Development of a new modelling concept for providing initial consultation on a federal state level

(6) Modellierung - Neue Ansätze der Modellierung des Energiesystems

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Motivation and research question

Due to the increasing deployment of variable renewable energies (VRE) and ongoing structural changes in energy demand, stakeholders frequently need to make decisions with regard to issues like long-term power supply investments or policy design. With an increasing share of VRE in the energy mix and a more decentralised management of the energy system, the decision-making competence of federal states is becoming more relevant. Model-based scenario analyses are a common approach to derive long-term strategies in this matter [1]. Due to the design of the energy system, well-established modelling tools often reflect its complexity by highly sophisticated computational algorithms, while a single model run can take up to two weeks or even more [2]. When also taking into account model calibration and scenario design definition this can take up to one or even two years until receiving the first modelling results. In contrast, the political discussion is characterised by a dynamic exchange on alternative system design approaches, where initial consultation usually takes place in the early phases of a discussion. Initial consultation is characterised by a prompt quantitative approximation of political considerations done by research institutes, to decide, which alternatives should be pursued further or rejected. In the present study, we develop, apply and validate a new modelling concept based on a complexity-reduced design to conduct initial consultation on a federal state level.

Methodical approach

The study builds upon the newly developed modelling tool ‘FederalPlan’ (Figure 1). Regarding energy demand, it features a bottom-up accounting framework for projecting energy needs in the four major demand sectors. Exogenous parameters include fuel and technology substitution towards electrification, improvements in energy efficiency, as well as socio-economic effects. These projections provide the basis for endogenous modelling of future electrical load curves using a partial decomposition approach [3], as well as an endogenous assessment of practical potentials for demand-side-management (DSM) [4].

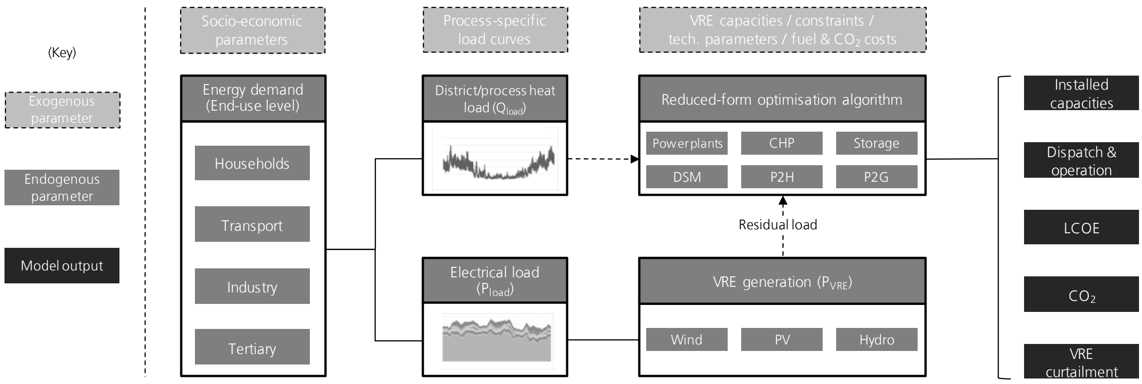

Figure 1. Overview of the structure and procedure of FederalPlan (own illustration).

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Considering power supply, the model optimises investments as well as the dispatch of generators and flexibility options, in order to minimise power system costs from a socio-economic perspective. Technologies are selected from a diverse portfolio of thermal power plants, cogeneration plants, storage facilities, as well as power-to-gas and power-to-heat converters. In addition, DSM is modelled for temporal shifting of electrical load. One model run results in a cost-effective power supply configuration at given parameters and policy constraints for a single target year. Using a reduced-form optimisation algorithm [5], the modelling tool is characterised by low computational times, making it promising for providing initial consultation. The complexity-reduced design is mainly accomplished by a selected representation of operational constraints for power plants (technological level of detail), as well as narrowly defined system boundaries with regard to a single federal state under consideration (spatial level of detail). In the full paper, core components of the algorithm are presented.

Results and conclusions

For the purpose of model validation, a comparative analysis is performed. Using the example of the federal state of Baden-Württemberg, the FederalPlan tool is calibrated to the base year 2015. Subsequently, model outcomes for the target year 2050 are compared to an established normative scenario of a reference study [6]. The comparison reveals the following key insights under similar boundary conditions: On the one hand, there are similarities between the modelling results in terms of total generation capacity required to cover power demand. On the other hand, deviations occur regarding the contribution of cogeneration plants and storage facilities in gross power generation. Accordingly, using either one of the two approaches, policy recommendations may differ with regard to least-cost investments in power generation assets. In addition to the scenario comparison, sensitivity analyses are carried out for the FederalPlan tool. Among other parameters, the hourly shape of the endogenously modelled load curve is found to have an influence on the deployment and dispatch of power plants and flexibility options. Overall, the modelling tool is considered to yield reasonable results. Given its reduced level of computational complexity and data needs, FederalPlan provides useful insights for initial consultation to federal state decision-makers with regard to long-term energy system strategies and the associated policy design.

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