Real Options Theory Applied to the Evaluation of Small Hydropower Investments in Brazil

Géremi Gilson Dranka[a,b], Jorge Cunha[c], Paula Ferreira[d], José Donizetti de Lima[e]

[a] ALGORITMI Research Center, University of Minho, Guimarães, Portugal, geremidranka@gmail.com
[b] Department of Electrical Engineering, Federal University of Technology, Paraná, Pato Branco, Brazil
[c] ALGORITMI Research Center, University of Minho, Guimarães, Portugal, jscunha@dps.uminho.pt
[d] ALGORITMI Research Center University of Minho, Guimarães, Portugal, paulaf@dps.uminho.pt
[e] Federal University of Technology - Paraná, Paraná, Pato Branco, Brazil, donizetti@utfpr.edu.b

Abstract:

There have been several challenges concerning the decisions and timing of new investments in the Brazilian power electricity generation due to irreversibility characteristics and uncertainty inherent in the sector, such as the volatility of electricity prices. Large hydropower plants are getting difficult to implement in the Brazilian generation sector, primarily due to environmental concerns and political pressure. Therefore, there has been an increasing focus on investments of small-scale hydropower plants (SHP). In this context, this paper analyses the use of Real Option (RO) theory for decision-making concerning the investment in SHP's in Brazil. This paper investigates the possibility for the entrepreneur of postponing its participation in the auctions proposed by the government. The deferral option can bring relevant value to the evaluation of SHP since the investor has the option to wait until more favorable conditions appear, e.g., better electricity prices or authorization. Therefore, the application proposed in this paper may be considered as a novel approach regarding the application of the RO theory. For this purpose, a real SHP of 7 MW of installed capacity was used as an investment case and it was assumed that the entrepreneur has the option to participate in the auctions in the next three years (2018 - 2020). A comparison of the results considering the traditional economic analysis (based on the discounted cash flows) is undertaken to evaluate the proposed approach. It can be concluded that the deferral option in participating in the auction can be considered a real option for investors and this time flexibility might bring financial advantages since the uncertainties are reduced. Furthermore, the methodology proposed in this paper has great potential to assess future SHP project evaluation and can be adapted to evaluate other power options.

Keywords:

Binominal Model, Economic Analysis, Project Evaluation, Real Options Theory, Small Hydropower Plants.

1. Introduction

The growing interest in Renewable Energy (RE) generation projects has become a reality over the last years worldwide mainly due to climate change concerns and sustainability aspects [1]. In this sense, Brazil stands out among other countries on using Renewable Energy Sources (RES) mainly because of its large-scale hydropower system [2,3]. Brazil accounts for the largest electricity market in South America with an installed capacity of 153.94 GW [4]. According to the Brazilian Energy Balance (BEN) in 2016 electricity generation was primarily composed by RES as illustrated in Fig. 1 divided into 68.1% of hydropower; 8.2% biomass; 5.4% wind and 0.01% from solar. Hydroelectricity presents several advantages compared to other power options including low operating and maintaining costs and high efficiency. However, large hydropower plants are getting difficult to implement in the Brazilian generation sector primarily due to environmental concerns and political pressure. Therefore, there has been an increasing focus on investments of Small-scale Hydropower Plants (SHP).

According to Brazilian Electricity Regulatory Agency (ANEEL), a Small Hydropower Plant (SHP) is defined as a power plant with an installed capacity below 30 MW and with a reservoir of less than 3 km^2. Currently, SHP represents 3.56% of Brazil's total installed capacity, representing 5.5 GW with 430 SHP projects in operation [4]. Currently, there are 29 projects under construction and 130 approved projects, but the construction has not yet started. According to [5], the potential of SHP is approximately 22.5 GW and the installed capacity is expected to be around 6.5 GW in 2020. Therefore, SHP investments are expected to increase considerably and develop a key role in the future in the Brazilian sector.

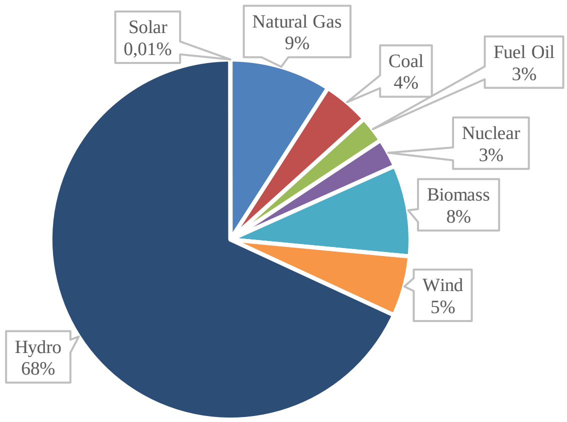

Fig. 1. Brazilian domestic electricity supply by source in 2015.

There have been several challenges concerning the decisions and timing of new investments in power electricity generation due to the uncertain environment of the sector, such as the volatility of electricity prices. The technical impacts of SHPs projects on power grids have been widely investigated in the literature [3]. Nevertheless, less attention has been paid to the economic evaluation of these investment projects [6]. In this context, several methods are available to evaluate investment in energy projects [7]. Typically, the economic analysis of energy generation projects has been assessed considering only a few set of indicators, highlighting the Payback, Net Present Value (NPV) and Internal Rate of Return (IRR) [1,8,9]. These methods, however, do not take into account the risks and uncertainties involved in the appraisal evaluation [10]. Therefore, several works and specialists have been criticizing the use of only these traditional methods in project evaluation primarily because it neglects managerial flexibility and might lead to the project undervaluation [1,10].

Additionally, considering the high capital expenditure, recent changes in the regulatory structure, management flexibility and irreversibility, the use of conventional financial analysis methods may lead to a oversimplified economic project evaluation [1], [7]. In this sense, new evaluation methods appear as a complement to evaluate investments, including RE projects, e.g., scenario analysis, sensitivity analysis and the Real Option Analysis (ROA). Risk is usually incorporated into the analysis of economic viability of Investment Projects (IP) using the sensitivity analysis [8]. Specifically for RE projects, ROA is considered by literature a more suitable tool for the investment assessment as it considers management flexibility [1]. In [1] the authors compare the traditional NPV methodology with the ROA approaches using a hydropower project case study. The work proposed by [7] applied ROA to analyse an investment in a mini-hydro plant using the binomial tree method. The authors highlight that ROA offer an advantage over traditional methods since the former takes into consideration aspects such as irreversibility, uncertainty and management flexibility. In [11], it is considered the use of ROA to evaluate both wind farms and SHP projects investment and the author concluded that the option to defer the construction can generate value for the investor.

Regarding SHP projects, there are two main alternatives for considering the investment deferral. The first one comprises the possibility of postponing the SHP set up after receiving the permission to start its construction. This case can be considered as a speculative behaviour of investors in situations for instance of insufficient financial requirements for starting the construction of the SHP. In those cases, in which the investor had permission but has not yet started the SHP construction, it has the option to postpone the start of constructing and might obtain economic advantages from this decision. Thus, through ROA the investor could defer the investment until energy prices are better to sell the energy produced by the SHP [12]. Nonetheless, the current Brazilian regulatory structure regarding SHP's has tried to minimize this kind of speculative behaviour. The second situation regarding the possibility of deferral the SHP construction encompasses the possibility for the entrepreneur of postponing its participation in the auctions proposed by the government. This latter analysis is the focus of this paper and to the best of authors' knowledge may be considered as a novel approach regarding the application of the RO theory. In this sense, this work will focus on considering the deferral option, which implies that the investor has the possibility to postpone the investment until better information is obtained to make a decision.

The remainder of the paper is organized as follows. Section 2 presents an overview of the actual structure of the Brazilian electricity sector and Section 3 highlights the main issues concerning the ROA in the context of energy investments. Section 4 presents the methodology proposed for the SHP project evaluation including the project's volatility estimation through Monte Carlo Simulation. Section 5 describes the investment project evaluation under analysis considering the use of traditional methods and the use of ROA. Finally, Section 6 draws the main conclusions of the paper.

2. Brazilian electricity market

Brazilian electricity market has special characteristics over other electricity markets worldwide primarily due to its continental dimensions, regional characteristics and high hydropower contribution in electricity generation. The Brazilian market operator (CCEE) is responsible to promote the electricity commercialization activities. Brazil's electricity market sector offers two different trade environments: the ACR – Regulated Contracting Environment, in which distributors acquire energy by auctions regulated by the government, and the ACL – Free Contracting Environment, in which buyers and sellers freely negotiate contract terms [13].

By delegation of ANEEL, the CCEE is in charge of executing regulated power auctions for the ACR. The main aim of auctions is to reduce risk of investor in the regulated market. Distribution companies are obligated to contract the most part of their electricity through public auctions promoted by CCEE in the ACR. Thus, investors compete for concessions in long-term contracts. The model distinguishes from "new energy" auctions (energy from new generation plants) and "existing energy" auctions (energy from existing generation plants), in which the time for starting operating and the contracts' extent are different.

3. Real Options Theory in the Electricity Generation Sector

Real options refer to current choices or opportunities of which an investor may take advantage. A real option gives to its holder the right, without obligations, of making an investment decision concerning real assets, e.g., abandon, build or defer it at a pre-determined cost during a pre-established time [1,7,14]. Investments in generation projects are considered irreversible [7,15]. Thus, when a decision maker chooses to make an irreversible investment, he exercises an option [15]. Investment opportunities in energy generation sector are strongly affected by future expected electricity prices. The high uncertainty in future electricity prices can lead the investor to have more than only one possible decision. For example, the investor might postpone the investment in order to consider timing of the investment. Therefore, he may choose to invest immediately or at an optimal time in the future as new information is revealed [15]. In these cases, ROA is considered worthwhile.

According to literature, the use of ROA is supposed to enhance the value of RE projects. There are two main sources of uncertainty regarding a SHP project: the final energy price [16] and the best moment to signing the Power Purchase Agreement (PPA) [6]. In the context of RE projects, the managerial flexibility most include the flexibility of delaying an investment decision. This option is expected to be valuable since optimal decisions might change over time as new information is released [17]. Managerial flexibility also expects to reduce the exposure of a project to market uncertainty [18]. The managerial flexibility of deferral an option should then be incorporated in the project evaluation and this can be done by using ROA. The risks and uncertainties had increased in the last years in Brazil due to a set of factors, including the political aspects and the economic crisis. One of the main uncertainties inherent to the electricity sector is related to predict the behaviour over time of such electricity prices. Several factors affect the expectation of long-term electricity prices. Thus, future profitability become highly uncertain and investments in this sector should be well evaluated [15]. The use of RO is then fundamental in the development of business strategies, mainly those relating to investments.

4. Methodology

The main objective of this study is to propose a new framework to evaluate SHP projects in the Brazilian electricity sector considering the possibility of postponing the investment decision. This research is characterized as applied aiming to generate knowledge to practical application [19]. The methodology approach applied in this research is illustrated in Fig. 2 and aims to supply a procedure of applying the use of ROA in projects of SHPs. In addition, the methodology proposed might be applicable to other types of investments mainly related to RE projects.

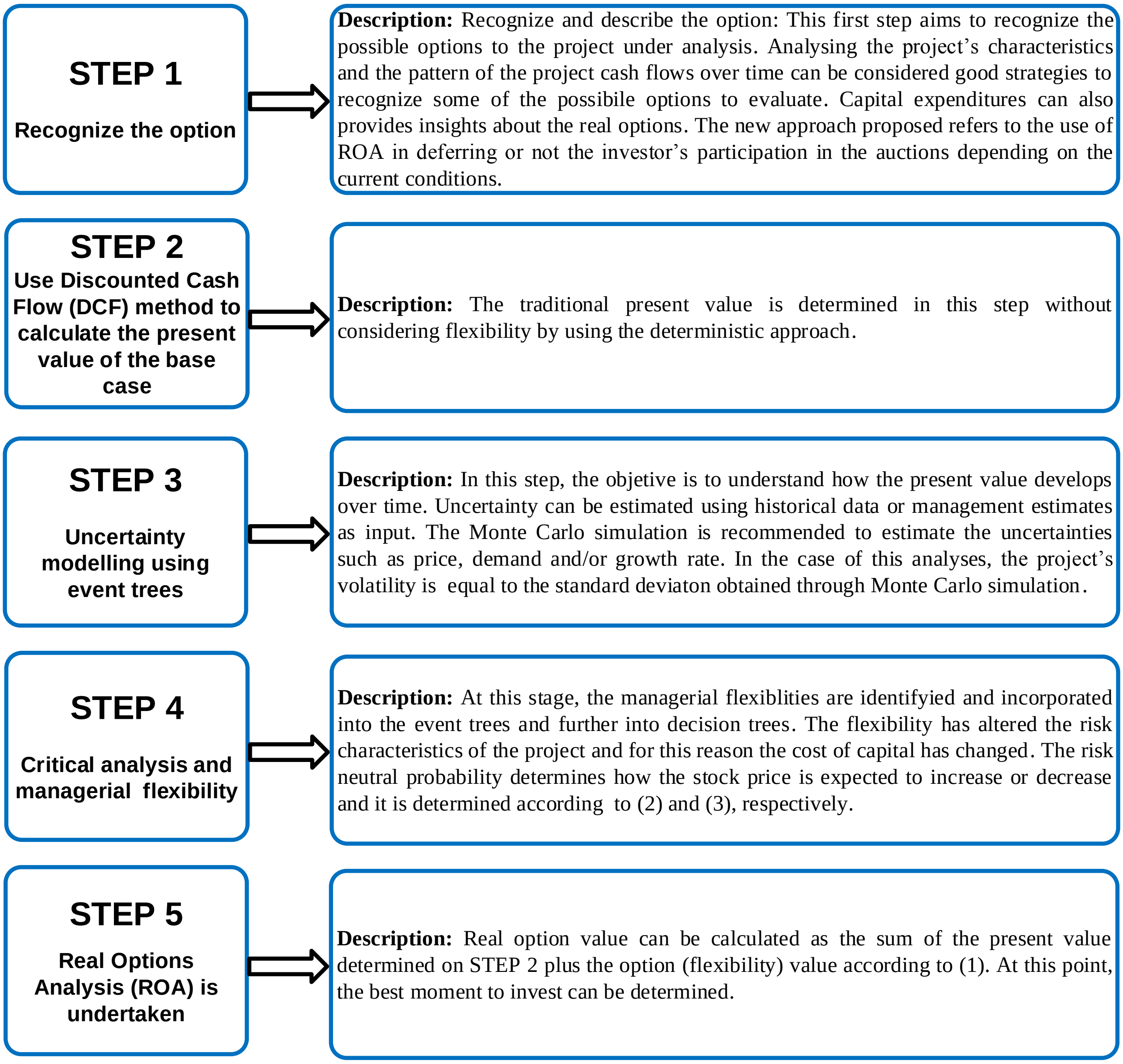

Fig. 2. Methodological approach of the research based on [10] *and* [20].

The real option value corresponds to the difference between the expanded NPV, which considers managerial flexibility, and the traditional NPV, that does not account for managerial flexibility, according to (1):

$$\text{Real option value} = NPV_{\exp anded} - NPV_{traditional}\,. \tag{1}$$

For both American and European options, numerical methods are needed to their evaluation. The main models described by literature to evaluate RO are the Black-Scholes and the binomial tree [10,21]. The binomial tree model has been widely applied concerning RO in the context of RE investment decisions [7,12]. The binomial tree helps the decision-maker between exercises the option or wait until its maturity date. Thus, this paper will use the binomial tree model as illustrated in Fig. 3.

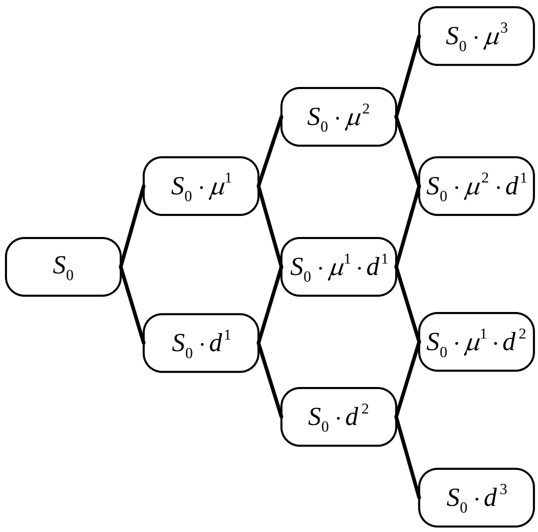

Fig. 3. The binomial tree.

The price of the underlying asset (S) might increase (by a factor u) or decrease (by a factor d) at each period (Δt). The coefficients μ or d reflects the favorable or unfavorable market conditions and are dependent on volatility (σ) according to (2) e (3)

$$\mu = e^{\sigma \cdot \sqrt{\Delta t}}\,, \tag{2}$$

$$d = e^{-\sigma \cdot \sqrt{\Delta t}}\,. \tag{3}$$

The volatility is equal to the standard deviation of the underlying asset and the risk neutral probability, *p*, determines how the stock price is expected to increase or decrease and it is determined according respectively to (4) and (5)

$$p = \frac{e^{r_f \cdot \Delta t} - d}{\mu - d}\,, \tag{4}$$

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

where r_f is the risk-free interest rate.

Estimating the project's volatility is not a trivial issue and literature usually describe this process without describing the step-by-step necessary to determine this value [22]. The volatility estimation of the underlying asset has considerable relevance when using ROA since this variable is taken into consideration to determine the ascending (μ) and descending (d) factors and further to build the event tree [10]. The Monte Carlo Simulation can be employed to combine one or more uncertainties to further obtain the probability distributions required [22]. Usually, the probability of the present value of a project is undertaken. However, in this case, the volatility required to build the binomial tree corresponds to the volatility of the rate of return, z, as illustrated in (6)

$$z = \ln\left(\frac{PV_1 + FCF_1}{PV_0}\right), \tag{6}$$

where PV_0 corresponds to the present value of the project obtained through the deterministic approach (STEP 2) and is kept unchanged during the Monte Carlo Simulation. FCF_1 is the cash flow at time 1 whereas PV_1 is determined according to (7)

$$PV_1 = \sum_{t=2}^{N} \frac{FCF_t}{(1+WACC)^{t-1}}. \tag{7}$$

where N corresponds to the number of years over which cash flows are received or paid and WACC represents the Weighted Average Cost of Capital. It should be emphasized that the standard deviation of the rate of return obtained through the Monte Carlo Simulation is equal to the project's volatility. After determining the project's volatility, the event tree binomial lattice can be build. Fig. 4 illustrates the process for building a value-based event tree using the Monte Carlo Simulation according to [10].

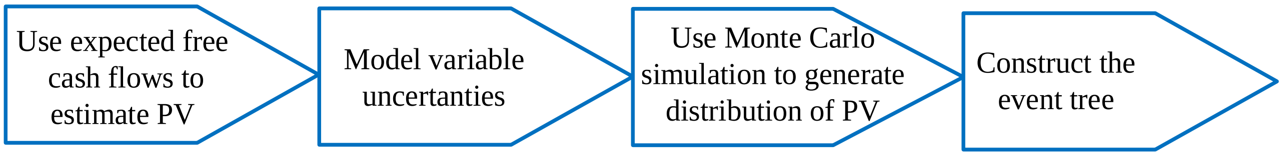

Fig. 4. Process for building a value-based event tree using the Monte Carlo Simulation.

5. Results and discussion

In this section, the framework proposed is applied to a case study of a real SHP project. According to the company's investment plan, the decision of participating or not of the auction should be done in the next three years (2018 - 2020) based on the right time to invest according to the use of ROA. This section also provides the main characteristics of the project under analysis regarding the capital and operational expenditures, variable costs and taxes. Firstly, in section 5.1 the traditional evaluation is applied determining a set of indicators, namely Net Present Value (NPV), Internal Rate of Return (IRR) and Payback. Secondly, the ROA is applied and a comparison between both methodologies is undertaken.

5.1. Case study: Small-scale hydro power plant

The investment under analysis is based on a real SHP project with an expected installed capacity of 7 MW and it is located in the South region of Brazil. The hydropower plant is expected to start operating preferable until 2022, according to company's information. In addition, the SHP investors' aims to sell the energy of the proposed investment in the Regulated Contracting Environment in which distributors acquire energy by auctions regulated by the government. The main characteristic of the

SHP and its associated costs are presented in Table 1. The expected annual power production and the forecast capital expenditures were estimated based on previous studies undertaken by the entrepreneur. Other data needed relies mostly on information collected from the company and are displayed on Table 1. The Weighted Average Cost of Capital (WACC) considered is equal to 8% annually based on [23]. Although the project's lifetime is expected to be about 50 years, for this type of project, the concession is in general only for 30 years. This assumption is considered to calculate the energy remuneration during the project's lifetime. The most part of the project funding (90%) will be obtained through companies' equity. Meanwhile, the remaining financing (10%) is supposed to come from a loan of the National Bank for Economic and Social Development (BNDES) at an interest rate of 9% per year that should be paid in ten years (amortization period) with a grace period of 2 years. BNDES is one of the few sources of long-term financing in Brazil.

Table 1. Description of the technical and economic characteristics of the SHP.

Data	Values
Installed capacity (MW)	7
Expected annual energy production (MWh)	36,792
Investment costs (millions of R$)	31.5
Operating & maintenance costs – annual (R$)	35,000
Variable costs (R$/MWh)	6
Feed-in tariff (R$/MWh)	178.42
Discount rate (%)	8
Remuneration period (years)	30
Residual value (millions of R$))	8
Period of construction (years)	2
PIS[1] (% over the annual gross revenue)	1.65
COFINS[2] (% over the annual gross revenue)	7.60
Service System Charge (% over the annual gross revenue)	6
Administrative expenses (% over the annual gross revenue)	0.5

Although the operational expenditures represent a small portion of the total costs, it should be taken into account in the investment evaluation. The costs presented in Table 1 comprise technical support, administrative charges, maintenance and replacement needs and other service supplies valued according to company's description.

5.2. Project evaluation using traditional methods

This subsection aims to present the use of traditional methods to evaluate the project's investment viability. The following indicators are take into consideration: NPV, IRR and Payback and a set of key assumptions are considered. Firstly, the feed-in tariff for the traditional analysis was defined considering the mean value of historical data available on [24] for Brazilian electricity generation auctions between 2005 and 2016. Energy remuneration is assumed to remain constant through the project lifetime. The same way, the gross revenue should remain constant, as it is assumed that the SHP under evaluation will be a participant of the Energy Reallocation Mechanism (MRE). This latter assumption is made considering that the SHP under evaluation will be a participant of the Energy Reallocation Mechanism (MRE). This mechanism was created in order to allow the National Electric System Operator (ONS) to seek the optimization of hydro resources [25]. Thus, some risks and

[1] PIS (in Portuguese, Programa de Integração Social)

[2] COFINS (in Portuguese, Contribuição para Financiamento da Seguridade Social)

uncertainties related to electricity production for each generating agent which is a participant of this compensation mechanism is considerably reduced as the production variations are financially compensated amongst the generation agents. Table 2 shows the cash flow projections for each year for the project under analysis.

The results of the project evaluation considering the assumptions previously mentioned are summarized in Table 3. Considering the traditional analysis, the investment is recovered in 14 years, with a positive NPV of R$ 12.61 million. The IRR is equal to 12.12%, higher than the discount rate of 8%. According to literature, it can be stated that considering the indicators obtained, the project has economic viability and should be implemented since NPV > 0, IRR > WACC and Payback < n, where n represents the number of years considered in the remuneration period.

Table 2. Projected cash flow for the project under analysis.

Variable	Values (thousands of R$)
Gross revenue	**6,564**
(-) PIS	108
(-) COFINS	499
Net revenue	**5,957**
(-) O&M	221
(-) Service System Charge	394
(-) Administrative expenses	33
(-) Depreciation	1,050
Cash flow before income tax and CSLL[3]	**4,260**
(-) Income tax (IR) and CSLL	1,448
(+) Depreciation	1,050
Free cash flow	**3,861**

Table 3. Results obtained using traditional analysis.

Indicator	Values
NPV (millions of R$)	R$ 12.61
IRR (%)	12.12
Payback (years)	14

5.3. Project Evaluation using ROA

The project evaluation is undertaken in this section considering the ROA. The data provided by the traditional evaluation (Section 5.2) are taken into consideration. This paper considers the volatility of energy prices as the main source of uncertainty, since other uncertainties as operational costs and technological changes does not suffer with high levels of uncertainty regarding this type of investments. As previously mentioned, since it is considered that the SHP will be a participant of the Energy Reallocation Mechanism the water flows are not taken into consideration as an uncertainty. However, if necessary, other sources of uncertainties can be added into the proposed framework. The Geometric Brownian Motion (GBM) is used for estimating the volatility of investment returns and software @RISK® is used for the distribution fitting of data. The energy price uncertainty is modelled as a lognormal distribution based on the historical values of energy prices practiced in the auctions from 2009 to 2016.

The descriptive statistics of electricity prices (R$/MWh) of SHP auctions in Brazil from 2009 to 2016 [24] are presented in Table 4. The mean and the standard deviation estimated is 178.42 and 36.4,

[3] CSLL (in Portuguese, Contribuição Social sobre o Lucro Líquido)

respectively. The following parameters (calculated using equations 2-6, respectively) are considered to build the event tree: $u = 1.3987$, $d = 0.7149$, $p = 0.4841$, $q = 0.5159$ and $\sigma = 33.56\%$. The risk-free interest rate considered is equal to 4.5% based on [23].

The project's volatility was obtained through a Monte Carlo simulation with 5,000 interactions using as output variable the volatility of the rate of return according to (6). The standard deviation of the rate of return estimated is equal to 33.56% (equal to the volatility of project). According to [10] the volatility of a project is not the same as the volatility of any input variable. Note, in this case, that the standard deviation of energy prices is equal to 20.40%, whereas project volatility is 33.56%.

Table 4. Descriptive statistics of electricity prices (R$/MWh) of SHP auctions in Brazil [24].

	2009	**2010**	**2013**	**2014**	**2015**	**2016**	**2009-2016**
Minimum	144.00	129.93	120.00	160.90	195.00	147.85	**120.00**
Maximum	144.00	154.49	139.20	162.50	207.64	235.00	**235.00**
Mean	144.00	146.54	134.52	161.97	204.63	204.69	**178.42**
Standard deviation	-	8.32	5.00	0.92	3.07	25.37	**36.40**
Quantity	1	11	23	3	15	40	**93**

The event tree gives the value of the underlying asset without flexibility as illustrated in Fig. 5. Fig. 6 presents the project value event tree with flexibility. Finally, Fig. 7 provides the option decisions into the nodes of the tree, coming up to a decision tree, which may be viewed as a collection of options on the underlying asset.

0	1	2	3
R$ 53.58	R$ 74.94	R$ 104.83	R$ 146.64
	R$ 38.30	R$ 53.58	R$ 74.97
		R$ 27.38	R$ 38.30
			R$ 19.57

Fig. 5. Present value tree without flexibility for the proposed project (millions of R$)

0	1	2	3
R$ 21.25	R$ 38.15	R$ 65.67	R$ 105.67
	R$ 7.28	R$ 15.72	R$ 33.98
		R$ 0.00	R$ 0.00
			R$ 0.00

Fig. 6. Project value of delay with flexibility for the proposed project (millions of R$).

0	1	2	3
Delay	Delay	Delay	Participate
	Participate	Delay	Participate
		Do not participate	Do not participate
			Do not participate

Fig. 7. Decision tree of the project under evaluation.

The value of the option to postpone its auction's participation is approximately R$ 21.25 million, which is 68.46% higher than the static NPV (R$ 12.61 million). Using (1), the option value of delay can be calculated given by the difference between the expanded NPV and static NPV, resulting in approximately R$ 8.63 million. Therefore, using ROA the investor should postpone its participation in the SHP auction until more favourable investment conditions appear. Because of the high level of uncertainty, the flexibility has added a relevant value to the project. Thus, the extra value of flexibility makes the project worthwhile. The value of a real option increases if the underlying project is very risky or if there is a long time before the investor is supposed to exercise the option. In this particular case, the project is risky because of the high volatility estimated. Moreover, the investor has three years before deciding, and then the option to wait is probable to be valuable.

6. Conclusion

This paper proposes a new approach in the use of real options as a suitable tool to guide decisions in auctions regulated by the Brazilian government in the regulated contracting environment. For achieving this objective, the RO theory is considered focusing on the evaluation of investment opportunities in a small-scale hydropower project case study. The deferral option can bring relevant value to the evaluation of SHP since the investor has the option to wait until more favourable conditions appear, e.g., better electricity prices or authorization. Therefore, it can be concluded that the application proposed in this paper may be considered as a novel approach regarding the application of the RO theory. The deferral option in participating in the auctions can be considered a real option for investors and this time flexibility might bring financial advantages since the uncertainties are reduced.

The first stage of the proposed framework evolves the project investment evaluation using a deterministic approach based on a discounted cash-flow method. The second stage comprises in applying the ROA to a SHP investment project. The new framework proposed in this work offers a set of advantages. Firstly, since the investor is analysing the possibility of deferring its auction's participation, the capital expenditure has not yet been made. Therefore, the option to abandon the project investment has no economic impact to the investor. Secondly, the framework proposed in this paper has great potential to assess future SHP project evaluation and can be adapted to evaluate other power options. For instance, since 2009 wind power auctions have been proposed for the Brazilian government. Thus, if the real option analysis undertook to evaluate the SHP does not offer the advantages expected by the investor, it could apply the analysis considering its participation in a wind power auction, for instance.

The results also indicate that the use of the framework proposed in this paper might impact the Brazilian electricity market since it can modify the timing of new investments. Specifically, the framework may help an entrepreneur or a company to optimally configure its portfolio for future RE project investments in terms of maximizing the value of the portfolio; creating the right mix of projects considering priority criteria; and maximizing goal alignment and/or optimizing resources. The use of the ROA for guiding the decisions on participating or not in power generation auctions may enhance the speculative behaviour of the entrepreneurs, which opens up important avenues for further research.

References

[1] Martínez-Ceseña E.A, Mutale J., Application of an advanced real options approach for renewable energy generation projects planning. Renew Sustain Energy Rev 2011; 15:2087-94.

[2] Khoodaruth A., Oree V, Elahee M.K., Clark W.W., Exploring options for a 100% renewable energy system in Mauritius by 2050. Util Policy 2017; 44:38-49.

[3] Sachdev H.S., Akella A.K., Kumar N., Analysis and evaluation of small hydropower plants: A bibliographical survey. Renew Sustain Energy Rev 2015; 51:1013-22.

[4] Brazilian Electricity Regulatory Agency (ANEEL). Generation Database (BIG). Available at:<http://www2.aneel.gov.br/aplicacoes/capacidadebrasil/capacidadebrasil.cfm> [accessed 9.3.2018).

[5] Ferreira J.H.I., Camacho J.R., Malagoli J.A., Júnior S.C.G., Assessment of the potential of small hydropower development in Brazil. Renew Sustain Energy Rev 2016; 56:380-7.

[6] Polatidis H., Haralambopoulos D.A., Munda G., Vreeker R., Selecting an appropriate multi-

criteria decision analysis technique for renewable energy planning. Econ Plan Policy 2006; 1:181-93.

[7] Santos L., Soares I., Mendes C., Ferreira P., Real Options versus Traditional Methods to assess Renewable Energy Projects. Renew Energy 2014; 68:588-94.

[8] Lima J.D. de, Gonçalves M., Oliveira G.A.O., Batistus D.R., Setti D., et al., Systematic Analysis of Economic Viability with Stochastic Approach: A Proposal for Investment. Eng. Syst. Networks. Lect. Notes Manag. Ind. Eng., Springer; 2017.

[9] Talavera D.L., Pérez-Higueras P., Almonacid F., Fernández E.F., A worldwide assessment of economic feasibility of HCPV power plants: Profitability and competitiveness. Energy 2017; 119:408-24.

[10] Copeland T., Antikarov V., Real Options, Revised Edition: A Practitioner's Guide. Penguin Group; 2003.

[11] Giorgetto T.M., Decisão de Investimento entre Pequenas Centrais Hidrelétricas e Usinas Eólicas: Aplicação da Teoria das Opções Reais. Escola de Economia de São Paulo, 2012 [in Portuguese].

[12] Fenolio L.M. da S., Minardi A.M.A.F., Monteiro L., Accioly Fonseca A.M., Applying real options theory to the valuation of small hydropower plants. Rev Econ E Adm 2009; 8:347-69.

[13] Maier S., Street A., McKinnon K., Risk-averse portfolio selection of renewable electricity generator investments in Brazil: An optimised multi-market commercialisation strategy. Energy 2016;115:1331-43.

[14] Fernandes B., Cunha J., Ferreira P., The use of real options approach in energy sector investments. Renew Sustain Energy Rev 2011; 15:4491-7.

[15] Kjærland F., A real option analysis of investments in hydropower-The case of Norway. Energy Policy 2007; 35:5901-8.

[16] Bøckman T., Fleten S.E., Juliussen E., Langhammer H.J., Revdal I., Investment timing and optimal capacity choice for small hydropower projects. Eur J Oper Res 2008; 190:255-67.

[17] Henao A., Sauma E., Reyes T., Gonzalez A., What is the value of the option to defer an investment in Transmission Expansion Planning ? An estimation using Real Options. Energy Econ 2017; 65:194-207.

[18] Saleh J.H, Mark G., Jordan N.C., Saleh J.H., Mark G., Jordan N.C., Flexibility: a multi-disciplinary literature review and a research agenda for designing flexible engineering systems 2009; 4828.

[19] Saunders M., Lewis P., Thornhill A., Research Methods for Business Students. England: Pearson Education Limited; 2016.

[20] Luehrman T., Investment Opportunities as Real Options: Getting Started on the Numbers. Harv Bus Rev 1998; 76:97-105.

[21] Fabrini K.L., Teoria das opções reais: Uma abordagem para análise de investimento em expansão do setor elétrico. UFMG, 2011 [in Portuguese].

[22] Neto JFC. Elaboração e Avaliação de Projetos de Investimento. Rio de Janeiro: 2009 [in Portuguese].

[23] ANEEL. Nota Técnica DEA 27/13. Brazil: ANEEL. Available at: <http://www.aneel.gov.br/> [accessed 01.10.2017] [in Portuguese].

[24] ANEEL. Resumo dos resultados dos leilões de geração no ACR de 2005 a 2016. Available at: <http://www.aneel.gov.br/> [accessed 14.11.2017] [in Portuguese].

[25] Pinheiro Neto D., Domingues E.G., Coimbra A.P., de Almeida A.T., Alves A.J., Calixto W.P., Portfolio optimization of renewable energy assets: Hydro, wind, and photovoltaic energy in the regulated market in Brazil. Energy Econ 2017; 64:238-50.