A SECTOR-COUPLING SPATIAL OPTIMIZATION MODEL FOR THE GERMAN ELECTRICITY MARKET – BRINGING GAS AND HEAT INTO THE EQUATION

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Overview

In the light of the Paris climate agreement the shift to a 100% renewable electricity supply is inevitable. While the current German electricity system already accommodates about one third of renewable energy in 2015, the future development towards a carbon neutral system is dependent on flexibility options accounting for an increased share of intermittent generation technologies. While batteries and transmission investments are possible flexibility options, power-to-X technologies are also considered to play a major role in a future system. Conventional electricity market models are mostly focused on the generation and electricity transmission side of the system. A detailed representation of the heating sector and the natural gas transmission system is often times being neglected. Therefore, a sector-coupling approach is necessary in order to model the electricity sector of the future in an integrated model, including technologies like power-to-heat or power-to-gas. Especially for the latter one, the natural gas transmission network is an essential constraint to pay regard to.

Methods

In this paper we develop a large scale spatial optimization model for the German and European electricity market. The model is based on the well-established electricity sector model ELMOD (Leuthold et al., 2012; Egerer, 2016), extended by a module giving a representation of necessary redispatch following the initial cost-minimal dispatch of power plants not regarding network topology.

Furthermore, combined heat and power plants (CHP) are integrated, depicting their lowered dispatch flexibility given the heat demand by households and industrial sites. The major German district heating systems are modelled as pools, increasing their supply flexibility.

The electricity sector model is complemented by a spatial model of the gas transmission network regarding technical parameters like pipelines and compressors, simulating the gas pressures and flows in the network given the technical specifics of the network (Midthun et al., 2009; Woldeyohannes and Majid, 2011; Osiadacz, 1987) and exogenous demand by households and industry as well as endogeneous demand and supply by power plants and power-to-gas facilities. In order to limit complexity, linearization approaches and steady-state assumptions are used.

The model has a nodal resolution for electricity generation and transmission on the level of the high voltage electricity grid and national gas transmission grid, respectively. Demand data for electricity and natural gas is considered on a NUTS-3-level. In a first step, the neighbouring European countries are included with fixed exchange time series. The scope of the model is to be extended to further European questions in the future.

Expected Results

Using data sets from 2014 and 2015, respectively, a backtesting of the model is conducted with regards to power plant dispatch by technology. When applied to future scenarios, especially comparing infrastructure investment alternatives, the detailed representation of interactions of the electricity with the gas and heat sector allows for a more holistic comparison of overall system costs.

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