ภาพอนาคตการปลดปล่อยก๊าซเรือนกระจกที่เกิดจากการใช้พลังงานของไทยในระยะยาว

The Outlook of Long-term Energy-related GHG in Thailand

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อจำลองภาพเหตุการณ์อนาคตเพื่อประเมินการปล่อยก๊าซเรือนกระจกที่เกิดจากการใช้พลังงานของประเทศไทยในระยะยาว โดยเน้นพิจารณาภาพอนาคตในลักษณะ ‘กรณีอ้างอิง’ กล่าวคือเป็นภาพอนาคตที่สะท้อนถึงการดำเนินนโยบายในรูปแบบตามที่เป็นอยู่ในปัจจุบัน ประเด็นด้านความมั่นคงในการจัดหาพลังงานเป็นปัจจัยหลักที่พิจารณาเป็นอันดับแรกในการติดสินใจกำหนดมาตรการและกำหนดทิศทางในการใช้ทางเลือกเชื้อเพลิงประเภทต่างๆ ด้วยแนวทางนี้แผนงานต่างๆที่มีอยู่แล้วในปัจจุบันไม่ว่าจะเป็นแผนพัฒนากำลังการผลิตไฟฟ้าหรือแผนส่งเสริมการใช้พลังงานทดแทนจะถูกนำมาพิจารณาในแบบจำลอง ผลการศึกษาชี้บ่งชี้ว่าแม้ว่าจะมีความพยายามส่งเสริมการใช้พลังงานสะอาดในรูปแบบต่างๆอย่างเต็มที่ ปริมาณก๊าซเรือนกระจกที่เกิดจากการใช้พลังงานของไทยก็ยังมีแนวโน้มเพิ่มสูงขึ้นกว่าสองเท่าตัวในปี 2030 เมื่อเปรียบเทียบกับปี 2008 โดยการใช้พลังงานในภาคคมนาคมขนส่งและการผลิตไฟฟ้าเป็นสาขาที่ก่อให้เกิดการปล่อยก๊าซเรือนกระจกสูงที่สุด

Abstract

The aim of this study is to draw the future scenario of energy-related GHG emission in Thailand to 2030. The picture with no change of government policy which is relied on the existing energy plan and measure namely ‘The reference scenario’ is focused. Energy security is considered to be the first priority among the major drivers to identify choice of fuel consumption and measures. In this case, the existing plans such as the power development plan (PDP) and renewable development plan (REDP) are taken into the account. The results indicated that the overall energy-related GHG in 2030 will be double from the base year of 2008, although various types of clean energy will be fully supported. Power generation and transportation will still keep their majority for GHG contribution.

คำสำคัญ : ภาพอนาคตพลังงาน การลดปริมาณก๊าซเรือนกระจก แบบจำลองพลังงาน ความต้องการพลังงาน

Key words: Energy outlook, GHG mitigation, Energy model, Energy demand

1. Introduction

The recent World Energy Outlook (WEO2009) states that beside China and India, South East Asia countries will be set to play increasingly an important role in global energy market in a decade ahead. Many challenges on energy-related GHG mitigation in this region are necessary to overcome, in particular the balance of energy security and global warming awareness under the circumstance of rapid economic growth in this region. To tackle these issues, it is necessary to draw the basic information on the outlook of energy-related GHG in the region to create the concrete action plan for GHG mitigation. In term of the national authority, projection of energy-related GHG by sectors could crucially be the basic information for evaluating emission trading potential and analyzing appropriated set of measures for national GHG mitigation.

A study on energy and GHG system in Thailand has been progressively developed by various approaches and dimensions. Santisirisomboon et al. [1] evaluated the power generation plan by least cost method and allowed the target of CO_2 emission mitigation into the calculation. Tanatvanit et al. [2] developed the model to simulate energy demand and supply of the major sectors and focused on renewable energy deployment. Charusiri et al. [3] developed the baseline scenario for Thailand power system by scenario approach. Load forecast and outlook for power generation has been evaluated. Wangjiraniran et al. [4] evaluated an impact of generation cost, emission and resource depletion on the fuel option for power generation.

The aim of this study is to draw the future prospect of energy-related GHG emission in Thailand to 2030. The picture with no change of government policy which is relied on the existing energy plan and measure namely 'The reference scenario' is focused. Energy security is considerably the first priority among the major drivers. Choices of fuel-mix and numbers of measures are identified by energy security role, where as climate change and energy efficiency becomes less important.

2. Methodology

In this study, a scenario-based energy accounting model, i.e. LEAP (Long-Range Energy Alternative Planning system) [6] has been applied for creating long-term future scenarios. It is particularly designed for balancing energy system with an integrated environmental database. Emission factors are mostly relied on the recommendation of IPCC.

The diagram of typical calculation structure is illustrated in Figure 1. Energy demands are initially derived by the products of key drivers, e.g. macro-economic growth, and energy intensities in the demand module. In the transformation module, the requirement of each fuel will be fulfilled with the production of existing installed capacities and conversion efficiency. Primary resource is withdrawal by the required feedstock during the transformation process. The entire energy system is balance by exporting the surplus and importing the shortage energy. Under this scheme, energy-related GHG will be evaluated endogenously based on the energy consumption at each stage with the emission factor of IPCC tier 1, integrated in the Technology Database (TED).

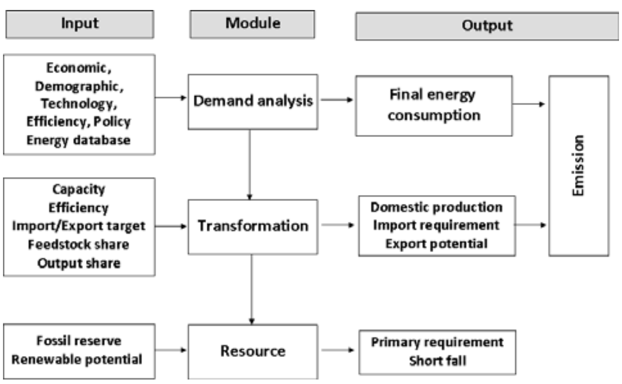


Figure 1 Calculation structure

In order to reveal the contribution of energy-related GHG, the analysis is disaggregated into a hierarchical structure, comprising of the six major energy-related sectors in harmony with the national energy database [5]. The structure of final energy demand is illustrated in Figure 2. Activities in transportation and industrial sectors are disaggregated by mode of transport and sub-industries, respectively. The remainders are divided by sector level. This structure relies definitely on the national energy database classified by ISIC and TSIC. For power generation, it is necessary to separate the structure into the individual technology in order to clarify the different characteristics of GHG emitted from each power production process as illustrated in Figure 3.

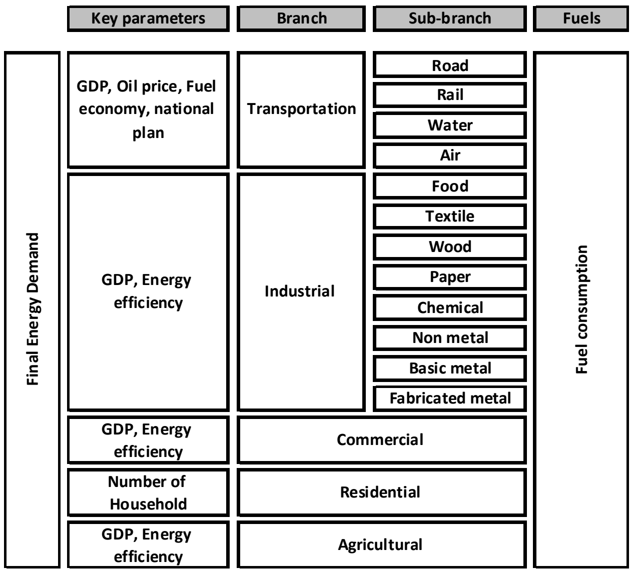


Figure 2 Structure of final energy demand

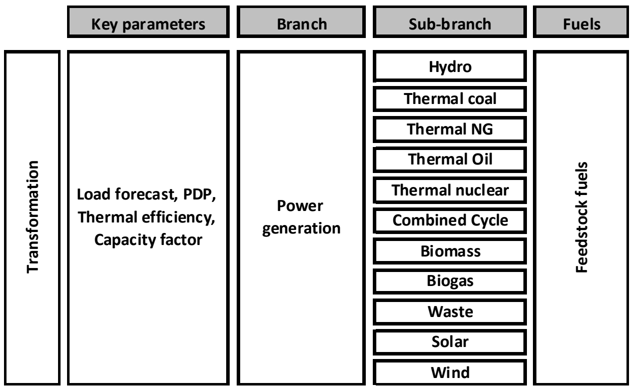


Figure 3 Structure of power generation

2.1 Final consumption: Transportation

In transportation sector, it is known that energy demand is basically evaluated from the travelling demand and number of vehicle ownership. These parameters are normally estimated as a function of income, population, local user behavior and so on [7]. However, the database for transportation activities in Thailand is insufficient to analyze by this approach.

In this study, it is assumed that energy demands in road transport are driven mainly by the growth of transportation value-added and partly influenced by the energy-price movement. Sensitivity of the oil price to the oil demand can be expressed in term of the oil intensity illustrated in Figure 4. Historical data shows that the rising of oil price caused the lower oil intensity in Thailand for the last decade. Double oil price will decrease by approximately 15 percent of oil intensity. Penetration rate of alternative energy utilization, e.g. bio-fuel, CNG/NGV and electric vehicle, are directly input into the model. In this case, substitution effect can be evaluated directly by the comparative fuel consumption rate of conventional and alternative fuel.

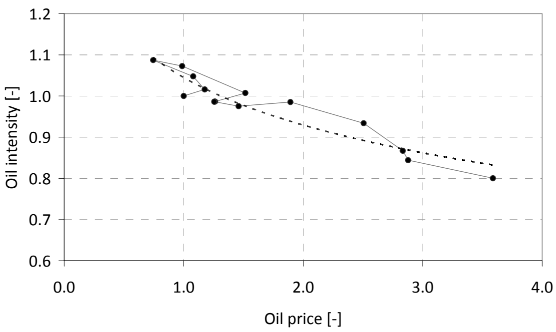


Figure 4 Correlation of oil intensity and crude oil price (Index 1995 = 1)

In rail mode, energy consumption depends strongly on the achievement of infrastructure development. Hence the current calculation scheme is designed to allow the exogenous input of energy consumption. Incremental energy consumption in rail mode will also reduce the conventional fuel in road transport. In this study, the energy conversion factor for road-to-rail switching to serve the desired traveling demand is assumed to be approximately 23.9 times. This figure is derived from the study of existing system; the current BTS and MRT.

For air and waterway transport, fuel consumptions are simply estimated by the product of transportation value-added and energy intensity.

2.2 Final consumption: Industrial, Commercial and agricultural sectors

Energy consumption in industrial, commercial and agricultural sectors has been proved that it depends highly on the economic condition [8]. Hence fuel consumption is presumably evaluated by the product of sectoral/sub-sectoral value-added and energy intensity in each branch. In this case, it is assumed that there is no significant change of fuel consumption structure in these sectors.

2.3 Final consumption: Residential sector

In the residential sector, numbers of households are considerably the major driver for the overall energy consumption [2]. The current scheme is designed to allow the direct input of fuel mix share to represent the development of energy use pattern, e.g. substitution of traditional fuel by modern energy.

2.4 Transformation: Power production

The simulation scheme of this study is definitely different from the model of authorized utilities, which relied on the optimization approach. Hence, the mirror simulation based on the concept of the power development plan will be adopted. The calculation scheme for this study can be described as follows.

In order to clarify the requirement of power supply, peak power requirement is evaluated from the electricity demand obtained from the previous module of final energy consumption and the averaged country load profile. Transmission loss of 5 percent has been assigned constantly over the calculation period. The entire power supply option is designated by the direct input of national plan. Electricity import target is allowed for direct input into the power supply module. Installed capacities of new and retired power plant as well as the required feedstock for each process have been taken exogenously into the account. Characteristic of power production technologies, utilized in this study, has been assumed based on available data as illustrated in Table 1.

Table 1 Characteristic of power production technology ([9],[10])

Technology	Characteristics			
	Size	Life time	Efficiency	Capacity Factor
	MW	yr	%	%
Hydro power	1000	50	38	45
Thermal: Oil-fired	700	30	35	80
Thermal: Coal-fired with FGD	700	30	35	90
Combined cycle	700	20	45	90
Gas turbine	230	20	35	90
Nuclear	1000	30	35	90
Biomass	80	30	35	50
Biogas	10	30	30	50
Waste	10	30	30	50
Wind	10	20	15	20
Solar PV	5	20	15	15

Accuracy of the utilized simulation scheme has been verified by comparing the calculated reserve margin with the actual data (2003 – 2008) and the official PDP revision 2 (2009 – 2021) under the identical load forecast and exogenous installed capacity of power plants. The results are illustrated in Figure 5. It is shown that the current scheme can capture the variation of reserve margin within margin of 5%. The deviation can be presumed by the averaged properties of power production by generation type.

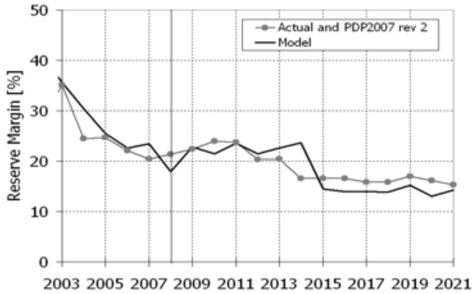


Figure 5 Verification of the mirror simulation compared to the actual data and the PDP.

3. The reference scenario

3.1 Definition

The reference scenario represents the target future prospect under the pathway of current government policy. Energy security is considerably the first priority among the major drivers. Choices of fuel-mix and numbers of measures are identified by energy security role, where as climate change and energy efficiency becomes less important. The existing plans such as the power development plan (PDP) and renewable development plan (REDP) are taken exogenously in the model.

3.2 Key assumptions

As described above, there are several input parameters required for shaping energy demand and supply of the model. This paper will focus only the major key drivers affecting the uncertainty of the results.

- **Macro-economic condition**

In this study, the assumption of GDP growth is illustrated in Figure 6. According to the NESDB economic outlook published in November 2009 [11], the annual GDP growth is expected to resume from -3 percent in 2009 to the range of +3 and +4 percent in 2010. In the long-run, the figures of GDP proposed in the PDP2007 revision 2 (2009-2021) [12] has been presumed. The highest annual growth rate of +5.8 percent is expected during 2015-2016 and slightly drop down into +5.5 percent in 2021. Beyond that, the annual GDP is assumed to be steadily decreased into +4.6 percent in 2030. It must be noted that these figures are understood as an ambitious target and comparatively higher than other references. In the latest WEO2009 [13], long-term economic growth of Thailand has been assumed approximately 3.3 percent per annum in the reference scenario, which is slightly lower than the entire ASEAN country of 3.8 percent. Sensitivity of GDP range on the calculated final energy consumption is illustrated in Figure 7. The different growth of 2.2 percent per annum will bring the deviation of final energy consumption by 20.9 percent

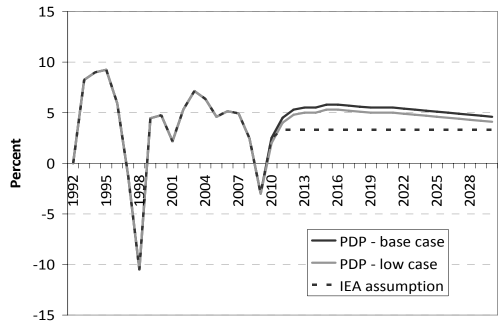


Figure 6 GDP assumptions (the figure of PDP-base case has been utilized in the reference scenario)

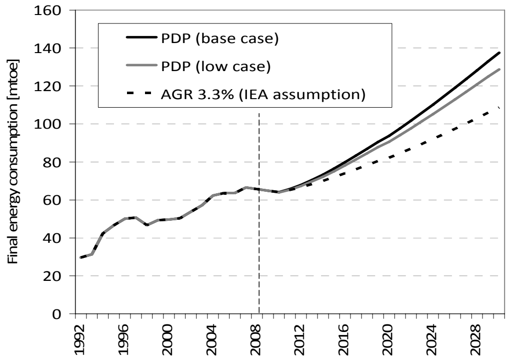


Figure 7 Sensitivity of GDP assumptions on the final energy consumption

The assumption of sectoral GDP is illustrated in Figure 8. In the last decade, the economic growth of Thailand depended strongly on the contribution on industrial and commercial sector, driven by the export engine. The portion of industrial GDP has been obviously increasing over time, while it has been opposite for commercial and agricultural sectors. In this study, it is assumed that the contribution of industrial sector will become saturated, while the role of commercial and trading will become slightly increased. This assumption is referred to the previous study of TDRI (2000 – 2016). Beyond 2016, it is assumed that there is no significant change on Thailand macro-economic structure from the year of 2016.

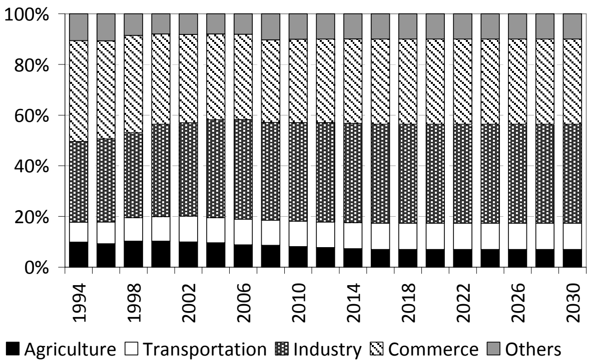


Figure 8 Assumption of sectoral GDP

Similar to the description above, the assumption of industrial sub-sector is illustrated in Figure 9. Based on the TDRI study, it is assumed that the fabricated metal and chemical industries will continue their majority on the overall industry economic. On the other hand, food and textile industries will become slightly falling. These trends are in harmony with the previous study of Thailand competitive matrix (TCM) [14] as illustrated in Figure 10. Most of economic activities in transportation (e.g. travel and tourism) and industrial sectors (e.g. chemical, office and household etc.) are located in the positive group. On the other hand, the activities in agriculture (e.g. rubber and cassava) as well as food industry are falling in the question mark group.

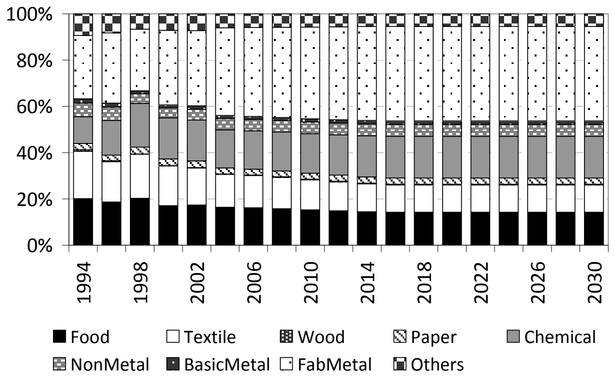
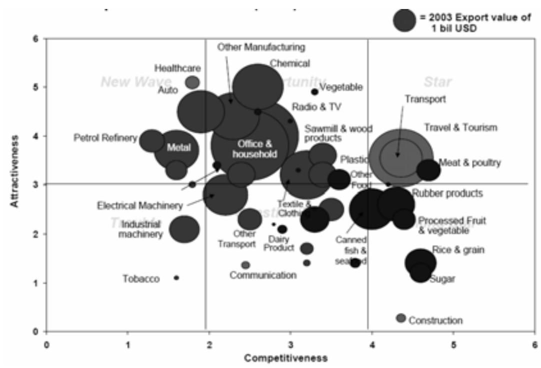


Figure 9 Assumption of industrial sub-sector share of GDP



(a) Industrial and transportation sectors

(b) Agricultural sector

Figure 10 Thailand Competitive Matrixes (TCM)

- **Demographic assumption**

Assumption for population and household are illustrated in Figure 11. Population forecast are relied on the official report released by NESDB [15]. Population in Thailand will continue to grow with slower rate until reaching its saturation at 70-71 million persons in 2024-2030. This trend is in line with population forecast report of UNDP [16]. In order to evaluate the number of household, it is assumed that size of unit household is reduced to approximately 3 persons at 2030 by averaging a single child for separated family.

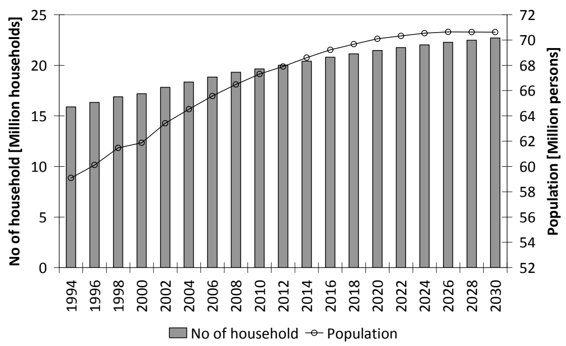


Figure 11 Assumption on population

- **Oil price assumption**

In this study, the assumption of oil price is based on the reference case of annual energy outlook (AEO2009) [17] as illustrated in Figure 12. The rising of oil price in the long-run has been expected from various studies due to the balance of energy demand growth and the constraint of energy resources. Final energy price will be presumably relied on the mention-above oil price with unchanged retail price structure.

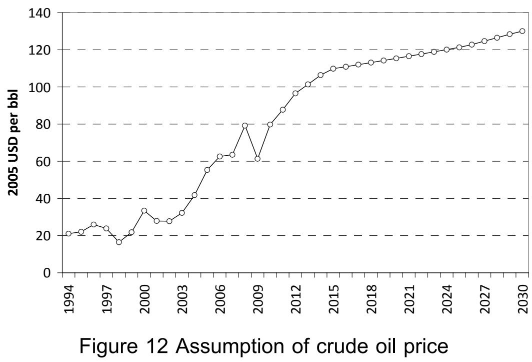


Figure 12 Assumption of crude oil price

- **Energy efficiency**

The assumption on energy efficiency in this study is relied on the historical development of energy intensity. It is presumed that achievement of future energy efficiency program is likely similar to the past. There is no structural change for energy industries, e.g. privatization, and/or government policy, which may cause the significant improve of energy efficiency. The utilized assumptions for the major sectors are illustrated in Figure 13. It is indicated that transport activity are known as an intensive energy sector, while industrial and commercial sectors are much more efficient in term of the energy intensity. Becoming more trading and commercial country would bring the benefit in term of the energy efficiency. In the other hand, the underdeveloped transport infrastructure and fuel subsidy scheme will bring the ultimate opposite result.

Similarly, the assumptions of energy efficiency for industrial sub-sectors are illustrated in Figure 14. It is obviously shown that there are wide ranges of energy intensity in industrial sector. Hence, the restructure of industrial economy would dramatically affects to the energy efficiency and fuel mix of energy use. However, it is assumed that there is no change in economic and industrial structure in the reference scenario.

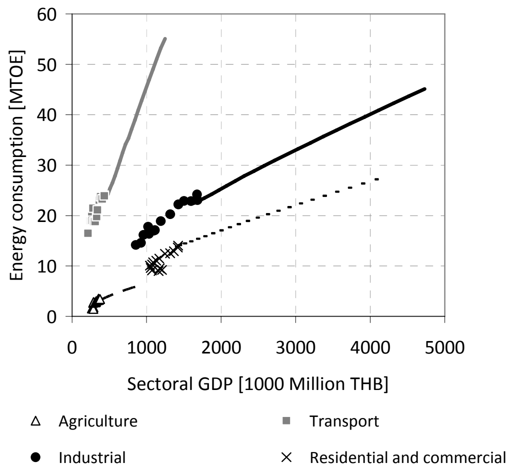


Figure 13 Assumption on energy efficiency by sectors

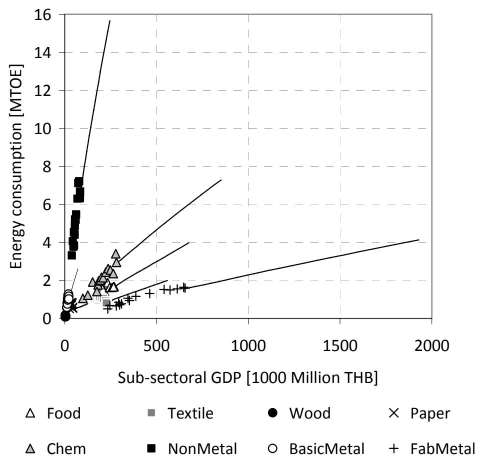


Figure 14 Assumption on energy efficiency by industrial sub-sectors

- **National plan and target**

Ministry of Energy has been released the long-term master plan for alternative energy promotion, namely Alternative Energy Development Plan 2009-2022 (REDP) in mid of 2009 [18]. The aim is to initiate the series of mandatory measures and incentives to achieve the desired alternative energy target. This plan covers on a wide range of alternative energy in various sectors, including the road map of bio-fuels. As illustrated in Figure 15, the mandated E10 and B5 has been planned to implement in 2010. Higher blending, i.e. E85 and B10, has been set as an option. This will lead to the requirement of ethanol by 9 million liters per day and biodiesel by 4.5 million liters per day within 2022. Natural gas for vehicle (CNG/NGV) is targeted to replace the conventional gasoline and diesel by 13 percent in 2012. In the reference scenario, it is assumed that all targets will be definitely achieved. Beyond the REDP period (2023-2030), consumption of alternative fuels will continue rising at the same rate as proposed in the REDP, regardless of the resource constraint. Roadmap of electric vehicle (EV) is not clearly defined in the REDP. In the reference scenario, it is assumed that penetration rate of EV in Thailand will be in line with the growth rate of the EV global market, represented by the expected total sales in U.S [17], scaling by the market size and applying the delayed time of 5 years. It must be noted that the economic of alternative fuels depends very much on the uncertain oil price, which may contribute to the uncertainty of the alternative energy penetration and achievement of the REDP.

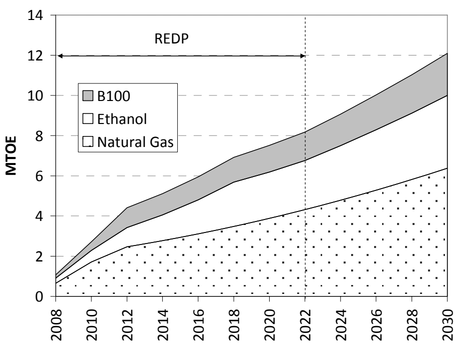


Figure 15 Target of alternative energy in road transport (REDP)

The assumption of master plan for railway mass transit in Greater BKK is illustrated in Figure 16. It is based on the available data of the original completed 10-lines master plan, released on the previous PDP2004 [19]. It is assumed that the projects will be postponed and the last system will be ready before 2030. Notice that the inter-city railway development is not taken into the account in this study. Hence, the consumption of diesel utilized for ordinary locomotives is presumably constant over time.

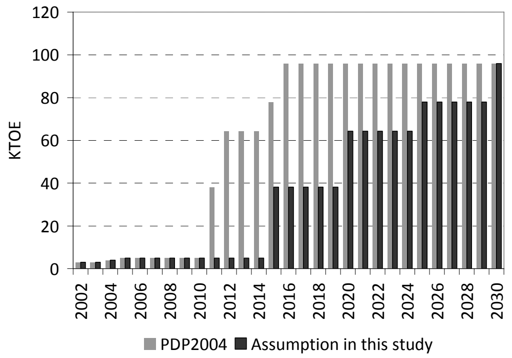


Figure 16 Electricity consumption for railway mass transit plan

Power sector is considerably one of the major sectors crucially affecting the energy consumption and the GHG emission. Under the official PDP2007 revision 2 (2009-2021) [12], the requirement of power supply is evaluated from the calculated peak power requirement and constantly 15 percent reserve margin. Target of electricity import is increase year by year and reach nearly 5,500 MW at the end of 2021. Beyond the year of 2021, it is assumed that capacity of electricity import will continuously expanded to nearly 9,000 MW in 2030. These import capacity will reduced the domestic energy-related GHG emitted in Thailand power sector, but will still add-up the global GHG as a whole.

For power production, the emitted GHG will strongly depend on power production technologies and feedstock for generation process. The assumption of feedstock share for power production in this study is illustrated in Figure 17, nuclear power plant will be introduced in 2020 under PDP. Beyond the 2021, it is assumed that (clean) coal and nuclear power plant (NPP) will play much more important role. Most of the natural gas combined cycle power plant will be decommissioned and replaced by coal-fired power plant with CCS and NPP, particularly at the period beyond 2021. The debate of nuclear and coal protest will be the key factor for the commissioning of the first NPP and the large expansion of coal-fired power plant in the future. In addition, the consequential construction of NPP must be relied on the concrete financial plan.

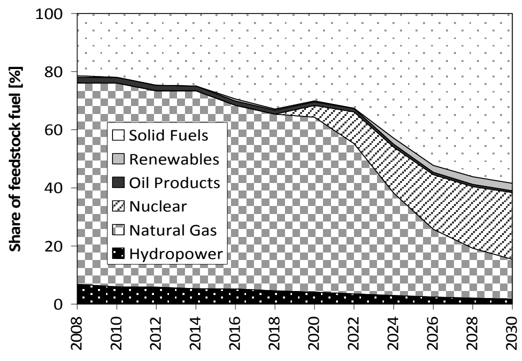


Figure 17 Assumption of feedstock share for power production

The RE-power generations (SPP and VSPP), e.g. biomass, biogas, wind and solar, are also presumably taken into the plan by approximately 5800 MW in 2030 as illustrated in Figure 18, but still has small portion compared to the total capacity requirement. These figures are presumably derived by the renewable potential assessment for power generation under the REDP. Biomass will play a crucial role for RE-power generation in Thailand, particularly the near-term. Solar PV will slightly increase their market share from less than 0.2 percent in 2008 into nearly 20 percent of the total RE-power generation in 2030 according to the perspective of cost reduction. In the other hand, power production from biogas, waste and wind energy would encounter the constraint of resource availability and be considered as an option.

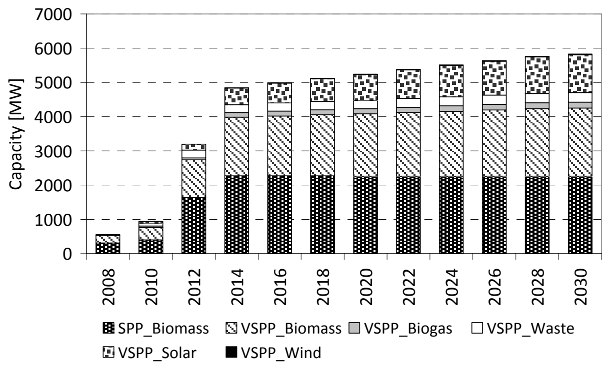


Figure 18 Penetration of SPP/VSPP-Renewable energy

4. Results

4.1 Overview

According to the above assumption, the prospect of energy-related GHG for the reference scenario is illustrated in Figure 19. The result indicates that the emitted GHG will slow down shortly due to the economic crisis and will recover very soon according to the economic recovery. This will not change the trend of long-term prospect similar to the key messages reported by the recent world energy outlook [13]. The results also show that energy consumption in power generation and transportation sector will contribute to more than 75 percent of the overall energy-related GHG in 2030. Notice that the attempt to promote green energy by the government has already accounted for the calculation.

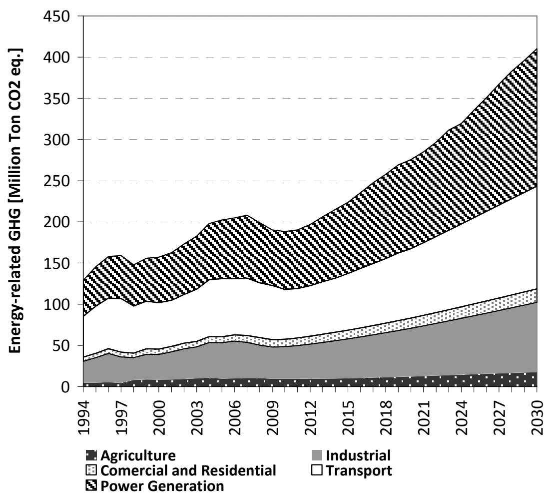
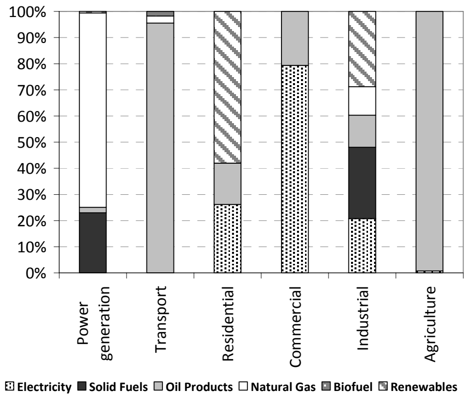
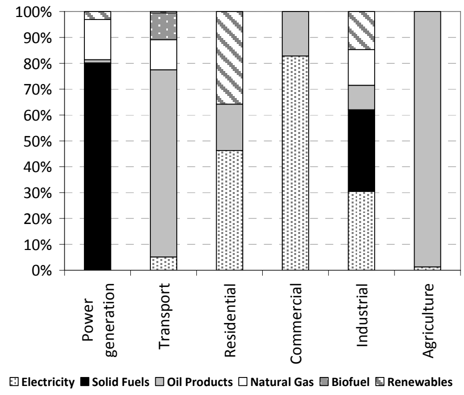


Figure 19 Outlook of GHG for major energy sectors in Reference scenario

As illustrated in Figure 20, it is obviously seen the major fuel switching in power generation and transportation sector. Electricity demand will be obviously increased in all final demand sectors. This leads to the burden of power supply and boosts up the importance of clean energy requirement in power generation. Clean coal with CCS and nuclear power plant will play the major role in the PDP as described previously. Bio-fuel and CNG/NGV would significantly build-up the market share of alternative fuel in transportation sector, but oil still dominates more than 70 percent of the entire market, in particular the diesel consumption for freight transport.



(a) 2008



(b) 2030

Figure 20 Share of fuel mix for the reference scenario

4.2 Sectoral analysis

The GHG per unit final energy consumption by sector is illustrated in Figure 21. This parameter represents how clean the fuel mix in each sector will be in the reference scenario. Since activities in agricultural and transportation sectors depends very much on oil product (Figure 20), the cleanliness of the fuel mix in both sectors is definitely higher than the others. However, the strategic plan of REDP will help reducing the GHG in transportation in the long-run. The mixture of various fuels causes the moderated GHG level in industrial sector. On the other hand, the high portion of electricity use in residential and commercial activities will transfer the GHG level to the power production process. According to the mirror simulation based on available data from the PDP2007 revision 2, fuel mix of power production will be continuously improved in term of the GHG level by the nuclear power plant and coal-fired power plant with CCS as illustrated in Figure 22.

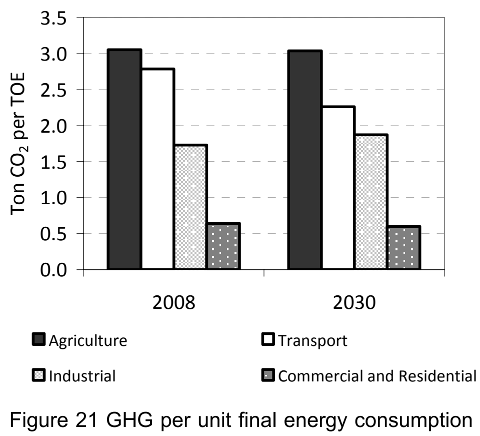


Figure 21 GHG per unit final energy consumption

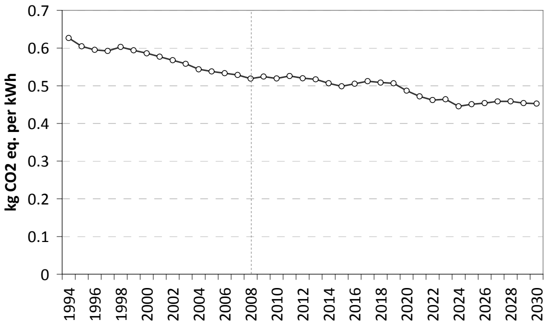


Figure 22 GHG per unit electricity produced from power production process

The intensities of GHG by sectors are comparatively shown in Figure 23. This parameter represents how much the energy-related GHG emits in order to create the value-added in each economic activity. It depends strongly on the economic structure and choice of fuel options. Transportation activities do not create directly the value-added compared to the industrial and service sector. In the mean time, the strongly oil dependency in transportation will double the level of GHG intensity. However, the implementation of REDP will help improving the GHG intensity by almost one-third in 2030.

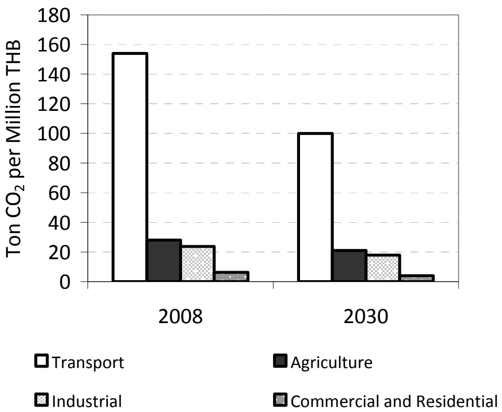


Figure 23 GHG intensities by sector

4.3 Impact of selected national policy

Impact of the selected national energy policy, e.g. on nuclear power plant, bio-fuel and CNG/NGV on the overall energy-related GHG is illustrated in Figure 24. Thailand has settled around 3 tons CO2 equivalent per capita in 2008. The attempts to promote bio-fuel and CNG/NGV under REDP will significantly slow down the growth of GHG in short-term. It must be noted that the reduction of GHG during the economic crisis will pull down the base level of GHG and reduce the efforts for the green investment in the long-run. However, the trend of energy ladder will inevitably continue in the long term according to the economic recovery. The results show that the current major policies of nuclear, bio-fuel and CNG/NGV would be able to reduce the GHG by approximately 14.8 percent in 2030 compared to the scenario without these policies.

The worldwide trend of energy-related GHG from the IEA study is illustrated in Figure 25. It is clearly seen that the growth rate of GHG in the emerging country, e.g. Russia China, India and Middle East, will be significantly rising, while the GHG level in the OECD country will be slow down. Double of GHG level for Thailand, as shown in Figure 24, is quite similar to the trends of the emerging country group. It must be noted that the assumption for long-term GDP for Thailand in the IEA study is slightly lower than this study (more detail in the macro-economic assumption mentioned above).

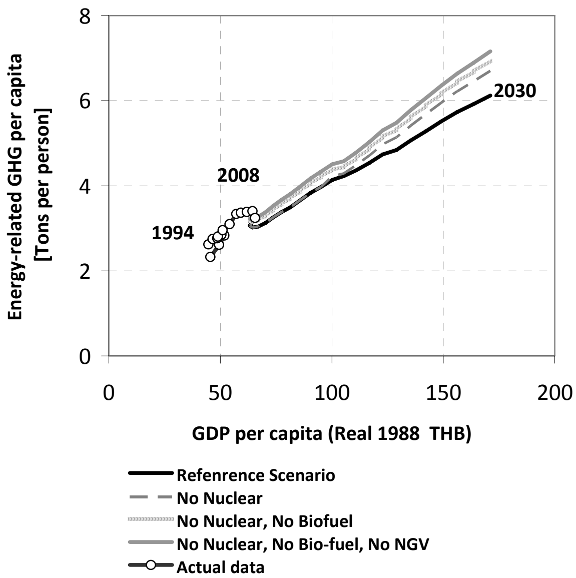


Figure 24 Impact of selected national energy policy on the overall energy-related GHG

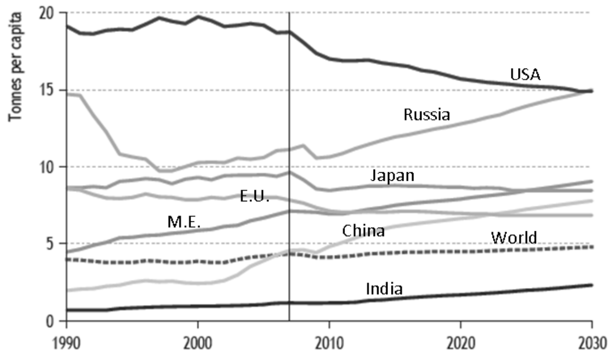


Figure 25 Worldwide energy-related GHG per capita [13]

5. Conclusions

In this study, the future prospect of energy-related GHG emission in Thailand to 2030 has been revealed, focusing on namely 'The reference scenario'. The key findings are as follows

- The overall energy-related GHG in 2030 will be double from the base year of 2008. Power generation and transportation will still keep their majority for GHG contribution. This trend is quite similar to the growth of GHG in the emerging countries from the IEA study.

- The emitted GHG from transportation activities is relatively higher than others in term of the cleanliness of fuel mix and GHG intensity. Various measures e.g. road-to-rail switching, and promotion of alternative energy will help improving by 18.9 percent in term of fuel mix cleanliness and by 35.1 percent in term of GHG intensity compared to the base year of 2008.
- Although the portion of GHG emitted from energy used in agricultural activities has relatively low, approximately 5.28 percent of the overall energy-related GHG, it has very high potential to improve the cleanliness of the energy use by diversify the dominated oil consumption.
- In power sector, the emitted GHG per unit electricity produced in 2030 will be slightly inclined by approximately 12.8 percent compared to the year of 2008. Introduction of nuclear power plant from 2020 and expansion of (clean) coal technology with CCS will be the major contribution for GHG mitigation.
- Improvement of GHG level caused by the fuel mix due to the PDP and REDP has been significantly revealed. Potential of per-capita GHG mitigation in 2030 is approximately 14.8 percent compared to the case without implementing of nuclear, bio-fuel and CNG/NGV. The attempts to pull-down the GHG level during the economic crisis will reduce significantly the GHG in the long-run. However, it would be necessary to evaluate the GHG emitted along the entire life-cycle of fuels in the future to reveal the negative effect on the GHG reduction, particularly the land-use change effect for bio-fuel.

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