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Low-carbon investments from the perspective of electric utilities: The burden of the past

Bianka Shoai-Tehrani*, Keigo Akimoto, Fuminori Sano

Systems Analysis Group, Research Institute of Innovative Technology for the Earth (RITE), Japan

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ABSTRACT

Within the Paris agreement, Europe has adopted ambitious climate targets. Achieving these targets through appropriate low-carbon investments is thus key. This study aims at providing new insight into this issue by considering the DNE21 + model, an optimization model that assesses global energy systems, and the Investment Preference Index model, a simulation model where decision-making is based on technology preferences from a utility's perspective. We evaluate the impact of a climate-policy scenario on the European electricity sector using these models with harmonized assumptions. The resulting investment choices provide insight into the effectiveness of a low-carbon investment policy. We find that various types of incentives are required before companies abandon their historical preferences and low-carbon technologies can flourish. Testing various options has revealed that a negative constraint on coal is more efficient than adding further positive incentives for low-carbon technologies (such as carbon pricing and support schemes). However, we also expect these preferences to shift over time.

1. Introduction

In the context of growing climate concerns, investments in low-carbon technologies are necessary to mitigate climate change. In particular, emission reductions are expected to occur in the electricity sector due to the diffusion of low-carbon technologies, such as wind and solar power, and improved efficiency in fossil fuel power plants. Europe has committed to reducing its CO_2 emissions by 40% in 2030compared to 1990 levels in the Nationally Determined Contributions (NDCs; UNFCC 2015). However, recent trends do not show a decline in fossil fuels: as an effect of the shale gas “revolution” in the United States, coal-fired power generation in Europe rose by 6% in 2012. This gain was also due to stagnating carbon prices in the European Union Emission Trading System (EU ETS; International Energy Agency, IEA, 2013; SIA, 2013), and oil prices have been decreasing for more than a year (IEA, 2015). At the same time, the European electricity market is undergoing a deep structural change with the liberalization process, affecting the status of companies and their strategic decisions (Boltz, 2013). Against this background, it is important to determine how the EU goals can be achieved by triggering the desired low-carbon investments.

Several sources have determined that carbon pricing triggers a shift to low-carbon energy sources, starting with a shift from coal to natural gas at around 30 euro/MWh (RTE et Ademe, 2016). Such calculations are usually based on the calculation of variable costs and are derived from considering plant operations. Long-term low-carbon investments are usually modeled in economic theory with a long-term economic rationality approach based on either the assessed costs or the assessed costs and future benefits. The DNE21 + model assesses global energy systems and global warming mitigation through detailed modeling of technologies and costs, by minimizing the total system cost (Sano et al., 2014). In particular, it assesses future energy mixes through the collection of large amounts of data and the modeling of energy-conversion processes. It is thus a powerful tool and allows a comprehensive view of global processes by providing a quantitative analysis of the links between them.

However, observation of the actual power generation mix in various countries reveals a large disparity in the technology partitioning, and this cannot be explained by such an approach. This is especially true within Europe, where the generation mix can be very different from one country to another. For example, nuclear power dominates in France (about 75% of total generation) while coal-fired power generation dominates in Germany (about 45%), (Shoai Tehrani, 2014). Multiple other factors are recognized as playing an important role; these factors include local resources, energy security, geopolitical factors, and political choices for technology development, which lead to investment decisions that are not consistent with those of cost-based approaches. The Investment Preference Indicator (IPI) model is a simulation model

* Corresponding author. Systems Analysis Group, Research Institute of Innovative Technology for the Earth (RITE), 9-2 Kizugawadai, Kizugawa-shi, Kyoto 619-0292, Japan.
E-mail address: bianka.shoai_tehrani@centraliens.net (B. Shoai-Tehrani).

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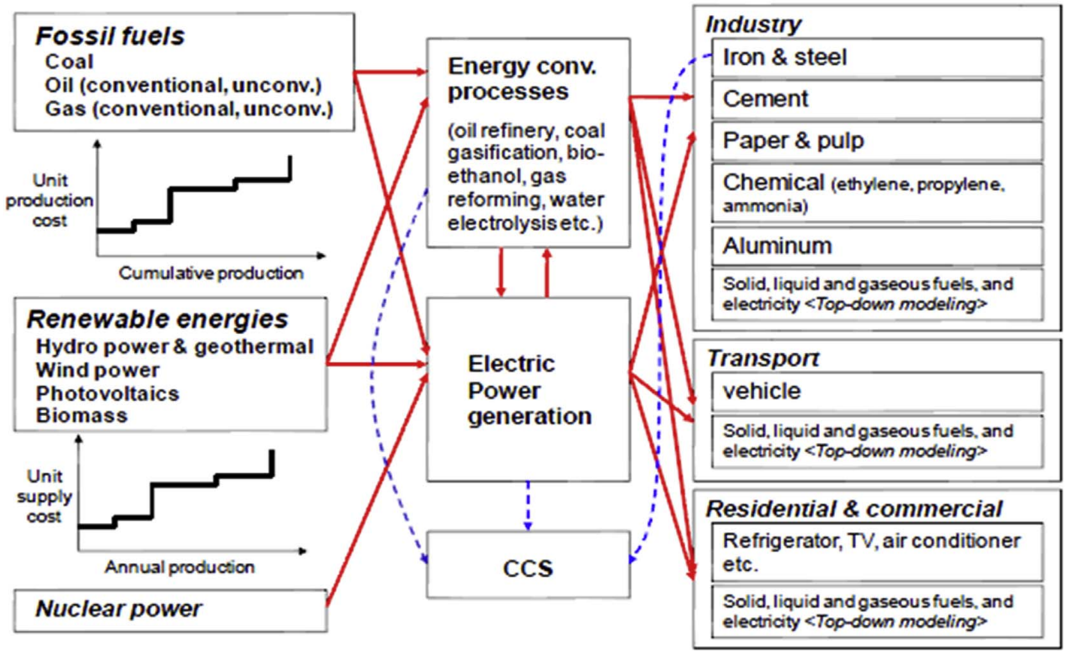

Fig. 1. Outline of energy flows in DNE21+ (Akimoto et al., 2010).

based on dependency and structure modeling methods and was developed to address this issue in the European scenario. In this model, technology preferences are assessed from the perspective of an electric power utility and are specific to each company. The model considers investors' choices and how they may not always minimize costs, and how that information can be used to forecast the future energy mix (Shoai et al., 2014). In this paper, we provide new insights into the issues surrounding investment in low-carbon electricity technologies. We do this by combining the IPI model with global cost assessment model DNE21+.

The goal of this study is thus to analyze the most efficient drivers of low-carbon investment by examining the nuanced results of combining the IPI model with the DNE21 + model. As DNE21 + is an optimization model based on total cost minimization, while the IPI model is a simulation model aiming at reproducing utilities' behavior based on a comprehensive set of drivers, this study tests carbon pricing as a low-carbon incentive with both scenarios and compares the outcome. While the implementation of relatively high carbon pricing is expected to result in a low-carbon energy mix for DNE21+, results from the IPI model may highlight hurdles that do not appear with DNE21+.

To do so, we evaluated both models by comparing the results obtained under a harmonized set of assumptions. We chose to focus on major electricity producers: France, Germany, the United Kingdom, Spain, and Italy, for they represent about two-thirds of European Union (EU27) power generation (Shoai et al., 2014). We performed a simulation of each model in the European scenario for both a baseline scenario and a climate-policy scenario, which is based on increased carbon pricing. In Section 2, we describe these models, and in Section 3, we provide details of the methodological framework developed for the comparison study. The results are then presented and discussed in Section 4.

2. Material and methods: the DNE21 + and IPI models

This section presents a brief introduction to the two models involved in this study, both of which were described in previous publications: For the DNE21 + model, see, e.g., Sano et al., 2014; Sano et al., 2013; Akimoto et al., 2014; Akimoto et al., 2010. For the IPI model, see Shoai et al., 2014.

2.1. DNE21+

The DNE21 + model is an optimization model that assesses global energy systems and global warming mitigation, based on detailed modeling of technologies and costs. It allows an assessment of the diffusion of low-carbon technologies on the global level, based on assumptions about costs, technical progress, and public policy (Sano et al., 2014).

Technically, DNE21 + is an inter-temporal linear programing model that minimizes the global sum of the discounted energy system costs (Akimoto et al., 2010). The output minimizes the total cost and is provided in terms of future energy consumption, energy mix, and CO_2 emissions. The results are specific to a particular country and are adapted to specific features (e.g., the nuclear phase-out in Germany and Italy, and the degree to which each source is renewable).

Energy supply and demand are modeled by connecting supply sectors to end-use sectors, as shown in Fig. 1. Various technology options are explicitly modeled, and costs, energy efficiencies, and the lifetime of facilities are assumed. Various exogenous assumptions are made for the end users (industry, transportation, etc.), while other sectors are modeled in a top-down fashion. The final energy demands are exogenously assumed as a scenario for each energy carrier. The model allows different kinds of constraints, such as carbon taxes and emission limits. Overall, about 300 specific technologies were explicitly modeled as available technology options, which allowed for a detailed assessment