Would renewable damp oscillations in power markets? An experimental analysis

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Extended abstract:

The article aims to develop a micro-world for learning and understanding the dynamics of diffusion of non-conventional renewable electricity generation technologies in Colombia by implementing different promotion policies. A system dynamics model was used to model the behavior of the available potential and the installed capacity of different electricity generation technologies in Colombia. With the diffusion model a game platform (microworld) was developed in which participants can implement different policies according to their needs and gain feedback.

A diffusion model was developed using systems dynamics to represent the new installed capacity of renewable energies, for different generation technologies (Solar photovoltaic, wind, Biomass and Hydraulic), this model was an adaptation of Arias-Gaviria, Carvajal-Quintero, & Arango-Aramburo (2019). The model calculates the expected profitability for the new installed capacity as a function of the electricity exchange price and the levelized energy costs (LCOE), taking into account the learning rate for the investment and operational costs.

Subsequently, the virtual environment for the learning-oriented microworld was designed following the methodology proposed by Valencia O, Víctor Riascos M, & Niño Z (2011), in it we defined characteristics such as the role of the player, as the regulator of the electricity market. In addition the player decisions were defined as the incentives that to implement for the generation technologies and in what period of time the player wishes to implement them. Also we define that the player can choose between several generation scenarios, in terms prices scenario, costs, plant capacity factors and learning rate. In the design of the virtual environment, we developed the technical architecture of the microworld, which is carried out through the Stella Architect (2.0) (Isee Systems, 2020).

The results of different microworld pilot tests are analyzed to evaluate the feedback on the diffusion of non-conventional generation technologies obtained by the tested subjects, and the learning effect that it has in them, using a pre and post test to verify the adquired knowledge by the game. Figure 1a presents the simulation results of the system dynamics model for the behavior of the available potential and the installed solar photovoltaic (PV) capacity. Figure 1b shows the levelizing costs of solar PV energy and the electricity

Figure 3 shows the results obtained on micro-world, after making decisions about high aggregate taxes and high expected prices. It can be seen that the potential available in the 2030 horizon is not achieved, since the expected profitability for the new installed capacity is not very high.

price of the Colombian market. The simulated scenario has as reference the operation and investment costs for a generation plant in Cauca Valley in Colombia. As it is shown the available solar potential will ran out in 2028 approximately.

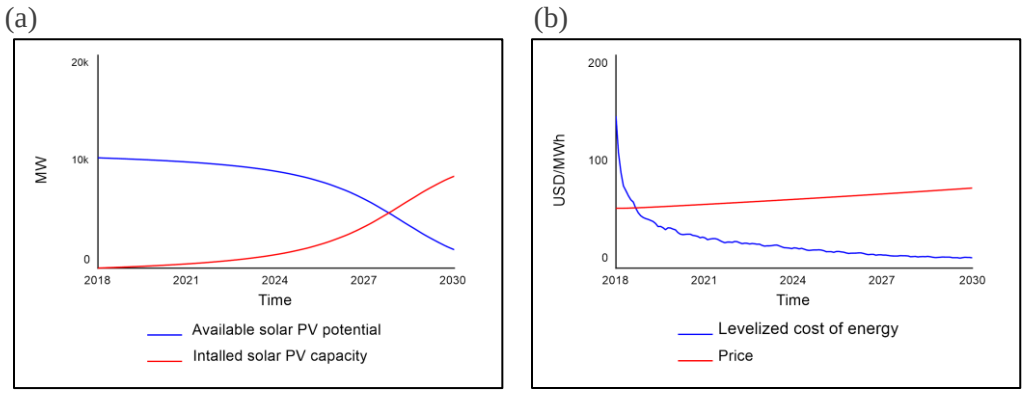

Figure 1: (a) Solar PV Diffusion (b) solar PV LCOE and price

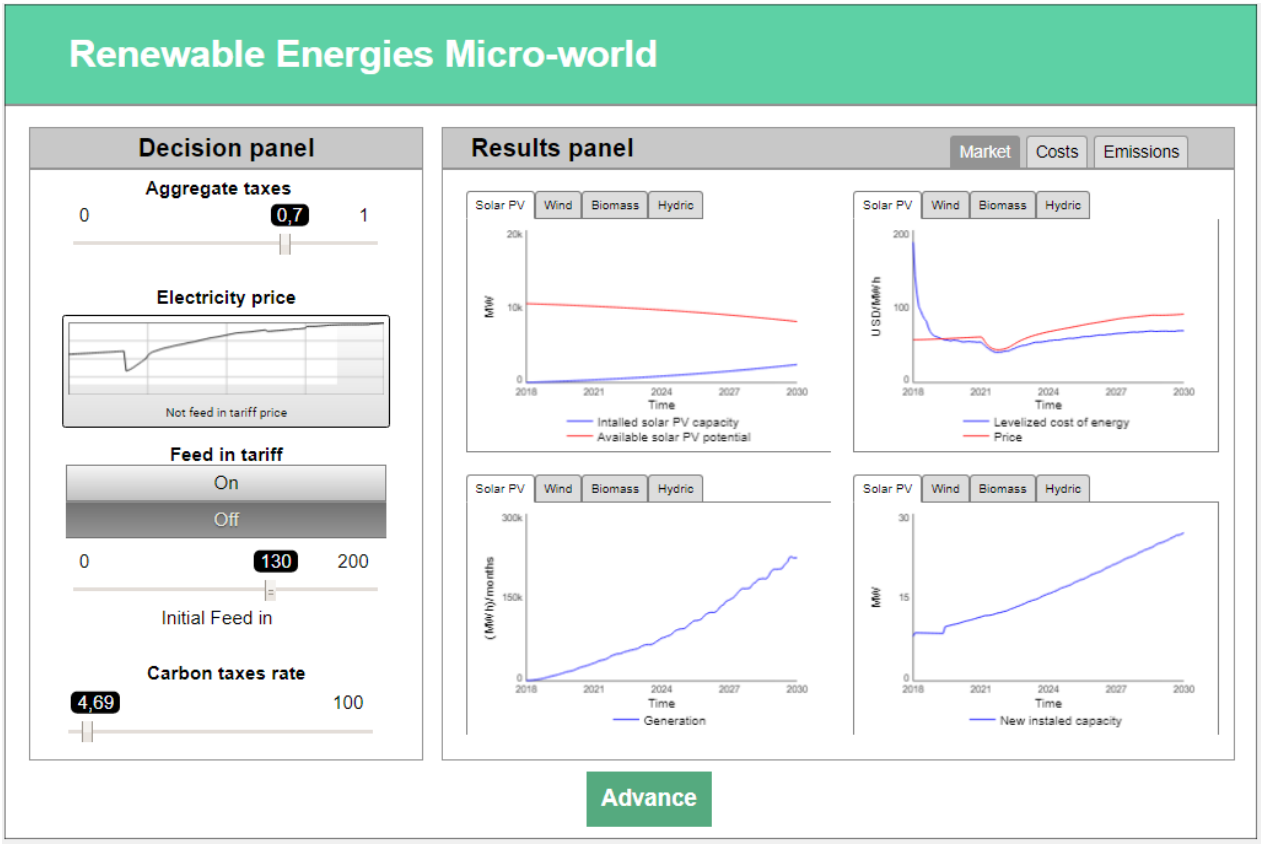

Figure 1: High prices and aggregated taxes scenario microworld screenshot.

The creation of different scenarios and policies in the micro-world has very wide limits, so users can recreate their needs and interact with the policies they want. The micro-world offers the possibility of observing results and having feedback regarding the Market, generation costs, emissions and the contribution of each technology to the total installed capacity of the country and the changes that are generated in the 2030 horizon when different incentives and policies are implemented.

Given the current situation of energy transition in Colombia to renewable energies, it is important to have tools such as micro-worlds, which facilitate the understanding of the energy system since it has multiple interactions and non-lieal behaviors, which make it a complex system.

In addition to the energy transition, the high rate of implementation of policies and regulations that generate changes in the Energy System make it difficult to understand it´s bahevior, the micro-world is expected to serve as a tool for understanding the dynamics of the electricity system, and also experts as users of electricity can understand the changes in the system.

The preliminary results allow us to conclude that micro-worlds can contribute to making better regulation decisions in the electricity market in Colombia, avoiding the implementation of policies that generate conflicts in the system, implementation delays and providing a holistic view of the system.

References:

Ackermann, E. (2001). Piaget's Constructivism, Papert's Constructionism: What's the difference? 5. https://doi.org/10.1111/j.1526-4610.2005.t01-1-05013.x

Arias-Gaviria, J., Carvajal-Quintero, S. X., & Arango-Aramburo, S. (2019). Understanding dynamics and policy for renewable energy diffusion in Colombia. Renewable Energy, 139, 1111–1119. https://doi.org/10.1016/j.renene.2019.02.138

Barrera, X., Gómez, R., Suárez, R., & García, C. (2015). El ABC de los compromisos de Colombia para la COP21 (WWF-Colombia, Ed.). Bogotá D.C., Colombia.

Bass, F. M. (1969). A New Product Growth for Model Consumer Durables. Management Science, 15(5), 215–227. Retrieved from http://www.jstor.org/stable/2628128

Boring, R., Kelly, D., Smidys, C., Mosleh, A., & Dyre, B. (2012). Microworlds, Simulators and Simulation : Framework for a Benchmark of Human Reliability Data Sources. 11.

Cárdenas Ardila, L. M. (2015). Plataforma para la evaluación de políticas de mitigación de gases efecto invernadero en el sector eléctrico. Universidad Nacional de Colombia, 245. Retrieved from http://www.bdigital.unal.edu.co/50866/

Climate Interactive, Ventana Systems, Todd Fincannon, UML Climate Change Initiative, & Sterman, J. (2019). En-ROADS. Retrieved July 22, 2019, from Climate Interactive Tools for a thriving future website: https://www.climateinteractive.org/tools/en-roads/

Congreso de la República de Colombia. Ley 1715 de 2014. , (2014).

CREG. SUBASTA DEL CARGO POR CONFIABILIDAD 2022-2023. , (2018).

Dyner, I., Larsen, E., & Franco, C. J. (2008). Games for electricity traders: Understanding risk in a deregulated industry. Energy Policy, 37(2), 465–471.

Hardin, G. (1968). The tragedy of the commons. Science, 162(3859), 1243–1248. https://doi.org/10.1126/science.162.3859.1243

IDEAM, PNUD, MADS, DNP, & Cancillería. (2016). Inventario Nacional y Departamental de Gases de Efecto Invernadero - Colombia (IDEAM, PNUD, MADS, DNP, CANCILLERÍA, & FMAM, Eds.). Bogotá D.C., Colombia.

IRENA. (2018). Hydropower. Retrieved from https://www.irena.org/hydropower

King, A. (1993). From Sage on the Stage to Guide on the Side. College Teaching, 41(1), 30–35. https://doi.org/10.5771/2196-7261-2016-4-288

MIT, Meadows, D., Sterman, J., & King, A. (2020). Fishbanks: una simulación de gestión de recursos renovables. Retrieved from LearningEdge A free learning resourse for management educators and students website: https://mitsloan.mit.edu/LearningEdge/simulations/fishbanks-spanish/Pages/default.aspx

MIT, Ventana systems, UML Climate, Change Initiative, & Todd Fincannon. (2019). C-ROADS. Retrieved from Climate interactive website: https://www.climateinteractive.org/tools/c-roads/

Morecroft, J. (2007). Strategic Modelling and Business Dynamics: A Feedback Systems Approach (John Wiley & Sons Ltd, Ed.). Chichester.

Papert, S. (1980). Mindstorms Children, computers, and Powerful Ideas (1st ed.; P. Basic Books, Inc., Ed.). New York: Library of Congress Cataloging .

Papert, S. (1986). Constructionism: A new opportunity for elementary science education (Massachuse). Boston.

Papert, S., & Harel, I. (1991). Situating Constructionism. In Constructionism (Ablex Publ).

Rieber, L. (2012). Multimedia Learning in Games, Simulations, and Microworlds. In R. Mayer (Ed.), The Cambridge Handbook of Multimedia Learning (pp. 549–568). https://doi.org/10.1017/cbo9780511816819.034

Sterman, J. (1992). Teaching Takes Off Flight Simulators for Management Education "The Beer Game." OR/MS Today, 40–44. Retrieved from papers3://publication/uuid/CBBF86A3-8229-422C-8AAD-B47F45F4CE88

Sterman, J. (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World (The McGraw-Hill Companies-Inc., Ed.). Massachusetts.

Sterman, J. (2014). Interactive web-based simulations for strategy and sustainability: The MIT Sloan LearningEdge management flight simulators, Part I. System Dynamics Review, 30(1–2), 89–121. https://doi.org/10.1002/sdr

Sterman, J., Fiddaman, T., Franck, T., Johnston, E., Jones, A., McCauley, S., … Siegel, L. (2019). World Energy: A Climate and Energy Policy Negotiation Game. Retrieved July 22, 2019, from MIT Management Sloan School Learning Edge A free learning resource for management educartors and students website: https://mitsloan.mit.edu/LearningEdge/simulations/world energy-spanish/Pages/default.aspx

UPME. (2015). Integración de las energías renovables no convencionales en Colombia. In La Imprenta Editores S.A. (Ed.), Ministerio de Minas y Energía. https://doi.org/10.1021/ja304618v

UPME. Resolución No. 000642 de 2019. , (2019).

Valencia O, R. F., Víctor Riascos M, E. A., & Niño Z, M. A. (2011). Método para la creación de micromundos inmersivos. Revista Avances En Sistemas e Informática, 8(2), 41–50. Retrieved from http://www.bdigital.unal.edu.co/28837/1/26724-93650-1-PB.pdf