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Real Options versus Traditional Methods to assess Renewable Energy Projects

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ABSTRACT

Several methods can be employed to evaluate investment in energy production. On one hand, traditional methods (Net Present Value (NPV) or Internal Rate of Return (IRR), for example) ignore certain project characteristics that may influence its evaluation, such as irreversibility, uncertainty and management flexibility. Nevertheless, the Real Option Approach (ROA) has an advantage over the application of traditional methods, since the prior uncertainties are taken into account. Thus, the main objective of this study is to apply ROA to a case-study (mini-hydro plant) through the use of the binomial tree developed by Cox, Ross and Rubinstein in 1979. This study concludes that the value of ROA is higher than the value of NPV because the investor can get better information and uncertainty is reduced when he has the option to defer the investment. In addition to providing a deep analysis on the major gaps in energy investment evaluation, this work contributes to a better understanding of the usefulness of ROA.

1. Introduction

In the last few decades, the liberalization of electricity markets has significantly influenced investment decisions in regards to electricity generation. Furthermore, electricity generation projects have specific characteristics, such as irreversibility and high levels of uncertainty that influence the choice of the best method to evaluate energy investments.

The Net Present Value (NPV) is commonly used to evaluate these investments. However, this method underestimates the value of investment when flexibility is one of the project characteristics because some management options are not taken into account, such as contraction or expansion actions [1]. Thus, this method is unsuitable for evaluating power generation investments.

The Real Option Approach (ROA) overcomes these shortcomings. When uncertainty and irreversibility are present in energy investments, ROA evaluates those investments considering that the investor's choice is subject to flexibility, i.e., the investor has the option whether to postpone his decision on irreversible investments [2].

Having this in mind, the main purpose of this article is to evaluate a renewable energy investment through ROA and traditional methodologies. The methodology used was the following: after a literature survey focused on the characterization of different methodologies and their main applications to energy investments, ROA will be presented in more detail. Subsequently, the study will analyze an investment in a mini-hydro plant through the application of traditional methods. Finally, ROA is applied to the same case study and the results are obtained and compared.

The article proceeds as follows: Section 2 makes a literature survey on the traditional methods used to evaluate energy investments; Section 3 presents the Real Option Approach; Section 4 evaluates an investment of a mini-hydro and presents the main results; and the last section presents conclusions.

2. The economic evaluation of energy investments

Energy investments have specific characteristics that distinguish them from other types of investments. First, this kind of investments is partially or completely irreversible because the capital of the industry cannot be used in other sectors or by different companies [3]. Second, investors have to assess their options under high levels of uncertainty associated with the liberalized electricity market [2]. Third, investments may occur in a flexible time, i.e., the investor can invest today or postpone his decision in order to obtain better

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information. Finally, investors have several generation technologies at their disposal that can be chosen when the project is defined. However, these technologies are associated with different uncertainty levels that should be considered. Therefore, investors should adopt a methodology to evaluate energy investments that takes into account risks and uncertainties regarding the investment.

Many authors have applied several methodologies to analyze the viability of these projects. Table 1 systematizes the different methods used to make that evaluation and presents some examples of application on energy investments.

As can be seen by Table 1, there are several methods applicable to evaluating energy investments, yet some of these are more appropriate than others. Thus, a question arises: What is the best method to evaluate energy investments?

According to Bracher [68], traditional methods include project risk but ignore management actions. Moreover, if those actions were considered, risk could be mitigated, maintaining or even increasing the project value. On the other hand, the Real Option Approach (ROA) combines uncertainty and risk with flexibility, taking into account the volatility associated with the evaluation process as a potential positive factor, which gives value to the project.

As mentioned previously, energy investments have specific characteristics, particularly in regards to uncertainty and irreversibility. The application of traditional methods with their static evaluation tools fails to regard flexibility and undervalues investments [42]. Therefore, according to Pindyck [69] the use of traditional methodologies can be inconsistent, supporting the application of ROA.

Mainly used to evaluate real assets, ROA factors in operational and managerial flexibilities over the project lifetime, differentiating itself from traditional methods (like Net Present Value (NPV)). Indeed, real options give flexibility to investors when making decisions about real assets, revealing uncertainty associated with cash-flows and allowing investors to make decisions that positively influence the final project value.

It can be concluded that traditional methods assess the risk but cannot study all uncertainties and flexibilities associated with the project. ROA overcomes these shortcomings since it considers management flexibility. Thus, investors of a renewable generation project can make informed decisions because better information on the project is obtained. For these reasons and since the evaluation of a renewable generation project is the main objective rather than to make a portfolio evaluation, traditional methods will not be applied, instead the application of ROA seems more suitable. Hence, the next chapter will present the real option approach as it is applied to this specific project.

3. Towards a new approach: real options as a suitable method for evaluating energy investments

ROA is claimed as the only asset evaluation method that considers the interaction between three main characteristics which define energy investments: irreversibility, uncertainty, and time flexibility [70].

Nevertheless, before starting the presentation of ROA, the difference between *financial options* and *real options* must be defined. A *financial option* is an asset where the holder has the right to but not the obligation of buying (call option) or selling (put option) a quantity of a specific asset (underlying asset), at a fixed price (exercise price) during a pre-established period or date. A *real option* gives to its holder the right but not the obligation of taking a share that affects a real physical asset, at a pre-determined cost during a pre-established time [71]. Table 2 shows the analogy between these two concepts.

Although the evaluation of real options is more complicated than that of financial options, the application of methodologies underlying the evaluation of financial options constitutes a good approximation to evaluate real options. Thus, the main models used to evaluate financial options will be presented: the Black–Scholes

Table 1
Assessment methods used in energy investment projects.

Methods	Definition	Numerical solution[a]	Decision Criterion to implement the Project	Applications	References
Net present value	Sum of the present value of all cash flows produced by the project, net of the necessary investments to implement the project.	$\mathrm{NPV} = -\sum_{t=0}^{n-1} I_t/(1+i)^t + \sum_{t=1}^{n} NR_t/(1+i)^t$	$\mathrm{NPV} > 0$	Oil and Gas industries. Renewable energy investments/projects.	[4–14]
Internal Rate of Return	Represents the discount rate that equalizes the NPV to zero.	$0 = -\sum_{t=0}^{n-1} I_t/(1+\mathrm{IRR})^t + \sum_{t=1}^{n} \mathrm{NR}_t/(1+\mathrm{IRR})^t$	$\mathrm{IRR} > k$	Renewable energy investments/projects.	[10,11,14,15]
Return on Investment	Measures the relation between the present value of cash flows and the necessary investments to implement the project.	$\mathrm{ROI} = [\sum_{t=1}^{n} \mathrm{NR}_t/(1+i)^t]/[\sum_{t=0}^{n-1} I_t/(1+i)^t]$	$\mathrm{ROI} > 1$ ($\mathrm{NPV} > 0$)		
Payback Period	Period of time required to recover the investments.	$P = [\sum_{t=0}^{n-1} I_t/(1+i)^t]/[\sum_{t=1}^{n} \mathrm{NR}_t/[(1+i)^t/n]]$	$P < n$	Renewable energy investments/projects.	[10,14,16]
Benefit-Cost Ratio	Identify, quantify and weigh the benefits and costs of the investment projects.	$B/C = [\sum_t (R_t - C_t)/(1+i)^t]/[\sum_t I_t/(1+i)^t]$	$B/C > 1$	Renewable energy investments/projects.	[10,14,16–20]
Levelized Costs	Compare the energy generation technologies with different characteristics and lifetimes.	$\mathrm{LC} = (C_\mathrm{I} + C_{\mathrm{O\&M}} + C_\mathrm{c} + C_\mathrm{d})/E_\mathrm{act}$	Lowest levelized cost	Energy investments/ projects Energy Market. Power Generation.	[13,16,21–32]
Real Options	Reformulates the NPV so that the scenarios of great uncertainty, which compose the investments, are considered.	$\mathrm{NPV}_{\mathrm{expanded}} = \mathrm{NPV}_{\mathrm{traditional\ or\ static}} + \mathrm{Value}_{\mathrm{management\ flexibility}}$	$\mathrm{NPV}_{\mathrm{expanded}} > 0$	Oil and Gas industries. Renewable energy investments/projects. Energy market. Power generation.	[6–8,33–67]

[a] Terminology: I_t: Investment Cash- Flows in period t; NR_t: Net Revenue in period t; i: Discount Rate; IRR: Internal Rate of Return; k: the reference interest rate or the opportunity cost of capital; n: number of years; $R_t - C_t$: Operation Cash-Flows in period t; C_I: Present Investment Cost; $C_{\mathrm{O\&M}}$: Present Value of Operation & Maintenance Costs; C_c: Present Value of Fuel Costs; C_d: Present Value of Various Annual Costs; E_act: Present Cumulative Value of Energy Production.

Table 2
Analogy between financial and real options [71,72].

Financial options	Real options
Stock price	Present value of cash flows from the project
Exercise price	New investment required
Time to expiration	Length of time until decision must be made
Risk-free rate of return	Time value of money
Volatility	Risk of expected returns

model and the binominal tree developed by Cox, Ross and Rubinstein (1979) [73].

Before those models are presented, it should be noted that there are different types of real options. However, for this study the deferral option was chosen, which can be defined as the possibility given to investor to postpone his investment until the necessary information to make a decision is obtained.

3.1. Black–Scholes model and binominal tree as a theoretical framework underlying real options methodology

Fisher Black and Myron Scholes developed the first mathematical formula for pricing European options (European call options[1]) [74]. In their article, Black and Scholes start from a non-arbitrage premise (proposed by Modigliani and Miller) to develop an equilibrium model, which comprises a risk-free portfolio where returns can be represented by the risk-free rate. The model proposed by these authors has the following assumptions:

1. The risk-free rate is known and constant over time;
2. The asset pays no dividends;
3. The option can only be exercised at the maturity date;
4. There are no transaction costs when buying or selling an asset or derivate;
5. It is possible to invest any fraction of assets or derivate to the risk-free interest rate;
6. There are no penalties when short-selling is made;
7. The model is developed from the concept that the option asset price has a continuous stochastic behavior, defined by the Geometric Brownian Motion (GBM) and given by the following equation:

$$dS/S = \mu dt + \sigma dz \tag{1}$$

where dS is the variation of the underlying asset price (S) at time dt, μ is a mathematical expectation of the instantaneous return rate related to underlying asset, σ is the instantaneous standard deviation of the underlying asset return, and dz is a standard process of Gauss–Wiener.[2]

The Black–Scholes equation for a European call option is given by:

$$c = SN(d_1) - K\exp^{-rt}N(d_2) \tag{2}$$

where,

$$d_1 = \left[\ln(S/K) + \left(r + \left(\sigma^2/2\right)\right)\tau\right]\Big/\sigma\sqrt{\tau} \tag{3}$$

$$d_2 = d_1 - \sigma\sqrt{\tau} \tag{4}$$

In the prior equations, $N(d)$ represents the normal cumulative distribution function, S is the stock price, K is the exercise price, r is the time to expiration, and σ gives the volatility associated with the underlying asset.

Regarding European put options, they can be easily deducted from the previous equation through *put-call parity*. *Put-call parity* happens when a portfolio composed of one unit of an underlying asset in a long position, a call option in a short position, and a pull option in a long position have the same value of the exercise price at the maturity date, regardless of the price of the underlying asset. Therefore, in the absence of arbitrage opportunities, the portfolio value is equal to the exercise price, discounted by the risk-free interest rate, at any time [71].

Considering p as the put option value of an asset at time t, a European put option can be defined as:

$$p = K\exp^{-r\tau}N(-d_2) - SN(d_1) \tag{5}$$

However, European as well as American options need numerical methods to evaluate them, such as the binominal tree developed by Cox, Ross, and Rubinstein in 1979. According to these authors, this simple and efficient method allows the holder of an option to decide whether it is most beneficial to exercise the option or to wait until its maturity date, at every time instant.

This model assumes that the maturity date of an option can be divided in discrete periods, whose dimension will be represented by Δt. Additionally, the price of the underlying asset is subject to a given behavior, and it will be multiplied by a random coefficient μ or d, at each period (Δt). It should be noted that random coefficients are defined as the price variation rate of the underlying asset. Since this rate can be ascending (μ) or descending (d), reflecting the favorable or unfavorable market conditions, these multiplicative factors are dependent on volatility (σ) and length of the periods (Δt). Fig. 1 shows a binominal tree for the underlying asset, illustrating its price evolution. The nodes at the right represent the distribution of possible future values for the underlying asset.

The multiplicative factors (μ) and (d) are given by:

$$\mu = \exp^{\sigma\sqrt{\Delta t}} \tag{6}$$

$$d = \exp^{-\sigma\sqrt{\Delta t}} \tag{7}$$

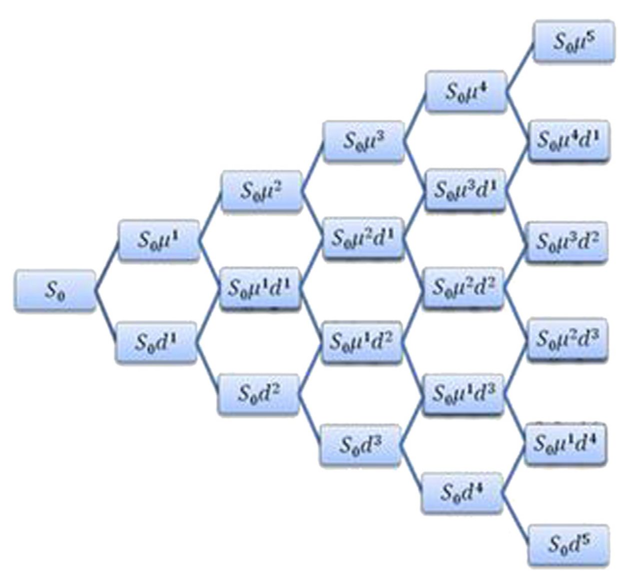

Fig. 1. The binomial tree for the evolution price of the underlying asset [71].

[1] It should be noted that, the sole difference between European and American options is that the first one may be exercised only at the option's expiration date, while the second one may be exercised at any time, before the expiration date.

[2] A stochastic process $W_t = \{W(t), t \geq 0\}$, defined in a probability space (Ω, F, P), is a Wiener process if: for $s \geq 0$ and $t > 0$, the random variable $W_{t+s} - W_s$ has a normal distribution $N(0,t)$; for $n \geq 1$ and $0 \leq t_0 \leq \cdots \leq t_n$, the random variable $W_{tr} - W_{tr-1}$ is independent; $W_0 = 0$; W_t is continuous for $t \geq 0$.

Table 3
Description of the main characteristics and costs of the mini-hydro plant.

Characteristics of the mini-hydro plant		Investment costs (% total)		Annual operating & maintenance costs (% total)	
Turbine type	Kaplan with vertical axis	Transformers	14.46%	Operating & maintenance costs (annual)	2.48%
Number of turbines	1	Generators	10.24%	Years 1 and 50	4.97%
Generators	Asynchronous three-phase 400 V	Turbines	10.24%	Maintenance year 10	4.97%
Number of generators	1	Electromechanical equipment	14.46%	Maintenance year 20	4.97%
Income generator	95%	Construction	24.10%	Maintenance year 30	4.97%
Transformers	400 V/15 kV	Line of 15 kV	12.05%	Maintenance year 40	77.64%
Number of transformers	1	Study and Project	2.41%	New transformers after 25 years	2.48%
Income of transformers	90%	Cost of land and expropriation	12.05%	Operating & Maintenance Costs (Annual)	4.97%
Capacity of each turbine (kW)	500				
Capacity of project (kW)	500				

The probability of the stock price to increase or to decrease is given by a risk-neutral measure. Therefore, the stock price increases with a probability equal to:

$$p = \left(\exp^{rf\Delta t} - d\right) \Big/ (\mu - d) \tag{8}$$

and decreases with a probability given by:

$$q = 1 - p \tag{9}$$

After determining those parameters, the option value can be obtained through a binominal tree. In this tree each gain obtained for stock price is represented. For the case of a call option, this value is given by the maximum difference between the value of the underlying asset and its exercise price, and zero, i.e. $\max(S - K, 0)$. For the case of a put option, the value corresponds to the maximum difference between the exercise price and its stock price, and zero, i.e. $\max(K - S, 0)$. From the option value given by the nodes at the right of the tree, it is possible to calculate the other values applying the neutral probability on each pair of vertically adjacent values. They are mathematically represented by the following equation:

$$C_t = \left[pC_\mu^{t+1} + (1 - p)C_d^{t+1}\right] \Big/ \exp^{r\tau} \tag{10}$$

When stock price is determined, different trajectories followed by price until its maturity date can be defined. Regarding the option value, an opposite route from the right to the left is adopted, based on prices defined in each node.

Since ROA was thoroughly presented, the next chapter will address the application of this method to a real case.

4. Case study: application of real option methodology to a small-hydro investment project

In this chapter a case study will be presented, addressing an investment project of a mini-hydro plant and its evaluation. To evaluate this project, two evaluation methodologies will be compared: the traditional one and ROA. Nevertheless, before beginning with the evaluation, the main characteristics of the case study need to be presented.

4.1. The main project characteristics

The project is characterized by an investment in a mini-hydro plant with an installed capacity of 500 kW. This plant is built on river margins and is composed by a low dropout capture (10.5 m) and a reservoir. The project began in 2006, and the plant started to operate at the end of this year, having a lifetime of 50 years. It is assumed that turbines and generator have the same lifetime (50 years). However, the transformer has a reduced lifetime of 25 years. The plant characteristics and its associated costs are presented in Table 3.

Regarding project funding, there is an incentive program which covers 40% of the investment up to 1000 €/KW. The company equity represents 25% of the investment and the remaining 35% are obtained through loan. The first 300 €/kW of the incentive are not refundable, and the remainder must be repaid in nine years with a grace period of 3 years, without interests (i.e. from the 4th to the 9th year in constant annual payments). The bank grants a credit over 10 years, which is repayable through constant annual payments, since the beginning of the plant operations. These annual payments are subject to an interest rate of 6.5% and an opportunity cost on capital of 10%.

Since the description of the project was made, the next section will present the results of the evaluation obtained by traditional methodologies.

4.2. Using traditional methodologies to evaluate the project

In this case study, NPV, IRR, and Payback methods were used to evaluate project viability, subject to three key assumptions that strongly affect the results. First, it is assumed that the plant will produce at full capacity and all energy will be sold during the project lifetime. This is an optimistic and unrealistic assumption, since the uncertainty of water flow throughout the year is not considered, putting the project's viability at risk. Second, energy remuneration is constant during the project's lifetime (50 years). This is another optimistic assumption because it is improbable that energy prices could remain constant over the course of 50 years, despite the government keeping constant energy remuneration. Nonetheless, this remuneration will likely occur over a maximum period of 25 years. Third, a discount rate of 10%[3] is assumed, which is defined disregarding the composition of funding sources. This assumption could strongly influence the project results. Finally, an inflation rate of 3% is considered.

Bearing in mind these assumptions, the results of the project evaluation are shown in Table 4.

Through these results, it can be stated that the project has economic viability and must be implemented. However, some issues such as price and production uncertainties were not considered.

Nevertheless, it was previously stated that ROA can overcome those uncertainties. Thus, the application of ROA in evaluating this project is suitable and it will be presented in the next section.

4.3. Evaluation of the project through ROA

In order to apply ROA to evaluate the project, two assumptions are taken into account. Firstly, all data provided by traditional evaluation

[3] The discount rate is based on a 12 months Euribor rate equal to 1.353%, in 2010, a high country risk measured by the interest rates of the treasury certificates (5.40% for the Portuguese treasury bonds with a maturity of 10 years); and assuming a risk aversion perspective [76,77].

Table 4
Results of the project.

Data	Values
Energy produced (MWh/year)	1.332,808
Energy remuneration (€)	96.672
Feed-in tariff (€/MWh)	72,53
NPV (€)	51.371
IRR (%)	11,22
Payback (years)	35

Table 5
Parameters of the binomial tree.

Stock Price (S)(€)	881.371
Exercise price (k) (€)	830.000
Time to option expiration (days) (T)	1.825
Volatility (σ)	0.40
Risk-free rate (rf)	0.07
Number of steps (n)	5
$\Delta T = (T/365)/n$	1
$\mu = \exp(\sigma\sqrt{\Delta T})$	1.49
$d = 1/\mu$	0.67
$\exp(\mathrm{rf}^{*}\Delta T)$	1.07
$p = (\exp(\mathrm{rf}^{*}\Delta T) - d)/(u - d)$	0.49

methods are considered. Although the assumptions made for those methods may seem unrealistic or overestimated, they will not invalidate our analysis because the results provided by traditional approach were satisfactory. Furthermore, possible corrections are difficult to make, since the necessary data is unavailable. Additionally, as the main objective of this study is to compare traditional and ROA methodologies, these drawbacks may be disregarded.

Secondly, operational costs of the power plant are not affected by high levels of uncertainty. As a simplifying assumption, other uncertainties such as technological changes or environmental policies were not considered. Moreover, as fuel costs have a slight impact on production costs in the case of mini-hydro investments, they were also not introduced in this study. Thus, the only uncertainty factor is the volatility of electricity prices. The prices considered in this study were the electricity prices of long-term contracts, which were taken from OMIP (the entity responsible for the management of the Iberian derivatives market) and observed over a four-year period. It should be noted that spot prices were not included because they may be strongly influenced by short-term factors.

Having this in mind, the premises of a Geometric Brownian Motion (GBM) were followed for modeling the long-term probability distribution of electricity prices and then for estimating the volatility of investment returns. Thus, a lognormal distribution was considered, since prices cannot be negative. After using Chrystal Ball software to estimate the probability distribution of parameters, a confidence interval of 5%–95% was defined, obtaining the lowest and highest market price over four years of €21.90 and €77.91, respectively. Mean and standard deviation were calculated by the program, reaching 44.50 and 17.2, respectively. Then, a Monte Carlo simulation with 5000 interactions was performed to calculate project volatility. The results show a standard deviation of 40%, approximately, corresponding to project volatility.

It should be noted that, investment in a mini-hydro plant is not implemented in phases, i.e., the probability of stopping power plant production after its start-up is low [75]. Therefore, the option of deferring the project within five years is considered and it is justified by the high uncertainty on regulatory change. In other words, given the current economic crisis, the government believes that the support given to electricity generation from renewable sources is no longer a priority and the legislation could be changed in the coming years. These observations limit the feasibility of the project. Thus, the remuneration of the new plants would no longer have a constant remuneration, being subject to the uncertainty of electricity prices on the open market.

A deferral option corresponds to an American call option, in which the decision to invest now will be taken if the NPV of the project exceeds the value of the deferral option. These options are typically evaluated through the binomial tree, developed by Cox, Ross and Rubinstein. The parameters used to build the tree are presented in Table 5.

It should be noted that, the risk-free rate of returns represents the return rate of Treasury bonds with a maturity of 10 years.

The tree presented in Fig. 2 shows the possible evolution of the underlying asset price and the deferral option, from the left to the right. Regarding the underlying asset, the value presented by the first node of the tree gives the current price of the underlying asset. The price can increase or decrease depending on coefficients μ and d, respectively. The last column of the binomial tree represents the possible values of the underlying asset at the option maturity date.

Since the deferral option is similar to a call option, the last values of the tree are determined by subtracting the values of the underlying asset to the exercise price. The result can fluctuate between $S-K$ and 0. The other values are determined by the application of a neutral probability to each pair of vertically adjacent values.

The project value with the option of delay is €433.659, which is higher than the static NPV (€51.371). The option value of delay is given by the difference between static NPV and expanded NPV, which results in a value of €382.289. Therefore, it can be concluded that the deferral option value is higher than the value of investing immediately (NPV). Thus, the project should be postponed until more favorable investment conditions appear.

Since investment decisions are subject to an opportunity cost in regards to deferring the decision, the investment should be made only when its NPV exceeds the value of the deferral option [71]. This happens because investing now implies a loss of opportunity to invest later, which corresponds to the value of delaying the

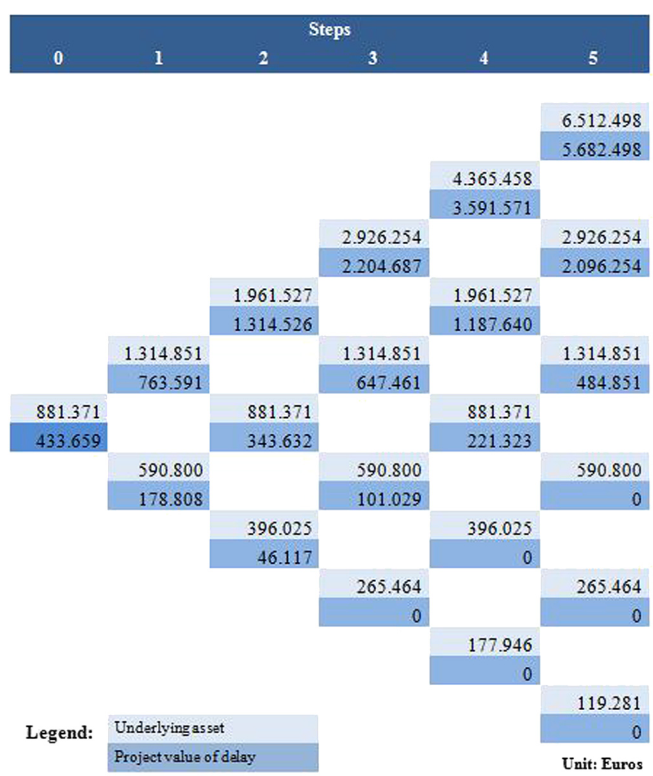

Fig. 2. Evolution of the underlying asset and the project value of delay.

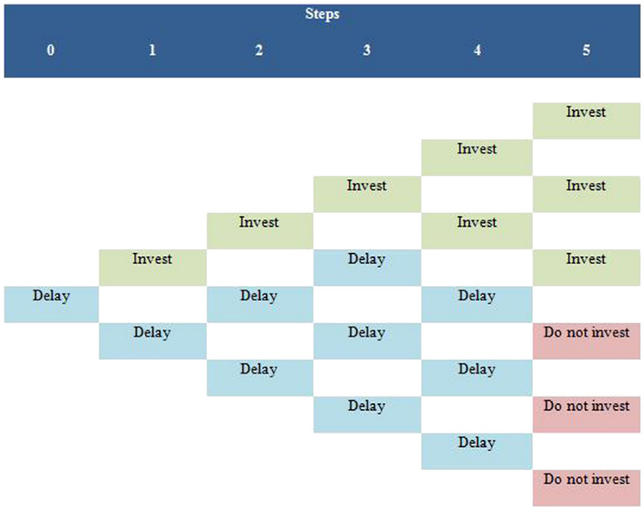

Fig. 3. The decision tree.

option. Therefore, the value generated by the project could not cover the investment, but it should be sufficiently high to cover the deferral option. Appling these assumptions to the prior tree, the decision tree of Fig. 3 can be built, showing the decision of invest or delay, at each moment.

This tree shows that the option of investing now is better when the underlying asset reaches higher values. If the underlying asset has lower values, then the option of postponing the project for the next period is a better choice. In other words, the investor will only invest if the evaluation of energy remuneration exceeds the investment and opportunity costs of not postponing the project.

The project presents a low static NPV, despite its positive outcome. Thus, it will be necessary to invest €830.000 to implement the project immediately. After 35 years, the investor will only obtain €51.371. According to those values, it can be stated that any investor will wait for more information in order to lower project uncertainty. Therefore, the tree shows that the project will be postponed even with a positive NPV static, since the value of the deferral option is superior.

However, in the last year, the investor should decide if there are favorable conditions to invest or not because the option to defer the project is no longer available. In this case, the investor will only invest if electricity prices are sufficiently high.

Furthermore, the project value grows as the decision is postponed because uncertainty is dissipated. Additionally, the option to defer the project involves losses at cash-flow and competition levels, which should be considered in order to obtain more information and lower uncertainty. If these losses are not taken into account, the project will not be implemented.

Generally, it can be concluded that the application of ROA gives more flexibility for the investor to re-evaluate his project and redefine his strategy. The NPV method does not consider that flexibility, underestimating the project value. Therefore, the incorporation of ROA increases the project NPV, supporting that a project subject to a deferral option has more value than another one without that option.

5. Conclusion

Electricity market liberalization has brought about a greater uncertainty for investments in this sector. It should be noted that in a monopoly, uncertainties such as demand for electricity and energy prices, entry of new competitors in the market as well as introduction of regulatory changes were relatively stable. With the introduction of liberalization in electricity generation (and supply), these issues increased uncertainty levels of new power plant investments.

Methods applied for evaluating energy investments have been the subject of several studies, due to high degree of uncertainty and irreversibility that characterizes them. Therefore, the decision should not be restricted to two options: invest now or never. Indeed, it should include some management flexibility.

Traditional methods, such as NPV or IRR, do not allow an investor to define the optimal time to invest or to estimate the true value of project uncertainties. Nevertheless, ROA is a methodology used to evaluate real assets that considers management flexibility over the project's lifetime. As new information is considered and uncertainties are revealed, the investor can make decisions that positively influence the final project value. Thus, ROA will maximize gains in favorable situations and minimize losses in unfavorable ones.

The main objective of this study is to assess a renewable generation project through ROA. To achieve this objective, the main characteristics and uncertainties of this kind of investments were identified, justifying the use of ROA together with traditional methods.

Through the application of ROA, the investor can analyze market conditions, since better information is obtained and uncertainty is reduced. Unlike NPV and IRR methods, which neglect uncertainty over electricity prices, ROA considers these and other uncertainties. Thus, the investor gets more comprehensive and realistic information, allowing him to avoid losses and to obtain higher gains from the project during the five years. Additionally, this case study has very low returns for a high investment, which proves that an analysis based on traditional NPV is not sufficient. Furthermore, it should be noted that small unfavorable changes in the project returns could put its viability at risk.

None of the evaluation methods are considered absolute; neither is the evaluation of investments an exact science. However, this does not mean that there is no need to search for assessment methods that consider the investment characteristics, uncertainties and management flexibility. Although ROA is a difficult and uncommon method for companies, it is the most current and suitable method to apply to issues related to uncertainty. Therefore, if an analysis takes into account uncertainty over time and includes real options in the project, the decision-making process will be more realistic.

Future studies will seek to work upon a more sophisticated model where other uncertainties, such as generation level, construction costs, regulation or demand levels, are considered. Furthermore, the cost of postponing the project is not considered in this study. Thus, future work on ROA evaluation should include a way to account for these costs so that their determination is less subjective.

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