Exploratory Analysis to Support Real Options Analysis: An Example from Electricity Infrastructure Investment

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Abstract *– Several approaches have been developed to analyze the potential of real options. Their assessments, however, are mostly based on limited future scenarios. In this paper two of the approaches, the option pricing and the decision analysis method, are combined and extended with exploratory analysis: computational experiments across a wide spectrum of future scenarios. The case study investigates the impact of various uncertainties (i.e. electricity price, and demand, natural gas price) on the net present value of two electricity power plant investments. Three uses of exploratory analysis are demonstrated: (i) providing the spectrum of future scenarios that give robust performance, (ii) estimating the range of option values across a wide spectrum of future scenarios, and (iii) calculating the regret value of an underutilized option. These insights can facilitate the decision on whether or not to include a real option in an infrastructure investment.*

Keywords: Uncertainties, electricity infrastructure investments, exploratory analysis, real options analysis

1 Introduction

Real options analysis (ROA) has been proposed as a tool that can make uncertain conditions beneficial. Its attractiveness is based on the premise that with options, one can maximize the upside potential of a project and at the same time, minimize its downside effects. This way, ROA can correct the rigidity of the go-no go decision suggested by traditional discounted cash flows methods (e.g. traditional Net Present Value, NPV and Internal Rate of Return, IRR). ROA, for example, makes it possible to value the flexibility of making mid-course changes in a decision ([1], [2]).

1.1 Real Options

Originally developed for financial instruments such as stocks or commodities, the concepts of option valuation are now applied to real assets (e.g. investments, projects). Generally speaking, an option is the right but not the obligation to benefit from uncertain future conditions [3]. For real assets, there are two types of real options: options built *in* the asset and option built *on* the asset. For the first, option is created inherently in the asset (or system) itself by designing elements of the system to be able benefit from future conditions. This type of option can be created by over dimensioning, that is, creating a kind of redundancy to the current requirements of for example capacity or technology. Such redundancy can take the form of land banking for a road and an airport or dual fuel source for a power plant. This paper only covers this type of option.

The second type of real option concerns more about the financial arrangement around the asset. One can acquire an option to, among others, defer, abandon, and hedge the projects. This can be achieved by, for example, acquiring an exclusive right for a product under development, leasing a manufacturing facility before building own one, selling assets at salvage value, etc. So far the examples of decisions coming from ROA have been mainly been in the areas of research and development of new products, manufacturing facilities, and oil exploration. Recently, however, works have also begun in the area of infrastructures (see [4] and [3]).

As mentioned above, ROA enables the valuation of flexibility. The value of flexibility can be given as [1]:

Flexibility (option) value =
NPV (with flexibility) – NPV (without flexibility) (1)

This formula simply entails the comparison of NPV between a project with an option and without one.

Another important aspect is that having an option comes at a cost. For example, creating a real option by over dimensioning an infrastructure project requires an extra investment cost (e.g. costs of building extra capacity to a power plant). As a general rule, an option should be chosen as long as the benefits from the flexibility are greater than the costs of creating it.

1.2 Real Options and Uncertainty

In essence, ROA is all about dealing with the uncertainties that affect the present value of a project's cash flows. Broadly, there are two categories of uncertainty affecting the project's value. The first can be called public uncertainties: factors whose values are significantly related to the volatility of the stock/commodity prices. The second one is considered as private uncertainties: factors whose values are independent from the volatility of stock/commodity prices.

Based on the treatments of the two kinds of uncertainty, ROA has taken at least five different approaches (see [5]). On one end there is the strict requirement of finding a correlated portfolio of stocks or commodities in the financial market (i.e. classic approach). On the other end is to use completely subjective data on the uncertainty of the value of asset or project (i.e. subjective approach). In the middle there is an integrated approach that distinguishes uncertainties that fall into public and private categories. The integrated approach handles the public uncertainties with the option pricing method (e.g. binomial method) as the basis for value calculation and the decision analysis method for private uncertainties.

For several reasons, this paper takes the integrated approach for valuing real options,. First, in the classic approach, it is problematic to find a replicating portfolio of stocks or commodities in the financial market that perfectly resembles the risk profile of a real asset investment. For example, the volatility of coal prices does not necessarily represent the volatility of the value of coal mining. On the other hand, the subjective approach is completely detached from the financial market. In addition to this conceptual difficulty, there are also practical ones. First, the nature of decisions on real assets differs from that on financial instruments. There are only a limited number of chances to make decisions. Second, the availability and accuracy of data is different. There are less empirical data for ROA, and if there are data, they are less accurate [3].

Nevertheless, the integrated approach still has some problematic issues. In particular, the application of the decision analysis method requires the assignment of a likelihood to each of the possible states of nature (scenario). Finding these probabilities figures are difficult and the findings are often disputable. In addition, the future scenarios that are considered are limited, typically characterized by low, medium or high categories. This paper attempts to correct and complement these drawbacks.

1.3 Exploratory Analysis (EXA) Approach

In this paper, a methodological approach called exploratory analysis (EXA) is proposed to deal with uncertainty in ROA. EXA broadens the limited scope taken in traditional sensitivity analysis [6]. It involves exploring as broad a range of assumptions and circumstances as are plausible, given the resources available for performing the analysis. Hence, exploratory analysis involves exploring a wide spectrum of scenarios, alternative model structures, and value systems. In handling future scenarios, EXA is also different from the decision analysis method. In EXA, all parameters are considered non-stochastic. Instead of using probability distributions on the different states of nature (scenarios), ranges of plausible values are used. EXA also uses minimization of maximum regret as the decision rule, which compares the relative performance among decisions rather than the absolute performance values.

EXA is especially appropriate for obtaining insights in cases in which there is deep uncertainty about external forces, system internal relationships (implying deep uncertainty about system outcomes), and the way outcomes are currently valued and/or will be valued in the future. These cases occur particularly when analysts do not know or actors involved in a decision cannot agree on major issues concerning the system model, such as (i) prior probability distributions representing parametric uncertainties with respect to external forces and internal factors, (ii) the model structure and (iii) the relative desirability of the various policy outcomes [7]. The exploration is carried out using computational experiments. A single computational experiment is a computer run for one set of assumptions about the system model, the external scenario, and the value system. Hence, a computational experiment refers in fact to a plausible hypothesis about the system.

This paper demonstrates how exploratory analysis can be used in combination with options pricing and decision analysis to analyze cash flow uncertainties in an electricity infrastructure investment. For this purpose, a simple investment model in a natural-gas-fueled power plant is described first. The model illustrates the creation of a real option by over-dimensioning a power plant investment. The following section presents the results of various computational experiments that are carried out across wide future scenarios. The rest of the paper shows how the insights of these experiments are used to assess the range of option values. Finally, the last section discusses the implications of the use of exploratory analysis to deal with uncertainty in ROA and gives some recommendations for further research.

2 An Electricity Power Plant Investment Model

From the electricity-generating companies' point of view, liberalized energy markets have brought in uncertainties in many respects. For a start, it is difficult to estimate the exact electricity demand function. Various kinds of structural uncertainty have also emerged: regulation on price mechanism (e.g. price cap) and environment (e.g. cooling water, emissions, and waste), the structure of natural gas industry (i.e. main fuel for power plant), and the arrangements of various market designs.

The interaction between these market uncertainties and commercial motives has lead to a so-called construction cycle in which there is a time lag between the need for more electricity and its actual delivery. To this phenomenon, energy producers have responded by choosing not to invest in capital intensive, long lead-time generating technology such as large nuclear or hydro power plant or in technology with relatively high pollution such as coal plant. Instead, enabled by the increased efficiency of for example combined cycle gas turbine, they opt for a cheaper, smaller and less polluted plant that has a shorter lead time to build [8].

2.1 The system model

The model is described using system model elements that are central to the policy analysis approach [9]. The elements include external forces (X), policies (P), internal factors (I), outcomes of interest (O), relationships (R) and a value system (V). In this paper, the natural gas fueled combined cycle plant technology is considered [10]. The plant consists of basically one or more gas turbine generators fueled by natural gas. The hot exhaust from the gas turbine is recovered to produce steam that will run a steam turbine generator, producing additional electricity. The model is not meant to be exhaustive, since it serves only as an illustration.

The system model is described as follows:

- External forces (X) are variables that are beyond the control of decision-makers. The model considers three external variables: natural gas price, electricity demand, and electricity price.
- Policies (P) are factors that are under the control of decision-makers. In the model, for the purpose of simplicity, there are two policy variables: the size of the plant and the timing of plant construction.
- Internal factors (I) are variables that are within the system boundary. In the model, they are the variables that determine the cash flow of the investment: (i) installed and used capacity, (ii) costs: construction (sunk cost), fixed and variable operations costs, and fuel, and (iii) revenues.
- There is a single outcome of interest (O): NPV.
- The relationships (R) are: (i) revenue function (ii) cost function and (iii) function that translates the costs, revenues, and discount factors into NPV.
- The value system (i.e. objective and interest) of the decision-maker is to maximize investors' wealth.

A diagram of system model for electricity power plant investment is given in Figure 1. The equations derived from the system model are given in the appendix.

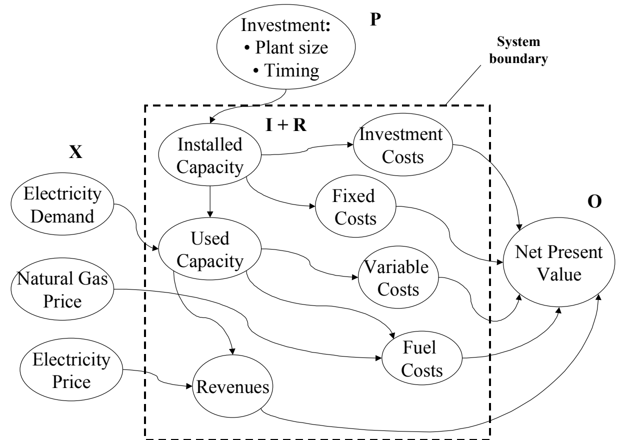

Figure 1. A system model for electricity plant investment

2.2 Investment alternatives and characteristics

The investment schemes considered consist of two alternative sizes of power plant. The details of each alternative investment are given in Table 1 (adapted from [10] and [11]).

Table 1. Alternatives for plant investment

	Plant1	**Plant2**
Net Plant Power (capacity in MW)	563	264
Development & Construction Costs (Million $)	303	178
Fixed cost ($/kW/year)	8	8
Variable cost ($/MWh)	2.8	2.8
Net Plant Heat rate (Btu/kWh)	5940	6700
Development and Construction time (yrs)	4	2
Service life (years)	20	20
Max annual utilization (%)	90	90
Fixed & variable cost change (%/year)	-0.5	-0.5
Heat rate decrease (%/year)	-0.5	-0.5

The above table also highlights some of the cost and technological characteristics of the two types of power plants:

- A larger plant gains from the economies of scale. A plant that is two times bigger does not cost twice as much. The development and construction costs as function of capacity are assumed to follow the relationship:

$$\text{Development and Construction costs} = 3.6 \text{ million} \times (\text{capacity in MW})^{0.7} \quad (2)$$

- The major cost component for this plant technology is the fuel cost. A larger plant gains an advantage from lower heat rate (i.e. energy, in British thermal unit Btu, required to produce one kilowatt-hour). As a result, fuel consumption per capacity production will be lower.

- Because the same plant technology used, fixed operating cost per capacity (i.e. labor, routine maintenance and overhead) and operating variable cost (i.e. consumables, water waste disposal cost, etc) are generally similar for different plant sizes.
- The learning curve effect and technological improvement result in decreasing fixed and variable operations costs.

2.3 The Real Investment Option

The focus of this paper is to illustrate an option of building an extra capacity. That is having more production capacity than necessary in order to be able to gain more profits when the circumstances turn out to be better than expected. For this purpose, a hypothetical investment option is developed. The context and assumptions of the case are described as follows (see Figure 2):

- Four years from now, the current power plant will come to the end of its service life and as a result, a replacement is needed. The considered time span of the new plant is 20 years (i.e. the plant's service life), which is divided into two periods.
- At the current demand of 225 MW per year, a slightly bigger plant (Plant2) can be build. The assumption is that demand will increase only slightly in the first period. Because it takes two years to build Plant2, the construction can start at year2. This later incurring of sunk cost benefits from having a lower present value.
- Or one can choose to create a real option by building a bigger plant (Plant1). If the demand turns out to be higher than predicted, the extra capacity will be able to accommodate it. The cost of the option will be the extra investment (sunk) and the fixed costs. If the option is to be exercised, Plant1 must be built now (Year0).
- When electricity demand is lower than supply, the used capacity is equal to the demand and is sold at the market price. One cannot sell more than the demand required even at a dump price. Therefore, a decision to build Plant2 at Year0 is ruled out.

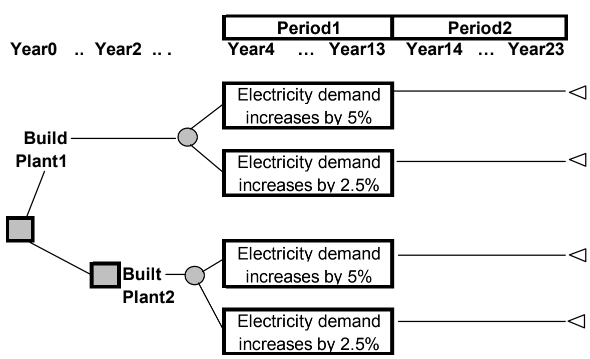

Figure 2. Option to build extra capacity

The two sides of the option will be shown in section 4. First are the values of having the option if the electricity demand for period1 increases higher than expected (i.e. by 5% in a yearly basis). Second is the downside of the option when the demand increases only moderately (i.e. by 2.5%).

2.4 Public and private uncertainty

The external forces (X) represent future scenario uncertainties. The uncertainties of natural gas price will be treated as public uncertainty, while those of electricity demand and price as private uncertainties. The uncertainty of natural gas price is derived from its volatility in the financial market. For simplification, volatility per period rather than per year is considered. The data in Table 2 resemble historical reality (see [5]).

Table 2. Public uncertainty for natural gas

Natural gas price at year0	5.25 US$ per MMBtu
Volatility per period	19 %
Upward movement factor (u)	1.22
Downward movement factor (d)	0.82

The gas price movements resulting from binomial method is given below (see [1] for details on the method).

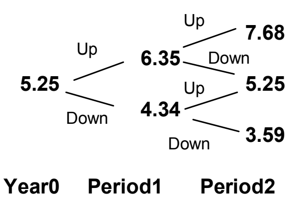

Figure 3. The volatility of natural gas price

The future scenarios for electricity demand and price are defined by the percentage change in their values. A sample range of –20 % to 20% and –5% to 5 % are taken for electricity price and demand respectively. The percentage figures encompass the historical data (see [11]). The growth figure of electricity price is the change per period, while for electricity demand is the change in a yearly basis. The initial electricity price at year0 is 50 US$ per MWh.

3 Applying Exploratory Analysis to Real Options

The application of exploratory analysis requires the performing of four steps:

- Modeling plausible future scenarios.
- Carrying out computational experiments across the plausible future scenarios.
- Designing a sampling strategy and a display system that provide information about investment performance.

- Defining decision criteria.

3.1 Plausible future scenarios.

Having defined the volatility of the three uncertain factors, future scenarios are defined using the path dependent tree structure (see Figure 4). This tree represents all possible scenarios regarding the states of the three variables. For example, the shaded block in the tree represents a condition in Period1 with the upward movement of natural gas price and the price and demand of electricity continuously rising by 20% and 5% respectively. For this condition, the notation Period1(Up, 20%,5%) is used for the rest of the paper.

Using this scenario in Period1, a whole range of plausible scenarios for Period2 can be laid out. This one sequence of events is a sample of future scenarios out of a complete set of scenarios defined by the design of experiment method. The model of plausible scenarios is more extensive than that usually prescribed by the decision analysis method because it extends the usually limited scenarios (e.g. low, medium, high categories) to more refined increments.

It is important to notice that the project value volatility is captured by the volatility of the three variables. Therefore, the use of subjective risk discounted rates can be avoided and the risk free interest rate, r, can be used as a discount rate instead. The value of r used in the model is 5%.

3.2 Computational experiments

Computational experiments are carried out across the whole range of plausible scenarios to calculate the NPV for each investment in each scenario. The result is a database containing the NPV figures. The database is then used for data-mining. Because of the size of the database, it is crucial that a sampling strategy is designed to extract important behavior of the investment. In this paper the sampling strategy used is question based sampling (see section 4). It is also important that the results of the computational experiments are displayed in a way that is easy to understand. All the factors involved should be organized and arranged so that the pattern of the performance of the investment in future scenarios can be revealed.

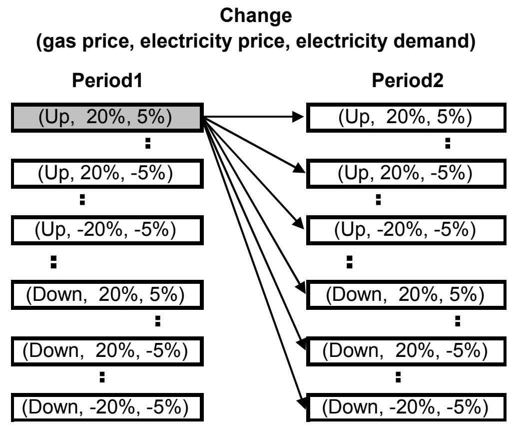

Figure 4. Tree of future scenarios (changes in external variables' value)

3.3 Decision criteria

Decision criteria determine whether a certain investment is economically viable and is therefore contributing in increasing the wealth of the investors. Two main criteria will be used for an investment decision. First, at the end of investment life (end of Period2), the return (NPV) must be positive and robust across a wide spectrum of futures, so not only for limited scenarios. Second, the performance of the investment must be superior to other investments considered.

For the second criterion, a regret function is introduced. Regret value informs how much worse an investment is, in terms of NPV value, compared to other investment. The regret function is given:

$$\text{Regret}(p,s) = \underset{p'}{\text{Max}}[\text{Performance}(p',s)] - \text{Performance}(p,s) \qquad (3)$$

Where p' indicates the investment that delivers the maximum NPV in a scenario s. In this paper, the following regret categories are used to determine the relative performance of the investments.

Table 3. Criteria of regret value

Category of regret	**Range of regret (in million US$)**	**Shade designation**
No regret	$0 \le \text{Regret} \le 0.09$	
Mild	$0.1 \le \text{Regret} \le 14.9$	
A lot	$15 \le \text{Regret} \le 99.9$	
Overwhelming	$\text{Regret} \ge 100$	

Using these two criteria, an investment can be considered robust if it has a positive NPV and has 'no' or 'mild' regret. When an investment is successful in a wide spectrum of futures, it will have a large robustness area.

The next section presents the results of the exploratory analysis applied to the model.

4 The Use of Insights from Exploratory Analysis

This paper demonstrates three uses of the insights from EXA:

1. EXA can provide the pictures of the paths of future that will provide robust performance.
2. EXA can estimate the range of option value across future scenarios.
3. EXA can also indicate the regret value of the built-in option when it is not used or fully used.

4.1 Provisioning the Pictures of Future Paths

As indicated in Figure 4, the future scenarios are unfolded in two periods. Depending on the realization in Period1, a spectrum of future scenarios for Period2 can be laid out. At the of end Period2, when the plant service life is due, NPV figures are calculated. Before that, let us see how the NPV figures for Investment1 will look like for scenarios in Period1 (see Figure 5). Notice that the minus signs mark the circumstances where the NPV is negative. The large area of minus NPV indicates that the investment is still having losses in the majority of the scenarios in Period1 (year13), except for some very favorable circumstances. For example when the gas price is down and electricity price rises combined with high demand growth : Period1(down, 20%, 2.5%) or Period1(down, 10%,5%).

Investment 1

(gas, eltrcity price) Period1:	-5.0%	-2.5%	0.0%	**2.5%**	**5.0%**
(up, -20%)	-	-	-	-	-
(up, -10%)	-	-	-	-	-
(up, 0%)	-	-	-	-	-
(up, 10%)	-	-	-	-	-
(up, 20%)	-	-	-	$\boxed{-}$	$\boxed{-}$
(down, 20%)	-	-	41	92	150
(down, 10%)	-	-	-	24	74
(down, 0%)	-	-	-	-	-
(down, -10%)	-	-	-	-	-
(down, -20%)	-	-	-	-	-

Electricity Demand

The scenarios on two electricity demand figures used for illustration in this paper

Figure 5. NPV figures for Investment1 at the end of Period1 (year13)

We can then query the database to reveal the behavior of the investment in terms of its NPV. As described in section 2.3, two predictions of electricity demand growth are involved in the decision to build the power plant : 2.5% and 5%. The other two variables : gas price and electricity price are considered to be up and 20% respectively. Therefore, the queries will be focused on two future realizations in Period1: (up, 20%, 2.5%) and (up, 20%, 5%) (highlighted in Figure 5).

Let us now ask, what the performances of Investment1 will be at the end of Period2 (year23), if the circumstance in Period1 is (up, 20%, 5%). The results are given in Figure 6. Notice that the negative NPV area is decreasing and starts to emerge from the top of the diagram. This pattern is given by the arrows indicating the direction where the value of NPV is increasing. At the most favorable future scenario, Period2(down, 20%, 5%), the NPV is around US$ 530 million.

Investment 1

Period1: (Up, 20%, **5%**)

(gas, eltrcity price) Period2:	-5.0%	-2.5%	0.0%	2.5%	5.0%
(up, -20%)	-	-	-	-	-
(up, -10%)	4	11		29	39
(up, 0%)	59	74		110	130
(up, 10%)	115	136	161	190	222
(up, 20%)	170	199	232	271	313
(down, 20%)		349	403	465	532
(down, 10%)	247	287	332	384	441
(down, 0%)	192	224		303	350
(down, -10%)	137	161		223	258
(down, -20%)	82	99	119	142	167

Electricity Demand

Figure 6. General pattern of Investment1 behavior at the end of Period2

4.2 Determination of Option Value

This section shows the values of the option built in Investment1 when the circumstances are better than expected. That is increase in electricity demand by 5% in Period 1 (Up, 20%, 5%). As can be seen from Figure 7.a, Investment1 is relatively robust in a majority of futures in period2. The dashed-line separates the robust area with non robust one. Investmennt1 is a viable investment when the demand and price of electricity continue to rise, coupled in particular with falling gas price. A cone shaped pattern is clearly shown. It fails for example in Period2(Up, -20%, 5%), that is when. because of decreasing electricity price, revenues cannot offset increasing fuel cost. In contrast, Investment2 (smaller size plant) reveals a different behavior (Figure 7.b). It excels in the left side of the diagram (i.e. when the demand turns low). It has 'overwhelming' and 'a lot' regret in the middle right hand side of the diagram (i.e. increasing electricity demand and price). Notice also that the negative NPV area occurs at similar scenarios for both investments.

The of option value Investment1 can be considered as the regret value of Investment2. The regret value given by equation 3 is actually similar to option value given by equation 1 above. For this set of scenarios, the option values of Investment1 range from 17 to US$ 224 million. Those values are for the scenarios of Period2(up,10%,-2.5%) and Period2(down,20%, 5%) respectively. These figures must be added by the value of not having to build a new plant to serve the higher demand. This value is the difference between the investment cost of Plant1, built in Year0 (Present Value, PV = 303 million) minus the cost of Plant2, built in Year2 (PV= 161 million) and the cost of a new plant of the size of 300 MW, that is the size of Plant1 minus Plant2 , which is assumed to built also in Year2. The present value of the cost gain, which comes from the economies of scale, is around US$ 63 million.

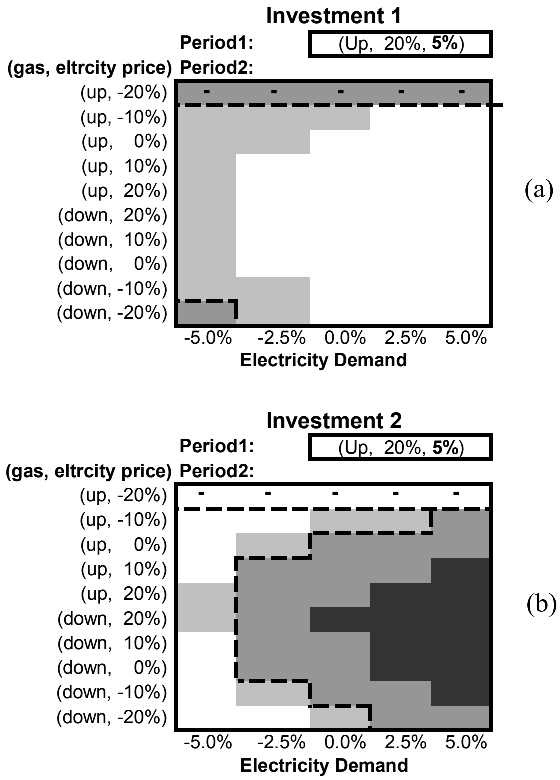

Figure 7. Robustness area for both investments at the end of Period2 (year23), when Period1 is (Up, 20%, 5%)

4.3 Determination of regret value of idle real option

What if the extra capacity, the real option, in Investment1 is idle or not fully used ? This happens when it turns out that the conditions in period1 is not (Up, 20%, 5%) but (Up, 20%, 2.5%), meaning that the demand of electricity does not increase by 5% but only by 2.5%. Let us now compare the performance of the two investments. Figure 8.a shows that Investment1 has a large area of ‘a lot’ regret and increased negative NPV area. This is mostly contributed by the higher sunk cost of a bigger plant, which is underutilized. However, it is still a robust investment, especially when the demand grows at 5% in Period2. In contrast, Investment2 clearly shows a more advantage of a smaller plant: a small ‘a lot’ regret area in Figure 8.b.

Figure 8.a indicates the regret values of a not fully used option. In this set of scenarios, the regret value ranges from US$ 22 to 67 million. These figures are much lower than US$ 240 million, which is the difference between the PV of investment cost of Plant1 and Plant2. This is mostly because of the benefits from the economies of scale that is lower unit cost, particularly fuel cost; and the fact that the dominant cost for this type of power plant is for fuel. Although most of the NPV area has ‘a lot’ regret, most of it has positive NPV. Therefore, in the most of the scenarios, Investment1 will deliver positive NPV, even when the extra capacity is not fully utilized.

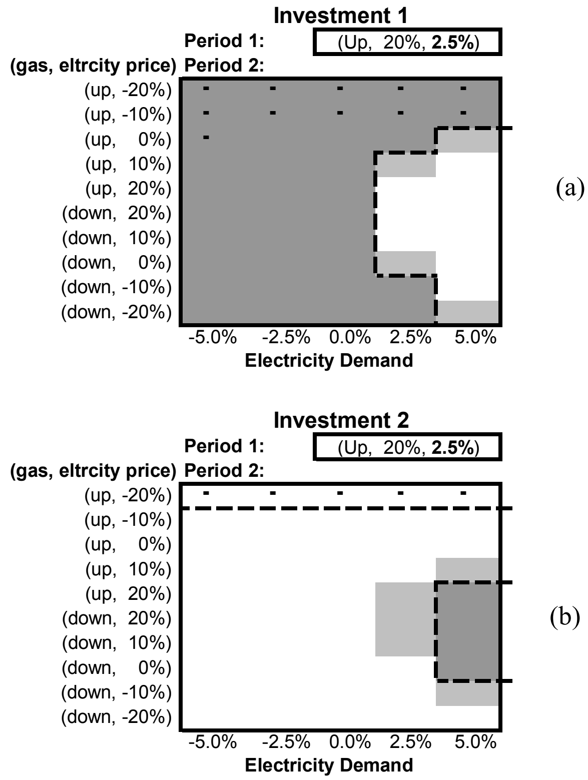

Figure 8. Robustness area for both investments at the end of Period2 (year23), when Period1 is (Up, 20%, 2.5%)

5 Conclusions and Discussions

The liberalization process in the energy markets and the typically long-term life cycle of energy infrastructure contributes to the significant uncertainty of infrastructure projects. This provides ample opportunities to consider the use of real options in making infrastructure investment and design decision. This paper shows that exploratory analysis can be a useful tool to facilitate the analysis. It has demonstrated the insights not gained by traditional practice of sensitivity and decision analysis method, where limited scenarios are considered and a likelihood is assigned to the future scenarios.

The performing of EXA requires the construction of system model that describes the relevant elements of the system of interest and their relationships. The EXA starts by modeling plausible scenarios on how uncertain variables will develop in the future. The choice of increments of the percentage change for uncertain variables is part of the exploration. As the uncertainty space to explore becomes almost infinite, it will require an insightful sampling of the space to find useful insights. In practice, the computational experiments can start very roughly, to first identify the general pattern of the investment performance, the regret value. Subsequently, areas that border the successful and failure investments can be more closely examined. Critical for getting the insight on the pattern of system performance is the availability a display system. An intelligent algorithm needs to be built in the display system for this purpose.

The insights of the value and regret value of real options provided by EXA can support decision maker in making a decision on whether or not to create such options. That decision is based on the weighing of two considerations:

- The risk of having increased negative NPV area when the option is underutilized and
- The high potential value of the options and the value of not having to make a completely new investment when conditions turn out better than expected.

The case study provided in this paper is a simple one. The expansion of the case can include the following:

- To include model structure uncertainty (e.g. technical uncertainty and more elaborate relations between supply, demand and prices).
- To study other types of option such as an option to expand or discontinue a project.
- To look at a combination of variety of energy generating technologies (e.g. thermo plant and hydro plant), since each has a different ratio between sunk costs and operating costs.
- To expand and refine the time periods of analysis.

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Appendix

Formulation of the Investment model in Electricity power plant.

$$NPV = \sum_{t=4}^{23} \frac{Revenues_t - Operating.Costs_t}{(1+r)^t} - \frac{Invest.Costs_t}{(1+r)^t} \quad (4)$$

Revenue formulas:

$$Revenues_t = Used.capacity_t \text{ x } Eltrcity.Price_{Period(i)} \quad (5)$$

$$Used.Capacity_t = Min\,[Eltrcity.Demand_t, Installed.\ Capacity_t] \quad (6)$$

$$Eltrcity.Demand_{t+1} = Eltrcity.Demand_t \text{ x } (1 + Demand.Growth) \quad (7)$$

$$Eltrcity.Price_{Period(i+1)} = Eltrcity.Price_{Period(i)} \text{ x } Price.Growth_{Period(i+1)} \quad (8)$$

Cost formulas:

$$Operating.Costs_t = Fuel.Costs_t + Fixed.Costs_t + Variable.Costs_t \quad (9)$$

$$Fuel.Costs_t = [Heat.Rate_t \text{ x } Used.Capacity_t \text{ x } Utilization_t] \text{ x } Gas.Price_{Period(i)} \quad (10)$$

$$Gas.Price_{Period(i+1)} = Gas.Price_{Period(i)} \text{ x } Multiplicative.Factor_{\,Upward,\ Downward]} \quad (11)$$

$$Fixed.Costs_t = Fixed.Cost.Parameter_t \text{ x } Installed.Capacity_t \quad (12)$$

$$Variable.Costs_t = Variable.Cost.Parameter_t \text{ x } Used.Capacity_t \text{ x } Utilization_t \quad (13)$$