WIND ENERGY IN COLOMBIA: An approach from the real options

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ABSTRACT

Key words: investment, decision, real options, system dynamics.

It is proposed to employ the real options methodology to assess an investment project of wind energy generation in Colombia, backed up by a model with systems dynamics which reproduces the interaction between market values that determine the operative conditions of the projects and that have an effect on the investment decisions.

With that purpose, the Colombian Electrical System (CES) and the investment conditions within it are characterized. Then the real options methodology to assess investment projects in the analyzed market is presented and the built model is described. Finally, the found results are shown and it is given a conclusion on profitability of the real options to assess investment projects of wind generation in Colombia.

1. INTRODUCTION

Investments in wind energy in Colombia and in other countries of the world are irreversible, costly, and are subject to numerous uncertainty sources, such characteristics draw complexity in the decision making process. Yet, some projects count on strategic flexibility that allows to decide an optimum moment of completion, expansion, contraction, interruption or quitting depending on the market conditions that determine its profitability. In this context the investor requires methodologies that ease the decision making process, specially when investments are done with unusual technologies without operative antecedents in the local market.

At several times investment projects with negative net present value have been carried out, this determination originates from investor's intuitive perceptions that contemplate implicit options in the project that may become profitable according to future evolution of market variables relative to this. The real options methodology (differing from the traditional methodology of project assessment based on discounted free cash flows) captures the implicit strategic flexibility in investment projects with high uncertainty, conferring a financial support to this flexibility, in order to extend the existing information in the decision making process.

Particularly, in Colombia -differing from other countries where the operation of wind energy parks is in a learning curve- technology has not a great background, therefore its future development is absolutely uncertain. Additionally, the generation of wind energy is characterized by its modularity, which facilitates investment in pilot wind energy parks whose expansion is subject to operation and performance of technology in the market. Facing this fact, the assessment of this kind of project must account for market uncertainty and strategic flexibility that is inherent to it.

An options methodology is attempted to analyze the development of a wind energy project value and its option to expand in a specific period of time, backed up with a model in systems dynamics that capture interactions of the Colombian electrical market, in which some variables intervening in the project assessment are produced. Thus, through a first approach it is sought to capture in an objective way (numeric or financial) the value of the expansion option inherent to a wind energy generation project in Colombia, and enrich the investor's decision project by offering him a greater financial support that lets the project to be managed and to decide in which moment the project can be carried out giving up the possibility of clarifying part of the uncertainty.

This paper is part of a research project in process, developed in association with Universidad Nacional de Colombia, Colciencias and Empresas Públicas de Medellín, and pretends to analyze the operation, risk and expansion possibilities of the wind energy market in Colombia.

2. INVESTMENTS IN THE COLOMBIAN ELECTRICAL SECTOR

2.1. Sector characterization

The structure of the Colombian Electrical System (CES) was substantially modified with the amendment agreed in 1994 by the law on public services (law 142) and the law on electrics (law 143). With such reform participation of different economic agents -public, private or mixed in the activities of the sector- is allowed, and the state -which used to play an administrative and economical role because of its position as an only investor- is given the duty of regulating and controlling the activities of the sector, aiming to have an efficient, safe and reliable national electrical system.

This liberalization initiated in 1995 is the result of the experience of England and Gales in the reform of their electrical systems (Millan, Lora y Micco, 2001, p.16-18), and of aspects such as the technological development in the generation industry and the energy crisis of 1992 (ISA, 1999, p.34). The reform also includes the regulation of the major energy market and vertically separates the activities of energy generation, commercialization, distribution and energy transmission.

The sector technological portfolio to December 2002 was formed by hydraulic generation (65.43%), gas-thermic generation (28.90%) and coal-thermic generation (5.67%) representing a gross connected capacity of 13678.43 MW (UPME, 2002, <on line>).

It is evident that the Colombian system depends on its hydraulic capacity, which makes it vulnerable to hydroclimatic phenomena that may eventually restrain the water resource availability as in past years, particularly with the El Niño phenomena in 1991-1992 and 1997-1998, when the former case led the country to blackouts and to quite high energy prices in the latter case (Osorio,2002,p.10).

2.2. Investment decisions in the sector

Differing from the previous centralized planning market, in the current one the investments infrastructure aim to social development by supplying the energy demand on the state part, but they also try to reach objectives of economic development, that is to say, obtaining profitability and risk management due to the fact that the investment comes not only from public agents but also from private ones. Nevertheless, the adopted market structure presents internal working mechanisms and an interaction with the market environment, such as the subjacent relations between supply and demand, regulatory policies, technological development, among others, which are mostly unknown by the investors, becoming sources of uncertainty in the moment of making investment decisions (Dyner y Larsen, 2001; Smith, 2002, p. 42). In such circumstances, the investor is exposed not only to the risk that an investment project involves , but also to the risk in the energy price.

In this high investment and uncertainty context, capacity investment projects include valuable strategic options stemming from the operative and management flexibility of the investor to decide whether to carry out the project, modify it during its construction and operation, or simply postpone it awaiting more information. The financial analysis of the projects on generation must give account of these options and of the characteristic uncertainty in the CES in order to improve investment decision scenarios.

In particular, as an answer to the system vulnerability and to international trends in energy generation with renewable resources, Colombia has been developing research projects tending to identify possibilities of development in the generation of wind energy -technology with no antecedents in the country-, which requires orientation in eventual investment decisions.

3. REAL OPTIONS IN INVESTMENT ASSESSMENT OF EOLIC ENERGY GENERATION IN COLOMBIA

3.1. Traditional approach in project assessment

The method based on discounted Free Cash Flows (FCF) has been traditionally used to assess investment projects, such method involves a deterministic nature that foresees variables that have to do with the assessment and offers few possibilities of future scenarios. Likewise, investment is taken as a now-or-never decision, not containing management and operative flexibility that lets the investor alter the project along the time when sources of uncertainty related to the project are solved.

In the CES, this method has been used to evaluate investments not only by public companies but also by private ones depending on the nature of the project and the goals sought. In the mean time uncertainty has incorporated by means of sensibility analyses.

However, discounted FCF methodology presents inconveniences when used to assess projects with strategic options (like energy generation). Among the problems we find the underestimating of projects reporting low or no cash flow, the non-consistent nature of capital cost along the time, the exclusion of risks that capital cost does not capture, the assessment of the project lead time, mistakes in projection of cash flows and sufficient proofs of validity of final results (Mun, 2002, p.57; Trigeorgis, p.121).

In spite of all this, methodology based on cash flows is a clear and consistent method for all projects, offering the same results regardless of risks preferences of each investor, it provides a satisfactory and economically rational level of accuracy, it is a relatively simple, widely taught and accepted method and it can be simply explainable to management (Mun, 2002, p.58).

The traditional method of assessment and decision criteria stemming from this one, are not mistaken, but its usage in investment projects with implicit strategic attributes may lead the investor to make decisions without the complete information of the real final state of the project due to the fact that the Net Present Value (NPV) might be negative but the eventual possibilities it has, may raise its value and make it a viable project.

Within the CES, in many cases investors have accepted investment projects whose NPV is negative, however, this acceptance has been the product of intuitive perceptions regarding the feasibility evolution of projects along the time and regarding strategic factors, such is the case of wind energy generation in Colombia.

3.2. Real options methodology

Interaction among factors such as the number of agents, the variety of investment alternatives, the wild competition to capture demand in liberalized markets, the opportunity cost of resources, among others, introduce complexity in the current business atmosphere and make the investment decisions a little trivial. The decisions are the result of rigorous analyses processes of endogenous and exogenous variables into companies, due to the fact that mistaken decisions may bring about disastrous consequences, however, in this context, business alternatives are plentiful, and the investor asks himself: Which path to follow? Are there valuable options included in the alternatives? At which point should I quit or invest in a project? How are investments assessed in the most objective way possible? In order to give a suitable answer to these questions, the investor requires instruments that enrich decision making and let him choose a way of action with the most accurate and available information at the moment.

The real options approach considers strategic alternatives that certain projects under uncertainty conditions, management and operative flexibility involve, in order to use these options in a temporary horizon, depending on the market conditions and the learning process reached with the time as uncertainty decreases.

Strategic options have an intrinsic value, but such value is only obtained when management decides to use the mentioned strategies (Mun, 2002, p.24), and when it is feasible to identify traits as: high uncertainty in operative, technological and market factors, among others, the project value is determined by the uncertainty level, the management has flexibility to decide, strategies are believable and achievable, and management in rational to use strategies (Mun, 2002, p.150).

This management flexibility to perform corrections during the process when uncertainty towards the future exists, should be considered within the value of the projects, because they represent rights and opportunities that any organization can possibly execute when subjacent conditions of a respective project are favorable or unfavorable accordingly.

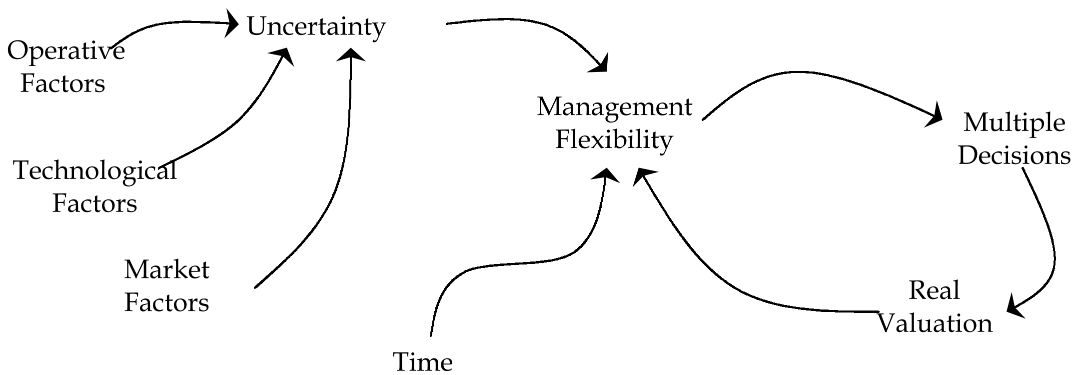


Figure 3.1. Real options assessment structure

In figure 3.1 it is shown the structure originating assessment with real options. As previously stated, several uncertainty factors, together with management ability to switch strategies along the time, determine strategic options in projects that must be included in its assessment.

The real options methodology employs the theory of options to evaluate physical or real assets (Mun, 2002, p.79; Trigeorgis, p.16). A real options resembles a financial option which represents the rights but not the compromise to acquire an asset within certain amount of time or within a deadline, at an agreed price called exercise price (Lamothe, 1993, p.3).

An investment project can be understood as an option that gives the investor the possibility but not the compromise to execute it, dealing with an investment cost and obtaining a return represented in a current value of cash flows expected in the project operation which are unknown and uncertain. The option does not represent a compromise as for the investor decides not to invest when he does not find it profitable.

Under this approach, the risk of obtaining undesirable results is limited (Mun, 2002, p.91; Mascareñas, 1999, p.146; Trigeorgis, p.69, 122), because the investor does not invest if market conditions are not favorable for the project, whereas the benefit obtained is limited and reinforced by the investor's flexibility to select the best strategy to implement when he obtain new information and clarifies uncertainty (Mun, 2002, p.82).

Now, the existence of options inherent to certain investment projects is clear and must be incorporated in the assessment of the projects.

The theory of options establishes the value of an option forming a portfolio from which all movements and changes are controlled and has the same returns of the options (mimetism). Under this non-arbitrage condition the equivalents between the value of the option and the portfolio is guaranteed as its price evolutions (Amram and Kulatilaka, 2002, p.61), that is the reason why the determination of the option value is based on the assessment of the subjacent asset in any respective market.

There are different solution methods to calculate the option value. The analytic method based on differential equations of Black&Scholes ,the Monte Carlo simulation and the binomial trees (Hull, p.987-408; Mun, p.139), which application depends on the characteristics of the option to be valued[1].

For the assessment of a real option (regardless of the method employed) it is necessary to identify the following elements (table 3.1):

Table 3.1. Elements needed for a real option assessment.

Element	Input
Underlying asset	Investment project
Underlying asset value	Investment's present value cash flow
Time to expiration	Period in which decision can be made
Exercise price	Project's initial investment
Underlying asset volatility	Underlying operative risk
Risk free rate	Temporary money value

[1] These methodologies are used to assess financial and real options. They differ in their approach, but in many cases if inputs and application frames are correctly structured, the lead to the option value itself with certain of accuracy.

These factors determine the option value, being volatility a crucial variable (Lamothe,1993, p.43-47). As long as volatility is higher the investment option is more valuable, due to the fact that this widens the potential results, however, this does not necessarily increases the desire of applying it, inversely, the increase in risk reduces the desire of investing. The option becomes more valuable because it reflexes the need to wait for more information (Mascareñas,1999, p.147).

This method consists in supposing that the price of the underlying asset (S) develops according to a binomial multiplicative process, that is to say, in an interval of short future time the underlying asset may increase to a *"Su"* extent, with probability *p*, or decrease to a *"Sd"* extent with probability *1-p*, until reaching the deadline (Amram and Kulatilaka, 2002, p.160) with a fixed number of steps that determine the time interval between a change in price of a underlying asset and another.

Particularly, in the electrical sector, the strategic alternatives that an investor has during the lead time of an investment project, characterize the flexibility for the delays in its beginning, searching the optimum moment to invest and to start operation, the possibility of quitting the operation of a plant temporarily or for good, the possibility of increasing or decreasing the production rate, or according to the type of project, the opportunity of alternating the production modes using different technologies (Trigeorgis, 1999, p.122; Integral-UN-Colciencias, 2000). The traditional assessment methodologies do not give account of this flexibility inherent to projects or investment options because they assume a constant and predictable nature of variables that intervene in assessment, they offer a few possibilities of future scenarios and define investments as now-or-never decisions. This situation supports the usage of the real options methodology in the study of an investment in an wind energy park. In order to develop the assessment in this term paper, a binomial tree will be used, which is a flexible method that permits to easily comprehend the different phases in the assessment of options as well as the complications that can come up during the process (Amram and Kulatilaka, 2000, p.154).

4. SISTEMIC METHODOLOGY

A company that interacts with the electric energy market is a system that presents dynamic complexities, that is to say situations where cause and effect are subtle, and where effects in the intervention through the time are not obvious. The forecast, planning and conventional analytic methods are not enriched enough to face dynamic complexity (Senge, 1995, p.96). Most of the "systems analyses" are concentrated in the complexity of details[2], not in dynamic complexity. Simulations with thousands of variables and complex detail displays keep from seeing patterns and interrelations (Senge, 1995, p.96). The systems dynamics is a simulation tool based on feedback and delay premises between decision making and its effect on the organizations, characteristics that make it different from other simulation

[2] Complexity of details is lineal and is characterized by the existence of many variables (Senge, 1995, p.95).

techniques used to support strategic planning. Its power comes not only from its predictive capacity but also from the possibility to support the design of policies and give answers to questions such as what would happen if this occurred? (Dyner, 1993, p.1). During the decision making process it is essential to be aware of available alternatives and their probable consequences. That is why it is important to count on instruments to select such alternatives and to simulate the behavior of organizations under diverse considerations (Dyner, 1993, p.2).

Because of the foundations described above, the objectives in this model will be reached using systems dynamics, in order to get -beyond a forecast of possible scenarios-, to a systematic analysis which permits an approach to the study of the influence of certain variables on the value of options of a wind energy generation project in Colombia.

4.1. Model description

The model is divided into two modules, the first one interprets the behavior of the electric energy market and the second one comprehends the financial working structure of an energy generation and commercialization company. Both of them interact with each other by means of processes that include feedback and delay.

Figure 4.1 shows the main variables to study in an energy generation and commercialization company (in blue), which interacts with the market (in red), identifying four great loops.

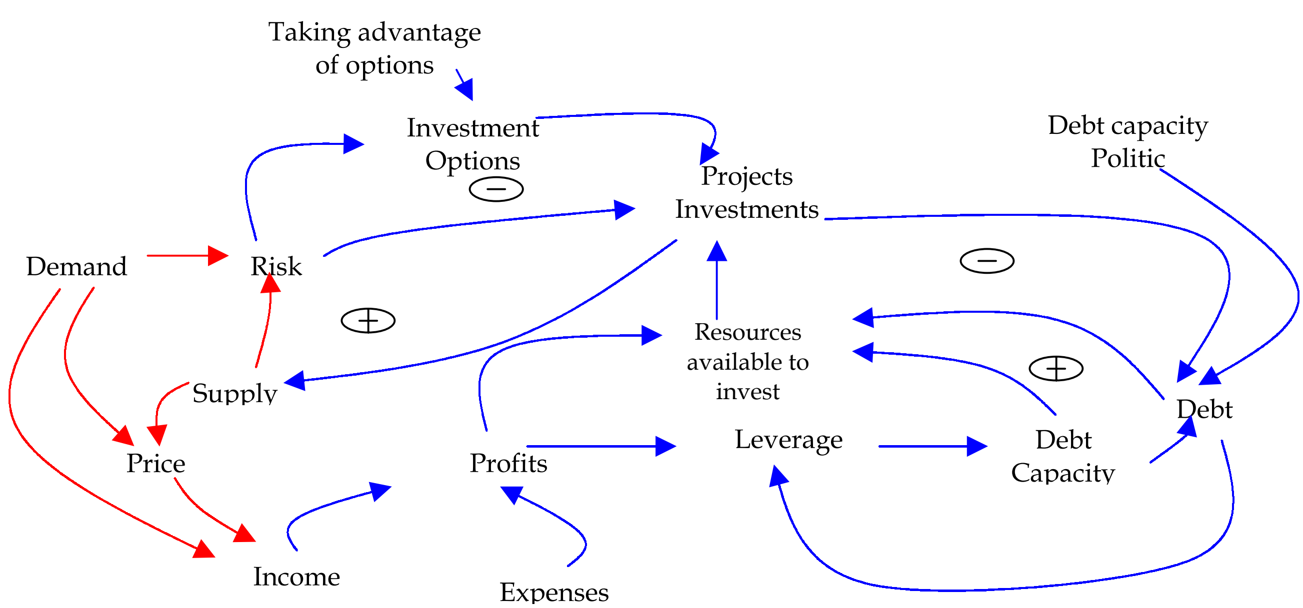


Figure 4.1. Energy generation and commercialization company dynamic.

4.2. Loops description

For a company, profits have an effect on leverage which at the same time determines the debt capacity, the greater the debt capacity, the more resources the company has for investment, which permits to financially carry out more projects. The eventual executions of investment projects in infrastructure increases demand and consequently lowers the energy price, such variable affects income and in this way it returns to profits (figure 4.2).

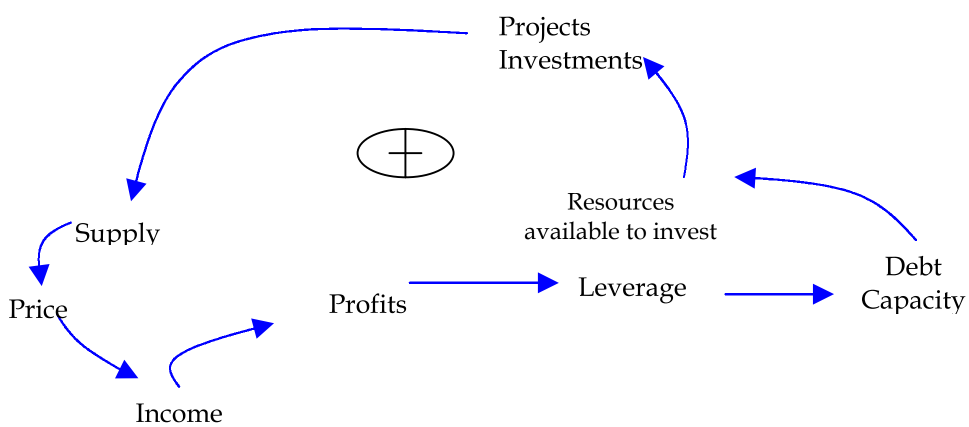


Figure 4.2. Loop 1: Company-market interaction

On the other hand, the more project investments made, the higher the debt required, which takes to a greater leverage, this leverage increases the debt capacity bringing about more resources to invest, necessary to invest more in projects. The borrowing policy is an exogenous variable that has an effect on the debt (figure 4.3).

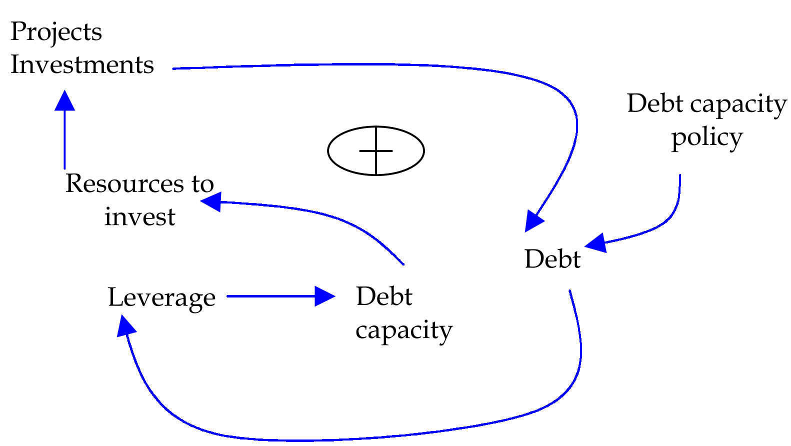


Figure 4.3. Loop 2: Leverage dynamic

When investing in electric infrastructure, energy supply rises, which affects the perceived market risk, this is a situation that leads to identify more investment options and the more existing investment options, the more project investments will be made. Taking advantage of options is the flexibility assessment of projects which directly affects investment options (figure 4.4.).

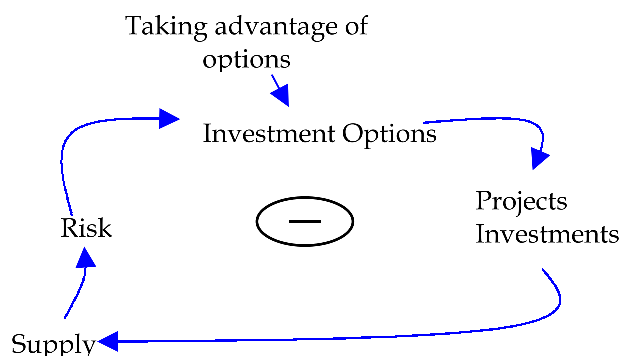


Figure 4.4. Loop 3: Investment options dynamic

Project investments increase debt, but this one reduces resources available to invest at any moment, as far as its handling increases as it grows, this is why a debt increment reduces resources for investing (figure 4.5).

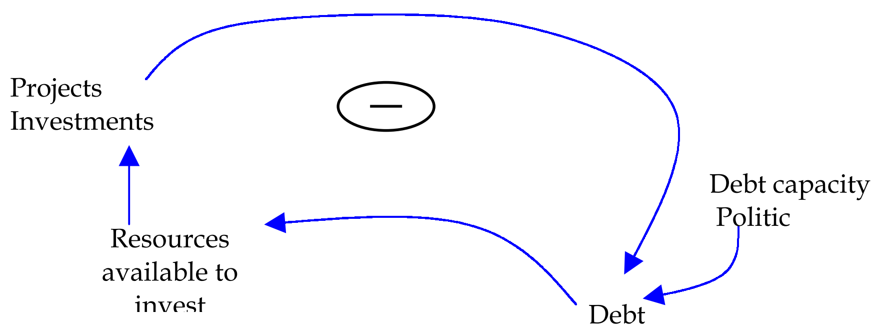


Figure 4.5. Loop 4: Investments- debt dynamic

4.3. Market behavior

Market behavior modeling was developed based on previous studies performed by the Universidad Nacional de Colombia along with Colciencias and Integral (Integral-UN-Colciencias, 2000), this model is attached to this research due to the current interactions between market and the analyzed company which play an important role thanks to the feedback between energy prices and energy supply.

The system margin, figure 4.6, representing the difference between generation capacity and electricity demand, affects electricity price and price then affects demand due to the existing elasticity between these variables, forming a feedback loop. On the other hand, electricity price and capacity margin represent incentives to invest, which affect generation capacity and another feedback loop closes again.

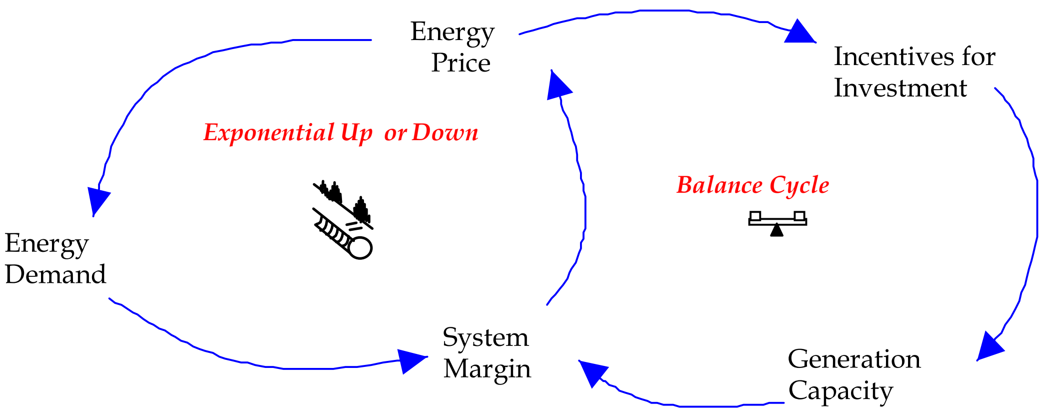


Figure 4.6. Colombia's energy market dynamic

When analyzing market behavior, what it is basically sought is to determine the spot market price and the price of contracts, which are variables that depend on the offer price, on accumulated availability, on supply-demand relation and on hydrologic scenarios, where hydrologic conditions of El Niño, La Niña and a normal state are reproduced. Taking these variables into account the market model was structured like this[3]:

- *Demand module*: It is built with scenarios determined by UPME (Energy and Mining Planning Unit) and the legal permitted limit for a company share in a total demand.
- *Hydrology module:* Considers different hydrologic scenarios to determine the reservoir operation.
- *Supply module:* Takes the system availabilities that have been separated by technology (hydraulic and thermic).
- *Dispatch module:* Determines the energy dispatch by technologies, taking into account the supply-demand interaction.
- *Expansion module:* Plans CES expansion according to three determined scenarios from an expected mean growing of GNP.

4.4. Financial structure

[3] For more details on how a market model is structured see (Integral-UN-Colciencias, 2000)..

- *Debt module:* In this module the debt in which the company incurs to finance its investments is analyzed[4]. The following variables are taken into account:
  - Leverage: The company borrowing policy for any investment project is 60% debt financed and 40% with equity.
  - Term: The debt has a 10-year term regardless the nature of the project to finance. The system of capital disbursement by the bank is done monthly in equal quantities to complete the debt balance amount.
  - Debt payments structure: These are done every six months during 10 years, time concession period is not considered.
  - Interests: They are done every six months at a monthly nominal rate of 5%.

- *Financial statements:* Allows to simulate the financial statements of the company under study and the project to evaluate, the cash flow is modeled as well as the profit and loss statement and the ROIC.
- *Investments*: This module is divided into two, the project options assessment and the expansion or not expansion of the company.

4.5. Options assessment process

4.5.1. Application frame

In order to initiate the option assessment it is important to gather information in an application frame that lets clearly identify the characteristics defining the option. This application frame constitutes the foundation on which all calculations to assess the option will be made, therefore "in the real options method it is more important to focus on the function of the application frame, making sure it comprehends the relevant points and gets a current balance between a simplicity that preserves intuition and a richness that brings about realistic and useful results" (Amram y Kulatilaka, 2000, p.131). Following, an application frame for assessing the option of expanding a wind energy park in Colombia will be explained in detail.

- *Decision:* Starting from an existent pilot project with a capacity of 20 MW, the goal is to assess the option of expanding the wind energy park or to continue with the existent production. The possible expansion decision is described in figure 4.7.

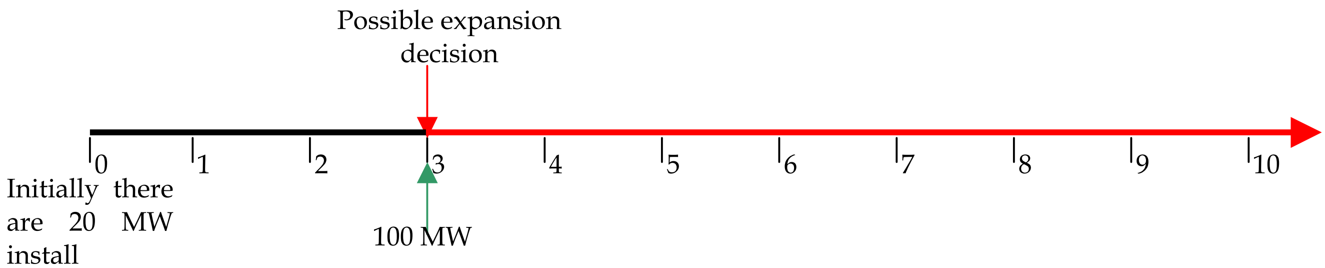
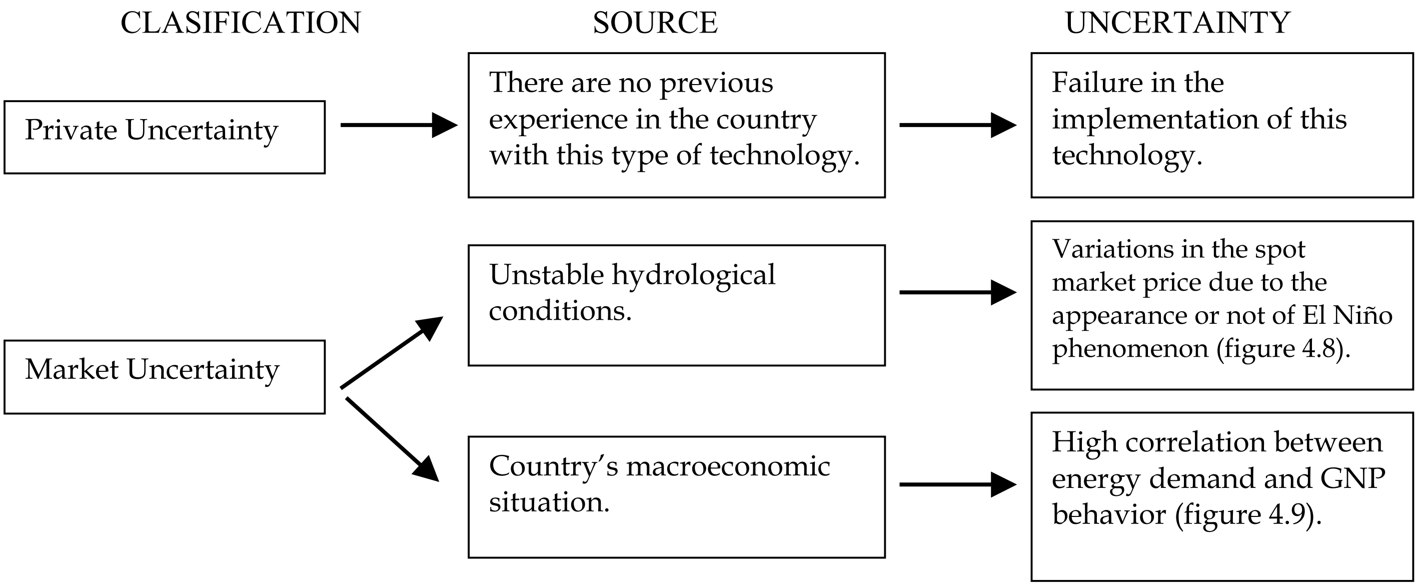


Figure 4.7. Possible expansion decision

[4] All figures used in this model are expressed in thousands USD.

- *Uncertainty sources:*



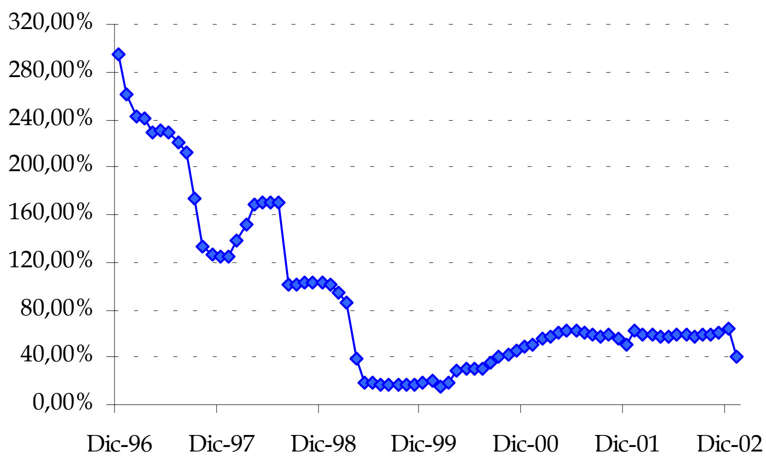


Figure 4.8. Yearly volatility of monthly energy spot price
Source: ISA.

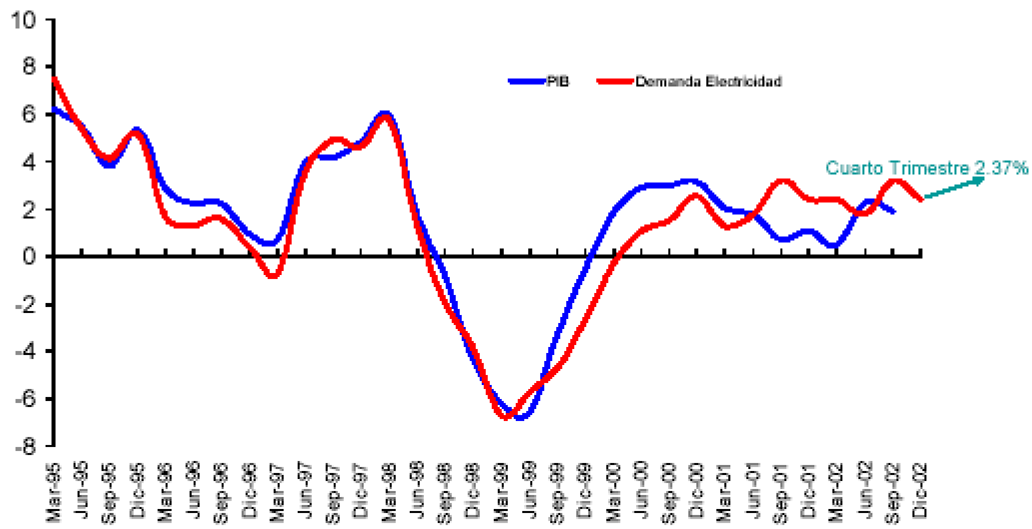


Figure 4.9. Evolution of energy demand vs. GNP.
Source: ISA.

4.5.2. Option to value description

Taking an existent pilot project with 20 MW of capacity, the company studied have the option to expand its wind energy generation capacity since 3-year in 100 MW. It was used a closed-form approximation of an American option call because the option to expand the firm's wind generation can be exercised at any time since 3-year up to the expiration date. To calculate the value of the expansion option it was used a binomial approach using 12 time-step[5] and do not consider dividend or income lost for not exercised the option. Table 4.1 shows the inputs to this option valuation:

Table 4.1. Input to a specific option value

Element	Input
Underlying asset	Energy spot price[6]
Underlying asset value	Random (23000 ,25000) USD
Time to expiration	10-years
Exercise price	100.000 USD
Underlying asset volatility	This is not a model parameter[7]
Risk free rate	0.0385 annual

5 In theory 12 time-step is a few number of steps, but for the paper's purpose this steps are enough.
6 The model takes the energy spot price like the underlying asset because the cash flows of the project are basically defined by this factor.
7 The model calculate the underlying asset volatility while the spot prices are being generated, thus, this variable change at any time.

4.5.3. Results

For a 10 year simulation period it was found that the value of the option not exercised to expiration[8], decreases as time to develop it decreases (figure 4.10). The variability that is present in the option price depends in high percentage on energy price volatility which is strongly influenced by the hydrological scenario considered for its calculation, for this reason, it is possible to observe different behaviors in the option price along the time according to the hydrological scenario[9] on which the model is developed. In figure 4.11 as well as in 4.12, great price fluctuations of the option can be observed during almost all the simulated period; while in figure 4.13 these changes are presented at the end of the time horizon and in figure 4.14 the option presents a significant drop in its price at the beginning of the period. It has a relatively stable behavior for the rest of the months maintaining low prices.

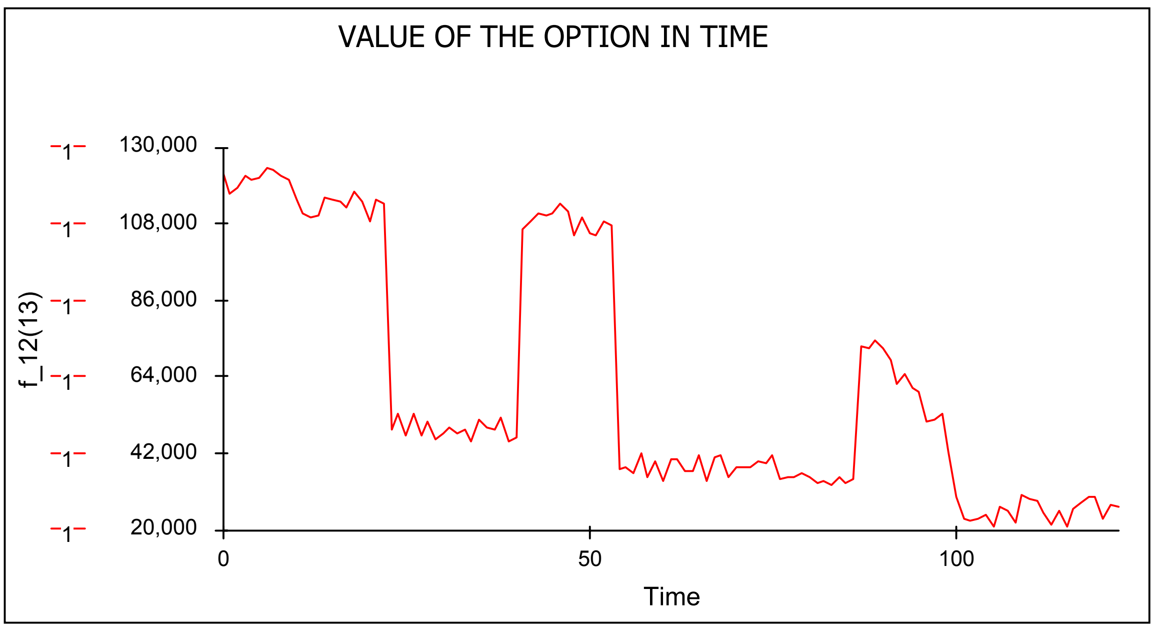


Figure 4.10. Option value in time under hydrological scenario #1

[8] It is supposed that no competitor will not exercise the option if the analyzed company does not do so.

[9] The hydrologic scenario includes the incidence of El Niño phenomenon at any moment during a 10-year period, and the yearly seasons of summer and winter which are characteristics of the Colombian weather.

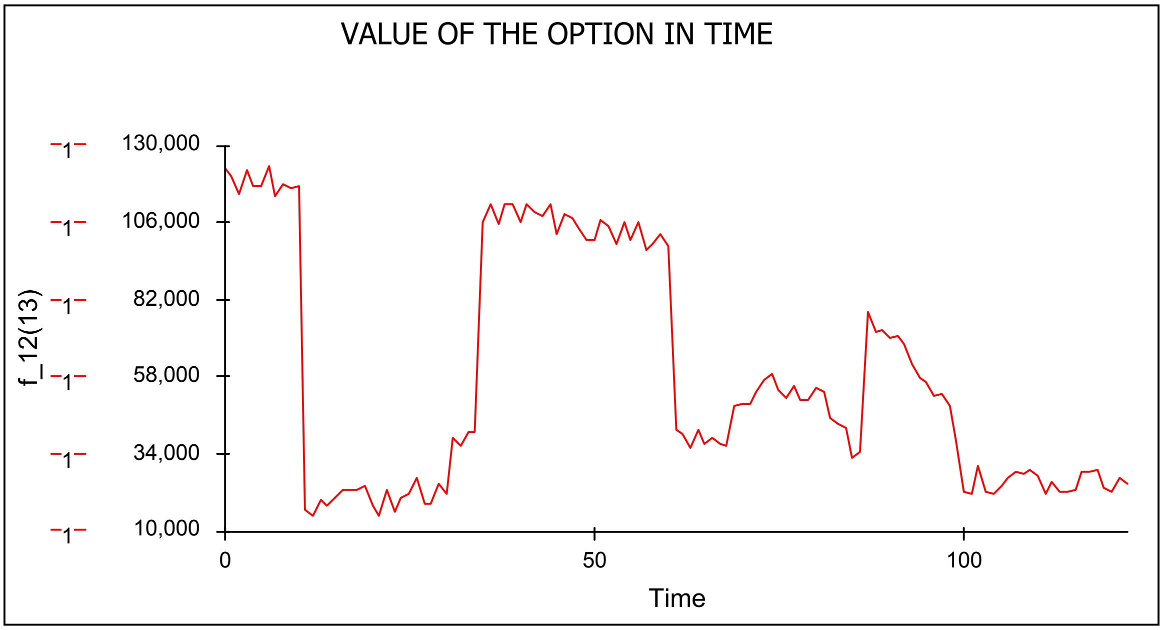


Figure 4.11. Option value in time under hydrological scenario #5

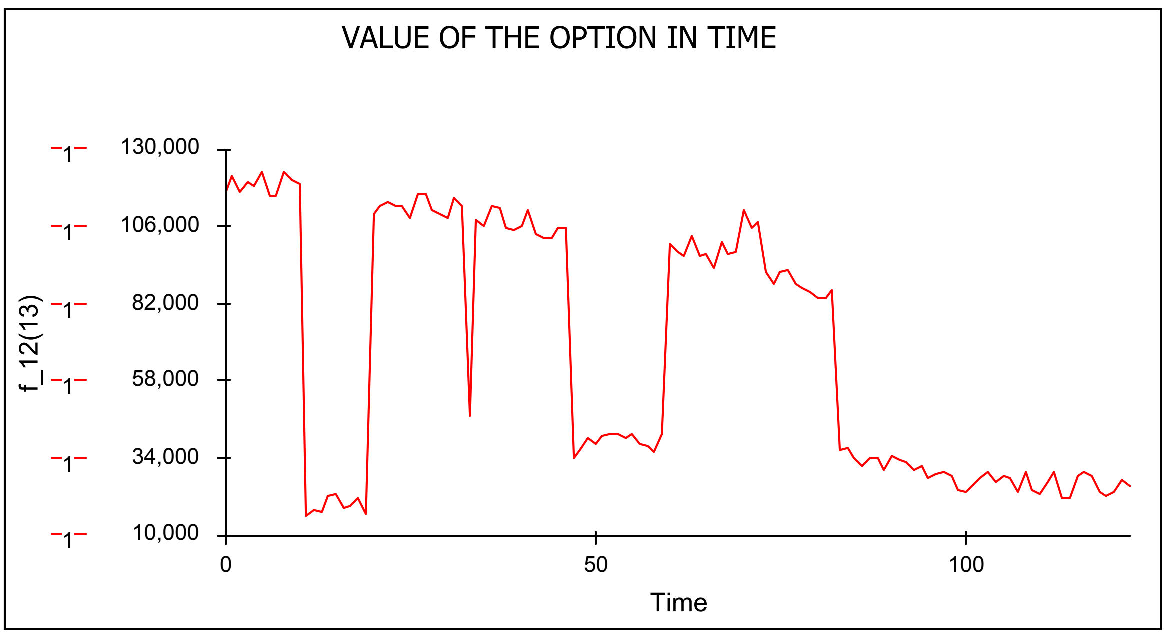


Figure 4.12. Option value in time under hydrological scenario #3

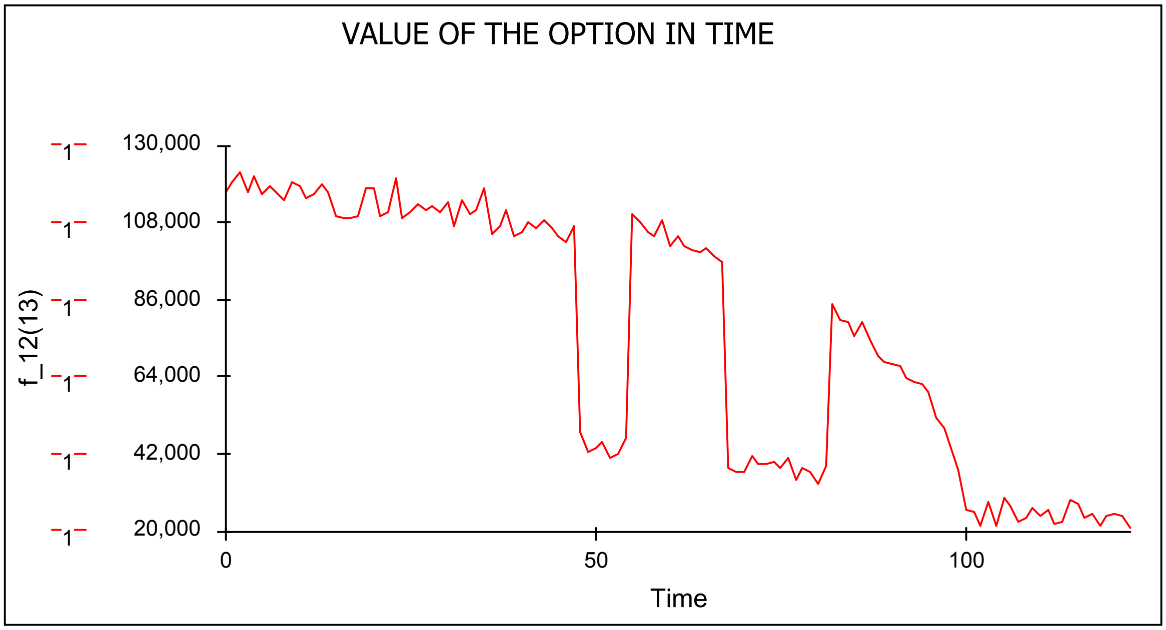


Figure 4.13. Option value in time under hydrological scenario #7

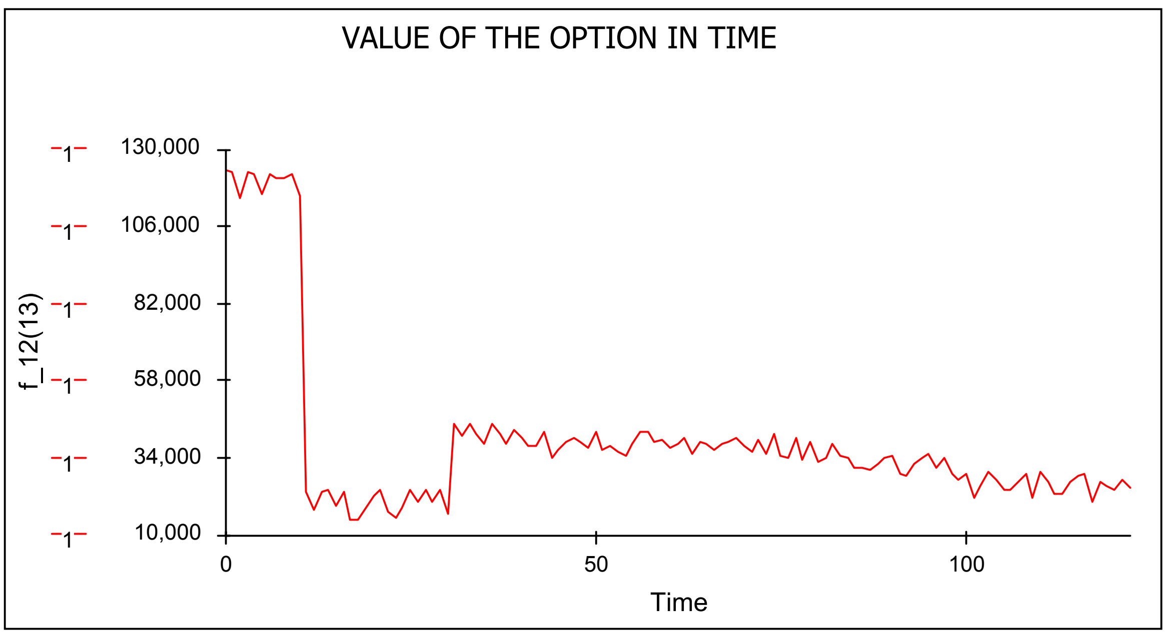


Figure 4.14. Option value in time under hydrological scenario #10

In figure 4.15 it can be clearly seen that traditional assessment (NPV) produces negative results, then, because of this criterion the project would never be financially feasible and its development would not be possible. However, the expanded NPV can sometimes turn the project into an achievable investment. For example, for the hydrological scenario #1 this occurs approximately between months 0-22 and 41-53 (figure 4.15), while in the rest of the months the project has no financial possibilities to be carried out, because the option value drops dramatically as the main consequence of low volatility in prices, consequently, the option value does not reach the initial investment, that is to say, low uncertainty turns the waiting for more information option into a non-value adding option for the project, this behavior is seen in all hydrological scenarios, from which we can conclude that in spite of the fact that the option price is high at the moment and is greatly valued for its future expansion opportunities consideration, in many cases, this over information lowers the financial possibilities of the studied project.

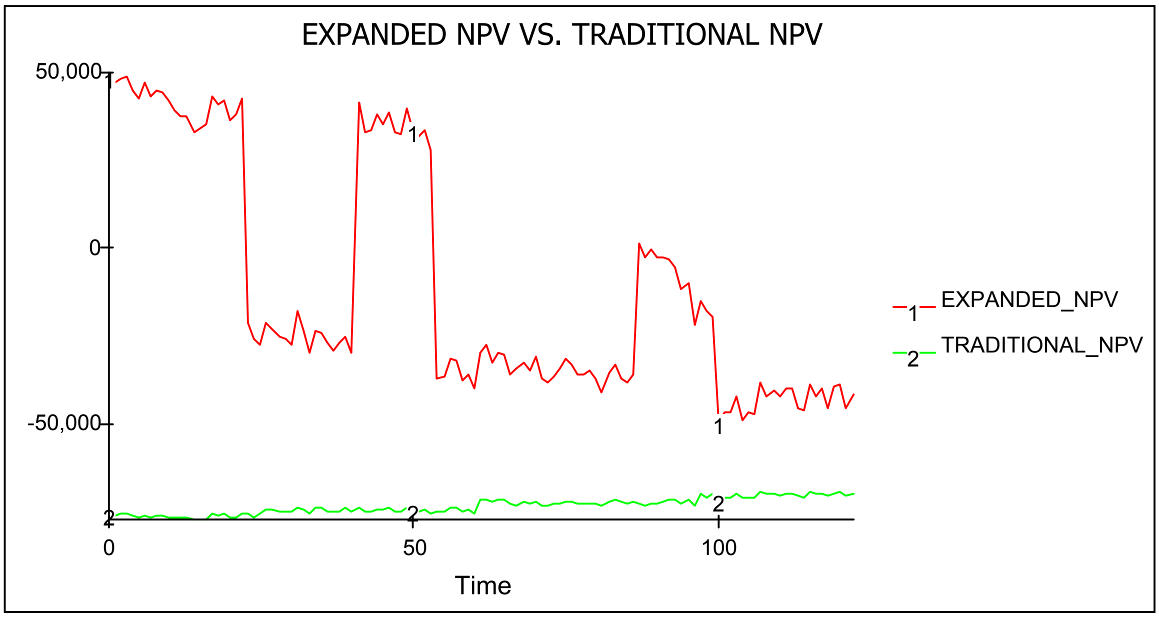


Figure 4.15. Expanded NPV vs. Traditional NPV

In figure 4.16 it is shown the dynamics of free cash flow of the company, which does not present considerable decrements due to the fact that the investment is not executed at any moment of the simulation period.

At any moment it is performed, the free cash flow expansion experiments a drop, figure 19 shows this effect. When expansion is performed in month 56, a cash deficit occurs which is immediately recuperated by the company superavit thanks to high incomes and few expenses.

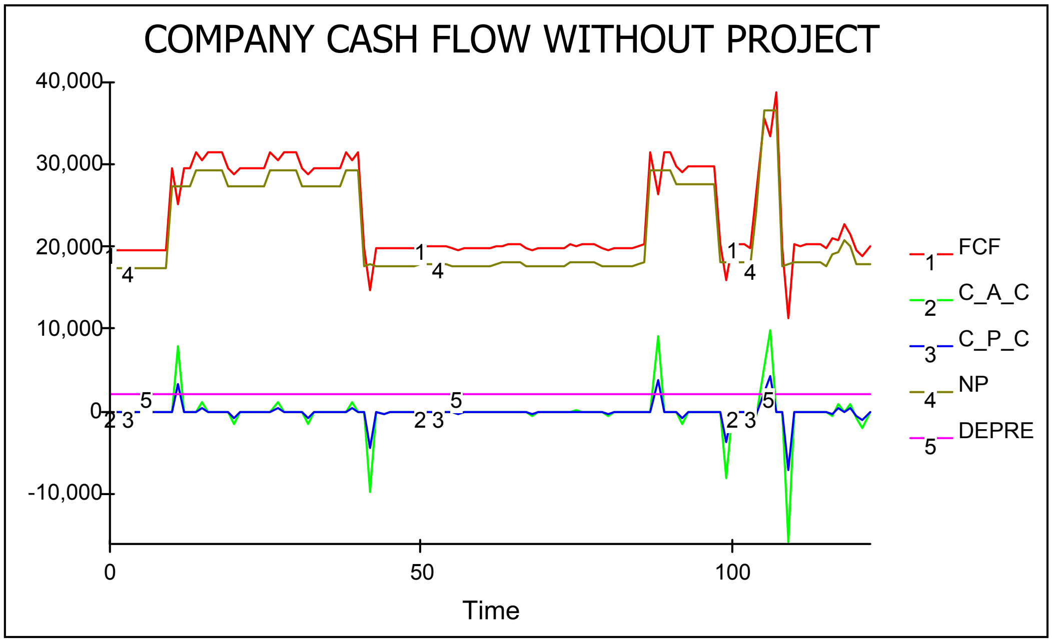


Figure 4.16. Company cash flow without project

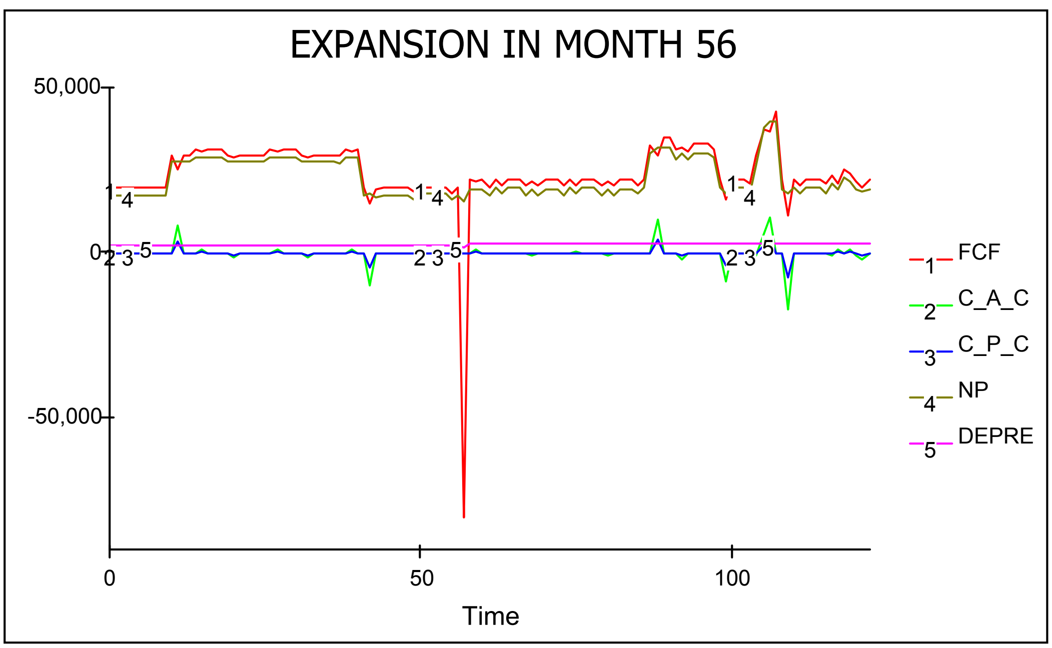


Figure 4.17. Expansion in month 56

Lastly, it is important to mention that the analyzed option behaves according to the theory of options.

5. CONCLUSIONS

The project assessment under real options permits to incorporate in it the option value to expand the planted capacity of the park, which is an option that originates in the investor to carry out the expansion depending on the market conditions, an aspect that is not considered by the traditional methodology of assessment which supposes a deterministic future. The assessment option adds value to the project, this fact makes sometimes the project financially feasible, but at times can not reach this point.

From simulation of evolution of project and option value during a 10-year period, it is seen the dynamic form in which the option value behaves in the influenced time by the interaction between variables determining its value, based on this behavior and its market expectations, the investor is the one who decides when to use the option and thus renounces to obtain more information. The posterior assessment of the decision must be done based on the available information in the moment of decision and not only based on the obtained result.

Actually, many options inherent to the projects are influenced by several sources of uncertainty, these options are called “rainbow options” (Damodaran, 2002, p.22) or options which assessment process is more complex. In the case of a wind energy generation project, besides uncertainty of spot future price of energy, there is also a failure risk of technology operation within the interconnected national system, therefore, in future studies it is essential to incorporate this uncertainty source within the assessment process to observe its influence in the project value. Likewise, modular projects like the one analyzed in this paper, enclose compounded options (Mun, 2002, p11-23) for example, expansion options at a higher level that depend on previous execution of expansion options, for these ones as well as for rainbow options, the assessment process is more complex. However, those are explicit alternatives and are expected to be studied by the Colombian electrical sector. Likewise it would be interesting to analyze investment projects of different technologies and incorporate a decision pattern in the model which shapes the investor’s decision process and allows to simulate the future expansion of the Colombian Electrical sector under this methodology.

The expanded NPV is the sum of traditional NPV and the option value Net Income (NI) which is mostly defined by the spot market price, and determines the free cash flow trend (figure 4.16), whereas oscillations are determined by variations in work capital.

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