Meeting the Energy Balancing Needs in a Fully Renewable European Energy System: A Stochastic Portfolio Framework

Iulia E. Falcan

Extended Abstract: The transition of the European power sector towards a clean, renewable energy (RE) system faces the challenge of meeting power demand in times of low wind speed and low solar radiation, at a reasonable cost. This is likely to be achieved through a combination of 1) energy storage technologies, 2) development of the cross-border power grid, 3) installed overcapacity of RE and 4) dispatchable power sources – such as biomass.

This paper uses NASA – derived hourly data on weather patterns of sixteen European countries for the past twenty-five years, and load data from the European Network of Transmission System Operators – Electricity (ENTSO - E), to develop a stochastic optimization model. This model aims to understand the synergies between the four classes of technologies mentioned above and to determine the optimal configuration of the energy technologies portfolio. While this issue has been addressed before, it was done so using deterministic models that extrapolated historic data on weather patterns and power demand, as well as ignoring the risk of an unbalanced grid – risk stemming from both the supply and the demand side.

This paper aims to explicitly account for the inherent uncertainty in the energy system transition. It articulates two levels of uncertainty: a) the inherent uncertainty in future weather patterns, and b) the uncertainty of fully meeting power demand. The first level of uncertainty is addressed by developing probability distributions for future weather data – and thus expected power output from RE technologies, rather than *known* future power output. The latter level of uncertainty is operationalized by introducing a Conditional Value at Risk (CVaR) constraint in the portfolio optimization problem. By setting the risk threshold at different levels – 1%, 5% and 10%, important insights are revealed regarding the synergies of the different energy technologies, i.e. the circumstances under which they behave as either complements or substitutes to each-other.

The paper concludes that allowing for uncertainty in expected power output - rather than extrapolating historic data - paints a more realistic picture and reveals important departures from results of deterministic models. In addition, explicitly acknowledging the risk of an unbalanced grid - and assigning it different thresholds - reveals non-linearity in the cost functions of different technology portfolio configurations. This finding has significant implications for the design of the European energy mix.

I. E. Falcan is a Ph.D. fellow at the United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (UNU - MERIT) (e-mail: falcan@merit.unu.edu)

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