EGU General Assembly 2023

EGU23-13862, updated on 11 Jul 2023
https://doi.org/10.5194/egusphere-egu23-13862
EGU General Assembly 2023

The impact of climate change on future electricity generation and demand patterns in Europe

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Motivation

With increasing decarbonisation and electrification of the energy system, the electricity system's vulnerability to extreme weather events is becoming a focus of energy system planning and operation. This requires intensified collaboration between the domains of climatology and energy system modelling for an accurate portrayal of the effects of climate change on future energy systems. In this study, we construct a consistent data set for Europe's future electricity generation and demand components (covering NUTS3-NUTS0 level) using current climate models, including hydropower generation, which is frequently absent in comparable data sets.

Method

The methodological approach combines climate and energy system modelling. Parameters like temperature, wind speed, radiation, and precipitation are processed to derive weather-dependent electricity generation and demand profiles in hourly resolution for Europe until 2100. On the electricity generation side (wind, solar, hydro run-of-river, hydro storage), technology-specific 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. On the electricity demand side, the impacts of electrification and changing temperature (e.g., increased cooling demand during heat waves) are assessed. We model various scenarios to evaluate the effect of different shares of renewable electricity generation and different grades of climate change impacts. Therefore, projections for the future energy system in two decarbonisation scenarios (DN and REF) are combined with two RCP pathways (RCP4.5 and RCP8.5).

The following weather-dependent generation and demand profiles are generated:

- E-heating, e-cooling, and e-mobility charging demand (dependent on temperature)
- Photovoltaics generation (dependent on radiation, losses dependent on temperature)
- Wind generation (dependent on wind speed)

▪ Hydro generation (dependent on hydro inflow)

Results and conclusions

From the processed climate data, we receive hourly profiles for electricity demand and supply for all European countries, which are used as inputs for the energy system modelling. The dataset allows for the systematic identification of critical situations in the electricity system (e.g., high demand and low renewable generation), which can pose a risk to supply security.

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 for e-cooling and e-heating in the 30 weather years surrounding the modelled year 2050. We observe a higher standard deviation in hydro generation than in the other two generation technologies, which is especially high in the RCP8.5 scenario. The demand shows relatively low variations between years, again stronger in the RCP8.5 scenario.

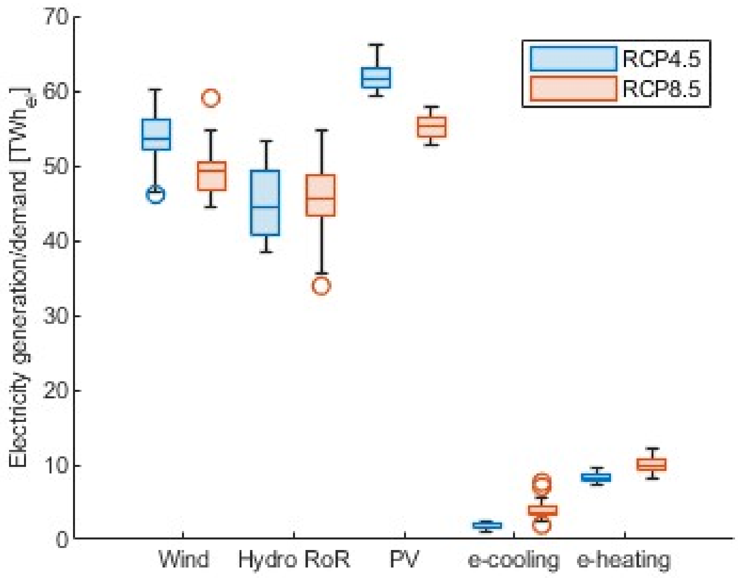

Figure 1: Annual wind, hydro run-of-river (RoR), and photovoltaics (PV) generation, as well as electricity demand for cooling and heating in the 30 weather years around 2050 in one RCP4.5 and one RCP8.5 scenario for Austria. The energy system projections are based on two scenarios for the year 2050: DN (RCP4.5) and REF (RCP8.5).

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

Funding

The project SECURES is funded by the Climate and Energy Fund (Klima- und Energiefonds) under project number KR19AC0K17532.