INFLUENCE OF BALANCING RESERVES ON THE ELECTRICITY INFRASTRUCTURE IN EUROPE UNTIL 2050

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Overview

The recent Paris Agreement confirms the long term goal of limiting global warming to 2°C compared to pre-industrial levels. The European Union reflects this with its ambitious decarbonisation targets of up to 80-95 % CO_2 emission reduction until 2050 compared to 1990 levels. The decarbonisation of the electricity sector requires far-reaching transformation of the electricity generation infrastructure. Possible pathways for the generation infrastructure until 2050 have been subject of many studies. These studies focus on availability of nuclear/CCS, cost assumptions for different technologies, HVDC interconnection or storages and demand side management. Currently few studies (Pineda et al., 2016; Stiphout et al., 2014), focus on the implications of balancing reserves for a future generation infrastructure, despite the fact, that very high shares of fluctuating RES will increase the necessary amount of balancing reserves in the long term (Hirth and Ziegenhagen, 2015). At the same time this balancing reserve demand influences the necessary power plant capacities. Therefore the inclusion of balancing reserves influences the outcome of an investment model in two ways: first, different technologies lead to different reserve demands and second, only to a certain extent different technologies can provide balancing reserves.

Method

We develop a dynamic electricity sector model which includes endogenous investments into conventional and renewable generation capacities while accounting for endogenous balancing reserve demand increase and necessary balancing capacity provision. This also includes the possibility of balancing reserve exchanges between countries. The model is based on an investment model (Gerbaulet et al., 2014) that has been further developed to include balancing provision, balancing exchanges and balancing demand calculations.

The model is formulated as a linear program with an hourly resolution within each calculated year. The important technical constraints as power plant status, minimum load or part load are approximated in a linearized version. This allows us to reduce computational complexity and apply the model to the entire region of Europe. Electricity exchanges between countries are implemented using a country-sharp power transfer distribution factor aggregation based on the actual underlying high-voltage transmission grid. This approach represents the recently introduced flow-based market coupling mechanism in the CWE region that includes loop-flows in its calculations. This approach is also used for the exchanges of balancing capacities as the latest network code on electricity balancing suggests to increase international cooperation (ENTSO-E, 2013) which can lead to significant cost savings (Lorenz and Gerbaulet, 2014). When using interconnector capacity for balancing exchanges, it can not longer be used for spot market exchanges. Hence there will be a trade-off between the usage of transmission capacity for spot market and balancing exchanges.

Electricity generation and transmission infrastructure investments are optimized in steps of five to ten years starting in 2015 to 2050, taking expected decommissioning of power plants into account. The possible investments are influenced by yearly CO_2 emission budgets, technological and cost assumptions as well as expansion potentials for renewables and interconnector capacities (Egerer et al., 2014). When determining the optimal investments, the model considers all future years and corresponding generation dispatch decisions in a single optimization step.

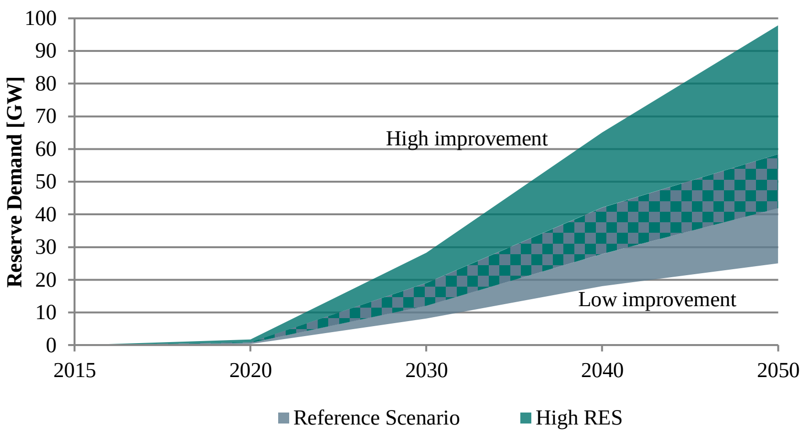

Figure 1: Additional balancing reserve demand in Europe depending on forecast quality development and assumed renewable deployment
Source: own calculations

Expected Results

Preparatory calculations for additional balancing reserves requirements show a wide range of results dependent on the assumptions regarding forecast quality and renewable share (see figure 1). For the EU reference scenario additional reserve demand would increase between 25 GW to 58 GW dependent on forecast accuracy improvements. For the high renewable scenario additional reserve demand would increase substantially between 41 GW and 97 GW. These calculations are accounted for in the investment decision and therefore endogenous in the final model formulation. Preliminary calculations indicate that results are highly sensitive to the assumptions regarding the possibilities of renewables to participate in the provision of reserves. Even with a very high share of renewables balancing reserves can be provided without conventional dispatchable capacities, when excess renewable capacities are available. Nevertheless this requires additional renewable capacities for Europe, which lead to a cost increase compared to the scenario without any reserve requirements. Without the possibility of renewables to provide positive reserves, cost will increase significantly and dispatchable generation capacities are mainly used to provide reserves. Hence mainly biomass, hydro and storages are used for balancing provision in this scenario.

This results in a tradeoff between the investment into dispatchable biomass, storages and excess renewable capacities. The assumption of reduced possibilities of fluctuating renewables to provide positive reserves leads to increased trade of balancing reserves across Europe. Especially hydro dominated countries tend to provide reserves for entire regions. This raises the question of security of supply in case of congested lines.

Conclusions

The paper analyzes the options and effects of providing balancing reserves when determining the cost-minimal generation and transmission infrastructure in Europe until 2050. We develop a bottom up electricity model that allows for investment into electricity generation and transmission infrastructure and includes endogenous determination of balancing demands and balancing reserve provision. In contrast to the literature we argue that balancing reserves can be provided without conventional dispatchable capacities even at very high shares of renewables generation. If possibilities for the provision of reserves through renewables are limited, the exchange of balancing capacity becomes more important. This highlights the necessity to foster cross-border balancing cooperation and the participation of fluctuating renewables in providing reserves.

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