Coping with Uncertainties in the Electricity Sector—Methods for Decisions of Different Scope

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1. Motivations underlying the research

Decision-making in the energy sector and notably the power industry has to cope with multiple uncertain factors such as renewable forecasts, technology developments or demand growth. At the same time, there is a burgeoning stream of research over at least the last three decades trying to develop decision support models that explicitly deal with risk and uncertainty in the energy context. As many of these models are optimization models, the paper at hand focuses on this model category. Optimization models are especially used to analyze pathways for the decarbonization of the energy system at different scales – which implies time horizons of several decades and correspondingly large uncertainties. Against this background, the present contribution primarily aims to bridge the gap between the specialist literature and the general and political debate on uncertainties related to energy systems and their transformation with a focus on the power system as a key sector for decarbonization. The question to be addressed is thereby less of the order on how to do things right but rather on how to do the right things, i.e., what are adequate models for different types of decision problems.

2. A short account of the research performed

In the perspective of matching models with decision problems, we first provide a typology of decisions in the energy sector and also discuss different types of uncertainties. We thereby distinguish operational and investment decisions at the company level as well as political decisions on regulatory settings.

Based on these typologies, we then provide an overview of different methods to incorporate uncertainties in various decision support models. Stochastic optimization, chance-constrained programming and robust optimization are scrutinized along with other, less known methods like information gap decision theory (IGDT) or modeling-to-generate-alternatives (MGA). Also, simple deterministic equivalents, scenario and sensitivity analyses are considered when it comes to solving operational decision problems, investment decisions and policy choices regarding regulatory settings.

Uncertainties are particularly challenging in the latter context – yet the use of optimization approaches may be questioned on epistemic, empirical and methodological grounds. Nevertheless, improved conceptual framings are expected to be helpful to address the still largely unresolved challenges of energy policy and deep decarbonization. These deserve particular scrutiny as the corresponding choices embrace several decades and multiple decision makers in a multi-level governance context. A promising route to avoid the pitfall of "penny-switching" is thereby to investigate the use of quadratic optimization approaches as well as a coupling of optimization models with discrete choice models.

3. Main conclusions and policy implications of the work

After several decades of research both on the decarbonization of energy systems and on the appropriate modelling of uncertainties in the context of decision support models, there is obviously not one silver bullet nor one single solution that fits all problems. The long-time horizon for the system transformation together with the multiplicity of involved investors and policy makers gives rise to multiple uncertainties and makes decision support in the field challenging.

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A first step to cope with uncertainties is certainly to identify and assess them thoroughly. This may be done outside any optimization model used for decision support, by enumerating possible sources of uncertainty and estimating their range. By varying then parameters in the optimization model, the sensitivity of the reference model results with respect to changes in the assumptions may be identified.

A particular challenge to modelling is the intertwined decision making in a multi-level governance setting. Further research efforts may be devoted to developing transparent modelling approaches that enable an in-depth analysis of the interdependencies without imposing strong theoretical priors like in Nash equilibria. Dealing with decisions of other institutions as part of the structural uncertainties may be a way forward to identify "robust" or rather error-tolerant strategies for decarbonization in a multi-polar setting.