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INTEGRATION OF WIND POWER IN THE INVESTMENT PLANNING MODEL

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Overview

Investment planning models inform investment decisions and government policies. Current models do not capture the intermittent nature of renewable energy sources, restricting the applicability of the models for high penetrations of Renewables. We provide a methodology to capture spatial variation in wind output in combination with transmission constraints. To allow for the numerical calculation of an equilibrium investment path we have to restrict the amount of wind data utilised within a model run. We use boot-strapping to test for the sensitivity of our results to the limited input data – and show that results are robust. We illustrate the potential of our new model under different scenarios and policy environments and show the impact of regional transmission constraints on new build both in terms of siting and technology choice.

Methods

Investment planning models simultaneously decide on the optimal investment and operation of power plants to serve a predetermined electricity demand pattern throughout the modelling horizon. They assumes rational and forward-looking agents to fulfil future demand with the least-cost technology- and fuel choices. This is represented as a linear optimisation problem. We integrate representation of wind data into this approach. After various experiments, first trying to match the data with the multi-dimensional Weibull distribution, we decided on using a subset of the historic data. The deterministic representation with 1024 dispatch scenarios per modelling period only allows for a very restricted representation of the extended space of regional wind output and demand situations. We use boot-strapping to test the robustness of the results to the selection of historic wind input data.

Results

Our baseline case was able to simulate the new build levels up to 2020, given our initial parameters and assumptions. We were able to assess the impact of wind power investment costs, transmission constraints, regional considerations and CO2 prices as well as several other key variables under various different scenarios. Figure 1 illustrates the extent and spatial distribution of new build of both Wind power and Combine Cycle Gas Turbines.

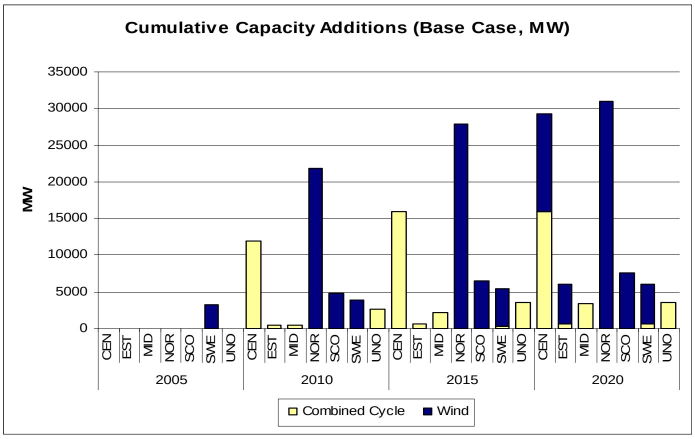

Fig. 1: Cumulative new build, by region

Fig 2. below illustrates the UK wide cumulative installed wind capacity that is modelled using wind data for different weekdays. It indicates the extent to which the results are robust to the choice of the weekday. We were also interested to what extend the spatial pattern that we observe in our model results is robust towards our random choice of the weekday for wind input data. We also calculate the range of volatility of the regional shares of wind build and observed that new investment in wind power is again robust to changes in weekday wind data.

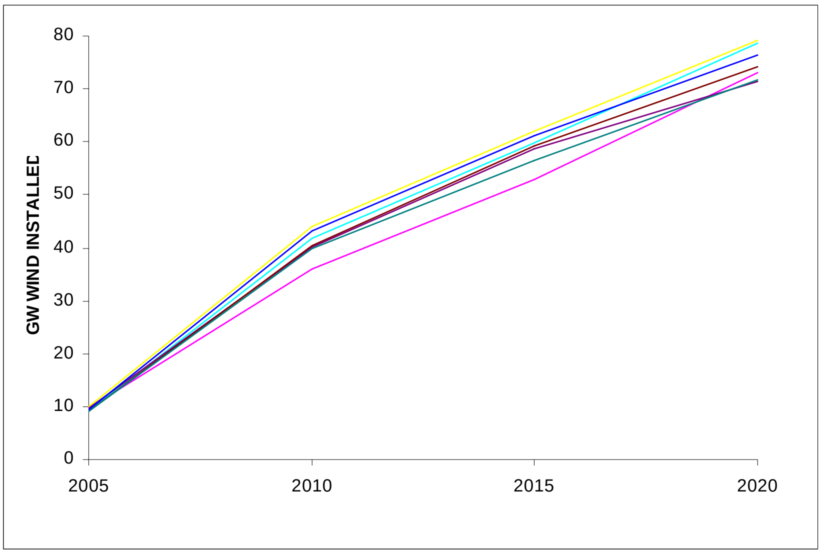

Fig. 2: Robustness test, global installed wind capacity for different wind data

Our modelling of transmission constraints between regions allowed us to assess the impact of an expansion of transmission capacity and it subsequent impact on technology choice and spatial distribution of new investment as well as overall system costs. Table 1 shows the cost savings that could be achieved in an optimal system if 1GW extra transmission capacity would be available. The new system exhibits lower fuel and CO_2 costs as wind power replaces conventional generation. The net effect is an average saving of 25milllion Euro/year.

	2005	**2010**	**2015**	**2020**
Variable	-9.1	-3.3	0.5	0
Fuel	-146.1	-132	-128.3	-148.9
Capital	168.5	158.6	145.8	157.5
CO2	-37.6	-49.7	-41.8	-44.8
Total	**-24.3**	**-26.4**	**-24.0**	**-36.2**

Table. 1: Changes of annual costs (in mill. Euro) if transmission capacity to Scotland were 1GW bigger. (excluding costs of extra transmission lines)

References

Baleriaux, H., E. , F. Jamoulle, et al. (1967). "Simulation de l'exploitation d'un parc de machines thermiques de production d'electricite couple a des stations de Pompage." Revue E edition SRBE(5): 225-245.

Berry, C. A., B. F. Hobbs, et al. (1999). "Analyzing Strategic Bidding Behavior in Transmission Networks." Utility Policy 8(3): 139-158.

Bessiere, F. (1970). "The Investment 85 model of Electricite de France." Management Science.

Blooms, J. A. (1983). "Solving an Electricity Generation Planning Problem by Generalized benders Decomposition." Operations Research 31(1): 84-100.

Booth, R. R. (1972). "Power System Simulation Model based on Probabilistic Analysis." IEEE Transaction on Power Apparatus Systems PAS-91: 62-69.

Cardell, J., C. C. Hitt, et al. (1997). "Market Power and Strategic Interaction in Electricity Networks." Resource and Energy Economics 1997(19(1-2)): 109-137.

Gabszewicz, J. J. and S. Poddar (1997). "Demand fluctuations and capacity utilization under duopoly." Economic Theory(10): 131-146.