Chanidaporn Lunsamrong; Atit Tippichai

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Energy Demand Modeling for the Eastern Economic Corridor of Thailand: A Case Study of Rayong Province

Chanidaporn Lunsamrong, Atit Tippichai*

Department of Architecture and Planning, Faculty of Architecture, Art, and Design, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand. *Email: atit.ti@kmitl.ac.th

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ABSTRACT

This paper assesses long-term energy consumption and greenhouse gas (GHG) emissions in Rayong Province which is one of the three provinces in the Eastern Economic Corridor (EEC) of Thailand. LEAP (the low emissions analysis platform) is used to project final energy demand for each economic sector by using the 2019 data as a base year. In the model, we defined the energy consumption into two scenarios; a business-as-usual (BAU) scenario and a low carbon scenario (LCS), to see different energy demand and CO_2 emissions up to the year 2050. There are different assumptions between BAU and LCS in each sector such as energy efficiency improvement, shift to modern energy, the share of high energy-efficient vehicles, etc. In the BAU scenario, the final energy consumption needed by Rayong Province will increase with an average annual growth rate (AAGR) of 3.49%, while only 1.52% for the LCS. CO_2 emissions in the LCS will be reduced by 41.7% by 2050 when compared with the BAU scenario. Most interestingly, even though energy demand in Rayong Province will be increasing up to 2050, CO_2 emissions will peak about 2035 and then reduce. The industry and transport sectors are the most final energy consumption and the highest CO_2 emissions. This is because EEC is driven by a production-based economy. The solution for this is to transform to alternative energies sourcing, shift all productions to sustainable ones, restructure the industrial estate to become the eco-industrial and GHG emissions management, which will also result in obvious carbon reduction. This kind of information will be beneficial to energy demand conservation and GHG emission mitigation at the provincial level which will depend on the energy policies initiated and implemented in the future.

Keywords: Energy Demand Modeling, Greenhouse Gas, CO_2 Emissions, Scenario Analysis, Low Carbon City, Thailand
JEL Classifications: O22, Q47, Q54

1. INTRODUCTION

Rayong is one of the three provinces in the Eastern Economic Corridor (EEC) project which is a highly important economic area of Thailand. This will be a huge source of employment with the most industrial estates in Thailand. With rapid industrial and infrastructure development, the energy demand is constantly increasing. If there is no energy policy, it can lead to an energy shortage crisis and other environmental problems such as air pollution and greenhouse gas emissions. In addition, energy imports are costly, thus making development inefficient. It could result in disruption to economic growth in the future. In the past, energy was not planned at the provincial level. However, in Thailand, energy policy and planning have been centralized to government agencies, the local governments had mainly functioned as implementing agencies of national policies and programs, which makes planning inefficient. Therefore, anticipating energy demand and finding ways to reduce energy consumption at the provincial level is an option to cope with future challenges. It can be used to plan energy appropriately and meet the potential of the province.

Energy modeling is commonly used to assess predictions of future energy needs. We compiled and summarized the research related to energy consumption projections as follows. Wangjiraniran et al.

(2017) conducted a study to analyze changes in the energy sector in Thailand. The results of this study showed that the high penetration of disruptive technologies will result in reducing greenhouse gas (GHG) emissions by 8.9% compared with Thailand's Integrated Energy Blueprint (TIEB) scenario. Electric vehicle (EV) is one of the disruptive technologies which will replace the use of oil in the transportation sector in Thailand. Chaichaloempreecha et al. (2019) conducted a study to evaluate the long-term energy demand in the building sector and the industrial sector during 2005–2050 through the perspective of GHG mitigation potential by end-use approach by using the LEAP model. Policies considered in this study include the Energy Efficiency Plan and the Alternative Energy Development Plan of Thailand. A review of the literature and models involved in the study found that the LEAP model is a favorite model for energy planning which can be used to evaluate policies and measures (Wangjiraniran et al., 2017; Chaichaloempreecha et al., 2019; Hu et al., 2019; Misila et al., 2020; Dioha et al., 2021; Chen et al., 2021; Gebremeskel et al., 2021; Kehbila et al., 2021). As a result of this study, the relevant authorities can apply the information to plan the implementation of energy efficiency improvements for future needs. In addition to creating energy security, it can also help reduce environmental problems effectively.

2. MATERIALS AND METHODS

2.1. Study Area

Rayong is a province located in the Eastern part of Thailand with an area of 3,552 square kilometers and a total population of 724,979 people. Rayong is a province with the highest gross provincial product (GPP) in Thailand at 993,977 million baht and the province with the highest gross provincial product per capita (GPP Per Capita) in Thailand, at 988,748 baht per year (Office of the National Economic and Social Development Council, 2019).

2.2. Data Collection

Data both top-down and bottom-up information was collected according to 5 economic sectors, i.e., household sector, building sector, industrial sector, agricultural and another sector, and transport sector. The collected data used in this study were obtained from previous studies and various official data sources in Thailand during 2010–2019. The collected data for each sector are as follows.

- Household sector: Urban and rural population, number of households, and end-use energy consumption per household
- Building sector: Sectoral value-added, and final energy consumption by fuel type
- Industrial sector: Sectoral value-added, and final energy consumption by fuel type
- Agricultural and other sectors: Sectoral value-added, and final energy consumption by fuel type
- Transportation sector: Number of vehicle registration by vehicle technology and fuel type, number of vehicle sales by vehicle technology and fuel type, fuel economy, vehicle kilometer-traveled, vehicle age distribution, etc.

2.3. LEAP Model

LEAP is developed by the Stockholm Environment Institute which is a software tool widely used for energy policy analysis and development of climate change mitigation assessment. LEAP is an integrated, scenario-based modeling tool that can account for both energy sector and non-energy sector greenhouse gas emission sources and sinks (Hu et al., 2019).

In general, LEAP calculates energy demand using four different methods: Final energy demand, useful energy demand, stock, and transport analysis (Dioha et al., 2021). Energy demand can be estimated in LEAP using Equations (1) - (4). For a detailed description of the Nigerian LEAP model, see the work of Emodi et al. (2017). In addition, emission factors (EF) are required by specific types of energy resources or fuel to analyze the environmental impacts used in Equation (5). The structure of the LEAP model in this study is shown in Figure 1 and the structure of the sectoral modules in the LEAP model is shown in Figures 2 and 3.

Final energy analysis= Activity level × Energy intensity (1)

Useful energy analysis = Activity level × (useful energy intensity/efficiency) (2)

Stock analysis = stock and x device intensity (3)

Transport analysis = stock (vehicle miles/fuel economy) (4)

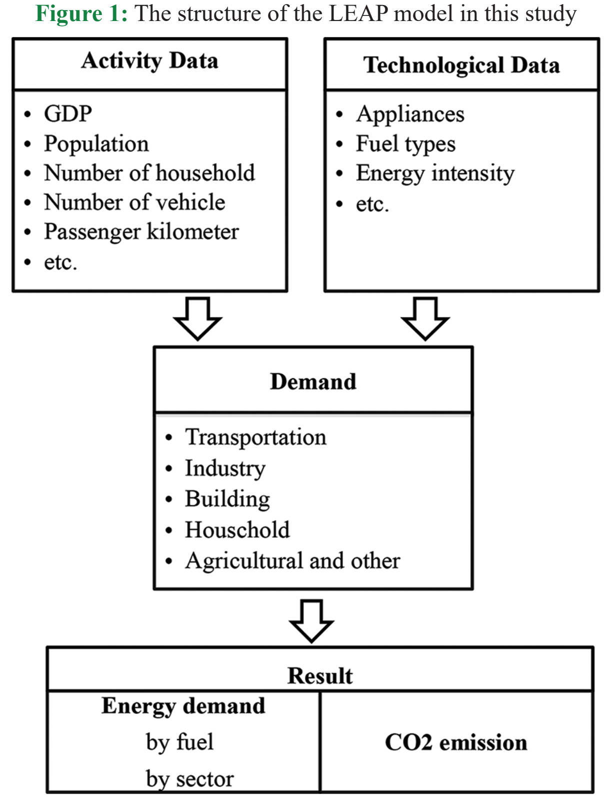
GHG emissions = Activity Data: AD × Emission Factor: EF (5)

2.4. Scenarios and Assumptions

The energy demand forecasting in this study is divided into two scenarios: (1) Business as usual (BAU) and (2) low carbon scenario (LCS) which are defined as follows.

- Business as usual (BAU) scenario: No change in economic structure, it is a normal energy forecast based on historical

Figure 1: The structure of the LEAP model in this study



growth data. With the key driver of enhancement of economic competitiveness among provinces under the current policy plans
- Low Carbon scenario (LCS): Transformation of economic structure towards quality and sustainable growth which aims at reducing the impact of GHG-emission and environmentally friendly, due to the energy development policy and technological change to meet the climate goal.

Specific assumptions of each economic sector for both scenarios are shown in Table 1.

Figure 2: The structure of the household, building, and industry modules in the LEAP model

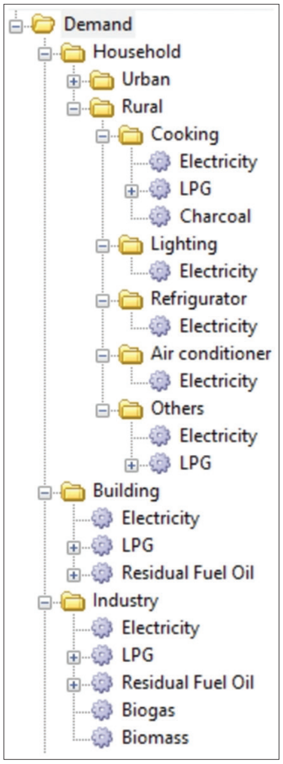
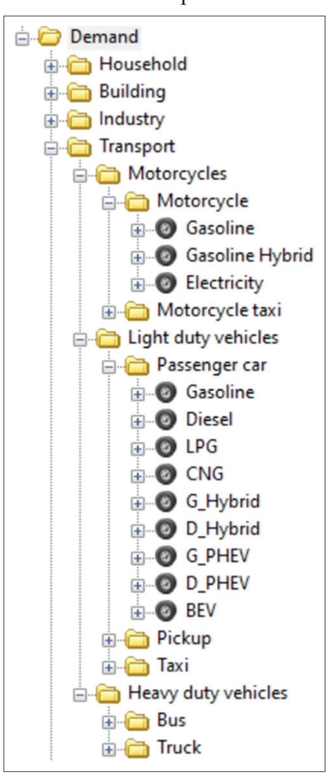


Figure 3: The structure of the transport module in the LEAP model



3. RESULTS AND DISCUSSION

3.1. Final Energy Consumption and GHG Emissions in the BAU Scenario

In the business-as-usual (BAU) scenario, during 2019–2050, results show that total final energy consumption increases from 2,109 to in 2019 to 5,915 ktoe in 2050 and accounted for an average annual growth rate of 3.49%. In 2050, the industrial sector will be the largest energy-consuming sector and accounted for 73.21% of total energy consumption. In addition, the transport, household, building agricultural and other sectors are accounted for 14.57%, 6.69%, 4.57%, and 0.95% of total energy consumption, respectively (Figure 4).

The total final energy consumption by fuel type in the business-as-usual (BAU) scenario in 2050, the highest proportion of electricity consumption at 53.01% followed by Biomass, Diesel, and LPG are accounted for 24.30%, 8.54%, and 6.80%, respectively (Figure 5). In the future, Rayong Province shall promote economic zones and industrial zones; consequently, Rayong Province has a large potential to increase energy demand, especially for electricity. When considering the non-electricity energy consumption in BAU, it found that the share of non-electricity energy consumption in 2050 will change slightly from 2019 because it is not affected by any future projects or measures.

In addition, during 2019-2050, CO_2 emission and accounted for an annual average growth rate (AAGR) of 3.20%, increases from 1,949.0 ktCO_2eq in 2019 to 3,756.9 ktCO_2eq in 2050. More than half of CO_2 emissions will be dominated by the transport sector. The transport sector accounts for 60% of total CO_2 emissions from fuel combustion, followed by the industrial, building, agricultural and other, and household sectors at 22.18%, 11.21%, 4.01%, and 2.73%, respectively (Figure 6). CO_2 emissions will increase from 26.76 ktCO_2eq in 2019 to 38.45 ktCO_2eq in 2050 in the rural area of the household sector (increased by 1.33% annually). Similarly, CO_2 emissions in an urban area will increase with an AAGR of 5.64%. Moreover, LPG demand for cooking in the urban area will be significantly higher than that in greater rural areas. Therefore, CO_2 emission will be 64.24 ktCO_2eq in the urban area or 62.6% of total CO_2 emission in the household sector in 2050. This is the reason why the household sector in an urban area has the highest CO_2 emission.

3.2. Final Energy Consumption and GHG Emissions in the Low Carbon Scenario

In the low carbon scenario, due to the vigorous efforts paid toward removing fossil fuels from the Rayong Province (Figure 4), during 2019–2050, the total final energy consumption slightly increases with an AAGR of 1.52%, from 2,077 to 2019 to 3,256 ktoe in 2050. The industrial sector still is the largest energy-consuming sector as accounted for 71.1% of total energy consumption. In addition, the transport, household, building agricultural and other

Figure 4: Final energy demand by economic sector in Rayong Province; (a) BAU; (b) LCS

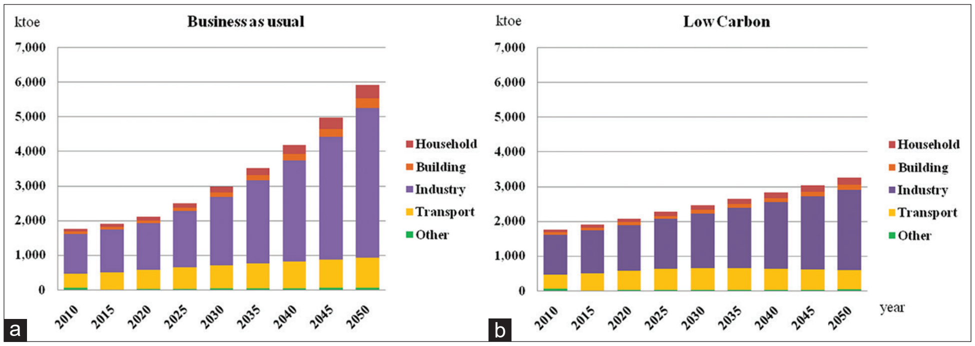


Figure 5: Final energy demand by fuel in Rayong Province; (a) BAU; (b) LCS

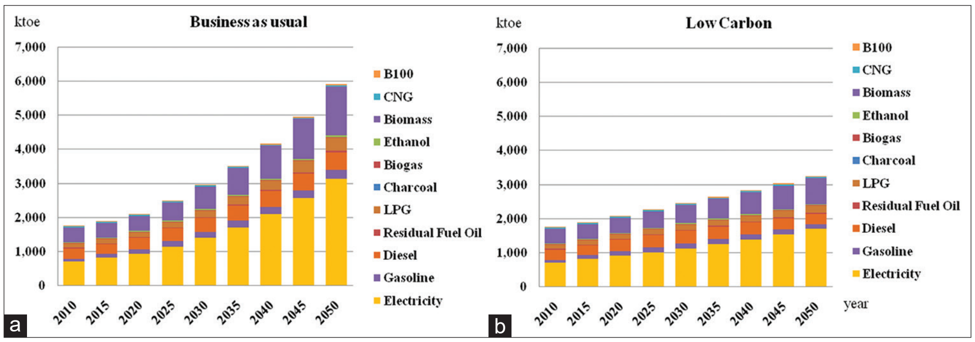


Figure 6: Energy-related CO_2 emissions by sector in Rayong Province; (a) BAU; (b) LCS

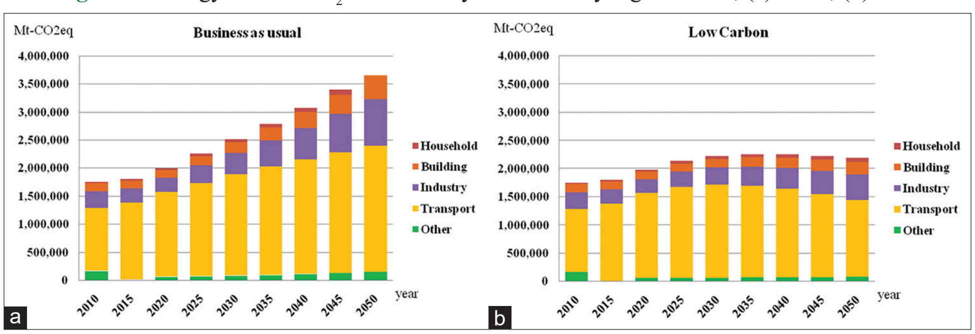


Table 1: Assumptions of each economic sector by scenario

Economic sector	Key driving force	
	Business-as-usual scenario	Low carbon scenario
Household	Urbanization, Shifting from traditional fuel to LPG	Energy efficiency improvement of appliances, Shifting from traditional fuel to LPG, electricity, and biogas
Building	Growth of value-added, Building energy code	Utilization of Photovoltaic Rooftop towards net-zero energy buildings
Industry	Driven by EEC and production-based economy	Factory energy management, Smart Factories
Transport	Vehicle ownership, Population, and income	Public transport promotion, Penetration of electric vehicles, Fuel economy improvement
Agricultural and other	Growth of value-added	Productivity and technological improvement, Smart framing

sectors are accounted for 17.33%, 6.21%, 4.44%, and 0.92% of total energy consumption, respectively.

In the LCS, the advanced technologies will have an impact on the non-electricity energy demand, as the result, the proportion of non-electricity energy consumption in 2050 will change significantly from 2019, especially fossil fuels, while the proportion of alternative energy and electricity consumption will increase.

In 2050, total CO_2 emission will be 2,190.2 ktCO_2eq with an AAGR of 1.31% per year. In addition, our analysis showed that CO_2 emission in the LCS will be reduced by 1,566.7 ktCO_2eq in 2050 when compared to the BAU scenario (Figure 6) or reduced by 41.7%, by 2050 when compared with the BAU scenario, and the transport sector contributes more than half (about 56%) of total CO_2 emission reductions from the Rayong Province.

Moreover, the entry of electric vehicles and fuel economy improvement can reduce demands for petroleum products, particularly gasoline and diesel. Although the increase of EVs on the road will lead to higher demands for electricity, it will reduce CO_2 emissions in the transport sector. CO_2 emission in the transport sector in 2019 were about 1,477 ktCO_2eq and will increase to 2,248 ktCO2eq in 2050. CO_2 emission will reduce by 878.9 ktCO_2eq in 2050 compared to the CO_2 emission level of the transport sector in the BAU scenario (Figure 6). As anticipated, the low carbon scenario proves to be the case with the largest CO_2 emission potential.

4. CONCLUSION

The results of the Low Emissions Analysis Platform (LEAP) can be used for inputting data, analyzing energy consumption, forecasting future energy, and assessing greenhouse gas emissions consumption to set appropriate energy measures correctly. It can be used to plan energy appropriately and meet the potential of the province. Furthermore, the quality of the scenario depends on the quality of the data and the analytical process of the user.

This paper defined two scenarios. The results of the Business-as-usual (BAU) scenario suggest a trend that it needs energy for all kinds of fuel. This is due to people lifestyles is changing gradually by income and quality of life rises. Environmental damages are increasingly becoming an issue. In the Low Carbon Scenario (LCS), the total final energy consumption will lower energy demand due to economic restructuring and intense energy efficiency push, moving toward a high value and low energy-intensive sector.

Given the overall energy use within the various sectors in Rayong, the industrial and transportation sectors are the most final energy consumption and the highest CO_2 emissions. The solution for this is to transform to alternative energies sources, e.g., clean electricity. The shifting of all production to the sustainable ones, by the successful restructuring of the industrial estate to become the eco-industrial and GHG emission management, will also result in obvious carbon reduction. The prospects of a sustainable urban energy system will depend on the energy policies initiated and implemented in the future.

5. ACKNOWLEDGMENTS

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