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Real Option Approach to Evaluate the Certified Emission Reduction sales in a Photovoltaic Energy Project of Colombia

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Abstract

Due to the urgency of establishing policies for the reduction of greenhouse gases, renewable energy projects have become relevant in the last decades. The governments have met to establish agreements that encourage clean production, the Kyoto Protocol is one of them which establishes the strategies to confront to global pollution. However, investors in clean energy projects look with caution and refrain from investing because the investment costs in these projects are high and their expected returns are affected. Therefore, this article evaluates a power generation project from solar source in Colombia. It considers the incentive by Certified Emission Reductions sales based in Kyoto Protocol. The project is evaluated by the traditional method of economic engineering Net present value that does not consider flexibility in decisions. and it is also evaluated by means of the real options approach that considers the flexibility and risk of the project for decision making, thus, it gives the investor an overview of the value or cost of the possible alternatives. Initially, the project is not profitable for investors, however, with the deferment real option the project is profitable if the energy price takes high values.

Keywords: Real Options, Energy Price, Certified Emission Reductions.

INTRODUCTION

Renewable energies are acquired by natural means, they are inexhaustible sources of clean energy where their use does not exceed their recovery. its growth in the electricity sector is driven by the need to create new sources of energy less polluting than the sources of fossil sources, its integration in the world is due to elements such as the profitability of new renewable technologies, improvements in global policies and locals seeking the generation of new projects, strategic financing to eliminate economic barriers, and others. [1]

According to the global outlook "Approximately 81% of the energy consumed worldwide comes from fossil sources, while the remaining 19% comes from renewable sources" [2] The lack of renewable energy projects affects the quality of life of humans due to the high carbon dioxide emissions generated by fossil fuels. According to the analyzes carried out by the National Planning Department of Colombia (DNP by the acronym in Spanish), Colombia presents one of the highest levels of environmental and atmospheric pollution that reduces the quality of life of the population. Health costs associated with environmental degradation in Colombia amount to $ 20.7 billion pesos, equivalent to 2.6% of GDP in 2015, related to 13,718 deaths and nearly 98 million symptoms and diseases. [3]

As the percentage of energy by fossil sources is high, several authors have incorporated into the studies a real options approach to evaluate renewable energy investment projects and that a result is obtained that motivates decision making and encourages investment in these projects. Detert & Kotani [4] analyze the changing environment of investments in renewable energy with real options and explore their potential in developing economies under the uncertainty of the price of coal. Under the results of the model, they argue that the increase in electricity prices makes alternative renewable energy investments more attractive and reduces negative external effects.

Loncar, Milovanovic, Rakic, and Radjenovic [5] using the binomial tree model examine the potential assessment of a wind farm project in Serbia over a period of 15 years. They conclude that applying the real options to renewable energy projects becomes a strategic tool since it obtains a more

realistic value of the projects and encourages decision making based on calculated risks.

Kim, Park, and Kim ([6] conducted an analysis with Real Options Approach - ROA to evaluate investments in renewable energy projects in developing countries. They took a hydroelectric project in Indonesia as a case study. The following variables were considered: tariffs, energy production, price of carbon emission certificates and operation and maintenance cost in a renewable energy source. they conclude that the proposed ROA can be used as a tool to make investment decisions in volatile renewable energy markets in developing countries.

Due to the investment needs in renewable energy projects in the world and specifically in Colombia, this study presents an analysis of a solar energy project in Colombia through ROA and evaluates the impact of a potential sale of Reduced Emission Certificates in its cash flows. Due to the investment needs in renewable energy projects in the world and specifically in Colombia, this study presents an analysis of a solar energy project in Colombia through ROA and evaluates the impact of a potential sale of Reduced Emission Certificates in its cash flows. For this, the background and theoretical framework is presented first, then the methodology is described from the real options approach valued by binomial trees, afterwards, the results for the "*Celsia Solar Yumbo"* photovoltaic farm project are presented and finally, the conclusions.

THEORETICAL BACKGROUND

Policies on renewable energies become important in the generation of new projects, Zuluaga and Dyner [7], Flórez Acosta, Tobón Orozco and Castillo Quintero [8], Radomes and Arango [9] conclude that the implementation of renewable energies will be is limited by inefficient policies such as exemption from income tax, which do not encourage the creation or investment of new projects, so the government must establish the appropriate incentives to efficiently exploit renewable energy resources to encourage private participation and the prioritization of sustainable energy alternatives. Ortíz and Hurtado [10], Calderón et al., [11], Rosso and Kafarov [12] conclude that Colombia must make greater efforts in order to deepen on the Non-Conventional Sources of Energy, where policies guarantee the elimination of legal barriers that will favor the economy and will bring benefits to the communities that belong to the areas where conventional electric power does not reach.

Currently, Colombia has the law 1715 that seeks to promote and promote the use of non-conventional renewable energy sources, for this purpose they integrate these energy sources in the national market, and establish them as alternatives for energy supply in non-interconnected areas of the country , with this the Colombian government seeks that the economic development of the energy sector is sustainable and that at the same time it is contributing to the reduction of greenhouse gas emissions[13].

From the global point of view, efforts have also been made to reduce the problem of carbon emissions and the lack of policies to foment renewable energy projects. The Kyoto Protocol is born from the union of countries around the world in the fight against climate change. Its main objective is the reduction of emissions of greenhouse gases in the atmosphere and is defined as an international agreement related to the convention of the framework of the United Nations to encourage the development of projects that reduce emissions. It was adopted in Kyoto (Japan) on December 11, 1997 and becomes operational on February 16, 2005 [14]. Mainly member countries must comply with national measures objectives however, the Kyoto Protocol offers three additional mechanisms to meet these objectives.

- International Trade in Emissions: It is the purchase and sale of emission rights between developed and industrialized countries. An emission right is the amount of tons of greenhouse gases that can be released into the atmosphere under the protocol [14]
- Clean Development Mechanism (CDM): It is a mechanism that allows developed countries that have emission reduction goals to support green energy projects in a sub-developed country, through the purchase of Emission Reduction Certificates (CER), each CER equals one ton of CO2 that was not released into the atmosphere [15]
- Joint Application (JA): These are mechanisms related to the CDM but with the difference that the project can be executed in a country in transition to a market economy, that country also has a commitment to reduce emissions [14]

Despite the importance given to these issues in the global scenario, the respondents about the correct policies for the implementation of incentives to motivate investors to a project of clean energy projects. Due to the uncertainty caused by changes in the price of energy and the implementation or not of fiscal incentives, investors face the low uncertainties that require a factor model; therefore, take an action that allows flexibility in decision making. [16]

From the above it is identified that the risk is the possibility of losses generated by changes in the factors that affect the value of an asset [17]–[19]Therefore, the ROA becomes a useful approach that provides a financial evaluation of a project in a scenario where uncertainty and speculation are high. The ROA is based on the combination of traditional project evaluation methods such as Net Present Value - NPV and Internal Rate of Return - IRR. According to Meza Orozco [20] NPV is a monetary value that results from discounting the sum of disbursements of money to present value using a rate agreed and compare them with the sum of money income to present value, IRR is the The profitability offered by a project is the discount rate that converts the NPV to zero, where the actual net cash flows discounted are equal to the initial investment at time zero [21]

The term of real options has been incorporated for several decades in the financial literature, Stewar Myers in 1977 established this term considering components of flexibility that are decisive in the decision-making of projects over time [22]. The real options are based on the thought that investment projects can be related to the financial options CALL and

PUT [18]. These are derived from financial derivatives that are instruments that are related by a well-called underlying and its value depends on it, this underlying asset can be a commodity (raw materials) or a financial instrument such as shares [23]. The main financial derivatives are: Forwards, futures, options and swaps contracts:

For instance, option is a contract in which the owner or possessor has the faculty or the right, but not the obligation to act on an underlying asset (buy or sell it) at a specific time at an agreed price. The option to purchase CALL gives the buyer the possibility to acquire the underlying asset in the future by paying a premium from the moment the agreement is agreed and the seller collects the premium and is obliged to sell the underlying asset if the holder of the contract decides to execute the option. The PUT sale option gives the option buyer the power to sell the underlying asset in the future by paying a premium from the acquisition of the contract and the seller of the PUT option collects the premium and is obligated to buy the underlying asset if the buyer decides to execute the option [24].

From the theoretical point of view, the value of the option consists of two components: the intrinsic value (immediate exercise value of the option) and temporary value (excess of the value of the option). An investment opportunity such as the construction of a new production plant, can be an analogy between a real option and a financial option, because it resembles a purchase option which gives the right to management, but not the obligation, of acquire the assets [25].The investment cost that is committed at the start of the project, plays the role of strike and the real asset corresponds to the project once it begins to produce cash flows [26], [27]

In the evaluation of investment projects, the RO is compared with the NPV, allowing management to reorganize the project, that is, assessing flexibility. The flexibility allows to divide in stages the investment in real assets and learn over time about the market and technology. In each stage, benefits are obtained by modifying the investment, so the evaluation with ROA is an effective strategic management tool for companies to carry out maneuvers in the market [28]

Many authors suggest integrating the real options in the NPV in the evaluation of projects. In other words, the NPV of the project with this methodology is equal to the estimated NPV of the cash flow projection plus the value of the Real Option or flexibility value, as shown in equation 1

$$NPVflex = NPVtraditional + RO \quad (1)$$

METHODOLOGY

Currently there are several models for the determination of the theoretical value of an option, one of them is the binomial model proposed by Cox Ross in 1979 [29]. It is a discrete model that considers that the evolution of the price of the underlying asset varies according to the binomial process multiplicative. It can only take two possible values, one upward and one downward, with associated probabilities p and 1- p. In this way, by extending this probability distribution over a certain number of periods, it is possible to determine the theoretical value of an option.[18]

In a Binomial model for only one period, the theoretical value of a call option is given by equation 2: [30]

$$Call = \frac{1}{r} \times [p \times C_u + (1-p) \times C_d] \quad (2)$$

Where:

$$p = \frac{r-d}{u-d} \quad (3)$$

And,

$$C_u = Max[0, uS - E] \quad (4)$$

$$C_d = Max[0, dS - E] \quad (5)$$

$r = (1 + free\ risk\ rate)$

u: multiplicative up motion.

d: multiplicative down motion.

C_u: Call option value at expiration of multiplicative up motion.

C_d: Call option value at expiration of multiplicative down motion.

Similarly, the theoretical value of a put option is given by :

$$Put = \frac{1}{r} \times [p \times P_u + (1-p) \times P_d] \quad (6)$$

Where:

$$P_u = Max[0, uS - E] \quad (7)$$

$$P_d = Max[0, dS - E] \quad (8)$$

P_u: Call option value at expiration of multiplicative up motion.

P_d: Call option value at expiration of multiplicative tion.

In a multi-period binomial model, when the planning horizon is generalized to N periods, the valuation of an option is the calculation of the values of the option at the end of the n periods and by a recursive procedure (going back in time) making use of the previous formulas. its value in each node of the diagram or tree is discounted to present value[31].

Celsia is a company belonging to the Argos group in Colombia, built the first large-scale photovoltaic farm in Colombia, which began operating on September 3, 2017, by commercially delivering electricity to the National Interconnected System. Celsia Solar Yumbo, used 35,000 photovoltaic modules and 9 DC-AC current inverters with an installed capacity of 9.8 MW, and can produce an average of 16.5 GWh per year. The cost of the initial investment of this project was 11 million dollars; in which were also included, expenses for the adaptation of the land, where the Termoyumbo thermoelectric plant used to operate; belonging to the same company [32]. It is expected that with the transition of fossil fuel as a source of generation, to renewable sources, the solar farm will stop emitting 165,000 tons of CO2

during twenty five years, on average 6,600 tons per year. This could generate additional income if it adopts the strategies determined by the Kyoto Protocol, with which it could issue Certificates of Reduced Emissions -CER and negotiate them in the carbon market.

For this study, an approximation was made of the cash flows of the project for the 25 years that Celsia has defined for the solar farm, in the first instance, the possible operational revenues were calculated, based on the radiation map of Valle del Cauca for the Cali and Yumbo areas; which allows having an average monthly generation of 1.57 GW per month [33], the energy price was determined stochastically, based on the Geometric Brownian Motion model, which complements the income of the project.

The Geometric Brownian Motion- GBM is also known as the Wiener process. It is a stochastic model that describe temporary evolution of a continuous aleatory variable. In beginning XX century, the usefulness of this model was uncovered, where it was used for modeling the behavior of stock prices. The GBM generalized for simulating financial assets is described by equation number 9:

$$B(t)^d = \sqrt{tZ}, \qquad Z \sim N(0,1) \tag{9}$$

this model complies with:

1. Start at the origin with probability 1: $P[b(0) = 0] = 1$.
2. The Brownian increments given by, $B(t)$, are independent random variables.
3. It has stationary increments.
4. The process increments are "*Gaussians*" with media cero and constant variance.

Kiyoshi Itô was a Japanese mathematician who developed a theory for the differentiation and integration of stochastic processes. This theory is known as the Itô Calculus. The basic concept of this calculation is the Integral of Itô and the most important result is the Itô motto. It fits note that the Itô Integral is the core of stochastic analysis, facilitates the Mathematical understanding of random events and differs from theory classical mathematics of integration and differentiation. Itô's lemma focuses on the exact calculation of the solution of an equation stochastic differential defined as follows (equation 10):

$$dX(t) = f\big(t, X(t)\big)dt + g\big(t, X(t)\big)dB(t). \tag{10}$$

The above leads to the Itô differential equation, with which predictions of asset prices can be made (see equation 11):

$$\left.\begin{aligned} dS(t) = \mu S(t)dt + \sigma S(t)dB(t), \\ S(0) = S_0 \end{aligned}\right\} \tag{11}$$

Where:

$S(t)$ is the value of underlying asset in t time.

S_0 represents the value of underlying asset in the initial time, t=0 and it is known.

μ ∈ ℝ is a model parameter known as drift or trend.

$\sigma > 0$ is the local volatility of asset.

$B(t)$ is a Wiener process or GBM.

In the second instance, the operational and administrative costs were calculated based on the report of the International Renewable Energy Agency - IRENA [34] for 2016, where it was indicated that the unit cost of the Kilowatt hour was USD 0.53 on average world for the generation of photovoltaic solar energy. For this study, two cash flows were made, one to study the effect of the issuance of Certificates of Reduced Reductions-CER on the value of the project, and another without the income generated by the sale of the certificates to compare.

Once the cash flows of the solar farm were determined, they were discounted to the Weighted Average Cost of Capital - WACC, of 9.75%, which is determined by the percentage reported in IRENA [34] of 7.5% for member countries. of the Organization for Economic Cooperation and Development-OECD and adding the country risk for Colombia, calculated at 2.25%. Based on this, the present values of the cash flows of the project with and without the effect of the certificates were calculated.

As an alternative method, in this study it was proposed to carry out a valuation through ROA, to include from the beginning the possibility of making the decision making of the investor more flexible. From the evaluation of an option to postpone the project; the investor can wait until there are better conditions for execution and not discard the investment by considering only a deterministic value. To identify the volatility and the average of the cash flows in the present value of the project, the Montecarlo simulation method was used.

RESULTS

When calculating the present values of the cash flows of the project with and without the effect of the certificates shown in Table 5, it is evident that by the traditional method of valuation of projects when discounting the initial investment; the NPV takes negative values so the project would be immediately discarded, even if the additional income is added for the issuance of the certificates (Table 1).

Table 1. Comparison of the present value of cash flows and NPV of the project.

PV CF without CER	PV CF with CER	NPV without CER	NPV with CER
USD 9.725.357	USD 9.731.467	-USD 886.831	-USD 892.885

The model of the Brownian Geometric Motion was used, with which the price of energy was predicted; As a result, it was found that the project has a volatility of 7.44% and an average for the cash flow without effect of the CER is USD 9.725.357, and for the model with effect of the CERs, USD 9.731.467, which improves the present value of cash flows.

The calculation of the deferment RO was assessed under the binomial trees method, for which the parameters indicated in Table 2 were taken, where the strike price of the option is the initial investment that the project had converted to Colombian

pesos. at a TRM of COP 2,949 per USD, for the risk-free rate, the average 10-year Colombian TES yield was used; The RO was valued for a period of five years, for which the coefficient of rise of the cash flows in each of them was 1,077 and 1,078 in the model without CER and with the CERs respectively. Likewise, the probabilities were increased by 95.7% for FC without CER and 95.2% without them.

Table 2. Parameters of the deferment real option.

Variable	Value without CER	Value with CER
Presenta Value od Cash Flow (S) [USD]	USD 10.107.115	USD 10.113.169
Strike (K) [USD]	USD 11.000.000	
Expirations Time RO [años]	5	5
Volatility Cash Flow (σ)	7,44%	7,44%
Risk Free Rate (Rf)	7,08%	7,08%
Steps (n)	5	5
Δt	1	1
u (Ascent coefficient)	1,077	1,078
d (Descent coefficient)	0,9283	0,9277
p (Ascent coefficient)	0,957	0,952

With the parameters specified, the binomial trees were constructed for the postponement options of the Celsia Solar Yumbo project without issuing the CERs and issuing them; Table 3 and Table 4 show the present values of the flexibilization in the decisions of the investors; for example, for cash flows without the effect of the CERs, a value was obtained for the option of USD 10.107.115, and for the FC without the effect of the CERs the value of the option was USD 10.113.169 (Table 4).

Table 3. Binomial tree for deferment option with cash flows without effect of the CERs

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
					USD 14.659.698
				USD 13.608.976	USD 3.659.698
			USD 12.633.564	USD 3.336.112	USD 12.633.564
		USD 11.728.064	USD 3.039.953	USD 11.728.064	USD 1.633.564
	USD 10.887.465	USD 2.769.048	USD 10.887.465	USD 1.459.736	USD 10.887.465
USD 10.107.115	USD 2.521.375	USD 10.107.115	USD 1.304.406	USD 10.107.115	USD 0
USD 2.295.057	USD 9.382.697	USD 1.165.603	USD 9.382.697	USD 0	USD 9.382.697
	USD 1.041.571	USD 8.710.200	USD 0	USD 8.710.200	USD 0
		USD 0	USD 8.085.904	USD 0	USD 8.085.904
			USD 0	USD 7.506.353	USD 0
				USD 0	USD 6.968.342
					USD 0

Table 4. Binomial tree for the deferment option with cash flows with effect of the CERs

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
					USD 14.722.341
				USD 13.657.114	USD 3.722.341
			USD 12.668.962	USD 3.384.250	USD 12.668.962
		USD 11.752.306	USD 3.075.365	USD 11.752.306	USD 1.668.962
	USD 10.901.975	USD 2.793.365	USD 10.901.975	USD 1.483.836	USD 10.901.975
USD 10.113.169	USD 2.536.086	USD 10.113.169	USD 1.319.244	USD 10.113.169	USD 0
USD 2.301.514	USD 9.381.436	USD 1.172.910	USD 9.381.436	USD 0	USD 9.381.436
	USD 1.042.808	USD 8.702.648	USD 0	USD 8.702.648	USD 0
		USD 0	USD 8.072.973	USD 0	USD 8.072.973
			USD 0	USD 7.488.857	USD 0
				USD 0	USD 6.947.005
					USD 0

From the previous trees it could be found that in the nodes where the value of the option is zero, the best decision is not to invest and wait until the conditions are improved and a positive value, the same exercise was carried out in each of them. the nodes per year and the decision tree that is presented in Table 5 was constructed, where it is observed that this project must be invested only until market conditions place the price of energy in an uptrend, which would happen Only from the second year.

Table 5. Decision tree for the investor for both effects (with and without CER). Based on the Real Option.

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
					INVEST
				INVEST	
			INVEST		INVEST
		INVEST		INVEST	
	NOT INVEST		NOT INVEST		NOT INVEST
NOT INVEST		NOT INVEST		NOT INVEST	
	NOT INVEST		NOT INVEST		NOT INVEST
		NOT INVEST		NOT INVEST	
			NOT INVEST		NOT INVEST
				NOT INVEST	
					NOT INVEST

By adding the value of the deferment real options to the initial NPV of the project, new present values were obtained for both cash flows, where the value of the flexibility for the investor is considered. Table 6 shows how they change to the project NPV, moving from negative values to positive values; however, it can be inferred that issuing CER affects the valuation of the projects but, regardless of the method by which the valuation is carried out, that is, the traditional NPVs of the FCs were compared with and without the issuance of the CERs and the change it was 1.05%, in the same way it happened with the evaluation of the RO and it gave the same result; therefore, this decision to issue or not to issue is not affected by the valuation method and will depend more on the financing decisions required by the project.

Table 6. Comparative traditional NPV and valuation by Real Option

Without CER		With CER	
Traditional NPV	**NPV + ROA**	**Traditional NPV**	**NPV+ROA**
($ 886.831)	USD 1.402.173	(USD 892.885)	USD 1.414.683

CONCLUSIONS

When the project was valued using traditional NPV and IRR methods, it was found that the project is not financially viable since it presents negative results in the indicators, even when adding the incentives derived from the sale of the reduced emission certificates. Therefore, the decision to issue or not issue the sale of CERs, does not affect the valuation method of the project because it is not significant, for this reason it can be taken as a source of additional financing as the project needs.

By using a real options approach by means of binomial trees to assess the project of the Celsia Solar Yumbo farm, it was found that from the second year it can be invested in the project, given the upward conditions in the market with respect to the price of energy. The real options allow not discarding the project in the first instance and offer a financial evaluation more adjusted to future decisions.

Based on the results found, it is pertinent to evaluate new mechanisms that lead to encourage the formulation and execution of renewable energy projects, although the Kyoto Protocol was created with the function of reducing gas emissions through its development mechanisms. clean, it is not efficient enough to eliminate the financial barriers to which the projects are linked.

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