Modelling the impact of climate change on electricity generation and demand

Energiesystem- und Klimamodellierung

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Motivation

Heat waves and other extreme events, as experienced globally during the summer of 2022, drastically show the energy system's vulnerability to climate change's impact. For an adequate representation of climate change's impact on energy systems, increased cooperation between the research fields of climatology and energy system modelling is required. Several studies have investigated the effect of climate change on the energy system [1], [2]. In this work, we use current climate modelling to generate consistent data sets for electricity demand as well as electricity generation components for all European countries, including hydropower generation, which is often missing in comparable data sets.

Method

The methodological approach combines climate and energy modelling and is conducted in the course of the project SECURES. The climate data sets generated are used to derive weather-dependent electricity generation and demand profiles in hourly resolution. For two RCP pathways (RCP4.5 and RCP6.5), we derive the weather parameters affecting the electricity system the most and combine them with two different decarbonisation scenarios of the energy system. Changes in temperature, wind speed, radiation, and precipitation have impacts on the electricity demand side (e.g. by increased cooling demand during heat waves) ([3], [4]) as well as on the power generation (e.g. changed hydro generation) [5]. Energy system data for 2030 and 2050 are combined with the weather years in the 30 years around that year to generate the following hourly profiles:

- E-heating demand (dependent on temperature)
- E-cooling demand (dependent on temperature)
- E-mobility charging demand (dependent on temperature)
- Photovoltaic generation (dependent on radiation, losses dependent on temperature)
- Wind generation (dependent on wind speed)
- Hydro generation (dependent on hydro inflow)

Individual processing steps are conducted to generate electricity generation profiles from climate data, e.g. the combination of wind speed levels with power curves of turbines in the case of wind power.

Results and conclusions

Resulting of the processing of climate data with energy system data, we receive hourly profiles for each 30 weather years around the modelled years 2030 and 2050 for all European countries. Figure 1 shows as an example the distribution of the annual wind, hydro run-off-river (RoR), and photovoltaics (PV) generation, as well as electricity demand in the 30 weather years around 2050 in the RCP4.5 scenario combined with a strong decarbonisation scenario ("Decarbonisation Needs"). We can observe a higher standard deviation in hydro generation than in the other two generation technologies in Austria. The demand shows a very low fluctuation between years.

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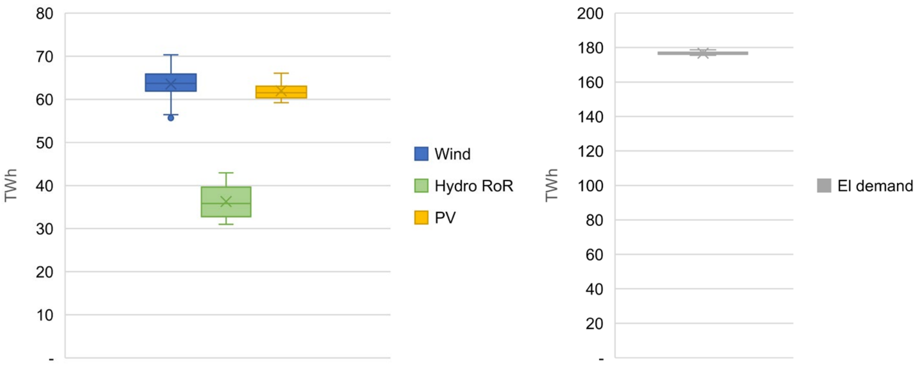

Figure 1: Annual wind, hydro run-off-river (RoR), and photovoltaics (PV) generation, as well as electricity demand in the 30 weather years around 2050 in the RCP4.5 scenario. The power plant fleet is based on projections for the year 2050.

The combination of critical situations in the electricity system (e.g., high demand and low wind generation) can lead to high residual load and pose a risk to supply security. Therefore, it is essential for energy modelling to identify weather years containing those critical compound effects. Figure 2 shows the identification of a representative year, a year containing a "Dunkelflaute", and a year containing a summer heat wave for the Austrian electricity system in 2030.

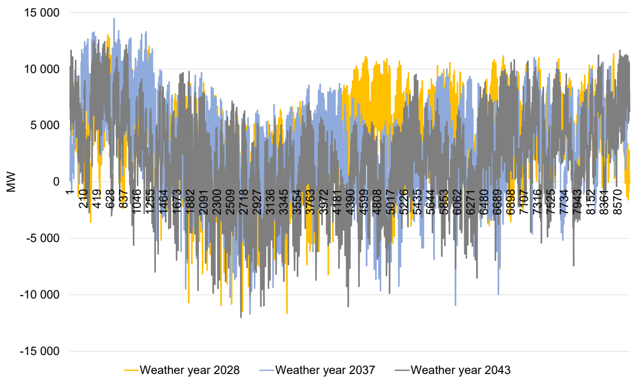

Figure 2: Hourly residual load in Austria of an average year (2043), a year containing a winter "Dunkelflaute" (2037), and a year containing a summer heat wave (2028). The power plant fleet is based on projections for the year 2030 (scenario Decarbonisation Needs).

The climate and energy data sets for the whole of Europe in hourly resolution until 2100 for RCP4.5 and RCP8.5 will be made available for open access in the course of SECURES.

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Literatur

[1] S. G. Yalew *et al.*, 'Impacts of climate change on energy systems in global and regional scenarios', *Nat Energy*, vol. 5, no. 10, pp. 794–802, Oct. 2020, doi: 10.1038/s41560-020-0664-z.

[2] J. Cronin, G. Anandarajah, and O. Dessens, 'Climate change impacts on the energy system: a review of trends and gaps', *Climatic Change*, vol. 151, no. 2, pp. 79–93, Nov. 2018, doi: 10.1007/s10584-018-2265-4.

[3] A. Rode *et al.*, 'Estimating a social cost of carbon for global energy consumption', *Nature*, vol. 598, no. 7880, pp. 308–314, Oct. 2021, doi: 10.1038/s41586-021-03883-8.

[4] V. Viguié *et al.*, 'When adaptation increases energy demand: A systematic map of the literature', *Environ. Res. Lett.*, vol. 16, no. 3, p. 033004, Mar. 2021, doi: 10.1088/1748-9326/abc044.

[5] Y. Zhang *et al.*, 'Assessment of climate change impacts on the hydro-wind-solar energy supply system', *Renewable and Sustainable Energy Reviews*, vol. 162, p. 112480, Jul. 2022, doi: 10.1016/j.rser.2022.112480.