UNDERSTANDING GLOBAL ENERGY TRANSITIONS THROUGH AGENT-BASED MODELLING OF INVESTOR BEHAVIOUR

[O. Kraan, Institute of Environmental Science Leiden University, +31612306645, o.d.e.kraan@cml.leidenuniv.nl]
[I. Nikolic, Faculty of Technology, Policy and Management Technical University Delft, +31152781135, i.nikolic@tudelft.nl]

Overview

With rapidly falling prices of renewable energy technology and substantial institutional consensus on climate change created at the Conference of Parties in Paris in December 2015, the energy transition has gained momentum in the last couple of years. This increase in pace of this transition has highlighted the need for quantified, plausible, internally consistent narratives in order to understand and manage an increase in pace of this transition.

The electricity sector is aimed to take a leading role in the decarbonisation of the energy sector as it is crucial for a low-carbon energy system in industrialised countries. The energy transition will therefore have a large influence on the complex electricity system as it may entail a transition from the centralised fossil fuel based energy system we have today to an much more heterogeneous and potentially distributed electricity system based on intermittent renewable energy resources.

The limited storability and the need for instantaneous balancing of electricity supply and demand, combined with the intermittent nature of the main renewable electricity sources (such as sun and wind) increase the complexity of the electricity system in the energy transition. The liberalisation of the electricity system in many countries led to entry of many new actors, further increasing the complexity of the system. Next to policy makers and households, investors (more specifically, investors in power generation) have a key role in this transition. The traditional perspective on investor behaviour assumes perfectly informed and rational behaviour. While there is no doubt that neoclassical models that depend on economic rational behaviour have provided key insights for business decisions and policy makers [1], literature however suggests that these assumptions do not hold, and these actors exhibit bounded rationality in their decision making behaviour. Modelling the energy system while encompassing properties of complex adaptive systems, such as adaptation, heterogeneity, bounded rationality, co-evolution, path dependence and emergence requires therefore different tools.

Agent-based modelling can be used to simulate complex adaptive systems (CAS) such as the electricity system and is well suited to model adaptive heterogeneous actors (agents) such as investors that can be part of emergent system behaviour. Modelling the energy transition this way can therefore complement the knowledge about the energy transition because it allows us to model the complex non-linear properties of the electricity system.

Whereas previous studies (for example [2]) used agent-based models in very descriptive model conceptualisations, our approach has focused of KIS*S* (keep it simple) approach and followed therefore a more conceptual approach. It has been aimed at enriching our understanding of the fundamental processes that underline the energy transition by including the main characteristics of intermittent renewables and focussed more specifically at the question how we can create quantified, plausible, internal consistent narratives of an increase in pace of the energy transition by including bounded rationality of power generation investors.

Methods

ABM is used to simulate complex adaptive systems (CAS) and is well suited to model adaptive heterogeneous agents that, based on their decisions, can be part of emergent system behaviour. This modelling study used the 10-step framework as proposed by Van Dam et al. [3] for the development of a model and is written in the software environment of Netlogo. Latin hypercube sampling experiments have been conducted and the software package R has been used for analysis.

The model is an abstract and conceptual representation of the electricity market and consists of investors that make investment decisions in power generation assets with particular resources (gas, coal or a renewable resource) based on Net Present Value (NPV) calculations these investors make. This NPV calculations are based on heterogeneous discount rates and the investor's expectation about how these assets will perform in the future. These expectations are based on the performance of the assets in the last period. The performance of the assets, the profit they make, is dependent on the existing asset stock, the demand, the Short Run Marginal Cost of all assets, their efficiency, the coal and gas price and the carbon price which are all reflected in the day by day calculated merit order. The SRMC of green power generation are assumed to be zero, OPEX costs are neglected. The incentive to invest in the marginal power generation asset has been ensured by introducing a scarcity rent which can be observed in reality. The interaction between investors runs via the electricity market and its associated merit order.

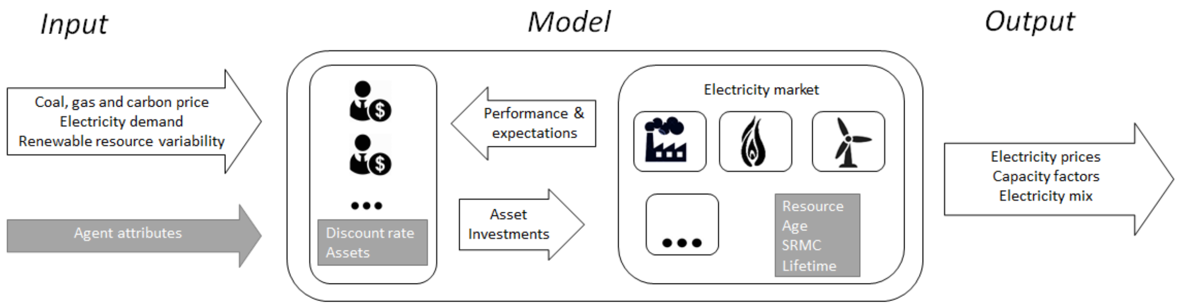

Figure 1. Model description

Results

The conceptualisation phase of the model has resulted in a model that has been and validated with recording and tracking behaviour, single-agent testing and multi-agent testing. Latin hypercube experiments have been used to narrow the multi-dimensional parameter space down to identify spaces that are likely to hold meaningful patterns. The first initial experiments show that a high carbon price will make investors more likely to invest in renewable energy technology. In our model increasing deployment of renewable energy assets decreases the electricity price making higher scarcity rents necessary to ensure investment in power generation to match supply with demand. Further experiments and analysis especially with regards to the influence of the variability of renewable energy resource in which we expect to distinguish more complex patterns and develop meaningful narratives are forthcoming.

Conclusions

In this research paper we argue that models that try to simulate the energy transition from the complex adaptive system perspective can contribute to the development of plausible internal consistent, quantified narratives of the increase of pace of the energy transition from an investor's point of view. A conceptual model has been implemented that focused on bounded rational behaviour of investors in the transition to an energy system that relies on intermittent resources Although the preliminary results of our model can be discussed in view of the many uncertainties, simplifications and assumptions, with the model we are able to simulate fundamental aspects of the energy transition which are present in the real world.

Current experiments show that this approach has large potential. Besides further experimenting with the current model, next steps would be including storage as investing option and extending the investor's decision making process. We can conclude that applying ABM to the electricity sector and focusing on the fundamental dynamics of the transition yields good prospects to further develop our understanding of the energy transition.

Acknowledgements

This research has been funded by Shell Global Solutions and has been carried out at the Future Energy Technologies team (Shell Global Solutions) in collaboration with Leiden University (Institute of Environmental Sciences) and Technical University Delft (Faculty of Technology, Policy and Management).

References

[1] Royal Dutch Shell, "40 Years of Shell scenarios," 2013.
[2] Chmieliauskas A., Chappin E., Davis C., Nikolic I. and Dijkema G., "New methods in analysis and design of policy instruments", in Gheorghe, A. V. editor, Systems of systems, Intech, 2012.
[3] Van Dam K., Nikolic I. and Lukszo Z., "Agent-based modeling of socio-technical systems," vol. 9, Agent-based social systems, 2013.