Energy consumption and GHG emission of Thailand's residential sector

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Abstract:
In this study, historical energy data from various sources were compiled to evaluate the energy consumption in residential sector in Thailand. The energy consumption was characterized for houses located within and outside municipality and for different activities in the houses: lighting, cooking, entertainment, amenity and other. Under the business-as-usual (BAU) scenario, the electrical energy consumption in the sector will increase from 48,611 GWh in 2010 (base year) to 100,475 GWh in 2030 and the greenhouse gas (GHG) emission will increase from 13,368 to 30,330 kTon carbon CO_2. However, under the energy efficient scenario, it was found that the GHG emission can be limited at 15,353 kTon carbon CO_2 in 2030. The GHG emission reduction from power generation also plays an important role in the emission mitigation from the residential sector.

Keywords: *Residential sector; Greenhouse gas emission; Urbanization, Household energy consumption*

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1. Introduction

Residential sector contributes significantly to the energy demand and production and the GHG emission of a country. In Thailand, the final energy consumption in the residential sector was at 10,650 ktoe in 2010; equivalent to 15% of the whole nation's consumption. It is expected that the consumption in this sector will continuously grow for the next decades due to urbanization, the increase in number of households, the decrease in family members, and the change in life style.

This paper investigates the energy consumption in residential sector in Thailand. In this study, the energy consumption was characterized for houses located within and outside municipality and for activities in the houses: lighting, cooking, entertainment, amenity and other. Using the predicted household numbers from the annual national statistics report, the energy consumption projection was made for the next 20 years from 2010 to 2030 for both business-as-usual scenario and energy efficient scenario. In determining the greenhouse gas (GHG) emission, the prediction was also accounted for the influence of the GHG emission reduction from power generation according to the power development plan (PDP 2010).

2. Current state of energy consumption

To assess the energy consumption in the residential sector, the number of households in 2010 was estimated from the Population Statistics reported by the Department of Provincial Administration (DOPA, 2008). The projection of the household number was also performed for the next 20 years with an assumption that family members will linearly decrease from 4.0 people per household in 2010 to 3.5 people per household in 2030.

The population growth was assumed at 0.5 percent per annum. Table 1 shows the projection where the buildings were categorized as residential houses and small commercial buildings. Each type of houses was further categorized by those located within a municipality and those outside a municipality. It can be observed that even though the Thai population will not increase by much during the considered period, the total number of households will increase nearly 25% by 2030. Due to urbanization, the houses in municipal area are expected to increase from 40% of the total houses in 2010 to about 60% of the total in 2030.

Table 1 Number of households within and outside municipal areas (Million)

Year	2010	2011	2012	2013	2014	2015	2020	2025	2030
Residential houses (RES)									
In M	5.44	5.60	5.77	5.95	6.13	6.31	7.34	8.55	9.96
Out M	8.05	8.01	7.96	7.91	7.86	7.80	7.43	6.91	6.23
Total	13.49	13.61	13.73	13.86	13.98	14.11	14.77	15.46	16.19
Small commercial buildings (SMC)									
In M	1.59	1.64	1.69	1.74	1.80	1.85	2.15	2.51	2.92
Out M	0.94	0.94	0.93	0.93	0.92	0.91	0.87	0.81	0.73
Total	2.54	2.58	2.62	2.67	2.72	2.76	3.02	3.32	3.65
RES&SMC	**16.03**	**16.19**	**16.36**	**16.53**	**16.70**	**16.88**	**17.79**	**18.77**	**19.84**

In Thailand, many forms of energy are used to power residential buildings including electricity, liquid petroleum gas (LPG), charcoal, and fuel wood. The last three fuel types have been used commonly for cooking; however, cooking by using electricity is increasing due to the changing living style. Energy consumption in residential buildings varies widely and is influenced by several factors such as the use of household appliances, change in life style, increase in average personal income, etc. From a survey study conducted by the Department of Alternative Energy Development and Energy Efficiency (DEDE), Ministry of Energy (MoEN) (DEDE, 2003), Table 2 presents the patterns of electricity use in residential buildings. In the table, the electricity use is described in terms of percentage shares of electrical energy consumption by appliances arranged in respect with activities such as lighting, cooking, entertainment, amenity and others. The equipment in each activity category are shown as below:

- Lighting category: fluorescent lamp and incandescent lamp.
- Cooking category: electric rice cooker, electric stove, LPG stove, electric frying pan, oven, microwave, blender juice, toaster and electric kettle.
- Entertainment category: television, stereo, VCD/DVD player, radio and computer.
- Amenity category: fan, air-conditioning, vacuum cleaner, washing machine, water heater, electric water pump, iron, refrigerator and freezer.

Table 2 The percent share of electrical energy use in residential building

Activities	Percent energy used in residential houses	
	Within Municipality	Outside Municipality
Lighting	12.45	16.50
Cooking	11.10	14.29
Entertainment	16.63	17.77
Amenity	56.22	46.82
Other	3.59	4.65
Total	**100**	**100**

Note that for all residential building categories, amenity is the largest-electricity-consuming activity, taking up 46.8-58.0% of the total electricity consumption. Air-conditioners and refrigerators are the major energy consumers in this activity. Electricity use for entertainment comes in second with the two main energy consumers including television and stereo. The consumption share in this activity ranges from 9.9% to 19.2%. For lighting, fluorescent lamps are most commonly used along with a small portion of incandescent lamps. Fluorescent lamps consume energy from 8.7-15.6%.

Table 2 presents the electricity use in residential buildings. The use of other energy forms is reported in Table 3, all of which are for cooking purposes. In the table, the consumption of LPG, fuel wood, and charcoal are presented in the unit of kilogram per household per year. Electricity is presented in kilowatt-hour per household per month. The data in Table 3 were compiled and analyzed from documents disseminated by the Petroleum Authority of Thailand (PTT), and by the Department of Alternative Energy Development and Energy Efficiency (DEDE).

Table 3 Annual fuel consumption for cooking in residential buildings

Energy source	Average annual energy demand for cooking (Unit/household /year)		Unit
	Houses within Municipality	Houses outside Municipality	
Electricity	211	354	kWh
LPG	82	180	kg
Fuel wood	32	568	kg
Charcoal	42	649	kg

Examining Table 3, fuel wood and charcoal are mainly used in buildings outside municipal areas. In general, small commercial buildings consume more energy for cooking. In Table 4, the useful heat from using different fuel types for cooking is presented. The heating value of the fuels and efficiency of using the fuel for cooking are shown in the table. The heating efficiency is based on the present performance of cooking technologies and methods. The useful heat in the table is reported in the unit of Mega Joule (MJ). In terms of the useful heat, LPG is the main energy source for cooking in residential houses in Thailand.

Table 4 Annual useful energy for cooking per household (MJ/household /year)

Energy source	Heating value	Efficiency (%)	Useful heat	
			Residential house	
			Within Municipality	Outside Municipality
Electricity	3.6 MJ/kWh	100	761	1,275
LPG	49.3 MJ/kg	49	1,969	4,355
Fuel wood	3.6 MJ/kg	15	76	1,362
Charcoal	3.6 MJ/kg	25	303	4,684

It can be observed that in terms of the useful heat, LPG is currently the major fuel type for cooking in Thailand. From the specific energy consumption in each household in Table 2-3 together with the number of households in Table 1, the current energy consumption for the residential sector in 2010 can be summarized as shown in Table 5.

From Table 5, the total electrical energy consumption in residential buildings is 43,006 GWh per year. Amenity activity consumes electrical energy 22,262 GWh per year, equivalent to 52% of the total consumption. Electrical energy for entertainment is the second large consumption at the amount of 7,030 GWh per year, but just one-third of that of amenity activity. Residential houses consume more energy than small commercial buildings due to its larger number of housing units. For Thailand, residential houses and small commercial buildings outside municipal area still consume energy greater than those in municipality.

Table 5 Energy consumption of the residential sector in Thailand in 2010

Activity	Energy	Residential house		Total (2010)
		Within Municipality	Outside Municipality	
Lighting	Electricity (GWh)	1,288	3,294	**5,875**
Cooking	Electricity (GWh)	1,149	2,852	**4,906**
	LPG (1,000 tons)	443	1,452	**2,360**
	Fuel wood (1,000 tons)	172	4,573	**4,986**
	Charcoal (1,000 tons)	228	5,224	**6,067**
Entertainment	Electricity (GWh)	1,719	3,546	**7,030**
Amenity	Electricity (GWh)	5,817	9,346	**22,262**
Other	Electricity (GWh)	371	928	**2,933**

Using the emission factors in the Appendix, the GHG emission from the residential housing sector in 2010 was calculated as shown in Table 6. The results show that the residential sector emits 7,133 Tons of carbon CO_2 into the atmosphere. Amenity and cooking activities emit 2,714 and 2,488 Tons of carbon CO_2 per year, respectively. This amount accounts for 73% of the total CO_2 emission from this sector. Energy for lighting and entertainment combined has a CO_2 emission of 1,575 Tons of carbon per year, or 22% of the total CO_2 emission.

Table 6 Greenhouse gas emission from the residential sector in Thailand in 2010

Fuel	Emission					
	CO_2	CH_4	N_2O	NO_X	CO	NMVOC
	kTon, C	Ton	Ton	Ton	Ton	ton
Year 2010						
Lighting	717	40	17	7,347	774	194
Cooking	2,488	139	486	13,903	1,702	447
Entertainment	858	47	21	8,793	927	232
Amenity	2,714	150	65	27,822	2,932	735
Other	357	20	9	3,660	386	97
Total	**7,133**	**396**	**597**	**61,524**	**6,721**	**1,705**

3. Projection of future energy consumption

A 20-year business as usual (BAU) scenario of the energy consumption in the residential sector was established using the projected number of households and the household energy consumptions described in Section 2. Under the business-as-usual scenario (BAU), it was assumed that the economic growth will grow at an annual average rate of 4.2% and that the population will grow at an annual average rate of 0.3%, without any significant change in the energy consumption structure, such as industrial restructuring, and without any special energy conservation measures introduced. The details and assumptions can be summarized as follows.

a) Influencing factors

- *Change in the number of households in municipality areas*

Although the energy consumption per unit of household was assumed to be the same, the overall energy consumption of the whole country would be varied with the change in the number of household units within and outside municipality area. Urbanization due to the immigration of people and the growth of the cities themselves increased the energy demand and consumption of a country. Complexity also increases due to behavioral changes in the use of household appliances both within and outside municipalities.

- *Saturation of energy used*

Projects of minimum energy performance standard (MEPs) of certain appliances, energy labeling and high energy performance standard (HEPs) are implemented continuously by the DEDE 9EGAT, 2004). These include fluorescent lamps, incandescent lamps, electric stoves, ovens, microwaves, electric kettles, TV's, computers, water coolers, air-conditioning, vacuum cleaners, washing machines, electric water heaters, refrigerators and freezers. Among various appliances, many can be found in nearly all households, suggesting that the number of equipment per household has reached saturation. Although the number of household is increasing, the saturation of equipment per household can be assumed. The energy conservation activities are assumed to also reach saturation. Appliances with increased use include air-conditioning and electric water heating which has increased each year about 718,980 and 200,000 units (MU, 2010), respectively. It is interesting to note that the increasing of air conditioning in Kasikorn Research (KRC, 2010) is around 1,090,000 to 1,150,000 units. Thus, the total energy use per household is on the increase and the numbers of households are also increasing.
In case of energy for cooking, charcoal substitution by LPG will occur not for economic reasons,

but for individuals' desire to improve one's quality of life in the context of modernization (Sanga, 2005). Although the number of household is increasing, the useful heat demand for cooking has also reached a saturation point. However, the use of electricity (such as electric stoves and microwave) and LPG (such as LPG stove) for cooking is increasing due to energy substitution, leading to the increase in the use of certain energy sources.

b) Assumptions

Followings are the assumption set for the BAU scenario:

- For residential housing and buildings, the energy consumption for lighting, cooking, entertainment and amenity, except air conditioning and water heating, have reached saturation point. In each year, the units of electric water heater will increase by 200,000 units (EGAT, 2006). On average, an electric water heater consumes 4,500 W of power for 1.5 hours a day for 8 months per year.
- The demand for air conditioning of both residential and small commercial buildings combined is increasing by 718,980 units each year (KRC, 2010). An air conditioner (EER=10) consumes 894 kWh per year.
- For small commercial buildings, the rate of electricity consumption increases in line with the growth of all activities.
- The number of residential and small commercial buildings within and outside the municipality in each year, as shown in Table 1.
- The implementation of conservation measures such as the minimum energy performance standard (MEPs), energy labeling and high energy performance standard (HEPs) for household appliances are still assumed to be in place.

The total electricity demand is estimated at about 47,863 GWh in 2010 and 98,904 GWh in 2030. In the residential sector, the energy demand in 2030 for within and outside municipal areas is more than 2.2 times and 1.1 times that in 2010, respectively. In small commercial buildings, the energy demand in 2030 is over 4.9 times and 2.3 times that in 2010 for within and outside municipal areas, respectively, as presented in Table 7. In this case, the electricity consumption for air conditioning and hot water were separated to clearly show the growth in demand from the two appliances.

Table 7 The energy consumption of the residential and small commercial buildings in each category in 2010 and 2030.

Activity			2010		2030	
			In M	Out M	In M	Out M
Residential Sector	Lighting (GWh)		1,288	3,294	2,360	2,548
	Cooking	Electricity (GWh)	1,149	2,851	2,106	2,205
		LPG (kton)	443	1,452	812	1,123
		Wood (kton)	172	4,573	315	3,536
		Charcoal (kton)	228	5,224	418	4,040
	Entertainment (GWh)		1,719	3,546	3,150	2,742
	Amenity (GWh)	Other	2,679	7,080	4,909	5,475
		Air-conditioning	5,138	2,984	13,314	7,732
		Electric hot water	1,375	902	3,994	2,620
	Other (GWh)		371	928	680	718
Small Commercial Sector	Lighting		638	655	3,519	1,524
	Cooking	Electricity (GWh)	391	514	2,158	1,196
		LPG (kton)	164	301	903	701
		Wood (kton)	10	231	56	539
		Charcoal (kton)	247	368	1362	855
	Entertainment (GWh)		1,047	718	5,770	1,671
	Amenity (GWh)	Other	1,995	3,840	10,998	1,206
		Air-conditioning	1,408	465	3,649	8,935
		Electric hot water				
	Other (GWh)		470	1,164	2,590	2,708
Total	**Total electricity (GWh)**		**48,611**		**100,475**	

According to the BAU scenario with no switch in energy in the cooking activity and assuming the same efficiency in stove technology, the percent growth of all energy is the same but the difference is in each sub sector due to the increase in number of houses. In 2030, for residential houses, although the energy demand for cooking within municipal area is expected to increase 83% from 2010 but outside municipal area is expected to decrease by only 23%. For small commercial buildings within and outside municipal areas, the energy demand is expected to increase more than five and two times that from 2010, respectively.

Tables 8 and 9 present the GHG emission from residential section in 2010 and 2030 based on the BAU scenario. Overall, the GHG emission in 2010 is one-half that of 2030.

In the EEDP development (EPPO, 2010), the energy consumption and the GHG emission from the residential sectors were evaluated for energy efficiency. Here, energy efficient appliances and equipment are introduced to the sector via various promotional measures. The assumptions of this scenario are:

- All incandescent lamps are replaced by compact fluorescent lamps.
- The use of fuel wood for cooking is replaced by charcoal, and the efficiency of the charcoal stove is improved by 25% to 30%.
- Hot water is produced using waste heat from air-conditioners, instead of electricity.
- Air-conditioning using solar energy contributes to 20% of the total energy required.

Table 8 Greenhouse gas emission from residential sector in 2010 (BAU case)

Description	**Unit**	**BAU**	**Ktoe**	**CO_2**	**CH_4**	**N_2O**	**NO_X**	**CO**	**NMVOC**
				kTon, C	**ton**	**ton**	**ton**	**ton**	**Ton**
Lighting	GWh	5,875	553	717	40	17	7,347	774	194
Cooking				2,488	139	486	13,903	1,702	447
Electricity	GWh	4,905	462						
LPG	10^6 kg	2,360	2754						
Wood	10^6 kg	4,986	1887						
Charcoal	10^6 kg	6,067	4148						
Entertainment	GWh	7,030	662	858	47	21	8,793	927	232
Amenity	GWh	27,866	2625	2,714	150	65	27,822	2,932	735
Other	GWh	2,933	276	357	20	9	3,660	386	97
Total	GWh	48,609		7,133	396	597	61,524	6,721	1,705
Total			13,368						

Table 9 Greenhouse gas emission from residential sector in 2030 (BAU case)

Description	**Unit**	**BAU**	**Ktoe**	**CO_2**	**CH_4**	**N_2O**	**NO_X**	**CO**	**NMVOC**
				kTon, C	**ton**	**ton**	**ton**	**ton**	**Ton**
Lighting	GWh	14,172	1,335	1,238	6	4	5	0	0
Cooking									
Electricity	GWh	11,683	1,100	1,020	5	3	4	0	0
LPG	10^6 kg	5,635	6,576	1,830	120	150	157	27	8
Wood	10^6 kg	11,367	4,302						
Charcoal	10^6 kg	13,838	9,460						
Entertainment	GWh	17,122	1,613	1,495	7	4	6	0	0
Amenity	GWh	40,540	3,818	3,540	16	11	15	1	0
Air-conditioning	GWh	12,106	1,140	1,057	5	3	4	0	0
Electric hot water heating	GWh	2,736	258	239	1	1	1	0	0
Other	GWh	7,829	737	684	3	2	3	0	0
Total	GWh	106,223							
Total			30,339	11,103	162	178	196	29	8

Table 10 exhibits the energy consumption and the GHG emission for this scenario. It can be observed that the energy consumption and the emission can be reduced by up to 30 percent compared to the

BAU case (Table 9). Electricity use for lighting is 50 percent lower than the BAU case. Energy and GHG emission is also reduced in all activities excluding air-conditioning which has a slightly higher emission.

Table 10 Greenhouse gas emission from the residential sector in 2030 (Energy efficiency case)

Description	**Unit**	**EE**	**Ktoe**	**CO_2**	**CH_4**	**N_2O**	**NO_X**	**CO**	**NMVOC**
				kTon, C	**ton**	**ton**	**ton**	**ton**	**Ton**
Lighting	GWh	6,010	566	525	2	2	2	0	0
Cooking									
Electricity	GWh	8,479	799	740	3	2	3	0	0
LPG	10^6 kg	2,989	3,488	971	64	80	83	14	4
Wood	10^6 kg								
Charcoal	10^6 kg	6,446	4,407						
Entertainment	GWh	13,301	1,253	1,161	5	3	5	0	0
Amenity	GWh	30,350	2,858	2,650	12	8	11	1	0
Air-conditioning	GWh	13,153	1,239	1,149	5	3	5	0	0
Electric hot water heating	GWh	1,251	118	109	0	0	0	0	0
Other	GWh	6,644	626	580	3	2	2	0	0
Total	GWh	79,188							
Total			15,353	7,886	95	101	112	16	5

4. Conclusion

The energy consumption was investigated for residential sector in Thailand. The results show that the amenity activity (air-conditioning and hot water heating) possesses that largest consumption share in the residential sector. The LPG is the main fuel sources for cooking but the penetration of electricity is dramatically rising. Under the business-as-usual (BAU) scenario, the electrical energy consumption will increase from 48,611 GWh in the base year 2010 to 100,475 GWh in 2030 due to the urbanization, increase in number of households, the decrease in family members, and the change in life style. The greenhouse gas will increase from 13,368 kTon carbon CO_2 to 30,330 kTon carbon CO_2. However, the replacement of incandescent lamp by fluorescent lamp, the use of efficient LPG stove, the use of hot water all produced from waste heat of air-conditioner will limit the GHG emission in 2030 at 15,353 kTon carbon CO_2. The GHG emission reduction from power generation also plays an important role in the emission mitigation from the residential sector.

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Reference

Department of Provincial Administration (DOPA). 2008. Thailand Population Statistics (2008).

Department of Alternative Energy Development and Efficiency (DEDE). 2003. Final report on energy consumption in residential sector. Submitted by King’s Mongkut University of Technology Thonburi.

Electricity Generating Authority of Thailand (EGAT). 2004. Report on Electric Appliances in Residential Houses (2004).

Mahidol University (MU). 2010. Project Review on Promoting and Study Plan of Energy Efficiency of High Performance Equipment and Materials for Conservation. On 8th September 2010, at The Twin Tower Hotel, commissioned by Department of Alternative Energy Development and Efficiency (DEDE).

Kasikorn Research Center (KRC). 2010. Air conditioners, 2010: Hot summer boosting sales, promotions abound (Issue No.2208).

Electricity Generating Authority of Thailand (EGAT). 2006. A report on an analysis of production and marketing of electrical and appliance labeling and not labeling. Submitted by Kasetsart University.

Sanga, AG. 2005. Impacts of efficient stoves and cooking fuel substitution in family expenditure of urban households in Dar es Salaam, Tanzania, International Energy Initiative (Latin America Office), Energy Discussion Paper No. 2.59.1/05.

Energy Policy and Planning Office (EPPO). 2010. The 20-year Energy Efficiency Development Plan (EEDP 2010-2030).

Office of Natural Resources and Environmental Policy and Planning (ONEP). 2010. Greenhouse Gas Inventory in Energy Sector, Thailand.

Electricity Generating Authority of Thailand (EGAT). 2010. Thailand Power Development Plan: 2010-2030.

Appendix

Table A.1: The reference values of GHG emission from fuel use for Thailand

Fuel	Unit (Million)	Energy		Emission					
		TOE	TJ	CO_2	CH_4	N_2O	NO_X	CO	NMVOC
				Ton, C	kg	kg	kg	kg	kg
Natural gas	cubic feet	24.2	1.0	15.6	1.0	0.102	153.0	20.4	5.1
Bunker oil	Liter	941.2	39.8	839.1	119.3	23.9	7954.0	596.6	198.9
Diesel	Liter	862.0	36.4	735.7	109.3	21.9	7284.0	546.3	182.1
Lignite	Kg	247.7	10.5	289.0	10.5	14.7	3141.0	209.4	52.4
Coal	Kg	624.2	26.0	696.8	26.0	36.4	7800.0	520.0	130.0
Liquid petroleum gas	Kg	1166.9	49.3	789.4	44.4	199.8	3174.1	435.0	117.6
Charcoal	Kg	683.6	28.9	745.1	28.9	40.4	8664.0	577.6	144.4
Wood	Kg	378.5	16.0	478.1	479.7	64.0	1599.0	15990.0	799.5

Note: The CO_2 emission shown in the table is in the unit of tonnage of carbon amount. To determine the amount of CO_2 emission, a factor of 44/12 has to be multiplied with the values in the table.

Table A.2 Commercial fuels for electric power generation in Thailand in 2010 and in 2030.

Fuel	Year 2010			Year 2030		
	Physical unit	ktoe	GWh	Physical unit	ktoe	GWh
Natural gas (Million cubic feet per day)	1,986	17,528	104,217	1,637	14,448	86,158
Bunker oil (Million liter per year)	227	214	910			
Diesel (Million liter per year)	26	22	112	6	5	21
Lignite (Million kilogram per year)	15,940	3,948	16,359	6,920	1,714	8,522
Coal (Million kilogram per year)	3,650	2,278	12,320	26,600	16,603	73,368
Total		23,990	152,954		32,770	347,948
kTOE/GWh		0.15685			0.09418	

Note: Table A.2 does not include hydropower, renewable energy, waste, biomass, and nuclear sources for power generation.

Table A.3 The GHG emission factor from electric power generation in Thailand

Fuel	Emission					
	CO_2	CH_4	N_2O	NO_X	CO	NMVOC
	Ton, C	kg	kg	kg	kg	kg
Year 2010						
Natural gas	73.96	4.83	0.48	725.11	96.68	24.17
Bunker oil	1.2454	0.1771	0.0354	11.8046	0.8853	0.2951
Diesel	0.1238	0.0184	0.0037	1.2258	0.0919	0.0306
Lignite	30.12	1.09	1.53	327.34	21.82	5.46
Coal	16.63	0.62	0.87	186.13	12.41	3.10
Total	122.07	6.74	2.92	1251.61	131.89	33.05
Year 2030						
Natural gas	26.80	1.75	0.18	262.74	35.03	8.76
Bunker oil	0.0	0.0	0.0	0.0	0.0	0.0
Diesel	0.0118	0.0018	0.0004	0.1172	0.0088	0.0029
Lignite	7.25	0.47	0.05	71.05	9.47	2.37
Coal	53.27	1.99	2.78	596.30	39.75	9.94
Total	87.33	4.21	3.01	930.20	84.27	21.07

Note: The amount of electricity generation was determined based on all energy sources, but the amount of the GHG emission was calculated only from those fuels in Table A.2. It can be seen that the GHG emission from power generation is rather low since natural gas is the major fuel source contributing to about 70% of the power generation. In 2030, the GHG emission will reduce significantly after the introduction of nuclear energy for power generation.