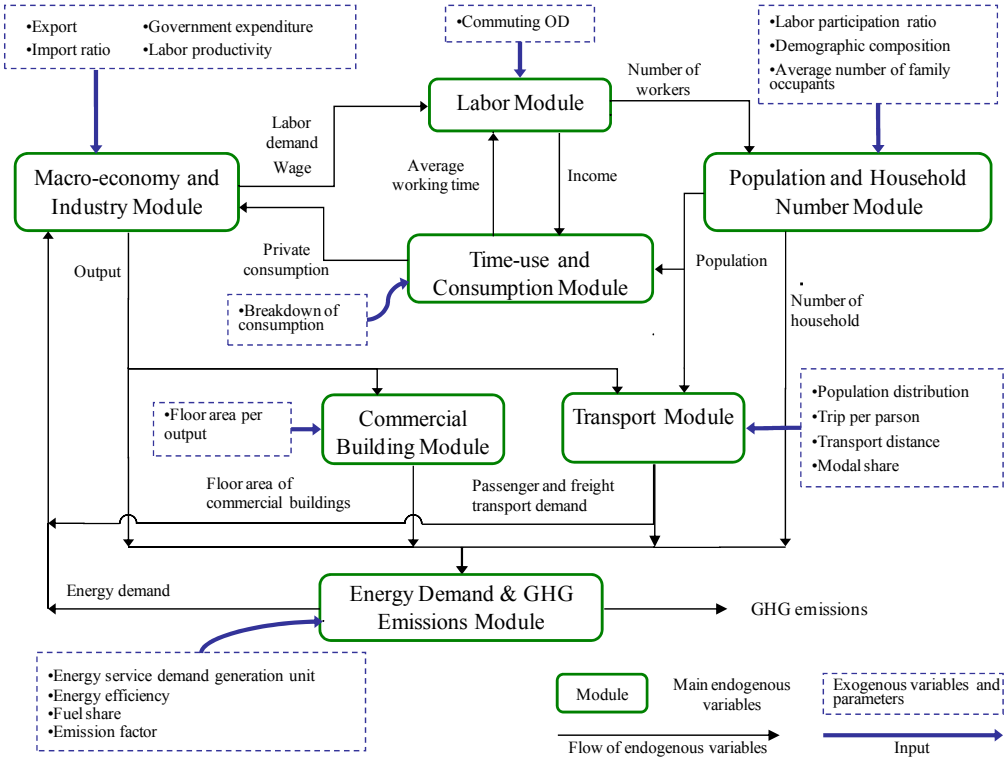


Figure 22 Overview of calculation system of Extended Snapshot Tool-Energy module

GHG Emission Estimation Methodology

To develop Khon Kaen's low-carbon society scenarios, we set a frame work of scenario which included target area: Khon Kaen, base year: 2005, target year: 2030 and 2050, environmental target: emission from energy consumption activities, waste management activities, agricultural activities, LULUCF activities, and counter measures (CM) that possible in the target year . Counter measures are based on the activities that local people have done so far. Then estimate emissions in the base year, the target year without CM, and the target year with CM.

Emission from energy consumption activities

Energy consumption activities in this study include industrial sector, passenger transport sector, freight transport sector, commercial sector, and residential sector. The GHG emissions in energy activities are estimated from ExSS-energy module (as shown in Figure 22). The projection of emissions in the target

year is based on socio-economic indicators as population, GPP, GDP, output of industry, transportation demand, and so on.

Emission from waste management activities
This study focuses only waste management activity in 31 municipalities in Khon Kaen. The GHG emissions are estimated from ExSS-waste module (as shown in Figure 23). The projection of emissions in the target year is based on the rate of generated waste and the growth rate of population.

Emission from agricultural activities
Agricultural activities include enteric fermentation, manure management, rice cultivation, open burning, and agricultural soil (N-fertilizer and agricultural residues). The GHG emissions in agricultural activities are estimated from 2006 IPCC Guidelines. The projection of emissions in the target year is based on the relationship between GPP-agricultural sector and the agricultural factors as the amount of animal, crop area, production, and fertilization.

Emission from LULUCF activities
LULUCF focuses only on the forest land remains forest land and crop land remains crop land (perennial crop). The projection of emissions in the target year is based on Khon Kaen land use and Khon Kaen's plan.

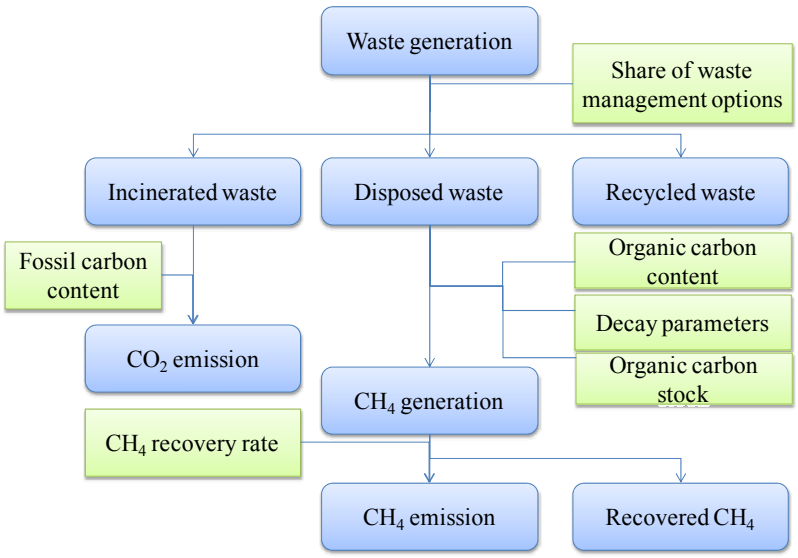


Figure 23 Overview of calculation system of Extended Snapshot Tool-Waste module

SOURCE OF INPUT AND BASE DATA

Table 5 Information Source

Sector	Data	Source
Demography	No of household	National statistical office Thailand (NSO)
	No of population	National statistical office Thailand (NSO)
	Type of living quarters	National statistical office Thailand (NSO)
Economy	Thailand GDP	National economic and social development board (NESDB)
	Thailand IO table	National economic and social development board (NESDB)
	Khon Kaen GPP	National economic and social development board (NESDB)
Building	Commercial area	Land development department (LDD)
Passenger transport	Khon Kaen trip generation	Office of Transport and Traffic Policy and Planning (OTP)
	Khon Kaen mode share	Office of Transport and Traffic Policy and Planning (OTP)
	Khon Kaen O-D table	Office of Transport and Traffic Policy and Planning (OTP)
	Khon Kaen travel time	Office of Transport and Traffic Policy and Planning (OTP)
	Khon Kaen travel distance	Office of Transport and Traffic Policy and Planning (OTP)
	Khon Kaen trip generation	Office of Transport and Traffic Policy and Planning (OTP)
	Growth rate of trip generation	Office of Transport and Traffic Policy and Planning (OTP)
Freight transport	Thailand freight transportation classified by product	National statistical office Thailand (NSO)
	Khon Kaen freight share	Sub-Regional plan, Department of Public Work and Town & Country Planning
	Khon Kaen freight	Sub-Regional plan, Department of Public Work and Town & Country Planning
Energy	Thailand electricity consumption classified by sector and fuel	Department of Alternative Energy Development and Efficiency (DEDE)
	Thailand electricity flow chart	Department of Alternative Energy Development and Efficiency (DEDE)
	Thailand energy consumption classified by sector	Department of Alternative Energy Development and Efficiency (DEDE)
	Khon Kaen energy consumption	Provincial Energy Agency (PEA)
Agriculture	Khon Kaen Agricultural Area	Office of Agricultural Economic (OAE)
	Khon Kaen Agricultural Product	Office of Agricultural Economic (OAE)
	Khon Kaen Livestock Product	Office of Agricultural Economic (OAE)
	Fertilization for rice cultivation	Office of Agricultural Economic (OAE)
	Water management of rice	Office of Agricultural Economic (OAE)
	Residue to product ratio (RPR)	Department of Alternative Energy Development and Efficiency (DEDE)

Sector	Data	Source
	Biomass load (BL)	Cheewaphongphan P., and Garivait S. 2013 : Bottom up Approach to Estimate Air Pollution of Rice Residue Open Burning in Thailand, *Asia-Pacific J. Atmos. Sci.*, **49** (2), 139-149.
	Rice residue utilization	Cheewaphongphan P., and Garivait S. 2013 : Bottom up Approach to Estimate Air Pollution of Rice Residue Open Burning in Thailand, *Asia-Pacific J. Atmos. Sci.*, **49** (2), 139-149.
	Rice residue open burning	Cheewaphongphan P., and Garivait S. 2013 : Bottom up Approach to Estimate Air Pollution of Rice Residue Open Burning in Thailand, *Asia-Pacific J. Atmos. Sci.*, **49** (2), 139-149.
Land use	Khon Kaen land use data (GIS)	Land development department (LDD)
	Khon Kaen land use 2002	Sub-Regional plan, Department of Public Work and Town & Country Planning
	Khon Kaen land use 2008	Sub-Regional plan, Department of Public Work and Town & Country Planning
	Average annual net increment in volume suitable for industrial processing	Intergovernmental Panel on Climate Change (2006 IPCC Guidelines)
	Basic wood density	Intergovernmental Panel on Climate Change (2006 IPCC Guidelines)
	Biomass Expansion factor for conversion of annual net increment (including bark) to above ground tree biomass increment	Intergovernmental Panel on Climate Change (2003 IPCC Guidelines)
	Root-shoot ratio appropriate to increments	Intergovernmental Panel on Climate Change (2006 IPCC Guidelines)
	Carbon fraction of dry matter	Intergovernmental Panel on Climate Change (2003 IPCC Guidelines)
	Annually extracted volume of round wood	Department of National Park Wildlife and Plant conservation, 2007
	Biomass expansion factor for converting volumes of extracted round wood to total AGB	Intergovernmental Panel on Climate Change (2003 IPCC Guidelines)
	Fraction of biomass left to decay in forest	Intergovernmental Panel on Climate Change (2003 IPCC Guidelines)
	Average biomass stock of forest areas	Intergovernmental Panel on Climate Change (2006 IPCC Guidelines)
EF-Coefficient	Carbon content of fuel	Intergovernmental Panel on Climate Change (2006 IPCC Guidelines)
	EF from manure management	Intergovernmental Panel on Climate Change (2006 IPCC Guidelines)
	EF from livestock	Intergovernmental Panel on Climate Change (2006 IPCC Guidelines)
	EF of N_2O from soil	Intergovernmental Panel on Climate Change (2006 IPCC Guidelines)
	EF of CO_2, CO, $PM_{2.5}$ from agricultural open burning	Kanokkanjana, K., and S. Garivait, 2010: Emission Factors of Particulate Matter Emission from Rice Field Residues Open Burning in Thailand, Proc., Climate Thailand Conf., Nonthaburi, Thailand, 512-527.

Sector	Data	Source
	EF of CH_4, N_2O from agricultural open burning	Andreae, M. O., and P. Merlet, 2001: Emission of trace gases and aerosols from biomass burning. *Global Biogeochem*., **15**, 955-966.
Plan	Khon Kaen plan Khon Kaen activities to approach KK's LCS	Khon Kaen plan 2011-2014 'Khon Kaen Low Carbon Society Workshop'

Table 6 Energy consumption of Khon Kaen, year 2005 (unit: ktoe)

	Coal	Oil	Gas	Biomass	Electric	Total	% of all sectors
Transport	**0.0**	**428.2**	**30.1**	**0.7**	**0.0**	**459.0**	**68.9**
Passenger transport	0.0	269.0	9.0	0.7	0.0	278.8	41.9
Freight transport	0.0	159.1	21.1	0.0	0.0	180.2	27.1
Residential	**0.0**	**0.0**	**11.1**	**0.0**	**36.0**	**47.0**	**7.1**
Industry	**0.0**	**29.0**	**5.2**	**54.5**	**39.8**	**128.5**	**19.3**
Agriculture	0.0	1.1	0.5	0.0	4.2	5.8	0.9
Mining and quarrying	0.0	3.2	0.6	0.0	5.1	8.9	1.3
Food manufacturing	0.0	1.7	0.3	36.8	2.7	41.6	6.2
Textile Industry	0.0	1.2	0.2	0.0	1.9	3.4	0.5
Saw mill and wood products	0.0	0.2	0.0	4.1	0.3	4.7	0.7
Paper industries and printing	0.0	0.6	0.1	0.0	0.9	1.6	0.2
Rubber chemical and petroleum	0.0	4.9	1.2	0.0	7.9	14.0	2.1
Non metallic product	0.0	0.6	0.1	13.6	1.0	15.4	2.3
Metal, metal product and machinery	0.0	14.8	1.8	0.0	14.5	31.0	4.7
Other manufacturing products	0.0	0.8	0.2	0.0	1.3	2.3	0.3
Commercial	**0.0**	**1.8**	**1.8**	**0.0**	**27.5**	**31.2**	**4.7**
Public utilities	0.0	1.7	0.4	0.0	15.8	17.9	2.7
Construction	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Trade	0.0	0.0	0.5	0.0	4.1	4.6	0.7
Transportation and communication	0.0	0.0	0.4	0.0	2.8	3.1	0.5
Service	0.0	0.0	0.6	0.0	4.4	4.9	0.7
Unclassified	0.0	0.0	0.0	0.0	0.4	0.4	0.1
All sector	**0.0**	**459.0**	**48.2**	**55.2**	**103.3**	**665.7**	**100.0**

Table 7 Energy consumption of Khon Kaen, BAU year 2030 (unit: ktoe)

	Coal	Oil	Gas	Biomass	Electric	Total	% of all sectors
Transport	**0.0**	**872.6**	**63.2**	**0.3**	**0.0**	**936.0**	**62.2**
Passenger transport	0.0	566.0	58.0	0.0	0.0	624.0	41.5
Freight transport	0.0	306.6	5.2	0.3	0.0	312.0	20.7
Residential	**0.0**	**0.0**	**23.1**	**0.0**	**74.9**	**98.0**	**6.5**
Industry	**0.0**	**108.7**	**17.6**	**91.1**	**136.7**	**353.9**	**23.5**
Agriculture	0.0	3.6	1.8	0.0	13.9	19.2	1.3
Mining and quarrying	0.0	14.1	2.9	0.0	22.7	39.6	2.6
Food manufacturing	0.0	2.6	0.5	56.5	4.2	63.8	4.2
Textile Industry	0.0	1.6	0.3	0.0	2.5	4.5	0.3
Saw mill and wood products	0.0	0.3	0.1	6.3	0.5	7.2	0.5
Paper industries and printing	0.0	0.1	0.0	0.0	0.2	0.3	0.0
Rubber chemical and petroleum	0.0	7.4	1.8	0.0	11.9	21.0	1.4
Non metallic product	0.0	1.3	0.3	28.3	2.1	31.9	2.1
Metal, metal product and machinery	0.0	73.6	9.1	0.0	72.1	154.9	10.3
Other manufacturing products	0.0	4.1	0.8	0.0	6.6	11.5	0.8
Commercial	**0.0**	**0.7**	**12.4**	**0.0**	**102.9**	**116**	**7.7**
Public utilities	0.0	0.7	0.1	0.0	6.4	7.2	0.5
Construction	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Trade	0.0	0.0	1.0	0.0	7.6	8.6	0.6
Transportation and communication	0.0	0.0	1.1	0.0	8.9	10.0	0.7
Service	0.0	0.0	10.1	0.0	79.4	89.5	6.0
Unclassified	0.0	0.0	0.1	0.0	0.5	0.6	0.0
All sector	**0.0**	**982.0**	**116.3**	**91.4**	**314.5**	**1,503.9**	**100.0**

Table 8 Energy consumption of Khon Kaen, CM year 2030 (unit: ktoe)

	Coal	Oil	Gas	Biomass	Electric	Total	% of all sectors
Transport	**0.0**	**643.0**	**27.0**	**110.9**	**0.0**	**780.9**	**57.9**
Passenger transport	0.0	571.7	15.3	21.6	0.0	608.6	45.1
Freight transport	0.0	71.3	11.7	89.3	0.0	172.3	12.8
Residential	**0.0**	**0.0**	**23.1**	**0.0**	**74.9**	**98.0**	**7.3**
Industry	**0.0**	**108.7**	**17.6**	**91.1**	**136.7**	**353.9**	**26.2**
Agriculture	0.0	3.6	1.8	0.0	13.9	19.2	1.4
Mining and quarrying	0.0	14.1	2.9	0.0	22.7	39.6	2.9
Food manufacturing	0.0	2.6	0.5	56.5	4.2	63.8	4.7
Textile Industry	0.0	1.6	0.3	0.0	2.5	4.5	0.3
Saw mill and wood products	0.0	0.3	0.1	6.3	0.5	7.2	0.2
Paper industries and printing	0.0	0.1	0.0	0.0	0.2	0.3	0.0
Rubber chemical and petroleum	0.0	7.4	1.8	0.0	11.9	21.0	1.6
Non metallic product	0.0	1.3	0.3	28.3	2.1	31.9	2.4
Metal, metal product and machinery	0.0	73.6	9.1	0.0	72.1	154.9	11.5
Other manufacturing products	0.0	4.1	0.8	0.0	6.6	11.5	0.9
Commercial	**0.0**	**0.7**	**12.4**	**0.0**	**102.9**	**116**	**8.6**
Public utilities	0.0	0.7	0.1	0.0	6.4	7.2	0.5
Construction	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Trade	0.0	0.0	1.0	0.0	7.6	8.6	0.6
Transportation and communication	0.0	0.0	1.1	0.0	8.9	10.0	0.7
Service	0.0	0.0	10.1	0.0	79.4	89.5	6.6
Unclassified	0.0	0.0	0.1	0.0	0.5	0.6	0.0
All sector	**0.0**	**752.4**	**80.1**	**202**	**314.5**	**1,348.8**	**100.0**

Table 9 Energy consumption of Khon Kaen, BAU year 2050 (unit: ktoe)

	Coal	Oil	Gas	Biomass	Electric	Total	% of all sectors
Transport	**0.0**	**1,274.9**	**64.3**	**0.7**	**0.0**	**1,339.9**	**54.4**
Passenger transport	0.0	776.0	13.1	0.7	0.0	789.9	32.1
Freight transport	0.0	498.8	51.2	0.0	0.0	550.5	22.3
Residential	**0.0**	**0.0**	**30.4**	**0.0**	**98.6**	**129.0**	**5.2**
Industry	**0.0**	**238.7**	**36.2**	**179.9**	**277.6**	**732.4**	**29.7**
Agriculture	0.0	4.6	2.3	0.0	17.9	24.8	1.0
Mining and quarrying	0.0	9.3	1.9	0.0	15.1	26.3	1.1
Food manufacturing	0.0	4.4	0.9	95.6	7.2	108.0	4.4
Textile Industry	0.0	4.9	1.1	0.0	7.7	13.7	0.6
Saw mill and wood products	0.0	0.7	0.2	13.4	1.1	15.3	0.6
Paper industries and printing	0.0	0.7	0.2	0.0	1.1	1.9	0.1
Rubber chemical and petroleum	0.0	20.6	4.9	0.0	32.8	58.3	2.4
Non metallic product	0.0	3.3	0.7	71.0	5.3	80.3	3.3
Metal, metal product and machinery	0.0	185.3	23.0	0.0	181.5	389.8	15.8
Other manufacturing products	0.0	4.9	1.1	0.0	7.9	13.9	0.6
Commercial	**0.0**	**2.9**	**26.6**	**0.0**	**231.5**	**261.0**	**10.6**
Public utilities	0.0	2.9	0.6	0.0	25.9	29.4	1.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trade	0.0	0.0	2.5	0.0	19.7	22.2	0.9
Transportation and communication	0.0	0.0	10.1	0.0	79.5	89.6	3.6
Service	0.0	0.0	13.3	0.0	105.5	118.9	4.8
Unclassified	0.0	0.0	0.1	0.0	0.8	1.0	0.0
All sector	**0.0**	**1,516.5**	**157.5**	**180.6**	**607.6**	**2,462.2**	**100.0**

Table 10 Energy consumption of Khon Kaen, CM year 2050 (unit: ktoe)

	Coal	Oil	Gas	Biomass	Electric	Total	% of all sectors
Transport	**0.0**	**749.8**	**64.3**	**442.5**	**0.0**	**1,256.6**	**52.8**
Passenger transport	0.0	526.5	13.1	19.9	0.0	559.5	23.5
Freight transport	0.0	223.3	51.2	422.6	0.0	697.1	29.3
Residential	**0.0**	**0.0**	**30.4**	**0.0**	**98.6**	**129.0**	**5.4**
Industry	**0.0**	**238.7**	**36.2**	**179.9**	**277.6**	**732.6**	**30.8**
Agriculture	0.0	4.6	2.3	0.0	17.9	24.8	1.0
Mining and quarrying	0.0	9.3	1.9	0.0	15.1	26.3	1.1
Food manufacturing	0.0	4.4	0.9	95.6	7.2	108.1	4.5
Textile Industry	0.0	4.9	1.1	0.0	7.7	13.7	0.6
Saw mill and wood products	0.0	0.7	0.2	13.4	1.1	15.4	0.6
Paper industries and printing	0.0	0.7	0.2	0.0	1.1	2.0	0.1
Rubber chemical and petroleum	0.0	20.6	4.9	0.0	32.8	58.3	2.5
Non metallic product	0.0	3.3	0.7	71.0	5.3	80.3	3.4
Metal, metal product and machinery	0.0	185.3	23.0	0.0	181.5	389.8	16.4
Other manufacturing products	0.0	4.9	1.1	0.0	7.9	13.9	0.6
Commercial	**0.0**	**2.9**	**26.6**	**0.0**	**231.5**	**260.9**	**11.0**
Public utilities	0.0	2.9	0.6	0.0	25.9	29.4	1.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trade	0.0	0.0	2.5	0.0	19.7	22.2	0.9
Transportation and communication	0.0	0.0	10.1	0.0	79.5	89.6	3.8
Service	0.0	0.0	13.3	0.0	105.5	118.8	5.0
Unclassified	0.0	0.0	0.1	0.0	0.8	0.9	0.0
All sector	**0.0**	**1,051.6**	**107.6**	**102.8**	**396.1**	**2,379.1**	**100.0**

Table 11 Khon Kaen IO table, year 2005 (unit: million $US)

	Agriculture	Mining and Quarrying	Food Manufacturing	Textile Industry	Saw Mill and Wood Products	Paper Industries and Printing	Rubber Chemical and Petroleum	Non Metallic Product	Metal, Metal Product and Machinery	Other Manufacturing Products	Public Utilities	Construction	Trade	Transportation and Communication	Service	Unclassified	Total intermediate input	Private compensation expenditure	Government compensation expenditure	Gross fixed capital formation	Export	Import	Total final demand	Total use (domestic production)
Agriculture	36.3	0.0	51.0	108.2	19.1	7.8	64.1	0.4	0.0	1.7	0.1	3.2	0.0	0.1	1.7	2.3	295.9	39.7	0.0	0.0	128.3	- 0.0	168.0	463.9
Mining and Quarrying	0.1	0.9	0.1	0.6	0.0	2.0	418.3	21.9	2.9	3.8	103.6	63.0	-	0.0	0.0	0.7	617.7	0.0	-	0.0	4.5	- 598.3	- 593.8	24.0
Food Manufacturing	32.2	-	26.9	1.1	0.0	3.1	4.8	0.4	0.0	7.7	-	-	0.5	0.6	3.5	6.3	87.1	134.2	0.0	-	31.8	- 94.9	71.2	158.4
Textile Industry	0.7	0.0	0.1	1,224.5	0.7	0.6	8.7	0.4	0.7	15.3	0.1	0.8	1.7	0.4	0.3	2.9	1,257.9	1.1	0.0	0.0	2,065.8	- 210.9	1,856.0	3,113.9
Saw Mill and Wood Products	0.6	0.0	0.0	0.4	25.2	0.1	0.6	0.3	0.8	1.2	0.0	23.7	0.4	0.1	0.0	0.2	53.7	0.1	0.0	354.8	65.6	- 310.4	110.2	163.9
Paper Industries and Printing	0.2	0.0	0.8	14.7	1.2	180.4	3.0	1.0	1.3	2.3	0.3	0.9	1.9	0.4	1.3	1.3	210.9	0.2	0.1	-	543.0	- 211.2	332.0	543.0
Rubber Chemical and Petroleum Industry	55.3	2.5	5.3	257.9	10.9	57.2	272.8	19.9	25.0	31.3	26.7	47.0	8.6	36.9	2.3	4.5	864.2	483.9	0.1	0.7	294.4	- 476.2	303.0	1,167.1
Non Metallic Product	0.2	0.0	0.8	0.3	0.6	0.1	1.1	12.7	3.1	3.8	0.0	226.3	0.2	0.0	0.0	1.7	250.9	0.1	0.0	0.0	31.8	- 138.7	- 106.8	144.1
Metal, Metal Product and Machinery	12.0	1.0	6.0	33.0	7.3	14.3	11.7	6.2	288.7	65.3	8.6	272.0	2.6	15.8	1.2	9.9	755.7	1.3	0.1	4.3	141.2	- 423.5	- 276.6	479.1
Other Manufacturing Products	0.2	0.0	0.1	69.4	1.6	0.9	1.6	0.3	2.0	101.3	0.3	1.5	2.1	0.2	0.5	2.9	184.7	884.0	0.0	0.3	179.4	- 839.1	224.6	409.3
Public Utilities	1.2	0.2	3.3	192.5	5.1	12.9	33.3	11.8	9.4	4.9	59.6	9.6	8.5	2.6	2.2	0.8	358.1	109.2	0.1	-	21.7	- 102.1	28.9	386.9
Construction	0.2	0.0	0.1	1.8	0.1	0.6	0.6	0.3	0.3	0.2	0.4	0.6	0.2	0.1	0.1	0.1	5.5	0.0	0.0	423.1	694.7	- 0.2	1,117.6	1,123.1
Trade	21.2	0.3	8.3	77.9	20.3	49.0	32.8	4.7	23.1	29.9	3.7	67.4	2.3	5.0	2.1	5.6	353.8	3.0	0.0	1.0	16.5	-	20.6	374.4
Transportation and Communication	5.9	0.4	2.9	40.2	4.3	13.9	13.4	4.7	6.6	8.0	2.8	98.8	12.5	22.2	1.7	5.6	244.1	1.6	0.1	0.1	37.6	- 120.4	- 81.0	163.1
Service	11.9	2.5	4.4	108.2	6.5	24.8	22.9	8.2	8.9	12.6	16.3	42.6	31.0	11.5	5.4	4.4	322.1	4.2	335.7	-	3.6	- 605.9	- 262.4	59.7
Unclassified	0.8	0.0	0.6	18.9	0.3	0.9	0.8	0.5	1.4	0.9	3.1	1.1	4.1	0.9	0.2	0.3	34.8	0.2	0.0	-	56.0	- 35.0	21.2	56.0
Total intermediate input	179.1	7.9	110.5	2,149.6	103.3	368.5	890.6	93.7	374.4	290.2	225.5	858.5	76.6	97.0	22.6	49.5	5,897.4	1,662.8	336.2	784.4	4,315.9	-4,166.8	2,932.6	8,830.0
Wage and Salaries	75.9	3.9	10.5	332.7	23.7	49.6	69.7	13.5	28.7	42.3	58.0	101.4	75.6	24.2	18.9	1.6	930.1							
Operating Surplus	191.3	7.3	19.7	466.5	29.0	98.5	111.9	26.7	53.3	60.2	47.7	100.1	186.9	27.1	10.8	2.1	1,439.0							
Indirect tax and subsidies	17.7	4.9	17.6	165.0	7.9	26.4	94.9	10.3	22.7	16.7	55.8	63.2	35.3	14.8	7.4	2.8	563.4							
Total value added	284.9	16.1	47.8	964.2	60.6	174.5	276.5	50.5	104.7	119.2	161.4	264.7	297.8	66.0	37.1	6.5	2,932.6							
Total gross output	463.9	24.0	158.4	3,113.9	163.9	543.0	1,167.1	144.1	479.1	409.3	386.9	1,123.1	374.4	163.1	59.7	56.0	8,830.0							

(1 $US = 30.00 baht)

Table 12 Khon Kaen IO table, year 2050 (unit: million $US)

	Agriculture	Mining and Quarrying	Food Manufacturing	Textile Industry	Saw Mill and Wood Products	Paper Industries and Printing	Rubber Chemical and Petroleum Industry	Non Metallic Product	Metal, Metal Product and Machinery	Other Manufacturing Products	Public Utilities	Construction	Trade	Transportation and Communication	Service	Unclassified	Total intermediate input	Private compensation expenditure	Government compensation expenditure	Gross fixed capital formation	Export	Import	Total final demand	Total use (domestic production)
Agriculture	407.8	0.0	3,533.4	193.5	166.2	20.0	736.3	5.9	0.9	21.4	0.5	6.0	0.0	1.4	210.8	5.8	5,309.9	1.3	0.0	0.0	727.7	- 701.0	28.0	5,338.0
Mining and Quarrying	0.6	5.5	6.6	1.0	0.2	5.0	4,808.3	333.8	158.7	48.2	416.0	119.6	-	0.0	0.1	1.7	5,905.3	0.0	-	0.0	6.0	- 5,762.8	- 5,756.7	148.6
Food Manufacturing	361.1	-	1,860.3	2.0	0.2	8.0	55.7	6.1	0.3	97.2	-	-	2.7	6.9	432.5	16.0	2,848.9	3.2	0.0	-	11,516.6	- 2,852.1	8,667.8	11,516.6
Textile Industry	8.1	0.0	6.0	2,190.7	5.9	1.6	100.5	6.4	39.9	194.5	0.3	1.6	8.1	4.2	31.2	7.3	2,606.2	1.4	0.0	0.0	5,648.3	- 2,279.2	3,370.4	5,976.6
Saw Mill and Wood Products	7.2	0.0	1.7	0.8	219.1	0.3	6.4	4.2	46.2	14.7	0.0	45.0	2.1	1.1	5.1	0.5	354.6	0.2	0.0	0.1	1,089.8	- 0.1	1,090.0	1,444.6
Paper Industries and Printing	2.4	0.1	52.3	26.4	10.7	464.4	34.1	14.8	68.7	29.0	1.1	1.7	9.2	4.8	160.5	3.4	883.6	0.2	0.1	-	550.7	- 0.3	550.7	1,434.3
Rubber Chemical and Petroleum Industry	620.6	15.4	367.3	461.4	94.3	147.2	3,136.3	303.3	1,371.1	397.2	107.3	89.3	41.9	393.4	281.2	11.6	7,838.8	1.7	0.1	0.0	13,710.8	- 7,350.5	6,362.1	14,201.0
Non Metallic Product	2.7	0.0	57.3	0.5	5.3	0.2	12.3	192.6	170.6	48.8	0.1	429.7	0.8	0.0	5.1	4.4	930.4	0.1	0.0	0.0	1,299.6	- 0.1	1,299.6	2,230.0
Metal, Metal Product and Machinery	134.8	6.0	416.7	59.1	63.8	36.8	134.3	94.1	15,804.0	829.6	34.7	516.5	12.9	168.5	142.5	25.2	18,479.4	1.6	0.1	5.2	12,436.2	- 102.9	12,340.2	30,819.6
Other Manufacturing Products	1.8	0.3	5.0	124.1	13.6	2.2	18.7	4.3	109.1	1,286.5	1.2	2.8	10.1	2.2	58.1	7.5	1,647.4	1.3	0.0	0.4	5,358.6	- 1,649.2	3,711.2	5,358.6
Public Utilities	13.8	1.3	256.2	364.2	45.2	33.7	437.6	182.8	685.7	65.1	242.9	18.7	42.3	28.5	305.2	2.1	2,725.2	0.8	0.1	-	51.9	- 1,198.5	- 1,145.7	1,579.5
Construction	2.6	0.1	3.7	3.2	0.8	1.4	6.9	4.1	18.2	2.7	1.5	1.2	0.9	0.7	14.8	0.2	62.9	0.0	0.0	2.9	2,152.7	- 0.0	2,155.7	2,218.6
Trade	277.1	2.0	618.3	358.0	185.9	149.0	549.9	75.5	1,553.8	433.1	16.6	179.9	12.4	56.7	266.6	14.6	4,749.4	3.7	0.1	1.2	117.9	- 2,866.7	- 2,743.9	2,005.5
Transportation and Communication	75.3	2.8	257.6	82.5	39.0	37.1	213.4	75.6	734.6	115.5	11.8	197.4	64.1	246.3	272.2	14.3	2,439.4	1.9	0.1	1,010.4	96.4	- 1,740.6	- 631.8	1,807.6
Service	193.2	15.4	673.0	292.9	62.5	70.6	705.4	145.1	4,126.6	232.3	73.0	94.3	174.3	138.7	1,543.3	11.4	8,552.0	2,459.7	423.7	-	888.2	- 12.1	3,759.5	12,311.5
Unclassified	9.5	0.1	39.4	33.9	2.2	2.3	9.4	8.1	74.3	11.3	12.3	2.1	20.2	10.0	19.4	0.8	255.2	0.2	0.0	-	13.2	- 125.3	- 111.8	143.4
Total intermediate input	2,118.6	49.1	8,154.8	4,194.0	914.8	979.9	10,965.4	1,456.9	24,962.6	3,827.2	919.1	1,705.7	401.9	1,063.3	3,748.6	126.7	65,588.6	2,477.1	424.4	1,020.3	55,664.7	- 26,641.3	32,945.2	98,533.8
Wage and Salaries	858.2	24.3	741.1	615.1	207.0	129.1	815.6	206.4	1,604.2	543.7	237.1	196.5	406.9	272.5	4,367.3	4.0	11,228.9							
Operating Surplus	2,161.4	44.9	1,385.5	862.5	253.3	256.6	1,309.5	408.5	2,980.4	773.4	195.1	193.9	1,006.7	305.6	2,487.9	5.4	14,630.6							
Indirect tax and subsidies	199.7	30.3	1,235.2	305.1	69.4	68.7	1,110.4	158.2	1,272.4	214.4	228.1	122.5	190.0	166.3	1,707.7	7.2	7,085.6							
Total value added	3,219.4	99.5	3,361.8	1,782.6	529.7	454.4	3,235.5	773.1	5,857.0	1,531.4	660.4	512.9	1,603.6	744.3	8,562.9	16.6	32,945.2							
Total gross output	5,338.0	148.6	11,516.6	5,976.6	1,444.6	1,434.3	14,201.0	2,230.0	30,819.6	5,358.6	1,579.5	2,218.6	2,005.5	1,807.6	12,311.5	143.4	98,533.8							

(1 $US = 30.00 baht)

Thai Contributors

The Joint Graduate School of Energy and Environment (JGSEE)
Center of Excellence on Energy Technology and Environment (CEE-PERDO),
King Mongkut's University of Technology Thonburi

Sirintornthep Towprayoon
Penwadee Cheewaphongphan
Awassada Phongphiphat
Savitri Garivait
Agapol Junpen
Komsilp Wangyao

Regional Environmental Office 10 (REO 10)
Ministry of Natural Resources and Environment

Tawat Patoompong
Virunpob Supab

Khon Kaen Province

Khon Kaen Municipality

Japanese Contributors

Kyoto University (KU)

Yuzuru Matsuoka
Kei Gomi
Nguyen Thai Hoa

National Institute for Environmental Studies (NIES)

Junichi Fujino
Yumiko Asayama

Asia-Pacific Integrated Modeling Team (AIM)

Institute for Global Environmental Strategies (IGES)

Shuzo Nishioka
Tomoko Ishikawa

Mizuho Information and Research Institute (MHRI)

Kazuya Fujiwara