ROBUST TRANSMISSION PLANNING – AN APPLICATION TO THE CASE OF GERMANY IN THE EUROPEAN CONTEXT TO 2050

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Overview

Transmission expansion planning has for a long time been a 'static' exercise: load centers were to be connected with generation sites, which in turn were to be connected with each other in order to realize economic gains from complementary technologies.

In light of the technological change in the energy sector, both with respect to generation, demand, and sector-coupling, new challenges to transmission planning emerge: These developments are subject to massive uncertainty, e.g. with respect to the availability of technologies, the level of cross-sectoral integration, and the level of international co-ordination.

Therefore, the objective of this paper is to explore the contribution of advanced planning methods to adress these challenges. We put a special emphasis on "robust" transmission planning, which focuses on minimizing costs across all possible scenarios, without evaluating probabilities of occurence: This approach is suitable when realizations of an uncertain set are low-frequent and largely irreversible, i.e. 'bad' realizations will not be compensated by 'good' realizations so that an expectation-value based decision calculus should rather not be applied.

However, while many realizations may be stable over time, they may not necessarily happen instantaneously: Often, there will be some time left for adapting transmission expansion decisions to the realization of uncertain parameters as they realize gradually.

To adress this, we generate Europe-wide country-level scenarios for generation and transmission expansion. These come in 10-year-timesteps and follow various paths. In addition, transitions between paths are allowed (where they are plausible). We apply those scenarios to a more detailed transmission grid model of Germany which we aim to expand using different optimizaiton techniques. Specifically, we compare robust, deterministic and expectation value based approaches, and whether dynamics (i.e. multiple investment steps under limited foresight) are taken into account.

Methods

To generate the scenarios, we use "dynELMOD", a fully-fledged generation and transmission invesmtent model for Europe. It covers the EU-28 Member States, the Balkans, Norway and Switzerland. It optimizes the deployment of generation and storage technologies, taking into account maximum technical lifetimes of the power plant fleet existing in 2015, cost reductions of technologies over time (such as storage) and allows for expansion of the European transmission grid.

We generate scenarios of the following kind:

- 80—95% decarbonization until 2050
- weak vs. strong "electrification" of transport and heating
- strong vs. weak integration with neigbour countries

Fig. 1 shows examples of generation mixes in Germany in 2050 for low- and high decarbonisation levels (SLOW vs. FAST) and strong vs. weak integration with neighbouring countries (XB vs. DE)

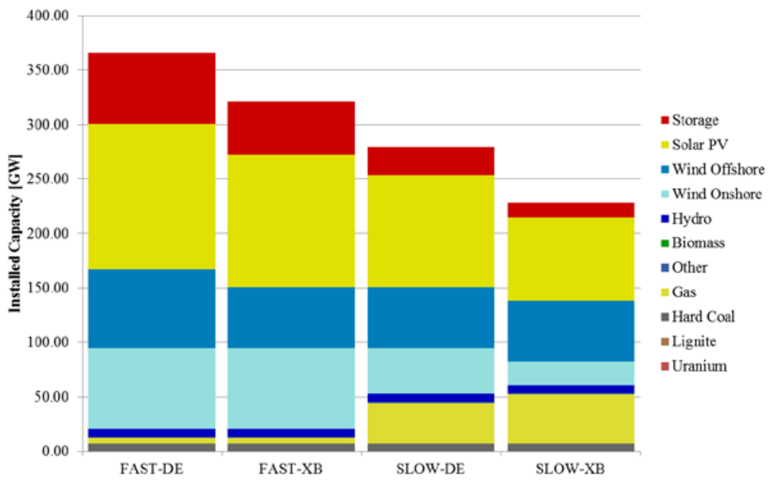

Figure 1: Generation capacities in Germany in 2050, generated with dynELMOD.

We do then allocate the identified generation units to nodes of the (currently, i.e. 2015) existing transmission grid and apply the aforementioned transmission expansion strategies to the problem. In order to keep the problem computationally tractable, we apply a DCLF linearization technqiue. The transmission expansion model is based on modification of "ELMOD-DE", which is a detailed representation of the german power system.

Results

Our results demonstrate that robust optimization techniques allow for significant savings when applied to transmission expansion planning in Germany. Yet, the possibiliy of gradually adapting to changes reduces the merits of robust optimization (but increases overall advantages): The more adaptation is allowed, the less transmission expansion needs to executed in order to hedge against uncertainties. However, the overall results underline that there is a merit in conducting transmission expansion planning with considering both robust and adaptive decision-making.

Conclusions

Our analysis has shown that robust transmission expansion planning has some merits, but that those can be increased if in addition adaptive decision-making is considered. This provides some support for enhancing real-world planning processes in this respect. However, the investigation was based on discrete and schematic scenarios, which would need to be enhanced for a reliable application of this method: As of now, it is unclear what elements of the scenarios are important drivers for the benefits of robust and adaptive transmission expansion planning. Furthermore, scenarios need to be assessed carefully: It may quiten often barely make sense to widen the "uncertainty set" to all thinkable and non-thinkable cases as this would probably induce massive "over-built" of transmission capacity. Although the robust "minimax regret" approach can reduce such problems, dedicated work on scenarios remains essential and cannot be replaced by advanced transmission expansion planning methods.