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Levelized Cost of Electricity in Colombia under New Fiscal Incentives

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Abstract

The full use of economic incentives becomes a complex process for investors, which reduce interest in the construction of electricity generation projects using Non-Conventional Renewable Energy Sources (NCRES). Thereby, it is necessary to establish investment methodologies that allow defining the most appropriate generation technologies with competitive costs. Therefore, an adjusted methodology of Levelized Cost of Electricity (LCOE) is proposed in this article to evaluate the potential effects of the current economic incentives on the generation costs of NCRES. It will serve as a tool to assess technical and financial viability of projects from different renewable energy sources (solar, biomass and wind), as well as define different investment strategies in order to take full advantage of current economic incentives. Finally, three solar photovoltaic plants were analyzed under seven investment scenarios, achieving a LCOE between 8.4 ¢USD/kWh and 32.3 ¢USD/kWh.

Keywords: Levelized Cost of Electricity, Economic Incentives, Non-Conventional Renewable Energy Sources, Investment Strategies.

I. INTRODUCTION

New electricity generation plants based on Non- Conventional Renewable Energy Sources (NCRES) have gained importance in recent years in Colombia because of new demands of the country in the energy, environmental and social fields. Then, the development of new NCRES projects seeks to reduce greenhouse gas (GHG) emissions, diversify the energy matrix (solar, wind, biomass), provide energy security since 63% of the installed capacity in Colombia corresponds to water resources [1], provide alternative solutions to demand response problems, contribute to the indicative action plan PROURE 2017-2022 [2], as well as guarantee new generation technologies distributed for rural areas and isolated regions, where energy supply is limited and inefficient [3].

Colombia, due to its large area, has high potential for electricity generation by forest biomass [4], [5], sugarcane bagasse [6], waste banana [7], and photovoltaic solar energy [8]. However, the use of these NCRES has been limited, since only 0.5% of the country installed capacity corresponds to [1].

In this way, projects with NCRES become an opportunity to the implementation of sustainable electricity generation systems, which are necessary to contribute to social development for the post-conflict period [9], to technify the land, to take advantage of the biomass potential for the installation of cogeneration systems [4], satisfy local demand, inject surpluses electricity to the grid, improve the living conditions of the population, add new local jobs, increase coverage of telecommunications services, and supply electricity to the homes in rural areas and isolated regions [3].

The approval of the renewable energy law, the development plan for the period 2018-2022, and the energy auctions for NCERS in Colombia, allow clean energy projects to have a series of fiscal incentives to reduce electricity generation costs and compete with other technologies based on conventional energy sources [10]- [12].

However, the use of the incentives will depend on the capital structure of the investing companies, the type of asset depreciation, the financing mechanism, the proportion of equity and debt, the grace period for payment of debt, the income from existing projects, the externalities, the class of electricity contracts, and the discount rate, among others; additionally, there is a lower benefit for those companies with lower incomes [4], [5].

Consequently, taking full advantage of incentives becomes a complex process for investors, and, for this reason, it is necessary to develop a methodology to structure investments in NCRES, which includes the impacts of incentives such as Law 1715 of 2014, the National Development Plan 2018-2022, the reliability charges, and green bonds and credits.

II. METHODOLOGIES TO EVALUATE COSTS AND INVESTMENTS IN NCRES

Various authors have proposed financial, mathematical and statistical methodologies to evaluate electricity generation projects, considering fiscal incentives. In [13] the authors used the discounted cash flow technique and real options to analyze wind energy projects in Colombia.

Also, in [14] the authors proposed real options to evaluate wind farms and determine the right time for investments. In [15] the application of this method is analyzed to assess decision-making in electricity markets; also, in [16] this method is used evaluate investments in renewable energy sources in emerging countries, which present economic uncertainty regarding the costs of technologies and government policies. The authors in [17] conducted a literature review on the real time options method for investments in NCRES and proposed the use of vertical and horizontal analysis as a complement.

In [11], the authors presented a methodology to evaluate LCOE of large-scale solar plants in Colombia. For this purpose, the used the LCOE methodology that evaluates investment costs, operation and maintenance expenses, as well as externalities, considering the fiscal benefits of Law 1715 of 2014. In [5] the authors analyzed the potential effects of Law 1715 of 2014 on the electricity generation through NCRES and proposed a methodology to include the effects of fiscal incentives in the LCOE. The authors evaluated two of four incentives included in the law: recovery up to 50% of the initial investment through income tax and accelerated depreciation of assets. The results demonstrated that LCOE will be reduced by up to 20%, although small or new low-income projects cannot achieve this benefit.

The authors in [4] analyzed the effects of the fiscal incentives of Law 1715 in the LCOE of forest biomass energy cogeneration plants in the state of Antioquia (Colombia). The results showed that LCOE is reduced when the incentives are applied with a depreciation of assets over 10 years and financing 50% of the initial investment with a grace period of 5 years.

On the other hand, in [18] a hybrid method is proposed in order to select the most appropriate low-cost self-generation technologies for shopping centers in Colombia. The method is made up of hierarchical analysis process techniques, the order of preference due to similarity with the ideal solution, the analysis of real options, Montecarlo simulation, and binomial method.

In [19] the authors conducted a financial analysis using the total cost and learning curve model in order to assess the economic impact of the integration of renewable energies in the Colombian electricity system. In [20] a multi-period mixed-integer linear mathematical program is developed to plan investments in NCRES for Argentina. In [21] the authors proposed a network optimization model using mixed-integer linear programming in order to determine the generation optimal configuration and time in which the investment should be made.

The authors in [22] adopted the Richardson model to evaluate the effect of the loan period on efficiency of investments in projects with NCRES. In [23] a semi-parametric regression model is used in order to assess the impact of government subsidies, green credits and environmental taxes on investments in NCRES. In [24] the authors used the Balmorel optimization model to structure long-term investment routes in renewable energy.

The authors in [25] analyzed the problem of investments under uncertainty in electricity generation projects by developing a methodology based pm GARCH, IGARCH and ARMAX volatility models. In [26] the authors used the network analytical process to assess risks in renewable energy project investments.

The effects of regional risks on the discount rate and the feasibility of the projects were analyzed in [27]. It is proposed a method to calculate regional discount rates (one for each state of the country) in order to have a more accurate evaluation of the upcoming renewable energy projects in Colombia. The results were consistent with the violence and corruption conditions in every region.

Based on the previous antecedents, an adjusted methodology to estimate the LCOE is proposed in this work in order to guide stakeholders towards the full use of fiscal incentives, support decision-making in public-private sector, and promote the development of NCRES projects in the current economic, social and regulatory context of Colombia [12], [18].

III. METHODOLOGY

III.I Definition of LCOE

The LCOE is a measure of the average net present cost of electricity generation for a generating plant over its lifetime. It can be defined as the cost per unit of energy (USD/kWh), which considers all project costs during its useful life, such as the initial investment, fixed and variable costs for operation and maintenance (OM), the cost of fuel and externalities [10]. Equation (1) presents the expression of the CNE.

$$LCOE = \frac{I_o + \sum_{t=1}^{n} \frac{C_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+i)^t}} \tag{1}$$

In this case, I_o is the cost of the initial investment, which includes equipment cost, civil engineering works, substations, designs and other investment items. C_t represents the annual operating costs, which includes fixed and variable OM costs, fuel costs and externalities costs that can be negative or positive. E_t is the amount of energy produced in one year (kWh). i is the discount rate or cost of capital (annual cash - E.A), which is calculated using the weighted average cost (WACC). Finally, n is the operational life of the project (years).

III.II Economic incentives in Colombia

In 2014, the government issued the Renewable Energy Law 1715, which encourages investment in electricity generation projects from NCRES, through the application of 4 tax incentives, which can be described as follows: 1). Investors can annually reduce their income, for the 5 years following the taxable year in which they made the investment, 50% of the total value of the investment made (Investment Tax Credit, ITC); 2). VAT exemption for national or imported equipment, elements, machinery and services that are intended for the pre-investment and investment of NCRES; 3). Exemption from the payment of fees for the components previously named; 4). Accelerated depreciation of assets, which will not be greater than 20% per year as a global rate [12]. However, with the entry into force of the National Development Plan 2018-2022, the benefit of the deduction of 50% of the investment through income tax can be used during the first 15 years of operation of the project [28].

On the other hand, in the Colombian electricity market, other economic incentives can be found, which favor the reduction of the LCOE of projects with NCRES, among which the green bonds stand out, which are credit titles to finance friendly and sustainable projects with the environment, the reliability charge, which is the payment of remuneration to generation plants for guaranteeing firm energy in critical supply conditions, and green credits, which are loans from banks at low interest rates .

III.III Adjusted LCOE

An adjusted LCOE equation is proposed to incorporate the economic incentives of Colombian tax legislation and the Colombian electricity market. The adjusted LCOE equation is presented in equations (2) and (3).

$$LCOE = \frac{1}{1-\mu\sum_{i=1}^{n} E_i}\left[I_o + \frac{B_v}{(1+i)^r} + \sum_{m=k}^{l+k}\frac{A_C}{(1+i)^m}\mu + \sum_{i=1}^{n}\frac{S}{(1+i)^n} - \sum_{j=1}^{d}\frac{I\,D_j}{(1+i)^j}\,\mu\right] \tag{2}$$

$$\mu = (1 - I_j)\,\beta \tag{3}$$

In this case, μ is the tax factor, which depends on the tax rate (β) and the rate of return on the ITC (I_j), and is calculated with equation (3). n is the operational lifetime of the project (years). E_i is the amount of energy produced in a year (kWh). I_o is the cost of the initial investment with own capital (USD). B_v is the future value of green bonds in USD (including yields). r is the term in years of the green bonds. i (annual effective rate, % E.A) is the discount rate or cost of capital. k (years) is the grace period for financial loan. l (years) is the term of the financial loan. A_C (USD) is the annual payment to the capital of the financial loan. S (USD) is the difference between the project's annual income and costs. On one hand, the income may include reliability charge positive externalities; however, the own income from electricity generation is not considered. On the other hand, the costs include fixed and variable OM costs, fuel costs, as well as interest payment. I (USD) is the total initial investment cost, which includes own and financed resources. D_j (%) is the accelerated depreciation rate of assets. j (years) is the time applied to the accelerated depreciation of assets.

The adjusted LCOE equation has the advantage of adapting to changes in the technical and cost structure of each energy project, allowing a sensitivity analysis as well as an evaluation of different investment strategies. It also may be used as a tool to evaluate projects in other countries with regulation and economic incentives different from the ones given in Colombia.

IV. TESTS AND RESULTS

Three electricity generation plants, that use photovoltaic solar systems, were considered to evaluate the impact of economic incentives on the LCOE. Table 1 shows the technical and financial data of the study solar plants [29], [30].

Table 1. Technical and financial information of photovoltaic plants

Plant	Installed Capacity (kW)	Capacity Factor	Specific Cost (USD/kW)	OM Specific Cost (USD/kW)
A	8100	0.18	2976	18.3
B	9400	0.18	2659	18.3
C	9900	0.18	3928	18.3

The LCOE of each solar plant was calculated without considering economic incentives (baseline scenario), using equation (1); this in order to define reference values to estimate the reduction of the CNE when economic incentives are considered in five investment scenarios, which are defined below: 1). Investment without financing; 2). Investment with financing of 70%; 3). Investment with financing of 50%; 4). Investment with financing of 70% and considering a taxable income of 50% of the initial investment; 5). Investment with financing of 50% and considering a taxable income of 50% of the initial investment; 6). Investment without financing considering a taxable income of 50% of the initial investment.

The LCOE of the six investment scenarios were calculated using equations (2) and (3), considering a depreciation of assets over 10 years, a tax rate of 33%, a discount rate of 8.1%, an inflation rate of 4%, a 10% financing rate (effective annual interest rate) and a 5-year grace period [4]. For the baseline scenario, an investment without financing was considered. The results of the LCOE are presented in Table 2.

Table 2. LCOE of the photovoltaic plants under different investment scenarios

Plant	Investment scenario (¢USD/kWh)							Reduction Max
	Base	1	2	3	4	5	6	
A	24.8	22.8	19.4	20.2	9.6	10.4	12.6	61.3 %
B	22.3	20.4	17.4	18.2	8.7	9.4	11.4	61 %
C	32.3	29.7	25.2	26.3	12.3	13.4	16.3	61.9 %

According to table 2, the best investment scenario for photovoltaic plants is # 4, since it allows to take advantage of the tax benefits of Law 1715 of 2014 and the National Development Plan 2018-2022 to a greater extent, mainly the one that corresponds to the recovery of 50% of the investment through ITC, during the first 15 years of operation of the project. It should be clarified that high incomes from other projects favor the positive value of the taxable income, which is defined as the economic base on which the investor can recover 50% of the initial cost of the project through income tax.

On the other hand, financial interests have the advantage of reducing the effect of the tax rate during the operating life of the plants, being more noticeable when they are applied with a grace period, since it allows reducing the payment of taxes in the project years where there are no deductions for accelerated depreciation of assets and for the ITC.

Finally, given that the plants have the same capacity factor, the same specific OM cost and the same additional revenues, plant B presents the lowest LCOE 8.7 ¢USD/ kWh, with a reduction of 61%, for having the lowest specific cost of investment. However, plant C presents the highest reduction, 61.9%, for having the highest specific cost of investment [4]. Thereby, plant C benefits in a greater proportion from the ITC and reduces the impact of the tax rate during its operating life. Whereas plant B can generate electricity at a lower cost than other plants due to the economic incentives, guaranteeing the investor's opportunity cost.

IV.I Sensitivity Analysis

Since the taxable income largely modified the LCOE without incentives, a sensitivity analysis was performed to determine the variation of the LCOE with the taxable income, considering investment scenario # 4. Figures 1a and 1b show the variation of the LCOE, of each plant, as a function of the taxable income.

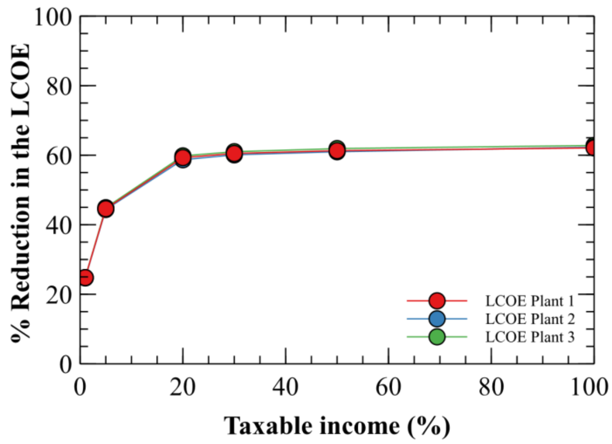

Fig 1a. Variation of the LCOE based on additional income

According to figures 1a and 1b, the LCOE is reduced when the taxable income increases, since the tax benefits, especially the benefit of the recovery of 50% of the investment through the ITC, are used in a greater proportion with the increase in pre-tax earnings from other projects of the investor. In figure 1a, the reduction of the LCOE presents a similar behavior, because the variation of the taxable income is expressed as a percentage of the initial investment. Plant C is the one with the greatest tendency of LCOE reduction, with a standard deviation of 15.1% since it presents the highest initial investment cost [4]. In figure 1b, when the taxable income percentage is above 20%, the plants can recover 50% of the initial investment; for this reason, the LCOE does not change greatly. Despite this, there are small variations because depending on value of the taxable income percentage that is above 20%, the years of recovery of 50% of the initial investment are different. It should be clarified that the maximum time allowed to take advantage of this benefit through income tax is 15 years, according to National Development Plan 2018-2022.

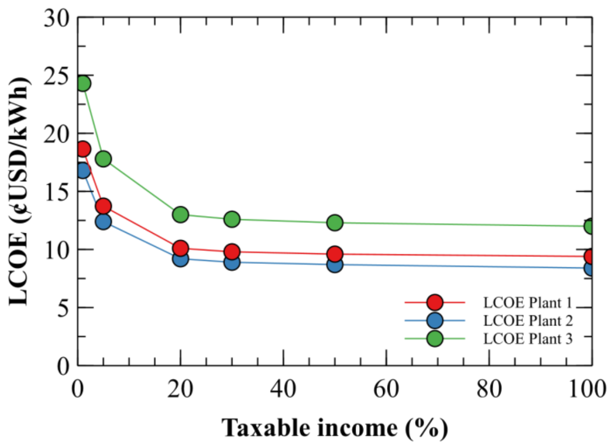

Fig 1b. Variation of the LCOE based on additional income.

Thus, for a taxable income of 100% of the initial investment, generated mainly from other projects for the same investor (it may be a company dedicated to the large-scale electricity generation business), the LCOE of each plant is equivalent to 9.4 ¢USD/kWh, 8.4 ¢USD/kWh and 12 ¢USD/kWh, obtaining a reduction of 62.1%, 62.3% and 62.9%, respectively. Whereas for a taxable income of 1% of the initial investment, (a small company), the LCOE of each plant is equivalent to 18.7 ¢USD/kWh, 16.8 ¢ USD/kWh and 24.3 ¢USD/kWh, obtaining a reduction of 24.6%, 24.7 % and 24.8 %, respectively. This means that the full use of incentives will depend on the capital structure of the companies. On the order hand, comparing with the average costs reported in [30] and [31], which correspond to 6.8 ¢USD/kWh and 7 ¢USD/ kWh respectively, a trend of feasibility of projects with NCRES is evidenced, which are necessary to mitigate energy, environmental and social problems of the country. Finally, it is essential to propose new economic incentives from the legislation and the Colombian electricity market to favor small companies so that they can obtain generation costs similar to those of the NCRES.

V. CONCLUSIONS

The adjusted methodology for computing the LCOE allows evaluating the potential effects of the economic incentives in force in Colombia, as well as determining an appropriate investment strategy to reduce generation costs. Thus, the best investment scenario was the investment with financing of 70% and considering additional income of 2.2 million USD, achieving a LCOE of 8.4 ¢USD/kWh with a reduction of 62.3 %. On the other hand, the full use of tax incentives will depend on the capital structure of each investor. For this reason, investment strategies and the impact of incentives will be different for each company.

Companies with large incomes can take full advantage of the tax incentives of Law 1715 of 2014 and the National Development Plan. Low-income companies must opt for other economic incentives such as a reliability charge, preferential credits or green bonds, in order to obtain competitive generation costs.

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