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Medium-term demand for European cross-border electricity transmission capacity

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HIGHLIGHTS

- A model for assessing the benefits of cross-border transmission capacity in Europe.
- Current cross-border transmission: not an important constraint for RES by 2025.
- CO_2 emissions from electricity generation decrease by 17% (2010–2025).
- Transmission investment necessary if demand is slightly higher than projected.
- Storage and transmission are at least partly complementary technologies.

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ABSTRACT

The aim of this paper is to discuss the needs for investment in electricity interconnectors in Europe by 2025. We evaluate the impact of cross-border transmission capacity on dispatch costs, curtailment needs for renewable energy sources (RES), on CO_2 emissions, on hydro storage utilisation and on security of supply (in terms of energy not served). The analysis is performed with EUPowerDispatch, a minimum-cost dispatch model. For the evolution of the electricity generation portfolio and electricity consumption we use the latest Scenario Outlook and Adequacy Forecast of the European Network of Transmission System Operators for Electricity (ENTSO-E). The model results show that the planned additional cross-border transmission capacity between 2010 and 2025 will reduce annual dispatch costs, will have limited impact on the security of supply and will not be a significant cause of variable RES curtailment. However, in case of more RES, it will reduce dispatch costs to a larger extent and will considerably reduce RES curtailment needs, and, if demand grows at the historical rate of 2%, it will be needed to maintain the current level of security of supply. Moreover, our study shows that hydro pumping and storage and cross-border transmission are partly complementary technologies.

1. Introduction

In this paper, we present the results of a modelling study of the effects of increasing volumes of electricity generation from renewable energy upon the electricity transmission network. In order to keep climate change below 2 °C, the European Council concluded on 4 February 2011 that 'reaching the EU objective [...] of reducing greenhouse gas emissions by 80–95% by 2050 compared to 1990 [...] will require a revolution in energy systems, which must start now' (European Council (EUCO), 2011). In order to achieve a low-carbon economy, electricity will have to a play a central role. Consequently, the European Commission (EC) has called for a European power sector that 'can almost totally eliminate CO_2 emissions by 2050' (European Commission (EC), 2011). The full decarbonisation of the power sector is technically feasible but, depending on the expected scenario, requires substantial investment in grid extensions, renewable energy sources (RES), carbon capture and storage (CCS) deployment, nuclear power, and increased energy efficiency (Roadmap2050, 2011). As also noted in Haller et al. (2010), 'if transmission and storage capacities are expanded well above their current levels a near complete decarbonisation of the power sector can be achieved'.

From the overall welfare point of view, research has shown that the European transmission network is experiencing serious

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underinvestment (Supponen, 2012). The benefits and needs of further expanding the European electricity transmission network have been frequently discussed in the literature. For example, as shown in Saguan and Meeus (2011), 'cooperative behaviour in developing renewable energy technologies across borders and/or cross-border transmission capacity investment can reduce the cost of achieving a renewable energy target'. A study stating that ' a large-scale wind, water, and solar energy system can reliably supply all of the world's energy needs […] at reasonable cost' highlights the need to expand the electricity transmission network considerably in order to accommodate the new sources of power (Delucchi and Jacobson, 2011). The expansion of the European electricity transmission network does not only face technical challenges; there also are political, economic and physical limitations.

The objective of the present study is to analyse expected generation and transmission investment by 2025 and compare expected CO_2 emissions to EU climate policy goals. We analyse the expected medium-term evolution of the European electricity transmission network and the needs for additional cross-border transmission capacity. In particular, the impact of cross-border electricity transmission capacity on dispatch costs, on RES curtailment needs, on energy storage utilisation (hydro storage in this case) and on security of supply (in terms of energy not served) is analysed.

The paper presents EUPowerDispatch, a minimum-cost dispatch model for the European electricity transmission network that was developed by the Smart Electricity Systems research group at the Institute for Energy and Transport of the EC Joint Research Centre (Smart Electricity Systems (SES), 2012) for this purpose. The generation and transmission scenarios (up to 2025) are based on the Scenario Outlook and Adequacy Forecasts (SO&AF) (European Network of Transmission System Operators for Electricity (ENTSO-E), 2011c, 2012) and Ten-Year Network Development Plan (TYNDP) (European Network of Transmission System Operators for Electricity (ENTSO-E), 2011f) produced by the European Network of Transmission System Operators for Electricity (ENTSO-E).

Several models have been developed in recent years in order to answer different questions about the European electricity transmission system. Due to current computational capacity limits and data unavailability, a single model with a high resolution that represents every element of the European electricity transmission network cannot be built. Therefore, depending on the scope of the research undertaken, each model focuses on different aspects, looks at different elements, has different temporal and spatial resolutions and sets different geographical boundaries. For example, ELMOD (Leuthold et al., 2008; Weigt et al., 2010), a non-linear optimisation model maximising welfare under perfect competition, includes a very detailed representation of the transmission grid of a European region, mainly Germany, but does not model every single hour of a year. In contrast, COMPETES (Lise and Hobbs, 2006) covers 20 European countries with a very detailed representation of every single power plant (in order to observe differences between perfect and strategic competition), but the representation of the electricity network is aggregated to one node per country and the year is divided into 12 demand periods. LIMES (Haller et al., 2010, 2012), a multi-scale power system model that integrates optimal investment allocation in grid and generation capacities into a single optimisation framework, represents 20 geographical regions connected by 32 transmission corridors. Long-term investment decisions are modelled with time-steps of 5 years, while short-term fluctuations are represented by 49 different periods. MTSIM (Grassi et al., 2011) is a zonal electricity market simulator that determines hourly market clearing prices for a whole year. The power system is modelled by an equivalent representation with one node per country. Both URBS-EU (Schaber et al., 2012) and PowerACE-Europe (Pfluger and Wietschel, 2012) include several nodes representing European regions or countries and simulating investment in power generation, network extensions and storage in order to obtain the least-cost solution for meeting demand in each hour of the year and in each hour of six representative weeks, respectively. The European Climate Foundation (Roadmap 2050, 2011) uses an electricity generation dispatch model within the study of potential decarbonisation pathways for Europe. Some of its key features are its hourly resolution, hydro optimisation, storage utilisation and the flexibility of demand. However, the model divides Europe into nine regions in order to reduce complexity. Neuhoff et al. (2008) uses an investment-planning model to analyse the cost savings from transmission expansion. The model, IPM, captures the variability of wind but it only considers 20 load segments for each of the 52 weeks in the year. Unsihuay-Vila et al. (2011) introduces MESEDES, a multi-objective model to identify optimal generation and cross-border transmission investments. The model only considers three load segments corresponding to low, medium and peak demand. Lynch et al. (2012) use a model to determine the optimal amount of investment in new generation capacity as well as optimal investment in cross-border transmission for a test system of eight Northern European countries from 2011 until 2030. The model has an hourly resolution but it does not consider start-up costs of conventional power plants. Most of the models that have been introduced are investment models, in other words, generation and/or transmission capacity are endogenous variables. These models provide the optimal generation and/or transmission capacity based on a single (or multiple) objective function that satisfies a set of equations, which can vary from power plant generation constraints to a specific CO_2 emissions target or a RES share target. The model described in this paper, instead, is simply a dispatch model of the European electricity system. The model is run for different generation and cross-border transmission scenarios and the results are compared in order to analyse the impacts of investments (e.g. in cross-border transmission) in terms of electricity dispatch costs, variable RES curtailment needs, CO_2 emissions, hydro pumping utilisation and unserved load. Brancucci Martínez-Anido et al. (2013) present a first study using EU Power-Dispatch, a techno-economic analysis of future North-African electricity imports on the European and the Italian power systems.

The model presented in this paper is designed in order to study a power system with increasing RES penetration. Due to the variable nature of RES, a high time resolution is of paramount importance for analysing their impacts on network planning and operation. Therefore, EUPowerDispatch's time-step is set to one hour. In addition, the model simulates the European transmission network for an entire year in order to account for RES variability in terms of seasonality and possible long periods (weeks/fortnights) of low or high wind. EUPowerDispatch uses actual weather data in terms of wind speed, solar radiation and precipitation. The available data for wind and solar have different temporal and spatial resolutions, but each data set covers the same entire year. This feature allows the model to account for potential correlations that may affect the management and operation of the European electricity transmission network. The distinctive feature of EU Power Dispatch compared with the other tools described above is the annual management of energy storage. At the moment, the only energy storage elements represented in the model are hydro reservoirs, which, depending on the country, may have natural inflows and/or pumping capacity. The detailed modelling of hydro energy sources in the model provides support for the annual management of hydro reservoirs, which can be very valuable for managing a network with a very high RES penetration for balancing purposes as well as for reducing overall annual