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Measuring Energy Security

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The continuity of energy supplies relative to demand, which is at the heart of concerns about energy security, depends on a large number of different risk sources. However, most of the models that are used to measure supply continuity focus on a small number of risks or use a strongly simplified representation of the energy system. Based on these individual models it is difficult to assess the overall continuity of energy supplies.

In this paper we introduce a stylised, probabilistic time-series model which quantifies the combined impact of natural, technical and human risk sources on the continuity of energy supplies. We calculate the widely used continuity metrics of Loss of Load Expectation (LOLE), Loss of Energy Expectancy (LOEE) and the Levelized Cost to Society (LCS) or Consumers (LCC) for a fixed infrastructure. The main difference between our model and other energy system simulations is, that we include a representation of the dependency structure between the different risks. We assume that the natural system state, which is described by weather variables such as wind speeds, temperature, and rainfall in different locations, is independent of the remaining model variables. The technical system state in our model is the result of stochastic outages with failure and repair rates that dependent on the natural system state. The political system state in our model is the result of stochastic outages - caused by intentional supply interruptions - with failure and repair rates that depend on the impact that would be caused by disruptions. Uncertain parameters, such as the average value of political failure and repair rates, are modelled as Bayesian variables.
We use a case study of Italian gas and electricity markets in order to investigate, whether the approach that is chosen for quantifying supply continuity could have an impact on policy decisions. The policy decision in our case study is whether in the case of 12 GW solar electricity imports from North Africa it would be more efficient to use a) no additional back-up, b) back-up in the form of 12 GW additional gas-fired plants or c) back-up in the form of 12 GW additional hydro pumped storage.

We find that with our parameters the solution without additional back-ups would be the most efficient option. As long as the cost for the back-ups remains high, most simplified measurement approaches reach the same conclusion. However, if the cost for back-ups is lower, simplified probabilistic models and alternative approaches may not detect the efficiency of back-ups which is revealed by more refined probabilistic models.

In our view, the main difficulty for the quantification of energy security is not that the potential measurement errors which we illustrate in this paper are unexpected. The larger problem seems to be that more detailed versions of the framework that we have introduced, as well as other frameworks, can quickly become very resource intensive, both in terms of the data requirements and the calculation speed. What seems to be the largest problem in the analyses of energy security is thus neither the lack of knowledge about individual interdependencies, nor the absence of modeling techniques for stochastic failures but the resources required to gather the data, build and run a model that includes all the known interdependencies and infrastructures at reasonable level of detail and precision. Nevertheless, given the cost that may be caused by inefficient policy decisions on energy security it would not seem unreasonable for models for policy support to use a similar level of detail as the models that are used by system operators.

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