doi:10.4186/ej.2010.14.3.35

A Study on Fuel Options for Power Generation in Thailand

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ABSTRACT

This study focuses on the impact of utilizing gas, coal and nuclear energy for long-term power generation on generation cost, emission and resource availability. A scenario-based energy accounting model has been applied for creating long-term future scenarios. A baseline scenario has been created on the basis of the existing power development plan (PDP). Three alternative scenarios of coal, nuclear and gas options have been projected for the period beyond the PDP, i.e. 2022-2030. The results indicate that nuclear energy has high potential for GHG mitigation and cost reduction. For the coal option, the benefit of cost reduction would be diminished at carbon prices above 40 USD/ton. However, clean technology development as well as the momentum of global trends will be the key factor for coal utilization. The results also show the need of fuel diversification, in terms of depletion of the natural gas reserves depletion. It is clearly seen that the natural gas supply in Thailand will inevitably depend very much on the LNG imports in the long term. Hence, the attraction of natural gas in terms of cheap domestic resource utilization will vanish.

KEYWORDS

power generation, generation cost, GHG mitigation, scenario

doi:10.4186/ej.2010.14.3.35

I. Introduction

Power generation in Thailand depends greatly on natural gas feedstock. Since the discovery of domestic resources in the Gulf of Thailand in 1970's, the utilization of natural gas quickly became favorable to substitute for the higher-price residual oil, which considerably changed the structure of power production from oil - to gas based generation. Until now, natural gas has accounted for approximately 70 percent of total electricity production as illustrated in Figure 1. However, under the competitive and uncertain environment, it is necessary to diversify energy types and sources to strengthen energy security and contribute to the long-term competitiveness of the country's economics.

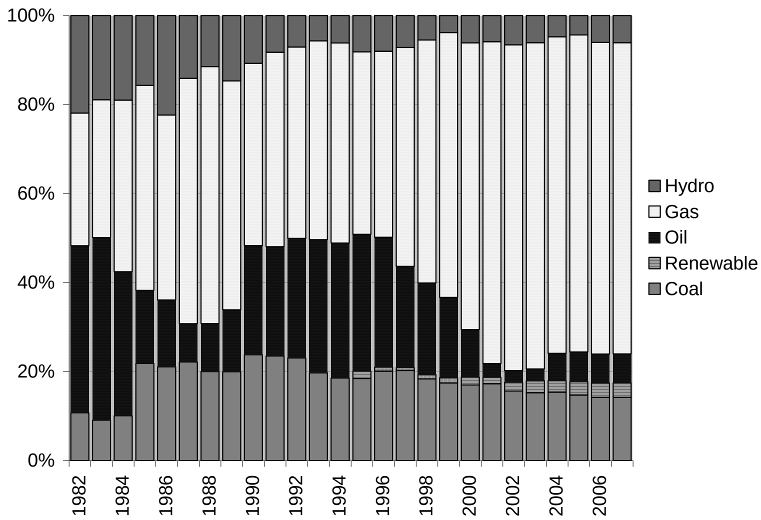

Figure 1
History of fuel mix for power generation in Thailand

Power supply planning in Thailand has relied on the "least cost approach" to evaluate the adequacy and security of the supply. However, the issues of global warming and the depletion of energy resources are currently unavoidable factors to be taken into account for policy decision. For this reason, several attempts have been developed to solve the problem. Santisirisomboon et al. [1] evaluated power generation plans using the least coast method and added the target of CO_2 emission mitigation into the calculation. It was found that nuclear energy has the highest potential for CO_2 mitigation and was considered to be the most effective abatement strategy for CO_2 reduction due to its reverse effect on carbon cost. Charusiri et al. [2] developed the baseline scenario for Thailand power system by scenario approach. A Load forecast and outlook for power generation was evaluated.

The objective of this study is to analyze fuel options for power generation expansion using the scenario-based approach. The consequences of fuel scheme options on the overall generation cost and greenhouse gas emission are comparatively evaluated. In addition, the depletion of domestic natural gas reserves is also considered.

II. Scope and Methodology

In this study, fuel options for power generation are simulated using a scenario-based approach. The impact of major fuel options, e.g. natural gas, coal and nuclear, on the perspectives of the overall generation cost, emission and resource depletion is considered. In this study, the conventional technology commercialized in the current Thailand power industry has been chosen for the simulation.

The energy-accounting model, i.e. LEAP (Long-Range Energy Alternative Planning system) [3] is utilized in this study. It is generally designed for balancing the energy system with an integrated environmental database. For the application of power generation, peak load requirementd can be evaluated directly using the product of electricity demand and the assigned load duration curve. Additional capacity of power generation technology can be calculated based on the merit order with the constraint of planning reserve margins. Primary resource is withdrawal by the required feedstock during the transformation process. Moreover, targets of electricity import and export are also allowed for the target planning of power purchasing in the future. As the result, total generation cost and environmental impact

doi:10.4186/ej.2010.14.3.35

can be calculated from the electricity generation process using each individual technology. The simulation structure has been summarized in Figure 2.

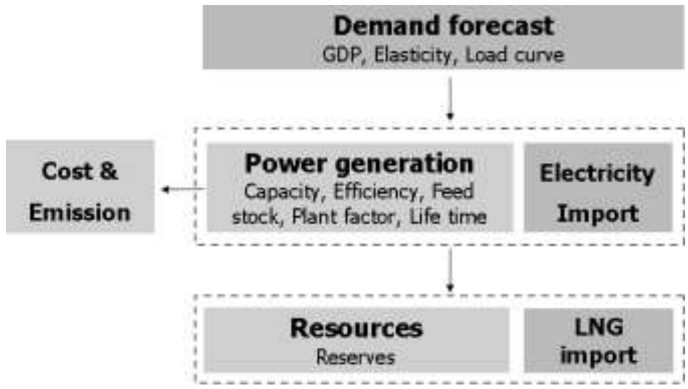

Figure 2
Calculation structure of the model

In this study, the characteristics of the existing power plant technology in Thailand are illustrated in table 1. With the variation of power generation cost, Figure 3 shows the comparison of the current cost assumption to the global range, summarized by the International Energy Agency (IEA) [5].

Table 1
Assumptions of power plant characteristics

Technology	Technical Assumption[a]				Cost Assumption[b]			
	Size	Life time	Efficiency	Capacity Factor	Capital	Fixed O&M	Varied O&M	Fuel Cost[c]
	MW	yr	%	%	M.THB/MW		THB/kwh	THB/MBTU
Hydro power[2]	1000	50	38	45	87.5	0.04	0.13	0
Thermal: Oil-fired[1]	700	30	35	80	38.5	0.17	0.14	335
Thermal: Coal-fired with FGD[1]	700	30	35	90	42.0	0.29	0.17	92
Combined cycle[1]	700	20	45	90	17.5	0.11	0.09	250
Gas turbine[1]	230	20	35	90	9.1	0.01	0.04	250
Nuclear[1]	1000	30	35	90	56.0	0.39	0.28	28
Biomass[2]	80	30	35	50	49.0	1.47	0.25	107
Biogas[3]	10	30	30	50	80.8	1.47	1.20	0
Waste[3]	10	30	30	50	49.0	1.47	0.25	107
Wind[2]	10	20	15	20	56.6	0.82	0.65	0
PV[2]	5	20	15	15	175.0	0.42	0.03	0

Note: a) Technical data: author's estimation
b) Cost data:
1 EGAT (2008)
2 APERC: Renewable Electricity in the APEC Region 2005 (Thailand) [4]
3 Author's estimation
c) Fuel cost data: Author's estimation based on PDP2004

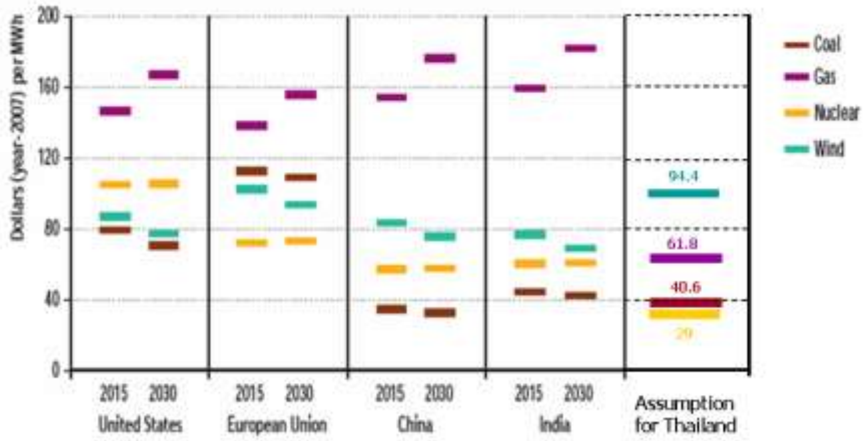

Figure 3
Power generation cost compared to worldwide data [4]

The annual cost of power production can be calculated by the summation of annualized capital cost, O&M and fuel cost, as described above, with 5% interest rate. Global warming potential (GWP) is calculated directly from the integrated environmental database, which relies on emission factor recommended by the IPCC [6].

Accuracy of the utilized simulation scheme has been verified by comparing the calculated reserve margin with the actual data (2003 – 2008) and the official PDP revision 2 (2009 – 2021) under the identical load forecast and exogenous installed capacity of power plants, as illustrated in Figure 4. It is shown that the current scheme can capture the variation of reserve margin within a margin of 5%. The deviation can be presumed by the averaged properties of power production by generation type.

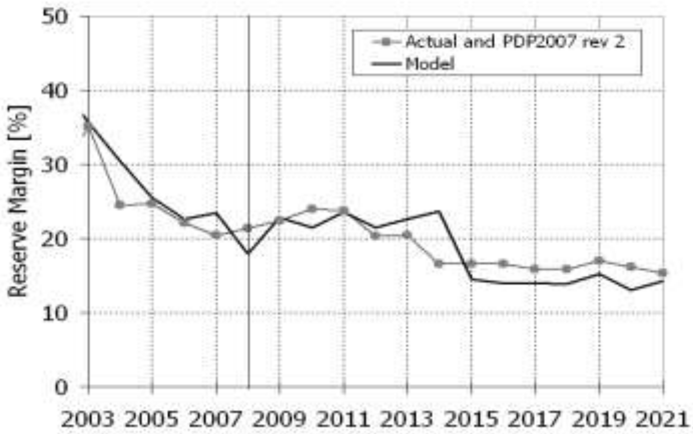

Figure 4
Verification of the model compared to the actual data and PDP 2007 revision 2

III. Scenario

3.1 The BASE scenario

The BASE scenario relies on the target-based future prospect. Ambitious macro-economic growth causes a rise in electricity demand in the long-run. The needs of diversification on the supply side lead to a lower share of natural gas. The Coal and nuclear options are the considered to be the major alternative fuels in the plan.

In this case, the peak power requirement relies on the recent official load forecast, which is the responsiblity of the Thailand Load Forecast Subcommittee. The key assumptions of economic growth and overall energy elasticity for the moderate case are illustrated in Table 2. Beyond the planning period of 2022 to 2030, it is assumed that the driver of electricity demand remains unchanged from the year 2021.

Years	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Growth of GDP	2	3	4.5	5.3	5.5	5.5	5.8	5.8	5.7	5.6	5.5	5.5	5.5
Elasticcity	1.11	1.14	1.03	1.12	1.12	1.10	1.09	1.06	1.05	1.04	1.02	1.01	0.98

Table 2
Assumption of economic growth and efficiency for BASE scenario

Capacity expansion of the Base Scenario is referred to in the existing power development plan (PDP2007 revision 2) [7], of which the increase of base-load capacity is mainly from natural gas combined cycle, coal-fired, and nuclear power plant, expected to be commissioned in 2020. Biomass and other renewable energy are also included in term of the intermediated and peak load under the mechanism of SPP and VSPP schemes. In this case, only firm contracts have been taken into the

doi:10.4186/ej.2010.14.3.35

account. After 2021, it is assumed that all of the fuel options for base load capacity will be dispatched by its merit order and specific commercialized capacity to restrain 15 percent of reserve margin, which is similar to the designated level in PDP. In this case, renewable energy capacity is assumed to be constant and power imported capacity is kept at the same level of 10 percent of total supply. The resulting feedstock requirement for the BASE scenario is illustrated in Figure 5 (a). In this case, natural gas will still be the major part for power generation, with lower market share compared to the year of 2008 by the expansion of coal and nuclear power plant.

3.2 The COAL scenario

In this scenario, it is assumed that the coal option becomes favorable to reduce the portion of natural gas utilization in power generation in long-term. Only coal-fired power plants will be installed for the incremental capacity of base load requirement after the year of 2021. All of the installed capacity and imported capacity during the PDP2007 period remain identical to the BASE scenario. The resulting feedstock requirement is illustrated in Figure 5 (b). In this case, coal will dominate Thailand power industry at 67 percent in the year of 2030.

3.3 The NUCLEAR scenario

Similar to the COAL scenario, the incremental based load requirement after the year of 2021 will be fulfilled with thermal nuclear power plants for the NUCLEAR scenario. All of the other supply options remain unchanged from the BASE scenario. The required feedstock is illustrated in Figure 5 (c). In this case, nuclear energy will dominate Thailand power industry at 58 percent in the year of 2030. However, this would be definitely based on the condition that the nuclear option must be approved for starting commissioning within 2020 and ready for large expansion in the long-run.

3.4 The GAS scenario

In this scenario, coal and nuclear options encounter barriers for expansion. Renewable energy and other options could not be introduced to the market as expected. Therefore, the conventional combined cycle gas turbine (CCGT) will cover the entire incremental base load requirement after 2021. It is based on the assumption that natural gas will have much more influence on the power market compared to the BASE scenario. It will account for 67 percent of total feedstock in the year of 2030, as illustrated in Figure 5 (d).

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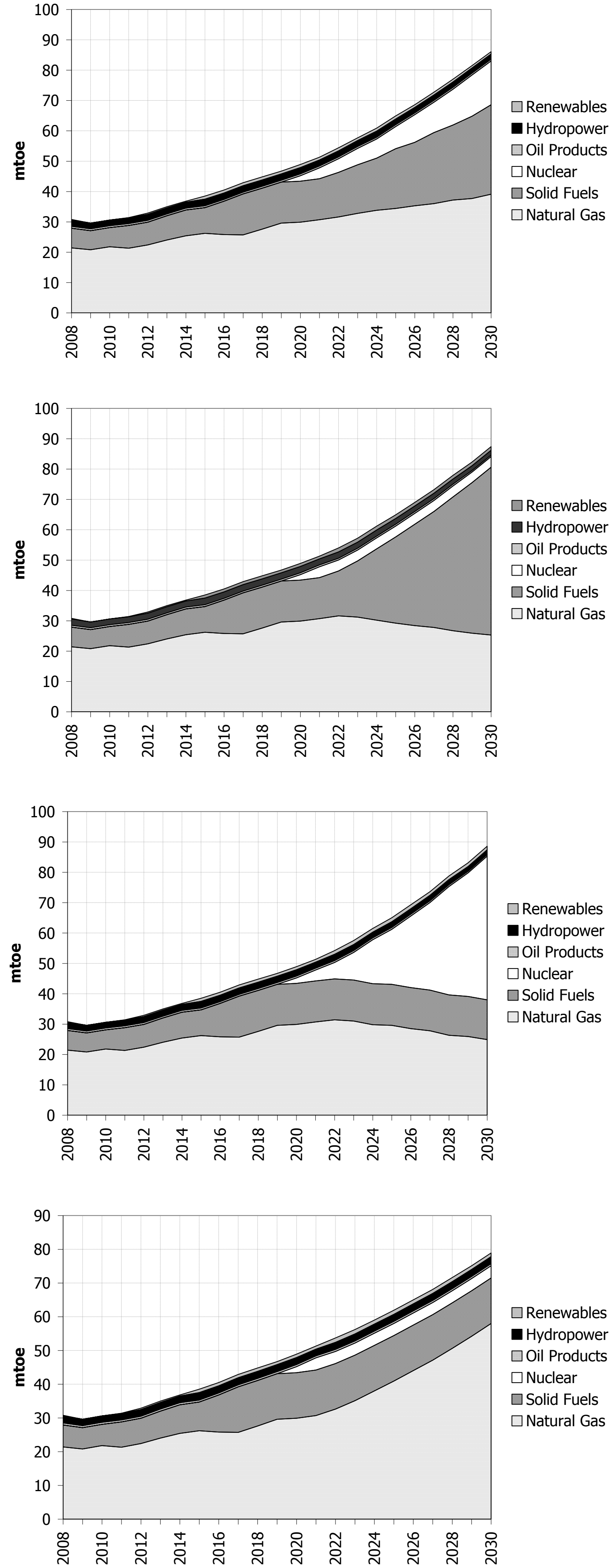

Figure 5
Mixtures of feedstock fuels for power generation

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IV. Results

4.1 Cost and emissions

Total generation cost and global warming potential (GWP) per unit power production in all cases are comparatively illustrated in Figure 6 and Figure 7 respectively. It is clearly seen that the NUCLEAR scenario can reduce overall production cost per unit power production by 24.6 percent and significantly decrease the GWP per unit power production by 46.8 percent compared to the BASE scenario. However, the needs of huge investment and long-term preparation for starting the operation are the major barriers to promote the nuclear option in short-term. The COAL scenario can reduce the overall cost by 4.5 percent, while the GWP increases by 32.6 percent in 2030 compared to the BASE scenario. In contrast to the others, the GAS scenario will continue to risie the cost per unit production in 2030 by 9.5 percent compared to the BASE scenario, and increasing by 4.8 percent compared to the cost at the end of PDP (year of 2021). The GWP of the GAS scenario is slightly lower than the BASE scenario by 8.7 percent. As the results, it can be seen that only the nuclear option has positive effect on both cost and emission aspect at the same time, while coal and gas have only one positive effect.

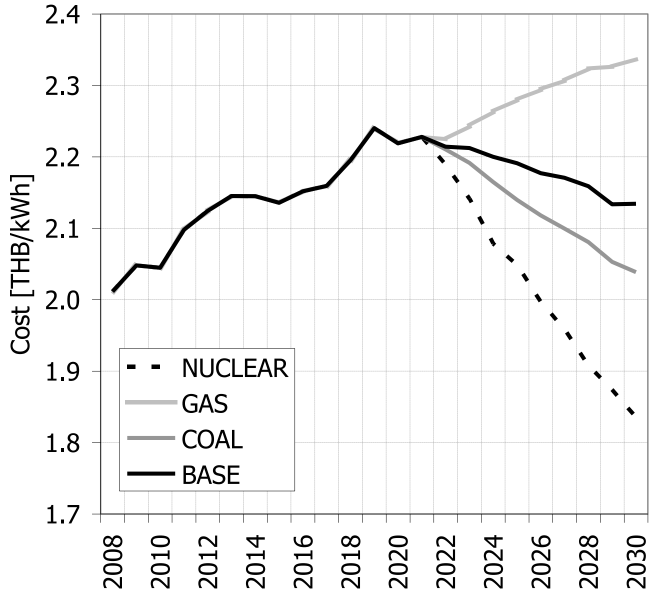

Figure 6
Cost per unit production

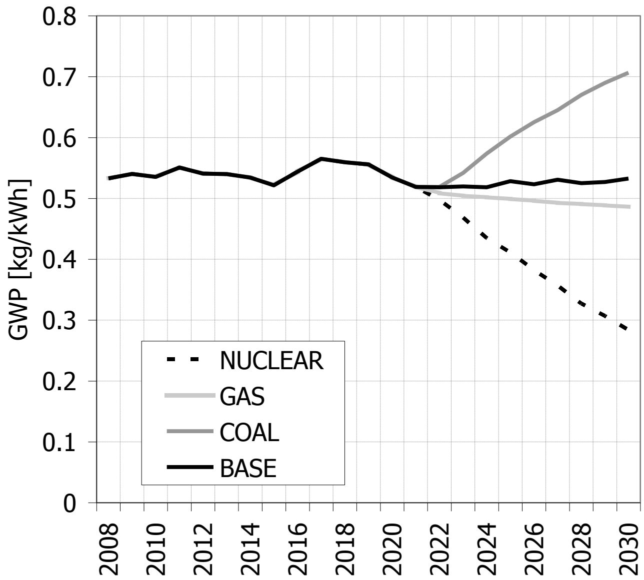

Figure 7
Global warming potential (CO2 equivalent) per unit production

With the hypothesis of a progressive development of carbon trading schemes, the total cost will be inevitably influenced by carbon price uncertainty in the future. Sensitivity of generation cost plus emission cost in term of carbon price has been illustrated in Figure 8. The result shows that total cost of the natural gas option will have slightly negative effect on the rising of carbon price, while the nuclear options will become much more cost competitive. It must be noticed that this result would be practical if nuclear power generations are allowed for carbon trading. In contrast, the coal option will suffer a higher cost and become economically unviable at the carbon price of 16 USD/ton compared to the BASE scenario, and at 40 USD/ton compared to the GAS scenario. Based on global warming concerns, the development of advanced clean coal and CCS technology would technically become an important factor to relieve the impact of carbon cost on the economic of coal-fired power. However, it is widely understood that coal option is currently the main feedstock fuel for power generation in the global scale. It accounts for 40 percent of the total feedstock utilization. The Reference scenario of the World Energy Outlook [4] also indicated that the share of coal utilization has a tendency to increase more in the global power market, particularly in developing countries [3]. Hence, coal-based power plants still have high potential in terms of clean technology development, and is still one of the fuel options for Thailand power industry.

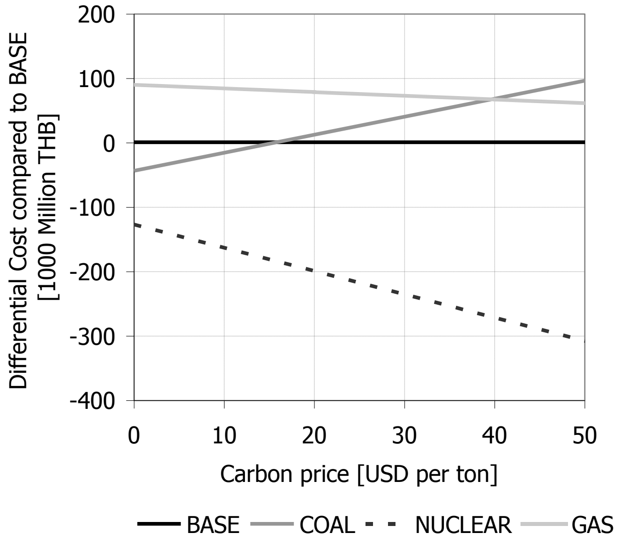

Figure 8
Sensitivity of carbon price on the differential generation cost

4.2 Resources

The discovery of domestic natural gas reserves in the 1970’s was considered to be the major factor in the increase of natural gas’ share if the Thai power industry. In terms of natural gas utilization in Thailand, the power sector consumes approximately 70 percent of the total supply, followed by industrial and transportation respectively. Almost 30 percent of the total supply has to be imported by pipeline connection from Myanmar. In long-term prospect, natural gas will be continuously consumed, particularly for power generation according to the PDP. The results from this study, show that natural gas domestic reserve at the end of PDP will be depleted by 70.2 percent compared to the probable reserve level (P2) as of 2008 [8]. The result is based on the assumption that the depletion of natural gas reserves is caused only by power generation. The incremental demands of natural gas in industrial and transportation remain at the level of 2008.

After 2021, the depletion rate of natural gas reserves in all cases has been simulated as illustrated in Figure 8. The results show that domestic reserve will be possibly depleted in the year 2026-2027 in all cases. Although the COAL and NUCLEAR scenarios will be able to slow down the rate of depletion, the depletion will still occur very soon. This means that in the long-run, the country would face the unsatisfied natural gas resource shortage. This results is based on the assumption that there is no new domestic exploration within the period of calculation.

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In order to diversify supply sources and to slow down the depletion rate of domestic reserve, imported LNG could be one of the key options. Sensitivity of LNG import levels on the depletion of natural gas reserve is illustrated in Figure 9. It is assumed that LNG imports will be start in 2012 [9]. The results show that increasing of LNG imports can slow down the depletion rate, and postpone the shortage period by approximately 10 years by increasing LNG imports up to 23 tonnes per year.

Figure 8
Depletion of domestic natural gas reserve

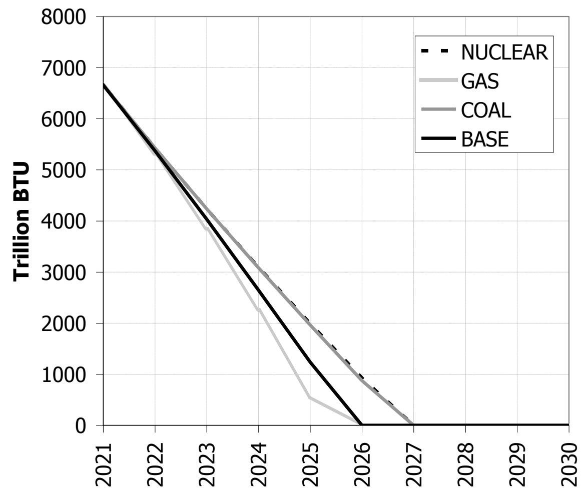
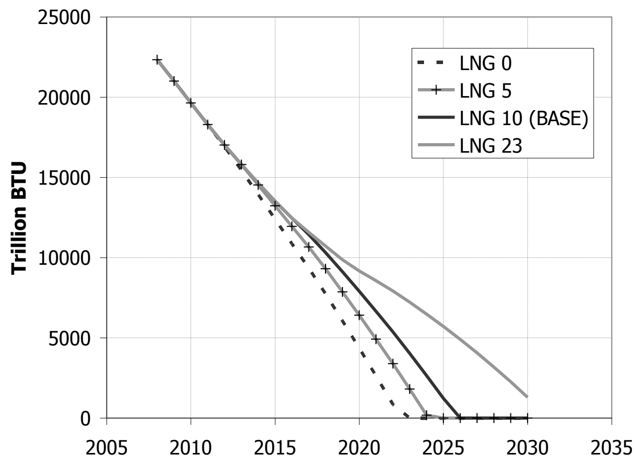


Figure 9
Sensitivity of LNG import on natural gas reserve



V. Conclusions

In this study, the consequences of utilizing gas, coal and nuclear for the main feedstock of long-term power generation on the generation cost, emission and resources have been investigated. The results show that nuclear energy has high potential for GHG mitigation and cost reduction. For the coal scenario, the benefit of cost reduction would be diminished at carbon prices above 40 USD/ton. However, clean technology development as well as the momentum of global trends will be jey drivers to support the coal option. The results also show the need of fuel diversification in terms of the natural gas reserve depletion. It is clearly seen that natural gas supply in Thailand would inevitably depend very much on the LNG imports in the long term. Hence, attraction of natural gas in term of domestic resource utilization will vanish.

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REFERENCES

[1] J. M. Santisirisomboon, B. Limmeechokchai, and S. Chungpaibulpatana, "Least cost electricity generation options based on environmental impact abatement," *Environmental science and policy*, vol. 6, no. 6, pp. 533-541, 2003.

[2] W. Charusiri, B. Eua-arporn, and J. Ubonwat, "Application of long range energy alternative planning (LEAP) model for Thailand energy outlook 2030: Reference case," *Power and Energy Systems (AsiaPES 2008)*, Langkawi, Malaysia, April 2-4, 2008.

[3] LEAP User Guide, *Stockholm Environment Institute (SEI)*. [Online]. Available: http://www.energycommuity.org.

[4] World Energy Outlook 2008, *International Energy Agency (IEA), OECD/IEA Publication*. [Online]. Available: http://www.iea.org.

[5] Renewable Electricity in the APEC Region 2005, *Asia Pacific Energy Research Center (APERC).* [Online]. Available: http://www.ieej.or.jp/aperc/

[6] Intergovernmental Panel on Climate Change, (1996). [Online]. Available: http://www. Ipcc.ch/

[7] Power Development Plan 2007 revision 2 (2009-2021), *Electricity Generation Authority of Thailand (EGAT)*. [Online]. Available: http://www.egat.co.th.

[8] Fact sheet (2009, August), *Department of Mineral Fuel (DMF)*. [Online]. Available: http://www.dmf.go.th.

[9] Natural gas supply master plan (2009-2021), PTT Public Company Limited. [Online]. Available: http://www.pttep.com