



## **APPLYING THE REAL OPTIONS THEORY TO EVALUATE SMALL HYDROPOWER PLANTS**

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### **Abstract**

In recent years, small entrepreneurs in Brazil have been authorized to set up Small Hydropower Plants (SHP), even if they lack the economic and financial capacity to build them. Many projects are extremely delayed according to their construction schedule, and in numerous cases the construction phase never starts. It seems that there has been speculative behavior over the planning of potential SHPs without the required financial plan to implement them. After receiving permission to set up an SHP, an entrepreneur can postpone construction for a certain period of time. The objective of this article is to apply the Real Options Approach to the managerial flexibility of delaying an SHP project during the 2004-2008 period. The results suggest that the deferral option has significant value, because the entrepreneur can wait until prices are high to sell the energy or the authorization. This estimation can serve as a guide to ANEEL on how to promote actions that prevent this kind of speculation, such as increasing the value of the deposit required for receiving authorization.

Key-words: Real Option, Small Hydropower Plants, Deferral Options, Binomial Model, Risk Neutral Valuation

### **Resumo**

Nos últimos anos, pequenos empreendedores obtiveram a autorização para implantação de Pequenas Centrais Hidrelétricas (PCHs) mesmo sem terem capacidade econômico-financeira para empreendê-las. Observa-se um elevado número de empreendimentos com obras excessivamente atrasadas ou que sequer saíram do papel e a existência de um comportamento especulativo de mapeamento de potenciais de PCHs, sem a existência de um planejamento financeiro para implantá-las. Após obtenção de autorização para explorar a PCH, o empreendedor pode adiar o início da construção durante um período de tempo determinado. O objetivo desse artigo é aplicar a Teoria de Opções Reais à flexibilidade gerencial de adiamento de um projeto de PCH, durante o período de 2004 a 2008. Os resultados indicam que a opção de adiar o investimento na construção de uma PCH gera valor significativo para o empreendedor, pois é possível aguardar um momento favorável de preços para vender energia ou a autorização. Essa estimativa pode servir como guia à ANEEL em promover ações que inibam esse tipo de especulação, como por exemplo, aumentar o valor do depósito de garantia para a concessão da outorga.

## **I. Introduction**

According to ANEEL (Brazilian Electricity Regulatory Agency), the definition of a Small Hydropower Plant (SHP) is a plant with reservoirs of less than 3 km<sup>2</sup> and installed capacity below 30MW. They account for 2.29% of Brazil's total energy generation capacity. Small entrepreneurs can get permission to set up an SHP even if they lack the economic and financial capacity to undertake such a venture. Thus, many entrepreneurs obtain the permits and sell the projects to wealthier investors. There are a large number of enterprises with excessively delayed works or that have never even left the drawing board, which has prompted speculative behavior in the market for SHP grants, without the existence of financial resources to construct them. After obtaining permission to set up an SHP, the entrepreneur can exercise an option to postpone the start of construction for a fixed period of time.

Real Options Approach can reveal whether the decision to defer the investment in constructing an SHP creates value for the developer, because they could wait until energy prices are favorable to sell energy or the authorization. The main source of uncertainty about an SHP's cash flow is regarding the final energy price and choosing the best moment to seal the contracts for purchase and sale of energy, which is important for the profitability of projects. The managerial flexibility of deferral, which allows one to choose the best time to seal the contracts, must then be incorporated in the assessment of projects.

The remainder of this paper is structured as follows: Section 2 presents an overview of the current regulation of the electricity sector regarding the process of granting permission for SHPs and the commercialization of energy, citing the existence of the deferral option for SHP construction. Section 3 presents a brief literature review of real options and their application in the electricity sector. Section 4 describes the model developed to price the deferral option and the model used to quantify the volatility of returns of SHPs. Section 5 presents the results and analyzes them in light of the sector's regulatory framework. Section 6 presents a conclusion.

## **II. Managerial Options involved in an SHP Grant**

Small Hydropower Plants (SHPs) are generation centers limited to an installed capacity of 30 MW and a reservoir of not more than 3 km<sup>2</sup>, as defined by the Atlas of Electrical Energy, ANEEL.

According to the Bank of Information Generation (BIG) and information from ANEEL's Atlas of Electric Energy, Brazil had, in November 2008, 1,768 power plants in operation, corresponding to an installed capacity of 104,816 MW (megawatts) - a figure that excludes the Paraguayan participation in the Itaipu plant. There are 159 hydroelectric plants, 1,042 thermal power plants supplied by different sources (natural gas, biomass, diesel and fuel oil), 320 SHPs, two nuclear stations, 227 central hydroelectric plants and one solar plant. This segment has more than 1,100 regulated agents including public service suppliers, traders, self-producers and independent producers. Thus, SHPs represent 2.29% of installed capacity in the country. Another constant in this report stands out: there are 166 small hydropower plants, accounting for 2.43 GW of potential power that has not been installed, which were authorized between 1998 and 2008 and whose construction has not begun.

The procedures for registration, preparation, acceptance, analysis, selection and approval of the basic project, as well as the authorization of potential hydraulic power with SHP characteristics, are governed by Normative Resolution No. 343 of December 9, 2008, issued by ANEEL.

This resolution has been amended, according to voting opinion, and an annex to

Resolution No. 343 and process No. 48500.003159/2007-56 of Mr Edvaldo Aleves de Santana, director of ANEEL, means that the entrepreneur is now subject to stricter deadlines and guarantees, which substantially limits speculation with approved inventories.

The problem of projects that are delayed or have not even left the drawing board is partly a result of poor-quality engineering projects that often need to be revised. However, uncertainty about the behavior of energy prices may cause speculative behavior with the inventories. When there is an expectation of rising energy prices, inventories increase in value and it becomes attractive to sell them. Likewise, when the expectation of the energy price is low, it is in an inventory-holding entrepreneur's own interest to wait for a more favorable time to develop the project or sell it to another entrepreneur who has the economic and financial capability to undertake such a venture.

From the date of the previous rules, ANEEL Resolution No. 395 of December 04, 1998, until the new regulations of 2008, there were many purchase transactions of SHP construction permits. It is a fact that during this period, many small entrepreneurs raced to plan and obtain the greatest possible number of construction permits, regardless of their financial and managerial capacity to construct these projects.

## II.1 Forms of Energy Trading

The rules for energy trading are set forth in Law 10,848 of March 15, 2004, also known as the New Model Law of the Electricity Sector. This law created two markets for power trading: the Regulated Contracting Environment (RCE) and the Free Contracting Environment (FCE).

According to current regulations, public service utilities, permit-holders and authorized electricity distributors must ensure compliance with all of their market by contracting energy in the RCE. From the entrepreneur's point of view, there is no legal determination on the minimum percentage of energy sales from an SHP on the RCE or FCE, unlike for large hydroelectric plants, where during a bid ANEEL indicates the minimum percentage of the sale of energy destined for the RCE. In recent years, the minimum percentage for hydroelectric plants was 70%, as was the case with the bids for the hydroelectric dams of Jirau, Santo Antônio, Mauá, Dardanelos, among others.

The contracting of energy on the RCE occurs under the following conditions: (a) for electricity from existing generation projects: delivery begins the year following the bidding and the contracting period is between 3 and 15 years; (b) for the electrical energy from new generation projects: delivery begins in the 3rd or 5th year after the bidding and the contracting period is between 15 and 35 years; (c) for adjustments to ensure that all the energy needed to meet the market of each utility distributor: limited to 5% of their respective loads with delivery beginning at the distributor's discretion and the contract period running for up to 2 years, as defined by the grantor. Law 10,848/2004, in art. 2, paragraph 6, defines New Generation Ventures as:

(...) those who up until the start of the bidding process for ongoing expansion: I –are not holders of concession, permit or authorization grants, or II - are part of an existing enterprise that will eventually be the subject of enlargement, restricted to capacity growth (...)

In addition, utility distributors may acquire energy that comes from: (a) distributed generation: observing the feed-in tariff and contract limits, based on the regulated market reference value and respective technical conditions, (b) power plants that produce electricity from wind sources, small hydroelectric and biomass centers, which are part of the first stage of the Program of Incentives for Alternative Sources of Energy - PROINFA or (c) the Binational Itaipu Dam. Distributed generation (DG) is a term used to describe electrical generation that takes place at the same place (or near to) where energy is consumed, regardless of power, technology and energy source.

The purchase and sale of energy involving utility agents and authorized providers, traders and importers of electric energy and the consumers that meet the conditions laid down in Articles 15 and 16 of Law No. 9,074 of 7 July 1995, called free consumers, can occur in the FCE.

Law 9,074, article 15, second paragraph, defined the profile of a consumer who can become free:

(...) consumers with a capacity equal or greater than 3,000 kW, supplied at a voltage equal or greater than 69 kV, may choose to purchase electricity from any utility, grantee or authorized electricity provider of the same grid system.

The law also gave free consumers the access rights to a public utility's distribution and transmission system, upon payment of the cost of transportation involved, calculated in accordance with criteria set by the grantor.

Finally, Law 9,074, under article 16, guarantees new customers (i.e. consumers who became established after the publication of this law) with capacity greater than 3,000 kW, regardless of the voltage to which they are connected, the right to become free consumers.

Subsequently, ANEEL ruled via Resolution No. 247 of 21 December 2006, conditions for commercialization of energy on the FCE, originating from renewable sources ventures, for consumers whose capacity is equal or greater than 500 kW. The capacity restriction can be applied also to an economic group, i.e., several industrial units of the same economic group can add together their respective capacities to reach the 500 kW limit. In this case, all plants must have the same registration number. This profile of consumer is now called the special free consumer. For these consumers, access to the FCE is restricted to purchase of energy from renewable sources, namely: (a) those that take advantage of potential hydraulic power greater than 1,000 kW and less than or equal to 30,000 kW, destined for independent or self-production, maintaining the characteristics of a small hydroelectric plant (b) enterprises with installed capacity not exceeding 1,000 kW, (c) enterprises based on solar, wind and biomass sources, whose installed capacity is less than or equal to 30,000 kW.

The sale of energy in the FCE is defined in Article 10 of Law 9,648, May 27, 1998, which covers short-term operations through settlements at the CCEE (Electric Power Commercialization Chamber) up to contracts of 15 years or more. The operations are formalized through contracts of purchase and sale of energy, with price conditions, deadlines and other contract characteristics being freely negotiated between the involved parties.

Article 4 of Law 10,848 created the CCEE, a non-profit, private, civil organization company, under authorization from the Grantor, and regulated and controlled by ANEEL, in order to facilitate electricity trading.

CCEE's role is to facilitate the electricity trading in the National Grid System in the Regulated and Free Contracting Ambiences, and carry out accounting and financial settlement of spot market transactions. The CCEE is responsible for investigating and disclosing the Settlement Price Difference (PLD) of the spot market. The PLD is the price to be disclosed by the CCEE, calculated in advance, with a maximum periodicity of a week, and based on the Marginal Operation Cost (MOC) or marginal cost of energy production, limited by minimum and maximum prices, valid for each period of assessment and for each submarket, for which electricity sold in the short-term market is valued.

The short-term market is the CCEE segment where the differences between the contracted amounts of electricity are commercialized and recorded by the agents and the amounts of generation or actual consumption recorded and attributed to their respective agents.

According to the CCEE, contracts are considered short-term if they are less than 6 months and considered long-term if they are over 6 months, as defined in the website CCEE: <http://www.ccee.org.br/>

The Energy Reallocation Mechanism ("ERM") is a mechanism for sharing hydrological risk associated with the optimization of the National Grid System's (SIN) electro-energy, concerning the centralized dispatch of electricity generation units.

## *II.2 Generation Investors - Market for Exercising Put Options*

One of the options to be studied in this work is the selling of the grant to electricity generation investors.

The profile of SHP grant buyers consists of both strategic investors and financial investors.

Strategic investors are mostly power generation utility companies, seeking to expand their portfolio of installed energy capacity. Some of these utilities even have a contractual obligation to expand their installed capacity. This is the case with Duke Energy International, Geração Paranapanema S.A. and AES Tiete S.A., who won the bids for privatization of power-plant utilities in Sao Paulo state during the late 90's. One of the obligations laid down in the privatization bidding was that they extend installed capacity by 15% within eight years.

Financial investors consist of Private Equity Investment Funds and Pension Funds. These investors believe that the electricity sector provides the opportunity to invest in real assets similar to fixed income.

During the period between the regulations of ANEEL Resolution No. 395 of 1998 and the new Resolution No. 343 of 2008, several SHP licenses were sold to strategic investors and financial investors.

To estimate the value of SHP managerial flexibility, the tree of expanded net present value of the project will consider at each issue the greater value of the following alternatives: (i) postponing the construction of the asset, (ii) selling the project to a third party; (iii) investing in the construction of an SHP.

### **III.Literature Review**

Copeland, Weston and Shastri (2005) compared the net present value (NPV) method of evaluation with the real options method. According to the authors, the NPV decision model is quite simple. The model calculates the expected value of cash flows of a project discounted by the weighted average cost of capital which is then subtracted from the investment. If the NPV is positive, then this generates wealth for the shareholders and the project should be developed.

NPV method discounts the most probable cash flow projections by a risk adjusted rate, while real option approach incorporates the value of managerial flexibility in the traditional NPV analysis. In our case, the managerial flexibility is the option of deferring the investment.

According to Copeland, Weston and Shastri (2005), three main assumptions support the use of the Real Options Theory in evaluating projects: (1) The traditional present value of the project, which does not take into consideration flexibility is the underlying asset; (2) real options are valued in a no arbitrage world and (3). Project's present value of cash flows fluctuates randomly. This result comes from a demonstration made by Samuelson (1965).

The literature on modeling long-term energy prices deals with the behavior of a series of prices in a similar way to the components of the energy price fluctuations in the short-term market. London (2007) points out that energy prices are heavily dependent on consumer demand and its determinants, including activity level and weather conditions. Obstacles to energy storage and transport can make unviable the application of assessment tools based on arbitrage over time and space. According to the author, in the long-term, energy prices are expected to be heavily dependent on time supply and demand. The author states that energy prices exhibit characteristics that are a result of their dependence on supply and demand: mean reversion, cyclical variations and price spikes at certain times. Given these characteristics, the series of energy prices are not well adjusted to Geometric Brownian Motion (GBM). The author proposes the use of processes with jumps and analyzes models of one and two-factor mean-reversion LogNormal jumps.

Associating the behavior of long-term energy prices with a process similar to Geometric Brownian Motion (GBM) has been a tendency in the literature, such as in Caporal & Brandão (2008), Castro (2000), Teisberg (1994) and Ethier (1999), who compared this method with a model of mean reversion with jumps. Some of these authors applied GBM analysis to model the value of a power plant asset, for example Teisberg (1994), who identified, however, that the source of uncertainty about the asset value lay in the volatility of energy prices.

Deng, Johnson & Sogomonian (1998) constructed a pricing model for a thermal

energy plant, valuing energy as a function of the spot price of energy, of fuel prices and of the consumption rate of the generating equipment.

Gomes, Baidya & Melo (2008) presented an energy pricing model for the short-term market as a function of variations in marginal system operation costs.

This paper models the energy price uncertainty using a historical Monte Carlo approach, based on observed prices, avoiding this way parameterization of energy price, like Geometric Brownian Motion or jump processes. Energy price scenarios reproduce energy contracting observed during the period 2004 to 2008, using a representative sample of contracts. Different energy prices result in different present values for SHP project. We use the return volatility of these scenarios to build the binomial model lattices (trees).

Caporal & Brandão (2008) applied the real options theory to an SHP to assess the flexibility of selling energy in the short-term or long-term market. Their assessment of an SHP was 35% higher than the rating that did not consider the value of flexibility. In their assessment, the authors did not include the flexibility of postponing the start of construction since they considered the start of investment as mandatory, once authorization has been received. For reasons explained in section II of this work, this option cannot be ignored and the important regulatory change brought by ANEEL Resolution 343/2008 aims, in fact, to minimize the importance of this flexibility. It is important to note, however, that the deferral option cannot be ignored in the period between 2004 and 2008, as studied by this paper.

## **IV. The Model**

This chapter is structured in three parts. The first part describes the method used for simulating long-term energy prices. The second part estimates the volatility of returns of SHP cash flows. The third part details the type of options, based on binomial lattices trees.

### *IV.1 Simulation of Energy Price Behavior*

The SHP's return volatility is highly correlated with long-term energy price. Except for the revenue, the SHP's cash flow's components are quite predictable.

To simulate the behavior of energy in the long term, we collected prices of electricity contracted by distribution utilities. We considered only the RTE contracts, since FCE contracts are not public information. We analyzed 137 technical notes, corresponding to the tariff review processes of major national distribution companies. In addition to the tariff review processes, cases of tariff adjustment were analyzed. In both cases, ANEEL publishes the position of procurement of energy that the utility possesses, in order to pass the cost of these contracts on to the end user.

We analyzed the following tariff revision and repositioning of the following distribution companies: AES SUL, AMPLA, BANDEIRANTES, CAIUÁ, CEAL, CEB, CEEE, CELESC, CELG, CELPA, CELPE, CEMAR, CEMAT, CEMIG, COELBA, COELCE, COPEL, CPFL, ELEKTRO, ELETROPAULO, ENERGISA, ENERSUL, ESCELSA, LIGHT, PARANAPANEMA, PIRATININGA and RGE. The analyzed distributors represent about fifty-four million consumers and 239 TWh, or about 90% of the Brazilian consumer market, according to data available on the website of the Brazilian Association of Electricity Distributors ("ABRADEE"): [http://www.abradee.org.br/dados\\_mercado.asp](http://www.abradee.org.br/dados_mercado.asp), consulted on 20/07/2009.

We also incorporated the New Energy Auctions data, that took place from 2005 to 2008, in which hydraulic energy generation assets were sold to a pool of distributors. We consolidated the data extracted from the processes of tariff revision and repositioning of the distribution utilities with the auctions of the New Generation Projects by seller (generator agent), resulting in a sample of ninety-six long-term energy sales prices.

This study also analyses short-term energy sales. In order to do this, we simulated series of short-term prices. The hypothesis of trading energy in the short-term market during

the period in which the entrepreneur possesses the authority to operate the SHP is, however, unrealistic. It is known that the funding of these projects requires the long-term contracting of energy from an SHP, since the transfer of energy contracts is one of the main guarantees for the creditors of SHP projects. The search by entrepreneurs for financing structures in the Project Finance modality, minimizing the impact of funding on the balance of the shareholders, means that entrepreneurs focus their strategies on negotiating the sale of energy in long-term contracts.

However, some investors may choose to use the strength of their financial statements and balance funding space to use Corporate Finance structures, incorporating energy selling strategies in the short-term market. Thus, the entrepreneur will not require contracted positions of long-term energy, and may be exposed to short-term price fluctuations.

The short-term market takes place at the CCEE, through financial settlement of the contract positions of all the agents of the system. We used the NEWAVE software provided by CCEE to simulate the behavior of short-term energy. This program created two thousand PLD scenarios for the Southeast / Midwest submarket, based on the configuration of the Monthly Program of Electroenergy Operation (PMO), of April 2009, released by the National Electrical System Operator (ONS). The scenarios created by the program cover the period from April 2009 to December 2013.

NEWAVE is the computational model of optimization for medium-term plans. The program allows the calculation of settlement of differences based on the system operation marginal cost, released by ONS.

The Monthly Program of Electroenergy Operation (PMO) is published by ONS. The PMO establishes short-term Electroenergy guidelines in order to optimize the utilization of SIN's generation and transmission resources, in accordance with procedures and criteria embodied in the grid's procedures, approved by ANEEL.

The series created by NEWAVE and used in this paper are equivalent to the result derived from the CCEE round, which uses the PMO released by ONS and adds some operational restrictions and minimum and maximum PLD limits, which are, BRL 16.31 and BRL 633.37, respectively.

This database is used to estimate the volatility of the return of the cash flows of the SHPs in a short-term setting.

#### *IV.2 Estimation of SHP Cash Flow Returns' Volatility*

In order to estimate cash-flow return volatility, we built 96 long-term energy sales scenarios by compiling a database of energy-sales contracts of utility distributors traded in the regulated contracting environment. Additionally, we also estimated scenarios for the short-term energy sales contracts using the two thousand series of PLD, that approximated prices in the short-term market.

We then ran a simulation process in which we projected 5 years of cash flows for each scenario contained in the energy sale contracts database.

The cash flow in each of the 5 years was estimated as follows:

Cash Flow = Net Profit + Depreciation

Net Profit = EBT - Income Tax - Social Contribution on Net Profit

EBT = EBITDA - Depreciation

EBITDA = Net Revenue - Operation and Maintenance Expenses - Fee for using the Transmission System - Administrative Expenses

Net Revenue = Gross Revenue - PIS - COFINS - TFSEE

We considered that there was no re-investment after the commercial operation starts. We ignored working capital investments, since receiving and payment periods are coincident. We calculated the standard deviation of SHP return according to the following expression:

$$R_i = \frac{VP_{1,k}}{VP_0} - 1 \quad (1)$$

Where:

$V_{1,k}$  is the Present Value of the Project in Year 1 according to scenario k.  
 $V_0$  is the present value of the project in the baseline case.

The volatility of returns equals the standard deviation of the k scenarios returns.

We used the following assumptions for estimating the baseline scenario:

Installed Capacity = 30 MW;

Assured Power= 22 MW;

Gross Operational Revenues = Assured Power \* Price Scenario (Short or Long Term) \*

Number of hours in the year;

Baseline Sale Price Scenario = BRL161.15/MWh;

PIS = 0.65% if tax regime is presumed profit and 1.65% otherwise;

COFINS = 3.0% if deemed income and 7.60% otherwise;

TFSEE = installed BRL1.6771/kW;

Operation and Maintenance Expenses= BRL5/MWh;

TUST – Fee for Use of Transmission System= Installed BRL 2.11/kW.;

Administrative Expenses = \$500,000.00/year;

Income Tax = 25%;

Social Contribution on Profit = 9% (Calculation Basis: IT (income tax): 8% on sales and

CSSL: 12% on sales if the company fits the presumed profit regime. If it fits real profit regime, the calculation base for IT and CSSL was either EBIT or gross profit);

CAPEX = BRL 6,000/kW installed (We did not considered reinvestments during the operational phase);

Construction Period = 2.5 years, and the disbursement schedule: 30% in the first year, 55% in the second year and 15% in the remainder;

Operation Period = 27.5 years;

WACC = 8%a.a

The data are based on the assumptions adopted in the National Energy Plan 2030, prepared by the Secretariat of Energy Planning and Development of the Ministry of Mines and Energy for hydroelectric power.

The value of energy sales in the baseline scenario was taken from Technical Note No. 29/2009 - SER/ANEEL, which represents the updated value for the sale of energy of SHPs to Eletrobrás, under PROINFA.

For projecting cash flows, we adopted a criterion for tax optimization: we considered the presumed profit regime if sales were less than BRL48,000,000.00 per year. Otherwise we adopted the real profit regime.

The Inspection Fee of Electric Energy Services (TFSEE) is compulsory for all agents in the electricity sector: generators, distributors, traders and transmitters. The amount collected makes up the budget of ANEEL.

We projected cash flows in real terms and ignored the real oscillation of energy prices over the projection period of each scenario.

Figure 1 shows the cash flow projections for the first 5 years of an SHP in the baseline scenario.

Figure 1 - Projected Cash Flow in the Baseline Scenario for the First 5 years

Rubrica	Unidade	2004	2005	2006	2007	2008
		1	2	3	4	5
Potência Instalada	MW	30	30	30	30	30
Energia Gerada	MWh	192.720	192.720	192.720	192.720	192.720
Meses de Operação	meses	12	12	12	12	12
<b>Receita Bruta</b>	<b>R\$ mil</b>	<b>31.057</b>	<b>31.057</b>	<b>31.057</b>	<b>31.057</b>	<b>31.057</b>
PIS	R\$ mil	(202)	(202)	(202)	(202)	(202)
COFINS	R\$ mil	(932)	(932)	(932)	(932)	(932)
TFSEE	R\$ mil	(50)	(50)	(50)	(50)	(50)
<b>Receita Líquida</b>	<b>R\$ mil</b>	<b>29.873</b>	<b>29.873</b>	<b>29.873</b>	<b>29.873</b>	<b>29.873</b>
O&M	R\$ mil	(964)	(964)	(964)	(964)	(964)
TUST	R\$ mil	(32)	(32)	(32)	(32)	(32)
Despesas Administrativas	R\$ mil	(500)	(500)	(500)	(500)	(500)
<b>EBITDA</b>	<b>R\$ mil</b>	<b>28.378</b>	<b>28.378</b>	<b>28.378</b>	<b>28.378</b>	<b>28.378</b>
Depreciação	R\$ mil	(6.000)	(6.000)	(6.000)	(6.000)	(6.000)
EBT	R\$ mil	22.378	22.378	22.378	22.378	22.378
IR	R\$ mil	(621)	(621)	(621)	(621)	(621)
CSSL	R\$ mil	(335)	(335)	(335)	(335)	(335)
<b>Lucro Líquido</b>	<b>R\$ mil</b>	<b>21.421</b>	<b>21.421</b>	<b>21.421</b>	<b>21.421</b>	<b>21.421</b>
<b>Fluxo de Caixa</b>	<b>R\$ mil</b>					
EBITDA	R\$ mil	28.378	28.378	28.378	28.378	28.378
IR/CSSL	R\$ mil	(957)	(957)	(957)	(957)	(957)
<b>Caixa Gerado</b>	<b>R\$ mil</b>	<b>27.421</b>	<b>27.421</b>	<b>27.421</b>	<b>27.421</b>	<b>27.421</b>

### IV.3. Modeling Real Options

We used a five year horizon to price the deferred option. It is known that between 1998 and 2008 there were at least 166 authorized and unfinished SHPs. With the new regulatory framework, supervision by ANEEL on the implementation schedule of the construction phase should be stronger, preventing so many projects from remaining unresolved for up to 10 years. The ANEEL Resolution 2008 already predicts tougher schedule control mechanisms than the previous rules. For the purposes of this study, the period of five years will be adopted as reasonable.

Furthermore, it should be stressed that investment in an SHP is not done in phases. Once the investment has begun, it is unlikely that an interruption option for later resumption will be exercised. Alternatively, the developer may abandon the project for a residual value.

We considered that it is possible to abandon the project or sell it for a fixed abandoned value of BRL 22,000,000. In order to estimate this value, we collected data of prices of SHP projects that were sold in the preliminary stages of development. In these transactions, a rate of \$ 1,000/kW.average was found, which according to the underlying assumptions in item 4.2, corresponds to BRL 22,000,000. As this is not public information, we cannot disclose further details.

The cash flow can be treated as a dividend effect, since the investor is only entitled to the cash flow at time t if he or she made the investment at t-1. Also, a realistic assumption is that free cash flow is withdrawn by the shareholders in the form of dividends rather than reinvested in the project.

The real options value is the difference between the expanded present value (taking managerial flexibility into account) and the traditional present value, which does not account for managerial flexibility.

$$\text{Real Options Value} = V_{\text{expanded}} - V_{\text{traditional}} \quad (2)$$

According to binomial tree model, we started the process by the underlying asset price tree. The price of the underlying asset can either increase by factor u or drop by factor d in period t+1. The underlying asset is the present value of the SHP. The factors u and d are related to the volatility of the underlying asset return according to the equations (Minardi (2004 p.39)):

$$u = e^{\sigma\sqrt{\Delta t}} \quad (3)$$

$$d = e^{-\sigma\sqrt{\Delta t}} \quad (4)$$

We estimated the neutral probability according to the following expression (Copeland and Antikarov (2001)):

$$p = \frac{(1 + r_f)^t - d}{u - d} \quad (5)$$

Where  $r_f$  is the risk-free interest rate. In this study, the risk-free interest rate in real terms was considered 4.0% per year, equivalent to the savings account income in 2009, adjusted for inflation.

The investor is only entitled to the cash flow at time t if he or she made the investment at t-1. Thus, the cash flow can be treated as a dividend effect. In this case, the possible values for the underlying asset at time 1 are  $V_0 \cdot u \cdot (1 - \delta_1)$  and  $V_0 \cdot d \cdot (1 - \delta_1)$ , where  $\delta_1$  is dividend yield at moment 1.

Figure 2 shows the binomial tree of the underlying asset without taking into account the dividend effect, where  $V_0$  is the present value of the SHP in the baseline case, i.e. in year 0 and without considering managerial flexibility.

**Figure 2 - Binomial Tree of SHP Project Present Value without considering the dividend effect**

Anos					
0	1	2	3	4	5
					$V_0 * u^5$
				$V_0 * u^4$	
			$V_0 * u^3$		$V_0 * u^4 * d$
		$V_0 * u^2$		$V_0 * u^3 * d$	
	$V_0 * u$		$V_0 * u^2 * d$		$V_0 * u^3 * d^2$
$V_0$		$V_0 * u * d$		$V_0 * u^2 * d^2$	
	$V_0 * d$		$V_0 * u * d^2$		$V_0 * u^2 * d^3$
		$V_0 * d^2$		$V_0 * u * d^3$	
			$V_0 * d^3$		$V_0 * u * d^4$
				$V_0 * d^4$	
					$V_0 * d^5$

Figure 3 describes the binomial tree of the project present value considering the dividend effect. In this case, the possible values for the underlying asset at time 1 are  $V_0 * u * (1 - \delta_1)$  and  $V_0 * d * (1 - \delta_1)$ , where  $\delta_1$  is dividend yield at moment 1.

Since the investment is not flexible and it is not possible to cancel next investment phases, we simplified the problem assuming that all investment flow occurs one time, in the beginning of the period, and that in the end of the one-year period it will be generated the first cash flow. In fact, the expected deadline for construction of the SHP is 2.5 years on average. In the simulations that were carried out, the investment was capitalized by WACC and affected the cash flow in year t-1.

Figure 3 – Binomial Tree of Project Present Value After Dividends

Anos					
0	1	2 ...	3	4	5
					$V_0 * u^5 * (1 - \delta_1) * (1 - \delta_2) * (1 - \delta_3) * (1 - \delta_4) * (1 - \delta_5)$
				$V_0 * u^4 * d * (1 - \delta_1) * (1 - \delta_2) * (1 - \delta_3) * (1 - \delta_4) * (1 - \delta_5)$	
		$V_0 * u^2 * (1 - \delta_1) * (1 - \delta_2)$		$V_0 * u^3 * d^2 * (1 - \delta_1) * (1 - \delta_2) * (1 - \delta_3) * (1 - \delta_4) * (1 - \delta_5)$	
	$V_0 * u * (1 - \delta_1)$		...	$V_0 * u^2 * d^3 * (1 - \delta_1) * (1 - \delta_2) * (1 - \delta_3) * (1 - \delta_4) * (1 - \delta_5)$	
$V_0$		$V_0 * u * d * (1 - \delta_1) * (1 - \delta_2)$		$V_0 * u * d^4 * (1 - \delta_1) * (1 - \delta_2) * (1 - \delta_3) * (1 - \delta_4) * (1 - \delta_5)$	
	$V_0 * d * (1 - \delta_1)$				
		$V_0 * d^2 * (1 - \delta_1) * (1 - \delta_2)$			
					$V_0 * d^5 * (1 - \delta_1) * (1 - \delta_2) * (1 - \delta_3) * (1 - \delta_4) * (1 - \delta_5)$

We estimated the tree of the project present value before dividends by dividing each tree node of the project's value after the dividend payment (Figure 3) by  $(1 - \delta_t)$ . The amount of the dividend at each node can be obtained by the difference between the present value before-dividend at node n of period t and the present value of the ex-dividend at node n in period t.

The tree of the expanded net present value takes into account at each node the greater of the following alternatives: (i) postponing the construction of the asset, (ii) selling the project to third parties for the residual value set at BRL 22,000,000.00 (iii) investing in the construction of the SHP.

The methodology is applied recursively, starting at the last period of time. At  $t = 5$ , for each node, only the alternative to investing or selling the project is considered, because the

regulator could question the validity of the granted authorization, which impedes the continuity of the option to postpone. At other times, between  $t = 1$  and  $t = 4$ , three alternatives are tested:

(i) The value of alternative to delay is obtained by the neutral risk present value of the nodes generated starting from node  $n$  at  $t + 1$ , i.e.

$$V_{n,t} = \frac{p * V_{nu,t+1} + (1 - p) * V_{nd,t+1}}{1 + r_f} \quad (6)$$

Where  $V_{n,t}$  is the risk-neutral present value of the solution of the optimization equation answered by the entrepreneur at  $t + 1$ ;  $V_{nu,t+1}$ : is the solution of optimization problem of the investor for  $t + 1$ , in the top branch of the tree ;  $V_{nd,t+1}$  is the solution of optimization problem of the investor for  $t + 1$  in the lower branch of the tree;  $p$  is the risk neutral probability, estimated according to equation (5) and  $r_f$  is the risk-free rate, in real terms.

(ii) The value of the alternative of investing  $V_i$  at  $t$  is calculated by subtracting the value of the investment planned for setting up the SHP from the risk-neutral present value discounted from the present expanded value at  $t + 1$ , not taking into account the flow of dividends, namely:

$$V_{i,t} = \frac{(p * V_{u,after\_dividend,t+1} + (1 - p) * V_{d,after\_dividend,t+1})}{1 + r_f} - Investment \quad (7)$$

We used Copeland and Antikarov (2001) methodology to estimate the dividend yields at year  $t$ . Our base assumption is that free cash flows are distributed to shareholders rather than reinvested in the project. The dividend yield at year  $t$  was calculated according to the following expression:

$$\delta_t = dividend\_yield = \frac{Cash\_Flow_t}{VP_{cash\_flow_t}} \quad (8)$$

There was no cash flow though between the periods  $t = 0$  and  $t = 2$ , , since it takes 2.5 years to finish constructing an SHP.

## V. Results

### V.1 Results for Long-Term Market Energy Sales

We used equations (2), (3), (4), (5), (6) and (7) to construct the expanded present value tree and estimated the following parameters:  $\sigma=24.75\%$ per year,  $u=1.280$ ,  $d=0.780$  and  $p=0.518$ .

The dividend yields applicable to the periods 3 to 5 were estimated based on the 96 scenarios.

Table 1 - Dividend Yield for the Long-Term Energy Sales Model V

	T=0	t=1	t=2	t=3	T=4	t=5
Dividend Yield		0.00%	0.00%	7.86%	7.90%	7.84%

Figure 4 shows the present value tree after the payment of dividends.

Figure 4 - Tree of Present Value After Dividend Payment in the Long-Term Model

t =	0	1	2	3	4	5	6
							952,137
						809,110	580,345
				581,042	685,420	493,168	353,732
		492,329		417,777		300,595	215,606
	384,369		354,156		254,643		131,416
300,084		300,084		215,865		183,219	80,101
	234,280		182,907		155,210		68,068
				131,574		111,675	
					94,603		
						68,068	
							48,823

Figure 5 shows the Present Value binomial tree before payment of dividends. Each node is obtained by dividing the value for the corresponding node in the Figure 4 tree by  $(1 - \delta)$ .

Figure 5 - Tree of Present Value Before Dividend Payments in the Long-Term Model

t =	0	1	2	3	4	5	6
							1,036,368
						877,937	631,686
				630,611	744,241	535,119	385,025
		492,329		453,629		326,165	234,680
	384,369		384,369		276,495		143,042
300,084		300,084		234,280		198,804	87,187
	234,280		182,907		168,529		73,858
				142,798		121,175	
					102,722		
						73,858	
							53,142

Note that in Figure 4, between periods 1 and 2, the present value does not suffer any dividend effect, since the estimated period of construction in this model is 2.5 years.

Figure 6 shows the tree of dividends for the long-term model.

Figure 6 - Tree of Dividends for the Long-Term Model

t =	0	1	2	3	4	5
						68,827
					58,821	41,951
				49,569	35,852	25,570
			-	30,213	21,853	15,585
		-		18,416	13,320	9,500
	-			11,225		
		-				

The value of the option to expand is obtained recursively. At  $t = 5$ , the defer option ceases to exist, and the investor decides optimally if he or she sells the asset at the abandonment value or invest in the SHP by solving equation (7). For example, the value at the top branch is obtained as follows:

$$VPL_{5,u} = \text{Máx}\left(\frac{0,518 * 952.137 + 0,482 * 580.345}{(1 + 0,04)} - 196.905; 22.000\right) = 546.444$$

The lower branch value is estimated as following:

$$VPL_{5,d} = \text{Máx}\left(\frac{0,518 * 580.345 + 0,482 * 353.732}{(1 + 0,04)} - 196.905; 22.000\right) = 256.180$$

In this case, the investor opts to invest in the implementation of the SHP. In previous periods, the investor must resolve the maximization equation between delaying, investing, resolving (6) and (7), respectively, and selling for a residual value.

At  $t = 4$ , for example, for the top branch:

$$VPL_{4,u} = \text{Máx}\left(\frac{0,518 * 546.444 + 0,482 * 256.180}{(1 + 0,04)};\right. \\ \left.\frac{0,518 * 809.110 + 0,482 * 493.168}{(1 + 0,04)} - 196.905; 22.000\right) = 434.780$$

Once again, in this example the investor chooses to invest in the SHP. Repeating the above procedure, recursively, the tree of expanded net present value, as well as the decision of the entrepreneur at each node for the long-term model is shown in Figure 7.

Figure 7 - Tree of Expanded Net Present Value for the Long-Term Model

t =	0	1	2	3	4	5
						546,444
					434,780	invest
			338,214	Invest	256,180	invest
		256,723	invest	188,119	invest	invest
	187,464	invest	129,260	Invest	79,259	invest
117,975	Invest	80,620	invest	49,695	invest	invest
delay	52,973	delay	34,959	delay	22,000	22,000
	Delay	27,613	delay	22,000	sell	22,000
		Delay	22,000	Sell	22,000	22,000
			Sell	22,000	Sell	Sell
				sell	22,000	22,000
					sell	sell

We estimate the option to delay value in the the long-term model as the difference between the expanded present value at  $t = 0$  and the present value of the baseline case, BRL 117,975 millions - BRL 103,178 millions, resulting in an option value: BRL 14,797 millions

5.2 Sensitivity Analysis - Sale of Energy in the short-term Market

We estimated the following parameters for the short-term market case:  $\sigma = 81.02\%$ ,  $u = 2.248$ ,  $d = 0.444$  and  $p = 0.330$ . Dividend yields applicable to periods 3 to 5 were extracted from the two thousand scenarios.

Table 2 – Dividend Yields for Energy Sales in the short-term Model

	t=0	t=1	t=2	t=3	T=4	t=5
Dividend Yield		0.00%	0.00%	8.61%	8.61%	8.61%

Figure 8 shows the present value tree after dividend payment.

Figure 8 - Tree of Present Value After Dividend Payment for the Short-Term Model

t =	0	1	2	3	4	5	6
							27,040,767
						13,160,113	
					6,404,721		5,349,089
				3,117,029		2,603,277	
			1,516,986		1,266,955		1,058,134
		674,702		616,597		514,969	
300,084		300,084		250,624			209,316
	133,467		121,973		101,869		
		59,361		49,577			41,406
			24,128		20,151		
				9,807			8,191
					3,986		
							1,620

Figure 9 shows the present value tree before dividend payment. Each node is obtained by dividing the value for the corresponding node in the tree of Figure 8 by  $(1 - \delta)$ .

Figure 9 - Tree of Present Value Before Dividend Payment in the Short-Term Model

T =	0	1	2	3	4	5	6
							29,588,928
						14,400,244	
					7,008,264		5,853,155
				3,410,759		2,848,595	

		1,516,986		1,386,345		1,157,846
	674,702		674,702		563,497	
300,084		300,084		274,241		229,040
	133,467		133,467		111,469	
		59,361		54,249		45,308
			26,402		22,050	
				10,731		8,963
					4,362	
						1,773

Figure 10 shows the tree of dividends for the short-term model.

Figure 10 - Tree of Dividends for the Short-Term Model

t =	0	1	2	3	4	5	6
							2,548,161
						1,240,131	
				603,543			504,066
			293,730			245,317	
		-		119,390			99,712
	-		58,104		48,528		
		-		23,617			19,725
	-		11,494		9,600		
		-		4,672			3,902
			2,274		1,899		
				924			772
					376		
							153

The tree of expanded net present value for the short-term model, and the entrepreneur's decision at each node are shown in Figure 11.

Figure 11 - Tree of Expanded Net Present Value for the short-term Market

t =	0	1	2	3	4	5
						11,829,875
					5,656,249	invest
			2,651,689			2,182,181
			invest		960,940	invest
		1,189,439		370,020		273,715
		invest		invest		invest
193,681	477,796			invest		invest
	Invest	147,202		delay		invest
	delay	delay		46,233		22,000
	65,293			delay		sell
	delay	28,844		22,000		22,000
		delay		sell		sell
			22,000		22,000	
			sell			
				22,000		

The option to defer value in the short-term model equals the difference between the expanded present value at  $t = 0$  and the present value of the baseline case, BRL 193,681 million - BRL103,178 million, resulting in BRL 90,503 mil.

The option to defer assuming long-term energy sale contracts, represents about 14% of the SPH's present value. On the other hand, the option calculated under the assumption of energy sales in the short-term market represents 88% of the SHP's present value.

The difference of both values is striking. As mentioned previously, the possibility of energy sales in the short-term market during an SPH's operating period is unrealistic. We estimated the SHP volatility without contracted energy as high as 80% in the sensitivity scenario, which would create a high risk for the entrepreneur. On the other hand, the securitization of energy purchase and sale contracts, is the main funding instrument for construction of these assets, whether through Project Finance structures, or through Corporate Finance operations.

Taking into consideration only the long term contracts analysis, we can conclude that the option is extremely valuable and can, in part, justify the large number of projects approved and not constructed. Currently, it is known that there are at least 166 (Atlas Aneel) authorized projects whose construction has not begun.

This problem led to the approval of ANEEL Resolution No. 343/2008, a new regulatory framework on issuing SHP permits. One of the main changes brought about by this resolution is the need for a registered guarantee deposit with ANEEL when the project is registered and the need to deposit a guarantee of faithful compliance after receiving permission.

For a 30 MW SHP and in accordance with the methodology available in this resolution, the values of this guarantee would be:

- (a) BRL 500,000 for guarantee of registration and
- (b) BRL 6,000,000 for the faithful compliance guarantee.

Although the figures are high, the deferral option is more valuable than the guarantees required by ANEEL. In other words, if the continuous inspection of work proposed by ANEEL in this resolution is not implemented, the entrepreneur will continue to be encouraged to delay construction if the price of hiring in the energy market is not favorable.

Resolution 343 / 2008 also implemented the need to present a basic engineering project before being granted a license. The aim of this is to eliminate the factor of delay in construction due to poor-quality engineering projects, leaving only the uncertainty brought about by fluctuating energy prices as an incentive to the investor.

## **VI. Conclusion**

In recent years, small entrepreneurs have been able to receive authorization to set up an SHP without having the economic and financial capacity to undertake such a venture.

This paper uses the Real Options Theory to value an American deferral option to construct an SHP, with the volatility of energy prices as the main source of uncertainty in the project's value.

We used the binomial tree approach, because it allows us to precify American options and is an intuitive approach. To measure the volatility of energy prices, we built ninety-six energy sales scenarios from the tariff review process for distribution utilities.

We estimated a volatility as high as 25%, and the option to defer represented a 14%

increase in value of the project without flexibility.

Additionally, we also ran a scenario of sensitivity under the assumption of a short-term market for energy trading. This model resulted in a volatility of 80% per year and in an option value of 88% of the present value. We considered these values greatly exaggerated. Moreover, the possibility of sale of energy in the short term over the life of the project seems unrealistic, since it would prevent efficient leverage structures of the project and equalization of funding for the project implementation.

These results are consistent with the new framework in the electricity sector for the granting of SHPs which requires deposit guarantees for registration and granting of SHPs. However, the simulated security values are still lower than the calculated deferral option, which means there are still incentives for the entrepreneur to wait for the best time to sell energy.

The new regulatory framework also turned mandatory the presentation of a basic engineering project before being granted a license. This new clause will probably reduce poor-quality engineering projects that delay construction, but there will still be incentives to postpone the construction phase due to fluctuations in energy prices.

We can improve the modeling of the long-term energy price and estimate more accurate values for the option to defer if FCE prices become public information.

In the future, it will also be possible to observe the influence of ANEEL supervision on the implementation schedule and see if the deferral option will continue.

Additionally, the regulator could adopt a system of progressive deposit guarantees for delays arising from the implementation schedule presented in the basic design, creating incentives for compliance with the initial schedule and penalizing the management option of postponement. In the future, new studies can be carried out with the spirit of suggesting to the regulator a formula of solicitation of guarantees when authorizing the developer in order to minimize the value of the managerial deferral option.

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