Optimal Strategies for Investment in Generation of Electric Energy through Real Options

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SUMMARY

The Brazilian electric sector has two market-environments for the energy supply: a regulated pool (ACR), with 64 power distribution companies, and the free market (ACL), including free-consumers and energy wholesalers. In the regulated market, the power generation competition is enforced via energy auctions, where the winning generator has to sign long-term standard power purchase agreements (PPA) simultaneously with all distributors at the bidding-price. In this work we use the Real Options Theory to valuate new hydraulic generation assets, which will be traded in the new energy auction. This approach models the uncertainties in setting up the cash flow for the investments and incorporates some possible managerial flexibility associated with the decision taken along the investment forecast. A real example is presented, in which we incorporated the flexibilities regarding the waiting to invest in a new hydro power plant and an abandon option, representing the transfer of concession rights. Since the project involves a multistage investment consisting of design, construction and operation phases, it can be treated as a sequential compound option. A binomial approach was elaborated to model this investment opportunity analysis.

KEYWORDS

Power Generation Investments, Real Options, Investment Analysis.

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1. Introduction

The current Brazilian electrical sector regulation is based on centralized planning that aims at attracting the private capital investments needed for power generation expansion consistent with the characteristics and singularities of the country. The main goals of the current regulation are to guarantee the required power generation expansion, to promote reasonable tariffs at the lowest feasible cost, and to integrate social goals into the sector through an electric energy universalization program

The Brazilian electric sector has two market-environments for the energy supply: a regulated pool (ACR), with 64 power distribution companies, and the free market (ACL), including free-consumers and energy commercializers. In the regulated market, the power generation competition is enforced via energy auctions, where the winning generator has to sign long-term standard power purchase agreements (PPA) simultaneously with all distributors at the bidding-price.

In the Brazilian electric system, about 90% of the electric power generation (91 GW) is hydraulic. They exploit a large, complex and highly integrated system that provides energy at low prices for long time periods, but that it is very vulnerable to water inflow uncertainty. The PPA signed at the new auction, complies with the energy availability modality, doesn't present any hydraulic risk to the generators. The costs of the hydrological risk are undertaken by the buyers, which guarantee their relaying to the final consumer [1].

Due to its importance for creation of value for the shareholders, the investment decision has always been of academic and managerial interest. With the discounted cash flow method (DCF), introduced in the 1950's, the value of a project is determined by discounting the future expected cash flows at a discount rate that takes into account the risk of the project. However, despite its advantages over the payback method, both methods have a static nature implying that, once the firm commits itself to a project, the project's outcome will be unaffected by future decisions, thereby ignoring any managerial flexibility the project may have. This management flexibility has value, and represents the real options associated with the project [2]. The real options approach to valuation and investment decision-making quantifies the effects of risk, identifies opportunities to accelerate, modify or abandon projects. In the volatile but extremely high potential new economy scenario, understanding the option value is absolutely critical.

Interesting papers which treats on Brazilian generation investments could be found in [3]-[5].

In this work we use the Real Options Theory to valuate new hydraulic generation assets, which will be traded in the new energy auction. This approach models the uncertainties in setting up the cash flow for the investments and incorporates some possible managerial flexibility associated with the decision taken along the investment forecast. A real example is presented, in which we incorporated the flexibilities regarding the waiting to invest in a new hydro power plant and an abandon option, representing the transfer of concession rights. Since the project involves a multistage investment consisting of design, construction and operation phases, it can be treated as a sequential compound option. A binomial approach was elaborated to model this investment opportunity analysis.

2. The Brazilian Electricity Market

Since 1997, the Brazilian government has attempted to introduce competition in the Brazilian electricity sector. Nevertheless, the Law 10848 enacted in 2004 created some drawbacks in this process. It established two market environments: a regulated and a free environment. The agents can freely establish bilateral contracts of buying or selling electricity under the free environment (ACL). The only constraint is related to the consumer that needs to have a load above 3 MW. The previous legislation supported these contracts and a schedule was proposed to alleviate the load constraint. The completion of the schedule would occur in 2006 when only a free market would exist with the spot market and the bilateral contracts. The new law created the regulated environment (ACR) where all distributors are obliged to participate. The generators and distributors make the contracts following the guidelines of the Brazilian Energy Commercialization Agency (CCEE), a kind of clearing house with additional power, which is under the government rules. These contracts result from an auction conducted by the Brazilian Regulatory Agency (ANEEL). The distributors need to previously inform their electricity demand to ANEEL for the coming five years. With this data, the Ministry of Mines and Energy (MME) established the amount of energy to be bought for the next few years. The time span of the contracts varies from 5 to 20 years and it is established before each auction. The longer contract period is devoted to new generation plants in order to stimulate increments in generation capacity.

Therefore, the generation agents can choose if they want to sell energy to distributors or directly to consumers. The problem is that the energy transacted in the regulated environment represents almost 90 % of the total demand. Moreover, the long-term contract assured by the distributors after the auction process means that the risks of over or under capacity are transferred to the consumers. In other words, the consumers buy the capacity, not the energy.

For existing generators, i.e., agents who already have generation assets, they can choose selling their energy:

- to the free consumer and establish the bilateral contract by setting quantity and price;
- to the distributors participating in the government auctions and accepting the conditions of the standard contracts (usually with a maximum period of 8 years); or
- on the spot market.

For agents who are planning to invest in new power plants, there are also three options:

- participate in the government auction selling the energy to the distributors. In this case, the contracts are standard and usually are for a period up to 20 years.
- try to find a consumer to buy their energy in a long-term condition
- sell their energy on the spot market

There are at least two rounds of auctions each year: one for the existing energy and another for the new energy. For the existing energy the contracts are made starting from the next year and with a period no longer than 8 years. The total energy involved is usually related to the expired contracts or new loads, which were not covered by the long-term contracts. The prices are guided by the current prices of the spot market and therefore the option of selling to the spot market may be relevant.

For the new energy, there are basically two kinds of contracts or two kinds of products: the one whose delivery starts five years ahead with a contracted period of 15 to 20 years (A–5) and other whose delivery starts three years ahead with the same contracted period (A–3). The amount of energy negotiated in A–3 represents an adjustment of the A–5 in order to match the demand. For instance, in this year (2006) there would be a round of auctions for A–5 contracts in which delivery starts in 2011. There would also be a round of auctions for A–3 contracts whose delivery starts in 2009. In the latter case, the negotiated amount captures the difference between the load predicted for the year 2009 two years ago (2004), and the energy contracted in the auctions for A–5 that took place also in 2004.

The creation of these types of contracts and the correlated government auctions was a response to the late rationing that took place in 2001. Thus, the main objective was to establish a more secured environment for the generation investors based on long-term contracts.

Although the government contracts represent a guaranty against electricity price fluctuations, there are still a lot of uncertainties that the generation agents need to deal with. Besides the common causes that affect the investment, like interest rates, construction costs, equipment costs, labor costs, there is one that has caused many headaches to the generation investors, namely the environmental regulation, which is crucial especially for hydro plant projects. Many hydro projects have stalled because of environmental problems. Government is trying to overcome them by incorporating a previous environmental license in each new possible generation plant.

3. Hydro-Power Plant Investment Analysis

Given the aforementioned environment, this paper will deal with the new energy, i.e., the long-term contracts which trigger the investments in new generating power plants. For the sake of simplicity, the proposed model will be described in parallel with an example. A real hydro-plant case will be presented and the main data are:

- Installed Power = 120 MW;
- Assured Energy = 66 MW;
- Building Investment Cost = 4 R$/MWh;
- Generation O&M Cost = 7.25 R$/MWh;
- Average Energy Price = 114.23 R$/MWh;
- Working Capital = R$1 million;
- Charge Rate = 5% of Gross Income;
- Tax Rate = 35%;
- Depreciation Rate = 4%;
- Discount Rate = 14%.

This new hydraulic generation asset will be traded in the new energy auction. The calculation of the average price of energy and the average investment cost shown in Table I was made based on the results of the first new energy auction (www.ccee.org.br).

Table I. New Energy Auction Results

	Contracted Energy (avg. MW)	Time (hour)	Energy (MWh)	Price (R$/MWh)
2008-2037	71	262992	8.672.432	106.95
2009-2038	46	262968	12.096.528	113.89
2010-2039	871	262968	234.304.488	114.83
Total Suply (MW)	1008	**Average Energy Price (R$/MWh)**		**114.23**

	Assured Energy (avg. MW)	Investiment (R$)	Investment Cost R$ million/avg.MW	Price (R$/MWh)
Cemig G&T	27,268	165.755.650,80	6..08	115.10
Eletrosul	39	267.595.880,00	6.86	112.55
Furnas	252,13	1.836.545.843,00	7.28	115.17
Orteng	38,5	262.417.880,00	6.82	114.86
Alusa	71,4	490.018.590,00	6.86	111.41
NeoEnergia	40,902	248.633.476,20	6.08	115.10
Total	469,2	6.971.371,10	**6.66**	

The hydro plant project will cost immediately R$1 million for environmental studies, which will take a year to complete. At the end of that year, the firm could invest R$5 million to complete the design stage. A simulation was made using the average energy price, R$ 114.23 per MWh, and the average investment cost derived in the last auction, R$ 6.66 million per average MW. With an assured energy of 66 MW, an investment of 6.66 x 66 = R$ 439 million is necessary, being 10 % down, and 45 % in the next two years. The IRR found without consider any financial leverage is 8.49%, so, there is no incentive in building this new plant based on the energy prices derived in the last auction.

A sensitivity analysis was made, using the average energy price, R$ 114,23 per MWh, and a discount rate of 14% [6], much more attractive, in order to calculate the minimum price and the highest possible investment cost, which, based on this data, the investment becomes viable. The minimum price found is R$186.29 and the highest possible investment cost is R$3.93 million per average MW. In our base case we use an investment cost of R$4 million per average MW.

Since the project involves a multistage investment, it can be treated as a sequential compound option: a R$1 million investment creates the right to invest R$5 million in one year, and the exercise of that choice creates the option to invest R$264 million to build the plant or the option to abandon the project, representing the transfer of concession rights that worth, we suppose, the gross income of a year, above R$66 million.

The investment analysis regarding this plant will be made in four steps that are usually followed when real options are incorporated into a binomial model [7], namely:

- Calculation of the present value with no flexibility, using the traditional discounted cash-flow (DCF) method;
- Building of an event tree, based on the set of combined uncertainties that drive the volatility of the project. The event tree models the set of values that may be taken through time by the underlying risk asset;
- Incorporation of the flexibilities, by building a decision tree. The decision tree shows the payoffs from optimal decisions, conditional on the state of nature. Therefore, its payoffs are those that would result from the option that is being valuated;
- Calculation of the real option value, by valuating the payoffs in the decision tree by means of risk-neutral probabilities;

3.1. Traditional Investment Analysis

Modeling the asset value involves elaborating an event tree, which shows the possible future values of the plant under plausible market scenarios [8]. Therefore it is necessary to estimate the value that the plant would have if it existed today, supposing it were immediately operational, using traditional valuation techniques, such as the discounted cash flow presented in Table II and Figure 1.

Table II. Traditional Investment Analysis R$

Year	Gross Income	Costs	EBITDA	Depreciation	EBIT	Taxes	Free Cash Flow
0							(1.000.000)
1							(5.000.000)
2							(25.400.000)
3							(118.800.000)
4							(118.800.000)
5 To 27	66.044.738	7.493.897	47.990.841	10.560.000	47.467.795	16.796.795	41.754.047
28 To 33	66.044.738	7.493.897	58.550.841		47.467.795	20.492.795	38.058.047
34	66.044.738	7.493.897	59.550.841	0	58.550.841	20.492.795	39.058.047
PV =	(R$ 1.787.356)	← Don't Invest					
NPV =	(R$ 2.787.355)	∑PV Operation CF=		172.668.838		∑PV Invest CF=	(175.456.193)
IRR =	13.78 %	< Discount Rate					

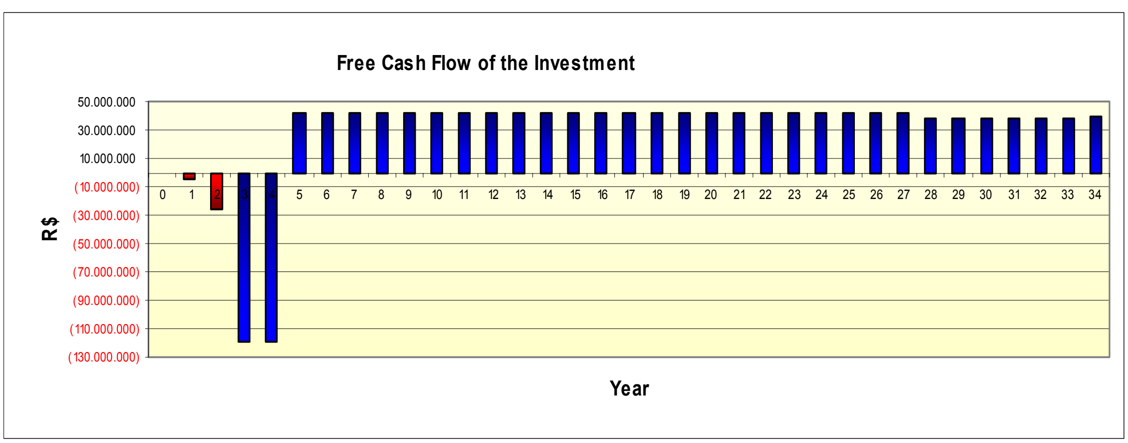


Figure 1. Investment Free Cash Flow

3.2. Monte Carlo Analysis for Project Uncertainty Determination

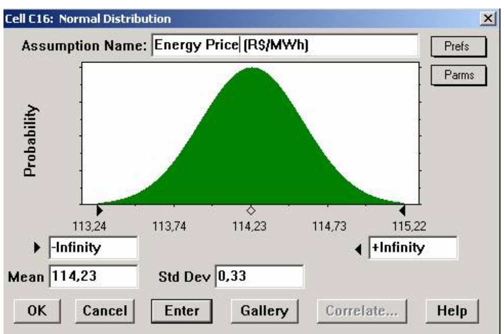
The Crystal Ball® program was used to make the Monte Carlo simulation necessary to estimate the percent variation of standard deviation from project present value along the years, named, the project's volatility [9]. This project return rate is, calculated by

$$Z = \ln\left(\frac{PV_1 + CF_1}{PV_0}\right) \quad (1)$$

where

$$PV_0 = \sum_{t=1}^{T} \frac{CF_t}{(1+WACC)^t} \quad (2) \qquad PV_1 = \sum_{t=2}^{T} \frac{CF_t}{(1+WACC)^{t-1}} \quad (3)$$

In the Crystal Ball® program, using the spreadsheet for cash-flow calculation, the uncertainty variable correspondent to the energy price was defined as Crystal Ball® assumption, using a normal distribution, with mean 114.23 and standard deviation of 0.33, shown in Figure 2-a.



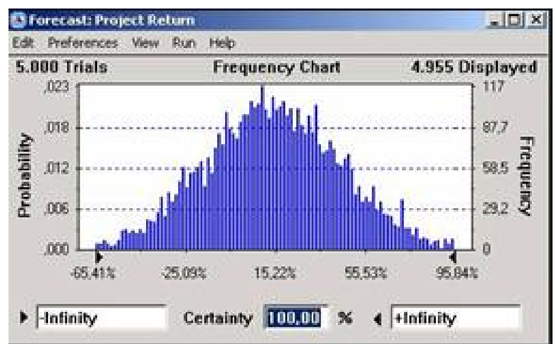


Figure 2. (a) Monte Carlo Simulation Assumption Definition for Energy Price Uncertainty

(b) Project Return Rate resulted from Monte Carlo Simulation

The spreadsheet cell containing the Z value was defined as the simulation forecast. During Monte Carlo simulation, the Z value distribution is obtained keeping constant the PV_0 value and leaving PV_1 and CF_1 varying according to the uncertainties introduced as assumptions. So, $Z = \ln\left(\frac{PV_1 + CF_1}{-1{,}787{,}355.73}\right)$

A simulation was made with five thousand trials, whose result is shown in Figure 2-b. The standard deviation value of the rate of return on the project is 31 %.

3.3. The Event Tree

The calculated uncertainty is applied in making an event tree. The event tree models the set of values that the asset subject to risk may assume along the time. The equations from binomial model used for the event tree are:

$$\Delta t = \frac{y}{N} \quad (4)$$

$$u = e^{\sigma\sqrt{\Delta t}} \quad (5)$$

$$d = e^{-\sigma\sqrt{\Delta t}} = 1/u \quad (6)$$

where:

y=option expiration time in years

N=quantity of tree steps

r=interest rate per year (continue capitalization)

σ= project volatility

$$p = \frac{\left(e^{(r-b)\Delta t} - d\right)}{(u-d)} \qquad (7)$$

b= dividends rate

p = rising movement probability

u = growth rate of rising

d = Reduction rate asset-object

This tree may be constructed by a very simple and practical procedure. Initially the present value of the asset is introduced in step 0. The other elements of the first line are calculated multiplying the previous element by u. Each remaining element is obtained multiplying the element from previous column at the previous line by d. The constructed event tree is shown in Table III.

	First Option	Second Option
Tree Steps Quantity	4	
Option Expiration Time (years)	1	3
Project Volatility	31%	
Project PV	R$172.668.837	
Risk Free Rate	6,00%	
Dividends Rate	0,00%	
Exercise Price	R$5.000.000	R$ 254.232.000
Initial Investment	R$1.000.000	

Intermediate Calculations	
Δt =	1,0000
u =	1,3634
d =	0,7334
p =	52,13%

* R254.232.000 is the Investment Present Value in the year 3 corrected by 14%: 26.400.000/1,14^{-2}+118.800.000 /1,14^{-1}+118.800.000 /1,14

Table III. Event Tree

Step 0	Step 1	Step 2	Step 3	Step 4
172.668.837	235.421.029	320.978.944	437.630.753	596.676.760
	126.643.433	172.668.837	235.421.029	320.978.944
		92.886.241	126.643.433	172.668.837
			68.127.130	92.886.241
				49.967.636

The tree shows the evolution of the plant values at each stage of the project's life. In the traditional valuation, we calculated that if the hydro plant existed today, its operation present value would be 172.668.837. With a sigma of 31%, the up and down factors are 1.3634 and 0.7334, respectively. In the first year the plant will be worth either 235.421.029 or 126.643.433 and at the end of the fourth year it will range from 49.967.636 to 596.676.760.

3.4. The Decision Tree

For the mentioned example, starting from a backward analysis on decision tree, it is possible to valuate the option to construct the plant. The valuation begins in the last tree columns. Therefore, in the last period the option value is calculated as follows:

$$V = Max[S - X;0] \qquad (8)$$

where V = Real Option Value, S = Event tree PV and X = price to exercise the option.

Table IV. Second Investment Option (construction phase) valuation Tree

Step 0	Step 1	Step 2	Step 3	Step 4
33.769.648	61.803.793	111.553.071	197.789.244	342.444.760
	7.805.460	15.961.590	32.640.272	66.746.944
		0	0	0
			0	0
				0

That is to say, when the project present value (S) calculated onto event tree is higher than the invested value (X), that is, the exercise price, the option should be exercised and its price will be S – X. Otherwise, the option should not be exercised, and its value is zero. For example

$$V = Max[596.676.760 - 254.232.000 \ ; 0] = 342.444.760$$

Each previous step is evaluated using the replicating portfolio method to estimate the value of the project if it were kept alive. For example

$m\ 596.676.760 + (1+r_f)B = 342.444.760$

$m\ 320.978.944 + (1+r_f)B = 66.746.944$

$m = \frac{(342.444.760 - 66.746.944)}{(596.676.760 \ - 320.978.944)}$

$B = (66.746.944 - m * 320.978.944) / (1 + r_f)$

$B = (66.746.944 - m * 320.978.944) / (1 + 0.06)$

	Step 3	Step 4
EVENT TREE	437.630.753	596.676.760
		320.978.944
OPTION VALUATION TREE	197.789.244	342.444.760
		66.746.944

Portfolio = m * 437.630.753 + b = 197.789.244

$V = Max[S - X; Portfolio] = 197.789.244$

$V = Max[437.630.753 - 254.232.000 \ , 197.789.244]$

Where:

m = number of units of the underlying asset in the portfolio

b = Quantity of portfolio risk-free bonds

We used the second option valuation tree as input to valuate the options to invest R$5 million to complete the plant design, an American call option, or the transfer of concession rights, a European put option.

$$V = Max[61.803.793 - 5.000.000,00;66.000.000 – 5.000.000 - 61.803.793; 0] = 56.803.793$$

Table V. First Option (invest R$5 million design phase) valuation Tree

Step 0	Step 1	Step 2	Step 3	Step 4
51.948.508	56.803.793	111.553.071	197.789.244	342.444.760
	53.194.540	15.961.590	32.640.272	66.746.944
		0	0	0
			0	0
				0

The right to invest R$5 million in a year's time is also determined by using the replication portfolio technique for either 56.803.793 or 53.194.540, resulting 51.948.508, which constitutes 50.948.508 more than the R$1 million initial cost of the project. This contrasts with the net present value of minus 2.787.355 calculated with no flexibility, using the traditional discounted cash-flow method.

The decision tree shows the optimal strategies to be applied to the investment forecasting.

Table VII. Project Decision Tree

Step 0	Step 1	Step 2	Step 3	Step 4
Invest R$1 mi	Invest R$5 mi	wait	wait	Invest R$254 mi
	Transfer Rights	wait	wait	Invest R$254 mi
		wait	wait	Don't Invest
			wait	Don't Invest
				Don't Invest

4. Conclusion

This paper presents a methodology to analyze the opportunity of new investment in electric generation considering the new market framework established by the Law 10884/04. The introduction of buying auctions conducted by the government to guarantee long-term contracts may be interpreted as a means of diminishing the generation risks but also a new limitation for the free market. The decision making was treated in this paper incorporating the real option valuation under this new environment.

The investment opportunity for a small power plant was analyzed throughout the paper emphasizing the usefulness of the methodology. The binomial approach was used to model the real option because of the inclusion of combined options into the analysis. The use of stochastic dynamic programming [10] in this particular case with combined options would bring more complexity to the problem without considerable gain. The advantage of the binomial approach is that it enables us to solve a much wider range of problems than the Black&Sholes [11] formula, which can be used to value financial options, but it is not appropriate for real options, because it requires a very restrictive set of assumptions that do not usually hold for project valuation.

In this particular example, with an assured energy of 66 MW and a capacity of 120 MW, it was proved that there is no incentive in building this new plant based on the energy prices derived in the last auction, R$ 114.23 per MWh. The reasonable price should be above R$186.29 per MWh without considering the managerial flexibilities. According to the traditional analysis of the base case, with energy price of R$114.23, 14% of discount rate and a building investment cost of R$4 millions per avg.MW, the investment must be rejected due to its NPV of minus R$2.787.355. Considering all the flexibilities available in the market such as transferring the concession, selling the energy to the free market, etc. the calculated NPV is R$50.948.508 due to the aggregated value of the options.

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