Integrated top-down and bottom-up model for energy and CO_2 emissions analysis from Thailand's long-term low carbon energy efficiency and renewable energy plan

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Abstract:
This paper builds the energy demand and supply model from the bottom-up LEAP software and focus on evaluating and providing insights to the long-term energy and greenhouse gas impact from the national energy efficiency plan and alternative energy plan focus from 2015 to 2036 under the 2010 base year. From the results, we found that the energy demand would increase from 84.77 Mtoe in 2015 to 172.29 Mtoe, or 103.24% in 2036, mainly from the energy efficiency plan by applying the three main programmes with full successive ratio. The co-benefit result from greenhouse gas emission mitigation would decrease from 503.34 $MtCO_2$ in 2036,161 and 116 Mt-CO_2 from energy efficiency and alternative energy development plan in 2036, respectively. We also found that this mitigation also impacts to the decrease of grid emission factor from 506 in the BAU to 339 and 140 $kgCO_2$-eq per MWh due to the higher renewable energy sources and imported hydro energy. From the LEAP results, the energy oriented input-output model with flexible production functions have been analyzed for the GDP and sectoral output, employment and trade balance impact from those integrated plans. We found that compared with the BAU, the integrated energy plans will have marginally negative impact on employment from 0.5% fewer jobs but higher energy efficiency targets would improve the trade balance as all non-energy sectors increase their outputs for international markets and also less dependent on energy imports of the country. Policy recommendations to deploy both energy plans are also raised.

Keywords: Energy efficiency plan; Renewable energy plan; Energy model; Greenhouse gas emission

1. Introduction

Energy is one major factor input in all goods and services in all economic sectors. After the industrial revolution in 1700s, world energy consumption have been continuously increased which results in higher extensively fossil fuels production and the risen of greenhouse gas (GHG) level from human activities. As one of ongoing developing countries of Asia which planned to increase her gross domestic products (GDP) from industry and commercial sector from the investment of foreign countries during the past 30 years, Thailand then experienced one of the region's highest energy and greenhouse gas growth rate. At present, as the region's second largest economy and energy consumer, Thailand alone contributes 20.82% of ASEAN primary energy consumption in 2011 and around 0.9% of the world (ERIA, 2014).

There have been several studies in different countries in order to assess the energy and environmental impacts in various sectors. Sahir and Qureshi (2006) studied the structure of various energy models and their applications. Kuhi-Thaleldt, et al. (2010), Avami and Farahmanpour (2008) used LEAP model for analyse the energy and GHG emission in Estonia and Iran energy sector, respectively while Rahmadi, Aye and Moore (2013) applied the LEAP model for Indonesian biofuel scenario.

For Thailand, LEAP model is the most preferable and reliable model for Thai researchers, Wangjiraniran and Eua-arporn (2010) and Wangjiraniran, et al. (2011) studied the outlook and future scenario of Thai energy and GHG scenario to 2030 while Tanatvanit et al. (2003) focused in the implications of energy demand management and renewable energy in Thailand. Other models such as AIM/End-use (Selvakkumaran and Limmeechokchai (2015), Selvakkumaran et al. (2015) and Selvakkumaran et al. (2014)), MARKAL (Pattanapongchai and Bundit Limmeechokchai (2011)), GAMS based least cost PGEP model (Promjiraprawat and Limmeechokchai (2012)) and MESSAGE (Selvakkumaran and Limmeechokchai (2013)) also frequently used for developing long-term energy and environmental scenario.

Considering the 1990 to 2010 period, we found that the energy consumption in Thailand continuously increased at an annual average rate of 4.4%. At present, energy consumption is 2.3 times the amount it was in 1990; the growth rate has been in line with the economic growth rate, of which the annual average rate is 4.5%. In particular, energy consumption growth rates in the industry and commercial building sectors are much higher than the GDP growth rate, i.e. 3.0 and 3.7 times respectively, compared with consumption in 1990 (EPPO, 2011). This means that the energy efficiency level of the country was far behind the suitable level. Another reason that impact Thailand to developing the long term plan is the rapidly increase of the world crude oil price since 2004 which also impacted Thailand, a heavily oil imported country, in many dimensions, e.g. rising in oil import, dependency, rising of energy import to GDP proportion and oil subsidization.

For long-term sustainable energy planning, Thailand has emphasized secure, adequate energy supply and sustainable energy use while maximizing self-reliance through the following energy policies (MoE, 2014);

(a) to promote energy supply security and diversities, emphasizing the use of indigenous energy resources,

(b) to promote efficient procurement and use of alternative energy sources, and

(c) to emphasize energy management to increase competitiveness of Thailand's production sector and to enhance stability of energy prices through appropriate monetary, fiscal and managerial measures.

From the above reasons, Thailand made policy response by developing her first long-term national energy efficiency development plan (hereafter, EEDP) covering the year 2011 to 2030 and alternative energy development plan (hereafter, AEDP) covering the year 2012 to 2021.

2. The Energy Efficiency Development Plan

This Energy Efficiency Development Plan (EPPO, 2015) is formulated with a target to reduce energy intensity by 30% in 2036, compared with that in 2010, or equivalent to reduction of final energy consumption by 56,142 thousand tons of crude oil equivalent (ktoe) in 2036. From this plan, the energy intensity, which means the final energy consumption per GDP, would reduce by 30% from 15.28 to 10.7 ktoe per billion Thai Baht in the year 2036, as shown in figure 1.

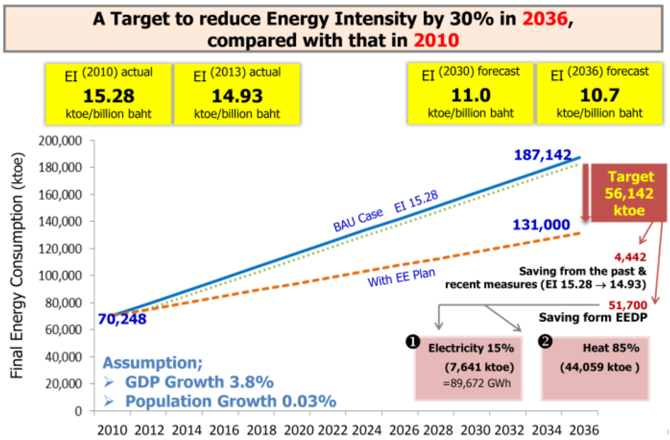

Figure 1. Thailand’s EEDP Target (EPPO, 2015)

3. The Alternative Energy Development Plan

Thailand energy demand forecasted by Energy Ministry that, an expected demand in 2036 would be at 131,000 ktoe growing from presently of 75,804 ktoe. The AEDP, as illustrated in figure 2, determined the renewable energy share increasing from 9,025 ktoe in 2014 to 39,388.67 ktoe in 2036 or 30 percent increase of total energy consumption from renewable for power, heat and biofuels (DEDE, 2012).

In details, the AEDP plans to deploy 19,684.4 MW installed capacity of power generation, 25,088 ktoe of heat generation and 14 million litres of biodiesel, 11.3 million litres of bioethanol and other bio-fuel production, all from domestic renewable energy sources.

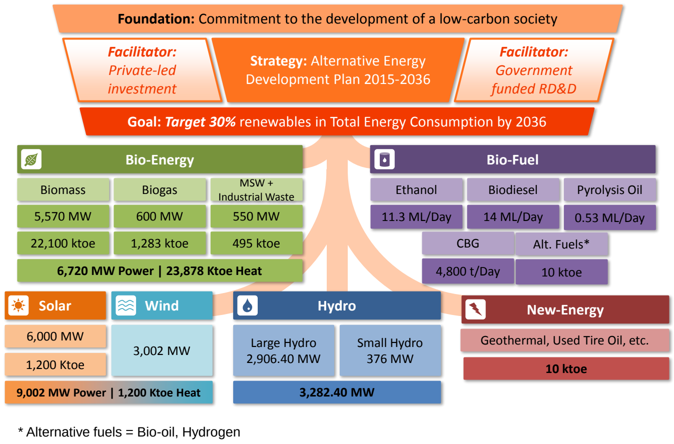

Figure 2. Thailand's AEDP Target (DEDE, 2015)

4. About The Model and Scenarios

In this paper, the Long Range Energy Alternatives Planning (LEAP) software was applied to forecast the energy demand and supply for Thailand. The Business as usual (BAU) was first estimated based on the data from the GDP, population, past energy and electricity consumption, current energy situation (year 2012), and energy intensity of the country, then the energy efficiency scenarios, with successive level, from EEDP have been internalized, as shown in figure 3. Greenhouse gas emission data also forecasted from the model. All details of the BAU and scenarios are as follows;

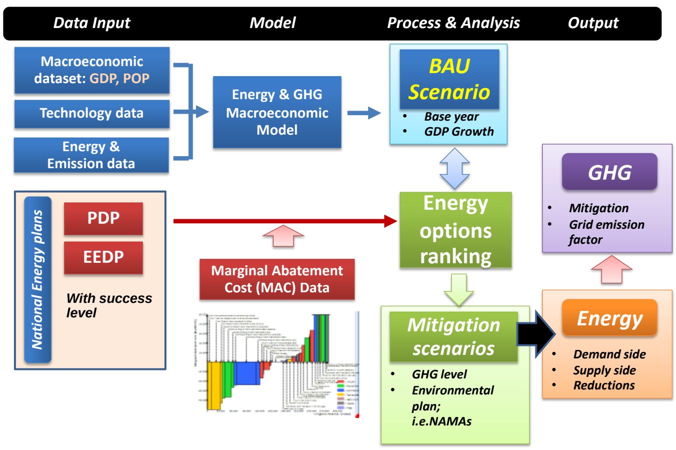

Figure 3. Model approach in this study

4.1. Business as usual (BAU)

To develop the BAU of this study, we applied the PDP (2007 version) along with the GDP growth rate from national data. The average annual growth rate (AAGR) of GDP, calculated from the constant 1988 price, would be 4.39% during 2011-2030 while the AAGR for the population growth in the same period would be 0.26%.

The demand-side comprises five main sectors, as follows;

- Industry sector,
- Large commercial building sector,
- Household and small building sector,

- Transport sector,
- Other sectors (agricultural, construction and mining sector)

However, Thailand final energy demand are from two main sectors; industry and transport with around 36% share of each sector while industry sector has high proportion at 45%.of electricity demand of the country.

4.2. Energy Efficiency Scenario

In this EEDP scenario, we prepared the data in each sector as follows;

Industry sector;

Disaggregate into five energy intensive sectors; i.e. cement, food, basic metal, chemical and pulp and paper industry. Those five sectors had proportion around 84% of total energy consumption in the year 2009 (DEDE, 2009a)

For energy efficiency improvement estimation, we used the potential energy reduction in each sector form the difference between Thailand and best practice benchmarking specific energy consumption (SEC) data from industrialized countries.

The wider gap of SEC between Thai and best practice countries means the higher potential of energy conservation and efficiency improvement.

Large commercial building sector;

In this sector, the future potential of energy reduction are taken from the difference between the existing energy consumption in building per area (in the unit of energy consumption per square meter) and the building energy code (BEC) of Thailand (DEDE, 2009b).

Household and small building sector;

The future potential of energy reduction are taken from the difference between the existing energy consumption in each main electricity appliances and the high energy performance standard (HEPs) of Thailand. Here, we focused in lighting, air conditioner, electric water heater for electric energy potential. For cooking device, we assume the higher efficiency in LPG and charcoal cooking stove.

Transport sector;

For transport sector, the future potential of energy reduction are taken from the difference between the existing consumption rate and the new fuel economy from Japan standard with 20% energy efficiency improvement. We also consider the substitute o road transport from conventional fuel to electricity by using the 70% of new motorcycle sale in 2030 would be electricity motorcycle (IEA, 2009 and Ogden et. Al, 2008, Pongthanaisawan and Sorapipatana, 2012).

4.3. Alternative Energy Scenario

Main For AEDP scenario, we follow the AEDP by disaggregate the renewable energy into three main tasks; i.e. power, heat and biofuels. The success factor is also considered in this study. The incremental cost of renewable energy technologies are taken from real domestic datatext paragraph.

5. Results

Even Thailand face slow economic growth in the past ten years, however, continued economic growth implies growth in energy use. How that energy use and energy efficiency plan would result in the coming years, we adopted the LEAP (Long-range Alternatives Planning software) model to forecast Thailand's future energy consumption by sector, as well as to describe potential future energy supply arrangements under EEDP and AEDP, respectively.

5.1. The Business as usual (BAU)

From the results, we found that the final energy demand from all sectors in Thailand in the year 2036 would double increase from 71.70 Mtoe in the base year 2010 to 173.14 Mtoe. As presented in figure 5, the highest proportion would be industry sector at 37%, followed by transport sector at 33%. Diesel and electricity would have the highest share in final energy demand in 2036 at 27% and 20%, respectively, as shown in figure 6. Figure 7 compare the final energy demand, by economic sector, between the year 2010 and 2036.

Considering to the greenhouse gas results, we found that the greenhouse gas from all energy sectors in Thailand in the year 2036 would be 503 million ton of CO_2 equivalent ($MtCO_2$-eq) while it was just 245 $MtCO_2$-eq in the base year 2010.Electricity generation would be the highest proportion with 34% of total emission in the year 2036. The greenhouse gas emission per capita would also rose in double from 3.34 to 7.10 tCO_2-eq per capita per year, from 2010 to 2036. Figure 8 presents the greenhouse gas emission from BAU by economics sector.

For the per capita energy consumption and energy intensity from BAU, as presented in figure 9, we found that the per capita energy consumption would increase from 1,065 to 2,430 ktoe per capita from 2010 and 2036, respectively while the energy intensity would decrease from 15.6 to13.2 ktoe per billion Baht in the same period.

5.2. The Energy efficiency scenario

The energy saving, from fully success scenario of EEDP, presents in figure 10. From the energy efficiency results, we found that the final energy demand would decrease from 173.14 Mtoe in BAU to 121.06 Mtoe from all sector energy efficiency scenarios in 2036. The highest share in energy saving would be industry sector with 48% of total energy saving in 2036.

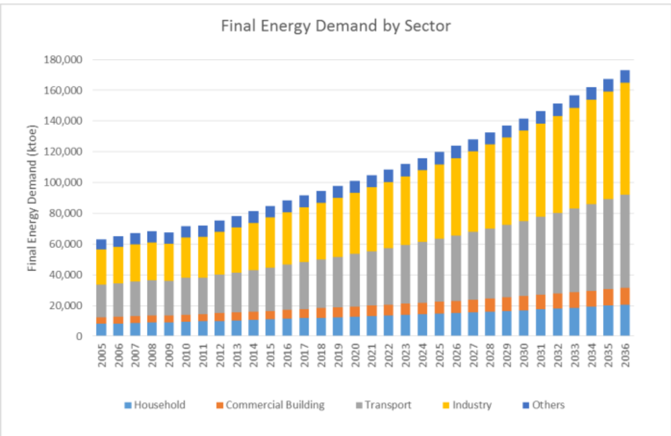

Figure 5. Final energy demand, BAU, by sector 2005-2036

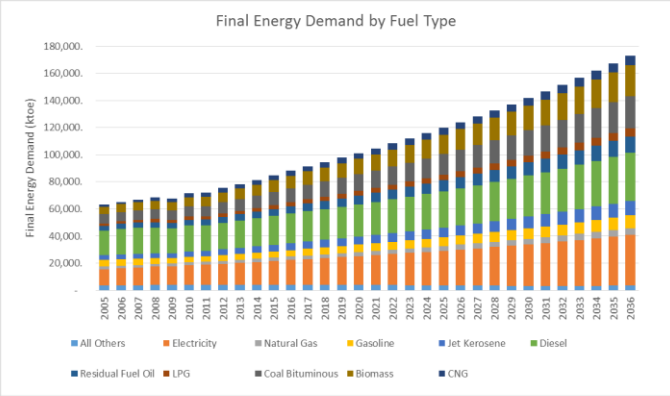

Figure 6. Final energy demand, BAU, by fuel type 2005-2036

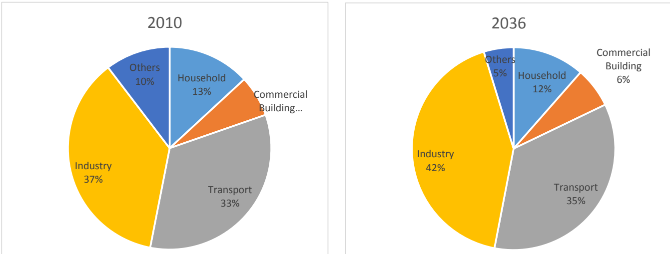

Figure 7. Final energy demand, BAU, 2010 and 2036

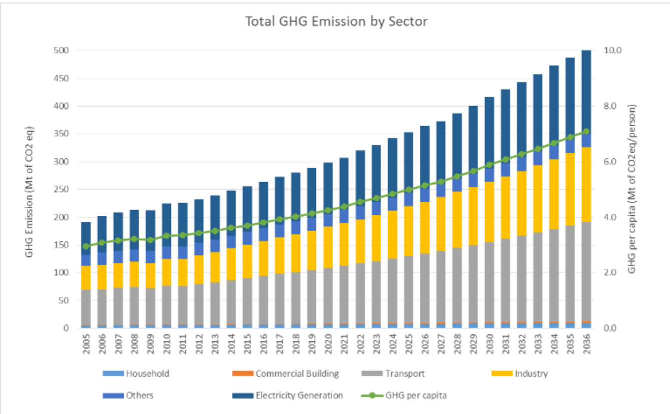

Figure 8. GHG emission in BAU, by sector, 2005-2036

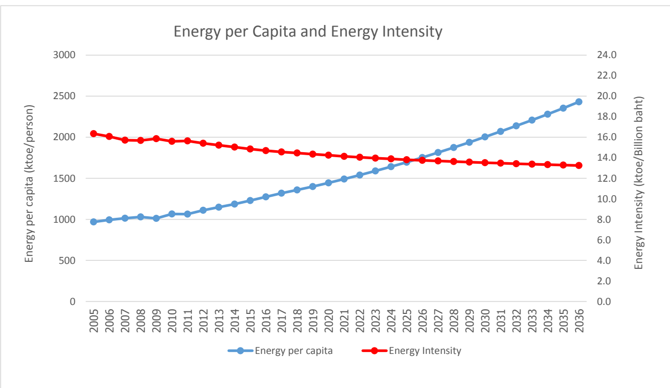

Figure 9. Results of energy per capita and intensity from BAU

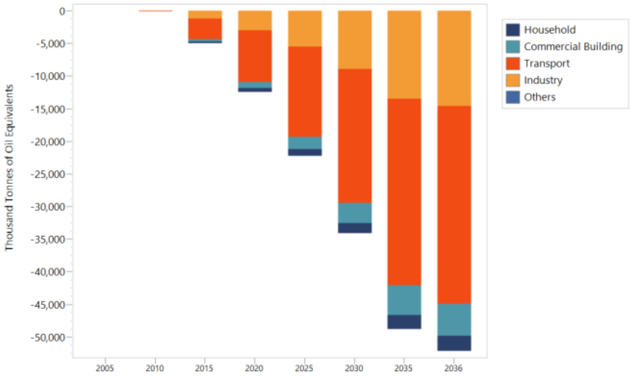

Figure 10. Energy saving from EEDP, by sector 2005-2036

Under the EEDP full 100% success approach (as planned) compared to BAU, the results from LEAP show that the greenhouse gas emission would decrease by 161 MtCO$_2$-eq (or 32.0 %) in the year 2036. Transport sector would be the highest reduction proportion at 61 MtCO$_2$-eq, followed by industry sector at 52 MtCO$_2$-eq, respectively. Figure 11 presents the greenhouse gas emission mitigation from energy efficiency plan, by sector.

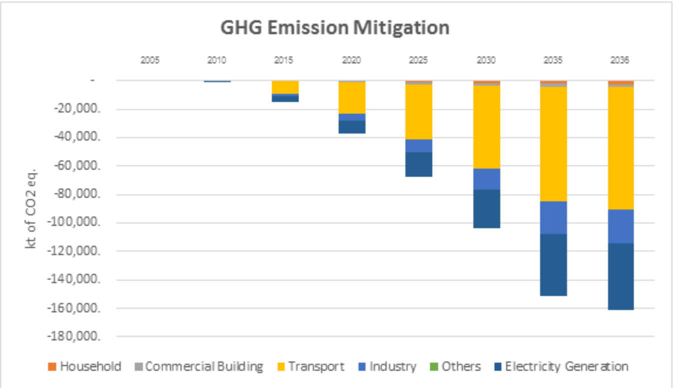

Figure 11. GHG emission reduction results from EEDP compared with BAU

5.3. The Alternative Energy scenario

Under the AEDP full 100% success approach (as planned) compared to BAU, the results from LEAP show that the greenhouse gas emission would decrease by 116 MtCO2-eq (or 23.06 %) in the year 2036. Renewable energy for heat generation, which would mainly applied in industry sector, would be the highest reduction potential at 52 MtCO2-eq per year in the year 2036, followed by renewable energy for power generation at 50 MtCO2-eq, and biofuel consumption at 11 MtCO2-eq, respectively. The greenhouse gas emission mitigation from renewable energy plan, by type of activities, was illustrated in figure 12.

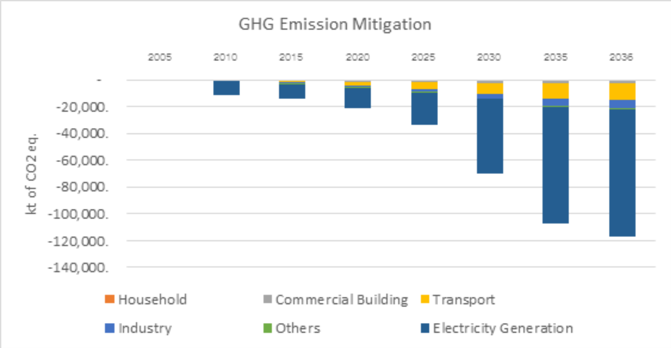

Figure 12. GHG emission reduction results from AEDP compared with BAU

However, due to GHG emission in transport sector are from mobile source, the energy efficiency policy in this sector would not easy to monitor and verify. Policy maker have to be careful in details on the policy and should considering both technology improvement along with human behavior.

6. Conclusions

Thailand has experienced rapid growth in oil import and the rising of energy price in the recent years. Meanwhile, Thai government plan for great efforts to improve energy efficiency and deploy renewable energy activities, and co-benefit of reduce greenhouse gas emission locally, by introducing the EEDP and AEDP. This study analyzed the energy demand and the greenhouse gas emission impact from the energy efficiency scenarios by using the LEAP software. From the results, we found that the energy demand would increase from 84.77 Mtoe in 2015 to 172.29 Mtoe, or 103.24% in 2036, mainly from the energy efficiency plan by applying the three main programmes with full successive ratio. The co-benefit result from greenhouse gas emission mitigation would decrease from 503.34 $MtCO_2$ in 2036,161 and 116 Mt-CO_2 from energy efficiency and alternative energy development plan in 2036, respectively. We also found that this mitigation also impacts to the decrease of grid emission factor from 506 in the BAU to 339 and 140 $kgCO_2$-eq per MWh due to the higher renewable energy sources and imported hydro energy.

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