Nakapreecha, Nitida; Vivanpatarakij, Supawat; Audomvongseree, Kulyos

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Feasibility Study of Fuel Oil and Coal Replacement with Natural Gas in Thailand Context

Nitida Nakapreecha*, Supawat Vivanpatarakij, Kulyos Audomvongseree

Energy Research Institute, Chulalongkorn University, 12th Floor, Institute Building III, Phayathai Road, Pathumwan, Bangkok 10330, Thailand. *Email: nitida.n@chula.ac.th

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ABSTRACT

Natural gas is a viable option to oil-based fuels and coal as it has advantage on reliability, domestic availability and more environmental friendliness. This paper assesses the feasibility of replacing fuel oil and coal with natural gas in Thailand's industrial sector. The study covers the identification of regulatory limitation, the projection of fuel demand and prices, and the assessment of financial and economic feasibility of the fuel replacement project. The financial feasibility study shows interesting investment opportunities only for fuel oil users located within 50 km from the compressed natural gas distribution center. On the contrary, the economic feasibility study shows that there is an outstanding value for investment, particularly for the coal replacement. Consequently, it needs strong measures from the government to drive the replacement. The results of the study are expected to be beneficial in energy management and planning for industrial enterprises. They are also expected to assist the government in developing policies to support the country's long-term demand for natural gas.

Keywords: Natural Gas, Fuel Oil Replacement, Coal Replacement, Energy Security, Carbon Emissions Mitigation
JEL Classifications: P28, Q42, Q47

1. INTRODUCTION

The development of natural gas industry has been one of the top priorities in Thailand as it strengthens security of supply for both energy sector and petrochemical sector. Based on statistical data, the share of natural gas in Thailand's commercial primary energy consumption has always been the highest (EPPO, 2021). In 2020 its share accounted for 42%, followed by petroleum products (37%) and coal (18%). Its consumption growth rate has been continuously expanding since 1986. Its average growth during 2000-2019 is 5.4% per annum. With indigenous resource availability, about 69% of natural gas consumed in 2020 are from domestic production, while about 87% of crude oil and 82% of coal have to be imported (EPPO, 2021).

Nevertheless, it is found that Thailand is facing dwindling natural gas reserves (DMF, 2018). Therefore, the country will need to increase its LNG imports to satisfy the rising demand (Dodge, 2017). This, fortunately, happens to be in line with the National Energy Reform Plan that supports LNG procurement (Royal Thai Government Gazette, 2018). According to the plan, importing LNG is considered to enhance national energy security as it helps prolong indigenous gas reserves and diversify source of energy. In addition, it will maximize the use of well-developed natural gas infrastructure and create opportunities for Thailand to become the regional LNG hub. Therefore, if natural gas is used to replace oil-based fuels and coal, the country should receive benefits in many aspects.

On the other side, natural gas composes mostly of methane, which means that combustion of natural gas generates less carbon emissions comparing to combustion of other fossil fuels (UCSUSA, 2014).It also releases nitrogen oxides, sulfur and particulates, but at a lower level than burning other fossil fuels (UCSUSA, 2014). Thus, in addition to being consistent with the national plan, replacing carbon-intensive fuels with natural gas can also help reduce overall pollution, which will benefit the public directly.

The objective of this study is to assess the feasibility of replacing fuel oil and coal in the industrial sector with natural gas. The study focuses mainly on the industrial sector as this sector has a relatively large consumption of fuel (DEDE, 2019). Furthermore, unlike the power generation sector, the industrial sector has no government restrictions on fuel mix (Ministry of Energy, 2019). Fuel oil and coal are focused as they have significant shares in industrial consumption (DEDE, 2020).

The study starts with the review of laws and regulations to identify any regulatory limitations for the fuel replacement. Then, total amount of natural gas required for the replacement and future price of each fuel are estimated. Finally, financial and economic feasibility of fuel replacement project is assessed. The results of the study will be useful for the industrial operators in their energy management and planning. It will also benefit the government in developing policies to support the country's long-term demand for natural gas.

2. METHODOLOGY

In order to assess possibility of replacing fuel oil and coal with natural gas, regulatory review is firstly conducted to examine regulatory limitations of the replacement. Fuel demand and price projection are then conducted to estimate the amount of natural gas for the replacement and to observe the price trend. Finally, an assessment of financial and economic feasibility is carried out to evaluate the benefits of fuel replacement projects.

2.1. Identification of Regulatory Limitation

The review of Thai laws and regulations is undertaken throughout the supply chain of natural gas. This is to observe any limitations on switching from fuel oil and coal to natural gas. Eight legislative and regulatory categories are reviewed as follows:

1. Operation of the energy business and authorization to do the business
2. Trading in and prices of fuel
3. Fuel transportation
4. Specification and quality of products
5. Fuel containers and storage
6. Preparation of report of environmental impact assessment
7. Safety and emergency response at site
8. Personnel operating in the energy business.

2.2. Projection of Fuel Demand

2.2.1. Projection of fuel demand

The supply chain of each type of fuel is investigated in order to identify sources of supply and demand. Next, historical data of supply and demand are collected. Relevant national energy plans i.e. the national power development plan (PDP) and the national gas management plan (2018-2037 version) are also studied to observe the prospect of national fuel demand for the related sector. After that, a projection model to forecast fuel demand is developed by applying the time series analysis with autoregressive model (equation (1) and (2)).

$$Q_t = Q_{t-1}(1+r_t) \tag{1}$$

$$r_t = \alpha + \sum_{k=1}^{m} \beta_k r_{t-k} \tag{2}$$

when Q_t = fuel demand in year t
Q_{t-1} = fuel demand in the year before year t
r_t = growth rate of fuel demand in year t
r_{t-k} = growth rate of fuel demand in the year before year t (year $t-k$)
α = constant
β_k = coefficient of fuel demand growth in year $t-k$
m = total number of years taken into consideration in the model.

The underlying assumption is that the statistical characteristics of the time series do not change over time (Rao, 2021). This suggests that, if there are no substantial changes on domestic and external macroeconomic factors, future fuel demand will follow historical trend. In order to calculate the constant and coefficient, maximum likelihood estimation and least squares technique are applied.

It is noted that this study refers the forecast of natural gas demand in power, transport and petrochemical sectors from the national gas management plan (Ministry of Energy, 2019).

2.2.2. Estimation of natural gas amount for fuel replacement

After the future fuel demand is forecasted, the amount of natural gas required for the replacement are calculated based on the assumption that fuel oil and coal used as heating fuels in the industrial sector are completely replaced by natural gas. With this assumption, the maximum requirement for natural gas will be obtained, which will be beneficial to future strategic planning. Moreover, it is assumed that the replacement starts in 2022.

2.3. Projection of Fuel Prices

In the projection of fuel price, the time series analysis with autoregressive model is applied to predict the future price of each fuel (equation 3).

$$p_t = \alpha + \sum_{k=1}^{m} \beta_k p_{t-k} + \gamma t \tag{3}$$

when p_t = fuel price at month t
p_{t-k} = fuel price at month $t–k$
α = constant
β_k = coefficient of fuel price at month $t–k$
γ = average monthly growth rate trend of fuel price
m = total months taken into consideration in the model.

As in the fuel demand projection, maximum likelihood estimation and least squares method are applied to calculate the constant and coefficient in the fuel price projection. Additionally, LNG prices are used in the price comparison because it is expected to play a leading role in supplying gas in the future (Dodge, 2017).

In order to verify the validity of the projected prices, the projected price trends from this study are compared with those from other sources i.e., the national power development plan (PDP) (Ministry of Energy, 2019) and the International Energy Agency (IEA) (IEA, 2018). Since the fuel price forecasts from IEA are in real term with 2017 as the base year, the IEA's prices are adjusted to nominal term with an assumption of 2% inflation rate, which is the 15-year average headline inflation in Thailand (TIF, 2017).

2.4. Assessment of Financial and Economic Feasibility

2.4.1. Development of possible business models

In order to assess financial and economic feasibility of the fuel replacement project, possible business models are firstly explored and developed. It is assumed in the study that most industrial plants adjacent to the transmission pipelines have already consumed natural gas from pipeline system due to its cost effectiveness and environmental friendliness (EPPO, 2016; Dodge, 2017). Accordingly, this study focuses the fuel replacement opportunities at those who are unable to directly access the pipelined gas and are inevitably using fuel oil and coal. In this regard, two simple business models are developed: the CNG model and the LNG model.

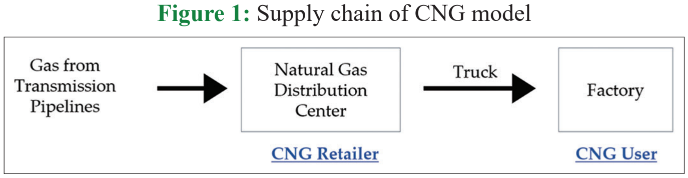
The CNG model involves supplying natural gas in the form of compressed natural gas (CNG) to the industrial user located not far from the transmission pipelines; whereas the LNG model is about supplying natural gas in the form of liquefied natural gas (LNG) to user located further away from the transmission pipelines. Nevertheless, it should be noted that real business models of natural gas procurement and distribution can be more complex than models presented in this paper.

In the CNG model, natural gas from the transmission pipelines will be transported via pipeline to natural gas distribution center, at which it will be stored as compressed natural gas (CNG). In practice, the existing natural gas vehicle (NGV) mother station can be utilized as a gas distribution center. Subsequently, the CNG retailer will transport CNG to user by truck. In this model, it is assumed that user is located within 50 km from the distribution center. Figure 1 shows the supply chain of the CNG model.

In the LNG model (Figure 2), the LNG will be transported from LNG receiving terminal by truck to LNG distribution center. After that, the LNG retailer will transport LNG to user by truck. Main assumptions of this model are as follows:

1. The 40 feet truck is used to deliver LNG from LNG receiving terminal to LNG distribution center
2. The 20 feet truck is used to deliver LNG from the LNG distribution center to user
3. The LNG distribution center is located within 200 km from the LNG receiving terminal
4. The LNG user is located within 50 km from the LNG distribution center

Figure 1: Supply chain of CNG model



2.4.2. Identification of project cash flow

Cash flow is defined as amount of cash transferred into and out of a business (Statt, 2003). Thus, cash flow of each player in the business models has to be identified, in order to assess financial and economic viability of the project. Cash flows of retailers and users in both CNG and LNG models are shown in Table 1. Figure 3 shows a simplified cash flow of a project throughout the project's life.

The project cash flow is further used to evaluate indices for investment appraisal.

2.4.3. Appraisal of project investment

This study focuses mainly on the industrial users as they are key decision maker for fuel replacement. Both direct and indirect benefits are assessed through financial and economic internal rate of returns. Simple payback period is also evaluated. A time period of 20 years starting from 2022 to 2041 is employed in the analysis.

2.4.3.1. Benefit analysis framework

Both direct and indirect benefits of the fuel replacement are considered by using financial and economic returns as indicators.

1. Financial return

Financial return is considered to be a direct benefit to project owner. This outcome can be obtained from comparing revenues (or cost saving) with total cost. In this study, the financial internal rate of return (FIRR) is used as an indicator to measure the financial return of the fuel replacement project.

2. Economic return

Economic return can be implied as a net benefit of the project. This is because it measures both direct and indirect benefits of the project (Liu et al., 2012). Direct benefits are generally in the form of revenue and cost saving, while indirect benefits cover the project's contributions to the national economy such as reduction of pollutions. Economic internal rate of return (EIRR) is employed to analyze the economic return.

In this study, an economic return of the fuel replacement project is assessed in terms of greenhouse gas emission reduction and PM2.5 reduction. The European Emission Allowance (EUA) price is employed to evaluate benefit of greenhouse gas emission reduction while the marginal external cost of emissions in European cities (Holland and Watkiss, 2002) is employed to evaluate benefit of PM2.5 emissions reduction. The CO_2 and PM2.5 emission factors from Statistic Norway are employed (Statistic Norways, 2017).

Figure 2: Supply chain of LNG model

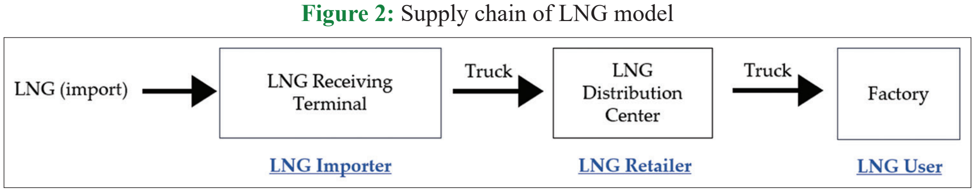
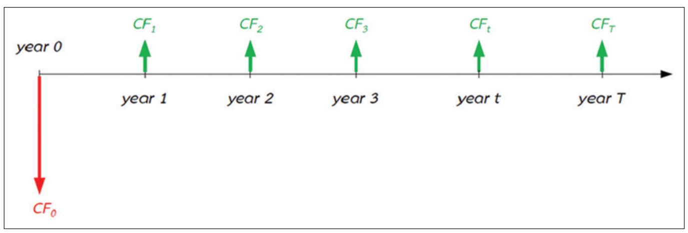


Table 1: Cash flow of retailers and users in the CNG and LNG models

Player	Cash in	Cash out
CNG Model		
CNG retailer	• Revenue from selling natural gas with markup price to cover investment and operating cost	• Natural gas cost • Service charge for transmission pipeline system • Investment and operating cost of natural gas distribution station • Cost of transporting CNG to customer by truck • Administrative and business operating cost
CNG user	• Cost saving from switching to cheaper fuel • Cost saving from thermal efficiency improvement (if any) (Tang et al., 2016)	• Cost of natural gas storage system • Cost of burner system modification • Cost of boiler modification • Cost of other relevant equipment
LNG Model		
LNG retailer	• Revenue from selling natural gas with markup price to cover investment and operating cost	• LNG cost • Investment and operating cost of LNG distribution station • Cost of transporting LNG to customer by truck • Administrative and business operating cost
LNG user	• Cost saving from switching to cheaper fuel • Cost saving from thermal efficiency improvement (if any) (Tang *et al*., 2016)	• Cost of LNG storage and regasification system • Cost of burner system modification • Cost of boiler modification • Cost of other relevant equipment

Figure 3: Simplified project's cash flow



2.4.3.2. Internal rate of return

Internal rate of return (IRR) is a discount rate when net present value of the project cash flow equals to zero (Atrill & McLaney, 2009). As it estimates earning from the investment, the greater IRR implies the stronger growth of the project. In the project appraisal, IRR is compared with the weighted average cost of capital (WACC). If IRR is higher than WACC, the project is considered to be acceptable. But if the IRR is lower than WACC, the project should be declined (Belyadi et al., 2017)

The IRR can be calculated by using equation (4).

$$IRR = \left\{ x \middle| \sum_{t=0}^{t=T} \frac{CF_t}{(1+x)^t} = 0 \right\} \quad (4)$$

when IRR = internal rate of return
t = time period that cash flow is obtained
T = time period that final cash flow is obtained
CF_t = net cash flow during a single period.

Cash flow for FIRR estimation can be calculated by adopting items listed in Table 1. Benefits on the reductions of greenhouse gas emissions and PM2.5 are taken into consideration of EIRR estimation.

2.4.3.3. Payback period

Payback period (PB) is the length of time for a business to regain their initial investment from net cash inflows (Atrill and McLaney, 2009). In the project appraisal, PB is compared with the maximum payback period that investor accept. If PB is shorter than maximum PB, project can be accepted. But if PB is longer than maximum PB, project should be declined.

The PB can be calculated by using equation (5).

$$PB = \min \left\{ x \middle| \sum_{t=1}^{t=x} CF_t > C_o \right\} \quad (5)$$

when PB = payback period
CF_t = net cash flow during a single period
C_0 = initial investment
T = time period that cash flow is obtained.

It should be noted that neither time value of money nor discount rate is considered in the simple payback calculation (Bragg and Burton, 2006).

3. RESULTS AND DISCUSSION

3.1. Identification of Regulatory Limitation

From the review, no regulatory prohibition for replacing fuel oil and coal with natural gas is found. However, existing regulations do not cover all aspects of LNG business operations. For example, there is no regulation on LNG specification and quality nor safety standard for LNG utilization. More importantly, there is no legislation specifying that LNG can be used as fuel. Despite the increasing role of LNG, the incomplete regulations may be deemed as limitation to the growth of LNG businesses in Thailand.

3.2. Projection of Fuel Demand

3.2.1. Projection of natural gas demand

There are 3 sources of natural gas supply for Thailand. In 2020, about 69% of supply is from indigenous reserves covering both offshore and onshore gas fields. Besides the domestic supply, Thailand also imports natural gas from Myanmar (15%) via pipeline. The remaining supply comes from other countries in the form of LNG (16%). On the demand side, natural gas has been used in 4 sectors: power generation (59%), petrochemical industry (21%), other industries (17%), and transportation (3%) (EPPO, 2021).

From the demand forecast (Figure 4), there will be an increase of natural gas demand in the power sector and the industrial sector. The possible reason behind the increase is that these sectors need to replace carbon-intensive fuels with more environmentally friendly one. Natural gas is an interesting option with an advantage on its

Figure 4: Projection of natural gas demand (1000 MMBTU/day)

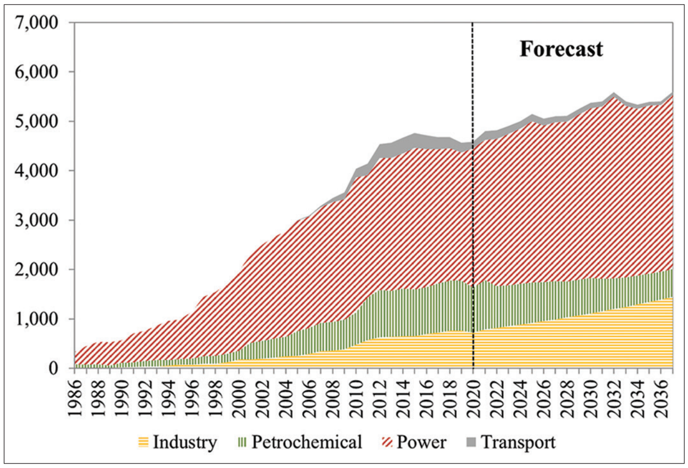


Figure 5: Retail price of petroleum products in Bangkok (EPPO, 2020)

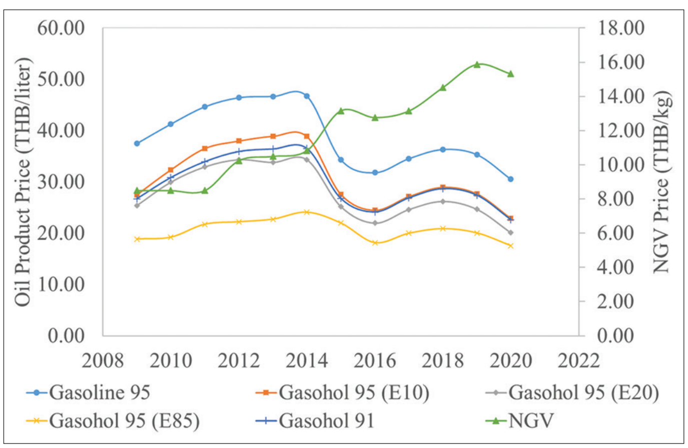
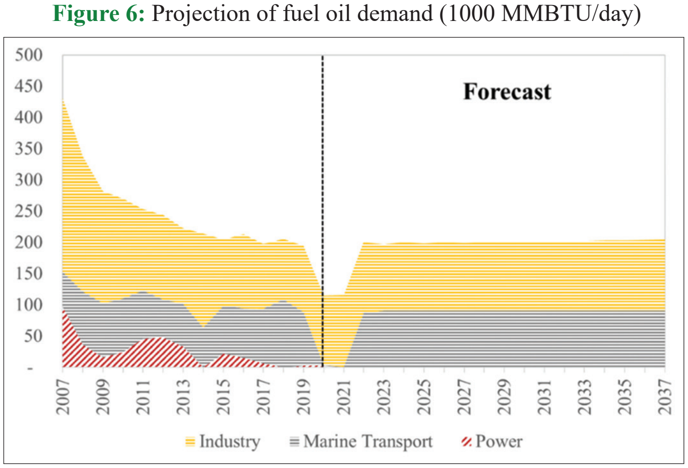


Figure 6: Projection of fuel oil demand (1000 MMBTU/day)



reliability and availability. On the contrary, the demand for natural gas in the petrochemical industry is expected to decrease. Due to the fact that natural gas is used as feedstock in this industry and is from domestic sources, the depletion of gas production in the Gulf of Thailand (DMF, 2018) will result in a decrease in the use of domestic natural gas in this sector.

The decrease of natural gas demand can also be seen in the transportation sector. As retail prices of oil products have dropped significantly since 2014, and NGV's price has been floated (Figure 5), there is no price motivation for consumers to use NGV cars. Thus, NGV usage in Thailand is expected to be lessened.

3.2.2. Projection of fuel oil demand

Fuel oil consumed in Thailand is from both imported crude oil (87%) and domestic crude oil (13%). Majority of fuel oil has been used as fuel in maritime transportation and industrial sectors. The rest is used in power sector and is continuously declining. In 2019, its share in maritime transportation, industrial and power sectors is 44, 54 and 1%, respectively (DOEB, 2021).

Based on the demand projection (Figure 6), fuel oil used in the industrial sector is expected to be stable or slightly increase. Due to the high prices of fuel oil, many industrial operators have previously turned to other cheaper fuels in an effort to minimize their costs. Only those cannot access to other types of fuel continue to consume fuel oil (Sahakij Charoen International, 2021; DEDE, 2015; EPPO, 2016). Thus, if there is no accessible alternative, fuel oil consumption in the industrial sector will not change significantly.

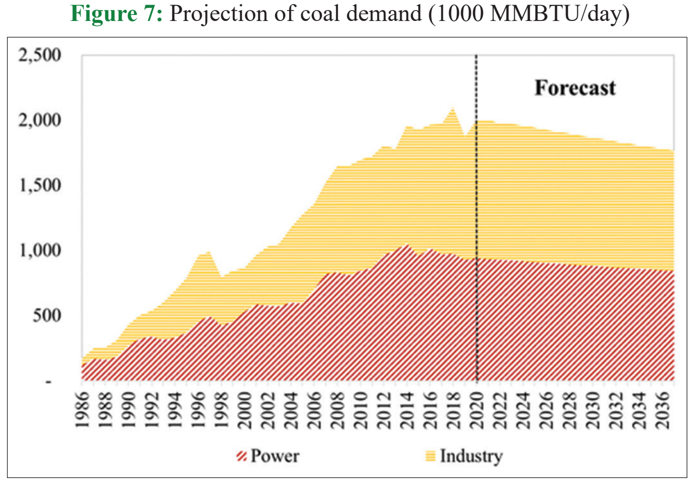
Although a great drop is seen in 2020 due to COVID-9 impact, demand for fuel oil in maritime transportation is expected to rebound to the pre-COVID level and remain there unless shippers are obliged to use cleaner fuels.

On the other hand, fuel oil consumed in the power sector is expected to shrink to zero as the sector needs to move to more environmentally friendly options.

3.2.3. Projection of coal demand

Similar to fuel oil, majority of coal consumed in Thailand is from imports, which accounts for about 82% contribution in the year

Figure 7: Projection of coal demand (1000 MMBTU/day)



2020. The rest of the supply is from domestic mining. As for the demand side, coal has been mainly used in the power generation sector (47%) and industrial sector (53%) (EPPO, 2019).

With the rise of the environmental concern, the demand for coal in both sectors is expected to decline despite its comparatively low and stable price (Figure 7). This implies that the price of coal, although low, does not incentivize the operators to change their fuels to coal in the future.

3.2.4. Estimation of natural gas amount for fuel replacement

It is estimated that the replacement of fuel oil and coal in the industrial sector will result in an increase in total national demand for natural gas of around 18-24% per annum (Figure 8). At the same time, the global LNG capacity is also expected to expand (BloombergNEF, 2018). Therefore, although the indigenous gas output capacity is dwindling (DMF, 2018), fulfilling the increase in demand for natural gas is considered feasible.

Figure 8: Overall natural gas demand inclusive of fuel oil and coal replacement in the industrial sector (1000 MMBTU/day)

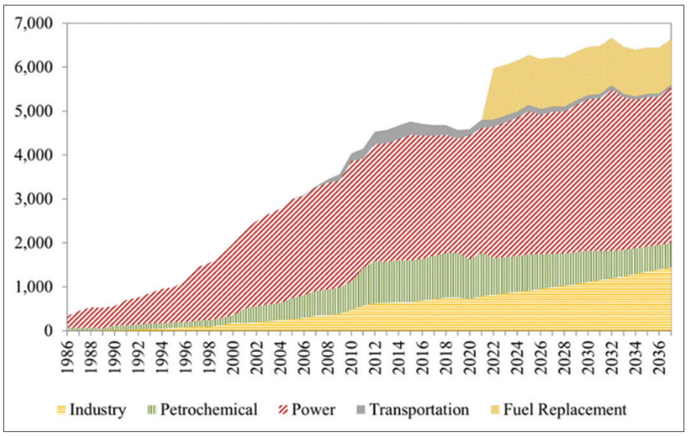
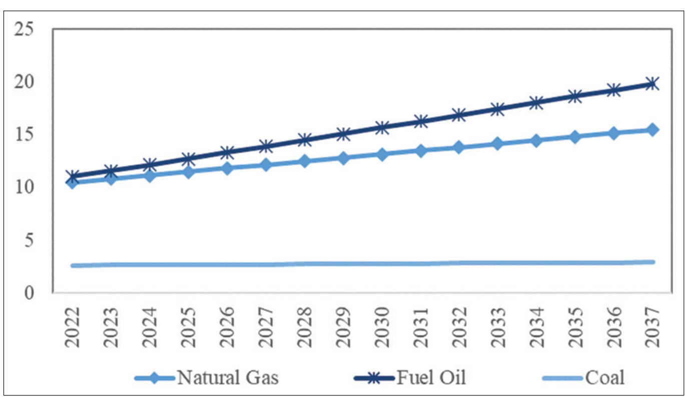


Figure 9: Fuel prices projection (USD/MMBTU)



3.3. Projection of Fuel Price

The 2022–2037 fuel price trends are shown in Figure 9. According to the chart, fuel oil price is expected to be greater than natural gas price and this price disparity will continue to widen. On the contrary, coal price is forecasted to be significantly lower than natural gas and fuel oil prices. It is noted that the price of natural gas shown in the figure is the price of liquefied natural gas.

In order to verify the validity of the projected prices, the projected price trends from this study (marked as ERI) are compared with those from other sources i.e., the national power development plan (marked as PDP) and the International Energy Agency (marked as IEA) (IEA, 2018). The results of the comparison are shown in Figure 10.

According to Figure 10, natural gas and fuel oil prices of this study (ERI) are consistent with the IEA's forecast, which predicts that the prices will rise continuously. However, the PDP's forecast predicts that the prices will rise over a certain period of time before plateauing. It is possible that the PDP intends to implement policy to control long-term gas and fuel oil prices in order to keep future electricity tariffs stable.

In term of coal price, this study's forecast is close to the PDP's forecast and is significantly lower than IEA's forecast.

3.4. Assessment of Financial and Economic Feasibility

Generally, key factor that drives industrial users to switch their fuels is cost saving from the differences in fuel prices that is worth investing in fuel system adjustment. However, switching from fuel oil and coal to natural gas will create addition benefits for the public, for example, reductions in greenhouse gases and PM2.5. Such benefits can be evaluated as economic benefits. Consequently, both financial and economic benefits should be evaluated to assess worthiness of the fuel replacement project. The result of financial and economic feasibility assessment is shown in Table 2.

According to the analysis, replacing fuel oil with CNG is considered to be financially attractive to factories located within

Figure 10: (a-c) Comparison of projected fuel prices (USD/MMBTU)

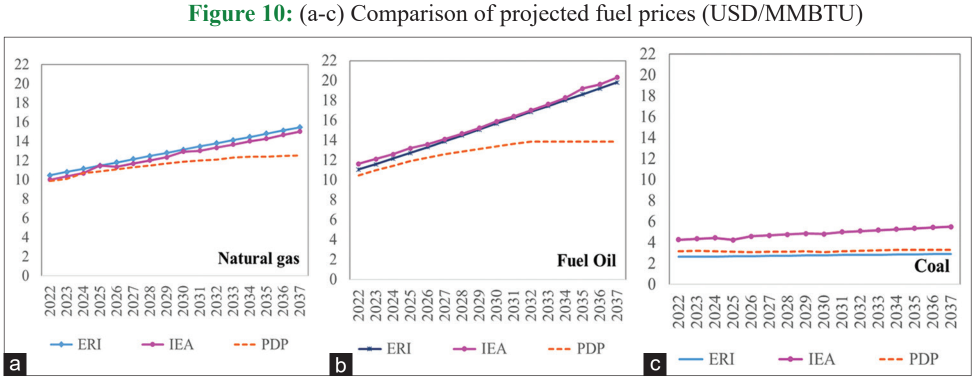


Table 2: Financial and economic feasibility assessment of fuel replacement projects

Model	Indicator	Fuel oil replacement	Coal replacement
CNG Model	FIRR (%)	104%	Not feasible[1)]
	EIRR (%)	675%	799%
	PB (year)	1.9	-
LNG Model	FIRR (%)	11%	Not feasible[1)]
	EIRR (%)	184%	226%
	PB (year)	13.7	-

Remarks: [1)]Not feasible means the project is not financially feasible

50 km from the natural gas distribution center (CNG model). With FIRR of over 100% and payback period of <2 years, it is most likely that the industrial users will find it worth investing in fuel system adjustment as they will be able to recover the investment cost in a short period of time.

On the contrary, it is found that replacing fuel oil with LNG is unattractive for factories located more than 200 km from the LNG terminal (LNG model). This is because the FIRR of the replacement project is only 11% but it will take almost 14 years to regain the investment costs.

Switching to natural gas (either CNG or LNG) is found to be not financially attractive to coal users at all. This is because coal price is much lower than natural gas price. But if the economic benefits are taken into account through EIRR, both fuel oil and coal replacement will bring tremendous benefits to public. Therefore, the government should have special measures to promote the replacement of such fuels.

4. CONCLUSION AND POLICY IMPLICATIONS

According to the study, it is possible to replace fuel oil and coal with natural gas in the industrial sector. The replacement will lead to about 18-24% increase in total national gas demand. As natural gas production in the Gulf of Thailand is depleting, it is expected that Thailand will need to import natural gas, which could be in the form of LNG, to satisfy this increment. Therefore, the country should carefully plan for the long-term natural gas imports to meet the growing demand for natural gas to be used as fuel in the industrial sector. Infrastructure development should also be integrated into the plan.

In term of using natural gas as feedstock, it may be essential for the country to expedite the new domestic natural gas exploration and production. Meanwhile, it is also worth for the business to seek alternative feedstocks, such as bio-based feedstocks, which will bring along great opportunities for the transition to bioeconomy.

Considering the financial feasibility analysis, replacing fuel oil with compressed natural gas (CNG) will financially benefit fuel oil users located within 50 km from the CNG distribution center. On the other hand, fuel oil users located further away may not find natural gas financially interesting enough to change their fuels at the moment, not to mention coal replacement that will certainly not be occurred based solely on the fuel prices. Nevertheless, the economic feasibility study shows important benefits especially from coal replacement.

In general, market mechanism will automatically drive the financially feasible projects. The government only needs to eliminate regulatory limitations for business operations. On the contrary, project with low financial return is not likely to attract investor. Therefore, projects with low financial returns but high economic returns such as coal replacement will require strong supportive measures from the government. Examples of such measures are funding for system adjustment, fuel price compensation and carbon pricing mechanism.

Furthermore, as the role of LNG in Thailand's energy supply is expected to increase, specific legislations relating to LNG are required. Although the study found no legal restrictions for the replacement of fuel oil and coal with natural gas, the lack of essential regulations may impede the LNG business in Thailand. Thus, it is important for Thailand to prepare fundamental laws and regulations to ensure smooth operations in the business. Priority should be given to regulations on (1) identifying that LNG can be used as fuel, (2) LNG specifications, (3) LNG safety standard. Regulations on other aspects may be derived from those of natural gas.

It is noted that liquefied petroleum gas (LPG), which is also used as heating fuel in the industrial sector, is not included in this study. Thus, in order to assess total fuel replacement opportunity for Thailand, it is recommended to include a feasibility study of LPG replacement in a further study. In addition, a further study on fuel replacement roadmap should be conducted as it will benefit the development of policies to support the long-term demand for natural gas.

5. FUNDING

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