Low-Carbon Society Vision 2030

Thailand

November, 2010

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Asia-Pacific Integrated Model

Preface

The Thailand's low carbon society (LCS) scenario is one of the joint research outcomes of support and collaboration among Sirindhorn International Institute of Technology (SIIT) Thammasat University Thailand, Asian Institute of Technology, the National Institute for Environmental Studies (NIES) Japan, Kyoto University, and Mizuho Information and Research Institute Japan.

This revised LCS scenario report includes energy efficiency improvement and alternative energy development for CO_2 mitigation options in the demand and supply sides as well as renewable electricity generation in the power sector.

We are grateful to thank Thailand Greenhouse gas management Organization for comments. We also would like to thank Prof. Yuzuru Matsuoka and his research team for the guidance in LCS modeling. We acknowledge the support by National Institute for Environmental Studies for the access to the Asia-Pacific Integrated Model (AIM) and Database.

This LCS scenario report is aimed at communication among policy makers, administrators, academic researchers, and the public on climate change response. The research findings hope to contribute to sustainable energy and environmental transition of Thailand, one of the fast growing economies in Southeast Asia, towards a Thai low carbon society.

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Executive summary

This report aims to discuss the possibility of developing a Thailand's low-carbon society. The methodology involves i) development of current GHG emissions inventory, and ii) quantification of socio-economic activity level in 2030 according to available information from Thailand's office of the national economic and social development board.

According to the proposed development, the amount of GHG emission increase is estimated based on (i) 2030 BAU (business-as-usual) without mitigation measures, and (ii) 2030 with counter mitigation measures (CM) assumptions of employed technologies as well as the potential to reduce the GHG emissions by low-carbon measures available during 2005-2030. Only selected GHG mitigation options, which have been found to be cost effective, are included in the 2030 CM scenario. The main findings are as follows:

1) The annual greenhouse gas (GHG) emissions of Thailand in the base year of 2005 are 185,983 kilo-ton (kt) of CO_2.
2) Under the scenario without mitigation measures (that is, the 2030 BAU scenario), the GHG emissions would increase to 563,730 kt-CO_2, that is, 3.0 times higher than the emission in the base year 2005.
3) By adopting the selected feasible GHG mitigation measures available by 2030, the GHG emissions can be decreased approximately by 42.5% to 324,170 kt-CO_2 (see Figure 1).

In 2005, the per capita emission of Thailand was about 3.1 t-CO_2/year. In 2030, it is estimated to increase to 8.2 t-CO_2/year, and 4.7 t-CO_2/year without and with counter-measures, respectively.

In order to mitigate the emission to a lower level, several comprehensive measures such as diffusion of low-carbon technologies in the residential sector, energy efficient buildings, energy efficient industry and fuel switching, and fuel substitution in the transport sector and electricity generation sector are needed.

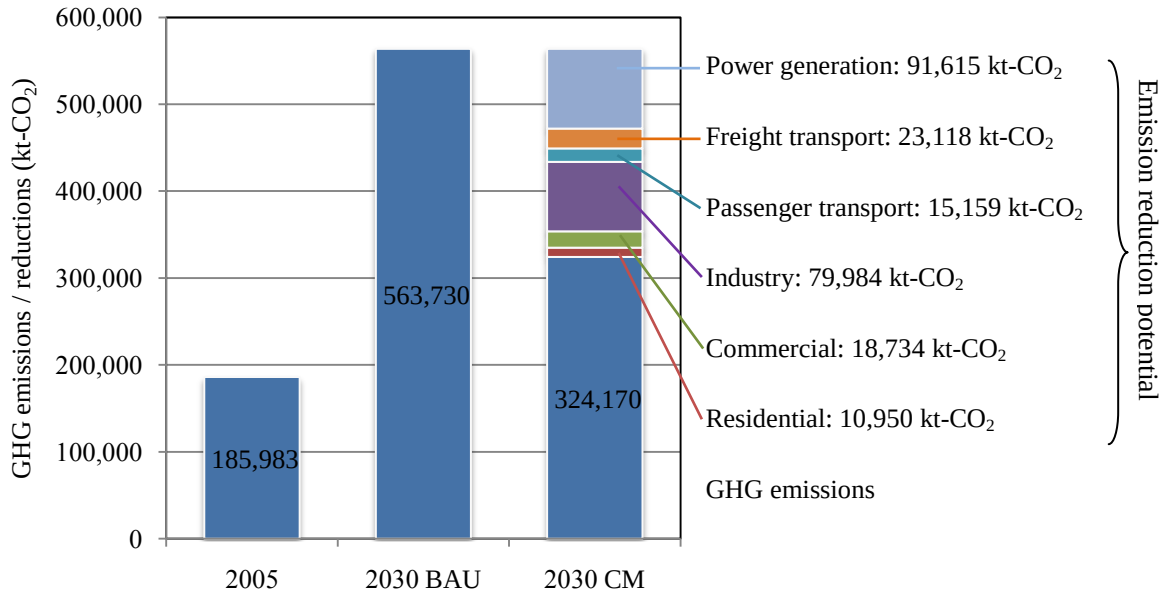


Figure 1: GHG emissions and mitigation by low-carbon technologies

However, a comprehensive policy to accomplish the implementation of the GHG mitigation measures is also required. Figure 2 shows recommended policies and related GHG mitigation options in the residential, commercial, industrial, transport, and power generation sectors. If those policies are planned from the early stage, Thailand will be able to develop not only as a premier growth center but also serve as a model for LCS.

In addition, the higher mitigation target could be achieved by a combination of initiatives on both supply and demand sides, thereby widening the technology use. On the supply side, renewable energy technologies and renewable power generation would play a crucial role, while on the demand side, energy efficient devices and fuel switching could play a key role.

Table 1: Estimated socio-economic indicators in 2030

	2005	2030	2030/2005
Population (persons)	60,991,000	68,815,004	1.1
No. of households	19,016,784	36,265,390	1.9
GDP (million Baht)	8,016,595	30,802,306	3.8
GDP per capita (Baht/capita)	131,439	447,610	3.4
Gross output (million Baht)	18,755,884	68,456,651	3.7
Floor space for commercial (million m^2)	88	394	4.5
Passenger transport demand (million p-km)	191,520	216,088	1.1
Freight transport demand (million t-km)	188,524	589,859	3.1

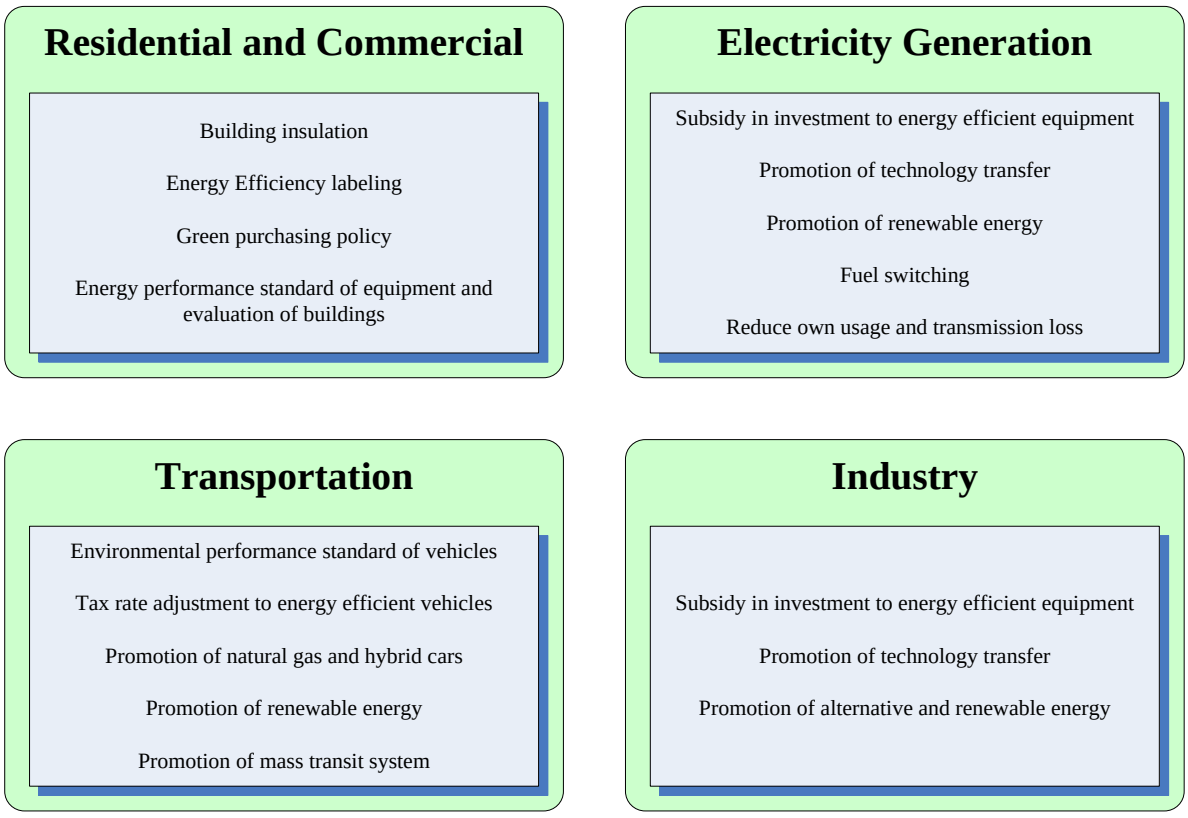


Figure 2: Policy package for Thailand's low-carbon society

About Thailand

Background

Area
- Total 513,115 km^2 (50th of the world) or 198,115 sq mile
- Water (0.4 % or 2,230 km^2)

Population
- 2010 estimate 63,723,953 (21st)
- 2000 census 60,606,947
- Density 132.1/km^2 (85th) or 342/sq mile

GDP (PPP) 2008 estimate
- Total $547.060 billion (24th)
- Per capita $8,239 (86th)

GDP (nominal) 2008 estimate
- Total $273.313 billion (33rd)
- Per capita $4,116 (92nd)

Exchange rate in 2009: 1 US$ = 35 Baht.

Figure 3: Thailand and nearby regions

Geography

Thailand lies in the heart of Southeast Asia. Its shape and geography are divided into four natural regions: the mountains and forests of the North; the vast rice fields of the Central Plains; the semi-arid farmlands of the Northeast plateau; and the tropical islands and long coastline of the peninsular South. It is bordered to the north by Burma and Laos, to the east by Laos and Cambodia, to the south by the Gulf of Thailand and Malaysia, and to the west by the Andaman Sea and the southern extremity of Burma. Its maritime boundaries include Vietnam in the Gulf of Thailand to the southeast, and Indonesia and India in the Andaman Sea to the southwest (see Figure 3).

The country comprises 76 provinces that are further divided into districts, sub-districts and villages. The largest city in Thailand is Bangkok, the capital, which is also the country's center of political, commercial, industrial and cultural activities. Thailand is the world's 50th largest country in terms of total area (slightly smaller than Yemen and slightly larger than Spain), with a surface area of approximately 513,000 km^2 (198,000 sq mi), and the 21st most-populous country, with approximately 64 million people. About 75% of the population is ethnically Thai, 14% is of Chinese origin, and 3% is ethnically Malay.

Economy

Thailand is an emerging economy and considered as a newly industrialized country. The economy of Thailand is export-dependent with exports accounting for 60% of GDP. For a nominal GDP at market rates of approximately US$ 273 billion, Thailand is the 2nd largest economy in Southeast Asia, after Indonesia, a position it has held for many years. After enjoying the world's highest growth rate from 1985 to 1996 – averaging 9.4% annually– increased pressure on Thailand's currency, the Baht, in 1997, the year in which the economy contracted by 1.9%, led to a crisis that undermined the financial sector.

Thailand's economy started to recover in 1999, expanding 4.2%, and 4.4% in 2000, thanks largely to strong exports. Growth (2.2%) was dampened by the softening of the global economy in 2001. Thailand's substantial industries include electric appliances, components, computer parts and cars.

Weather

Thailand weather is described as tropical and humid for the majority of the country during most of the year. The area of the north has a climate determined by three seasons while southern Thailand has only two.

In northern Thailand the seasons are clearly defined. Between November and May the weather is mostly dry. In the period from November to February it has lower ambient temperature and relative humidity. In the period from March to May, it has higher ambient temperature and relative humidity. The northeast monsoon does not directly affect the northern area of Thailand. The other northern season is from May to November and is dominated by the south-west monsoon.

The southern region of Thailand really has only two seasons - the wet and the dry. These seasons do not run at the same time on both the east and west side of the peninsula. On the west coast the southwest monsoon brings rain and often heavy storms from April to October, while on the east coast the most rain falls between September and December. The southern parts of Thailand get rain with around 2,400 millimeters of rain per year, compared with the central and northern regions of Thailand, both of which get around 1,400 millimeters per year.

Thai Society and Religion

The national religion is Theravada Buddhism, a branch of Hinayana Buddhism, practiced by more than 90% of all Thais. The remainder adheres to Islam, Christianity, Hinduism and other faiths, all of which are allowed full freedom. Buddhism continues to cast strong influence on daily life. Thus, in towns and villages, the temple is at the heart of social and religious life. Meditation is one of the most popular aspects of Buddhism and is practiced regularly for inner peace and happiness.

Energy Situation in Thailand

In 2008, the total energy demand of Thailand amounted to 66,284 ktoe, which rose 2.2% from the previous year, while the Thai economy expanded by 2.6%. Modern or commercial energy shared 54,023 ktoe or 81.5% of the total energy demand, whereas traditional renewable energy was consumed at 12,261 ktoe or 18.5%. The total energy supply was 110,074 ktoe, and rose 0.01% from 2007, with the net import of 48,144 ktoe, i.e., 43.7% of the total energy supply, while the domestic production was 61,930 ktoe (i.e., 56.3%).

In 2008, biofuel production comprises ethanol blended with gasoline (gasohol E10 octane number 91 & 95), and biodiesel blended with diesel (high-speed diesel B2 & B5 and palm diesel) which totaled 582 ktoe. The ethanol exported was 34 ktoe with a total value of 669 million Baht.

Background of LCS

What is a "Low-Carbon Society"?

A low-carbon society (LCS) or low-fossil-fuel economy is a concept that refers to an economy which has a minimal output of greenhouse gas (GHG) emissions (in particular, carbon dioxide) into the biosphere. The over-concentration of these gases is producing global warming, which affects climate in the long term, with negative impacts on humanity in the foreseeable future. In a LCS, the society will adopt a lifestyle that makes more use of energy efficient devices and renewable energy technologies. Therefore a globally implemented LCS is proposed as a means to avoid catastrophic climate change, and as a precursor to the more advanced, zero-carbon society and renewable-energy economy.

The policy research and activities of an LCS in developed countries should have the following attributes:

i) Take actions that are compatible with the principles of sustainable development, ensuring that the development needs of all groups within the society are met.
ii) Make an equitable contribution towards the global effort to stabilize the atmospheric concentration of CO_2 and other GHG such as CH_4 at a level that will avoid dangerous climate change, through deep cuts in global emissions.
iii) Demonstrate a high level of energy efficiency and use low-carbon energy sources and production technologies.
iv) Adopt patterns of consumption and behavior that are consistent with low GHG emissions.

However, the LCS concept for developing countries would be different from that for the developed countries such as Thailand, having lower per capita emissions and low emissions per GDP. Nevertheless, the LCS study would provide opportunities for Thailand to decide the future energy system, related infrastructure, and lifestyle related choices.

Today Thailand faces challenges in energy-environment-economic development with limited resources availability, minimal externalities, and global climate change. One of the approaches to overcome this development paradox is through adoption of a sustainable development paradigm. Energy-environment modeling results for Thailand show substantially increasing system cost to meet the GHG reduction targets. This higher cost would result in GDP loss that could be compensated through international transactions and mechanisms such as the Clean Development Mechanism (CDM).

Therefore, the LCS framework should also look at opportunities of co-benefits apart from direct GHG reduction. Such co-benefits, like improved local air quality in Thailand, provide an opportunity to minimize social costs.

Principles for a low-carbon society

Under the initiatives of the Japan-UK low-carbon society movement, it is emphasized that the world needs to cooperate to make concerned efforts to establish a low-carbon society by "reducing global emissions by half from the current level by 2050". Under the principle of common but differentiated responsibility, developed nations will take the lead on climate change mitigation and developing countries will adopt the necessary technologies and expertise to reduce the inefficient and carbon intensive

development path of the past.

All countries, organizations, and entities have to take action based on the following philosophies:

1) Carbon minimization in all sectors

"A low-carbon society" in the ultimate sense would be a society that emits greenhouse gases only in an amount which can be absorbed by nature (carbon neutral society). To achieve this goal, we have to have a social system where all sectors, such as industries, governments, and citizens, will naturally or automatically give special consideration to their selection and decisions in order to minimize carbon-dioxide emissions.

2) Toward simpler life styles that realize richer quality of life

People would need to forgo the mass consumption society, mainly formed by developed countries, and build a new society in which value is placed on family or community ties, health, interactions, and the "Mottainai" spirit to improve the quality of life. This type of consumer choice would lead to a revolution in the social system, moving toward a low-carbon and rich society, and the "Self-sufficiency economy" in Thailand.

3) Coexistence with nature

We recognize humans and their society as a part of the global ecosystem. In order to secure the CO_2 absorption essential for a low-carbon society and to adapt to the avoidable global warming, it is important to maintain and restore rich, diverse natural environments, such as forests. To achieve this symbiosis, local communities should place importance on harmony and coexistence with nature, and promote "nature-friendly technologies" such as utilization of renewable energy.

Objectives of this study

The objectives of this study are:

a) To prepare a summary of a quantitative scenario study on the establishment of a sustainable LCS in Thailand.

b) To create awareness among Thailand's authorities, government, stakeholders and the communities for urgent and decisive actions to be taken to realize a robust growth and low-carbon Thailand.

Socio-Economic Scenario in 2030

Estimated Socio-Economic Indicators of Thailand

In energy demand modeling and GHG emissions in Thailand in 2030, several quantitative assumptions were made (see Table 2).

Table 2: Quantitative assumptions of socio-economic indicators' change during 2005 to 2030

Average population growth	0.5% p.a. increase (2005-2030)
Demographic composition	0-14: 21.0%, 15-64: 71.3%, 65+: 7.7%
GDP increase by industry	Primary industry: approximately 3.9% p.a. increase Secondary industry: approximately 5.1% p.a. increase Tertiary industry: approximately 6.4% p.a. increase
Exports	3.2% p.a. increase
Private consumption	8.4% p.a. increase
Government consumption	3.2% p.a. increase
Modal share of passenger transport	[Railway] 12%, [Buses] 20%, [Motorcars] 20%, [Motorcycles] 10%, [Walking] 25%, [Bicycles] 12.8%, [Air] 0.2%

Scenario Description

The future socio-economic indicators in 2030 in Thailand are estimated by using a macroeconomic model. The following is the estimated results of the economy, establishments, and transportation.

Economy: Modelling results based on a Thailand's macroeconomic model show that gross domestic product (GDP) in 2030 is expected to be approximately 30,802,306 million Baht (3.8 times the performance in 2005). An input-output analysis based on final demands in the macro economy is used to estimate the future industrial structure in Thailand. Results show that the share of the primary industry will decrease from 6.0% (2005) to 4.1% (2030). In addition, the share of the secondary industry will decrease from 61.1% (2005) to 55.5% (2030). However, the share of the tertiary industry will increase from 33.0% in 2005 to 40.4% in 2030 (see Table 3). Figure 4 shows the composition of output by industry.

Establishments: The number of households in Thailand will increase from 60.9 million (2005) to 68.8 million (2030), and the average household size in Thailand will decrease from 3.2 (2005) to 1.9 (2030). The total floor space of commercial buildings in Thailand will increase from 88 million square meters (2005) to 394 million square meters (2030).

Transportation: Passenger transport demand in Thailand will slightly increase from 191,520 million passenger-kilometers (2005) to 216,088 million passenger-kilometers (2030). Freight transport demand in Thailand will increase from 188,524 million tonne-kilometers in 2005 to 589,859 million tonne-kilometers in 2030 (see Table 3).

Table 3: Estimated socio-economic indicators in 2030

	2005	2030	2030/2005
Population	60,991,000	68,815,004	1.1
No. of households	19,016,784	36,265,390	1.9
GDP (million Baht)	8,016,595	30,802,306	3.8
GDP per capita (Baht/capita)	131,439	447,610	3.4
Gross output (million Baht)	18,755,884	68,456,651	3.7
Primary industry (million Baht)	1,116,621	2,801,864	2.5
Secondary industry (million Baht)	11,453,496	38,008,931	3.3
Tertiary industry (million Baht)	6,185,767	27,645,856	4.5
Floor space for commercial (million m^2)	88	394	4.5
Passenger transport demand (million p-km)	191,520	216,088*	1.1
Freight transport demand (million t-km)	188,524	589,859*	3.1

* In the 2030 BAU scenario.

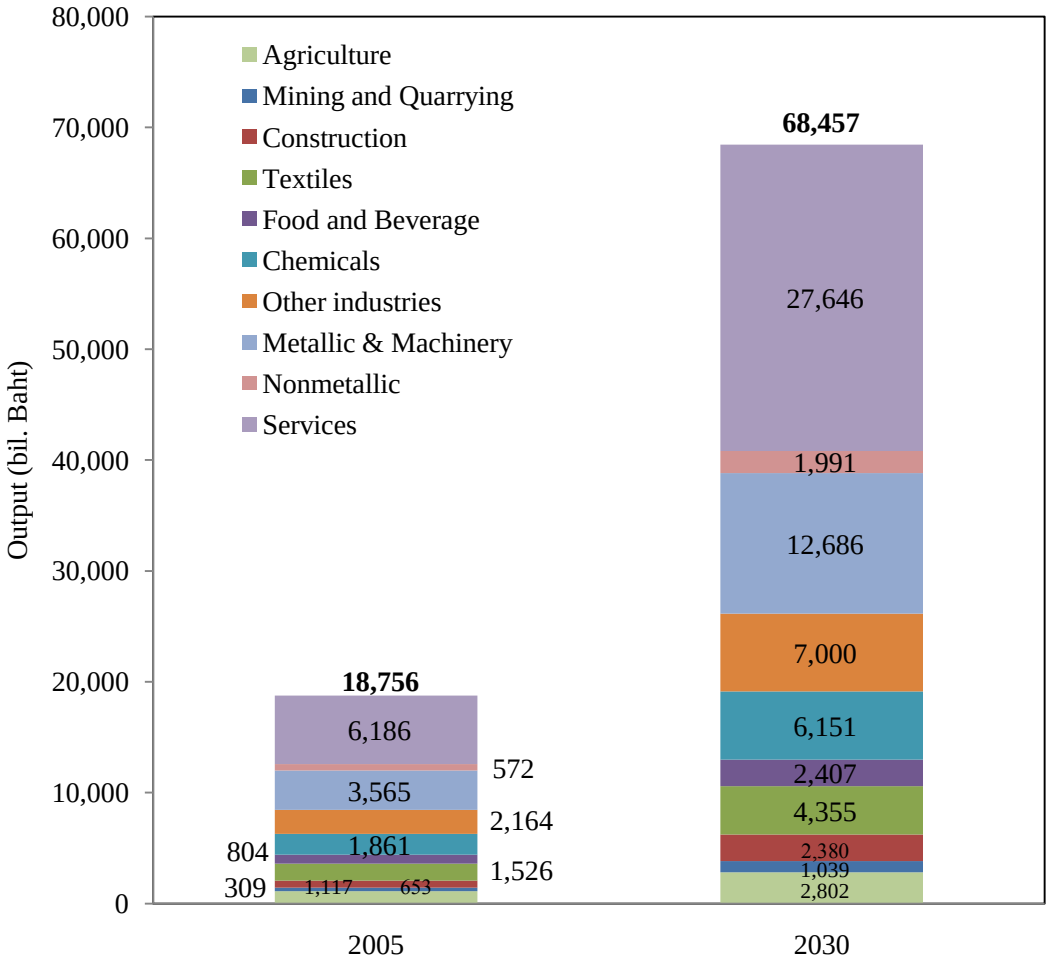


Figure 4: Outputs by industry in 2005 and 2030

GHG emissions in 2030

Energy Demand and GHG Emissions

A macro-economic model is used to estimate future energy demand and GHG emissions for the year 2030 based on the scenario quantification. The estimated results on energy demand and GHG emissions are presented in Figures 5 to 8 and Table 4.

In the business-as-usual (BAU) scenario, final energy demand would increase from 57,327 ktoe in 2005 to 164,863 ktoe in 2030. Final energy demand of the industrial sector is estimated to be 81,189 ktoe and would maintain the largest share of 49.3%, followed by the transport sector (42,918 ktoe; 26.0%), and the residential and commercial sectors (40,756; 24.7%) in 2030 (see Figure 5).

In the BAU scenario, primary energy demand in Thailand is projected to increase from 74,845 ktoe in 2005 to 226,165 ktoe in 2030 (see Figure 6). There will be a total of 76,142 ktoe of petroleum and 73,644 ktoe of natural gas consumed in 2030 in the BAU scenario. In 2030, the demand for coal would increase by 3.5 times when compared to 2005, and the demand for natural gas will increase by 3.5 times. Use of biomass, solar, wind, and hydro energy in the primary energy in 2030 countermeasure (CM) scenario would together be 40,580 ktoe, accounting for 26.1% of the total primary energy supply.

Based on primary energy demand by energy sources, total GHG emissions in the BAU scenario are projected to increase from 185,983 kt-CO_2 in 2005 to 563,730 kt-CO_2 in 2030. The modeling results also show that GHG emissions from the industry sector will be 276,045 kt-CO_2 in 2030 accounting for 49.0% of total CO_2 emissions in 2030. In 2030, GHG emissions from passenger and freight transport are also found to be about 2.3 times the amount in 2005, and their share would be 23.1% of total GHG emissions (see Figure 7). In the BAU scenario, GHG emissions per capita would increase from 3.1 t-CO_2 per capita in 2005 to 8.2 t-CO_2 per capita in 2030 (see Figure 8).

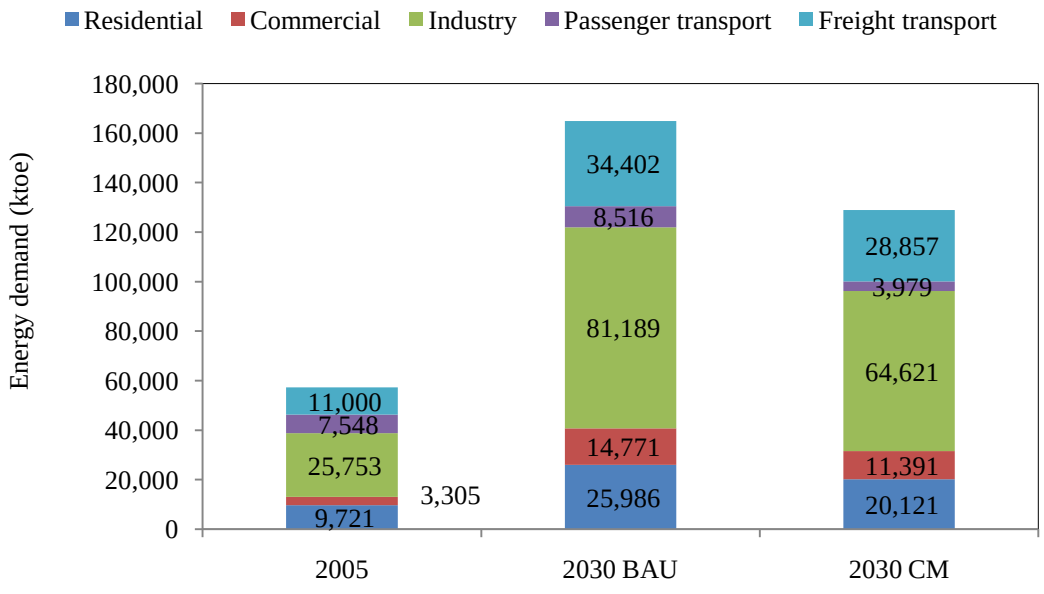
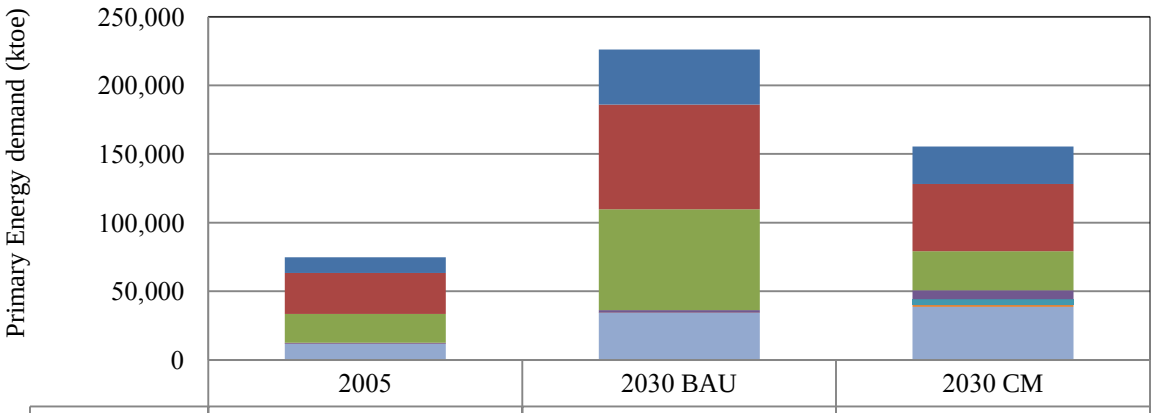


Figure 5: Final energy demand by economic sector



	2005	2030 BAU	2030 CM
Coal	11,608	40,201	27,504
Petroleum	29,677	76,142	48,917
Natural gas	21,190	73,644	28,316
Hydro	515	1,802	6,627
Nuclear	-	-	3,618
Solar & wind	2	7	1,922
Biomass	11,853	34,369	38,658

Figure 6: Primary energy demand by energy sources

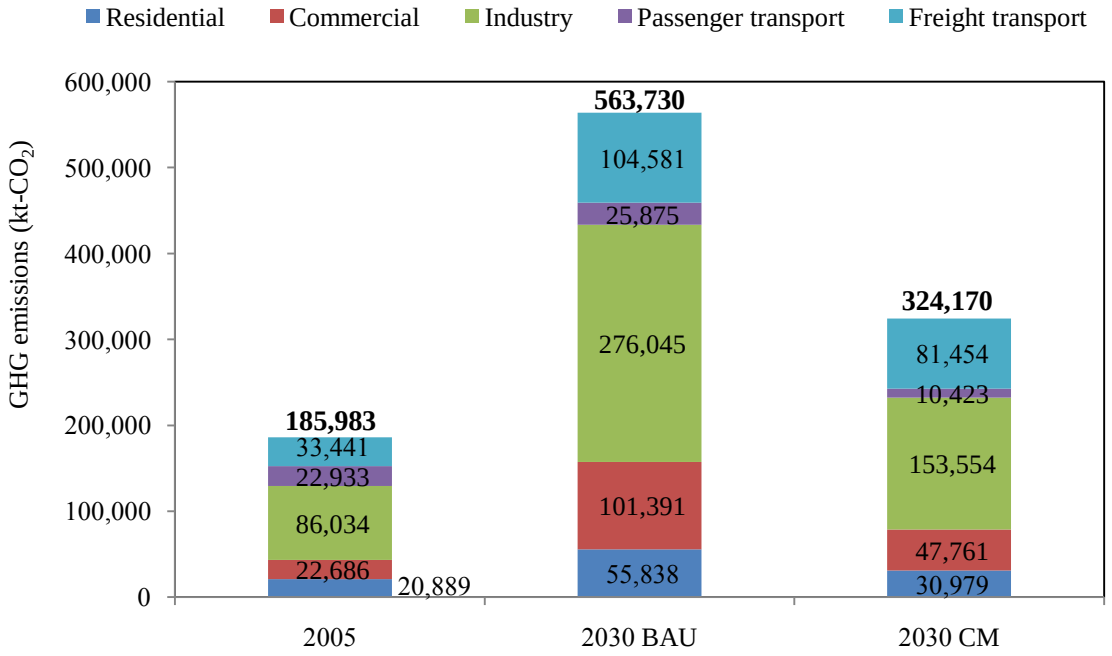


Figure 7: GHG emissions by sector

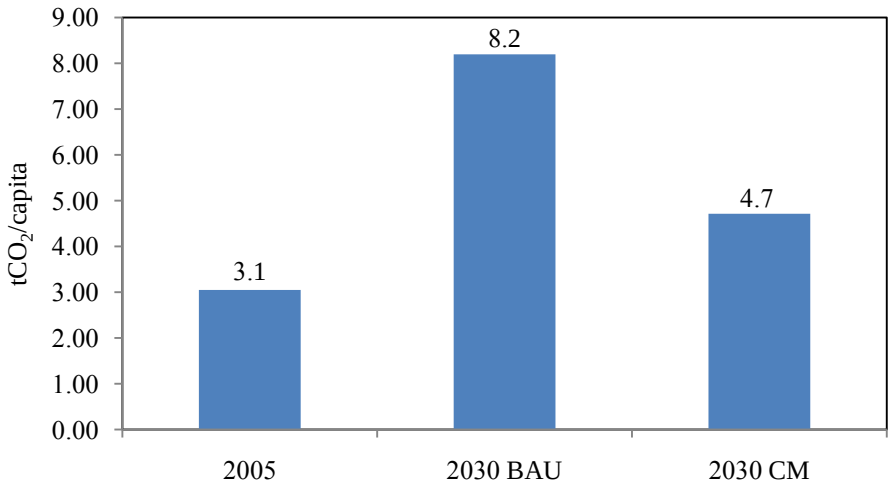


Figure 8: Per capita GHG emissions

Table 4: Final energy demand by sector (unit: ktoe)

	Coal	Petroleum	Natural gas	Biomass	Solar & Wind	Electricity	Total
2005							
Residential	-	1,897	-	5,621	-	2,203	9,721
Commercial	-	-	-	-	-	3,305	3,305
Industry	6,755	7,233	1,520	5,332	-	4,913	25,753
Passenger transport	-	7,499	44	-	-	5	7,548
Freight transport	-	10,999	1	-	-	0	11,000
Total	**6,755**	**27,628**	**1,565**	**10,953**	**-**	**10,426**	**57,327**
Share	**11.8%**	**48.2%**	**2.7%**	**19.1%**	**0%**	**18.2%**	**100.0%**
2030 BAU Scenario							
Residential	-	5,071	-	15,026	-	5,889	25,986
Commercial	-	-	-	-	-	14,771	14,771
Industry	23,217	21,043	4,917	16,193	-	15,818	81,189
Passenger transport	-	8,461	49	-	-	5	8,516
Freight transport	-	34,397	4	-	-	1	34,402
Total	**23,217**	**68,972**	**4,971**	**31,219**	**-**	**36,484**	**164,863**
Share	**14.1%**	**41.8%**	**3.0%**	**18.9%**	**0%**	**22.1%**	**100.0%**
2030 CM Scenario							
Residential	-	3,940	-	11,649	-	4,532	20,121
Commercial	-	-	-	-	-	11,391	11,391
Industry	9,353	13,537	5,512	22,506	-	13,712	64,621
Passenger transport	-	3,128	191	549	-	111	3,979
Freight transport	-	26,697	117	2,038	-	5	28,857
Total	**9,353**	**47,301**	**5,820**	**36,743**	**-**	**29,751**	**128,968**
Share	**7.3%**	**36.7%**	**4.5%**	**28.5%**	**0%**	**23.1%**	**100.0%**

Note: The 2030 BAU scenario is a modeling result without any additional measures to improve energy efficiency or CO_2 intensity. In 2030 CM scenario, higher energy efficiency and fuel substitution of less CO_2 intensive fuel is assumed. Details of energy demand and supply tables are shown in Tables 15-17.

CO_2 Mitigation Potential in 2030

In 2030, the model results estimate that total GHG emissions in Thailand is to be reduced from 563,730 kt-CO_2 in the BAU scenario to 324,170 kt-CO_2 in the countermeasure (CM) scenario (i.e., a reduction of 42.5% of total CO_2 emission) through the adoption of countermeasures for mitigating GHG emissions. (see Figure 9). Based on the model simulation, the reductions in GHG emissions by types of countermeasures are contributed by comprehensive measures.

In the 2030 CM scenario, among the measures, energy efficiency improvement in power generation sector accounts for the largest proportion of 38.2% of the total CO_2 reductions, followed by efficiency improvement in the industrial sector (33.4%), efficiency improvement in the freight transport sector (9.6%), efficiency improvement in the commercial sector (7.8%), efficiency improvement in the passenger transport sector (6.3%), and efficiency improvement in the residential sector (4.6%).

Among the categories of countermeasures, it is desirable to take effective measures in the industrial sector, the commercial sector, and the transport sector, and help with the penetration of renewable energy. In order to realize a low-carbon society, Thailand needs to have new set of strong policies to encourage and promote these countermeasures.

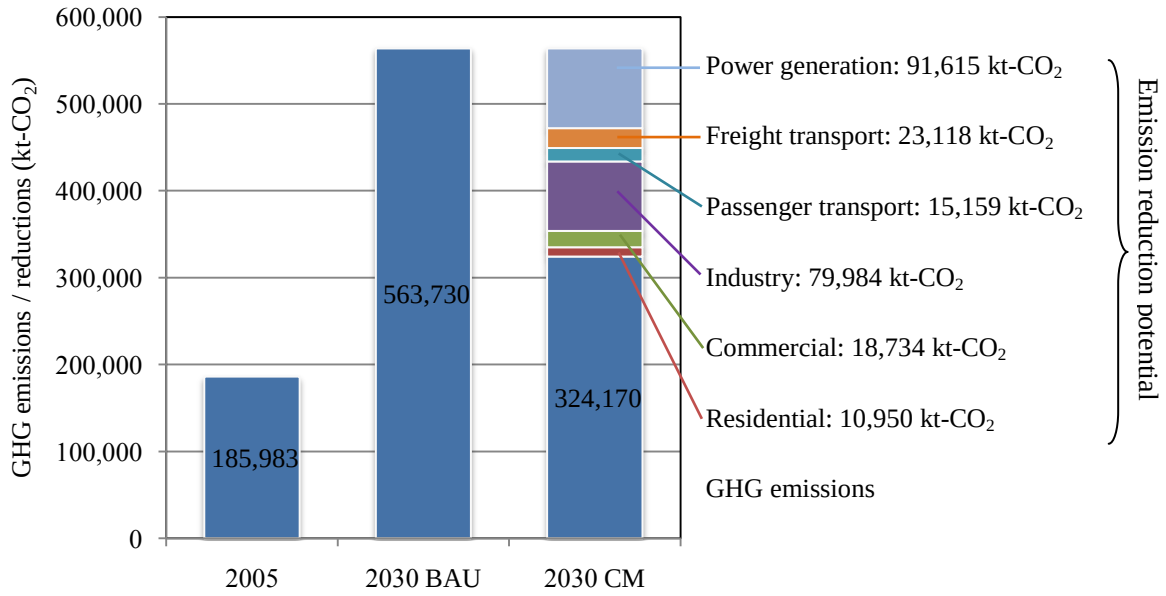


Figure 9: Breakdown of CO_2 emissions reduction potential

GHG Mitigation Options

Residential Sector

The forecasted population of Thailand in 2030 is 68.8 million. Energy demand in the residential sector is determined based on GDP, number of households and population. In 2005, the average household size was 3.2 (3.2 members per household), and it is forecasted to be only 1.9 in 2030. The number of households will increase from 19 million in 2005 to 36 million in 2030 (see Figure 10). In the BAU scenario, energy consumption in households would increase to 25,986 ktoe and GHG emissions increase to 55,838 kt-CO_2, 2.7 times greater than 2005, respectively (see Figure 11). The GHG emissions in the CM scenario is estimated to be 44.5% lower than that in the BAU scenario. There would be a GHG mitigation 30,979 kt-CO_2 in the residential sector , mainly with efficiency improvement of electric devices and efficiency improvement in the electricity generation sector (see Figure 12).

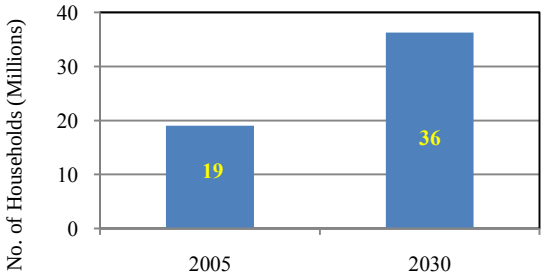


Figure 10: Number of households

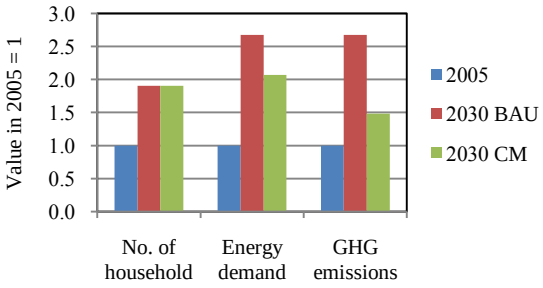


Figure 11: Change from base year in the residential sector

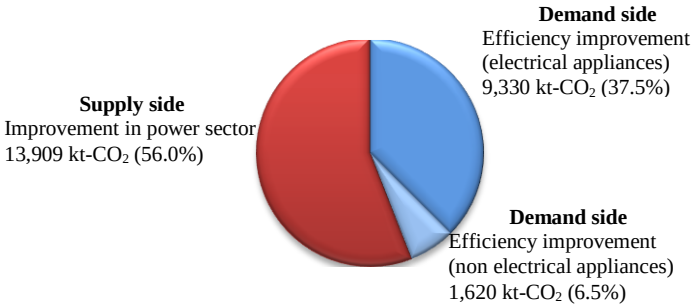


Figure 12: Breakdown of GHG mitigation by means of demand side and supply side




Commercial Sector

Energy demand in the commercial sector is estimated based on the floor space of the buildings. Driven by the growth of tertiary industry, in 2030, it will increase to 4.5 times greater than 2005 (see Figure 14). In the BAU scenario, energy consumption in this sector would increase to 14,771 ktoe and GHG emissions would increase to 101,391 kt-CO_2, i.e., 4.5 times greater than that in 2005, respectively (see Figure 14). The emissions in this sector under the CM scenario, would be 53,630 kt-CO_2 or 52.9% lower than that in the BAU scenario. The mitigation measures identified in this sector are efficiency improvements in electric devices, building insulation, and the power sector (see Figure 15).

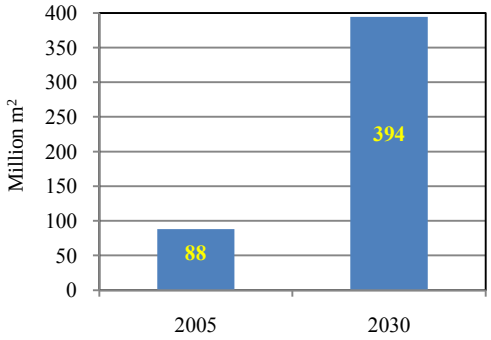


Figure 13: Floor space of commercial sector

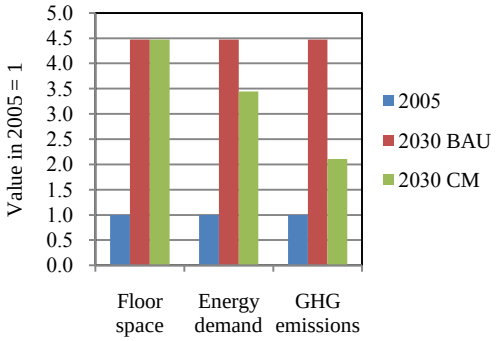


Figure 14: Changes from the base year in the commercial sector

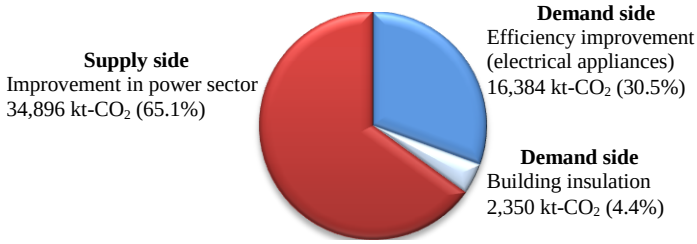


Figure 15: Breakdown of GHG mitigation by means of demand side and supply side

Policy for Promotion of Mitigation Measures in the Residential and Commercial Sectors

In order to promote GHG mitigation measures in the residential and commercial sectors, it would require policies related to building design, building codes, energy efficient equipment and use of renewable energy. Figure 16 shows key policies; i.e., energy performance standard of buildings, building insulation, building codes, energy efficiency labeling of electric devices, and green purchasing policy of the government. The demand-side management (DSM) programs of the Ministry of Energy, Thailand could play an important role in energy efficiency labeling, and funding companies need to adopt corporate social responsibilities in energy efficiency improvement and promotion of the use of renewable energy. In addition, the more advanced DSM activities in Thailand would also contribute larger energy saving and more GHG reduction.

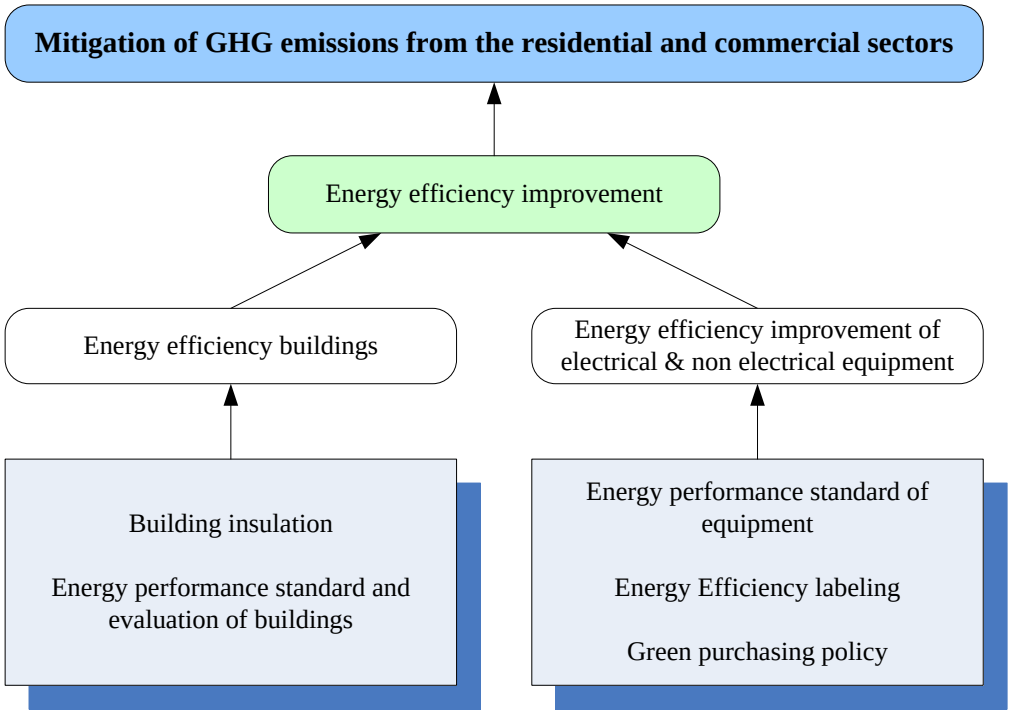


Figure 16: Mitigation measures and policies for buildings (residential & commercial)

Industry

In this report, "industry sector" as an energy consuming sector includes both primary and secondary industries. Assuming average GDP increase of 5.5% per year, output of such industries will increase to 40,810,794 million Baht in 2030, i.e., 3.3 times more than in 2005 (see Figure 17). Without any energy efficiency improvement, i.e., under the 2030 BAU scenario, energy demand and GHG emissions would increase to 3.2 times and 3.2 times from the base year 2005, respectively (see Figure 18). In the 2030 CM scenario, energy efficiency improvement and fuel shifting in this sector could reduce GHG emissions by 122,492 kt-CO_2 accounting for 44.4% of CO_2 reduction in industry (see Figure 19).

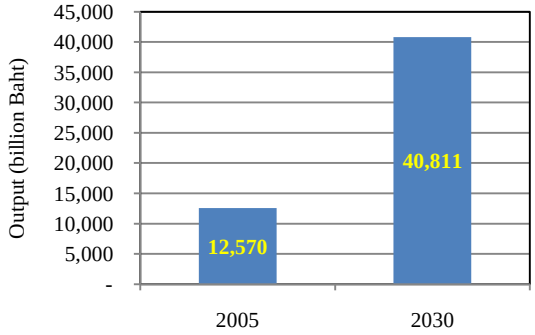


Figure 17: Industrial output

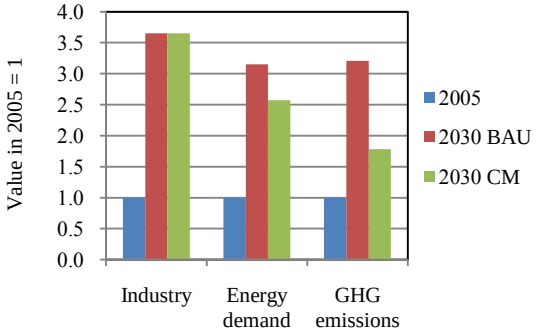


Figure 18: Changes from the base year in the industrial sector

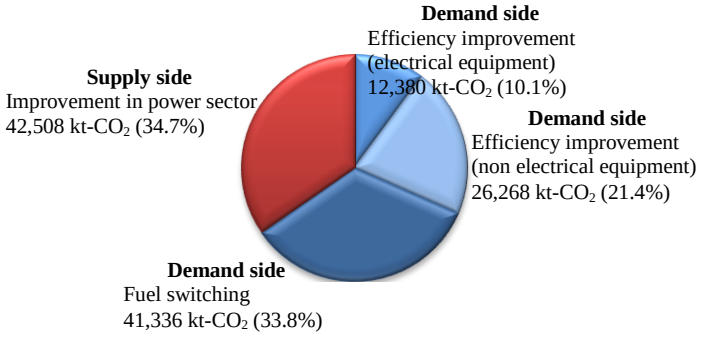


Figure 19: Breakdown of GHG mitigation by means of demand side and supply side

Policy on Promotion of Mitigation Measures in the Industrial Sector

The measures for emissions mitigation in this sector include promotion of energy efficiency improvement in both electrical and non electrical equipments as well as alternative and renewable energy. To promote mitigation measures in this sector, incentives to invest in energy efficiency improvement is very important. Policies on taxes, subsidies and low interest loans would play key roles in this sector. Promotion of advanced technologies from abroad is also considered effective (see Figure 20).

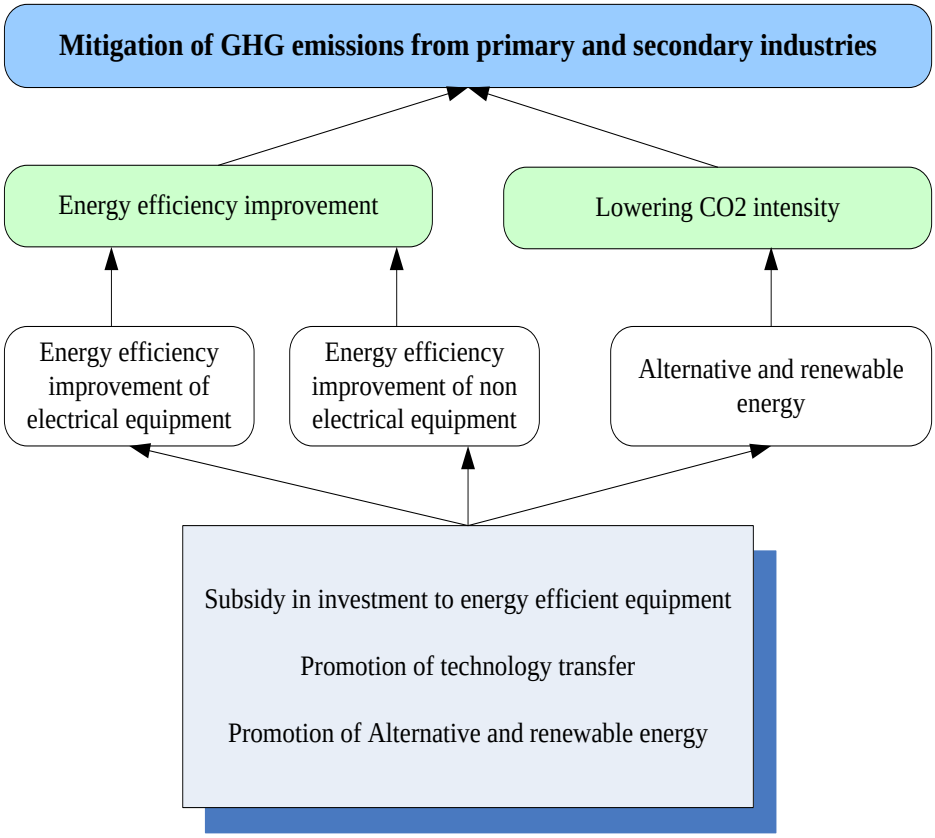


Figure 20: Mitigation measures and policies for industries

Transport (Passenger)

In the passenger transport sector, the transport demand is estimated to increase from 191,520 million passenger-km in 2005 to 216,088 million passenger-km in 2030, i.e., it would be 1.1 times greater than 2005 due to population growth (see Figures 21 and 22). This results in an increase in energy demand in passenger transport from 7,548 ktoe in 2005 to 8,516 ktoe in 2030. Currently, small vehicles and motorcycles are the main mode of mobility in Thailand. If modal share does not change, GHG emissions from passenger transportation will increase from 22,933 to 25,875 kt-CO_2 in the 2030 BAU scenario. However in the countermeasure (CM) scenario, energy efficiency improvement, travel demand management, modal shift, and fuel substitution could mitigate GHG emissions at around 15,452 kt-CO_2, accounting for 59.7% of CO_2 reduction (see Figure 23).

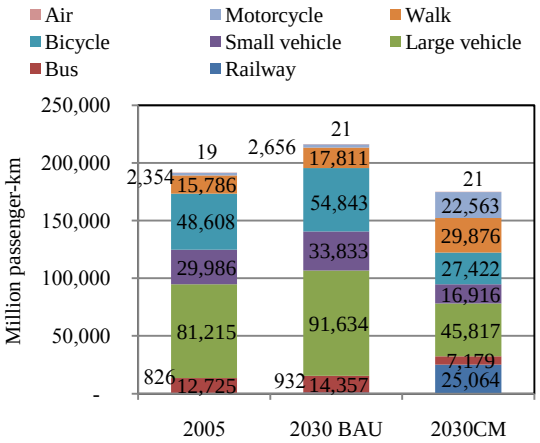


Figure 21: Passenger transport demand

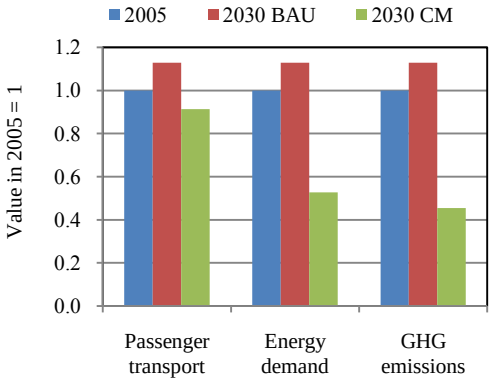


Figure 22: Changes from the base year in the passenger transport sector

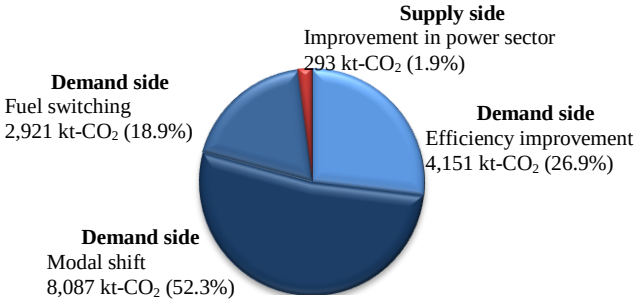


Figure 23: Breakdown of GHG mitigation by means of demand side and supply side

Transport (Freight)

In the freight transport sector, due to the growth of the manufacturing sector output, freight transport demand is estimated to increase from 188,524 million tonne-km in 2005 to 589,859 million tonne-km in 2030 (see Figure 24), resulting in an increase in energy demand in freight transport to 34,402 ktoe and an increase in GHG emissions to 104,581 kt-CO_2, i.e., 3.1 times greater than 2005 (see Figure 25). The freight transport demand in Thailand is much greater than the passenger transport demand because Thailand is the largest market for pick-up vehicles in Southeast Asia. In the countermeasure scenario, energy efficiency improvement, modal shift, and fuel substitution could together mitigate GHG emissions at about 23,127 kt-CO_2 (see Figure 26).

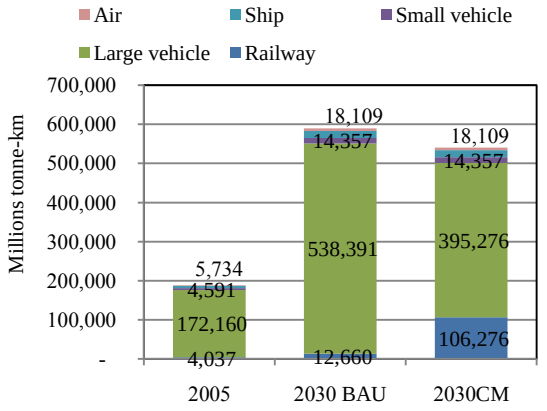


Figure 24: Freight transport demand

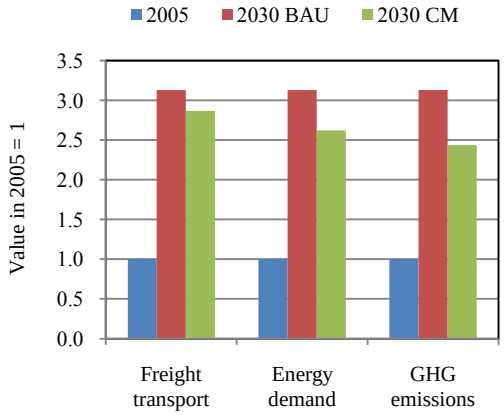


Figure 25: Changes from the base year in the freight transport sector

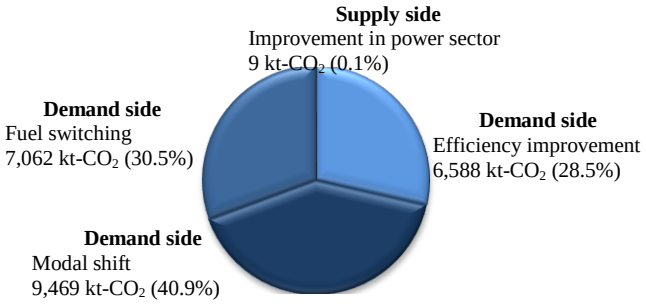


Figure 26: Breakdown of GHG mitigation by means of demand side and supply side

Policy on Promotion of Mitigation Measures in the Transport Sector

One important aspect of the emission mitigation in this sector is the promotion of energy efficiency improvement, travel demand management, and alternative energy. Promotion of alternative energy results in the substitution of natural gas and hybrid engines for conventional engines. Energy efficiency improvement, such as improving fuel economy and eco-car promotion, needs incentives such as taxes or subsidies (see Figure 27). In the present study , the GHG mitigation measures in the transport sector are found to be cost effective. Furthermore, in this study comprehensive policies on bio-fuels such as ethanol 20%: E20, ethanol 85%: E85, biodiesel 5%: B5, and biodiesel 10%: B10, and mass transit system in Thailand, which would contribute more GHG reduction, are included.

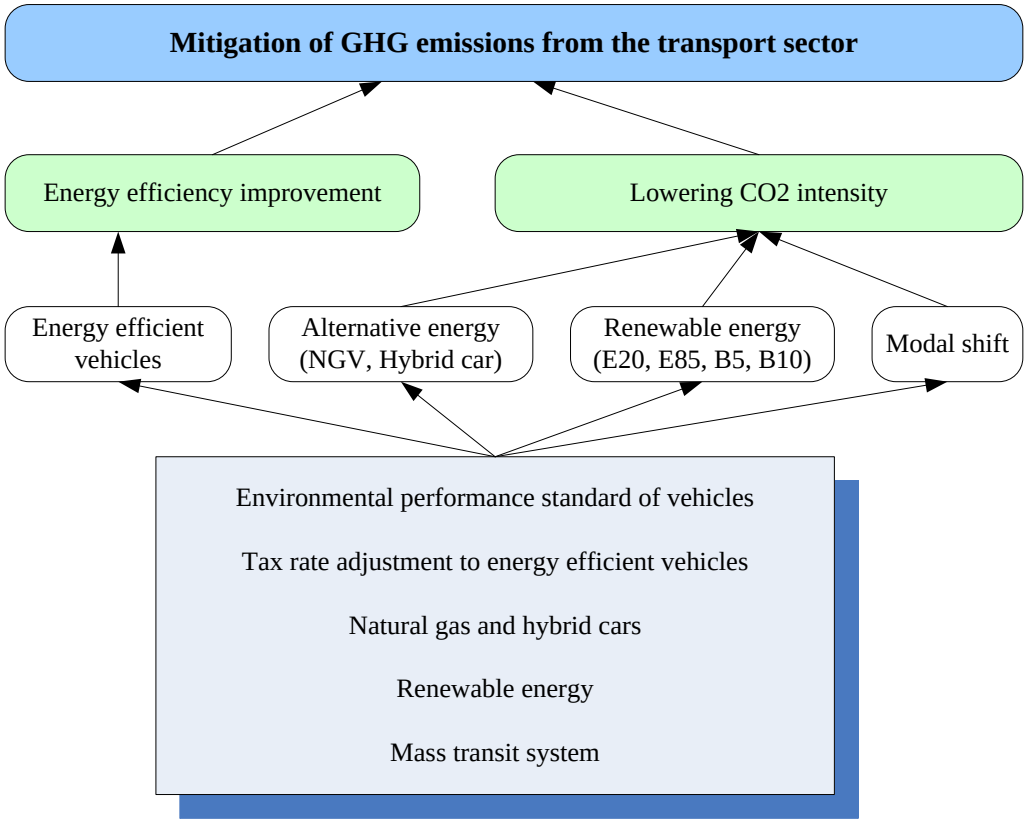


Figure 27: Mitigation measures and policies for transport

A Policy Package towards Low-Carbon Thailand

To achieve the CO_2 reduction of 42.5% in the 2030 CM scenario towards Thailand's low-carbon society, comprehensive policy planning and actions are necessary. Figure 28 shows the policies aforementioned in the mitigation measures of each sector. In general, it takes time to implement low-carbon measures and change the current status. Therefore, it is important to consider creating a low-carbon society in the goals of development at an earlier stage. Hence it is imperative to set a GHG emissions target as one of the goals of national development.

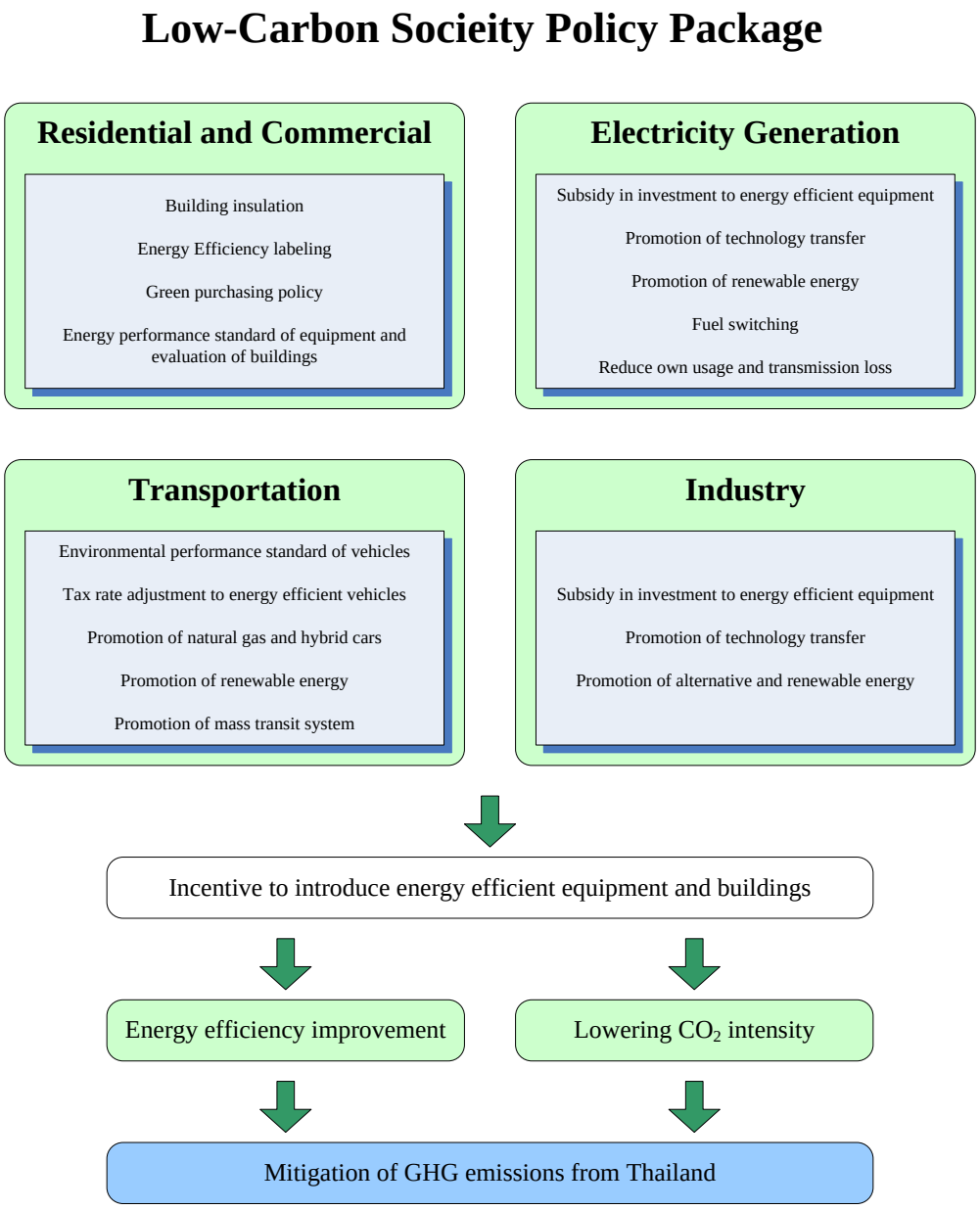


Figure 28: Policy package for Thailand's low-carbon society vision 2030

Thailand's Environmental and Energy Policies on Climate Change

Thailand is a signatory to the UN Framework Convention on Climate Change (UNFCC) and is in the Non-Annex 1 group. As such, Thailand is not obligated to reduce the level of greenhouse gas (GHG) emissions. Thailand is only responsible for about 0.6 percent of the world's total GHG emissions. In addition, the average per capita emission of Thailand is lower than the world average.

However, the impacts of overall climate change on Thailand will not relatively as low as its greenhouse gas emission rates. The impacts of climate change on Thailand can be categorized under the following issues: sea level, temperature rise, health and hygiene, biodiversity, drought and flooding.

Implementation of Climate Change Mechanisms in Thailand

Thailand recognized the significance of climate change and ratified the UNFCCC in December 1994 with enforcement taking place in March 1995, and the Kyoto Protocol in August 2002. The reasons are i) climate change has international consequences, ii) Thailand was one of the GHG emitters, and iii) Thailand would be affected by climate change.

The Office of Natural Resources & Environmental Policy and Planning (ONEP), under the Ministry of Natural Resources & Environment (MONRE), is the climate change focal point of Thailand. The strategy outlines mechanisms and measures that would need to be undertaken by various agencies. These include measures for GHG mitigation and adaptation to adverse impacts of climate change, as well as incorporation in Thailand's National Social and Economic Development Plan the details on i) enhancing capabilities on adaptation to climate change impact and vulnerability, ii) reducing greenhouse gases emission, iii) promoting public awareness and participation on climate change, iv) strengthening capacity building, and v) strengthening climate change research and development.

In 2006, the Thai cabinet approved the setting up of National Board on Climate Change Policy, Climate Change Coordinating Office and Thailand Greenhouse gas management Organization (TGO) to overlook clean development mechanism (CDM) in Thailand. The CDM is a mechanism established by the Kyoto Protocol to assist the industrialized nations with commitments for reducing GHG emissions to meet their targets, and to promote sustainable development in the developing nations.

TGO is the autonomous governmental organization established with a specific purpose, i.e., as an implementing agency on GHG emission reduction in Thailand. TGO promotes low carbon activities, investment and marketing on GHG emission reductions, establishment of GHG information centers, review of CDM projects for approval, and provides capacity development and outreach for CDM stakeholders. TGO operates as the Designated National Authority for CDM (DNA-CDM) in Thailand.

Thailand's CDM Policies

The current increase in prices of fuel sources (oil, coal, natural gas), coupled with a high demand for energy has made it necessary to seek out the use of renewable energy sources. CDM will encourage the private sector in utilizing renewable energy sources. TGO has implemented CDM projects in the energy sector in order to help support the strategies of the Ministry of Energy and to encourage the private sector to reduce GHG emissions. The present CDM activities are in i) the energy sector: production of energy from bio-energy and renewable energy, and ii) environmental sector: waste to energy.

Energy Conservation Law 1992 (B.E. 2535)

The Energy Conservation Promotion Act 1992 (B.E. 2535) or briefly Energy Conservation Law was published in the Government Gazette in 1992. The ECP Act has the following objectives:

1. Regulate, supervise, promote and support the people being affected by the law (the designated buildings and factories) to save energy.
2. Promote and support energy efficient machines and equipment, and the materials used for energy conservation.
3. Promote and support energy conservation through a financial mechanism in the form of "Energy Conservation Promotion Fund".

The ECP Act has been implemented by the Department of Energy Development and Promotion (DEDP). DEDE is responsible for national energy conservation policies, and has taken up a supervising and directing role in energy production and use, while encouraging greater energy efficiency in energy consuming sectors.

In addition, in 2010, the Ministry of Energy has proposed a 15-year alternative energy development and energy efficiency plans, and a 20-year power development plan (PDP2010) that includes green electricity from renewable energy for up to 5% of total generation. These policies show the importance of a low-carbon Thailand.

Actions to Thailand's LCS 2030

Up to this point, Thailand's LCS vision 2030 envasages the possibility of reducing about 42.5% of the total CO_2 emission related to energy supply and use in the country in the 2030 BAU case. In the 2030 CM scenario, there are 9 actions or GHG mitigation measures in the residential, commercial, industrial, transport, and power sectors. The next step is the brief roadmap to achieve this GHG mitigation target in the 2030 CM scenario.

Action 1: Energy efficiency improvement in households

Action 1.1: (Electricity related) Details of energy efficiency improvement in electric devices in the household sector are shown in Table 5. In the residential sector, it is expected that these efficient electric devices will have penetration rates up to 100% in 2030. The mechanism of Thailand's demand-side management (DSM) and energy efficiency development plan could readily achieve this target.

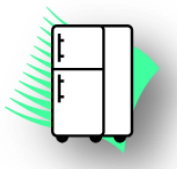
Table 5: Expected efficiency improvement of electric devices in households

Appliance	Efficiency improvement (%)	Penetration in 2030 CM (%)
Cooling devices	30	100
Heating devices	30	100
Lighting power	30	100
Refrigerators	30	100
Cooking stoves	30	100
Cooking appliances	30	100

Action 1.2: (Non-Electricity related) Details of energy efficiency improvement in non-electric devices in the household sector are shown in Table 6. In the residential sector, it is expected that efficient devices such as energy efficient wood stoves and LPG stoves will have penetration rates up to 100% in 2030. The mechanism of Thailand's energy efficiency development plan would readily achieve this target.

Table 6: Expected efficiency improvement of non-electric devices in households

Appliance	Efficiency improvement (%)	Penetration in 2030 CM (%)
Wood stove	30	100
LPG stove	5	100



Action 2: Energy efficiency improvement in buildings

Energy efficiency improvement and penetration rates required in 2030 under this category of actions are shown in Table 7. In buildings, it is expected that these efficient electric devices will have penetration rates up to 100% in 2030. The mechanisms of Thailand's ECP Act, DSM and energy efficiency development plan could readily achieve this target.

Table 7: Expected efficiency improvement in buildings

Appliance	Efficiency improvement (%)	Penetration in 2030 CM (%)
Cooling	30	100
Lighting	30	100
Refrigerators	30	100

Action 3: Energy efficiency improvement in buildings (Building codes)

In this action, building insulation and building envelope must comply with Thailand's building codes 2010. New buildings must comply with this code. It is assumed that penetration rates will be up to 100% in 2030. The new Thailand building codes could readily achieve this target.

Action 4: Energy efficiency improvement in industry

Action 4.1: (Electricity related) This action assumes that the technologies in agriculture, mining, and construction sub-sectors will not be changed, while the technologies in textiles, food & beverage, chemical, others, metallic, and non metallic sub-sectors will be improved as shown in Table 8. The mechanism of Thailand's ECP Act, DSM and energy efficiency development plan could readily achieve this target.

Table 8: Expected efficiency improvement of electric devices in industry

Industry	Device	Efficiency improvement (%)	Penetration in 2030 CM (%)
Textiles	Motor	10	100
	Lighting	30	100
	Others	20	100
Food & beverage	Motor	10	100
	Lighting	30	100
	Others	20	100
Chemical	Motor	10	100
	Lighting	30	100
	Others	20	100
Others	Motor	10	100
	Lighting	30	100
	Others	20	100

Action 4.2: (Non-electricity related) This action assumes that the technologies in agriculture, mining, and construction sectors will not be changed, while the technologies in textiles, food & beverage, chemical, others, metallic, and non metallic industries will be improved as presented in Table 9. The mechanism of Thailand's ECP Act, and energy efficiency development plan could readily achieve this target.

Table 9: Expected efficiency improvement of non-electric devices in industry

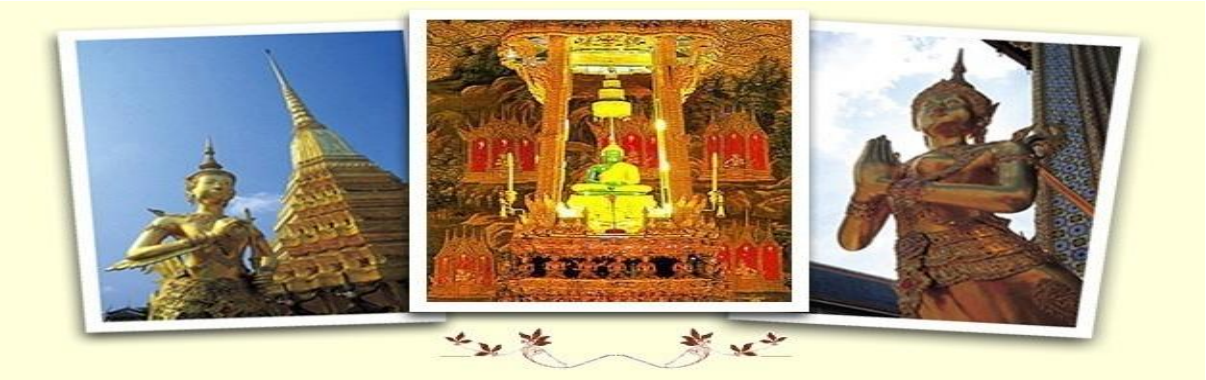
Industry	Device	Fuel type	Efficiency improvement (%)	Penetration in 2030 BAU & 2030 CM (%)
Textiles	Boiler	Coal	30	4.2
		Oil	30	92.5
		Electricity	30	3.3
Food & beverage	Boiler	Coal	30	0.1
		Oil	30	6.5
		Biomass	30	93.2
		Electricity	30	0.2
Chemical	Boiler	Coal	30	92.4
		Electricity	30	7.6
Others	Boiler	Coal	30	11.4
		Oil	30	45.8
		Gas	30	40.5
		Biomass	30	1.2
		Electricity	30	1.1
Metallic	Furnace	Coal	30	1.7
		Oil	30	3.5
		Electricity	30	94.8
Non metallic	Kiln	Coal	30	81.2
		Oil	30	4.2
		Biomass	30	5.1
		Electricity	30	9.5

Action 5: Fuel switching in Industry

This action assumes that the technologies in agriculture, mining, and construction sectors will not be changed, while the technologies in textiles, food & beverage, chemical, others, metallic, and non metallic industries will be switched to lower carbon fuels (see Table 10). The mechanism of Thailand's ECP Act, and energy efficiency development plan could achieve this target without much difficulty.

Table 10: Expected fuel switching of non-electric devices in industry

Industry	Device	Fuel type	Share in 2030 BAU (%)	Share in 2030 CM (%)
Textiles	Boiler	Coal	4.2	4.2
		Oil	92.5	46.2
		Biomass	-	46.2
		Electricity	3.3	3.3
Food & beverage	Boiler	Coal	0.1	0.1
		Oil	6.5	6.5
		Biomass	93.2	93.2
		Electricity	0.2	0.2
Chemical	Boiler	Coal	92.4	46.2
		Biomass	-	46.2
		Electricity	7.6	7.6
Others	Boiler	Coal	11.4	5.7
		Oil	45.8	22.9
		Gas	40.5	40.5
		Biomass	1.2	29.8
		Electricity	1.1	1.1
Metallic	Furnace	Coal	1.7	1.7
		Oil	3.5	3.5
		Electricity	94.8	94.8
Non metallic	Kiln	Coal	81.2	40.6
		Oil	4.2	4.2
		Biomass	5.1	45.7
		Electricity	9.5	9.5



Action 6: Fuel economy improvement (FEI) in the transport sector

Action 6.1: (Efficiency improvement) In this action, energy efficiency improvement in both the passenger and freight transports such as small vehicles, large vehicles, buses, and motorcycles needs to increase up to 20% in 2030 by using advanced automotive technologies. In addition, in this action eco-cars in Thailand will also be promoted with tax reduction and partial subsidy in investment. In addition, environmental performance standard of vehicles is needed.

Action 6.2: (Travel demand management) In this action, comprehensive promotion of travel demand management (TDM) in the passenger transport is required. It is estimated that travel demand in small vehicles, large vehicles, buses, and motorcycles decreases by 7.4% in 2030 by using eco-driving, bus priority, and non-motorized transport. Several studies of Ministry of Energy show that this action does not require any capital investment except the incentives and promotion, and the TDM action is readily cost effective.

Action 7: Fuel switching in the transport sector (Natural gas vehicle & Hybrid vehicles)

Action 7.1: (Natural gas vehicles) In this action, technology of both the passenger and freight transports such as small vehicles, large vehicles, and buses will switch from oil to compressed natural gas (CNG). In addition, the technology improvement in CNG engines will increase by 20% in 2030.

Action 7.2: (Hybrid vehicles) In this action, hybrid and plug-in hybrid cars will replace conventional gasoline engines, resulting in energy savings of 30% when compared to the 2030 BAU scenario.

Action 8: Modal shift in the transport sector

Action 8.1: (Passenger transport sector) In this action, the modal mix of passenger transport will change such that the shares of walking, bus, small vehicles, bikes, train, motorcycles, large vehicles, and airplanes would be 25%, 20%, 15%, 12.8%, 12%, 10%, 5%, and 0.2% respectively.

Action 8.2: (Freight transport sector) In this action, the modal mix of freight transport will be changed only in the large vehicles and train categories. The modal share of small vehicles, ships, and airplanes will not be changed. The share of large vehicles will decrease by 28% and will be substituted by train.

Action 9: Efficiency improvement and fuel switching in power generation

Action 9.1: (Transmission and distribution loss) In this action, the transmission and distribution losses will improve to 5%.

Action 9.2: (Fuel switching) In this action, Thailand's Power Development Plan 2010 (PDP 2010) has been considered. This action increases the share of renewable energy and nuclear energy in power generation as shown in Table 11.

Action 9.3: (Technology transfer) In this action, the new power plant technology such as Integrated Gasification Combine Cycle (IGCC) and Combined Cycle Gas Turbine (CCGT) will be added to substitute the old technologies such as coal and lignite-based power plants. Therefore, the efficiency of power plants will improve to be 56% and 48% for CCGT and IGCC power plants, respectively.

Table 11: Expected fuel switching in power generation

Fuel type	Share in 2005	Share in 2030 BAU scenario	Share in 2030 CM scenario
Natural gas	71.4%	71.4%	39.0%
Oil	6.6%	6.6%	-
Coal	15.1%	15.1%	23.6%
Hydro	4.4%	4.4%	20.5%
Nuclear	-	-	11.2%
Renewable energy	2.5%	2.5%	5.7%

Summary of GHG mitigation measures in the 2030 CM scenario

According to the 9 actions of the roadmap, Thailand's LCS vision 2030 could contribute a CO_2 reduction of 42.5% to the nation. In the 2030 CM scenario, GHG mitigation measures in the residential, commercial, industrial, transport, and power sectors could achieve GHG mitigation of 239,560 kt-CO_2 accounting for 42.5% reduction in the GHG emission under the 2030 BAU scenario. Table 12 shows summary of GHG mitigation measures from the selected actions.

Table 12: Summary of GHG mitigation measures from all actions

Action	GHG Reduction (kt-CO_2)	(%)
1. Energy efficiency improvement (EEI) in households	**10,950**	**4.6%**
- EEI in electric devices	9,330	3.9%
- EEI in non-electric devices	1,620	0.7%
2. Energy efficiency improvement in buildings	**16,384**	**6.8%**
3. Building codes	**2,350**	**1.0%**
4. Energy efficiency improvement in industries	**38,648**	**16.1%**
- EEI in electric devices	12,380	5.1%
- EEI in non-electric devices	26,268	11.0%
5. Fuel switching in industry	**41,336**	**17.3%**
6. Fuel economy improvement in transportation	**10,739**	**4.5%**
- Passenger transport	4,151	1.7%
- Freight transport	6,588	2.8%
7. Fuel switching in transportation	**9,983**	**4.2%**
- Passenger transport	2,921	1.2%
- Freight transport	7,062	3.0%
8. Modal shift in transportation	**17,556**	**7.3%**
- Passenger transport	8,087	3.3%
- Freight transport	9,469	4.0%
9. Efficiency improvement and fuel switching in the power sector	**91,614**	**38.2%**
Total GHG mitigation in 2030	**239,560**	**100.0%**
Total GHG emissions in the 2030 BAU scenario	**563,730 kt-CO_2**	
Total GHG emissions in the 2030 CM scenario	**324,170 kt-CO_2**	

Methodology

A Procedure to Create a Thai LCS Scenario

In order to create a local low-carbon society scenario, we developed a methododology based on the idea of "back casting", which sets a desirable goal first, and then seeks a way to achieve it. Figure 29 shows an overview of the method.

(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. In this study, we set the target year of Thailand to 2030. This is also a suitable time span for an LCS study for the reasons above. As an environmental target, we targeted CO_2 from energy use because it will be the main source of GHG emissions in 2030.

(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. In this research we employed the measures shown in preceding studies in Thailand on energy efficiency improvement and renewable energy utilization, and GHG mitigation of Ministry of Energy.

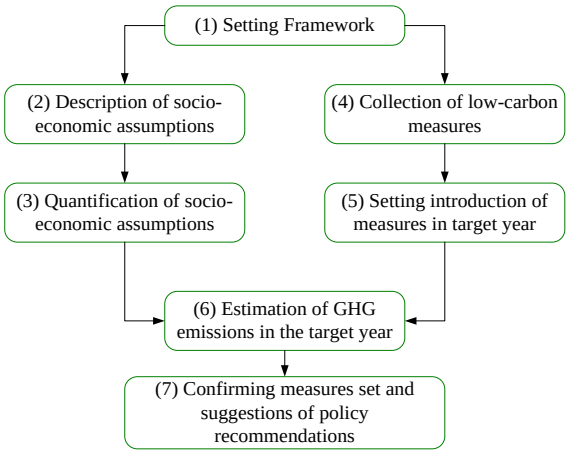


Figure 29: Procedure to create an LCS scenario

(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 30 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, ESS 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.

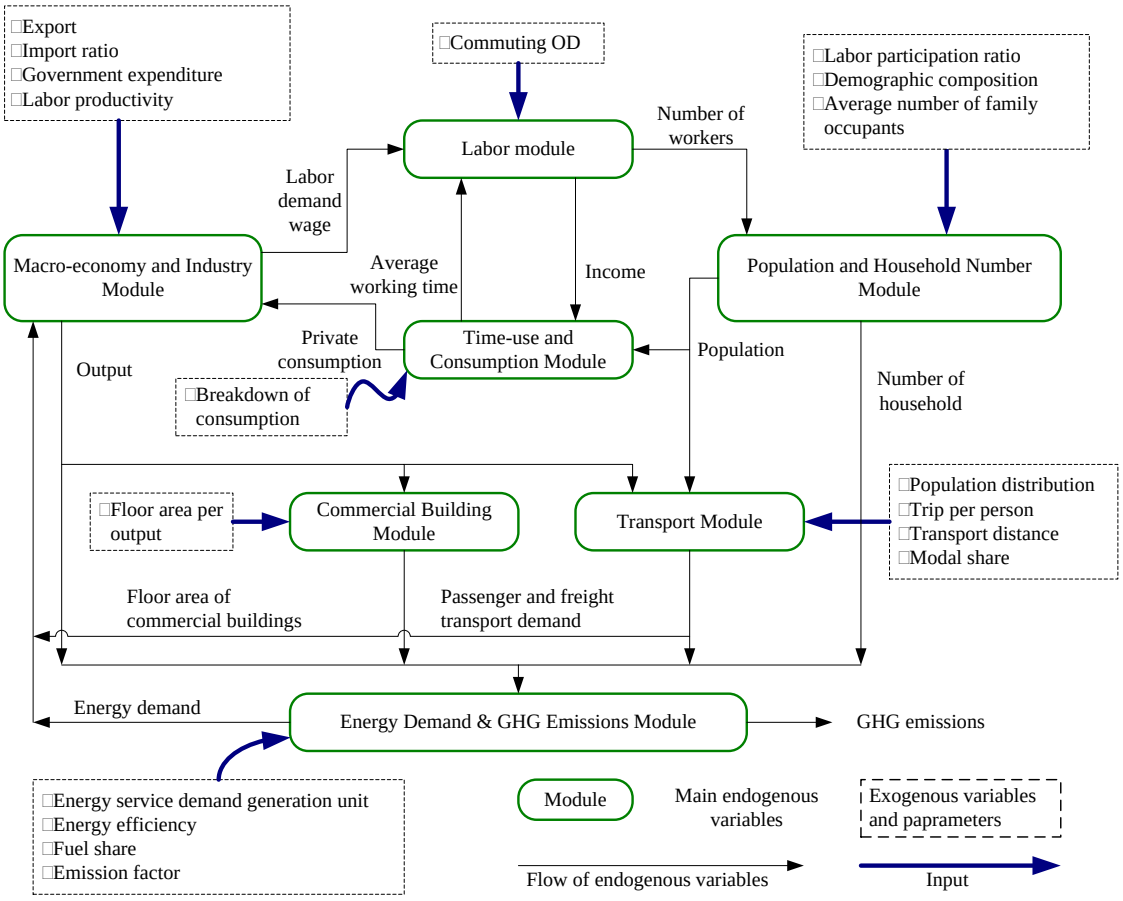


Figure 30: Overview of calculation system of Extended Snapshot Tool

Collection and Estimation of Information

The estimated results of future socio-economic indicators and energy demand in 2030 are based on the modeling of the socio-economic variables and energy balance table in 2030. Most of the socio-economic indicators and energy balance table in Thailand are obtained from published statistics and secondary sources. Assumptions are used where information for macroeconomic analysis is not available for Thailand.

The following are the procedures for estimation of socio-economic indicators and energy balance table (final demand sector).

SECTOR	PROCEDURE TO MAKE THAI ENERGY BALANCE TABLE	REFERENCES
Energy Supply Sector		
Indigenous Production Imports Exports Error term		- Department of Alternative Energy Development and Efficiency, *Thailand Energy Situation Report (2005)*, Ministry of Energy, Thailand. - Department of Alternative Energy Development and Efficiency, *Electric power in Thailand Report (2005)*, Ministry of Energy, Thailand.
Power supply		- Thailand's Power Development Plan, PDP2010. - Pattanapongchai, A. and Limmeechokchai, B., 2010, CO2 mitigation model of future power plants with integrated carbon capture and storage in Thailand. *Nuclear & Renewable Energy Conference (INREC), 2010 1st International*
Energy Demand Sector		
Transformation Sector		
Utility generation Refineries Losses & own use Statistical discrepancy		- Department of Alternative Energy Development and Efficiency, *Electric power in Thailand Report (2005)*, Ministry of Energy, Thailand.
Industry Sector		
Agriculture Mining & construction Textile Food & beverage Chemical Others Metallic Non metallic		- Department of Alternative Energy Development and Efficiency, *Thailand Energy Situation Report (2005)*, Ministry of Energy, Thailand.
Residential & Commercial Sector		
Residential Sector		- Department of Alternative Energy Development and Efficiency, *Thailand Energy Situation Report (2005)*, Ministry of Energy, Thailand.
Commercial Sector		- Department of Alternative Energy Development and Efficiency, *Thailand Energy Situation Report (2005)*, Ministry of Energy, Thailand.
Transport Sector		
Passenger Transport		
Small vehicles	Energy for small vehicles = No. of vehicles x Average distance x Average fuel economy	
Large vehicles	Energy for large vehicles = No. of vehicles x Average distance x Average fuel economy	
Buses	Energy for bus vehicles = No. of vehicles x Average distance x Average fuel economy	
Trains		- Department of Alternative Energy Development and Efficiency, *Thailand Energy Situation Report (2005)*, Ministry of Energy, Thailand.
Ships		- Department of Alternative Energy Development and Efficiency, *Thailand Energy Situation Report (2005)*, Ministry of Energy, Thailand.
Aviation		- Department of Alternative Energy Development and Efficiency, *Thailand Energy Situation Report (2005)*, Ministry of Energy, Thailand.
Freight Transport		
Freight vehicles		- Thailand transport portal, Ministry of Transport of Thailand.
Trains		- Thailand transport portal, Ministry of Transport of Thailand.
Ships		- Thailand transport portal, Ministry of Transport of Thailand.
Aviation		- Thailand transport portal, Ministry of Transport of Thailand.

SOCIO-ECONOMIC INDICATOR	UNIT	PROCEDURE TO ESTIMATE THAI SOCIO-ECONOMIC INDICATORS 2005	REFERENCES
Population	Persons		- Department of Provincial Administration, Ministry of Interior.
No. of households	Household		- National Statistic Office of Thailand, Ministry of Information and Communication Technology, Thailand.
Gross Regional Domestic Product (GRDP)	Baht (constant price in 1988)		- Office of the National Economic and Social Development Board, Prime Minister's office, Thailand.
Value of gross output	Baht (constant price in 1988)		- Office of the National Economic and Social Development Board, Prime Minister's office, Thailand.
Intermediate input	Baht (constant price in 1988)		- Office of the National Economic and Social Development Board, Prime Minister's office, Thailand.
Value added	Baht (constant price in 1988)		- Office of the National Economic and Social Development Board, Prime Minister's office, Thailand.
Paid wage	Baht (constant price at 1988)		- Office of the National Economic and Social Development Board, Prime Minister's office, Thailand.
Private consumption expenditure	Baht (constant price in 1988)		- Office of the National Economic and Social Development Board, Prime Minister's office, Thailand.
Government consumption expenditure	Baht (constant price in 1988)		- Office of the National Economic and Social Development Board, Prime Minister's office, Thailand.
Gross fixed capital formation	Baht (constant price in 1988)		- Office of the National Economic and Social Development Board, Prime Minister's office, Thailand.
Private investment expenditure	Baht (constant price in 1988)		- Office of the National Economic and Social Development Board, Prime Minister's office, Thailand.
Government investment expenditure	Baht (constant price in 1988)		- Office of the National Economic and Social Development Board, Prime Minister's office, Thailand.
Floor space of building stocks	m^2		- Santisirisomboon, J., Environmental Emission Abatement Strategies in the Energy Sector: the Integrated Economic, Environment and Energy Approach. *SIIT Doctoral Dissertation*. 2001.
No. of vehicles	Vehicles		- Department of Land Transport, Ministry of Transport of Thailand.
Trips per person per day	Trips/person/day	Trips per person per day = 2.61	- WDI, GDF & ADI Online Databases: The World Bank.

SOCIO-ECONOMIC INDICATOR	UNIT	PROCEDURE TO ESTIMATE THAI SOCIO-ECONOMIC INDICATORS 2005	REFERENCES
Modal share of passengers	%		- WDI, GDF & ADI Online Databases: The World Bank
Average trip distance	km		- Chanchaona, S., Suwantragul, B., Sasivimolphan, S., Jugjai, S., and Chuntasiriwan, S.A., 1997. Study of strategies for energy conservation in vehicles, Department of Mechanical Engineering, King Mongkut's University of Technology Thonburi.
Average fuel economy			- Chanchaona, S., Suwantragul, B., Sasivimolphan, S., Jugjai, S., and Chuntasiriwan, S.A., 1997. Study of strategies for energy conservation in vehicles, Department of Mechanical Engineering, King Mongkut's University of Technology Thonburi.
Passenger transport volume: Passenger vehicles (motorcar, motorcycle, bus)	Passenger-km		- Tanatvanit, S., Limmeechokchai, B., and Chungpaibulpatana, S., 2003, Sustainable energy development strategies: implications of energy demand management and renewable energy in Thailand. *Renewable & Sustainable Energy Reviews*. 7: 367–395.
Passenger transport volume: Railways	Passenger-km		- WDI, GDF & ADI Online Databases: The World Bank
Modal share of freight	%		- Thailand transport portal, Ministry of Transport of Thailand
Freight transport volume: freight vehicles	Tonne-km		- Thailand transport portal, Ministry of Transport of Thailand
Freight transport volume: Railways	Tonne-km		- Thailand transport portal, Ministry of Transport of Thailand
CO_2 emissions factor	kt-C/ktoe		- *IPCC Guidelines for National Greenhouse Gas Inventories*, 1996.

Table 13: Input-output table of Thailand in 2005 (Unit: billion Baht)

	Agriculture	Mining	Construction	Textiles	Food products & beverages	Chemical	Other Manufacturing	Metallic & machinery	Nonmetallic	Services	Total intermediate input	Private consumption	Government consumption	Fixed capital formation	Export	Import	Total final demand	Total use (domestic production)
Agriculture	110	0	3	540	30	112	48	0	1	108	952	541	2	(358)	62	(82)	165	1,117
Mining	0	48	52	1	0	747	169	22	67	0	1,106	0	-	(90)	62	(769)	(798)	309
Construction	1	0	0	1	0	1	2	3	1	8	17	0	1	635	1	(0)	637	653
Textiles	81	-	-	291	0	8	26	0	1	194	602	827	12	(225)	510	(199)	925	1,526
Food products & beverages	2	0	0	1	362	17	36	6	1	29	453	269	1	(133)	329	(117)	350	804
Chemical	182	36	35	60	73	478	237	240	144	485	1,969	577	46	(741)	802	(793)	(108)	1,861
Other Manufacturing	8	3	29	41	65	114	578	108	53	346	1,345	679	75	(4)	532	(463)	819	2,164
Metallic & machinery	31	13	171	64	8	19	211	2,254	19	206	2,997	437	17	640	2,235	(2,761)	568	3,565
Nonmetallic	1	0	146	7	0	2	12	27	82	3	279	47	1	214	68	(38)	292	572
Services	28	33	51	40	25	38	89	81	20	615	1,019	1,531	758	2,639	625	(387)	5,167	6,186
Total intermediate input	444	134	487	1,045	564	1,535	1,406	2,741	389	1,995	10,739	4,910	912	2,577	5,227	(5,609)	8,017	18,756
Compensation of employee	221	42	60	113	87	87	256	210	58	1,506	2,639							
Operating surplus	452	102	102	249	146	190	476	390	125	2,260	4,491							
Other value added	0	30	5	119	7	49	26	225	1	425	887							
Total value added	673	174	166	481	240	326	758	824	183	4,191	8,017							
Total input (domestic production)	1,117	309	653	1,526	804	1,861	2,164	3,565	572	6,186	18,756							

Note: Exchange rate, US$ 1 = 35 Baht.

Table 14: Input-output table of Thailand in 2030 (Unit: billion Baht)

	Agriculture	Mining	Construction	Textiles	Food products & beverages	Chemical	Other Manufacturing	Metallic & machinery	Nonmetallic	Services	Total intermediate input	Private consumption	Government consumption	Fixed capital formation	Export	Import	Total final demand	Total use (domestic production)
Agriculture	277	1	10	1,542	89	369	155	1	3	483	2,928	1,143	7	(1,301)	224	(200)	(126)	2,802
Mining	0	162	189	4	0	2,468	545	79	234	0	3,682	0	-	(329)	224	(2,539)	(2,643)	1,039
Construction	1	1	1	2	1	3	6	9	4	37	65	1	3	2,308	4	(1)	2,315	2,380
Textiles	203	-	-	829	1	28	84	1	3	869	2,018	1,747	43	(817)	1,853	(489)	2,337	4,355
Food products & beverages	4	0	2	3	1,085	56	115	21	4	127	1,417	569	2	(482)	1,198	(297)	990	2,407
Chemical	456	123	128	172	217	1,580	767	853	500	2,166	6,962	1,220	168	(2,693)	2,918	(2,423)	(811)	6,151
Other Manufacturing	21	11	104	116	195	377	1,869	385	183	,548	4,809	1,435	272	(15)	1,935	(1,436)	2,191	7,000
Metallic & machinery	78	43	624	182	25	63	683	8,019	68	922	10,707	925	60	2,327	8,128	(9,461)	1,978	12,686
Nonmetallic	2	0	531	19	1	7	38	95	286	15	993	100	5	777	248	(133)	998	1,991
Services	71	112	185	114	73	125	287	289	69	2,747	4,072	10,712	2,757	9,597	2,274	(1,767)	23,573	27,646
Total intermediate input	1,113	452	1,774	2,982	1,688	5,075	4,549	9,752	1,354	8,916	37,654	17,854	3,318	9,370	19,006	(18,745)	30,802	68,457
Compensation of employee	555	143	218	322	260	289	827	745	200	6,731	10,289							
Operating surplus	1,134	344	372	711	439	627	1,540	1,387	434	10,099	17,086							
Other value added	1	101	16	340	21	161	84	801	3	1,900	3,428							
Total value added	1,689	588	606	1,373	719	1,077	2,451	2,933	637	18,730	30,802							
Total input (domestic production)	2,802	1,039	2,380	4,355	2,407	6,151	7,000	12,686	1,991	27,646	68,457							

Note: Exchange rate, US$ 1 = 35 Baht.

Table 15: Energy demand table of Thailand in 2005 (Unit: ktoe)

Industry		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
Non manufacturing	Agriculture	-	3,218	-	-	21	3,239	5.7%
	Mining	-	25	-	-	-	25	0%
	Construction	-	140	-	-	-	140	0.2%
Manufacturing	Textiles	43	345	-	-	661	1,049	1.8%
	Food &	28	702	-	4,798	801	6,329	11%
	Chemical	809	606	-	190	798	2,403	4.2%
	Others	540	1,586	1,520	18	1,477	5,141	9%
	Metallic	162	342	-	-	553	1,057	1.8%
	Non metallic	5,173	269	-	326	602	6,370	11.1%
Total		6,755	7,233	1,520	5,332	4,913	25,753	44.9%
Residential		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
		-	1,897	-	5,621	2,203	9,721	17%
Commercial		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
		-	-	-	-	3,305	3,305	5.8%
Transport		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
Passenger transport	Small vehicles	-	2,165	8	-	-	2,174	3.8%
	Large vehicles	-	2,517	32	-	-	2,550	4.4%
	Buses	-	2,797	3	-	-	2,800	4.9%
	Trains	-	20	-	-	4.9	25	0%
Freight transport	Small vehicles	-	4,767	1.4	-	-	4,768	8.3%
	Large vehicles	-	6,153	-	-	-	6,153	10.7%
	Trains	-	79	-	-	0	80	0.1%
Total		-	18,498	45	-	5	18,548	32.4%
All sectors		6,755	27,628	1,565	10,953	10,426	57,327	100%

Table 16: Energy demand table of Thailand in 2030 BAU (Unit: ktoe)

Industry		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
Non manufacturing	Agriculture	-	8,075	-	-	53	8,127	4.9%
	Mining	-	83	-	-	-	83	0.1%
	Construction	-	512	-	-	-	512	0.3%
Manufacturing	Textiles	123	984	-	-	1,886	2,993	1.8%
	Food &	84	2,104	-	14,372	2,399	18,959	1.5%
	Chemical	2,674	2,003	-	628	2,638	7,943	4.8%
	Others	1,747	5,130	4,917	58	4,778	16,630	10.1%
	Metallic	576	1,217	-	-	1,968	3,761	2.3%
	Non metallic	18,013	937	-	1,135	2,096	22,181	13.5%
Total		23,217	21,043	4,917	16,193	15,818	81,189	49.2%
Residential		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
		-	5,071	-	15,026	5,889	25,986	15.8%
Commercial		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
		-	-	-	-	14,771	14,771	9%
Transport		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
Passenger transport	Small vehicles	-	2,443	9	-	-	2,452	1.5%
	Large vehicles	-	2,840	37	-	-	2,877	1.7%
	Buses	-	3,155	4	-	-	3,159	1.9%
	Trains	-	22	-	-	5	28	0%
Freight transport	Small vehicles	-	14,907	4	-	-	14,911	0%
	Large vehicles	-	19,241	-	-	-	19,241	11.7%
	Trains	-	248	-	-	1	249	0.2%
Total		-	47,858	54	-	6	42,918	26%
All sectors		23,217	68,972	4,971	31,219	36,484	164,863	100%

Table 17: Energy demand table of Thailand in 2030 CM (Unit: ktoe)

Industry		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
Non manufacturing	Agriculture	-	6,458	-	-	53	6,511	5.0%
	Mining	-	83	-	-	-	83	0.1%
	Construction	-	512	-	-	-	512	0.4%
Manufacturing	Textiles	109	485	247	-	1,671	2,511	1.9%
	Food &	69	1,481	-	11,144	2,162	14,857	11.5%
	Chemical	1,094	835	-	2,452	2,318	6,698	5.2%
	Others	710	2,027	5,265	1,109	4,383	13,494	10.5%
	Metallic	443	936	-	-	1,514	2,893	2.2%
	Non metallic	6,928	721	-	7,801	1,613	17,062	13.2%
Total		9,353	13,537	5,512	22,506	13,712	64,621	50.1%
Residential		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
		-	3,940	-	11,650	4,532	20,121	15.6%
Commercial		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
		-	-	-	-	11,391	11,391	8.8%
Transport		Coal	Oil	Gas	Biomass	Electricity	Total	Ratio of all sectors
Passenger transport	Small vehicles	-	658	7	444	-	1,108	0.9%
	Large vehicles	-	958	173	25	-	1,187	0.9%
	Buses	-	1,120	11	80	-	1,111	0.9%
	Trains	-	462	-	-	111	573	0.4%
Freight transport	Small vehicles	-	12,885	47	1,047	-	13,978	10.8%
	Large vehicles	-	12,207	71	991	-	13,269	10.3%
	Trains	-	1,604	-	-	5	1,609	1.2%
Total		-	29,825	308	2,587	116	32,836	25.5%
All sectors		9,353	47,301	5,820	36,473	29,751	128,968	100.0%

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