

## **RENEWABLE ENERGY PENETRATION INTO ELECTRICITY MARKETS AND ITS EFFECTS ON ENERGY SECURITY A SYSTEM DYNAMICS APPROACH**

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The paper will be written in English and the final work at the conference will be presented in Spanish.

### **Overview**

Preventing further climate change due to high greenhouse gases emissions has demanded higher control and understanding of the problematic from governments and institutions (IEA/IRENA, 2016). In particular, the energy sector is key to stand against such emissions, especially the electrical power industry. The transition from fossil fuel to renewable energies, mainly wind and solar, is being encouraged all across the globe as sources of green electricity generation, supported by the agreements achieved in the Kyoto protocols and, recently, in Paris (UN/FCCC, 2015; OECD/IEA, 2016). However, the inclusion of renewable resources in the electricity spot markets entails great challenges and uncertainty regarding the price stability and energy supply, thus affecting the energy security. The investment costs in renewable resources technology; current prices of fossil fuel –oil, gas, and coal; electricity dispatch in spot markets; supportive government policies; and intermittence associated to climate variations make highly complex the decision-making process on investment in new installed capacity and generation of electricity with renewable resources.

One way to address the impact of such resources in electricity spot markets is using System Dynamics models; which, based on feedback, cycles and delays allow for better understanding of the dynamics of spot markets when it is necessary to evaluate several alternatives in different scenarios. In this paper, we present a dynamic hypothesis associated to the electricity spot systems - represented by the causality among system variables. Our results pave the way towards better decision-making by authorities in order to solve latencies associated to the system.

This article is structured as follows: we first present an introduction followed by the theoretical fundamentals on electricity spot markets. Furthermore, in the third section, we develop the System Dynamics methodology and present the conceptual model, the mathematical formulation and the results of the base-case and scenarios analyses in the context. In the fourth section we discuss the results to finally conclude.

### **Methodology**

In this paper, we study the impact renewables resources using System Dynamics models to simulate the electricity spot market behaviour in multiple scenarios that can, in turn, facilitate future decisions

within the energy sector. To do so, we use a model based on causality between system variables such as electricity demand, supply and price, expected profitability, and installed capacity; feedback; cycles; and delays, and using data from IEA (2016), and the methods from Sterman (2000); Stoft (2002).

### **Expected results**

The renewable sources of energy are being promoted to reduce climate change. However, it is necessary to understand the effects of such sources on price and energy security in electricity spot markets. Our numerical approach suggests that renewable energy inclusion in the electricity spot markets generate positive effects in the energy supply curve, thus eliminating firms with high production costs. On the other hand, the inclusion of this energy produces high variations in the electricity price level due to the intermittence in the electricity generation; thus impacting the profitability of conventional firms, installed capacity, and energy security. Furthermore, we analysed different scenarios to understand the behaviour of electricity spot markets under current conditions and future participation of renewable energies in the energy matrix. Results suggest it is necessary to diversify the matrix, to permit the inclusion of renewable sources into electricity market, given that there is a serious problem with revenues and energy security in one day in a day-ahead market.

### **Conclusions**

In the current context, the electricity spot markets structure requires significant changes to include a balance among cost of electricity, environmental impact and negative externalities. A larger inclusion of electricity supply from renewable resources emerges as the path to follow. In this direction, different energy generation sources can compete in the electricity spot markets under real benefits and cost production. A stable energy price based on a stable energy supply would not affect new investments in installed capacity. However, it is required that the investment cost in new installed capacity using renewable resources continues dropping, thus being more profitable than the conventional technologies (especially given the current fossil fuel price level) and allowing to truly stand against greenhouse gases emissions (Lund , Lindgren, Mikkila, & Salpakari, 2015).

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