A Study of Electricity Planning in Thailand: An Integrated Top-down and Bottom-up Modeling Analysis

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Abstract

This study illustrates the impact of three electricity policies to Thailand economy in terms of macroeconomics performance, sectorial output, income distribution, and unemployment rate. The three considered policies are the disruption of imported natural gas used in electricity generation, the different of fuel feedstock portfolios for electricity generation, and the rising of investment and local electricity consumption. The evaluation employs Computable General Equilibrium (CGE) approach with the extension of electricity generation and transmission module to simulate the counterfactual scenario for each policy.

The first simulation shows that the consequence of imported natural gas disruption. The result shows that the entire reduction of imported caused RGDP to drop by almost 0.1%. On portfolio mixed of power generation, promoting hydro power is the most economical solution; nonetheless, adverse effect to RGDP is recognized. Rather the second best alternative of domestic natural gas dominated portfolio is recommended. Last simulation suggests that several power plants such as South Bangkok, Siam Energy should be upgraded to cope with expected 30% spike in power consumption due to regional trade and domestic investment.

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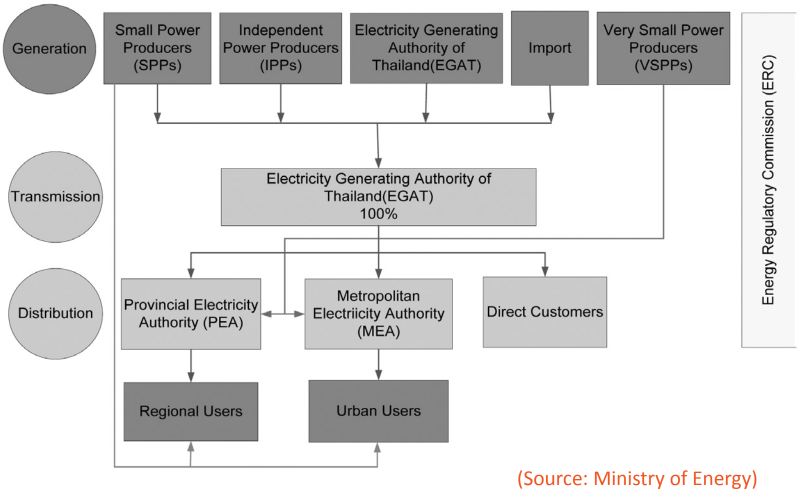
1. Introduction

Electricity is one of the most important public utilities. It facilitates both social and industrial development of the modern world. Economic expansion usually requires not only supplementary raw materials but also greater energy supplies for its activities. The subject of electricity supply and security has ultimately become a top priority of the Thailand. The country has always required continuous increments in electrical power generation to nourish its growing economy. It is important to explore carefully and truly understand how the effects of changes in electricity generation and transmission patterns affect the Thai economy.



(Source: Ministry of Energy)

Figure 1. The structure of Thailand Electricity Industry.

Like many developing countries, the Thai Electricity Supply Industry (ESI) is engaged in three main activities: (1) generation, (2) transmission, and (3) distribution. These activities are regulated by the Energy Regulatory Commission (ERC) under the Ministry of Energy.

1.1 The Structure of Electricity

For the electricity generating mission, as shown in Figure 1, there are five sources of electricity in Thailand: (1) Electricity Generation Authority of Thailand (EGAT), (2) Independent Power Producers (IPPs), (3) Small Power Producers (SPPs), (4) electricity imported from neighboring countries, and (5) Very Small Power Producers (VSPPs).

Of all the producers, EGAT is the leader in the electricity industry since EGAT is a major power producer, an electricity single buyer, and the sole distributor. It presently is a state-owned enterprise under the Ministry of Energy. The mission of EGAT ranges from generating electricity and providing power resources to distribution networks.

Thailand has met its need for electrical power by importing electricity from Laos and Malaysia. Imports have accounted for 7% of total consumption. Once power is generated by various types of producers, EGAT purchases almost all of it and resells the power to distribution bodies. These are the Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA).

Over the past decade (2002 -2011), the Industrial sector has the highest share of electricity consumption at 47.1%, followed by the Residential and Business sectors at 21.7% and 15.4%, respectively (Energy Policy and Planning Office, 2012). Geographically, Metropolitan Bangkok accounts for 49.1% of total electrical power consumed for the past ten years.

Traditionally, more than 90% of electricity is generated from fossil fuels, especially natural gas. Roughly 3% is hydroelectricity. The remainder of the electricity is imported from neighboring countries, Laos and Malaysia (Electricity Generation Authority of Thailand, 2012). In 2011, to produce electricity, the country relies on natural gas by (66%), followed by Coal and Lignite (19%) and hydroelectricity (5%).

Many government and international agencies are of the opinion that energy security is threatened Thailand by increasing prices and scarcity of energy commodities. An academic investigation shows that Thai energy insecurity is rooted in three major sources: rising energy demand, limited fossil energy reserved, and political market risk of energy imports and the energy price in the world market. (Martchamadol & Kumarn, 2012). Among the three main sources, rising energy demand is seen to be least avoidable, since the relationship between electricity consumption and economic growth of Thailand show significant correlation (Yoo, 2006). On the other hand, the world price and supply of energy product is the least controllable factor. Thus, it is important to have a robust electricity plan for Thailand.

2. Literature Review

In many studies of energy policy related issues (Bergman, 1991; Grubb et al., 1993; Yang et al., 1996; Rutherford & Montgomery, 1997; Burniaux & Truong ; 2002; Frei et al., 2003; Sue Wing, 2006; Kuster et al., 2007), there are usually 3 important elements missing: (1) the linkage between the electricity supply system and macroeconomic perspective, (2) the provision for transition mechanisms from the micro to macro point of view, and, (3) failure to include the electrical transmission system in analyses.

The present electricity module employs a linear optimization bottom-up type methodology aiming to minimize the total costs incurred from power production activities using information from published literature (Anderson , 1972; Hobbs, 1995; Meza et al., 2007). The objective cost function of this model comprises four major components: costs of fuel, varied costs of operation and maintenance of the power plants, transmission costs, and power outage costs. The constraints are set to avoid violation of the existing power infrastructures and their actual capacities.

The objective of this study is to illustrate and assess different energy policies by employing a Computable General Equilibrium (CGE) framework that has been integrated with a module of electricity generation and transmission. In Thailand, there are studies on an application of CGE analysis in the study of energy policies (Limmeechokchai & Suksuntornsiri,2007; Timilsina & Shrestha, 2008; Watcharejyothin & Shrestha ,2008; Wianwiwat & Asafu-Adjaye, 2011; Thepkhun et al., 2013). However, none of them has integrated the top-down and bottom-up approach.

In this study, three counterfactual scenarios are simulated and their effects assessed with reference to macroeconomic performance, the distribution of income, as well as the configuration of electricity generation and distribution. The simulation results are presented in three scenarios: (1) imported natural gas disruption, (2) different input compositions for electricity generation, and (3) the increases in investment and local demand of electricity, by utilizing the integrated top-down and bottom-up model presented. The analysis of each case study and simulation as well as its applications to the policy makers and planners are discussed.

3. Methodology

This research focuses on the evaluation of policies involving provision of electricity in Thailand. The counterfactual scenarios are based on data from the Social Accounting Matrix (SAM) for the year 2006. Based on availability, the alternative substitute fuels considered are hydro power, and imported electricity.

Regarding generation and transmission, only the existing electricity generating infrastructure is considered. Data on the consumption of electricity are collected at 13 reference points. Lastly, the additional module is combined with the CGE model using the two-way feedback method of integration.

3.1 Computable General Equilibrium (CGE) Model

Computable General Equilibrium (CGE) analysis provides many insights into the factors and mechanisms that determine relative prices and the allocation of resources within and between market economies. It is a useful tool for long-term economic forecasting and economic policy evaluation for three reasons: (1) its consistency with other types of analysis, (2) CGE models can overcome particular problems such as some structural rigidities and institutional constraints that other models fail to capture, and, (3) CGE models provide consistent frameworks to assess the linkage and tradeoffs among different policy packages (Devarajan & Robinson, 2002). CGE modeling is embraced by many policy research institutions, such as the World Bank, International Food Policy Research Institute (IFPRI).

In this study, The 2006 Social Accounting Matrix (SAM) of Thailand is used as a data system in the standard CGE model based on Anatsuksomsri (2013). The SAM data is obtained from the office of the National Economics and Social Development Board (NESDB). The SAM table has a size of 192 accounts by 192 accounts. It contains 2 production factors, i.e., labor and capital, 58 production sectors, domestic intermediate, and imported intermediate inputs, Trade and transport margin, 5 types of taxes, i.e., direct tax, value-added tax, exercise tax, tariff, and other indirect taxes, a subsidy, 5 types of households categorized by income level, Government, Private, State-own enterprises, Rest of the world, and Capital account.

3.2 Electricity Information

3.2.1 Power Supply Information

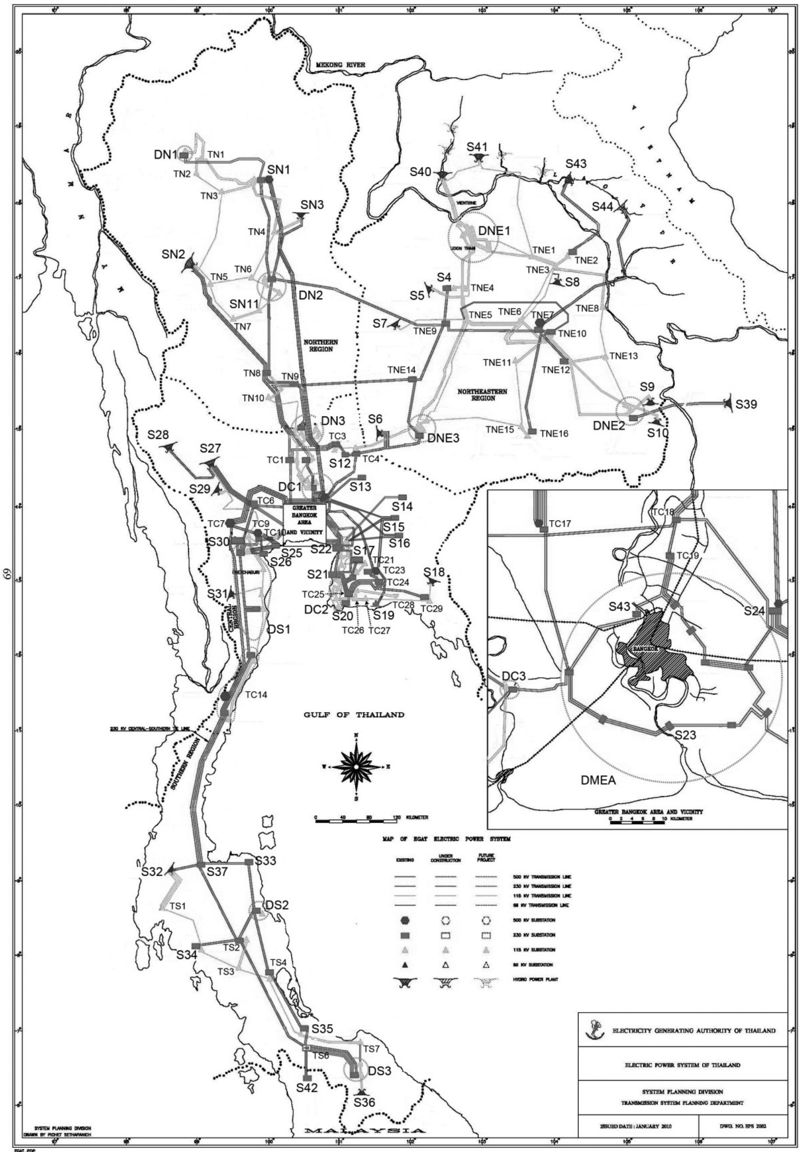
From total power resources list in Thailand Power Development Plan (EGAT, 2007), the current study examines 44 power resources having individual supply capacities of more than 5 MW and using one of seven types of utilization fuels. These fuels are domestic natural gas, imported natural gas, domestic coal, imported coal, fuel oil, hydro- and imported electricity.

3.2.2 Demand for Electricity

There are13 nodes on the demand side. They consist of 12 PEA regional offices and 1 MEA Metropolitan office. The daily national power consumption data used as the reference for the aggregated demand is calibrated from the data during a peak day in April 2010. The quantities of daily required power in Megawatt-hours (MWh) at each place are determined from the load duration curves.

3.2.3 Distribution Network

The transmission network represents the flow of electricity from its generation points to the referenced demand locations. The original network diagram is simplified and presented in Figures 2. As shown in the network diagram, there are 10 transshipment nodes in the Northern region, 16 transshipment nodes in the Northeast region, 21 transshipment nodes in the Central region, and 8 transshipment nodes in the Southern region. The transshipment nodes are connected by 4 different types of power lines.



(Source: EGAT, 2007)

Figure 2. A Simplified Electric Network of Thailand with Power Plants.

3.3 The Method of Integrating CGE and Electricity Network Submodules

The integration method in the current study follows a decomposition strategy (Böhringer & Rutherford, 2008). The solution involves iteration of a top-down CGE model given the demand of fuel for electricity generation from a bottom-up model. Figure 3 illustrates the steps of this iterative model solution. To combine bottom-up electricity generation model and top-down CGE, the objective function of electricity generation model is changed to maximizing profit of the electricity sector rather than minimizing cost of electricity activities. This is compliment to the cost minimization problem.

The solution procedure starts from the bottom-up network model calculating the demand for 7 different fuels. The solution is then calibrated and fed into the general equilibrium model as the import and domestic intermediate inputs. Next, the CGE proceeds to determine the price and quantity of electricity sectors and other macroeconomic variables. Then, price and quantity of electricity sectors are brought back to the bottom-up model to solve the profit maximization problem of the electricity sector. In addition, fuel, as total domestic and total imported intermediates inputs, is determined from the CGE model for electricity production and passed along to the submodule as fuel supply constraints. The aggregation continues recursively until two models reach equilibrium.

4. Results

4.1 Baseline Simulation

The primary attempt of this current study is to replicate economic conditions and electricity generating configuration of Thailand prior to perturbing the model and observing the responses. The year 2006 is selected as a reference due to the year of SAM data system. Since the CGE model has a static equilibrium orientation, intertemporal analysis is not available in this study.

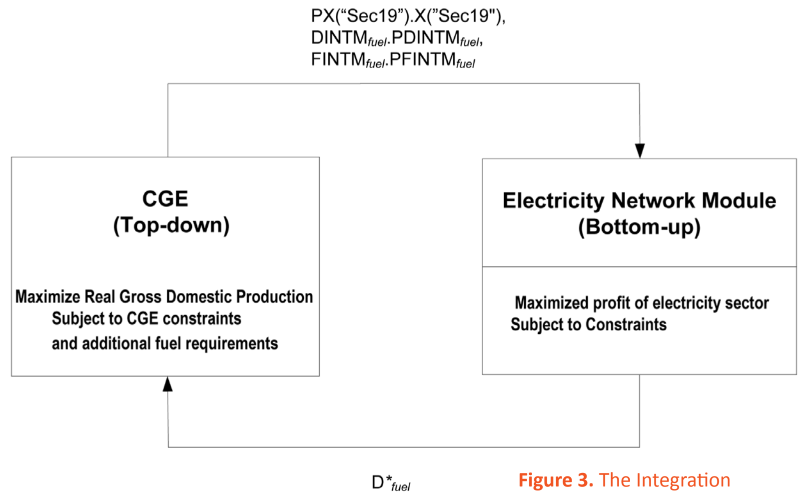


Figure 3. The Integration Scheme of Top-down and Bottom-up Models.

Variable	Unit	Simulation	2006
GDP	Billion Baht	7,464.26	7,848.67*
EXR	Bath/USD	35.00	37.90*
Government Revenue	Billion Baht	1,318.86	1,747.90**

* Bank of Thailand (BOT)
** International Monetary Fund (IMF)

Table 1. The Selected Macroeconomics Variables of the Baseline Simulation Result.

To validate the model's ability to characterize the behavior of the Thai economy, three macroeconomic variables are examined: Gross Domestic Product (GDP), the Exchange Rate (EXR), and Government Revenue. The solution values of these variables are compared to their actual historical values obtained from Central Bank of Thailand (BOT) and the International Monetary Fund (IMF). Overall, the extended CGE model shows that the predicted variables are slightly lower than those of the reference year (2006). The result of the baseline is illustrated in Table 1

On the actual production side, the amount of electric power is the most critical variable because it would be translated to costs of fuels and then interacts with the CGE model. The simulated numerical outcome of amount of power generated from different fuel types compared with actual values of the year 2006 is given in Table 2. The result confirms that the simulated mixed portfolio is close to actual generation. However, the simulated amount of gas-based electricity slightly surpassed an actual generation value. This may have occurred due to a lack of diesel and other fuel resources in the baseline case.

Fuel Type	Electricity Production (GWh)		Electricity Production (%)	
	Simulation	2006*	Simulation	2006*
Domestic gas	74,607	94,439**	53.83%	66.56%
Imported gas	24,888	n/a	17.96%	0.00%
Domestic coal	18,118	18,028	13.07%	12.71%
Import coal	1,877	6,441	1.35%	4.54%
Hydro	7,205	7,950	5.20%	5.60%
Oil	6,405	7,808	4.62%	5.50%
Import	5,489	5,152	3.96%	3.63%
Diesel	0	77	0.00%	0.05%
Other sources	0	1,996	0.00%	1.41%
Total	138,589	141,891	100.00%	100.00%

* Energy Statistic of Thailand 2012, EPPO
** The number including electricity produced from domestic and imported gas

Table 2. The Electricity Generation Variables of Baseline Simulation Result.

4.2 The Simulation Result and Analysis

4.2.1 The Disruption of Imported Natural Gas Case

The first scenario attempts to explore the effects of disruption of imported natural gas from Myanmar in 3 ways: (1) actual generation, (2) macroeconomically, and (3) socio-economically. In this counterfactual scenario, the model simulates the effects of 45%, 75%, and 100% disruption of imported gas supply from Myanmar. From actual generation point of view, the variables considered are the amount of electricity produced from different fuels and unmet demand at each location. With regard to economics, there are 3 important variables: (1) Gross Domestic Production (GDP), (2) Real Gross Domestic Production (RGDP), and(3) Price Index (PINDEX). These are selected to measure the economic health. On socio-economics, four indices are considered: (1) Income of the poor households (Income less than 30th percentile), (2) Income of non-poor households, (3) Income distribution, and (4) Unemployment rate, are chosen to evaluate the social welfare of the country. The income distribution index is the ratio of income of the poor household to income of non-poor households.

Unit: GWh

Fuel	Base case	45%Drop	%Change	75%Drop	%Change	100%Drop	%Change
Domestic natural gas	74,607	72,004	-3.49%	68,848	-7.72%	67,817.51	-9.10%
Imported natural gas	24,888	14,745	-40.76%	3,928	-84.22%	0	-100%
Domestic coal	18,118	18,118	0%	18,118	0%	18,117.71	0%
Imported coal	1,877	7,491	299%	7,987	325.61%	8,149.90	334.30%
Hydro	7,205	7,205	0%	7,205	0%	7,205.43	0%
Oil	6,405	6,085	-5.00%	5,789	-9.62%	5,692.78	-11.12%
Imported electricity	5,489	7,480	36.27%	7,849	42.98%	7,968.99	45.18%
Total	138,589	133,127		119,724		114,952	

Table 3. The Result of Electricity Generation Configurations Responded to Imported Gas Disruption.

Overall, the results show that as higher levels of disruption occur, worse impacts to the country are seen in every aspect. Table 3 illustrates the changes in real generation obtained from the electricity network model. Firstly, the figure confirms that the portion of the electricity generation from imported gas is fallen due to the lower fuel supply. By exploring the generation pattern, the generation system response is to compensate for lost power by increasing power produced from imported coal and imported electricity. However, since these two resources account for little generation capacity, they are not able to compensate for this significant power shortage. There are three power plants, namely Ratchaburi Power, Ratchaburi Thermal, and Tri Energy, which depend on imported natural gas. The result shows that Ratchaburi Power and Tri Energy are always operated in the case of 45% gas drop but with limited capacity.

Table 4. The Result of Electricity Shortage Responded to Imported Gas Disruption.

Location	Power Shortage (MWh)		
	Peak load	Intermediate Load	Base load
45% Gas Drop			
DMEA	8,729.88	5,869.81	171.99
DS2	0.00	0.00	150.04
75% Gas Drop			
DMEA	18,748.86	24,457.96	7,833.94
DS2	0.00	0.00	501.67
100% Gas Drop			
DMEA	20,129.06	26,968.80	8,062.72
DS1	2,153.16	4,114.99	2,397.61
DS2	0.00	0.00	753.59

Table 5. The Fuel and Outage Cost Incurred from Imported Gas Disruption.

Unit: Thai Baht/Day

Fuel Type	Fuel Cost			
	Baseline	45% Drop	75% Drop	100% Drop
Domestic Gas	227,207,100	219,507,100	209,585,900	206,349,600
Import Gas	48,540,010	28,924,130	8,465,948	0
Domestic Coal	13,250,870	13,250,870	13,250,870	13,250,870
Imported Coal	91,499,010	365,231,900	389,431,000	397,376,700
Hydro	204,716	204,716	204,716	204,716
Oil	3,429,590	3,264,524	3,079,033	3,018,284
Imported Electricity	31,182,660	43,693,010	46,010,050	46,766,380
Total	415,313,956	674,076,250	670,027,517	666,966,550
Demand node	**Outage Cost**			
	Baseline	45% Drop	75% Drop	100% Drop
DMEA	0	782,120,733	2,695,847,523	2,967,584,279
DS2	0	8,123,391	16,570,753	40,801,095
DS1	0	0	0	477,812,675
Total	0	790,244,124	2,712,418,275	3,486,198,049
Fuel and Outage Cost	**415,313,956**	**1,464,320,374**	**3,382,445,792**	**4,153,164,599**

Table 6. Numerical Result of the Effect of Imported Gas Disruption.

Variable	Baseline	45%Drop	%Change	75% Drop	%Change	100% Drop	%Change
Macroeconomics variables							
RGDP	7,464.27	7,461.41	-0.04%	7,458.43	-0.08%	7,457.32	-0.09%
GDP	7,464.27	7,456.35	-0.11%	7,448.56	-0.21%	7,445.71	-0.25%
Price Index	1	0.999323	-0.07%	0.998677	-0.13%	0.998443	-0.16%
Socioeconomic variables							
Income of the poor	1,523.92	1,521.43	-0.16%	1,519.01	-0.32%	1,518.10	-0.38%
Income of the non-poor	3,914.67	3,911.63	-0.08%	3,908.70	-0.15%	3,907.59	-0.18%
Income distribution	38.93%	38.89%	-0.09%	38.86%	-0.17%	38.85%	-0.20%
Unemployment rate	15.00%	15.65%	4.34%	16.31%	8.77%	16.56%	10.37%

Figure 4. The Macroeconomics Indicators Response to Imported Gas Disruption.

An imported gas shortage has different levels of severity in 3 areas: (1) the Metropolitan area (MEA), (2) the central part of the Southern region (DS2), and (3) the northern part of the Southern region (DS1). Table 4 presents numerical results of power shortages in each location. The results show that in every scenario, the Metropolitan area always experiences the worst effects.

The result of Fuel cost and Outage cost is provided in Table 5. In the case of complete gas disruption, the result shows that the additional fuel cost is increased by roughly 250 million Thai Baht per day and the Outage cost of roughly 3,500 million Thai Baht per day. To prevent this critical incident, one may suggest building new gas storage. Nonetheless, building new storage capacity for imported natural gas at 485 million standard cubic feet per day (MMSCFD would require massive investment. Therefore, it would not be economical to establish a new gas storage facility.

From macroeconomic and socio-economic points of view, overall the shortfalls of imported gas result in detrimental effects to the Thai economy. The summary of numerical results is presented in Table 6.

From the macroeconomic point of view, the country's GDP and RGDP monotonically decrease as a result of gas disruptions as shown in Figure 4. Of these three locations, the Bangkok Metropolitan area (DMEA) has the highest volume of business activities while the other two locations (DS1 and DS2) serve in tourism and small manufacturing. Therefore, the combination of production loss and limited effects on some locations makes the effect considerably significant on a regional scale. The price index shows a very small drop suggesting that the inflation seems to be almost constant.

Sector	Description	Basecase	45% Drop	% change	75% Drop	% change	100% Drop	% change
SEC9	Natural gas (raw)	52.369	48.671	-7.062%	45.3926491	-13.322%	43.8109629	-16.342%
SEC18	Natural gas (separated)	101.303	97.183	-4.067%	92.7416016	-8.452%	91.7651272	-9.416%
SEC19	Electricity (Non-renew)	585.314	581.616	-0.632%	578.214628	-1.213%	577.126893	-1.399%
SEC35	Basic Chemical Products	384.842	384.284	-0.145%	383.712942	-0.293%	383.549376	-0.336%
SEC17	Fuel oil	48.884	48.813	-0.145%	48.7475755	-0.278%	48.7246897	-0.325%

Table 7. Top Five Output Loss Sectors as a Consequence of Imported Gas Shortage.

Table 7 shows the impacts on the five sectors that are severely hit as a consequence of imported gas shortage. The results are presented in sectoral output values (its price multiplied by quantity) and the percentage change. Almost all industries that lost their outputs are electricity-related industries.

On socio economic impact, all indicators worsen as a consequence of power disruption. As presented in Table 6 and Figure 5, income of poor households and non-poor households are lowered by increasing magnitudes of import gas disruption. However, the results show that the incomes of non-poor households are less impacted and ultimately yielding an improvement of income distribution between poor and non-poor household. The disruption in power supply also leads to a higher unemployment rate in the long run since there would not be sufficient energy to conduct business activities. When a disruption occurs, the cost of gas-substituted fuels is always paid by Thai government. An alternative response to consider that would compensate the government for the additional cost it incurs would be to charge the supplier a penalty fee. Currently, imported natural gas trading contracts are signed on a take-or-pay basis, which requires that Thailand be responsible for either taking gas produced on a Daily Contracted Quantity (DCQ) basis from Myanmar or paying a penalty. In the situation when the seller is not able to provide the agreed upon minimum gas demand, the current contract expresses that the purchaser is allowed to pay for only the portion of gas received. In addition, the payer has a privilege only to receive a refund of 20-25% of total price of shortage gas for the next purchase (Petroleum Authority of Thailand, 2012). The contract, however, does not completely address different levels of gas disruption that perhaps are not anticipated when the contract is signed.

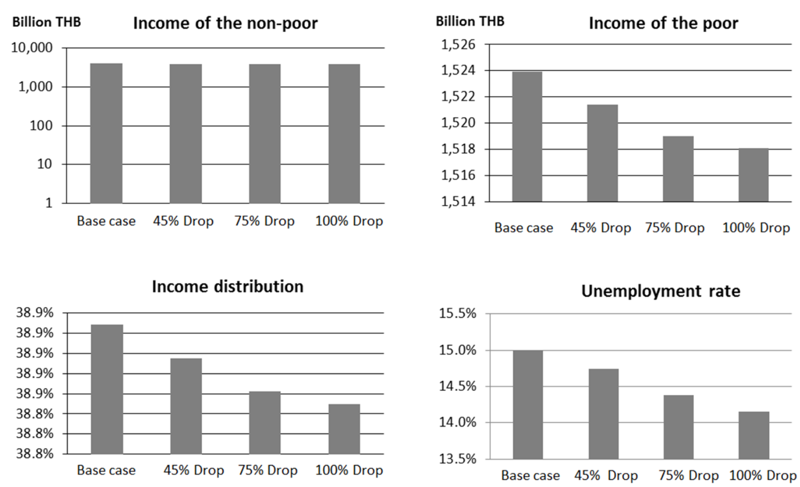


Figure 5. The Social Indicators Response to Imported Gas Disruption.

As a buyer, Thailand therefore must assume the burden of an unfair trade practice. The result of this experiment provides the data that can be used as a guide for either renewing the existing contract or drafting a new one that is fairer to Thailand. The result of power loss can be interpreted as a referenced scale for different compensation. With quantity of power loss coupled with the macroeconomic outcome, policy makers can see a big picture of the impacts of an imported gas shortage which can be used to drive energy policy decisions, such as whether or not to improve the capacity of candidate power plants and transmission cables around the most critical location, the Bangkok Metropolitan area and its vicinity.

5.2.2 The Case of Three Different Portfolios of Electricity Generation

This second case aims to investigate an adjustment of the input composition in electricity generation and its consequences. There are 3 important counterfactual scenarios: (1) Portfolio 1-Increasing in hydro-power, (2) Portfolio 2-Increasing domestic gas-based power with less reliance on imported gas-based power by 14%, (3) Portfolio 3-Further dependence on domestic gas-based power and lesser reliance on imported gas-based power by 19%. The first counterfactual scenario follows the Green Energy path as it reduces the consumption of high emission fuels. This scenario deemed to promote the usage of hydro-power which currently accounts for quite small portion (5% of total generation). Since natural gas is still expected to dominate power generation for the next few decades, it is therefore necessary to explore this case. The remaining two scenarios aim to predict the effects of different allocations of domestic and imported gas to power production.

Three scenarios are simulated and investigated using an extended CGE model while the electricity demand are fixed at 138,588.59 GWh per annum as indicated in the base case. The numerical results are presented in Table 8. Portfolio 1 shows a significantly greater portion of hydro-power production which is approximately 250% of the baseline while the imported gas-based is cut by about half. Portfolio 2 presents a reduction of imported gas-base power by roughly 70% and larger domestic gas-base power and imported electricity accounting for roughly 14% and 94% respectively. The proportions of domestic gas-based power and imported electricity are increased by 19% and 45% respectively in Portfolio 3 while the imported gas-based power is reduced by 50%.

Table 8. Three Different Portfolios of Electricity Generations.

Unit: GWh

Fuel	Base case	Portfolio 1	%Change	Portfolio 2	%Change	Portfolio 3	%Change
Domestic natural gas	74,607	72,283	-3.11%	84901	13.80%	88,819	19.05%
Imported natural gas	24,888	12,821	-48.48%	7267	-70.80%	12,173	-51.09%
Domestic coal	18,118	18,118	0%	18118	0.00%	18,118	0.00%
Imported coal	1,877	0	-100%	8395	347.36%	2,191	16.75%
Hydro	7,205	24,226	236.22%	7205	0.00%	7,205	0.00%
Oil	6,405	6,192	-3.33%	2075	-67.61%	2,099	-67.23%
Imported electricity	5,489	4,949	-9.85%	10628	93.61%	7,983	45.44%
Total	138,589	138,589		138,589		138,589	

Table 9. The Fuel Cost Incurred from Different Portfolios.

Unit: Thai Baht/Day

Fuel Type	Fuel Cost			
	Base case	Portfolio 1	Portfolio 2	Portfolio3
Domestic Gas	227,207,100	215,994,400	261,714,400	271,906,200
Import Gas	48,540,010	25,006,020	14,173,840	23,741,950
Domestic Coal	13,250,870	13,250,870	13,250,870	13,250,870
Imported Coal	91,499,010	0	409,331,800	106,824,700
Hydro	204,716	558,513	204,716	204,716
Oil	3,429,590	3,383,918	1,069,104	1,081,513
Imported Electricity	31,182,660	27,785,660	63,473,040	46,855,520
Total	415,313,956	285,979,381	763,217,770	463,865,469

Table 9 illustrates the breakdown fuel cost of each portfolio. As a result of higher hydro-based power supply, portfolio 1 shows the lowest cost of fuel. An increase in Hydro-based power completely eradicates imported coal-based power and reduces the consumption of imported gas by half. Next Portfolio 3, domestic gas dominated portfolio, shows the second best alternative in fuel cost. Comparing with the basecase, Portfolio 3 lowers cost of imported gas by half and slightly increases cost of imported coal. Lastly, Portfolio 2 shows an attempt to reduce imported gas and electricity by two thirds. Whereas the generation system unfavorably responses by shifting to more expensive imported coal. Interestingly, Portfolio 2 turns out to be the most costly scenario.

From the fuel cost perspective, Portfolio 1 seems to be the most desirable. However, excess hydro-based power may cause the shortage of water for agricultural activities or, in the worst case, sudden flood.Therefore, water management needs to be extensively studied and evaluated before following this direction. Portfolio 3 is the second best direction. Although, its cost is slightly higher than the current base case, a reduction of imported gas by half significantly helps promote the country's energy security.
In terms of macroeconomic and socio-economic criteria, model solutions indicate that Portfolio 3, with its heavy domestic gas dependence, would outperform the other two portfolios of fuel stocks. The numerical results are presented in Table 10

On the macroeconomics level, the result shows that Portfolio 3 is the best to help improve the real GDP (RGDP) and curb inflation (PINDEX) followed by Portfolio 2. Although, Portfolio 2 may performs better in inflation control, Portfolio 1 wins in the final result in terms of real GDP (RGDP). The heavier use of domestic gas therefore brings a positive effect to the economy as it helps stimulate domestic energy-related activities and reduces the cost of imported gas. Interestingly, Portfolio 1 does not contribute much on the economics level and even brings an adverse effect to the real GDP (RGDP). This may due to the fact that most of the hydro-power belongs to EGAT, a government authority which has little spillover effect to other industries. Figure 6 shows the graphical representation of three macroeconomic variables.

Figure 6. The Change of Macroeconomic Variables Compared to the Baseline under Different Electricity Generation Portfolios.

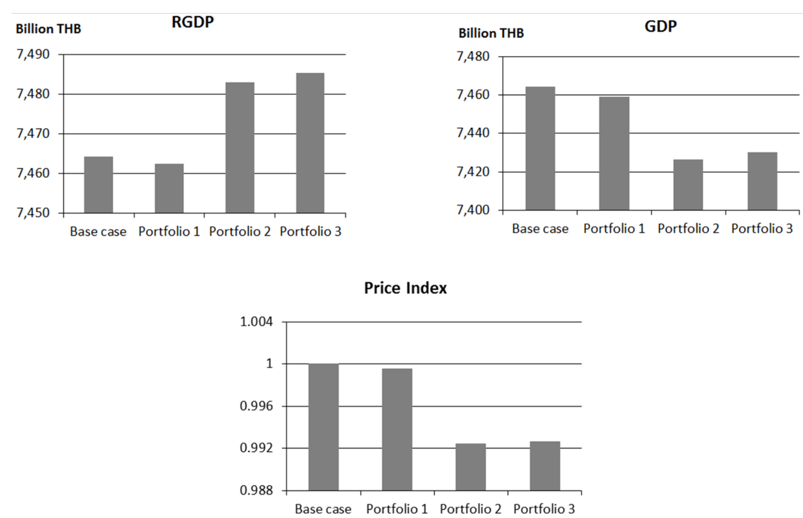


Table 10. Variables' Responses to Three Different Portfolios.

Variable	Base case	Portfolio 1	%change	Portfolio 2	%change	Portfolio 3	%change
Macroeconomics variables							
RGDP	7,464.27	7,462.41	-0.02%	7,483.04	0.25%	7,485.40	0.28%
GDP	7,464.27	7,459.07	-0.07%	7,426.34	-0.51%	7,430.02	-0.46%
Price Index	1	0.999553	-0.04%	0.992423	-0.76%	0.992602	-0.74%
Socioeconomic variables							
Income of the poor	1,523.92	1,522.28	-0.11%	1,512.25	-0.77%	1,513.34	-0.69%
Income of the non-poor	3,914.67	3,912.67	-0.05%	3,900.48	-0.36%	3,901.81	-0.33%
Income distribution	38.93%	38.91%	-0.06%	38.77%	-0.41%	38.79%	-0.37%
Unemployment rate	15.00%	15.43%	2.84%	13.68%	-8.83%	13.27%	-11.55%

Sector	Description	Basecase	Portfolio 1	% change
SEC7	Coal	19.218	19.983	3.978%
SEC6	Ethanol	1.623	1.624	0.054%
SEC40	Cement and Concrete Products	161.104	161.162	0.036%
SEC30	Spinning and Weaving	338.986	339.068	0.024%
SEC22	Metal Ore and Non-Metal Ore	51.367	51.379	0.023%

Sector	Description	Basecase	Portfolio 2	% change
SEC19	Electricity (Non-renew)	585.314	619.159	5.78%
SEC7	Coal	19.218	20.053	4.34%
SEC9	Natural gas (raw)	52.369	54.253	3.60%
SEC18	Natural gas (separated)	101.303	101.980	0.67%
SEC40	Cement and Concrete Products	161.104	161.679	0.36%

Sector	Description	Basecase	Portfolio 3	% change
SEC9	Natural gas (raw)	52.369	56.459	7.81%
SEC19	Electricity (Non-renew)	585.314	623.650	6.55%
SEC7	Coal	19.218	20.284	5.55%
SEC18	Natural gas (separated)	101.303	104.782	3.43%
SEC40	Cement and Concrete Products	161.104	161.655	0.34%

Table 11. Top Five Output Gained Sectors as a Consequence of Portfolio Changed.

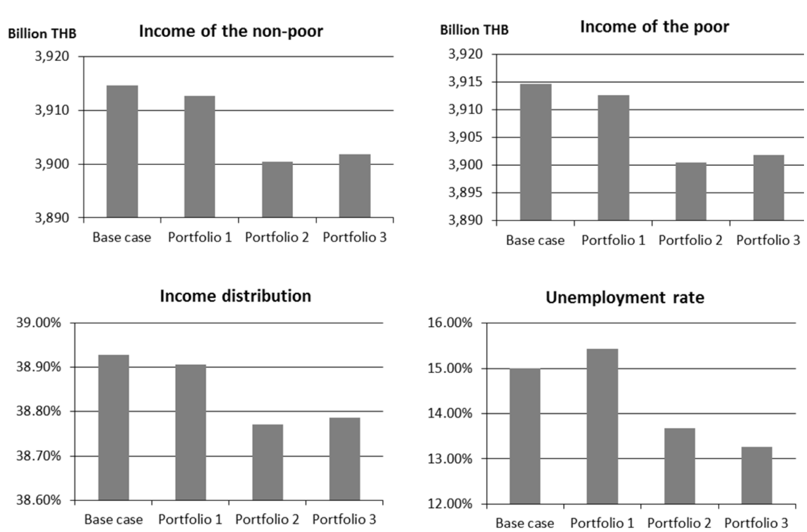
Table 11 presents impacts on the five sectors that would benefit most economically from adopting the three different portfolios. At equilibrium, all sectorial outputs adjust according to various allocations of power fuel feedstock. Overall, the Coal sector is always ranked among top of positive gainers for all scenarios. Therefore, it can be inferred that coal is one of the most significantly substitutable fuels for national power generation. Considering portfolio 1, Hydro power dominated the portfolio. Ethanol gains the second most positive effect, followed by Cement and Concrete Products. In the domestic gas dominated cases, Portfolio 2 and Portfolio 3, four out of the five sectors (Electricity, Raw natural gas, Separated natural gas, and Coal) that rank among the top five gainers are electricity related sectors. The electricity sector's output increases by 5.78% and 6.55% in the cases of Portfolio 2 and 3, respectively. Hence, the simulation outcomes reveal the positive relationship of consuming more domestic gas in power production and electricity sector output.

Regarding socio-economic indicators, Portfolio 3 performs well in terms of reducing the unemployment rate and income distribution. However, in detail it does worsen income of poor and non-poor households. Portfolio 1 has a minimal effect on household income but fails to control the unemployment rate and income distribution. Portfolio 1 and 3 therefore can be regarded as reflecting a trade-off in socio-economic impacts when promoting hydro and domestic gas-base technologies. Although the results shows nominal incomes of households are slightly lower than that of the baseline in all 3 cases, the real incomes of households would be higher due to inflation. The result of changes in household income in all cases thus would hurt the economy less than one expects as presented in Figure 7.

In conclusion, this case provides evidence to support the promotion of hydro and domestic natural gas used in power generation. Although increased Hydro-based energy would reduce emissions, its capacity may not compete with existing gas-based power resources or be able to meet continuously increasing demand in the long run.

The next results show that heavier reliance on domestic gas helps improve macroeconomic conditions as well as particular socio-economic conditions. Even though concern about gas reserve depletion exists, the country has some prospective resources for gas

Figure 7. The Change of Socio-economic Variables Compared to the Baseline under Different Electricity Generation Portfolios.



replacement. On a small scale, biogas from agricultural and farming waste would be another alternative to offset currentusage. On a large scale, according to one industry estimate, a possibility is a raw gas well lain beneath the disputed overlapping area of Thailand and Cambodia which is estimated to have at least six Tera cubic feet of natural gas (U.S. Energy Information Administration, 2013). This could relieve Thailand from gas shortages for at least four years with the current consumption rate of about 4,000 MMSCFD.

Regarding policy makers, this case study has a twofold application. First, it gives a warning to the government authorities for the preparation and acquisition of gas inventory in near future. Second, since domestic gas is expected to be the least expensive among fossil fuel choices, if the government decides to follow either Portfolio 2 or 3, electricity tariff should be revamped. Currently, the structure of electricity tariff in Thailand has two major elements, Base Tariff and Automatic Tariff Adjustment (F_t). Fuel cost is represented in both base tariff and Ft. The estimation of the weighted average of mixed fuels costs is included in the base tariff and it would be readjusted to actual cost at the time of purchase by F_t. Once a higher share of domestic gas is present in the portfolio, the weighted average of cost of mixed fuels should be lower. Further, the improvement of domestic gas price stability would lead to less Ft adjustment. The twin reduction in fuel cost and fluctuation resulting from higher share of domestic natural gas therefore should eventually push the electricity tariff down.

5.2.3 The Case of Rising in Investment and Local Electricity Consumption

The impact of the incoming ASEAN Economic Community (AEC) will certainly promote trade liberalization and investment among Southeast Asian countries and ultimately stimulated ASEAN member countries' economy. Economic growth is always perceived to cause soaring consumption for electricity. This case study aims to investigate the impact of national investment and higher consumption of electricity in three locations, the Bangkok Metropolitan area (DMEA), the Northern part of the Central region (DC1) and the Eastern region (DC2). In Thailand, these locations, which are home to various businesses and manufacturing clusters, are expected to benefit much from the AEC framework.

This third case simulates the effect of increasing in national investment by 2%, 5%, and 7% as well as growing loads in the three above locations to 3 different levels, 10%, 20%, and 30%. The details of estimated increased electricity consumption are shown in Table 12. Increasing power consumption without significant supply improvements definitely encourages system failure. Therefore, it is most important to identify the potential power failure locations. Table 13 presents the simulated result of these blackout locations and amount of resulting deficiencies. The result shows that the outages occur only after the demand exceeds 20%, an increment that corresponds to power reserve margin. By location, the Bangkok Metropolitan area is the most critical, followed by the Eastern region. However, in reality the Eastern region seems to be well prepared in terms of number of power plants and their installed capacities. This region also is regularly monitored since it is an industrial intensive zone

To deal with this increasing consumption, two candidate power plants, South Bangkok and Siam Energy, are considered for upgrades in their capacities. Although many feasible alternatives exist, these two power resources are the most attractive because of their significant power outputs and the shortest distance from the high demand: Metropolitan and eastern area. For further simulation, the capacity of these two power stations is expected to be increased from 1,500 MW to 3,700 MW for the South Bangkok power station and from 1,500 MW to 2,500 MW for Siam Energy power station.

The result of change in electricity generation configuration is presented in Table 14. The result shows that both imported and domestic gases still dominate other fuels in all scenarios. The system responds to a 10% increase in local power consumption with a 17% increase in imported gas-based power while maintaining an almost constant portion of domestic gas-based power. In the case of 20% and 30% increases in local power consumption, the share of domestic natural gas-based power is greater by approximately 8% and 43%, respectively, while the portion of imported natural gas-based power is expanded by roughly 65% and 83%, respectively. Power from domestic coal also presents a significant larger portion. These outcomes ensue because increasing power consumption at the Northern part of the Central region (DC1) can be balanced by a domestic coal power plant via a 500kv power line. The portion of hydro-power remains stable since none of hydro-power resources are near these three locations with increasing consumption. The higher portion of gas is contributed to less imported electricity from neighboring countries. The results show a decline of roughly 4% and 10% in scenario 3.2 and 3.3, respectively.

Table 12. The Increase in Consumption for Local Electricity.

Unit MWh

Demand Node	Peak Load	Intermediate Load	Base Load
DN1	2,601.44	4,758.55	1,629.49
DN2	2,844.64	4,992.03	1,792.51
DN3	3,758.68	6,889.99	2,839.65
DNE1	3,709.91	6,479.45	2,512.51
DNE2	3,286.95	5,022.21	1,972.89
DNE3	4,695.96	8,479.96	3,039.45
DC1	9,857.49	18,879.40	8,415.58
DC2	27,894.38	46,959.86	14,667.07
DC3	10,388.55	19,461.80	5,358.45
DMEA	31,684.51	41,700.00	27,300.00
DS1	4,125.16	7,942.59	3,237.61
DS2	4,473.54	8,096.77	3,420.00
DS3	3,758.68	6,889.99	2,839.65
Total	**113,079.89**	**186,552.60**	**79,024.86**
	Daily Grand Total		**378,657.35**
	Annual Grand Total		**138,588,589.37**

The Basecase

Unit MWh

Demand Node	Peak Load	Intermediate Load	Base Load
DN1	2,601.44	4,758.55	1,629.49
DN2	2,844.64	4,992.03	1,792.51
DN3	3,758.68	6,889.99	2,839.65
DNE1	3,709.91	6,479.45	2,512.51
DNE2	3,286.95	5,022.21	1,972.89
DNE3	4,695.96	8,479.96	3,039.45
DC1	10,843.24	20,767.34	9,257.14
DC2	30,683.82	51,655.84	16,133.78
DC3	10,388.55	19,461.80	5,358.45
DMEA	34,852.96	45,870.00	30,030.00
DS1	4,125.16	7,942.59	3,237.61
DS2	4,473.54	8,096.77	3,420.00
DS3	3,758.68	6,889.99	2,839.65
Total	**120,023.53**	**197,306.52**	**84,063.13**
	Daily Grand Total		**401,393.18**
	Annual Grand Total		**146,909,902.71**

Scenario 3.1 : 10% increasing in local power demand

Unit MWh

Demand Node	Peak Load	Intermediate Load	Base Load
DN1	2,601.44	4,758.55	1,629.49
DN2	2,844.64	4,992.03	1,792.51
DN3	3,758.68	6,889.99	2,839.65
DNE1	3,709.91	6,479.45	2,512.51
DNE2	3,286.95	5,022.21	1,972.89
DNE3	4,695.96	8,479.96	3,039.45
DC1	13,011.89	24,920.81	11,108.57
DC2	36,820.59	61,987.01	19,360.54
DC3	10,388.55	19,461.80	5,358.45
DMEA	41,823.55	55,044.00	36,036.00
DS1	4,125.16	7,942.59	3,237.61
DS2	4,473.54	8,096.77	3,420.00
DS3	3,758.68	6,889.99	2,839.65
Total	**135,299.53**	**220,965.16**	**95,147.31**
	Daily Grand Total		**451,412.00**
	Annual Grand Total		**165,216,792.06**

Scenario 3.2 : 20% increasing in local power demand

Unit MWh

Demand Node	Peak Load	Intermediate Load	Base Load
DN1	2,601.44	4,758.55	1,629.49
DN2	2,844.64	4,992.03	1,792.51
DN3	3,758.68	6,889.99	2,839.65
DNE1	3,709.91	6,479.45	2,512.51
DNE2	3,286.95	5,022.21	1,972.89
DNE3	4,695.96	8,479.96	3,039.45
DC1	16,915.45	32,397.05	14,441.14
DC2	47,866.76	80,583.11	25,168.70
DC3	10,388.55	19,461.80	5,358.45
DMEA	54,370.61	71,557.20	46,846.80
DS1	4,125.16	7,942.59	3,237.61
DS2	4,473.54	8,096.77	3,420.00
DS3	3,758.68	6,889.99	2,839.65
Total	**162,796.34**	**263,550.70**	**115,098.84**
	Daily Grand Total		**541,445.88**
	Annual Grand Total		**198,169,192.89**

Scenario 3.3 : 30% increasing in local power demand

Table 13. The Results of Electricity Shortages as a Result of Increasing in Investment and Local Electricity Consumption.

Location	Power Shortage (MWh/day)		
	Peak load	Intermediate Load	Base load
Scenario 3.1			
None	0	0	0
Scenario 3.2			
DMEA	7,766.99	0	0
DS2	0	0	19.68
Scenario 3.3			
DC2	3,022.95	5,327.48	0
DMEA	20,509.25	9,088.78	1,802.26

Table 14. Electricity Generation Configuration Responses to Increasing Investment and Local Electricity Consumption.

Unit: GWh

Fuel	Base case	Scenario 3.1	%Change	Scenario 3.2	%Change	Scenario 3.3	%Change
Domestic natural gas	74,607	74,330.45	-0.37%	80,745.29	8.23%	106,563.50	42.83%
Imported natural gas	24,888	29,097.00	16.91%	40,992.00	64.71%	45,422.56	82.51%
Domestic coal	18,118	19,477.49	8%	22,211.59	22.60%	23,058.00	27.27%
Imported coal	1,877	2,733.08	46%	1,147.25	-38.86%	3,337.81	77.87%
Hydro	7,205	7,205.43	0.00%	7,205.43	0.00%	7,205.43	0.00%
Oil	6,405	7,028.27	9.73%	7,635.58	19.21%	7,633.31	19.18%
Imported electricity	5,489	7,038.17	28.22%	5,279.65	-3.82%	4,948.58	-9.85%
Total	**138,589**	**146,909.89**		**165,216.79**		**198,169.20**	

The detailed outcomes of fuel cost are displayed in Table 15. Strikingly, the costs of fuel in scenarios 2 and 3 are lower than in the baseline. The breakdown of fuel costs in scenarios 2 and 3 shows that the cost of imported coal drops substantially. This phenomenon occurs owing to an effect of natural gas-based Siam Energy power plant upgrading. As consequence, the generation system shifts from costly imported coal to domestic natural gas.

Electricity consumption and the growth of an economy usually move in tandem. This phenomenon is confirmed by the outcome of this case study. All macroeconomic variables show improvements as a result of higher volumes of electricity demand. The results show that Real GDP (RGDP) grows by 0.15%, 0.37%, and 0.52% when local electricity demand increases by 10%, 20%, and 30% and national investment rises by 2%, 5%, and 7% respectively. However, the levels of prices of goods and services also exhibit an upward trend which is represented in a small inflation of the Price Index (PINDEX). The numerical results for macroeconomics variables are shown in Table 16 and Figure 8.

Table 17 presents impacts on the five sectors that benefit most from policy examined in this case study. The Construction sector always beats other sectors. From the outcomes it can be seen that almost all of the top five sectors are construction and raw material producers.

Unit: Thai Baht/Day

Fuel Type	Fuel Cost			
	Base case	Scenario 3.1	Scenario 3.2	Scenario 3.3
Domestic Gas	227,207,100	234,080,300	244,060,900	323,963,900
Import Gas	48,540,010	56,748,980	79,948,250	88,589,340
Domestic Coal	13,250,870	14,245,380	16,245,040	16,864,080
Imported Coal	91,499,010	0	3,479,389	159,765,100
Hydro	204,716	204,716	204,716	204,716
Oil	3,429,590	3,674,815	4,063,697	4,160,046
Imported Electricity	31,182,660	27,785,660	29,866,130	27,785,660
Total	415,313,956	336,739,851	377,868,122	621,332,842

Table 15. The Fuel Cost Incurred from an Increasing in Investment and Local Electricity Consumption.

Variable	Baseline	Scenario 3.1	%Change	Scenario 3.2	%Change	Scenario 3.3	%Change
Macroeconomics variables							
RGDP	7,464.27	7,475.60	0.15%	7,492.06	0.37%	7,502.82	0.52%
GDP	7,464.27	7,491.88	0.37%	7,532.99	0.92%	7,561.00	1.30%
Price Index	1.00	1.002179	0.22%	1.005463	0.55%	1.007755	0.78%
Socioeconomics variables							
Income of the poor	1,523.92	1,527.93	0.26%	1,533.88	0.65%	1,537.91	0.92%
Income of the non-poor	3,914.67	3,919.53	0.12%	3,926.77	0.31%	3,931.66	0.43%
Income distribution	0.3893	0.3898	0.14%	0.3906	0.34%	0.3912	0.48%
Unemployment rate	15.00%	14.75%	-1.69%	14.38%	-4.13%	14.15%	-5.67%

Table 16. Responses of Macroeconomic and Socio-economic Variables to an Increase in Investment and Local Electricity Consumption.

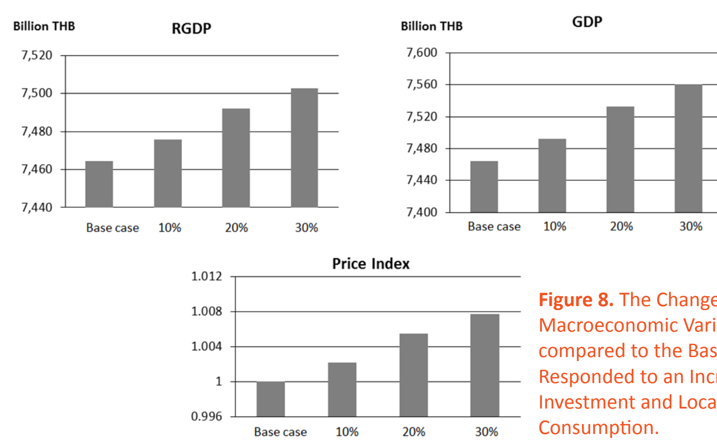


Figure 8. The Change of Macroeconomic Variables compared to the Baseline Responded to an Increasing in Investment and Local Electricity Consumption.

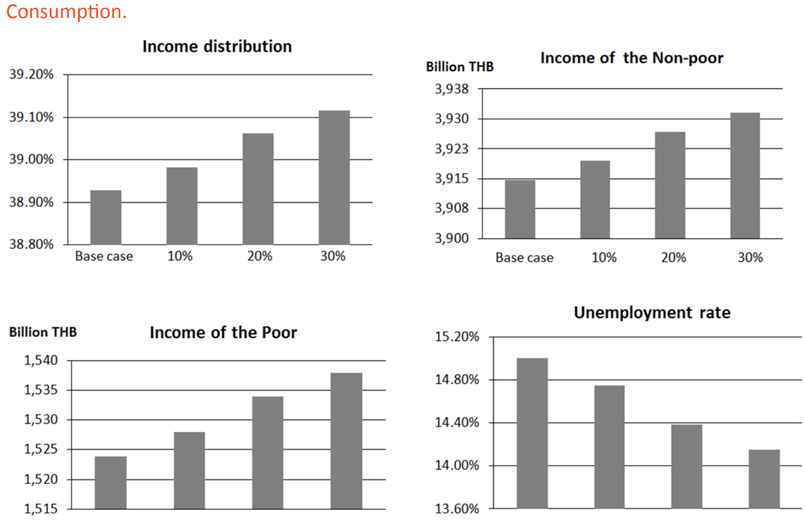
Sector	Description	Basecase	Scenario 3.1	% change	Scenario 3.2	% change	Scenario 3.3	% change
SEC55	Construction	601.567	612.959	1.894%	630.049	4.735%	641.458	6.631%
SEC49	Other Transportation Equipment	80.479	81.523	1.297%	83.085	3.238%	84.124	4.529%
SEC40	Cement and Concrete Products	161.104	163.170	1.283%	166.234	3.185%	168.239	4.429%
SEC22	Metal Ore and Non-Metal Ore	51.367	51.815	0.872%	52.478	2.163%	52.911	3.005%
SEC41	Other Non-metallic Products	121.501	122.489	0.814%	123.967	2.030%	124.949	2.838%

Table 17. The Five Sectors Whose Output Increases Most as a Consequence of an Increase in Investment and Local Electricity Consumption.

Heavier utilization of electricity also brings favorable impact to the socio-economic indicators. Overall, household income is higher than in the baseline as shown in Table 16. A graphical representation of socio-economic variables is shown in Figure 9. With increasing power consumption, income of both poor households and non-poor households increases. The result also reveals that the rate of change of income of the poor households always exceeds that of the rich. As a consequence, the gap of income distribution between the poor and non-poor households is slightly widened. In the labor market, the unemployment rates reduce due to increased business activity. In this case, the interaction of labor and goods markets responded positively. The mechanism basically starts from an investment and an increasing demand for power mostly in the manufacturing clusters. This subsequently attracts new labor force and increases the income of the current workforce.

Regarding policy makers and planners, this case study suggests an alternative way to understand the effects of future increases in power consumption. An alternative of upgrading two power plants, i.e., South Bangkok and Siam Energy power stations, is recommended to meet increasing demand for power in the Bangkok Metropolitan area, the Northern part of the Central region, and the Eastern region.

Figure 9. The Change of Macroeconomic Variables compared to the Baseline Responded to an Increasing in Investment and Local Electricity Consumption.



5. Conclusions

This paper has investigated potential consequences of changes in the structure of the electricity sector of the Thai economy. nstead of employing a Computable General Equilibrium (CGE) model alone, the study has also made use of an extended module of actual electricity generation and transmission. The CGE model and the extended module are integrated by using the approach simply called "Top-down and Bottom-up," which allows the policy makers, planners, and scholars to observe the adjustments of economies and actual power generation simultaneously. For energy economics researchers, this type of hybrid model is one of the premier research tools because it integrates depictions of both real power production at the individual plant level and the wider network of electricity transmission with a depiction of the workings of the macro-economy. At the time of this writing, such a hybrid model had yet to be developed and applied in the case of the Thai economy.

Three counterfactual cases which have high possibilities of occurring have been investigated by simulation and the results of the each simulation have been analyzed. The 3 cases are: (1) The imported natural gas shortage, (2) The different input compositions for electricity generation, and (3) An increase in investment and local demand of electricity. Of these 3 cases, the first case is the most likely to appear in the near term and have the least effect on the economy, while the other two cases would be expected to materialize and adjust over the long run. The sensitivity analyses of different levels of imported gas disruption and rising local power demand have been provided for cases 1 and 3.

For the first case considered, the result reveals that disruption of imported gas causes sudden power outages and has detrimental economic and socio-economic effects. It is estimated that entire depletion of imported gas would lead to a reduction of 17% of total generation and the Bangkok

Metropolitan area would bear the most critical consequences. Imported natural gas storage is not recommended because of its high construction cost. Rather, it is proposed that additional fuel costs be offset by collecting penalty fees from the supplier-Myanmar in the case of failure to deliver contracted natural gas. The result further presents that income distribution and unemployment rate are decline due to power loss.

In the second case, in which alternative portfolios of fuel stocks are considered, the simulation results obtained suggest that increasing the used of hydro power and domestic gas in power production is desirable. Heavier use of hydro power significantly lowers the cost of fuel for power generation. However, the intensive use of hydro power still needs further study because of its potential environmental impacts. On the other hand, the outcome reveals that promotion of domestic gas-based power could stimulate higher Real Gross Domestic Product (RGDP) and dampen inflation (PINDEX). Socio-economic impacts are also favorable as income distribution and unemployment rate are likely to improve due to the upward trend of domestic energy-related activities.

In the last case study, the effects of the increasing local electricity demand due to the AEC's onset are examined. Three intense businesses and industrial locations: (1) Bangkok Metropolitan area (DMEA), (2) Northern part of the central (DC1), and (3) East region (DC2), are selected to be the representatives of country's high growth engine area. The demand of electricity is varied by increments of 10%, 20%, and 30% from the baseline and national investment is increased by 2%, 5%, and 7% to provide the productive capacity to meet anticipated demand for traded goods. Simulation results suggest that, with respect to power generation, domestic and imported gas-based power are the two prime resources that can offset the rising power requirement. In addition, two power plants: South Bangkok and Siam Energy natural gas-based power stations are recommended for upgrade due to their significant capacities and positions in the national network of power generation and distribution. In terms of economic impacts, growth of RGDP is seen to consistently follow increasing electricity consumption. In the scenario with the largest increment of additional power demand, 30%, a 0.5% increase in RGDP is indicated. However, the result reveals the existence of a trade-off in economic and socio-economic indicators since the income distribution and unemployment rate are worse when power demand increases. Therefore, the policy makers should be mindful of this trade-off and examine it further.

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