# Investment Incentives in the Korean Electricity Market

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**Abstract**

*This paper develops a model-based analysis of the effects of various capacity incentive systems on new investment in the Korean electricity market. The restructuring process in Korea allocated power generation to six firms, competing within a wholesale market, albeit strictly on a cost basis. Because of this cost-based pool, capacity payments were also introduced to encourage new investment. However, it is an open question whether the current fixed capacity payment scheme is enough to secure resource adequacy and consideration is being given to alternative mechanisms such as the use of LOLP. Using a detailed market simulation model, based on system dynamics, we compare these approaches in terms of how they may influence the investors' decisions and thereby determine the system reserve margin. The simulation results suggest that there may be serious problems is staying with the current fixed capacity payments in order to achieve resource adequacy. In contrast an LOLP based capacity mechanism may, in the longer term, increase the reserve margin compared to a fixed capacity payment. More generally, this paper indicates how crucial the effective modeling of the investment behavior of the independent power producers is for adequate policy support, even if they only constitute a fringe in a substantially centrally influenced market.*

Keywords: System dynamics; Electricity; Investment

## 1. Introduction

The government of South Korea has designed a cautiously staged progression towards full restructuring of its electricity sector, which it intends, ultimately, to culminate in full wholesale and retail competition. The nation is currently in an early stage of this process, where generation facilities have been allocated to six firms, who compete in a wholesale market, albeit strictly on a cost basis. However, the separation of distribution from the national utility, KEPCO, was halted after the California market crisis. To meet the growth in energy demand, resource adequacy continues to be a very fundamental and crucial political concern. Without firm central planning, there is no obligation on the generating companies to collectively maintain an adequate reserve margin, and so, whilst the government does produce a basic plan, this is only indicative based upon the reasonable, survey-based, inclinations of the firms to invest, together with some central estimates. New capacity investments in the 3$^{rd}$ long term basic plan (2006) are displayed in Table 1, for the six main generating companies, plus independent power producers (IPPs). Although this indicative plan does provide some coercive pressure on the six main generating companies to the extent that they are subsidiaries of KEPCO, their autonomous requirements to achieve profitability means that they will still evaluate each investment on its merits at the time. Furthermore, new investment by the IPPs is always essentially opportunistic. Thus, overall there is considerable uncertainty in the plan, such that, for example, even compared to the 2$^{nd}$ long term basic plan of 2004, there have already been several substantial delays and even cancellations.

As with most cost-based pools around the world, a fixed capacity payment was introduced to provide the additional financial return for new investment. The fixed payment system is controversial, however, as it is generally set in an ad hoc way for a period of time, not precisely and transparently linked to actual market conditions, and therefore presents an additional element of regulatory risk to market participants. Hence, an alternative, explicit formulaic approach, such as a linkage to the periodic loss of load probability, LOLP, has theoretical appeal and some market attraction. Although the dynamic properties of the LOLP based approach have been modeled before (eg Bunn and Larsen, 1992), a direct comparison with fixed payments remains under-researched.

**Table 1. The 3rd basic plan for new capacities (2006~2020), MW**

| Year | KHNP | | KOSEP | KOMIPO | | | WP | | KOSPO | | | KEWESPO | IPPs | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | hydro | nuclear | coal | coal | oil | LNG | coal | LNG | coal | oil | LNG | coal | coal | oil | LNG |
| 2006 | - | - | - | - | - | - | - | - | - | - | - | 500 | - | 14.3 | 989.2 |
| 2007 | - | - | - | - | - | - | 500 | - | - | 200 | - | 500 | - | - | - |
| 2008 | - | - | 870 | 500 | - | - | 500 | - | - | - | - | 500 | - | 664.9 | 500 |
| 2009 | - | - | - | 500 | 40 | - | - | - | 1,870 | - | - | - | - | - | 500 |
| 2010 | - | - | - | - | - | - | - | 700 | - | - | - | - | 200 | 953.2 | - |
| 2011 | 60 | 1,000 | - | - | - | 500 | - | - | - | - | 900 | - | 200 | 747.3 | 2,000 |
| 2012 | - | 2,000 | - | - | - | 500 | - | - | - | - | - | - | - | 100.3 | 2,250 |
| 2013 | - | 1,000 | - | - | - | 700 | - | - | - | - | - | - | - | - | 300 |
| 2014 | - | 1,400 | 870 | - | - | - | - | - | - | - | - | 1000 | - | - | 700 |
| 2015 | - | 1,400 | 870 | - | - | - | - | - | - | - | - | 1000 | - | - | - |
| 2016 | - | 1,400 | - | - | - | - | - | 300 | - | - | - | - | - | - | - |
| 2017 | - | 1,400 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2018 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2019 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2020 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Total Capacity | | | | | | | | | | | | | | 33,599.2 | |

Thus, in this study, a simulation model based on system dynamics is developed in order to analyze the effects of different capacity payments on investment decisions and hence the system reserve margin. Two cases are considered for this study. In the first, the reserve margin together with wholesale prices and fuel mix are estimated for a fixed capacity payment system. And in the second case, the reserve margin, wholesale prices and fuel mix were calculated with an LOLP based system. Then, these results are compared with the 3rd long term basic plan developed by the government. Even though new plants are included in the 3rd long term basic plan, if the expected return on investment is lower than their criteria, the companies will cancel or delay the new investment. In our model, we recognize that different investment criteria may be applied depending on technology and type of company, and a survey was undertaken to identify this aspect.

This paper is organized as follows; Section 2 gives an overview of the Korean wholesale power market and investigates some issues of the current fixed capacity payments. Section 3 presents the results of survey conducted to find out how generating companies make their investment decisions. In Section 4, the system dynamics model is described and the experimental simulations are discussed in Section 5. Section 6 provides some conclusions.

## 2. Capacity payments in the Korean electricity market

In the current cost-based pool, the revenue of a generating company is composed of both an energy-related, system marginal price (SMP) and a fixed capacity payment (CP). The wholesale market clearing price, i.e. system marginal price (SMP), is determined by the production cost of the marginal unit needed to meet demand in each hour from the aggregate supply function submitted to the market by all generators. The capacity payment (CP) is paid to all available plants, regardless of whether they are actually called upon to produce. In the Korean system, there are two market segments depending upon whether the plant is providing baseload or peaking capacity. There is a separate energy price for each, baseload marginal price (BLMP) and SMP, as well as separate capacity payments. The CP is the price paid to the generating units that have submitted their hourly available capacities and is based on the pre-determined hourly and seasonal values. In 2006, the base load CP (20.49 won/kWh) was derived from the capital and a fixed O&M cost of a most recently planned 500 MW coal unit, whereas the peak load CP (7.17 won/kWh) reflected the capital and a fixed O&M cost of a standard gas turbine peaking unit. Thus, the fixed CP in the Korean market was designed to recover the capital cost of each unit, which the energy prices (BLMP & SMP) do not remunerate. However, these fixed capacity payments are not related directly to the market conditions, especially overall and local reserve margin considerations. In the short term, according to the $3^{rd}$ basic plan, the reserve margin after 2011 will be over 20%, which may be excessive, but in the longer term, it is not clear that investment decisions will respond adequately to market conditions.

## 3. Investors' behavior in the Korean electricity market

A small representative series of interviews was conducted in order to acquire information regarding the investment decision-making criteria of the different generating companies. Table 2 summarizes the interview results.

**Table 2. Generating company investment criteria: Interview results**

| Genco | Nuclear company | 5 fossil fuel companies | IPPs |
|---|---|---|---|
| **Investment Decision** | KHNP can only invest if annual levelized cost of nuclear is lower than that of coal and LNG, but there are limitations due to site planning and the government's policy. | They would like to invest aggressively, but there are limitations due to site planning and the government's regulation of the competitive market. | Strategic investment intentions restrained due to difficulties in project financing and required return on investment. |
| **Target** | No target. It depends on government policy | Maintaining current market share | Growth and profits |
| **Required Rate of Return** | NA | 7% | 10% |

## 4. Model description

### 4.1. Model overview

The model presented here was developed to analyze the effects of capacity payment systems on generators' investment decisions. The model is based on system dynamics (SD), which is a branch of control and system theory applied to economical and managerial systems. Following Forrester (1961), the methodology[1] of SD is based on identifying the structure of the system and the logic of the inter-relationships among the different components in order to explore its dynamic responses. Figure 1 shows a simplified causal-loop diagram of an electricity market investment cycle, following Bunn and Larsen (1992) with an LOLP capacity payments system. Causal relationships between two variables are identified by arrows. The positive (negative) sign at the end of each arrow can be understand as the response to a small positive change in the source variable creating a positive (negative) variation on the target variable. The diagram shows the essential balancing feedback that governs the long-run development of the electricity market. Recall that the wholesale market price is composed of the marginal energy price (BLMP/SMP) and a capacity payment (CP). Market revenues influence investment decisions, and the construction of new plants will affect total capacities generated in the electricity market. Since market prices are very sensitive to the reserve

[1] A complete and modern reference book on the SD methodology can be found in Sterman (2000).

margin, not only does this feedback creates a very responsive loop, it also means that prices and investments are very dependent upon what other companies are doing.

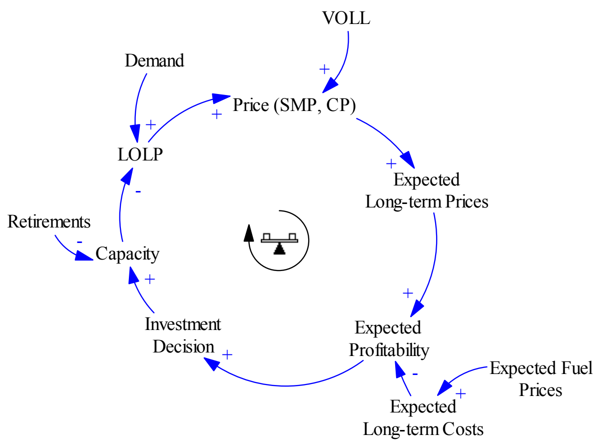


**Figure 1. Causal-loop diagram of the electricity market.**

Figure 2 gives an overview of the conceptual framework for the model in this paper. The model has three sub-modules: a price module, a capacity mechanism module, and an investment decision module. These modules are linked together by system dynamics modeling for a year-by-year simulation, extending over 30~50 years. The objective of this study is to make an estimate of long-term prospects for the Korean electricity market based. Many assumptions are taken from the 3rd basic long term plan, but we analyze the effects of different capacity mechanisms within this framework.

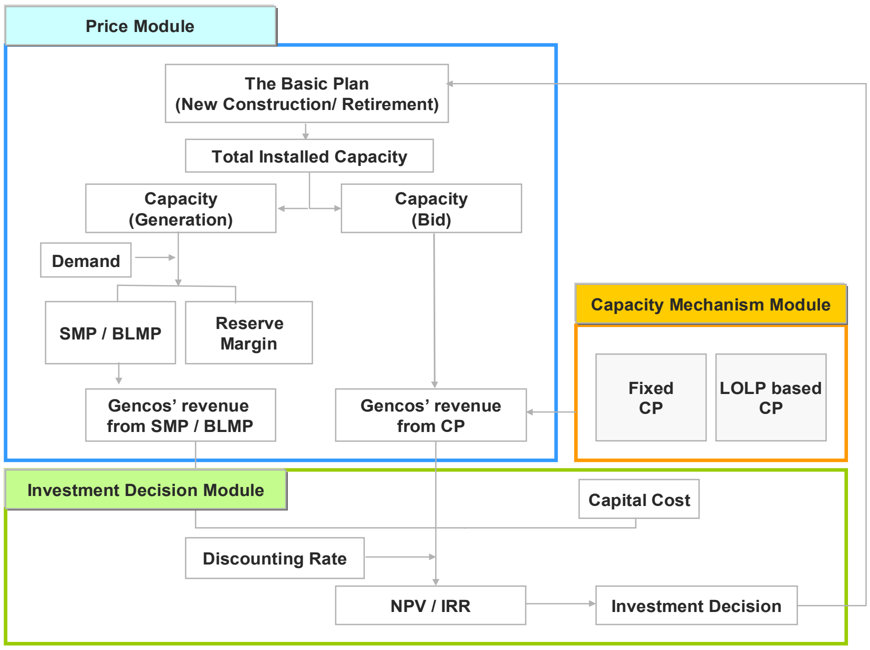


**Figure 2. The conceptual framework for the SD model**

In order that the modules could be developed and updated flexibly with detailed market data, the overall model was developed as a dynamic interaction of various Excel modules, controlled through Visual Basic programming.

4.2. Price modules

This model is designed to reflect price formation in the current Korean cost based power pool. The price module is a core component in this model to determine SMP and calculate each company's revenue from the energy market year by year. The output from this module is used as an input for the capacity mechanism module and the investment decision module.

The plants are aggregated into groups by technology and companies. Each year, the simulation shows the reserve margin, which is the difference between installed capacity and demand (expressed as a fraction of demand). The price module can determine a single market price as well as the dual BLMP/SMP pricing.

4.3. Capacity mechanism module

The capacity mechanism module considers the inclusion of LOLP based capacity payments, as an alternative to fixed capacity payments. LOLP based capacity payment is calculated from LOLP, the value of loss of load (VOLL), and SMP by equation (1)

LOLP based capacity payment = LOLP (VOLL – SMP) (1)

Each year, as the simulation advances, a comparison between demand and capacity is made in order to evaluate the LOLP. Depending upon the reserve margin, which is the difference between installed capacity and demand (expressed as a fraction of demand), LOLP can be computed as the convolution of the probabilities of failure of the individual plants in the system. Figure 3 presents an estimate of LOLP as a function of reserve margin in the Korean electricity market.

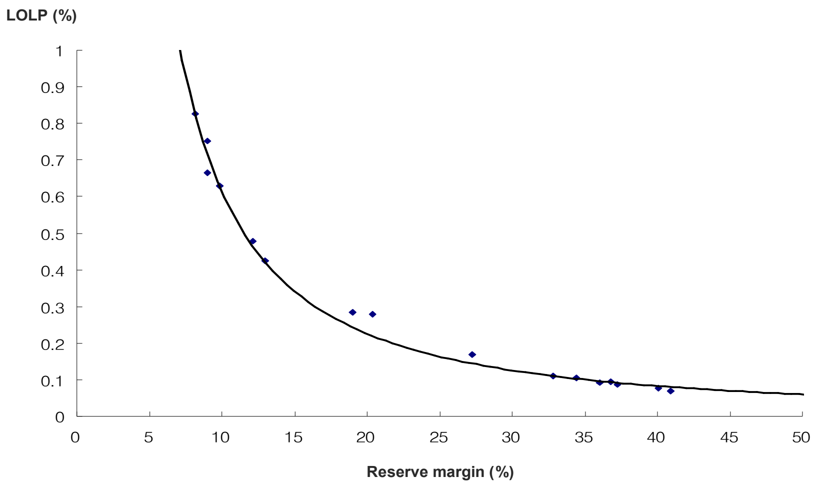


**Figure 3. LOLP as a function of reserve margin**

Following industry discussions, we assume VOLL as 3,000 won/kWh, whilst the LOLP based capacity payment depends upon reserve margin, as above. The basic idea of the LOLP based capacity payment is that, when there are periods of excess capacity, the system should have relatively high reserve margin and low LOLP, on average, and there should be little economic incentive to invest in new capacity. Alternatively, when there is heavy demand relative to available capacity, LOLP will rise steeply as reserve margin declines and this should provide the required investment incentive.

4.4. Investment decision module

In the Investment module, it is assumed that investment will occur whenever the NPV of a new investment is positive or IRR is higher than the required rate of return (cost of capital). From the face-to-face interviews, it appeared that the six main generating companies will make a new investment if IRR is higher than 7% while IPPs will invest only if IRR is higher than 10%. However, as mentioned earlier, the strict implications of these for the nuclear and fossil power companies are dubious, because these are all subsidiaries of KEPCO, and ultimate subject to the politicized intent of the KEPCO board. However, the investment decisions of the IPPs are quite individualistic and profit motivated. Apart from cost of capital, advantageous sites for quicker new build and project financing can be important factors for an investment decision, but they are not considered in this study. The output from this module, as new capacity build, goes into the price module and influences the total installed capacity, market price, reserve margin and fuel mix. This change affects generating companies' revenue again and hence the subsequent investment decisions are changed dynamically. These are therefore classic cyclic causal loops with feedback through the price module, the capacity mechanism module, and the investment decision module.

## 5. Simulation Results

The simulation was conducted for two cases and compared to the reference case.

1. The reference case is a 'base' case assumption that all companies including IPPs will build or retire their plants according to the basic plan without any change. This case reflects the current energy market rule (BLMP/SMP) and capacity mechanism (fixed dual capacity payments).

2. Case 1 presumes all companies will make investment decisions on their own criteria. They can delay or give up their planned construction if they decide that it isn't profitable. The energy market and capacity mechanism are identical to the current market design (dual energy market prices and fixed dual capacity payments).

3. Case 2 has different rules from the current market and allows companies to make their own investment decision. The market has a single energy market price (SMP) and LOLP based capacity payments.

Table 3. Summary of cases in the model analysis

| | Genco's Investment Decision | Energy Market | Capacity Payment |
|---|---|---|---|
| **Reference Case** | No | BLMP/SMP | Fixed CP (Baseload CP & Peakload CP) |
| **Case 1** | Yes | BLMP/SMP | Fixed CP (Baseload CP & Peakload CP) |
| **Case 2** | Yes | SMP | LOLP based CP = LOLP(VOLL-SMP) |

5.1. Reference case

In the reference case, a year-by-year simulation (2006~2020) is developed with output graphs for market price, reserve margin, fuel mix, and market shares for generators, based on the government's basic plan. The plants are aggregated into groups by technology (hydro, nuclear, domestic coal, coal, oil, and LNG) and generators (KHNP, KOSEP, KOMIPO, WP, KOSPO, KEWESPO, and IPPs).

According to the 3rd basic plan, reserve margin is increasing to 25.1% shown in Figure 4. On the assumption that the optimal reserve margin would be 14~18% in the Korean electricity market, the overinvestment of new capacity will have indeed become cause for concern after 2012. SMP is stable, however. Any changes in the fuel costs of oil and gas over the planning period were not considered in this model, otherwise SMP would follow them.

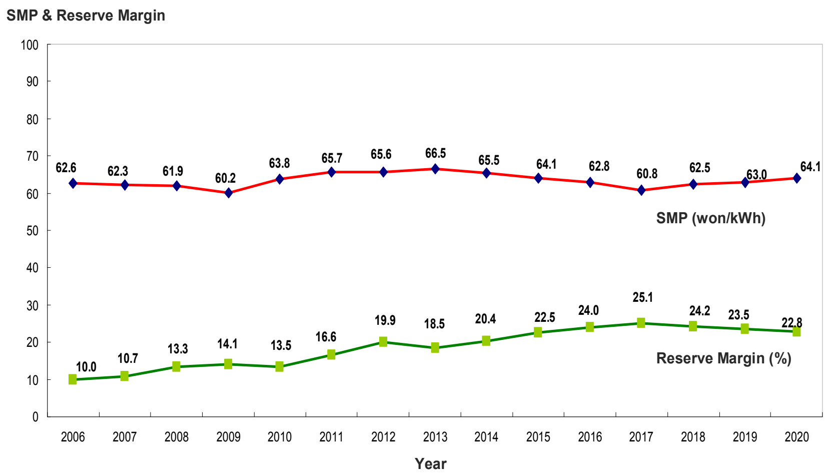


**Figure 4. SMP and reserve margin in the reference case**

Figure 5 shows the prospects for fuel mix and these are consistent with the government's guideline.

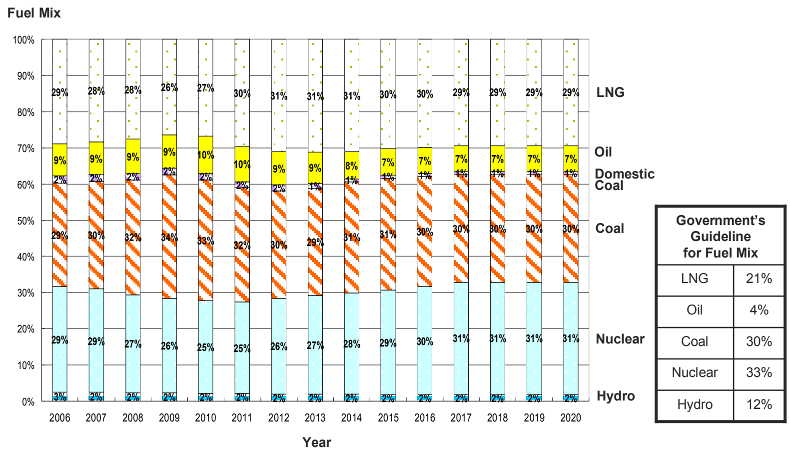


**Figure 5. Fuel mix in the reference case**

Figure 6 shows the market share profiles for the six main gencos and IPPs. KHNP, nuclear company, maintains a 30% market share in terms of the installed capacity. The IPPs increase market share, encouraged by the construction of new LNG plants, whilst, proportionally, the five fossil fuel companies decrease market share, mainly due to the retirement of oil and coal plants.

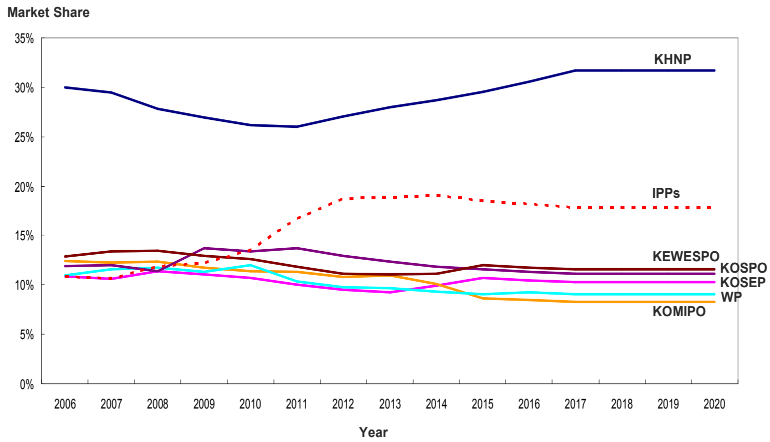


**Figure 6. Market share (Installed capacity based) in the reference case**

5.2. Case 1

In Case 1, generating companies are allowed to make an investment decision on its own merits. The energy market and capacity mechanism are identical to the current market design (dual energy market price and fixed dual capacity payments). This model assumes that generating companies will not build new plants unless they estimate the IRR to be higher than the required rate of return.

The result of the simulation in this case shows that IPPs will decide not to build some of plants, while all the six main gencos follow the 3rd basic plan without any change. The change of IPPs' investment decision is shown in Figure 7. In this case, IPPs will abandon or delay building new plants in 2006, 2008, and 2014, and only build the two coal plants planned in 2010 and 2011, in the absence of further financial incentives. The changes of IPPs' investment decision would have an effect on the system reserve margin shown in Figure 8, to the extent that it could cause an overall problem of reliable supply in the electricity market.

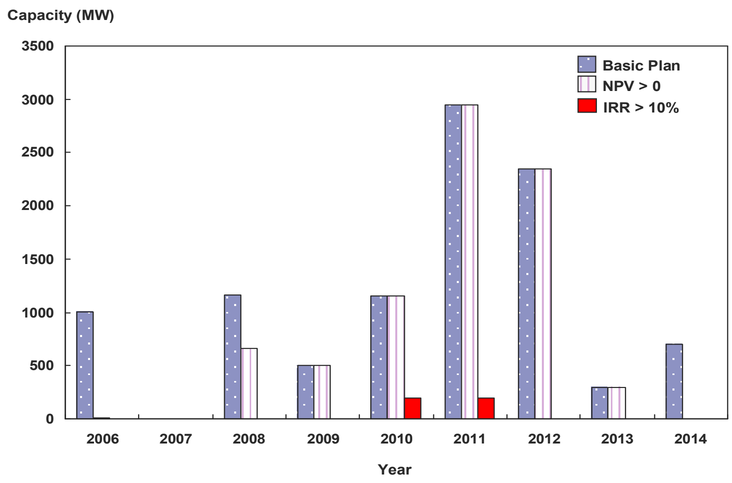


**Figure 7. IPPs' investment decision in Case 1**

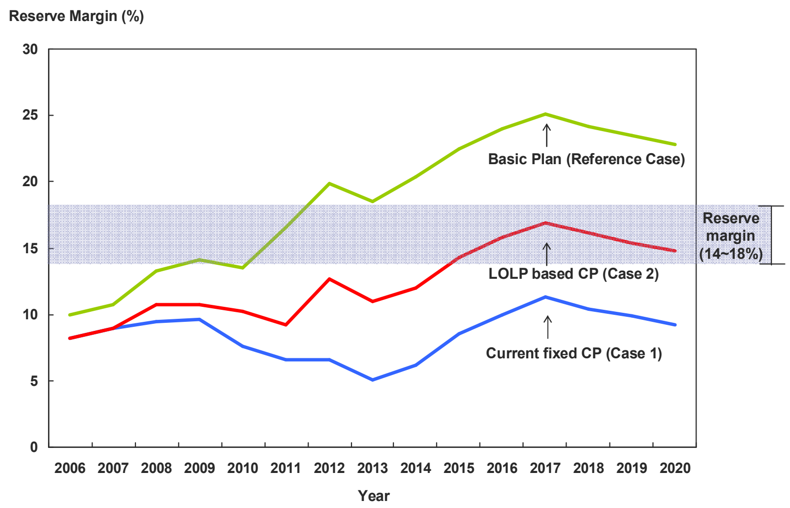


**Figure 8. Reserve margin in the Korean electricity market**

Thus, the fixed capacity payments paid to all the generating units that have submitted their available capacities do not seem to be efficacious for inducing generating company's appropriate investments, especially the LNG plants of IPPs. Furthermore, we see how sensitive this market is to the behaviour of IPPs.

5.2. Case 2

Case 2 also allows generating companies to make their own investment decisions. The market rule, however, is different from the current one. In this case, the market has a single energy market price (SMP) and a single LOLP based capacity payment. The result of the simulations in Case 2 shows that IPPs will still decide not to build some of plants, while all the six main gencos follow the 3rd basic plan without any change as well. The change of IPPs' investment is shown in Figure 9, where unlike Case 1, the IPPs do actually build many of plants planned.

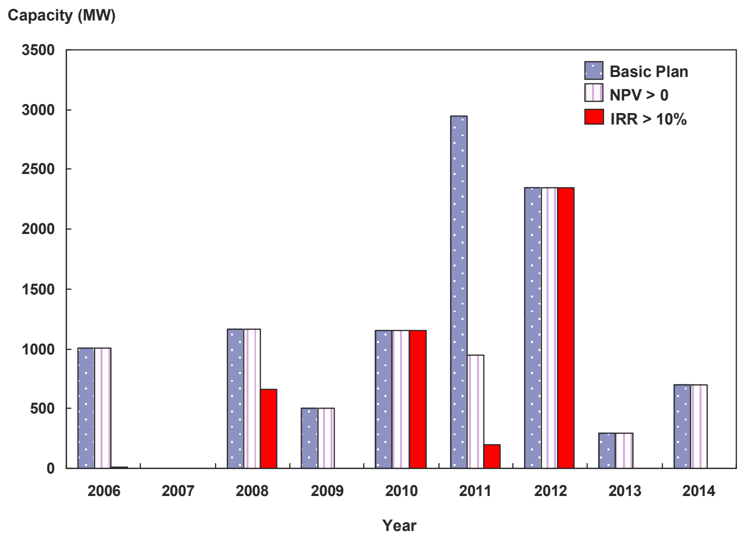


**Figure 9. IPPs' investment decision in Case 2**

The system reserve margin in Case 2 is presented in Figure 8. Although LOLP based CP was slow to change the investment and reserve margin in the initial stage of the overall period, however, it makes an appropriate response in the longer-term between the unrealistic over-investment indicated in the national plan, and the under-investment that might follow if the IPPs were only induced by the fixed capacity mechanism

## 6. Conclusions

A simulation model was developed to analyze the generating companies' investment decisions and the long-run reliability of supply in the Korean electricity market. The model is based on a system dynamics approach, where investment behaviours are conditioned by dynamic feedback formed by market price and capacity payments. The simulation results show that major fossil and nuclear companies, still partially under the influence of central planning, construct the new capacity indicated in the latest national long term basic plan for both a fixed capacity payment and LOLP based capacity payment systems. However, although the national plan suggests substantial IPP building, and in fact our model indicates a rather excessive reserve margin if that were followed, our model also shows that so much IPP capacity is inconsistent with their stated investment criteria, and that the IPPs may under the investment under the current fixed CP mechanism. The wholesale price decreases due to the excess supply and it leads to lower the IRR of IPPs. The return is too low for IPPs to invest. This leads to very low system reserve margin and causes concern about the long-term security. However, the LOLP based CP mechanism shows some improvement in reserve margin in the longer term to an appropriate a sustainable level.

Clearly, such model-based results are only indicative, but they do raise substantial questions about current misplaced confidence in the fixed capacity payment system. Further detailed research is essential in the Korean context.

More generally, this model shows how important it is to understand the fringe players in power markets. Reserve margins are very sensitive to market prices, and market prices in turn are very sensitive to reserve margins. Even in a market such as Korea where liberalization is progressing slowly, with the major portion of the market still under central planning influence, the performance of the IPP fringe appears to be crucial. An inability to model them effectively would ultimately undermine the usefulness of any long-term market model and the consequent insights into energy security.

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