Modeling concept for renewable energy expansion and interaction in Europe: The case of Germany and Greece

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(1) Overview

The aim of this paper[1] is to investigate in detail the electricity systems of Greece and Germany in the context of high penetration of intermittent renewable energy sources (RES). The paper enriches the debate on energy strategies and policies to reach high shares of renewable energy in the electricity system. Both countries have a high and also complementary potential of additionally installed renewables (offshore wind power in addition to current developments for photovoltaic PV and onshore wind power in Germany, high solar irradiation for PV systems and onshore wind in Greece and its islands). Therefore, synergies and complementarity of solar and wind resources between these two countries should be analyzed within the European renewable energy strategies by 2020 and 2050 (EC 2013).

A modeling concept is presented to analyze the expansion of the whole electricity system in both countries. This concept includes the coverage of the expansion and dispatch of renewable energies, conventional power plants and storages as well as the grid. To achieve this goal each country is divided in national sub-regions. The linkage between the two countries Germany and Greece is additionally modelled to show potential energy flows between both countries. Renewable energy plants, conventional power plants and storages can be built within the sub-regions and transmission capacity between regions and countries. Additionally the effect of other countries on the system in Germany and Greece is taken into consideration.

Two different aspects provide interacting results: The regional coverage of the model impacts the expansion path of each country strongly. On the other hand, interconnected electricity systems supports balancing of fluctuating electricity generation.

(2) Methods

The optimization model RESlion (Kost, Schlegl et al. 2013) is used in the European model version. The model covers expansion planning of renewable energy sources over the next 40 years. As a key issue this modeling approach covers the integral expansion optimization and unit-commitment of conventional power plants, storages and renewable power plants as well as grid extensions between local regions and the electricity transmission via HVDC or HVDC lines between Central and Southern Europe. The current status of the elements of the energy system is taken as given in the model and the system development is optimized until the year 2050. The investment decision in renewable energy technologies includes a temporally and spatially high-resolution simulation of renewable energy generation based on hourly weather data and potential of each technology within each simulated model-region to account for the intermittent and unequally distributed electricity generation of wind and PV.

The relation between model input and model output is displayed in the following Figure 1. A coupling to the results of PRIMES (by National Technical University of Athens (NTUA)) is planned and supports the evaluation of the German and Greek electricity system.

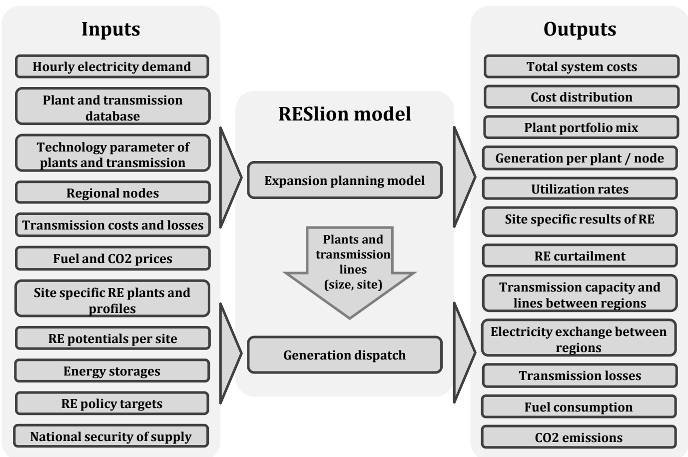

Figure 1: Model input and output of RESlion

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(3) Results

For the model calculation several scenarios are defined, which are adapted to the climate change targets of the European Union and national targets such as the German “Energiewende” and the nuclear phase-out. The potential of renewable energy technologies are based on a detailed technical and economic analysis (processed with GIS). The potential and costs for PV are evaluated within each NUT3 region (refer to Figure 2; left). Then, several hourly weather and generation profiles are generated for each model region (node).

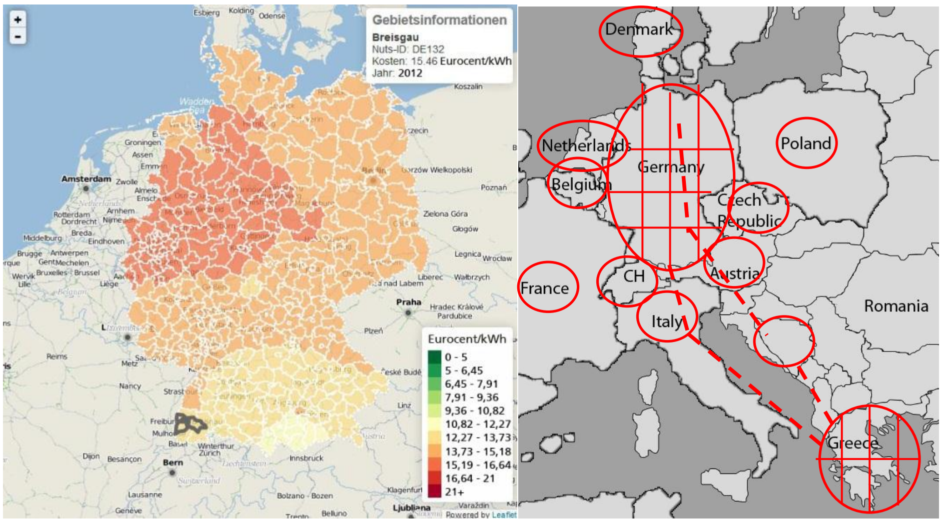

Figure 2: Model input (left: PV costs per node) and model concept (right: model regions and interconnections)

Each country (Germany and Greece) was divided into several (up to fifteen) regions (general layout in Figure 2; right). The selection of each model region was based on population and energy system aspects. Additionally the surrounding countries of Germany and Greece are each defined as one model region. Due to the not well known energy flow within the Balkan region, this area is modeled as one node. With this approach, the effect of exchanging electricity of one region with its neighboring regions is analyzed. All existing high voltage transmission lines between two regions are included in the database of current infrastructure and the maximum net transfer capacity between the regions was obtained. By considering their geographic location, all generation capacities are assigned to the correspondent region. A central modeling focus was set on including renewable potentials per region and optimizing the renewable portfolio and conventional power plants with constraints of demand, supply and transmission capacities. Within the objective function of the model the annual system costs are minimized.

In a first step Germany is modelled with its neighboring countries. Then, the expansion planning for Greece is set up in the model. Last, the extension of the model containing the potential to transfer electricity between the both countries is included.

(4) Conclusion

This model concept for the European electricity system targets at detailing the expansion planning of the European electricity system by introducing a high regional model resolution combined with an integral optimization and unit-commitment planning of conventional power plants, storages, renewable energies and the grid. With this concept, the site selection and consequently the expansion paths for all technologies were improved. Compared to other models (e.g. PRIMES), the roadmap for the renewable energy portfolio can be detailed and extended. As an example, grid capacities clearly constraint the optimal mix of renewables in the future. By using a modeling concept with high regional resolution within the countries, not only grid constraints are accounted for but also an optimal site selection of different renewable energies, influenced by hourly weather data and generation profiles at many different sites, can be accounted for.

References

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