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Article

Scenarios on Power Generation in Thailand: Uncertainty of Nuclear and Coal Options

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Abstract. The objective of this study is to explore the possible scenarios under the constraint of nuclear and coal-fired power development. In addition, the consequence on the overall cost, greenhouse gas and diversification index of Thailand power generation system is also investigated. The reference scenario has been created on the basis of the power development plan (PDP2010). Three alternative scenarios with the repeal of nuclear power plant (NPP), coal-fired power and their combination have been comparatively simulated. The results show that the overall cost for the worst case without NPP and coal-fired power will increase significantly the overall cost up to 33.8 percent in 2030 compared to the reference scenario. It is caused by the replacement with higher price technology of natural gas combine cycle together with the higher fuel price due to the LNG import. In addition, diversification index will be double in this case. In term of the environmental concern, the GHG emission will possibly increase by 25.1 percent for the case of coal replacing NPP.

Keywords: Energy scenario, power generation, public acceptance, generation cost.

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1. Introduction

Fuel mixes of power generation in Thailand depends mainly on natural gas, accounted for 70 percent of total input requirement. The rest are consisting of coal-fired power, hydro power and other renewable energy. Large portion of natural gas can be explained by the availability of domestic natural gas reserve in the Thai gulf as well as its competitive generation cost. The official Power Development Plan (PDP2010), released on April 2010, has been announced to prepare and secure the capacity of power supply in the future. Majority of this plan is to diversify the large portion of natural gas by using more alternative fuels e.g. renewable energy (RE), coal-fire power and the first commissioning of nuclear power plant (NPP).

The incident of NPP accident at Fukushima has a great impact on the perception of nuclear power in the region, particularly the issue of nuclear safety. Potential of economic growth and public acceptance would be the key driving force to drive the decision of the policy maker for nuclear policy. China and Vietnam will still kept their nuclear power projects on tracking, while some counties including Thailand are still in the decision phase and has possibility to postpone the project for a while. In the mean time, public acceptance becomes the critical barrier for the development of power plant capacity in Thailand from time to time. The direct survey of key stakeholders shows that NPP and coal-fired power are the most unfavorable options, while energy efficiency and renewable energy are the promising solution [1]. According to the recent official plan [2], ambitious target of RE has been set to achieve the installed capacity of 6066 MW within 2030, compared to the capacity of 754 MW in 2009. Furthermore, the RE for power generation can be treated as an intermittent resource and expects to serve the partial load for local distribution. Thus, uncertainty of NPP and coal would definitely shape the future fuel mix of power generation in the long-run.

The previous results indicated that nuclear and coal options are able to reduce significantly the overall generation cost of the system. Benefit of cost reduction for coal-fired power would be diminished at carbon price above 40 USD/ton [3]. Penetration of renewable would affect to the grid reliability under the current power system, and should not be considered as a single dependable option for the GHG mitigation target in power sector [4], [5]. Most of results are relied on the economic perspective before global financial crisis in 2009, and the recent Japanese NPP accident in 2011. The objective of this study is to explore the possible scenarios under the constraint of public acceptance after the major change of economic condition in 2009 and NPP accident in 2011. In addition, the consequence on the overall cost, greenhouse gas emission (GHG) and diversification index of Thailand power generation system is also investigated.

2. Methodology

The energy-accounting model, i.e. LEAP (Long-Range Energy Alternative Planning system) [6] 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 requirement can be evaluated directly by 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 margin. 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 results total generation cost and environmental impact can be calculated from the electricity generation process by individual technology. The simulation structure has been summarized in Fig. 1.

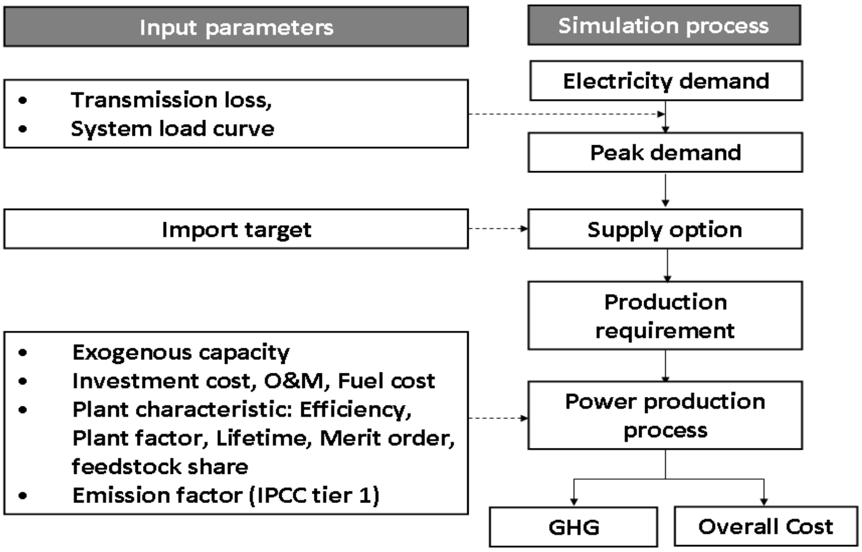


Fig. 1. Calculation scheme for power production process.

In this study, the characteristics of the existing power plant technology in Thailand are illustrated in Table 1. Annual cost of power production can be calculated by summation of annualized capital cost, O&M and fuel cost as described above with 5% interest rate. Practically, cost of power generation for each technology can be varied depending on various factors, e.g. cost of land, source of supplier and etc. Cost assumption for this study is relied on the present averaged figure for each technology and does not take the factors of cost reduction due to future technology improvement into the account.

Table 1. Characteristics of power plant classified by fuel type.

Technology	Technical Assumption				Cost Assumption			
	Size	Life time	Efficiency	Capacity Factor	Capital	Fixed O&M	Varied O&M	Fuel Cost
	MW	year	%	%	M.THB/MW		THB/kwh	THB/MBTU
Hydro power	1000	50	38	45	87.5	0.04	0.13	0
Thermal: Oil-fired	700	30	35	80	38.5	0.17	0.14	335
Thermal: Coal-fired with FGD	700	30	35	90	42.0	0.29	0.17	92
Combined cycle	700	25	45	90	17.5	0.11	0.09	250
Gas turbine	230	20	35	90	9.1	0.02	0.04	250
Nuclear	1000	30	35	90	56.0	0.39	0.28	28
Biomass	80	30	35	50	49.0	1.47	0.25	107
Biogas	10	30	30	50	80.8	1.47	1.20	0
Waste	10	30	30	50	49.0	1.47	0.25	107
Wind	10	20	15	20	56.6	0.82	0.65	0
PV	5	20	15	15	175.0	0.42	0.03	0

Remarks: *1. Cost and technical assumption are based on author's estimation adapted from [7].*
2. Exchange rate at 30 THB for 1 USD.

To calculate GHG emission, energy requirement for each technology is evaluated according to the electricity production process. Input parameters such as installed capacity, conversion efficiency, plant factor and dispatch order are taken into the account in order to evaluate energy requirement for power production by technology. Reserve margin of 15 percent is adopted to maintain electricity production for each scenario at the same level. Then, GHG emission can be calculated directly by product of energy requirement and emission factor individually by each technology. Methodology and emission factors database are relied on the IPCC Guidelines for National Greenhouse Gas Inventories [8].

3. Scenario

3.1. Reference Scenario (REF)

The reference scenario represents the future prospect with the achievement of the plan. Demand forecast and supply options are based on the latest official load forecast and power development plan (PDP2010). It is assumed that the growth rate of gross domestic production is approximately 4.2 percent annually. Capacity expansion and supply option are referred to the recent power development plan (PDP2010), of which the increase of base-load capacity is mainly from natural gas combined cycle, coal-fired, and nuclear power plant, expected to commissioning in 2020. The target of 6000 MW of renewable energy capacity in 2030 has been set to build up the market with their full potential under the current prospective. Biomass will take the majority among renewable energy due to their competitive cost. However, the limited potential of agricultural residual will be the major constraint. Solar and wind energy are treated as intermittent resources and aim to reduce partial load of local distribution.

3.2. No Nuclear Scenario with Minimized Cost (NN-LC)

This scenario represents negative perspective of public acceptance on NPP. Barriers of the NPP commissioning are built up from time to time, such as difficulty of commissioning site development, delay of nuclear development program and etc. In order to slow down the electricity tariff due to the repeal of NPP, coal-fired power will be selected replacing the missing 5,000 MW of NPP installed capacities. Renewable energy deployment can be implemented on target similar to the REF scenario.

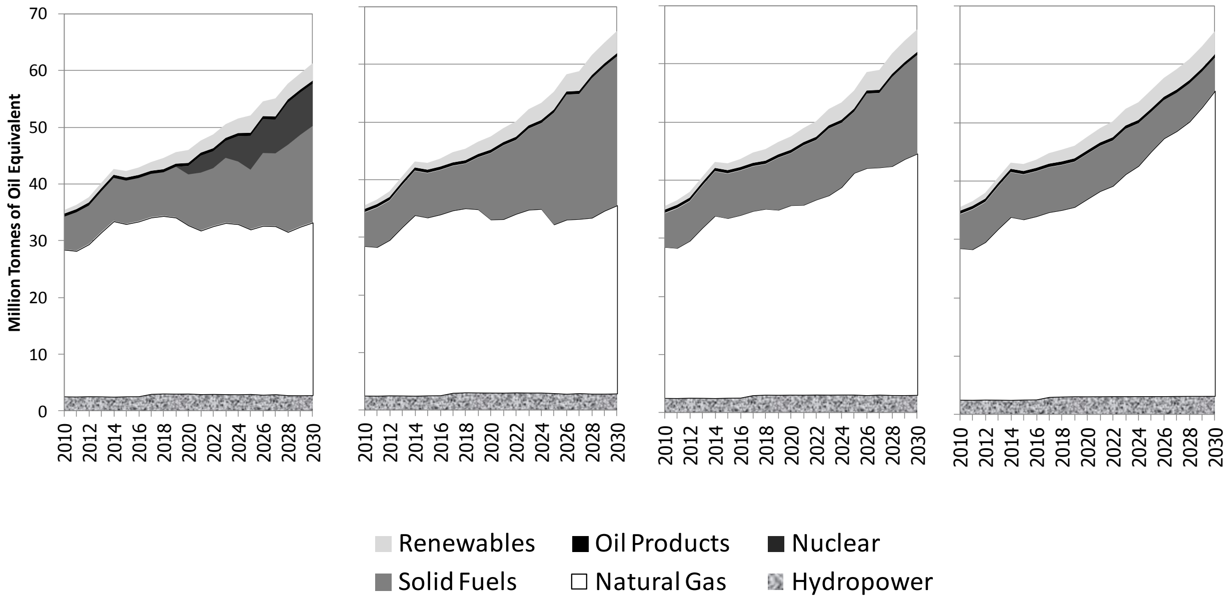
3.3. No Nuclear Scenario with Gas Replacement (NN-Gas)

This scenario also represents negative perspective of public acceptance on NPP. In contrast to the NN-LC scenario, climate change and environmental impact becomes the more concern instead of cost reduction. In this case, renewable energy deployment can be implemented on target with their full potential similar to the REF scenario. Thus, the multiple units of 700 MW natural gas combine cycle are selected to replace the missing NPP capacity in order to minimize the emitted greenhouse gases level, while coal-fired powers are still kept going on target of the plan to reduce the dependency of natural gas.

3.4. No Nuclear and No Coal Scenario (NN-NC)

This scenario represents the negative perception on both NPP and coal-fired power generation. Beside the difficulty of NPP development, coal-fire power also becomes unacceptable option due to its environment impact. Clean coal technology cannot be competitive with the current conventional technology. Therefore, natural gas combined cycle is the only option allowed to serve the rising of electricity demand, and recover the missing capacity of NPP and new coal-fired power plant.

Assumption of fuel mix for each scenario is illustrated in Fig. 2.



(a) REF (b) NN-LC (c) NN-Gas (d) NN-NC

Fig. 2. Scenario of fuel mix for power generation.

4. Results and Discussions

Comparison of overall cost and greenhouse gases emission for each scenario are illustrated in Fig. 3 and Fig. 4 respectively. The result indicated that the overall cost per unit production for the case without nuclear and coal-fired power in the same time (NN-NC) is much higher than the REF case by 16.3 percent in 2030. The replacement of nuclear by natural gas (NN-Gas) and coal (NN-LC) will rising the overall cost by 6.8 and 2.0 percent respectively. In term of the GHG emission, the case of NN-LC become the worst case. The GHG emission for NN-LC case is increasing continuously, higher than the REF case by 25.1 percent, following by the NN-Gas case (14.6 percent) and the NN-NC case (10.3 percent). It can be clearly seen that the uncertainty of nuclear and coal-fired power construction will affect significantly to the overall cost and GHG emission of Thailand power generation system. It must be noted that the maximum range of GHG emission variation between each scenario (25.1 percent) is much higher than the maximum range of cost per unit (16.3 percent). It can be implied that the GHG emission is more sensitive to the national policy on fuel mix than the overall cost.

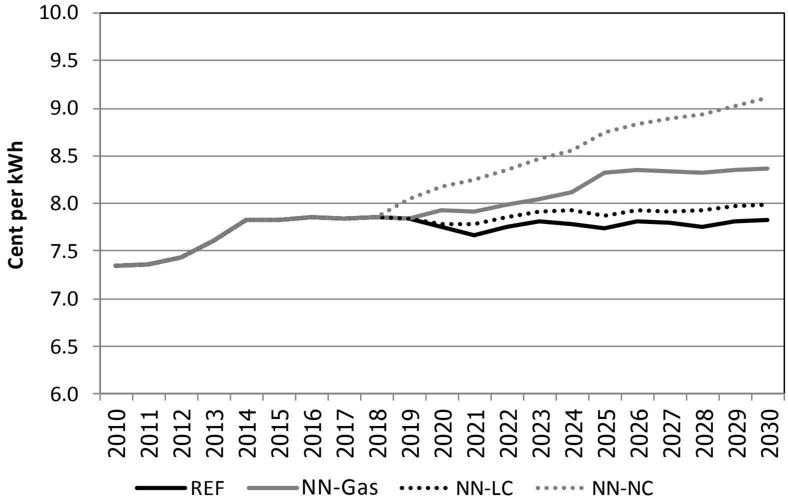


Fig. 3. Overall cost for power generation (exchange rate at 30 THB for 1 USD).

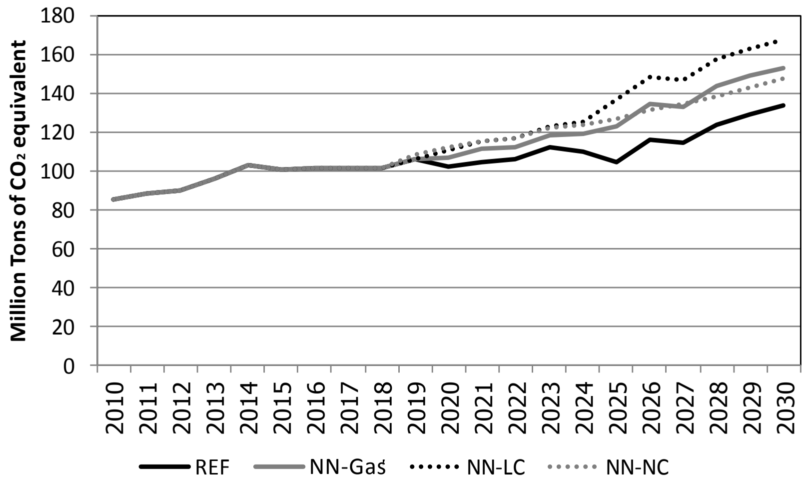


Fig. 4. Energy-related GHG for power generation.

One of the major concern for Thailand power development plan is to diversify the input fuel types and sources in order to reduce the dependency of natural gas and minimize risk of fuel shortage. The diversification index in this study can be represented in term of normalized Herfindahl (*H**), which is defined by Eq. (1) and (2) as follows

$$H^* = \left(\frac{H-1/N}{1-1/N}\right) \tag{1}$$

$$H = \sum_i^N S_i^2 \tag{2}$$

where H^* = Normalized Herfindahl index; H = Herfindahl index; N = Number of feedstock fuel type for power generation; S_i = Portion of fuel type.

Comparison of diversification index represented by the normalized Herfindahl index (H^*) is illustrated in Fig. 5. The result shows that Thailand will be able to maintain the dependency of natural gas in power sector, and kept it at lower level compared to the current status except for the case that nuclear and coal-fired power cannot be implemented at the same time (NN-NC). In this case, the index will be rising from 0.52 in 2010 to the level of 0.61 in 2030.

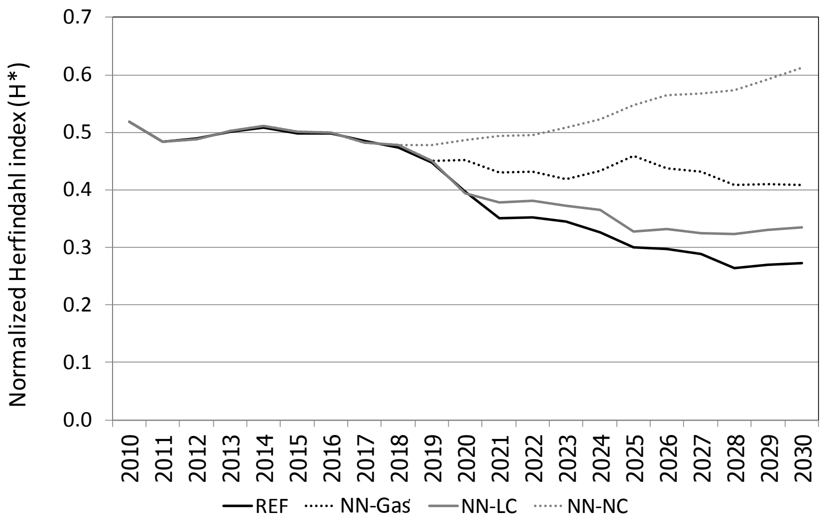
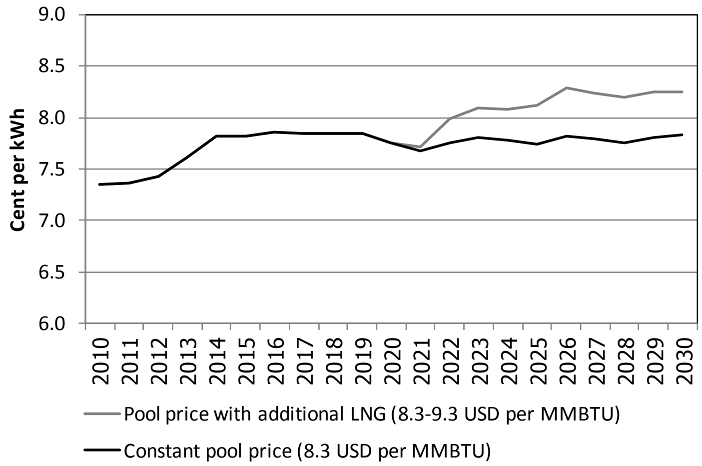
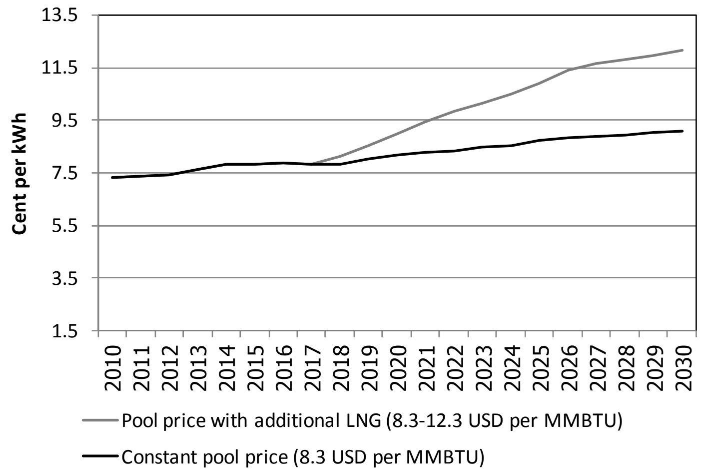


Fig. 5. Diversification index (normalized Herfindahl index, H^*).

Fuel price volatility becomes one of the major concerns for power generation cost especially natural gas combined cycle and gas-fired power plant. In the mean time, Thailand was starting to import the costly LNG since 2011, and plan to increase the import capacity continuously. Thus, an impact of LNG import on the overall cost is also investigated. Based on the current gas price structure, the incoming LNG import will be added into the component of the current pool price. Requirement of LNG for each scenario is relied on the incremental demand of natural gas compared to the REF case. Under the LNG price forecast [9], the result of incremental cost due to LNG import is illustrated in Fig. 6. Averaged pool price of natural gas with additional LNG for the NN-NC case (12.3 USD per MMBTU) is much higher than the REF case (9.3 USD per MMBTU) due to the higher portion of LNG import requirement. The result shows that the overall cost of the REF case with consideration of LNG price movement will increase by 5.3 percent, compared with the case of constant pool price. The impact will be getting worst for the case without nuclear and coal at the same time (NN-LC case). In this case, additional cost for the rising of gas price due to LNG is approximately 33.8 percent.



(a) Reference scenario



(b) NN-NC scenario

Fig. 6. Impact of LNG import on the overall generation cost (exchange rate at 30 THB for 1 USD).

5. Conclusion

The objective of this study is to explore the possible scenarios when nuclear and coal options are impossible for Thailand power generation. Without NPP and coal-fired power plant (NN-NC scenario), the overall for power generation will be increased up to 16.3 percent in 2030. It is caused by the replacement with higher price option of natural gas. Combined with the import target of LNG, the overall cost can be rising up to 33.8 percent in 2030, compared to the REF scenario. In the mean time, diversification index will be double in this scenario. The worst case on environmental perspective can be observed by the case of no nuclear with low cost scenario (NN-LC). In this case, GHG emission will increase by 25.1 percent, while the overall cost will be close to the level on REF scenario. It can be seen that national policy on fuel mix of power generation can affect significantly to the energy cost of power production and GHG emission. Balance of economic and environmental perspectives should be taken into the account for policy maker.

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