International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 17 (2018) pp. 13188-13194

Systems Dynamics on Incentives to Invest in Renewable Energy in Colombia

Natalia Acevedo-Prins

Instituto Tecnológico Metropolitano- Departamento de Finanzas,
Medellín, Antioquia, Colombia.
nataliaacevedo@itm.edu.co

Miguel Jiménez-Gómez

Instituto Tecnológico Metropolitano- Departamento de Finanzas.
Universidad Nacional de Colombia- Departamento de Ingeniería de la Organización.
Medellín, Antioquia, Colombia.

Miguel Rojas-López

Universidad Nacional de Colombia- Departamento de Ingeniería de la Organización.
Medellín, Antioquia, Colombia.

Abstract

The energy basket in Colombia is mainly composed of power generation from water sources. Although this source corresponds to renewable energy, there is a risk associated with the little diversification of this market. To diversify the energy basket it is necessary to introduce other sources of non-conventional renewable energy, for this purpose, the Colombian government created Law 1715 of 2014 to encourage investment in projects that diversify the market. This paper evaluates this law by means of system dynamics on a wind farm. The simulation shows that with this law, wind farms continue to be a non-attractive investment to invest, which shows that the tax deductions granted by the law do not achieve the increase of unconventional renewable energy sources.

Keywords: systems dynamics, wind farm, renewable energy, tax incentive.

INTRODUCTION

The majority of power generation in Colombia is from hydroelectric plants followed by thermoelectric plants that run on coal, diesel and natural gas. In the last 20 years the demand for energy grew over 2% per year, and due to the country's hydraulic potential, it made large hydroelectric plants the most efficient option to meet demand. The function of the thermal plants is to operate in the seasons of droughts [1]. However, the ecological and human impact of large hydroelectric plants and the use of non-renewable energy sources in thermoelectric plants increase the need to diversify the energy basket towards non-conventional renewable energy sources such as wind energy [2]. In addition, energy security and the reduction of CO_2 emissions motivate the diversification of the energy basket with renewable technologies [2], [3].

In the last decade, the costs of producing electricity from renewable sources have decreased, but their adoption by developing countries varies significantly [4]. However, in Colombia, costs have not facilitated the adoption of these technologies, their costs are higher than those of conventional technologies, although there are abundant resources such as wind in some isolated areas and the highest average wind speeds coincide. with the seasons of drought [1], [3]. After the first wind farm built in 2003, the diffusion of this technology did not continue in the country. Colombia has an average wind speed of 9 m / s to a height of 50 meters, which demonstrates the potential to generate electricity from wind energy and also, wind farms are a complement to the predominant hydraulic generation in the country, increasing the reliability of the energy market [2].

The energy basket in Colombia consists of 80% generation by hydroelectric plants and almost 20% by thermoelectric plants [5]. Non-conventional renewable sources have a ratio of less than 1%, showing the deficiency in the diversification of the energy basket. In the last decade, the demand for energy increased from 28 TWh to 55 TWh per year [6], and the trend in the share of thermoelectric generation also increased, motivated by water shortages that affected the hydroelectric plants. Consequently, deficiencies in the generation of hydroelectric plants are compensated by thermoelectric plants [2].

Due to the blackouts in 1983 and 1992-1993 and the lack of capacity of the Colombian government to finance the expansion in the energy market, the energy industry was deregulated. This was done through the laws 142 and 143 approved in 1994 by the Congress of the Republic of Colombia [7], [8]. These laws initiated the restructuring of the energy sector allowing the participation of private companies and the division of the production chain in generation, transmission, commercialization and distribution. After this deregulation, there are practically no blackouts and the electricity companies have a good financial position [1]. Later, Law 697 of 2007 was passed, which promotes the efficient use of energy and the use of alternative sources of energy, but this was not effective in the implementation of renewable resources due to the lack of support schemes [4]. With the tax reform in 2002, direct and indirect incentives were established, exempting generators selling wind power for 15 years from income tax, conditioned to obtain and sell certificates of carbon dioxide emissions in accordance with the Kyoto Protocol and that at least 50% of the income obtained from the sale of the certificates is invested in works for social benefit in the region where the generator operates. Although this law established these tax incentives, the procedures to put them into practice are not well defined [9].

The most recent effort of the Colombian government was made with Law 1715 of 2014, regulated by Decree 2143 of 2015. This law was enacted to establish a legal framework for the promotion and use of non-conventional sources of energy in the electricity system in Colombia. This law provides a new legal framework to promote investment, research, development and use of these technologies. Fiscal incentives were created, such as a reduction of income tax of around 50%, exemptions in taxes on the value added to national equipment and services, tariff exemptions on imported equipment and materials, and annual depreciation rates of 20% [10]. With this law it is expected that the participation of non-conventional renewable energies in generation would be between 6% and 15% by the year 2028 [1], [11]. However, there is uncertainty in the implementation and effects on the adoption of renewable technologies, in the price of energy and in energy security [12]. In addition, the Law does not use the FIT mechanism (Fedd in Tariff) to encourage investment in projects for generating electricity from renewable sources as developed countries do. FIT refers to the minimum price guaranteed per kWh that has to be paid to a producer of renewable energy. FIT offers investors a long-term guaranteed minimum price for the electricity they produce (Shahmohammadi, Mohd, Keyhanian, & Shakouri, 2015) in projects for the generation of electricity from renewable sources. Therefore, it encourages investment by providing financial reliability and reducing investment risk [13], with risk being the possibility of losses generated by changes in the factors that affect the value of an asset and is one of the central issues among researchers. in finance [14]–[16]. For this reason, the FIT policy is the main mechanism for the expansion of renewable energy in Europe and the United States, although this requires a large budget from the governments that adopt the mechanism. The rates are set as fixed rates (above the market price) or as bonuses that add to the current market price. These rates cover the disadvantage of renewable energy sources. Most of the time, they are calculated to grant an investment bonus to the producer [17]. FIT rates must be high enough to recover the cost of the investment within a reasonable timeframe [18] and, in addition, small enough to avoid imposing a heavy financial burden on the states [19].

On the other hand, in the research of Alishahi, Moghaddam & Sheikh-El-Eslami [20] systems dynamics were used to determine the impact of the incentive mechanisms on investment in wind farms, determined that the FIT mechanism is the main policy effective to promote the rapid and sustained deployment of wind power generation. They conclude that energy generation would recover part of the investment through different incentive mechanisms, although most of the incentives reflect only short-term signs of the energy market. The FIT method they propose is advantageous because it is done on the basis of long-term expansion planning.

For their part, Goh, Chua, Goh, Kok & Teo [21] used systems dynamics for the management of wind turbine projects in Malaysia, studying the relationship between government policies, the allocation of funds for projects with renewable energy, the demand of energy, environmental impacts and geographical location. In the study, the authors note that each increase of 1% of GDP (Gross Domestic Product) would lead to a 0.41% increase in long-term electricity consumption. It is evident that electricity consumption increases corresponding to the increase in GDP. The study concludes that the dynamics of systems allow establishing a causal relationship for the development of wind energy projects and that for new investors, government support plays an important role in the development of this type of energy.

Finally, Shahmohammadi, Mohd, Keyhanian, S., & Shakouri [22] used systems dynamics to assess the impact of the FIT mechanism adopted by the Malaysian government since 2011 to expand the use of renewable energy in electricity generation. They determined that the FIT tariff is not enough to obtain sustainable generation, which would cause greater fuel consumption and, in addition, tax incentives must be provided for renewable energies, as long as the cost of generation from renewable resources is greater than the cost of power generation from conventional sources.

Based on the studies mentioned above and taking into account the mechanisms to encourage the generation of energy from unconventional sources, this paper evaluates the tax incentives proposed in Law 1715 of 2014 and regulated in Decree 2143 of 2015. A project to generate electricity from a wind source is analyzed in order to determine the effect of these incentives on the Net Cash Flow (FCN) of the project. Additionally, the effect of the FIT policy on investment is evaluated. Most research suggests that the FIT mechanism is the most effective policy to promote the rapid and sustained deployment of wind power generation. For the long-term analysis, a dynamic model is essential for the representation of the problem, which is why system dynamics are used for the evaluation of energy policies.

MATERIALS AND METHODS

In this study, a system dynamics model is used to analyze the effect of some policies recently implemented in Colombia and another not included, such as the FIT policy. System dynamics allows to understand and model the behavior of complex systems whose conditions change over time [23], using basic elements such as feedback, delays and non-linearities [24]. In the analysis of energy systems, system dynamics have been used for more than 30 years [25]. In addition, uncertainty in power generation projects and regulatory interventions as incentive mechanisms are some factors that can be considered in a dynamic model [20].

The system dynamics simulation modeling method was first developed by Forrester in 1950 to analyze complex systems in the social sciences through computer simulations. The process of modeling in systems dynamics begins with the articulation of the problem to determine the limit of the system. The causal diagrams are drawn with the variables linked together in the form of feedback. The system variables are linked by arrows. The dates show the direction of the influence and the polarity that accompanies them represents the influence effect: positive for direct and negative for inverse influence [26].

In this way, power generation is formed by a causal model to evaluate the impacts of incentive mechanisms on the long-term dynamic behavior of investment in wind farms [20]. The causal diagram for this study is shown in Figure 1. Included in the analysis are the variables that affect the cash flow of investors and are related to the measures implemented in Decree 2143 of 2015, including depreciation, the taxes, the price and the generation of energy. The causal diagram presents three cycles of reinforcement (represented by the letter R) and three of balance (represented by the letter B).

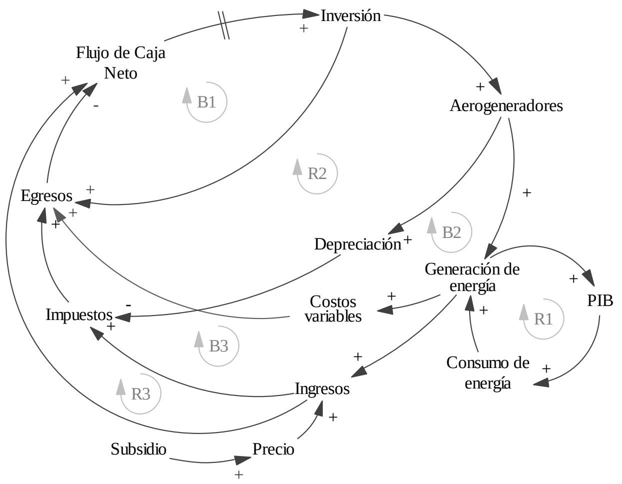

Figure 1. Dynamic hypothesis.

Where:
Flujo de Caja Neto: Net Cash Flow.
Inversión: Investment.
Aerogeneradores: Wind turbines.
Depreciación: Depreciation.
Impuestos: Taxes.
Egresos: Expenses.
Costos variables: Variable costs.
Ingresos: Income.
Subsidio: Subsidy.
Precio: Price.
Generación de energía: Energy generation.
PIB: GDP.
Consumo de energía: Energy consumption.

The reinforcement cycle R1 represents how the GDP could affect the energy consumption. Several studies show a positive relationship between the increase in GDP and energy consumption [21], [27]. When incomes increase, families can choose to spend their extra income on computers, better accessories or transportation, activities that use energy intensively. In addition, economic growth expands the activities of the productive sector, where energy is a representative input [28], [29]. In the case of Colombia, the demand for energy and GDP are presented in Figure 2, where a positive relationship is observed.

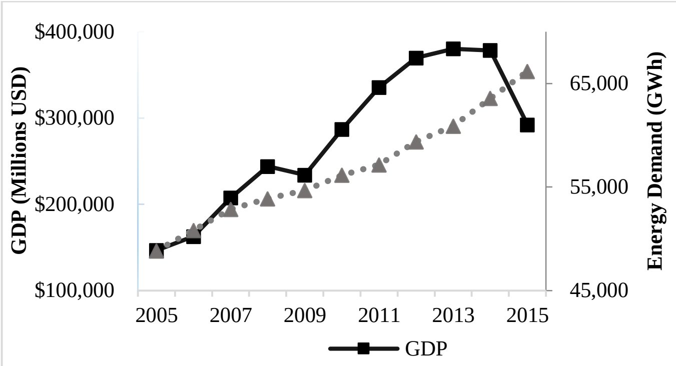

Figure 2. GDP and Energy Demand in Colombia from 2005 to 2015.

The percentage increase in GDP between 2005 and 2015 was on average 3.7% per year, while the increase in energy consumption was 4.30% (see Figure 3). The consumption of electricity increases corresponding to the growth of GDP. The average GDP growth rate with respect to electricity consumption is 1: 1.16.

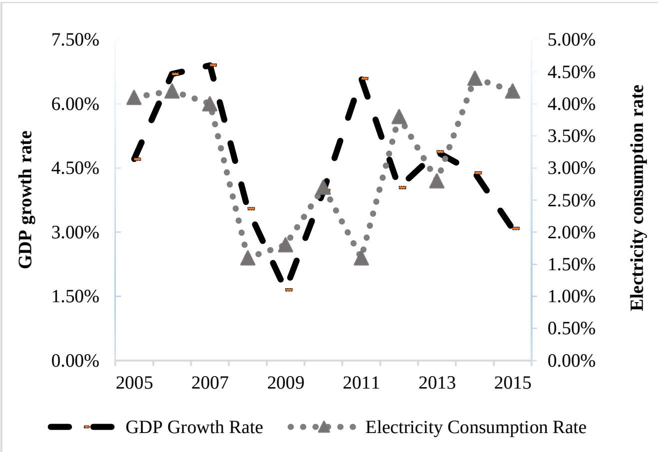

Figure 3. Percentage of GDP increase and Demand for Energy in Colombia from 2005 to 2015.

The other balance and reinforcement cycles represent the relationship between the Net Cash Flow with variables such as income and expenses, increasing and decreasing it, respectively. Cycle R2 represents how depreciation decreases the payment of taxes and, therefore, decreases the expenses by increasing the Net Cash Flow. The R3 cycle represents how the generation of energy increases income. The Balance B1 cycle represents how investment increases expenditures. The cycle B2 represents how a higher generation of energy increases the costs and therefore the expenses. Cycle B3 represents how a greater generation of energy increases revenues, increasing the tax base and consequently, leading to a higher tax payment decreasing the FCN.

RESULTS AND DISCUSSIONS

In the context of the relationship between the growth rate of electricity consumption, the flows and levels diagram is shown in Figure 4. An initial GDP of USD $ 292,080,155,633 is considered, value corresponding to the year 2015, with an increase 4% annual Likewise, the initial value of the 2015 energy consumption is considered, which was 66.17 TWh.

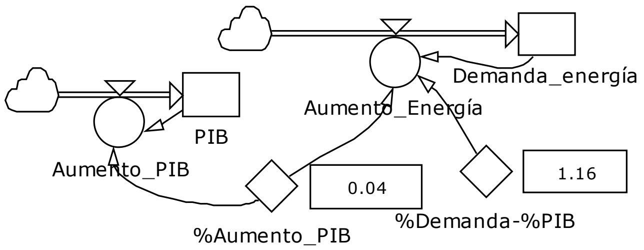

Figure 4. Flow chart of electricity demand corresponds to the GDP growth rate.

Where:

Aumento_PIB: GDP increase.

PIB: GDP.

Aumento_Energía: Increase energy.

Demanda_energía: Energy demand.

%Aumento_PIB: % GDP increase.

%Demanda-%PIB: % GDP Demand.

In Figure 5, it is observed that in a period of 20 years, consumption increases proportionally to GDP growth, a country with high incomes will consume more energy, due to the consumption of families and industry.

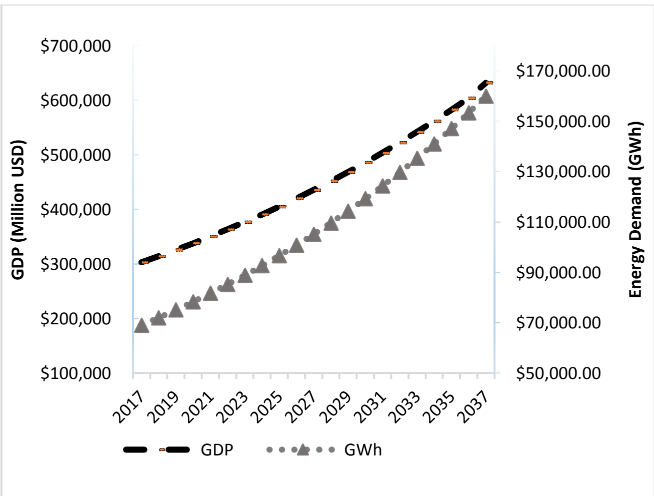

Figure 5. Relationship between GDP and energy consumption.

To analyze the effect of depreciation, two methods, accelerated depreciation and linear depreciation are considered (Figure 6). The Decree allows the accelerated depreciation of wind turbines. However, observing the effect on taxes does not show a significant difference when using either of the two methods (Figure 7).

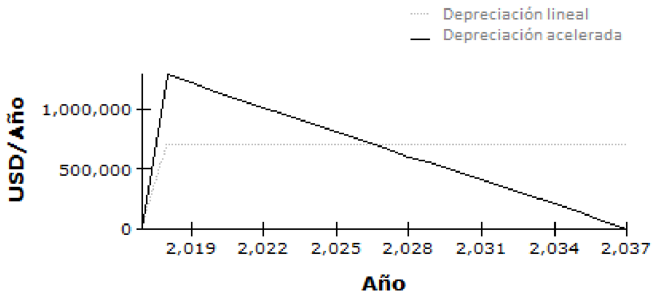

Figure 6. Annual depreciation.

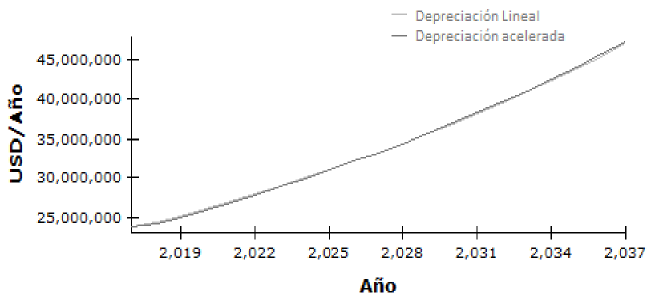

Figure 7. Taxes to be paid according to the depreciation method.

Where:

Depreciación Lineal: Linear Depreciation

Depreciación acelerada: Accelerated depreciation

Through Decree 2143 of 2015, a special deduction is applied to the income tax, which consists of the deduction of up to fifty percent (50%) of the value of the investments. In the project being evaluated, this deduction has a small effect on the Net Cash Flow (see Figure 8 and Figure 9).

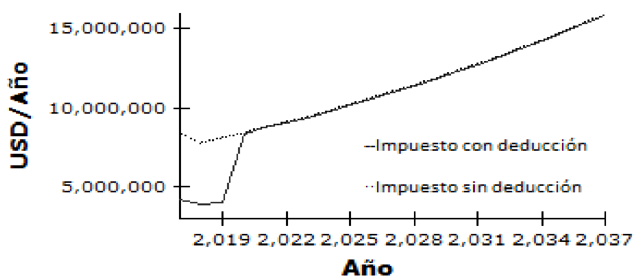

Figure 8. Effect of the special deduction income tax.

Where:

Impuesto con deducción: tax with deduction.

Impuesto sin deducción: tax without deduction.

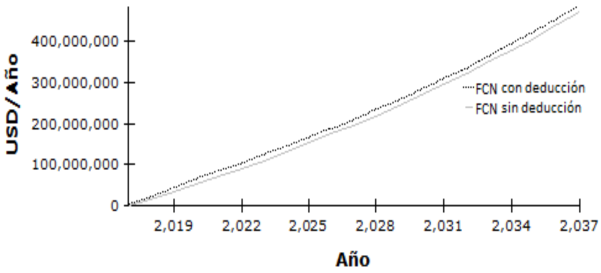

Figure 9. Effect on the Net Cash Flow of the special deduction income tax.

Where:

FCN con deducción: NPV with deduction.

FCN sin deducción: NPV without deduction.

Assuming a variable price similar to the behavior of the stock price, it is observed that in some cases when the price is below the Unitary Variable Cost (CV-U) (Figure 10), a payment must be made under the FIT scheme (Figure 11), which leads to a greater Net Cash Flow (Figure 12). The FIT scheme is a policy that is excluded in the current energy policy of the country.

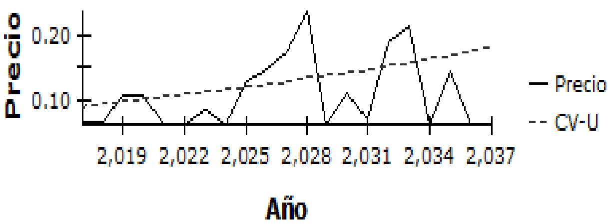

Figure 10 Average price of kWh of energy in USD.

Where:

Precio: Price

CV-U: unit variable cost.

Año: year.

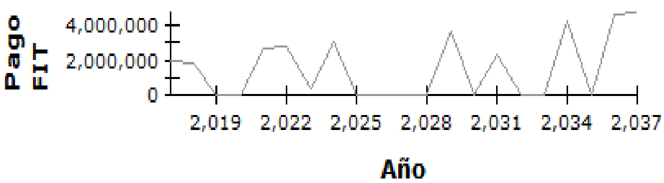

Figure 11 FIT payment value in different years.

Pago FIT: FIT payment.

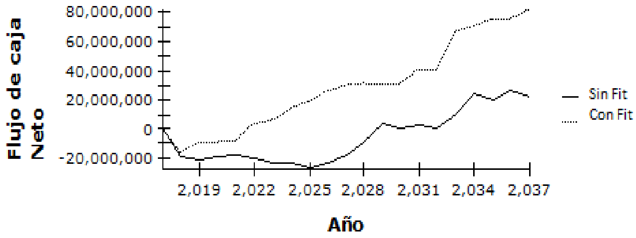

Figure 12. Effect of the FIT payment on the Net Cash Flow.

Sin Fit: without FIT.

Con Fit: with FIT.

Flujo de caja Neto: Net cash flow.

The FIT scheme, being an energy policy adopted by developed countries, is the only incentive that makes the FCN increase, on the contrary, current policies such as 50% tax deduction and accelerated depreciation do not encourage investment in these projects.

CONCLUSIONS

For investors of wind generation projects, the implementation of policies to encourage the use of unconventional energies in Colombia plays an important role because currently these projects do not have financial viability. On the other hand, encouraging these projects would increase Colombia's energy security by diversifying the energy basket, which is mainly composed of the hydrological source. However, the policies recently adopted in the country do not show a significant improvement in the investor's cash flows. Applying the tax incentives for accelerated depreciation and tax deduction of 50% of the investment in renewable energy projects does not increase the FCN. Consequently, the incentives of Law 1715 of 2014, regulated by Decree 2143 of 2015, do not promote the diversification of the energy basket in Colombia because they do not cause financial viability for electric power generation projects from non-conventional renewable sources. However, the FIT policy used in several countries in Europe and the United States would guarantee a price for these projects and, according to the simulation, the FCN increases, but this incentive is not included in this law.

REFERENCES

[1] Y. Olaya, S. Arango-Aramburo, and E. Larsen, "How capacity mechanisms drive technology choice in power generation: The case of Colombia," *Renew. Sustain. Energy Rev.*, vol. 56, pp. 563–571, 2016.

[2] H. Edsand, "Identifying barriers to wind energy diffusion in Colombia: A function analysis of the technological innovation system and the wider context," *Technol. Soc.*, vol. 49, pp. 1–15, 2017.

[3] J. Contreras and Y. E. Rodríguez, "Incentives for wind power investment in Colombia," *Renew. Energy*, vol. 87, pp. 279–288, 2016.

[4] A. A. Radomes and S. Arango-Aramburo, "Renewable energy technology diffusion: an analysis of photovoltaic-system support schemes in Medellín, Colombia," *J. Clean. Prod.*, vol. 92, pp. 152–161, 2015.

[5] L. JIMÉNEZ, N. ACEVEDO, and M. ROJAS, "Valoración de opción real en proyectos de generación de energía eólica en Colombia," *Espacios*, vol. 37, no. 26, p. 26, 2016.

[6] IEA, "Colombia, Key Indicator (1990-2013)," 2016. [Online]. Available: http://www.iea.org/%0Astatistics/statisticssearch/report/?country¼Colombia&product¼indicators. [Accessed: 05-Jun-2017].

[7] E. Larsen, I. Dyner, L. Bedoya, and C. Franco, "Lessons from deregulation in Colombia: successes, failures and the way ahead," *Energy Policy*, vol. 32, pp. 1767–1780, 2004.

[8] S. Arango-Aramburo, I. Dyner, and E. Larsen, "Lessons from deregulation: Understanding electricity markets in South America," *Util. Policy*, vol. 14, pp. 196–207, 2006.

[9] B. Ruiz and V. Rodríguez-Padilla, "Renewable energy sources in the Colombian energy policy, analysis and perspectives," *Energy Policy*, vol. 34, pp. 3684–3690, 2006.

[10] E. E. Gaona, C. L. Trujillo, and J. A. Guacaneme, "Rural microgrids and its potential application in Colombia," *Renew. Sustain. Energy Rev.*, vol. 51, pp. 125–137, 2015.

[11] A. Haghighat, S. Avella, A. Escandon, B. Naja, A. Shirazi, and F. Rinaldi, "Techno-economic feasibility of photovoltaic, wind, diesel and hybrid electrification systems for off-grid rural electrification in Colombia," *Renew. Energy*, vol. 97, pp. 293–305, 2016.

[12] M. Jimenez, C. Franco, and I. Dyner, "Diffusion of renewable energy technologies: The need for policy in Colombia," *Energy*, vol. 111, pp. 818–829, 2016.

[13] J. Lesser and X. Su, "Design of an economically efficient feed-in tariff structure for renewable energy development," *Energy Policy*, vol. 36, pp. 981–990, 2008.

[14] L. Franco Arbeláez and L. Franco Ceballos, "El valor en riesgo condicional CVaR como medida coherente de riesgo," *Rev. Ing. Univ. Medellín*, no. enero-junio, pp. 43–54, 2005.

[15] L. Franco and J. Murillo, "Loss distribution approach (LDA): metodología actuarial aplicada al riesgo operacional," *Ing. Univ. Medellín*, vol. 7, no. 13, pp. 143–156, 2008.

[16] F. Venegas-Martínez, G. Agudelo Torres, L. Franco Arbeláez, and L. Franco Ceballos, "Precio del dólar estadounidense en el mundo Procesos de Itô económicamente ponderados en un análisis espacial," *Econ. y Soc.*, vol. 34, no. 20, pp. 83–105, 2016.

[17] M. Ringel, "Fostering the use of renewable energies in the European Union: the race between feed-in tariffs and green certificates.," *Renew. Energy*, vol. 31, pp. 1–17, 2006.

[18] L. Dusonchet and E. Telaretti, "Economic analysis of different supporting policies for the production of electrical energy by solar photovoltaics in western European Union countries," *Energy Policy*, vol. 38, pp. 3297–3308, 2010.

[19] R. Rüther and R. Zilles, "Making the case for grid-connected photovoltaics in Brazil," *Energy Policy*, vol. 39, pp. 1027–1030, 2011.

[20] E. Alishahi, M. P. Moghaddam, and M. . Sheikh-El-Eslami, "A system dynamics approach for investigating impacts of incentive mechanisms on wind power investment," *Renew. Energy*, vol. 37, no. 1, pp. 310–317, 2012.

[21] H. H. Goh, S. W. Lee, Q. S. Chua, K. C. Goh, B. C. Kok, and K. T. K. Teo, "Renewable energy project: Project management, challenges and risk," *Renew. Sustain. Energy Rev.*, vol. 38, pp. 917–932, Oct. 2014.

[22] M. S. Shahmohammadi, R. Mohd, S. Keyhanian, and H. S. G, "A decision support system for evaluating effects of Feed-in Tariff mechanism: Dynamic modeling of Malaysia's electricity generation mix," *Appl. Energy*, vol. 146, pp. 217–229, 2015.

[23] M. Radzicki and R. Taylor, "Origin of system dynamics: Jay W. Forrester and the history of system dynamics," *US Dep. Energy's Introd. to Syst.*, 2008.

[24] J. D. Sterman, *Business dynamics: systems thinking and modeling for a complex world*, no. HD30. 2 S7835 2000. 2000.

[25] F. Teufel, M. Miller, M. Genoese, and W. Fichtner, *Review of System Dynamics models for electricity market simulations*. KIT Scientific Publishing, 2013.

[26] S. Ahmad, R. Mat, F. Muhammad-sukki, A. Bakar, and R. Abdul, "Application of system dynamics approach in electricity sector modelling: A review," *Renew. Sustain. Energy Rev.*, vol. 56, pp. 29–37, 2016.

[27] N. Acevedo Prins, L. Jiménez Gómez, and N. Castaño, "Relación de causalidad de variables macroeconómicas locales y globales sobre el índice COLCAP," *Espacios*, vol. 38, no. 21, p. 38, 2017.

[28] R. Mahadevan and J. Asafu-Adjaye, “Energy consumption, economic growth and prices: A reassessment using panel VECM for developed and developing countries,” *Energy Policy*, vol. 35, no. 4, pp. 2481–2490, 2007.

[29] L. M. Jiménez and N. Acevedo, “Índice para la medición de la competitividad en colombia,” *Rev. CEA*, vol. 1, no. 2, pp. 109–121, 2015.