BRAZIL'S QUEST TO ALSO FOSTER WIND ENERGY IN THE DEREGULATED MARKET: WILL IT WORK?

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1. Introduction

Brazil began fostering wind energy in 2004 through a feed-in incentive program named Proinfa, with limited success. In 2009 wind energy began to be contracted through a series of government auctions within the regulated market, known in Brazil as ACR, with the objective of increasing the current 1.8GW in installed capacity to over 8 GW by 2016.

The auctioning system has put considerable pressure on the profitability of wind farms, but the government has partly compensated the sector through guaranteed purchase of energy for 20 years - and at the auction's defined price plus inflation -, along with certain rules that spread part of the risk of intermittent generation throughout energy buyers/consumers. Several auction designs have been tried so far, with great success.

Despite this, both the government and the investors would like to see wind energy also negotiated in the deregulated market (known as ACL[1]), where wind farms and distribution companies sign bilateral agreements after a free price negotiation. Investors see the ACL market as an opportunity to recover their profitability, since auctions have caused wind energy prices to drop from USD 150/MWh (Proinfa wind farms) to the current USD 50/MWh in the ACR. The government, on the other hand, perceives the ACL as a healthy development of the market. Nevertheless, only a few contracts involving wind energy have been signed in the ACL market so far.

Negotiating wind energy in the ACL market is not simple. First, while in the ACR market the generation risk is minimized by a portfolio effect, as all buyers buy from all sellers in a same auction and the rules for the financial settlement of deviations from committed energy generation are pre-defined, free market players must decide how to share the generation risk. Secondly, wind farms in the ACL market do not enjoy the benefits inherent to negotiations in the ACR, such as: a) government plans transmission expansion following ACR auctions, which include the possibility of wind farms sharing grid connection installations with significant reductions in capital expenditures; b) the government accepts the energy committed at auctions as part of energy distributors' requirement to contract 100% of their expected energy demand, but this rule is not defined yet for wind farms in the ACL market; c) last but not least, the 20-year contract at fixed prices make auctioned wind farms very attractive for raising debt capital.

While solutions for the ACL problems are being discussed, the wind sector and government arrived at a creative solution: to include wind farms in the auctions for energy with first delivery date 5 years ahead the auction, known as the 'A minus 5' (A-5) auctions. Prior auctions were A-3, therefore consistent with the lead time required to build a wind farm, which averages 2-3 years.

Under the A-5 auction design, investors have the option to anticipate the construction of the wind farm and sell whatever energy is generated before year A in the ACL market. These farms will also enjoy the benefits of being included in the government's plans for transmission and, since they are also granted a 20-year contract in the ACR market from year 5 on, they can have easy access to debt financing. Therefore, this new scheme eliminates two of the most important difficulties in selling wind energy in the ACL.

However, what is the value of being able to anticipate or postpone construction? When is the optimal time to invest? Will the deregulated market for wind energy actually take off with the A-5 auctions? This paper analyzes this problem by modeling this investment decision under the Real Options approach. Using the actual rules of the first A-5 auction held in Dec 2011, the model shows that given the low prices averaging USD 50/MWh, some winners may be tempted to defer the investment due to an expectation of lower equipment prices and/or higher energy prices in the future. Our analysis also shows that bidders that take into account the flexibility to bear the cost of eventually abandoning the project may have bid more aggressively in the auction. On the other hand, this behavior increases the chances that part of the contracted wind farms will never materialize and that less than expected wind power energy will be negotiated in

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[11] ACR=*Ambiente de Contratação Regulada*= regulated market, refers to energy negotiated in auctions organized by the Brazilian government ; ACL=*Ambiente de Contratação Livre*=deregulated or free market, energy is negotiated through free bilateral power and purchase agreements.

the ACL market. Finally, the decision to wait to invest is highly dependent on eventual efficiency improvements, if any, that can be attained in the wind farm's micrositing thanks to a longer wind data series. This highlights the importance of translating this additional knowledge about the site's potential into economic/financial data that can be actually used by decision makers.

This paper is organized as follows. In section 2 we present a brief review of the literature on Real Options, highlighting the advantages of using this approach to analyze the problem. In section 3 we describe the problem and detail the Methodology and our model assumptions. In section 4 we discuss the results and perform a sensitivity analysis to the assumptions, in section 5 we conclude with policy recommendations.

2. Literature Review

Traditionally, the corporate capital budgeting decision is based on the Discounted Cash-Flow Method (DCF), in which the myriad of possible future scenarios are represented by the expected scenario, regardless of the volatility inherent to a project's cash flow generation. A more coherent way of analyzing an investment decision is to assume that the firm has rational expectations on how a project's uncertainties will develop probabilistically in the future (Dixit & Pindyck, 1994, p.219).

While analysis of scenarios and simulations help device the impact of uncertainty in a project's value, none of these alternatives can correctly deal with situations where managers have the flexibility to make optimal decisions during the life of a project and in the light of new information that is revealed along time, such as the cost of equipment and prices in the ACL market. After all, when new optimal decisions are taken, the project's risk is altered, as well as the fair discount rate to be used in calculating the project's net present value (NPV); in addition, the more the flexibility to make new and better decisions, more valuable is a project. How, then, can one assess the value of decision flexibility or, rather, the value of managerial options?

Tourinho (1979) used financial option theory, based on the seminal works of Black, Scholes (1973) and Merton (1973), as an inspiration to value a project with embedded options and subject to uncertainty. This work marked the beginning of the literature field that is now known as Real Options Analysis (ROA), and which was further consolidated by the contributions of authors such as Brennan & Schwartz (1985), McDonald & Siegel (1986), Trigeorgis (1993), Dixit & Pindyck (1994).

Depending on the characteristics of the embedded options, the investment decision may be either modeled in continuous time, such as in the Black&Scholes&Merton analytic solution, or numerically, or through dynamic programming. A very common solution is the one first proposed by Cox, Ross & Rubenstein (1979), who developed a binomial method that can easily value American options[2] with a limited time span to be exercised; these are the characteristics of the problem we are attempting to solve in this article, so the Cox, Ross & Rubenstein binomial method, enhanced by contributions such as Copeland & Antikarov (2003) and Brandão, Dyer & Hahn (2005), is the theoretical framework adopted in this article.

The binomial method is a solution in discrete time (e.g.: one step/year) and it reduces the future possible evolutions of a project's uncertainty to only two outcomes: an upside scenario and a downside scenario. The binomial method adjusts the up and down movements, and their respective probabilities of occurrence, in a way that the present value of the outcomes, weighted by their adjusted probabilities (risk-neutral probabilities), can be calculated using the risk free rate. This mathematical artifice eliminates the cumbersome problem of having to find the fair risk-adjusted discount rates in different branches of the decision tree. This binomial approximation is also done in such a way that both the expected outcome and the volatility of outcomes are the same as the true expected results, that is, those using the real underlying

[2] American options can be exercised any time until maturity, while European options can be exercised only at maturity date.

stochastic process that describes the uncertainty (hereon also referred to as 'stochastic variable' or 'state variable').

A commonly used stochastic process is the Geometric Brownian Motion (GBM), which implies that the variations of the state variable undertake a Gaussian distribution. This also means that the probability distribution of the state variable is lognormal, which is adequate to describe the behavior of share prices and financial assets, for example. There are other stochastic processes, as well as combinations of stochastic processes, with varied levels of complexity. For example, Mean-Reverting Processes (MRM) are adequate to describe a state variable that tends to revert to a certain equilibrium level, such as commodity prices (Hahn & Dyer, 2006), while Poisson processes can be better to describe sudden and large changes, as usual in spot energy prices or in the oil market (Dias & Rocha, 1999). Ozorio, Bastian-Pinto & Brandão (2012) discuss the tests and theoretical considerations that support the choice of the stochastic process that best describes a state variable.

Overall, the literature is abundant in applications of Real Options Theory that use the GBM process, not only due to its simplicity when compared to other stochastic processes, but also because it is harder to infer a long term equilibrium level in most of real world's uncertainties, or to have long enough data series to describe Poisson processes with statistical significance.

In our problem, we will use the GBM process, for reasons better described in section 3, which means that a state variable, say *Y*, follows the diffusion process shown in Eq. 1.

$$dY = \alpha Y dt + \sigma Y dz \;, \qquad dz = \xi\sqrt{dt}, \xi \sim N(0,1) \;, \tag{1}$$

where dY is the variation of Y after dt, α is the drift and σ is the volatility, that is, the standard deviation of the Gaussian probability distribution of returns.

Considering this GBM stochastic process, equations (2)-(5) describe the Cox, Ross & Rubenstein binomial tree. The up movement of variable Y in a certain step of the binomial tree is:

$$Yu_{t+1} = Y_t * u = Y_t * e^{\sigma} \text{ , that is, } u = e^{\sigma} \tag{2}$$

Likewise, the down movement of variable Y is described by:

$$Yd_{t+1} = Y_t * d = Y_t * e^{-\sigma} \text{ , that is, } d = e^{-\sigma} \tag{3}$$

As noted, d=1/u, that is, the adjacent branches of the decision tree recombine in the following steps, with the additional benefit of reducing computational work in certain softwares.

The risk-neutral probabilities that the up and down movements will occur are, respectively:

$$p = \frac{1 + r_f - d}{u - d} \tag{4}$$

$$q = 1 - p \tag{5}$$

The resulting decision tree is illustrated in Figure 1.

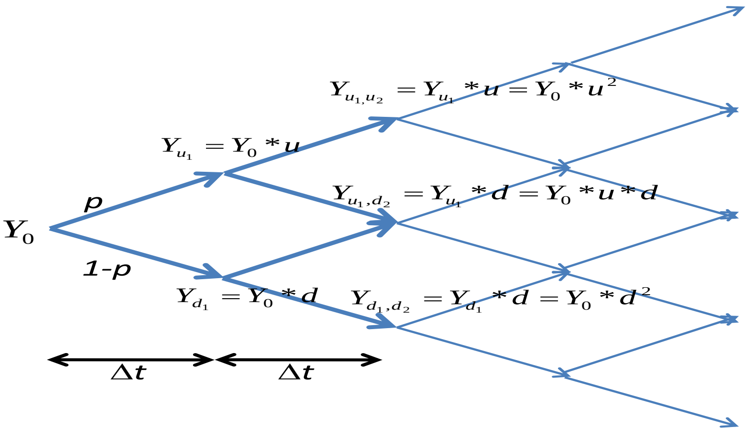

Figure 1: a recombinant binomial decision tree

Having built a decision tree for each state variable based on equations (2)-(5), the valuation problem is then solved backwards, first finding the optimal choice/decision – the one that yields the highest output – related to the outer branches of the decision tree. Working the tree backwards, the expected present value, in a preceding node (t-1), of the decision to wait to invest, is:

*[Expected value of waiting, at time t-1]=[(optimal output in the up branch, at time t)*p+(optimal output in the down branch, at time t)*q]*[1/(1+rf)]*

(6)

The option to invest will only be taken if the expected value of investing at a certain point in time exceeds the expected value of deferring the decision to later on. This procedure is repeated until the first node at t=0 is reached, and the expected value at this point is the 'expanded value' of the project, that is, it also considers the value of the embedded options. Therefore, a firm will only accept a certain price for its wind energy in an A-5 auction if this expanded value at t=0 is positive.

When the decision is to be based on two state-variables, equipment cost and energy price in the ACL market, a binomial tree is constructed for each state-variable and combined in a quadrinomial tree, as in Copeland & Antikarov (2003, chapter10) or Brandão & Dyer (2011).

Wind energy has been occasionally addressed in the Real Options literature, especially in Europe where wind energy in more consolidated and where flexibilities/options are in general very different from the Brazilian case. For example, Scatasta & Mennel (2009) analyze how the investment decision is changed, depending on the incentive policies for the sector in Europe; Venetsanosa, Angelopouloua & Tsoutsosb (2002) e Méndez, Goyanes & Lamothe (2009) assess the value of the flexibility to abandon, defer or expand wind farms in Europe. Hernández (2009) uses a trinomial model in which the only state-variable is the net present value of a wind farm to assess the options to invest, postpone the decision or abandon the project. Frolund & Obling (2010) values a learning option, that is, the value of having the option to invest or abandon the wind project during its development studies. Yu et al (2006) estimate the value of switchable tariffs in Spain, while Dykes & Neufville (2008) analyze the option to build steadily, instead of making a major investment in wind in the US market. Honda, Goto & Ohno (2005) value hybrid wind-diesel plants in Japan. In Brazil, Luna (2011) makes a simplified analysis of the option to abandon a project, for a fixed value.

None of these works perform an analysis similar to the one presented in this article, which adopts a differentiated way of dealing with stochastic and non-stochastic components of a project's value, and also proposes a way to reflect on eventual learning gains that can be reaped from waiting, as a result of a longer wind data series. This article is also innovative, when compared to prior works, in analyzing two typologies of investors, one with an opportunistic view, in the sense that it considers the option to abandon the project, while the other would build the wind farm anyway, in order not to jeopardize its image in the sector.

3. Methodology

Considering the rules of the A-5 auction held in Dec 2011, whatever energy generated before year 5 can be negotiated through bilateral agreements in the ACL market. We assume that building a wind farm takes 2 years and that projects that win A-5 bids can therefore anticipate construction to any time before year 3; so, these projects hold an American option to invest. However, this problem can be simplified, without significant impact on core conclusions, by considering that the option to invest exists only in discrete points in time, e.g., at the end of each year (Y0, Y1, Y2, Y3).

At the end of Y3, construction can no longer be postponed, or else the firm will fail to perform the energy delivery contract. However, based on the history of energy projects in Brazil, there is a percentage of entrepreneurs that keep on postponing in court the date to begin operations (based on 'material adverse condition' clauses) or that have even abandoned projects. In those cases, the auctions' rules call for the execution of performance bonds, equivalent to 5%

of the originally forecasted investments in the project. Other penalties might also be imposed, but at this point there are few contracts in the energy market as a whole that reached a final resolution of litigations. So, we simplify the analysis by considering only the financial impact of the performance bond and assume that this would be acceptable if the government is notified of the default 2 years before what had been settled as first energy delivery date.

Therefore, a project participating in an A-5 auction has the following options:

- Option to invest immediately after the auction (Y0)
- Option to invest one year after the auction (Y1)
- Option to invest two years after the auction (Y2)
- Option to either invest three years after the auction (Y3), or abandon the project.

The option to abandon the project was included here just to mimic the rationale of a more opportunistic investor; a conservative investor, that one concerned with the image impacts of not performing an energy contract, would not consider this abandonment option. The model will be run for these two typologies, in order to compare results.

The project is subject to the following uncertainties (state variables), only defined when the option to invest is finally exercised:

- the price of the energy to be sold in the ACL market (*PriceACL*). *PriceACL* is a term price, that is, it is settled in year *i*, but starts to be delivered at year *i+2*, adjusted by inflation rates. So, it remains fixed, in real terms, for the whole available period;
- the investment to build the wind farm (*Capex*).

After having won an A-5 auction, a firm owning a wind project is confronted with two opposing incentives: if it invests immediately after the auction, it can sell energy in the ACL market for 1-3 years, but it also has to anticipate capital expenditures, bank loans and, therefore, the timeline of debt service (=amortization of debt + interest expenses). On the other hand, if the firm waits to invest, it loses revenues but postpones capital expenditures and debt service. It may also be able to close a better deal on equipment costs and energy prices in the deregulated market in the years to come, and also get a better knowledge about the site's wind behavior before deciding over the optimal turbine and micro siting.

This gain in engineering efficiency was taken into account by considering that, for the same capital expenditures, the wind farm would be able to produce more energy and, therefore, increase revenues. For each additional year of wind data, a certain percentage – hereon named '*learning gains*' - is added to the revenues of the wind farm's 20-year contract in the ACR market. Such learning gains are undoubtedly hard to estimate, but including them as an assumption in the model allows for sensitivity analyses.

Based on this model, this article analyses the investment decision of a hypothetical firm that owns a 25 MWm wind project and under the A-5 auction rules. This project's characteristics describe adequately the conditions of a wind farm in Northeastern Brazil: 48% capacity factor, 93% availability. The firm's cash-flows are exclusively generated by this wind project, so we might refer to it as firm or project, interchangeably.

The first step in the analysis is to build the expected cash-flow generation, available to the firm's shareholders along the 20 years of a contract in the ACR market (Free Cash-Flow to Equity, $FCFE_{,ACR}$). The $FCFE_{,ACR}$ in a certain year *i* can be generally described as (Titman & Martin, 2011, p.44):

$$FCFE_{,ACR\,i} = EBIT_i*(1-t) - Interest\ Expenses_i*(1-t) - \Delta Working\ Capital_i + \Delta Debt_i - Capex_i + \\ + Depreciation\&Amortization_i \quad , \qquad (7)$$

where: *EBIT*=earnings before interest expenses & taxes; *t*=income tax rate; *Capex*=capital expenditures, net of the amount that was financed by banks or other debt holders.

This yearly $FCFE_{,ACR}$ must be brought to its present value by using the cost of capital required by the providers of equity, *ke*. Both the $FCFE_{,ACR}$ and *ke* are in real terms, excluding inflationary effects.

In order to account for the possibility of anticipating construction – and the consequent impact of anticipating debt service -, equation (7) can be rearranged as follows:

$$FCFE_{,ACRi} = [EBIT_i*(1-t) - \Delta Working\ Capital_i + Depreciation\&Amortization_i] - Capex_i - - [Interest\ Expenses_i*(1-t) - \Delta Debt_i] \qquad (8)$$

A quick note on one of Brazil's peculiarities: very small companies (sales < USD 24M/year) enjoy the possibility of not calculating exactly their earnings before taxes; instead, they can pay a certain fixed percentage of its gross revenues. In general, the tax impact is much lower in this simplified tax regime. In addition, energy companies with small installed capacity enjoy a 50% discount on transmission/distribution costs. As a result, entrepreneurs have split their wind farms in smaller pieces, each one representing a wind firm/project. This eliminates the tax benefit of debt, reflected by the *(1-t)* term that multiplies *Interest Expenses*, in equation (8), as well as the fiscal benefit of depreciation and amortization. To account for this country peculiarity, equation (8) should be rewritten as:

$$FCFE_{,ACRi} = [EBIT_i - tax\ impact\ on\ gross\ revenues - \Delta WorkingCapital_i + Depreciation\&Amort_i] - Capex_i - [Interest\ Expenses_i - \Delta Debt_i] \qquad (9)$$

Either using equation (8) or (9) as a reference, one can easily interpret it as:

$$FCFE_{,ACRi} = [Operating\ Cash\text{-}Flow_{,ACR\ i}] - Capex_i - [DebtService_i] \qquad (10)$$

Neglecting the option to anticipate investment and sell whatever energy is generated before year 5 in the ACL market, the company's value is simply the sum of each year's $FCFE_{,ACR}$ present values at date zero, and using the cost of capital, *ke*. To take into account the available options, the three terms at the right side of equation (10) need to be analyzed separately, as described in Figure 2.

The second step in the valuation process is to analyze what would be the company's value, depending on the time the decision to invest is taken. When the company opts to anticipate construction to years 0,1 or 2, *Capex* is anticipated, beginning at the date the option to invest is exercised. *DebtService* cash flows begin 2 years after the option to invest is exercised, complying with the 2-year grace period banks usually grant in their wind energy project financings. When construction is anticipated, we assume that the company simultaneously closes a term sale of energy in the deregulated market (ACL) for the term price *PriceACL*, with energy delivery starting 2 years after the option to invest is exercised.

In summary, the value-drivers of our reference firm, depending on the date it exercises its option to invest, are illustrated in Figure 2 by their respective net present values, at the dates each specific cash-flow begins.

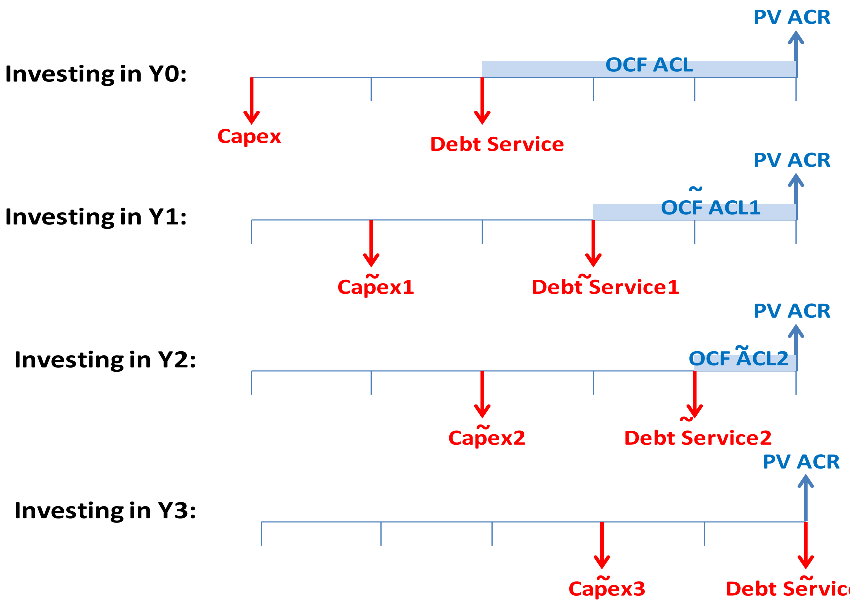

Figure 2: The company's value drivers, depending on the date the option to invest is exercised

The variables represented in Figure 2 with a '~' superscript are stochastic variables, so the firm's value is subject to the realizations of those uncertainties at the time the option to invest is exercised. The *OCFACL* variable is the operating cash-flow to be obtained from the sale of energy in the ACL market, and is composed of two parcels: *OCFACLstoch* and *OperCosts*.

OCFACLstoch refers to the gross revenues, net of the tax burden (changes in working capital are being neglected here due to its irrelevance in the energy sector). *OCFACLstoch* is linearly dependent on the realization of the stochastic variable *PriceACL* when the decision to invest is finally taken, so it is also stochastic. Using Itô's Lemma it can be shown[3] that *OCFACLstoch* follows the same stochastic process, and with the same parameters, as *PriceACL*. The second parcel of *OCFACL*, *OperCosts*, is deterministic and refers to the operating costs, which are basically composed of fixed costs in the case of wind farms.

Likewise, *DebtService* is stochastic because it is linearly dependent on the realization of the stochastic variable *Capex*, both variables following, the same stochastic process and with the same parameters.

We assume that the two basic uncertainties of the model, *PriceACL* and *Capex*, follow GBM stochastic processes, because they are influenced by a combination of several factors and it is hard to infer a long term equilibrium that would justify the use of mean-reversion processes. In the case of *PriceACL*, for example, market players state that core drivers are the forecasted demand for energy in Brazil versus capacity increases, coupled with the forecasted affluences to the hydro-power plants, which currently account for 67% of Brazil's power generation. *Capex*, on the other hand, is highly influenced by turbine prices which, given the still preponderant stake of Europe, Asia and the USA in wind capacity expansion, have been geared by the overall impacts of the economic crisis on those regions' clean energy investments. In addition, *Capex* is influenced by the R$/USD parity (which affects imported capital goods, that is, around 40% of equipment), by steel prices and logistics costs to build the plants and connect them to transmission lines. In summary, *PriceACL* is driven by the country's energy issues, while *Capex* is basically influenced the by global issues and the country's logistic matters.

Given these characteristics, coupled with very short data series on equipment prices and energy term prices in the wind market, it is hard to infer the parameters of any stochastic process through econometric techniques. However, managers keep on making decisions in daily life and we observe that a normal distribution of returns, as obtained in GBM processes, usually fit the way managers analyze complex problems. Managers can therefore reflect on which parameters for the drift α and volatility σ should be used in equations (1), (2) and (3) for each of the two state-variables, in order to make the GBM stochastic process fit their opinions on the range of possible future realizations of those two uncertainties. Figure 3 illustrates how this inferring process could be done.

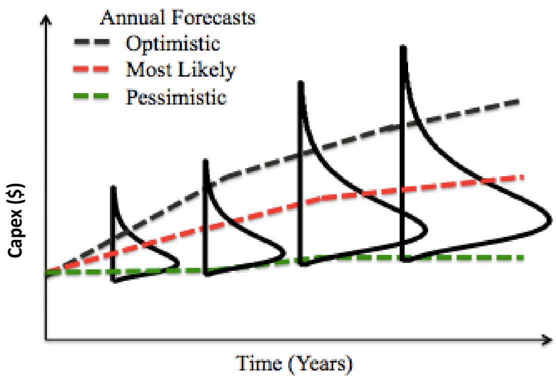

Figure 3: lognormal distributions are used to fit management projections for the state-variable, determining the expected annual growth and volatility parameters of the stochastic process. Source: Barton & Lawryshyn (2010, p.8).

[3] Please refer to Shimko (1995) for this demonstration.

As the behavior drivers of the two state variables are very different in nature, we assume the two variables to have zero correlation, that is, the probability of *PriceACL* stochastic changes along time are not conditional on the realizations of *Capex*, and vice-versa. Being the state variables independent from each other, the probability of any branch in the quadrinomial tree, built from the two binomial trees, is simply the multiplication of the individual probabilities.

Consulting with a market player, the chosen assumptions to describe the problem and the hypothetical 25MW wind farm are:

- *MWm*: expected energy generation, 25 MWm, equivalent to 25*8760 MWh;
- *PriceACL*: R$100/MWh[4] in Y0, for the three possible term sale contracts, those related to energy delivery in years 3-5, or years 4-5, or just in year 5, as depicted in Figure 2. There is not much liquidity in this market to infer a differentiated term price for these three possible negotiations. In the future, this state variable will follow a GBM diffusion process with volatility σ=30% and α=*rf*=6% p.y. As a result, the future realizations *Price ACL1* and *Price ACL2* will be represented by the binomials detailed in section 3 and by equations (2)-(6);
- *Capex*: R$ 63M in Y0, recalling that this is the share financed by shareholders' capital, which is assumed to be 40% of total *Capex*, in line with the sector's average. In the future, this state variable will follow a GBM process with volatility σ=20% and α=*rf*=6%p.y. Likewise, equations (2)-(6) are used to construct the *Capex* binomial tree, representing the realizations of *Capex1*, *Capex2* and *Capex3;*
- *DebtService*: equivalent to R$ 82M in Y2, if the option to invest were to be exercised in Y0. Future realizations will vary proportionately to the variation of *Capex* when compared to its original value or, in other words:

  *DebtService1 =DebtService0*Capex1/Capex0,* and so on;
- *PVACR*: refers to the sum of the present values of the operating cash-flows, net of operating costs and taxes, to be obtained from the sale of energy in the regulated market in the 20-year life of that contract. In equation (10), this is expressed by the first term in brackets in the right-hand side. *PVACR* is linearly dependent on the price closed at the A-5 auction; through a sensitivity analysis, the model identifies the minimum price to be accepted at the auction, considering the value enhancements available thanks to the options to defer investment and/or abandon the project. Having won the auction, *PVACR* is deterministic;
- *OperCosts*: R$ 5.8M/yr;
- *rf*: risk-free rate, 6% per year, in real terms;
- *ke*: capital cost, 10% per year, in real terms;
- *learning gains*: arbitrated at the 0-15% range, in order to perform sensitivity analyses to its influence on the firm's value.

When the decision to invest is taken in Y1, Y2 or Y3, the project value depends on the realizations of the state-variables of the quadrinomial tree. The value equations used for that purpose are detailed in Appendix A.

The third step in the valuation process is to choose the optimal decision, described as below:

Optimal decision n,i = max [value of investing n,i; expected value of waiting n,i]

where *Optimal decision n,i* is the one to be taken in a certain node *n* of the decision tree, and at year *i*. There are 2^(2*i*) decision nodes in each year $i \in \{0,1,2,3\}$. The *value of investing n,i* is calculated based on the value equations A.0-A.3, detailed in appendix A; the *expected value of waiting n,i* is calculated backwards to each decision node, and weighed by their binomial probabilities, as detailed in equation (6). Both the value of investing and the value of waiting are expressed by their equivalent at Y0.

[4] As a reference, the R$/USD parity is at 2.0, so R$100=USD50

The quadrinomial tree can be developed in Excel or other softwares, but in this article we opted to use the DPL^{TM} software, by Syncopation, which is a user's friendly platform for decision trees, and adaptable to the Real Options approach. Figure 4 illustrates the decision model, as it is shown in DPL^{TM}.

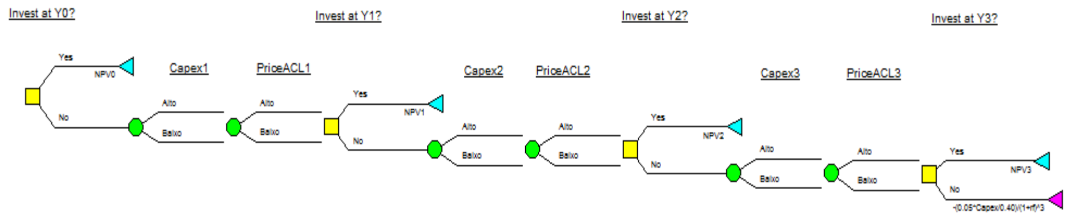

Figura 4: the decision problem, modeled in DPL^{TM} ; this example reflects the case where there are options to invest at Y0, Y1, Y2 or Y3, and an option to abandon the project at Y3.

The squared nodes reflect a decision to be made (Invest at Y0?... Invest at Y3? Abandon at Y3?), being followed either by a triangle, which means that the option was exercised, or by new circular nodes, which represent the binomial realizations of the two stochastic variables - *PriceACL*, *Capex* - in the next year. As an illustration, Figure 5 is an excerpt of the decision tree, showing just the nodes out to time *i*=1. The optimal decision is emphasized by bold lines.

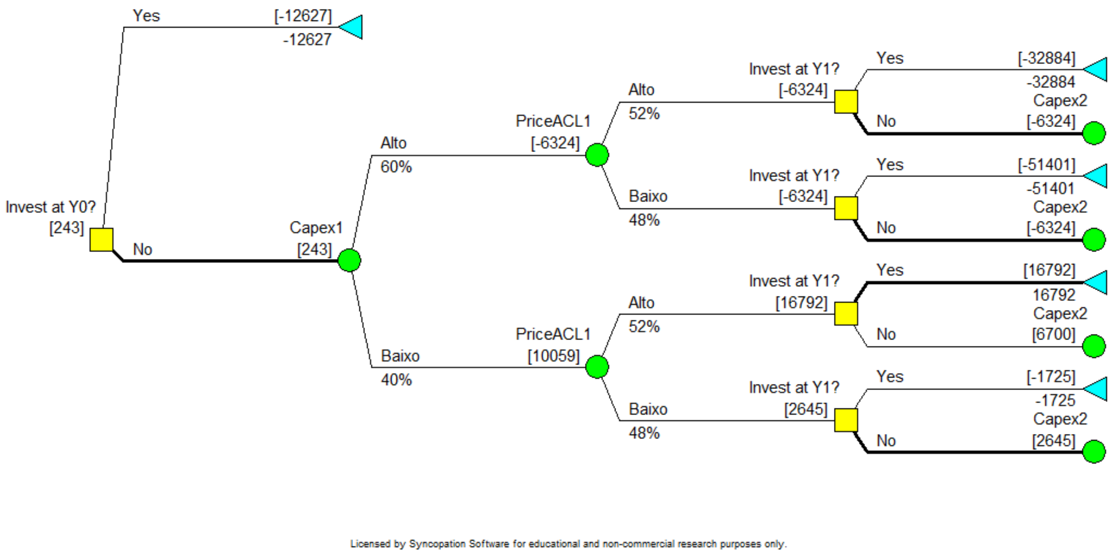

Figure 5: the first step in the decision tree (assumptions: *PriceACR*=R$ 101/MWh, *learning gains*=0, with option to abandon).

4. Results

The hypothetical wind project would be economically unviable if negotiated in auctions other than the A-5 auction: for example, if energy were negotiated at R$113.5/MWh (USD 56.75/MWh) in an A-3 auction, this project's NPV would be (R$ 0.1M). This same project, if negotiated in an A-5 auction, would yield a positive NPV of R$ 0.3M, considering that construction begins at Y0 and energy is sold in the ACL market in years 3-5 for R$ 100/MWh (calculated as in equation A.0). This is still a deterministic value, without considering any options, and it shows that the additional revenue in the ACL market more than compensates the postponement of revenues in the regulated market. However, the ACR break-even price is still near R$ 113.5/MWh, above the levels currently prevailing in Brazil's wind energy auctions.

At a winning ACR price, e.g. R$ 101/MWh, the same project would yield a negative (R$18M) NPV if the deal was closed in an A-3 auction. In an A-5 auction (construction beginning at Y0 and *PriceACL* at R$100/MWh in years 3-5), NPV would improve, but would still be negative at (R$ 13M). This value still neglects any flexibility to wait for a reduction in equipment prices or a better price negotiation in the ACL or, in a worst case scenario, the option to eventually abandon the project at Y3.

Considering such options, the project's expanded value is R$ 0.2M. This is exactly the example previously illustrated in Figure 5, which shows that investment does not start immediately after the auction and that there is a 20.8% chance of initiating construction at Y1. The 20.8% chance reflects a 40% chance of *Capex* going down in the first step of the binomial tree, and the 52% chance that *PriceACL* will go up after the same one year. In this example, no *learning gains* were considered.

Going farther out to year 3 in this quadrinomial tree, the model estimates a 63% chance that the firm will abandon the project in Y3, having won the A-5 auction at this tight R$ 101/MWh price. A conservative investor would not take into account this abandonment option, though. In such case, the project's expanded value is still negative at (R$13,0M). In other words, in this example the option to postpone investments have no value because waiting involves a high risk of reaping an even worse result than investing in Y0. Table 1 and Table 2 summarize the project's value under different assumptions, including the introduction of learning gains.

Table 1 – The project's value (in R$ M) when the option to abandon the project is not taken into account

Learning gains	PriceACR		
	R$ 97/MWh	R$ 101/MWh	R$ 109.4/MWh
0%	**(17.0)**	**(12.6)**	**(3.5)**
3%	**(17.0)**	**(12.6)**	**(3.5)**
10%	**(15.6)**	**(10.5)**	**0.3******
15%	**(5.6)**	**0.7**	**13.9**

**this is the base-case for the sensitivity analyses illustrated in Figures 6-8. R$ 109.4/MWh was the highest price closed in the Dec 2011auction; only with learning gains of 10%p.y. would a conservative investor have accepted such a deal for our reference wind-farm

Table 2 – The project's value (in R$ M) when there is no option to abandon the project

Learning gains	PriceACR		
	R$ 97/MWh	R$ 101/MWh	R$ 109.4/MWh
0%	**(1.3)**	**0.2**	**4.4**
3%	**0.3**	**2.3**	**6.8**
10%	**5.5**	**7.9**	**13.1**
15%	**10.3**	**13.7**	**24.2**

Figures 6-8 illustrate sensitivity analyses to the core assumptions of the model. Figure 6 makes it clear that only for learning gains above 10% would a conservative investor still be competitive in an A-5 auction. Given the high sensitivity of results to the existence and materiality of learning gains, further research on how to better estimate this important assumption is necessary.

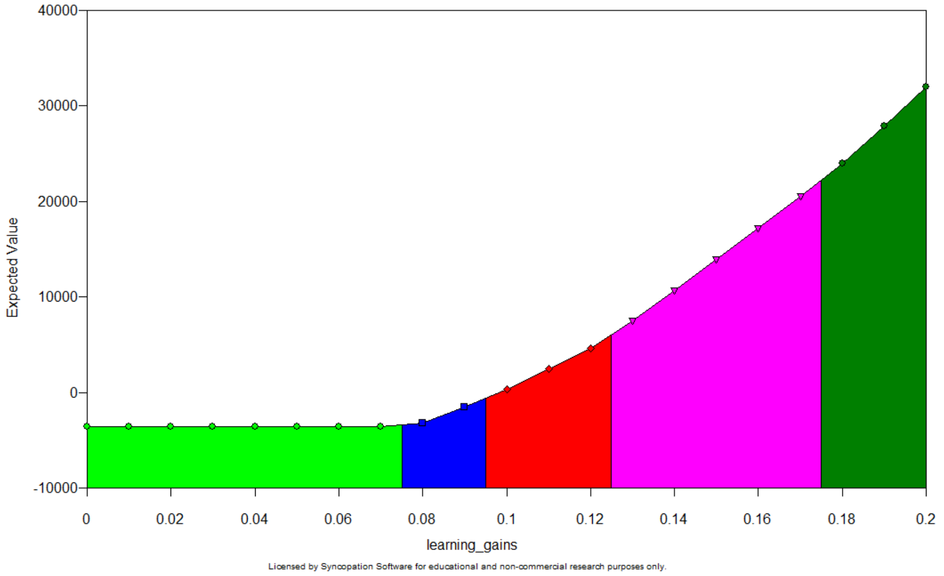

Figura 6 – Expected expanded value of the project, depending on the expected *learning gains* (without option to abandon, price in the ACR market at R$ 109.4/MWh, *PriceACL*=R$ 100/MWh)

A similar sensitivity analysis, this time drawn on the price for the 20-year energy contract in the ACR market, help managers easily device the minimum price to be accepted in an A-5 auction. Figure 7 shows an example where this break-even price is near R$ 109/MWh.

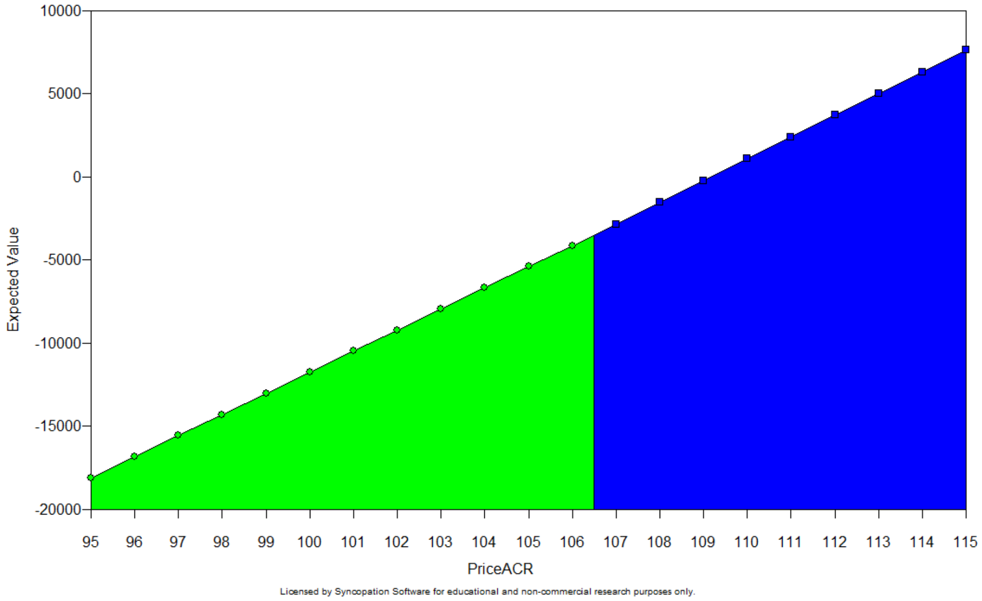

Figura 7 – Expected expanded value of the project, depending on the price negotiated in an A-5 auction (without option to abandon, *learning gains*=10%aa; *PriceACL*=R$ 100/MWh)

Figure 8 shows, on the other hand, that the investment decision is not significantly sensitive to *PriceACL*, reducing the concerns with estimating this assumption precisely.

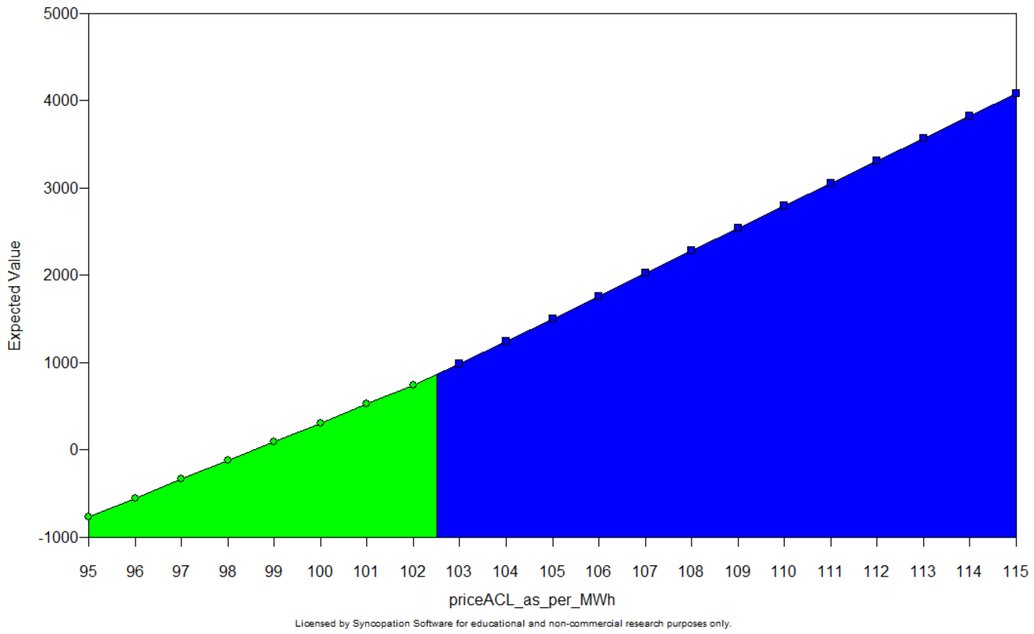

Figura 8 – Expected expanded value of the project, depending on *PriceACL* (without option to abandon, *learning gains*=10%aa; price in the ACR market at R$ 109.4/MWh)

Table 3 summarizes the chances the option to invest will be exercised, each year, for the breakeven prices detailed before in Tables 1 and 2.

Table 2: Probabilities of Investing, at breakeven prices

Assumptions	Expanded Value	Probability of investing in each year
PriceACR= R$ 109.4/ MWh *learning gains*= 10% without Option to Abandon at Y3	R$ 0.3M	Y0 – 0% Y1 – 59% => energy to be sold for 2yrs in the ACL Y2 – 0% Y3 – **41% => no energy in the ACL**
PriceACR= R$ 101/ MWh *learning gains*= 15% without Option to Abandon at Y3	R$ 0.7 M	Y0 – 0% Y1 – 0% Y2 – 41% => energy to be sold for 1 yr in the ACL Y3 – **59% => no energy in the ACL**
PriceACR= R$ 101/ MWh *learning gains*= 0% with Option to Abandon at Y3	R$ 0.2 M	Y0 – 0% Y1 – 18% => energy to be sold for 2 yrs in the ACL Y2 – 12% => energy to be sold for 1 yr in the ACL Y3 – **6% => no energy in the ACL** **Abandonment at Y3 – 64% => no energy**
PriceACR= R$ 97/ MWh *learning gains*= 3% with Option to Abandon at Y3	R$ 0.3 M	Y0 – 0% Y1 – 18% => energy to be sold for 2 yrs in the ACL Y2 – 12% => energy to be sold for 1 yr in the ACL Y3 – **6% => no energy in the ACL** **Abandonment at Y3 – 64% => no energy**

It is noteworthy that for the price range currently prevailing in wind energy auctions, high are the chances that investment will not be anticipated or that the project might be abandoned. For conservative investors, there is a 41-59% probability that no energy will be ever sold in the ACL market. For opportunistic investors, the model predicts a 70% probability that no energy will be supplied to the ACL, including a 64% probability that the project will not be constructed, at all.

In summary, under the assumptions of the hypothetical wind farm, when the 20-year price in the ACR market is at the currently low levels, and also considering that some opportunistic investors may win the bid, the inclusion of wind energy in A-5 auctions might not foster negotiations in the ACL market to the extent originally expected.

5. Conclusions

This article analyses the investment decision in a hypothetical wind project in Brazil, considering that it is given the opportunity to negotiate energy in auctions held 5 years before first delivery commitment (A-5 auctions, which are held in the regulated market - ACR). This alternative was opened for Brazilian wind farms in Dec 2011, as a way to allow them to pursue higher profitability through also negotiating energy in the deregulated market (ACL): should the investor decide to begin construction immediately after the auction, energy produced from years 3-5 might be negotiated in the ACL market.

This investment decision was analyzed in the light of Real Options Theory, leading to the conclusion that at the very low wind energy prices currently prevailing in Brazil, the flexibilities inherent to A-5 auctions would not foster the hypothetical wind project to negotiate a significant amount of energy in the ACL market. Hoping for better results, this auction winner tends to wait for better *Capex* and price conditions in the ACL market, before initiating construction. Construction is more likely to be initiated in 2 or 3 years, with little time left for delivering energy in the ACL. With the adopted assumptions, in line with a standard wind farm in Northeastern Brazil, construction is not anticipated with a 41-59% probability, so no wind energy will be sold in the deregulated market in those cases.

The tight prices at the auctions also increase the chances that opportunistic entrepreneurs, those that consider the option to abandon the project, will win the bids. In this case, wind farms are not to be constructed, at all, in 64% of the scenarios, using a set of feasible assumptions. Construction is never initiated immediately after the auction, and there is only 18% and 12% probabilities that energy will supplied to the ACL market, and for just 2 years and 1 year, respectively. Therefore, this attempt to foster the ACL market for wind energy might not pay-off and the government should otherwise expedite new measures to eliminate the structural problems that are currently hampering this market to blossom: lack of financing, high costs to connect to the grid, difficulties in considering such wind energy negotiated in the ACL market as part of energy distributors' compliance requirements.

It is worth emphasizing that, given the chance to wait for better conditions before investing, chances are high – over 60% - that an opportunistic investor will fail to perform the contract in the ACR market, unless high learning gains are attained, thanks to a better knowledge of the site's wind potential and a more efficient micrositing. The high sensitivity of results to this assumption – learning gains – highlights the importance of translating the additional knowledge about the site's potential into economic/financial data that can be actually used by decision makers.

Appendix A: the value of investing

Value equations are developed based on equation (9), adequate to the Brazilian case. Figures presented here are just excerpts of Figure 2, and are repeated here to ease comprehension.

In Case 0, value is deterministic; in Cases 1, 2 and 3, value is stochastic and is being represented by a combination, in each branch of the quadrinomial tree, of the binomial realizations of the stochastic variables. In Case 3, value is deterministic if there is no option to abandon the project (which is the case for a conservative investor, but not for the opportunistic investor, whom would also consider Case 4 in his analysis).

The realizations of stochastic variables, as detailed in section 2, follow a mathematical artifice that allows for using the risk free rate when bringing them to their present value. So, when the decision to invest is taken at Y1, for example, that stochastic value at Y1 must be divided by (1+*rf*) in order to obtain its value at Y0. A stochastic value at Y2 must be divided by (1+*rf*)^2 to obtain its value at Y0, and so on. The non-stochastic cash-flows, on the other hand, are not subject to the binomial mathematical artifice, so they are brought back to Y0 using *ke*.

In each branch of the quadrinomial tree, values are calculated at Y0, not at the decision node.

Case 0: Option to Invest is exercised at Y0

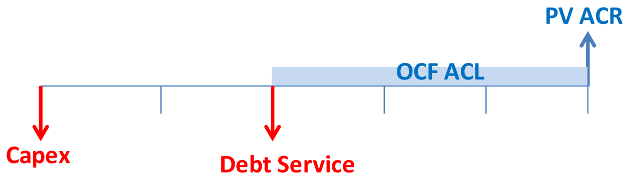

Figure A.0: Cash-Flows when investment begins at Y0

Terms in parentheses reflect the tax burden, considering Brazil's simplified tax regime for small companies

$$NPV_0 = \left[PriceACL_0 * MWm * (1-3,65\% - 8\% * 25\% - 12\% * 9\%) - OperCosts\right] * \left[\frac{1}{(1+k_e)^2} + \frac{1}{(1+k_e)^3} + \frac{1}{(1+k_e)^4}\right] + \frac{PVACR}{(1+k_e)^5} - \frac{DebtService}{(1+ke)^2} - Capex \qquad (A.0)$$

This part of the formula calculates the present value, at Y0, of the net operating cash-flow to be obtained in the deregulated market (OCFACL)

Case 1: Option to Invest is exercised at Y1

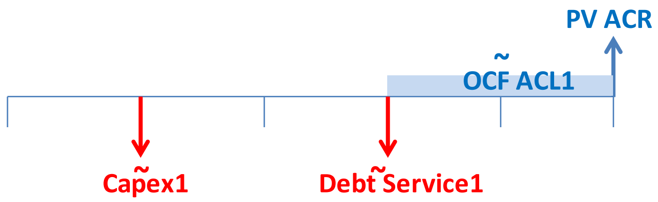

Figure A.1: Cash-flows, when investment begins at Y1

$$\tilde{NPV}_1 = \left\{ \begin{array}{l} \tilde{Price}ACL_1 * MWm * (1 - 3,65\% - 8\% * 25\% - 12\% * 9\%) * \left[\frac{1}{(1+k_e)^2} + \frac{1}{(1+k_e)^3} \right] - \\ - DebtService * \frac{\tilde{Capex}_1}{Capex} * \frac{1}{(1+k_e)^2} - \tilde{Capex}_1 \end{array} \right\} *$$

$$* \frac{1}{(1+r_f)} + \frac{PVACR * (1 + learning\_gains)}{(1+k_e)^5} - OperCosts * \left[\frac{1}{(1+k_e)^3} + \frac{1}{(1+k_e)^4} \right]$$

(A.1)

Case 2: Option to Invest is exercised at Y2

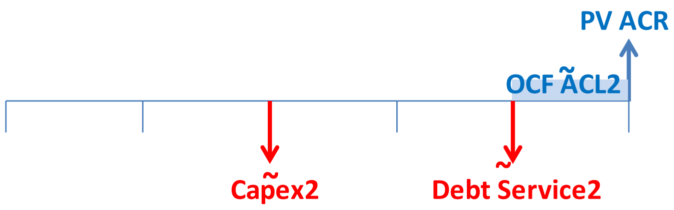

Figure A.2: Cash-Flows when investment begins at Y2

$$\tilde{NPV}_2 = \left\{ \begin{array}{l} \tilde{Price}ACL_2 * MWm * (1 - 3,65\% - 8\% * 25\% - 12\% * 9\%) * \left[\frac{1}{(1+k_e)^2} \right] - \\ - DebtService * \frac{\tilde{Capex}_2}{Capex} * \frac{1}{(1+k_e)^2} - \tilde{Capex}_2 \end{array} \right\} *$$

$$* \frac{1}{(1+r_f)^2} + \frac{PVACR * (1 + learning\_gains)^2}{(1+k_e)^5} - OperCosts * \left[\frac{1}{(1+k_e)^4} \right]$$

(A.2)

Case 3: Option to Invest is exercised at Y3

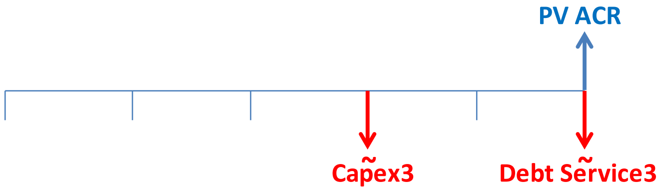

Figure A.3: Cash-Flows when investment begins at Y3

$$\tilde{NPV}_3 = \left\{ -DebtService * \frac{\tilde{Capex}_3}{Capex} * \frac{1}{(1+k_e)^2} - \tilde{Capex}_3 \right\} * \frac{1}{\left(1+r_f\right)^3} + \frac{PVACR*(1+learning\_gains)^3}{(1+k_e)^5}$$

(A.3)

Case 4: Option to Abandon the project at Y3

Figure A.4: Cash-outlay when the project is abandoned at D3

This option exists only for the opportunistic investor. In Case 4 the performance bond, equivalent to 5% of Total Capex, is executed. The performance bond is written on the Total Capex originally forecasted at the A-5 auction date, that is, near Y0, so this value is deterministic. Total Capex equals *Capex*/40%, considering the assumption that shareholders account for 40% of total investments, while banks finance the remaining 60%.

Being a cash-outlay that is not tied to the risks of the wind sector (wind risk, engineering risks, performance risk), it is brought to D0 using the risk-free rate, *rf*, instead of *ke*. It also seems fair that this cash-outlay, which can be higher due to additional and still unpredictable penalties, is more inflated than other deterministic cash-flows, justifying a lower discount rate.

The value of the project in D0, if it is abandoned at D3, is negative and equivalente to:

NPV3, abandonment= **(5%*Capex/(1+rf)^3/0.40)** (A.4)

In summary, equations A.0 through to A.4 reflect the expected payoffs, at Y0 currency, upon the exercise of available options at each t in each year $i \in \{0,1,2,3\}$. The expected payoff, when the best alternative is to wait, is the result of optimal payoffs in the following nodes, weighted by their risk neutral probabilities. In each node, the optimal decision is the one with the highest payoff.

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