Abstract
This paper evaluates the impact of the Feed-in-Tariff mechanism on the profitability of a wind farm in Colombia using systems dynamics. The Feed-in-Tariff mechanism is a policy used to encourage the investment of renewable technologies in the generation of electric power. This mechanism offers a long-term contract for the sale of energy. The development of this type of energy under the policy to be evaluated mainly affects the profitability of the wind farms. The results show that the subsidy under this mechanism makes the wind farms profitable in Colombia, but without this policy they are not.

Keywords: wind farm, systems dynamics, Feed-in-Tariff, renewable energy.

INTRODUCTION
Renewable energy technologies for the generation of electricity have a significant positive impact on the environment and society. Renewable energy has been applied in a number of areas, including power generation, transportation fuel, and rural household energy supply. Energy policies focus on how to improve the diffusion and adoption of renewable energies. However, the diffusion and adoption of innovations in renewable energies, such as solar energy, wind energy and biomass, is a complex process that faces a series of barriers, restrictions and changes in policies [1].

Many countries look for renewable energy sources and promote effective policies to reduce greenhouse gases and carbon emissions through the use of solar energy products and energy saving applications in homes. However, renewable energies can only be adopted successfully when they are promoted with incentives [2]. Financial support mechanisms gain importance in improving the development of renewable energy. Conventional energy sources could be replaced with renewable energy technologies to mitigate the environmental damage caused by power generation technology [3].

To encourage investment in renewable energies, there are different mechanisms, among them the Feed in Tariff -FiT, where the State subsidizes the price of renewable energy, taking into account the long-term marginal costs of renewable energy generation. This subsidy is a higher price, which directly determines the prices of renewable energy in the network. The FiT scheme increases the enthusiasm of investors to develop new renewable energy projects since, renewable energy can compete in the market at a lower price in the network and ensures that investors recover the investment of their renewable energy projects. In addition, profits in the industry are a major factor affecting investment decisions [4].

Research on renewable energy support schemes shows that stable long-term FiT systems based on paying a fixed price or a price premium to renewable energy generators are more effective than most other renewable energy schemes. Support used. In addition, by providing long-term stability of energy prices in the renewable energy market, private investors have the incentive to make long-term investments, such as the construction of new energy plants that use renewable energy or finance research projects. and development [5].

In Colombia, the conventional renewable energy source is hydroelectric with 80.61% of electricity generation, followed by thermal sources by 19.25% and other sources with a proportion of 4.53%. Within non-conventional renewable sources there is only one wind farm with 0.14% of capacity. The foregoing demonstrates the low interest to implement non-conventional renewable sources to generate electricity [6], [7]. Currently, Colombia does not have the FiT scheme, the most recent policy was approved in 2014 with Law 1715, which aims to promote energy generation projects from non-conventional renewable sources; However, this policy is not enough to encourage projects of this nature, so it is important for the energy policy of Colombia, the analysis of the FiT scheme in
renewable energy projects; in this case, the System Dynamics method is useful to address the problem, because it has a non-linear behavior.

The method of modeling and simulation of Systems Dynamics, was developed for the first time by Professor J.W. Forrester in 1950 to analyze complex behaviors in the social sciences by means of computer simulations [8]. Prior to System Dynamics, decisions made to address a problem often yielded unexpected results; hence the need to develop a new methodology [9]. The System Dynamics approach is used to describe and model the activities of complex systems over time. System Dynamics uses the various control factors of the system and observes how the system reacts and behaves to trends. Therefore, System Dynamics can be used to help decision-making when the target systems are complex and dynamic [2].

Based on the foregoing, the objective of this study is to determine the effect by means of systems dynamics, of the introduction of a FiT-type energy policy on electricity generation projects from a wind source in Colombia. In this way, the article presents first, a conceptualization of the FiT mechanism as an incentive policy, then a definition of the methodology used in the study and, finally, the results are presented with their respective conclusions.

**FiT**

The FiT (Feed in Tariff) mechanism is a policy used as a support mechanism to accelerate investment in renewable energy (RE) technologies. A FiT offers a long-term purchase agreement for the sale of ER electricity. Technologies such as wind energy have a lower price than photovoltaic solar energy due to its higher cost. However, FiT policies could be considered a measure of control regulation due to the ability of governments to direct the market in accordance with the rates defined in the contracts. An expectation of lower rates in the future could cause an incentive in the market to receive the existing FiT rate. Rates can be used as a fixed rate (higher than the market price) or as a surcharge that is added to the current margin [10]. The adjustment of the rates must be high enough to recover the cost of the investment within a reasonable period but small enough to avoid imposing a heavy financial burden on the States. Tax incentives must be provided for renewable energies, as long as the cost of generating from renewable resources is greater than the cost of generating power from conventional sources [11].

There are some advantages of the FiT mechanism: to provide a higher price to the generators to stimulate a greater supply of ER to the network; guarantee a shorter amortization period for investments that encourage small and medium enterprises; avoid the monopoly of the market of big companies eliminating the barriers of entry to the market for small investors; be a flexible system that can be designed for different ERs, market structures, locations and price adjustments, when necessary after a fixed period; have an assured performance for years for investors that will reduce risks for projects. However, rates are not always easy to determine at the beginning, since it is not always possible to discover the exact costs [3].

Ringel [12] examined the most common types of support systems in the European Union, including FiT and green certificates, in order to assess the advantages and disadvantages in terms of effectiveness and efficiency. Based on the study, both mechanisms contribute to increasing the share of energy generation through renewable energy. However, many member states tried to switch to an admission system for green certificates while experiencing both systems. The results show that the FiT mechanism is successful in promoting the use of renewable energy sources. The author concludes that FiT is an effective instrument to promote the deployment of renewable energies in Europe [10].

For its part, the government of the United Kingdom introduced a mechanism of support for FiT in 2010 to promote the investment of small-scale renewable energy and low-carbon energy generation technologies. This policy covers five technologies: solar photovoltaic, wind, hydroelectric, anaerobic digestion and micro-cogeneration plants [10].

In Portugal, FiT is the main policy used to improve the energy generated by renewable energy sources. Abolhosseini and Heshmati [10] simulated a model to evaluate the economic and environmental impacts of a regulated tariff policy in Portugal. They used a model to analyze the interaction between energy, economic and environmental issues in relation to energy policies. The results showed that the FiT policy provides an efficient and profitable instrument to promote renewable energy sources for electricity generation. In addition, the cost of economic adjustment was low, and the deployment of renewable energy led to significant reductions in carbon emissions.

**MATERIALS AND METHODS**

System Dynamics is a systems simulation methodology based on feedback and information delays, for the modeling and simulation analysis of complex problems centered on the analysis and design of policies. The methodology consists of flow diagrams and levels and causal diagrams. The latter represent the causal hypotheses of a system and the flow diagrams and levels represent the flow structure of the system. Mathematically $S(t)$ represents the level at time $t$, the flow or inflows and the flow or outflows denote the input and output values at any time $S$ (see equation 1) [1].

$$S(t) = \int_{t_0}^{t} (\text{Input flows} - \text{Output flows})dt + S(t_0) \quad [1]$$

On the other hand, the flow variables describe the exchange rates. Thus the levels change according to the net flows. In turn, the net flows are equivalent to the rate of variation of the levels according to equation 2 [1].

$$\frac{d}{dt}(S) = \text{Input flows}_t - \text{Output flows}_t \quad [2]$$

System Dynamics is applied in a series of practical problems, including corporate planning, policy design, policy evaluation, supply chain management, public management, economic behavior, among other issues [1, 13]. According to the review by Ahmad [14], the evaluation of policies and the expansion of
the generation capacity are the two most modeled themes in Systems Dynamics and also suggest a future direction for researchers who use Systems Dynamics in the energy sector, these include the development of models focused on the elimination of fossil fuel technology in general, and nuclear technology in particular.

System Dynamics is a simulation methodology for the understanding, visualization and analysis of complex dynamic feedback systems. It can be used to understand the behavior of complex systems over time and to develop the simulation model of a complex system. In general, it involves aggregate levels of detail and deals with internal feedback loops and delays that affect the behavior of the entire system. What makes the use of System Dynamics different from other approaches to study complex systems is the use of feedback and stock and flow circuits. These elements help to describe how even seemingly simple systems show disconcerting non-linearity [11].

System Dynamics is a simulation methodology for the analysis of dynamic complexities in socioeconomic and biophysical systems that have characteristics such as delays, non-linearities and feedback [9]. Based on the principle of systemic thinking and the theory of control systems, System Dynamics helps to understand the behavior over time of complex systems. The development of renewable energy generation projects under FiT schemes represents a dynamic system that contains a range of factors such as investment, costs, installed capacity, prices, taxes, depreciation, which affect and restrict the behavior of the system. The flow diagrams and levels that represent these interactions are shown in Figure 1.

To study the impact of incentives such as the FiT in the renewable energy market, specifically wind generation, this study used a period of 20 years, with step size 1 year. A generation wind farm with 3 turbines was simulated, with a swept area of 6,362 m² each, a wind speed of 9.5 m / s, an air density of 1.15 kg / m³ and losses of 0, 81.

**Figure 1.** Diagram of flows and levels of wind power generation.

Where:
- Velocidad del viento: wind speed
- Densidad del aire: Density of the air
- Densidad de potencia: Power density
- Pérdidas: Losses
- Betz: Betz
- Energía aprovechada x hora: Energy used per hour

Área de barrido: Sweeping area
- Horas x año: Hours per year
- Energía generada x año: Energy generated per year
- Número de turbinas: Number of turbines

The construction of free cash flow was based on the annual average of the historical price of the last 20 years of the Colombian electricity market, that is, prices are replicated (Figure 2).
For the costs, a variable unit cost of generation of 0.05 USD / kWh and an annual increase of 3% per year is assumed. Fixed assets are depreciated by the accelerated depreciation method and the payment of taxes is in accordance with the provisions of Decree 2143 of 2015.

**Figure 2.** Prices of electric power generation in the country.

**Figure 3.** Net cash flow of a wind generation Project

Where:
- Energía generada x año: Energy generated per year
- Subsidio: Subsidy
- Precio: Price
- PrecioYFIT: Price with FiT
- Ingresos: Income
- Inflación: Inflation
- Impuestos: Taxes
- FCN: Net cash flow
- Inversión año 0: Investment year 0
- Inversión0: Investment year 0
- Costos: Costs
The development of this type of energy under FiT is affected mainly by the profits of the investors and by the subsidy under different schemes that increase them.

RESULTS AND DISCUSSIONS

The simulation of the wind power generation project under FiT was carried out under 3 scenarios. Scenario A is a situation where the subsidy is around 30% of marginal generation costs, while scenario B and C are comparative scenarios with subsidy rates of 40% and 50%, respectively.

Scenario A: FiT is 0.065 USD / kWh
Scenario B: FiT is 0.070 USD / kWh
Scenario C: FiT is 0.075 USD / kWh

The results of the simulation of the wind generation project under the FiT scheme are shown in figure 4.

When analyzing the accumulated value of subsidies during the useful life of the project under the different FiT schemes, scenarios A, B and C, these are 102, 110 and 118 million USD, respectively; representing an increase of 16% from scenario A to C. On the other hand, when reviewing the Net Cash Flow of the Project, an important improvement is observed in the FCN when subsidies are granted under the FiT scheme (figure 5), going from -24 USD 6 to 19.7 million in scenario A. For scenarios B and C, the Net cash flow is USD 27.3 and USD 35.6 million, respectively; that is, an increase of 49% when moving from scenario A to C.

It is also observed that the taxes to be collected, taking into account the provisions of Decree 2143 of 2015, increase with respect to the scenario without subsidies under the FiT scheme. When analyzing the increase of the collection when going from scenario A to C, it has an increase of 66%.

The results show that the subsidy by means of the FiT scheme, improve in a significant percentage the cash flow of a wind power generation project in Colombia. However, the payment of subsidies implies a fiscal burden for the country, when the 3 scenarios are analyzed, the value of the FiT is significant in the
contributions that the country must make to promote renewable energies, particularly wind energy.

CONCLUSIONS

Currently Colombia does not have a FiT policy to encourage the generation of electricity from renewable sources, the most recent policy adopted with Law 1715 of 2014 aims to encourage renewable sources, but does not include the FiT scheme. This document by means of the System Dynamics evaluates the FiT scheme on a wind farm. The results of the simulation show that the projects of generation of electrical energy from wind power will present losses generating the rejection of the investor. The above in the scenario without incentives for these projects; however, under the assumptions of a FiT type incentive, the simulation shows that a positive Net Cash Flow would be obtained. For the incentives, three scenarios were considered, FiT of 0.065 USD / kWh, FiT of 0.070 USD / kWh and FiT of 0.075 USD / kWh. Comparing the last scenario with the first one, an increase of 49% is obtained, evidencing the sensitivity that exists with respect to the incentive. On the other hand, implementing the FiT scheme also generates an increase in tax collection, with the simulation an increase of 66% is obtained.

REFERENCES