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Evaluation of Photovoltaic Energy Projects using the Real Options Valuation

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ABSTRACT

The purpose of the article is to analyze from a current perspective how Real Options Valuation facilitate the evaluation of projects for the adoption of photovoltaic energy in countries such as Colombia. A mixed descriptive approach is proposed, using techniques of documentary analysis and analysis of figures. To this end, an exhaustive review of recent research on energy, project evaluation and the method of real options is carried out. As part of the results, it is highlighted that the real options method allows a greater projection of the economic/financial evaluations and also proposes lines of action thus responding to new demands of the energy markets. Due to the characteristics of the activities of the theme, real options are gaining ground in the economic/financial evaluation of projects, since until recently only traditional methods were considered for this purpose.

Keywords: Renewable Energy, Photovoltaic Energy, Real Options Method, Feasibility
JEL Classifications: Q42, Q48, G17

1. INTRODUCTION

Sustainable development is everyone's responsibility on the planet and, therefore, we must be aware of the current reality regarding the environment; thus, it is essential to implement measures that promote favorable changes in consumption patterns, in the production of goods and services, and in the use of natural resources that allow favorable economic growth without causing adverse effects on environmental and social environments (Toscano et al., 2019). The energy is an aspect of special relevance in the daily life of the human being, the reason why great efforts are dedicated to generating it, often with a high environmental price, for this reason, within these policies for the achievement of a sustainable development; the use of alternative sources of energy occupies the first places of interest (Bravo, 2015). Among the most common generation methods can be found solar photovoltaic, solar thermal, hydraulic, wind, or bioenergy.; the first two use sunlight either through radiation or through the heating it produces; the third option uses the movement of water as the main element; the fourth uses the force of wind; while the last is derived from the management of organic matter of plant or animal origin (Martinez et al., 2019).

When adopting an energy generation system using renewable sources, it is essential to analyze the conditions and the impact of these in the long term; aspects such as the potential of the available resources, the levels of solar irradiation and the effects on the ground are some of the issues to be considered (Bhandari et al., 2014). Global energy demand and environmental concerns are the driving force for the use of alternative, sustainable and clean energy sources (Hosenuzzaman et al., 2015); Thus, hydroelectric, wind and photovoltaic energy are used as the main sources of renewable energy depending on the installed capacity on the planet (Bhandari et al., 2014). Solar energy is considered to be an inexhaustible source and free of greenhouse gas emissions of CO_2; the surface of the Earth receives from the sun a power of 1.4×10^5 TW, of which you can use approximately 3.6×10^4 TW of this (Hosenuzzaman et al., 2015); Therefore, photovoltaic systems have experienced strong market growth in the last decade (Yu et al., 2016). When analyzing and implementing projects of this nature, it is important to measure not only the economic projections but also the impact they can generate in the ecosystem (Rodriguez et al., 2018).

An example of this is plasma Capel (2015), who proposes to delve deeper into the effect that this type of system generates in the landscape, stopping at its typological uniqueness and the effects on the intensity of the visual incidence; at the same time the location, extension, orientation and distribution of elements. On the other hand, Cabrera et al. (2015), propose that environmental impact should be measured in relation to abiotic (air; soil), biotic (ecosystems; vegetation; fauna) and socio-economic (local economy; education, science, technology and innovation; social and cultural aspects) factors.

Based on the above, it is possible to establish the large number of opportunities for the use of these systems, which have also resulted in research of all kinds ranging from the analysis of the impact of the penetration of photovoltaic energy in electricity distribution systems (Correa et al., 2016), going through the economic impacts on society (Simpson and Clifton, 2016), or even studies for the optimization of these generation techniques based on hybridization with other renewable sources (Sinha and Chandel, 2015). For this reason, it is proposed to develop this research in order to propose a method of economic-financial evaluation, using the Real Options Valuation, which considers not only the technical aspects of the project, but also its sustainability in the future.

2. MATERIALS AND METHODS

The method developed for the present study is addressed by the qualitative approach, which provides a space for introspection, analysis and discussion of data based on its qualitative elements, thus allowing a human understanding of various phenomena. In turn, the type of research worked was documentary, to carry out this first step of approach towards evaluation of photovoltaic energy projects using the real options valuation. Based on this theoretical review, a series of analysis categories were developed to deeply understand the variable under study in a comprehensive way. The information was collected through a documentary review of documents and studies located on high-level research platforms such as Springer, Scielo or Google Scholar.

3. RESULTS

3.1. Methods of Evaluation of Renewable Energy Sources Projects (FRE)

3.1.1. Photovoltaic energy (PE)

Photovoltaic solar energy is that resulting from the process of transforming the sun's radiation into electrical energy through the use of photovoltaic cells and is part of the group of non-conventional renewable energy sources. This process is based on the motive force generated by the photovoltaic effect in a semiconductor device, due to electromagnetic radiation (Bravo, 2015). This is how the system consists of the elements represented in Figure 1.

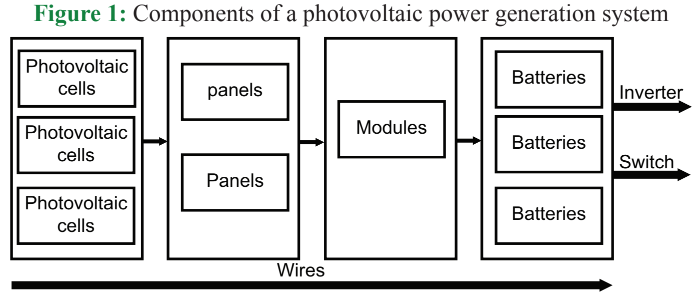
This type of energy results from rapid recovery, and its environmental impact is minimal in comparison with other non-renewable energy sources, so it becomes a fundamental resource for sustainable development alternatives, therefore, both in industry and commerce and in several countries residential sectors, have initiated the study and research of energy projects based on this modality mentioned above (Bravo, 2015).

3.2. Energy Background in Colombia

The 2012 WEC Energy Sustainability Index report draws attention to Colombia's position in the ranking of countries where energy security predominates, that is, the country is considered a territory with sufficient natural resources to meet energy demand from renewable generation. This can be compared with the report on the exploitation and national production capacity of primary energy resources and the installed capacity in Colombia (Figures 1 and 2).

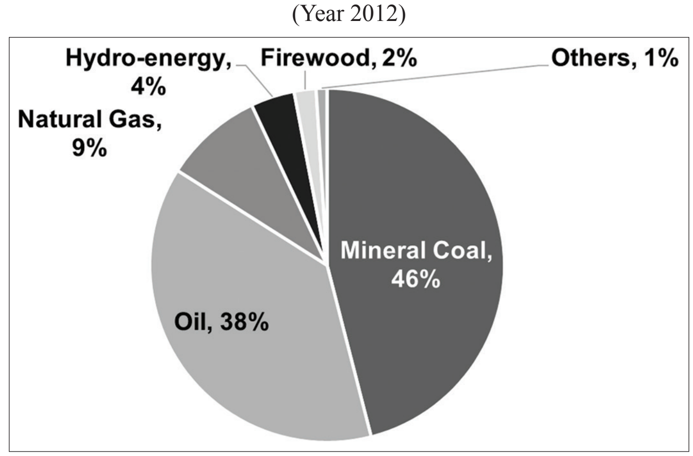
As can be seen in the figures, in Colombia there is a high component of generation from hydropower, even so the national government advances the Programme for the rational and efficient use of energy and other non-conventional forms of energy (PROURE) which aims to achieve a participation of this type of sources in 6.5% of the installed capacity of the National Interconnected System (SIN), by 2020; although it can be seen that by 2014 only 0.7% of the share had been achieved (biomass and wind cogeneration) (UPME, 2019). In response to this need in Colombia was issued Law 1715

Figure 1: Components of a photovoltaic power generation system



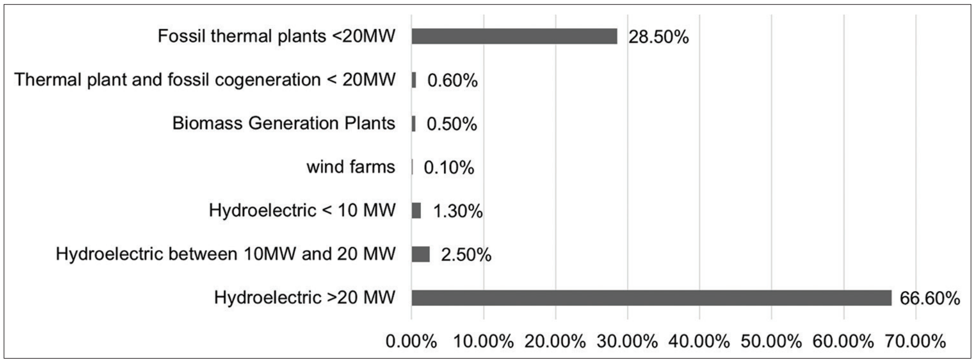
Source: Own elaboration, 2019

Figure 2: Exploitation and production of primary energy resources (Year 2012)



Source: UPME (2019)

Figure 3: Electricity generation capacity of the National Interconnected System in 2014



Source: UPME (2019)

of 2014, which incorporates incentive plans for the development of projects, at the national level, with the support of multilateral entities such as the Inter-American Development Bank (BID), the Global Environment Facility (FMAM), the United States Agency for International Development (USAID), the World Bank (BM), and the United Nations Development Programme (PNUD), which has been reflected in the number of projects currently in force (Figures 3 and 4) (UPME, 2019).

3.3. Real Options for Decision Making

A large number of variables are involved in the decision-making process in the electricity market, which have an impact on the possible results in different ways, and by virtue of this, some researchers use analysis methods with real options in which an assessment is made of flexibility in management decision-making under uncertainty scenarios. Depending on this, a real option is defined as the possibility of variation of a project as a response to the evolution of the uncertainty of its underlying elements. Under this concept Isaza and Botero (2014) proposes different analysis alternatives that can be used according to the characteristics of each case; some of them are: differential equations, binomial meshes and trees, simulations, among others, and whose application model will be detailed in the following section.

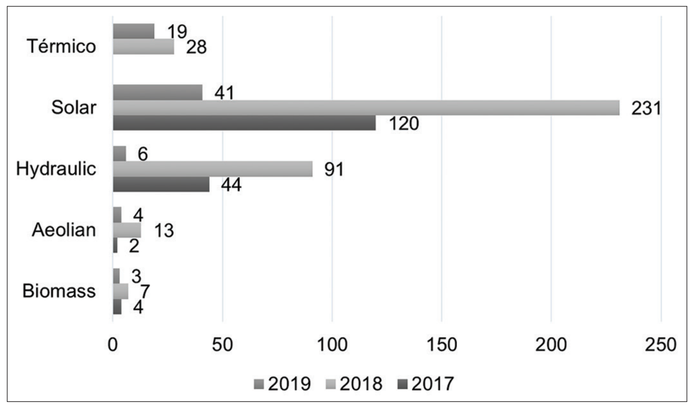
3.4. Real Options Valuation

The real options valuation is used in cases in which the uncertainty of the investment is considerably high, and therefore the options should be considered, as a result of the fluctuations that the price of the asset may manifest over time. For this purpose, the present value of the cash flow and the value of the options that may be associated must be considered. Said valuation must be made based on the estimation of the following variables:

- The value of the underlying asset at risk.
- The exercise price or value of the investment.
- The term of the option.
- The standard deviation or volatility of the risky underlying asset.
- The risk-free interest rate.

In order to make an adequate estimation of the proposed variables, it will be necessary to contemplate a conceptual and analytical review of the project in order to subsequently establish the uncertainties involved in it, which can be as follows:

Figure 4: Generation projects in force by 2019



Source: UPME (2019)

- Investment costs.
- Electricity price.
- Consumer price index.
- Electricity produced.

For each of the variables with identified uncertainties, it is necessary to develop a simulation of the results, for which Monte Carlo or Binomial methods can be used. Next, it is necessary to develop a theoretical valuation of the real options that contemplates the alternatives of differing, abandoning, reducing or expanding; based on the results obtained, it is possible to carry out the analysis of the economic performance of the project such as the current effective value of the project, the return on the investment, or any other economic calculation considered for its valuation. As documentary support are considered below, several studies as they provide important information for the proper development of this research, in this sense, the process developed in Spain by Balibrea (2013) provides an example of applying state-level analysis of power generation projects through the application of Real Options Valuation, contributing a valuable point of view comparable to the central theme of the current proposal, the conclusions of which are presented in the publication called valuation of electricity generation projects with renewable energies: a comparative study based on real regulatory options.

To this end, the author elaborates this research around an assessment of the wind farm project in four European Union countries, such as Denmark, Finland, Spain and Portugal, in which he proposes to identify and assess the real options existing in the regulatory framework that regulates the production of renewable electricity, and thus determine whether they benefit the project promoter or the state administration. In this regard, Balibrea (2013) proposes as methodology the calculation of the net present value of investment projects as a result of the identification of real options, the estimation of cash flows and their volatility, which is developed from the application of the Monte Carlo Methods and the Binomial Method (Table 1).

Among its results, the author highlights the identification of real options that are not usually used in the economic valuations of projects, and that derive from state regulatory frameworks in relation to production or price. Another aspect to highlight is the use of the valuation methods used, since, for all cases, the Binomial and Monte Carlo Methods yield similar results around (Balibrea, 2013):

- As the number of iterations increases, the difference in results decreases, so when a minimum number (25 iterations) is used, the difference in results reaches 30%, while with a greater number (20,000 iterations) this percentage decreases to 1%.
- The use of the same level of volatility increases the convergence between the two methods; and,
- The greater the number of nodes in the binomial tree, the greater the convergence of the results.

In general, their conclusions had the opportunity to demonstrate the impact generated by state and political decisions on the sustainability of this type of projects, as they increase the uncertainty of the operation (Table 1) (Balibrea, 2013). On the other hand, the investigation of Sánchez (2017), also works on an approach of application of the methodology of analysis with real options, but directed to the study of the companies related to the generation of solar energy; from this point of view it is analyzed the impact that the variability of this market generates in the performance and economic sustainability of the companies studied.

That's how the investigation valuation of solar energy companies with real options, carried out in Spain, focuses on the analysis of a group of companies of European and North American origin in such a way that it is possible to verify if the value of the shares of these companies corresponds to the real market value, for it the Real Options Valuation is used; on the other hand the author seeks to establish if there are significant differences between the group of American companies versus the corresponding European ones; and finally she sought to develop a comparison between the use of the Real Options Valuation in relation to the traditional method of Discount of the Free Cash Flow (Sánchez, 2017).

The group of companies studied was composed of world-class companies that produce equipment necessary for the manufacture of solar cells and modules; suppliers of silicon ingots; manufacturers of semiconductors; manufacturers of other electrical equipment for solar modules such as trackers, inverters, meters, batteries, among others; and companies specialized in the installation, maintenance, production, distribution and sale or rental of photovoltaic systems. Also, within the variables that were taken into account, are the regulatory systems in Europe and the U.S., environmental regulations, the price and availability of the main raw material and new materials, technological changes in semiconductors and new hybrid and organic technologies, energy storage (batteries), interest rates and state of the financial system, oil price, and finally the cost of nuclear energy (Sánchez, 2017).

Among the outstanding results for this research is the identification of the main variables of instability in the sector present at the end of 2013, which affected the valuations of the companies, such as: the Great Recession between 2007 and 2008; the fall in the sale prices of photovoltaic products, by nearly 65% by 2013; and unfair competition as a result of the abundant and cheap supply of solar modules and cells from China. On the other hand, a high level of uncertainty is established in the renewable energy sources industry, with real options being a useful tool for detecting sustainable growth options; however, the use of the traditional discounted free cash flow (DFCL) method is considered as a useful complement for investment decision making; in this regard, the results of the technical comparison of the shares of the companies evaluated using the real options (RO) and DFCL method are presented, with reference to the market quotation value (Table 2). The results show significant differences ranging from −97.98% to 1,568.89% between the OR and DFCL valuations; on the other hand, the differences between the price values and the figures obtained by the valuation methods range from −98.08% to 461.82% (Sánchez, 2017).

On the other hand, the investigation of Collado (2009) photovoltaic solar energy, competitiveness and economic evaluation, comparative and models, provides important information on projects related to photovoltaic solar energy, highlighting the main aspects of this market, analysing in depth the competitiveness of its sector from an economic point of view, although evaluated in a stable environment without major variations in the future.

The author then seeks to analyze the projection of the photovoltaic sector in Spain, for which he starts from a current analysis of the power of photovoltaic generation, the development of the industry, the costs of generation, and the potential impact of development, at the same time that he develops a revision of the state mechanisms used for the impulse of this type of generations in states of the European Union, and the United States. Additionally, information is obtained about the remuneration models around the use of this energy, in the markets of Germany, Spain, United States, Japan,

Table 1: Comparison of valuation results with different methods

Country	VAN without flexibility	VAN with montecarlo method	VAN with the binomial method
Denmark	109.914.272 €	62.502.239 €	62.478.920 €
Finland	91.227.287 €	91.173.227 €	91.170.749 €
Portugal	55.114.645 €	55.114.645 €	55.114.645 €
Spain	86.541.724 €	66.941.004 €	66.953.836 €

Source: Own elaboration from Balibrea (2013)

Table 2: Comparison of valuation of the shares of companies in relation to their quotation value

American companies	OR value	DFCL value	OR variation versus DFCL (%)	Quotation on the market	OR variation versus market (%)	DFCL variation versus market (%)
AEIS	$ 25.13	$ 23.32	7.76	$ 22.88	9.83	1.92
ASYS	$ 8.78	$ 9.06	−3.09	$ 7.05	24.54	28.51
ENPH	$ 4.77	$ 8.19	−41.76	$ 6.78	−29.65	20.80
FSLR	$ 65.71	$ 66.72	−1.51	$ 57.44	14.40	16.16
GTAT	$ 37.55	$ 2.25	1.568.89	$ 9,12	311.73	−75.33
SCTY	$ 27.83	$ 59.90	−53.54	$ 59.71	−53.39	0.32
STRI	$ 14.10	$ 5.40	161.11	$ 4.59	207.19	17.65
SUNE	$ 78.99	$ 16.08	391.23	$ 13.92	457.46	15.52
SPWR	$ 24.49	$ 30.96	−20.90	$ 32.30	−24.18	−4.15
MSZ	$ 70.15	$ 62.29	12.62	$ 82.91	−15,39	−24.87
MBTN	$ 18.79	$ 17.27	8.80	$ 14.51	29.50	19.02
PS4	$ 17.85	$ 5.94	200.51	$ 6.56	172.10	−9.45
REC	$ 0.49	$ 0.33	48.48	$ 0.41	19.51	−19.51
RECSOL	$ 16.92	$ 16.60	1.93	$ 13.29	27.31	24.91
S92	$ 176.58	$ 34.68	409.17	$ 31.43	461.82	10.34
SLR	$ 0.02	$ 0.99	−97.98	$ 1.04	−98.08	−4.81
SWVK	$ 83.08	$ 92.54	−10.22	$ 109.81	−24.34	−15.73

Source: Sánchez, 2017

South Korea, France, Italy, Greece, China, India, Australia, Austria, Canada, Israel, Portugal, United Kingdom, Switzerland, Holland, Belgium, Bulgaria, Cyprus, Czech Republic and Romania. And finally, an analysis is made of the future competitiveness of photovoltaic installations in relation to domestic tariffs, generation costs and possible economic returns (Collado, 2009).

As a main conclusion, the author manages to demonstrate an important competitive level of this sector, in the medium and long term, as a product of the need to reduce the dependence of the generation of energy from fossil fuels, and the use of the development plans that are being deployed in the world; therefore, the investment in the industry of photovoltaic energy generation is attractive in consideration of all the variables currently involved (Table 3) and those state regulations that may be developed in the near future (Collado, 2009).

Finally, in the Colombian context Isaza (2015) presents its publication Valuation of non-conventional renewable sources of electricity generation: a real options approach (Valuation of non-conventional renewable sources of electricity generation: an approach from real options), in which it presents the most outstanding aspects of its research on the valuation of investment opportunities for emerging electricity generation technologies, considered to be high risk due to their high level of volatility. To do this, a comparison of the valuation of the projects is carried out using the Real Settings templates of Dixit and Pindyck (1994) in order to determine whether the best decision to take advantage of the investment would be at the present time or, on the contrary, the option of deferring it to 20 years.

The author considers that in the Colombian market, electricity projects are impacted by variations in the sector where, in order to ensure a constant and reliable supply of electricity, generation must be permanently adjusted to the characteristics of demand, which makes market prices highly volatile, which is why he uses the Real Options Valuation to calculate the underlying value of this asset. On the other hand, Isaza (2015) determines as fundamental

Table 3: Percentage regression of tariffs in Germany Investment costs per technology and estimated at 2030

Technology	Investment cost (Dollars/kW)	Cost estimation at 2030 (Dollars/kW)
Onshore Wind Farm	1.200	9.00
Offshore wind farm	2.600	1.600
Photovoltaic	5.500	1.900
Solar thermal	4.500	1.500
Biomass	2.500	2.000

Source: Collado (2009)

variables the investment, which can represent an entry barrier, and the operating costs of the technologies. In order to analyze the application of the methods, a project cash flow was taken into consideration by estimating typical values of costs and conditions over a 20-year horizon (Table 4).

Based on these values, the optimal price of the investment was estimated, understood as the minimum value of the forward price of the electricity that motivates the decision, which resulted in 223.9 (COP/kW-h). Once this value was obtained, the option of deferring was analyzed, taking as an example a 137.2 kWh project, resulting in that if the decision to use the investment is taken at this time, the value of the project would be 18,104 (COP/kW-h), while if the decision is deferred to 20 years, the value obtained would be 29,982 (COP/kW-h). According to the above, the author concludes that it is better to postpone the decision to use the investment in order to wait for future electricity prices to achieve more favorable conditions in relation to the expected profits (Isaza, 2015).

Therefore, it is considered that these investigations constitute a fundamental contribution to the optimal development of the objectives contemplated in this investigation, since the results derived from them have the basic elements to break down the uncertainties defined and thus give way to the model that is sought to design using the Real Options Valuationas mediation. See below:

3.5. Application of the Real Options Valuation for Photovoltaic Energy Projects

Once the case studies reviewed in the previous paragraphs have been reviewed, and taking into account the information gathered for the development of the project, the application of the case study proceeds (Figure 5). Table 3 has been taken as a base to reference the investment price of photovoltaic technology in the present study and whose value was \$5,500 USD/Kw in 2009, this value for 2019, applied estimation and proportionality techniques, would be \$3,786 USD/Kw as shown in Figure 6.

With the generation price estimated for 2019, the total investment cost of installation and commissioning for a 2000 kW plant would be \$7,572,000 USD. The exchange rate from dollar to Colombian peso has presented a variation in the last 6 months as shown in Figure 7.

Based on the above, an exchange rate value of \$3100 COP per dollar is taken, taking into account the average of the graph, the total investment cost of the installation and start-up for a 2000 kW plant would be increased to \$23,473,200,000 Colombian pesos. (Dólar Colombia, 2019). Bearing in mind that the hours per day that make the most of solar radiation are between 10 am. and 3 pm., 365 days, 1825 working hours would be used, which when applied to 2000 kW would result in 3,650,000 Kw/h generated in the plant during 1 year of operation.

Then it was noted that the cost of selling energy in the photovoltaic market is in 2019 at COP \$400 Kw/h according to the validation made with expert consultants in the photovoltaic sector. In relation to this value, the highest value of the last 5 years was taken from the general price index in Colombia, and applied to a forecast of the increase in the sale price of photovoltaic energy in the following 25 years, values necessary to obtain the total annual generation cost of the system.

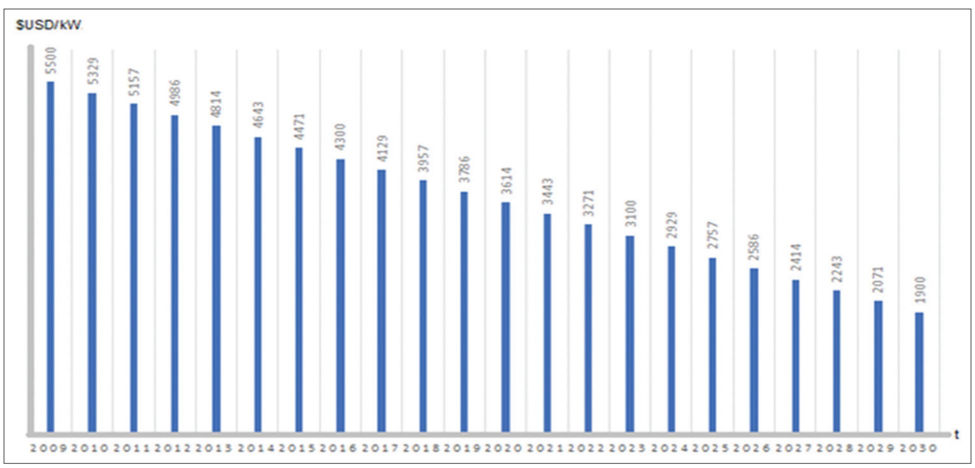
With the values determined in Table 5, it is possible to calculate financial projections taking into account cash flow, discount rate

Table 4: Theoretical parameters for valuation of investment opportunity using real options

Project parameters	Solar photovoltaic
Capacity factor	21%
Annual expected generation (kW-h)	350.400.000
Investment (USD/kW)	\$ 4.988
Installed capacity (kW)	5.000
Evaluation horizon	20
Cost of operation (c) (COP/kWh)*	\$114
Unit investment (I) (COP/kwh)*	\$759

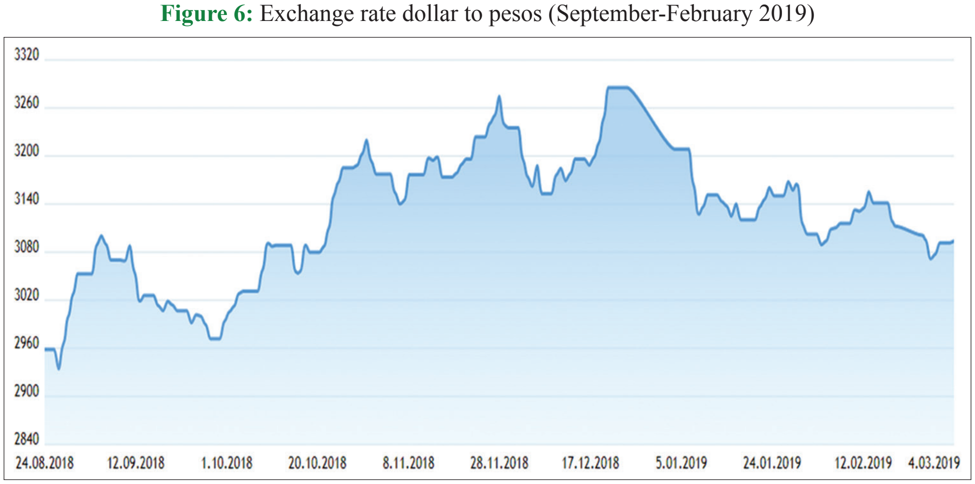
*An exchange rate of 2.100 COP/USD. Source: Isaza (2015)

Figure 5: Estimation of photovoltaic generation costs (2009-2030)



Source: Own elaboration, 2019

Figure 6: Exchange rate dollar to pesos (September-February 2019)



and initial disbursement. Thus, the Annual Net Value is calculated using the following mathematical formula (Table 6):

$$ANV = -A + \frac{Q_1}{(1*k)^1} + \frac{Q_2}{(1*k)^2} + \frac{Q_n}{(1*k)^n}$$

Table 5: Estimated selling price of photovoltaic energy per unit (kw/h)

Year	Previous year's price	Annual weight increase	Total price
2020	400.0	27.1	427.1
2021	427.1	28.9	456.0
2022	456.0	30.9	486.9
2023	486.9	33.0	519.8
2024	519.8	35.2	555.0
2025	555.0	37.6	592.6
2026	592.6	40.1	632.7
2027	632.7	42.8	675.5
2028	675.5	45.7	721.3
2029	721.3	48.8	770.1
2030	770.1	52.1	822.2
2031	822.2	55.7	877.9
2032	877.9	59.4	937.3
2033	937.3	63.5	1000.8
2034	1000.8	67.8	1068.6
2035	1068.6	72.3	1140.9
2036	1140.9	77.2	1218.1
2037	1218.1	82.5	1300.6
2038	1300.6	88.1	1388.7
2039	1388.7	94.0	1482.7
2040	1482.7	100.4	1583.0
2041	1583.0	107.2	1690.2
2042	1690.2	114.4	1804.6
2043	1804.6	122.2	1926.8

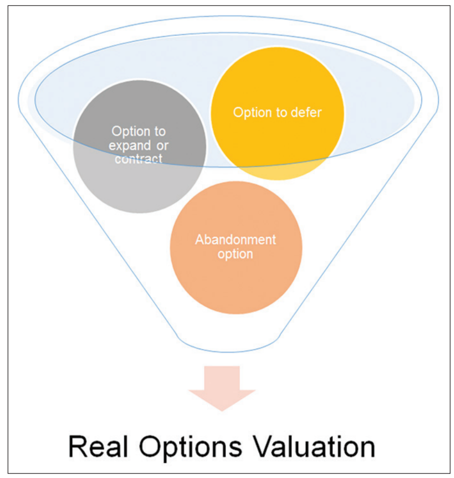
Source: Own elaboration, 2019

Where:
Q = Cash flow
K = Discount rate
A = Initial disbursement

Once the different NPV corresponding to Table 7 were calculated, the correlation factors, annual sales and cash flows were estimated forecasting the results for the period 2019-2043. This procedure allowed to total the difference between annual income and expenses taking into account the correlation factor, Table 6 shows the data resulting from this analysis.

Subsequent to this procedure, the total operating cost of the plant was calculated based on the operating cost of Table 4, whose value

Figure 7: Recommended decision options in the actual options method



Source: Own elaboration, 2019

Table 6: Correlation factor and cash flow data (2019-2040), plant 2000kW

Year	Result factor of correlation ((1*k) ^n	Annual sales (COP$)	Annual cash flow (revenue-breaks)	Annual cash flow (revenue-breaks)/((1*k) ^n
2019	1.08	$ 1.460.000.000	$ 999.900.000	$ 925.833.333
2020	1.17	$ 1.558.842.000	$ 1.098.742.000	$ 939.095.726
2021	1.26	$ 1.664.375.603	$ 1.204.275.603	$ 955.774.288
2022	1.36	$ 1.777.053.832	$ 1.316.953.832	$ 968.348.406
2023	1.47	$ 1.897.360.376	$ 1.437.260.376	$ 977.728.147
2024	1.59	$ 2.025.811.674	$ 1.565.711.674	$ 984.724.323
2025	1.71	$ 2.162.959.124	$ 1.702.859.124	$ 995.824.049
2026	1.85	$ 2.309.391.457	$ 1.849.291.457	$ 999.617.004
2027	2	$ 2.465.737.258	$ 2.005.637.258	$ 1.002.818.629
2028	2.16	$ 2.632.667.671	$ 2.172.567.671	$ 1.005.818.366
2029	2.33	$ 2.810.899.272	$ 2.350.799.272	$ 1.008.926.726
2030	2.72	$ 3.001.197.153	$ 2.541.097.153	$ 934.226.894
2031	2.94	$ 3.204.378.200	$ 2.744.278.200	$ 933.427.959
2032	3.17	$ 3.421.314.604	$ 2.961.214.604	$ 934.137.099
2033	3.43	$ 3.652.937.603	$ 3.192.837.603	$ 930.856.444
2034	3.7	$ 3.900.241.478	$ 3.440.141.478	$ 929.767.967
2035	4	$ 4.164.287.826	$ 3.704.187.826	$ 926.046.957
2036	4.32	$ 4.446.210.112	$ 3.986.110.112	$ 922.710.674
2037	4.66	$ 4.747.218.537	$ 4.287.118.537	$ 919.982.519
2038	5.03	$ 5.068.605.232	$ 4.608.505.232	$ 916.203.823
2039	5.44	$ 5.411.749.806	$ 4.951.649.806	$ 910.229.744
2040	5.87	$ 5.778.125.268	$ 5.318.025.268	$ 905.966.826
2041	6.34	$ 6.169.304.349	$ 5.709.204.349	$ 900.505.418
2042	6.85	$ 6.586.966.253	$ 6.126.866.253	$ 894.433.030
2043	7.4	$ 7.032.903.868	$ 6.572.803.868	$ 888.216.739
				$ 23.611.221.091

Source: Own elaboration, 2019

Table 7: Correlation factor and cash flow data (2019-2040), plant 5000 kW

Year	Result correlation factor ((1*k) ^n	Annual sales (COP$)	Annual cash flow (revenue-breaks)	Annual cash flow (revenue-breaks)/((1*k) ^n
2019	1.08	$ 3.650.000.000	$ 2.609.750.000	$ 2.416.435.185
2020	1.17	$ 3.897.105.000	$ 2.856.855.000	$ 2.441.756.410
2021	1.26	$ 4.160.939.009	$ 3.120.689.009	$ 2.476.737.308
2022	1.36	$ 4.442.634.579	$ 3.402.384.579	$ 2.501.753.367
2023	1.47	$ 4.743.400.940	$ 3.703.150.940	$ 2.519.150.300
2024	1.59	$ 5.064.529.184	$ 4.024.279.184	$ 2.530.993.198
2025	1.71	$ 5.407.397.810	$ 4.367.147.810	$ 2.553.887.608
2026	1.85	$ 5.773.478.642	$ 4.733.228.642	$ 2.558.501.968
2027	2	$ 6.164.343.146	$ 5.124.093.146	$ 2.562.046.573
2028	2.16	$ 6.581.669.177	$ 5.541.419.177	$ 2.565.471.841
2029	2.33	$ 7.027.248.180	$ 5.986.998.180	$ 2.569.527.116
2030	2.72	$ 7.502.992.882	$ 6.462.742.882	$ 2.376.008.412
2031	2.94	$ 8.010.945.500	$ 6.970.695.500	$ 2.370.984.864
2032	3.17	$ 8.553.286.510	$ 7.513.036.510	$ 2.370.043.063
2033	3.43	$ 9.132.344.007	$ 8.092.094.007	$ 2.359.211.081
2034	3.7	$ 9.750.603.696	$ 8.710.353.696	$ 2.354.149.648
2035	4	$ 10.410.719.566	$ 9.370.469.566	$ 2.342.617.392
2036	4.32	$ 11.115.525.281	$ 10.075.275.281	$ 2.332.239.648
2037	4.66	$ 11.868.046.342	$ 10.827.796.342	$ 2.323.561.447
2038	5.03	$ 12.671.513.080	$ 11.631.263.080	$ 2.312.378.346
2039	5.44	$ 13.529.374.515	$ 12.489.124.515	$ 2.295.794.948
2040	5.87	$ 14.445.313.170	$ 13.405.063.170	$ 2.283.656.417
2041	6.34	$ 15.423.260.871	$ 14.383.010.871	$ 2.268.613.702
2042	6.85	$ 16.467.415.632	$ 15.427.165.632	$ 2.252.140.968
2043	7.4	$ 17.582.259.671	$ 16.542.009.671	$ 2.235.406.712
				$ 60.173.067.522

Source: Own elaboration, 2019

corresponds to $COP 114 kW.h, additionally, for the estimation of the operating time in the study, use was made of the 25 years of useful life, being for this study COP$416,100,000 per year in operating costs. Once these aspects are determined, values are replaced in the formula and the value of NPV resulted in a positive value of COP$138,021,091 as profitability, in addition to recovering the value initially invested with the respective depreciation of money in the time of operation (25 years) with an interest rate of 8%.

4. DISCUSSIONS

During the execution of the case study, an electric power plant was selected using 2000 kW photovoltaic solar panels. To analyze the working capacity of the solar power plant, a capacity factor of 21% was used. This value was deducted from the average daily solar radiation generated in its maximum power (net), equivalent to 5, 24 h, in cities such as Barranquilla - Colombia, which mostly has sunny days and its tropical characteristics (Hosenuzzaman et al., 2015). The net present value is calculated for the forecast of the value of the investment to be recovered in the long term and to check if the project is really profitable for the investor. In the results obtained, it was noted that in the operation of the plant (close to 25 years of useful life), a value of COP$ 23,611,221,091 gross would be obtained, greater than the total investment cost of the installation and start-up of the plant of 2000 kW of $23,473,200,000, which means that the plant would only be able to be paid for and the returns obtained would be very small for the totality of the time and work invested, making it unattractive.

The real options valuation uses inflation as support, considering that this long-term forecast is executed. When applying a model of these characteristics where the behaviors in the cash flow, investment cost and operation term vary, its final value will depend on how high those annual cash flows are and how low the applied interest rate is. The latter plays an important role and only depends on the facilities offered by the market for the development of its projects, this is, the lower it is, the greater the profitability of the generation project. For this reason, it is insisted that the government support the renewable sector to provide the initial capital. On the other hand, in the Annual Net Value formula, the sub-formula (1*k) ^n represents the discount factor; the formula shows the depreciation of money over time. Applying ANV with inflation adjustments to the selling price and most current market values added a more realistic component to the financial method applied with real options.

According to Figure 7, there are three options or alternatives of decision to apply according to the results obtained, we start that the last option to take would be the one of abandonment because it is the most drastic, it is analyzed previously what would happen when deciding the other two alternatives. Taking as a reference, the expand or contract option, when evaluating a 5000 kW plant, the results shown in Table 7 will be obtained.

With the generation price estimated for the year 2019, the total investment cost of installation and commissioning for a 5000-kW plant would be $18,930,000 USD. The total investment cost of installation and commissioning for a 5000-kW plant would be increased to $58,683,000,000 Colombian pesos. Bearing in mind that the hours per day that take full advantage of solar radiation are between 10 am and 3 pm, 365 days, 1825 working hours would be taken advantage of, which applied to 5000 kW would result in 9,125,000 Kw/h generated in the plant during 1 year of operation.

For the calculation of the total operating cost of the plant, the operating cost of Table 4 was taken as the base, whose value corresponds to $COP 114 kW.h. To take the estimate of the operating time in the study, it will be done according to the 25 years of useful life, being for this study COP$416,100,000 per year in operating costs. Values in the formula are replaced and the NPV value resulted in a positive value of COP$1,490,067,522 as profitability, apart from the fact that the initially invested value is recovered with the respective depreciation of the money in the operation time (25 years) with an interest rate of 8%.

According to the results for a plant of 5000 kW, benefits are obtained in greater proportion of money compared to that stipulated in the plant of 2000 kw, however, when comparing this value with the initial investment of the project still remains an insignificant value, therefore, would shrink the option to defer, to expect changes and better conditions of both price and flexibility of the market, through the regulations and statutes of the government. Applying techniques of evaluation of photovoltaic energy projects with high degree of uncertainty for plants of 2000 kW and 5000 kW, it follows that the return on investment is long term.

5. CONCLUSIONS

The Real Options Valuation has become a valuable tool for the evaluation of investment projects, with a high degree of uncertainty. It can be applied to various sectors, in this case, in the photovoltaic solar energy generation sector, which belongs to the energy sector, one of the most variable in price and by the intermittence in the information of resources. By using methodologies to simulate reality in the face of uncertainty scenarios, profitability and losses generated can be projected by means of the consumer price index and the determination of other investment costs, market prices, among others. In this context, the Real Options Valuation is used as an alternative decision, seeks economic quantification, rationalizing decisions, considering flexibility, abandonment, expansion or waiting. Pilot testing, factory design, conceptual engineering are prime examples, where the option of expanding a business can be determined. The wait option can undoubtedly be applied when the VNP is negative, feasibility studies determine if cash flows are not as expected, so that the wait option is very valuable for inclusion of projects at another time with better opportunities. These valuations undoubtedly avoid risks and losses in the future.

The results of low economic feasibility make necessary the presence of the government, as a regulating entity that flexibilizes the market and guarantees economic subsidies, tax incentives and opportunities to SMEs and interested companies for the incorporation and development of renewable energy projects in the Colombian territory. The matrix should be diversified, avoiding the purchase of electricity from neighboring countries by promoting autogeneration with clean alternatives that support the environment. It is necessary to increase the percentage of participation in the Colombian energy matrix of innovative projects that eliminate the high costs of consumption of fossil fuels in the operation of plants, and excessive pollution of the environment, this will undoubtedly wipe out resources, remembering that they are not renewed or can be re-established.

Colombia, has cities with high potential for solar energy generation to be a tropical country with a prestigious geographical location and still has great scope for exploration for the creation of opportunities in the renewable sector, where solar energy promotes the development of projects with short installation time of approximately 6 months to a year, compared to other power generation plants. La Guajira, Magdalena, Atlántico, and other sectors of the Northern Region are attractive destinations for this type of projects.

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