THE IMPACT OF CLIMATE CHANGE ON ELECTRICITY GENERATION AND DEMAND PROFILES

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Overview

Future decarbonised and highly electrified energy systems will be exposed to climate change impacts on the demand and supply side of the electricity system. The scientific interest in understanding the effects of climate change on the different electric demand and supply components has increased in recent years (e.g., Yalew et al. 2020) since current extreme events like the heat waves and droughts in Europe during the summer of 2022 have already shown the energy system's vulnerability. This paper combines state-of-the-art climate and energy modelling to generate consistent datasets for hourly electricity demand and generation components for all European countries until 2100 and concludes climate change impacts on the electricity system. The datasets include hydropower (run-of-river (RoR) and reservoir) generation, which makes them more comprehensive than most available datasets.

Methods

Several climate and energy modelling steps are combined to derive the weather-dependent demand and generation profiles in hourly resolution. The underlying climate datasets represent two RCP pathways (RCP4.5 and RCP8.5[1]) and are combined with two different decarbonisation scenarios of the energy system to analyse sensitivities in further modelling steps. Analysed meteorological parameters include temperature, wind speed, radiation, and precipitation. Possible impacts range from the electricity demand side (e.g. increased e-cooling demand during heat waves) ((Viguié et al. 2021)) to the generation side (e.g., changed inflow to hydrogeneration) (Zhang et al. 2022). The following hourly profiles are generated until 2100:

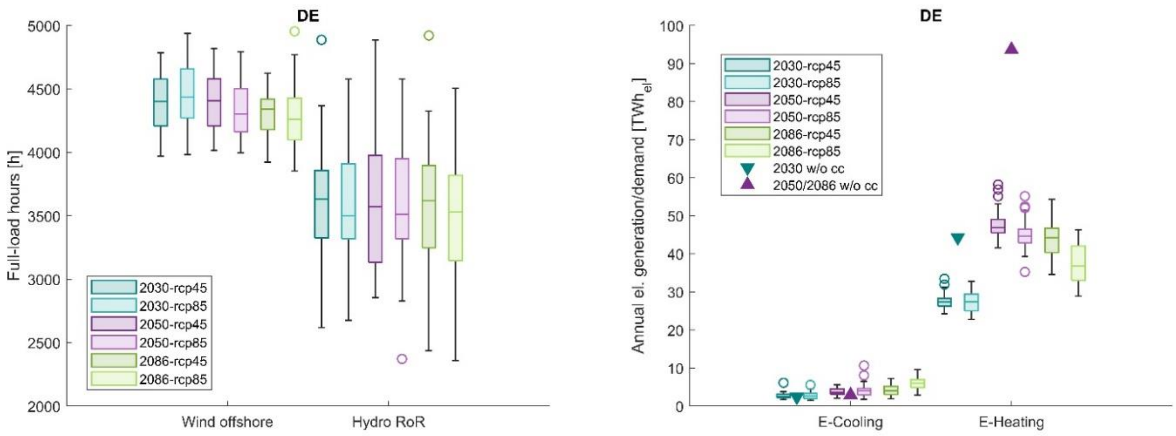
- E-heating/e-cooling/e-mobility charging demand (dependent on temperature)
- Photovoltaic generation (dependent on radiation, losses dependent on temperature)
- Wind generation (dependent on wind speed)
- Hydro generation (dependent on hydro inflow)

The different processing steps to generate electricity generation and demand profiles from climate data include, e.g., the combination of wind speed levels with power curves of turbines or demand regressions in dependence of temperature for e-cooling. The climate and energy datasets 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 the project SECURES[2].

Results and conclusions

While the generated dataset can be applied to a wide range of research questions, we focus on the 30 weather years around 2030, 2050, and 2085 to interpret the results in the following. Figure 1a shows, as an example, the distribution of the annual wind offshore and hydro RoR full-load hours (FLH) for the two assessed climate scenarios (Panel (a)). We observe a higher standard deviation in the RoR generation than in the offshore wind generation and no strong trend for the FLH due to climate change. In contrast, the e-heating demand is almost half compared to the demand without climate change impact in Germany in 2050 (see Figure 1b). The underlying installed e-heating/e-cooling capacities represent a strong decarbonisation scenario ("Decarbonisation Needs").

[1] ICHEC-EC-EARTH - KNMI-RACCMO22E RCP4.5/8.5
[2] https://www.secures.at/



(a) **(b)**

Figure 1: Wind offshore and hydro RoR FLH [h], and e-cooling and e-heating demand [TWh$_{el}$] for the RCP4.5 and RCP8.5 scenarios and without climate change impact ("w/o cc"). Each boxplot shows the 30 climate years around the displayed year: 2030 (2015-2044), 2050 (2035-2064), and 2085 (2071-2100).

Various technology-specific findings can be derived from the hourly profiles: For the example of hydro RoR generation in Germany, Figure 2 shows that with increasing climate change impact, hydro RoR generation decreases during summer and slightly increases during winter.

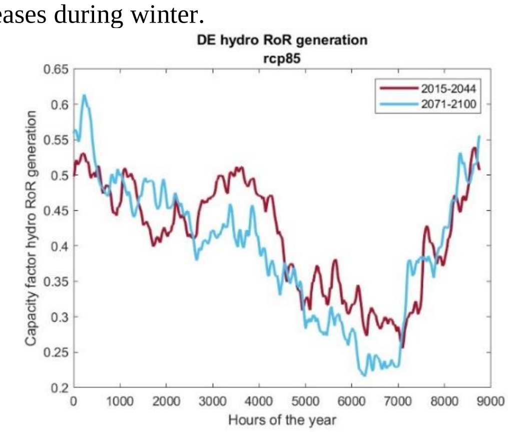


Figure 2: Hourly capacity factor of the hydro RoR generation in Germany in the RCP8.5 scenario for 30 weather years around 2030 (red) and at the end of the century (blue).

This is due to changing precipitation patterns and more rain instead of snow during the winter resulting in immediate runoff instead of melt water during spring. Based on the supply and demand profiles, we identify compound effects in the electricity system (e.g., high demand and low wind generation) that can lead to high residual load and pose a risk to supply security.

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References

Viguié, V, S Juhel, T Ben-Ari, M Colombert, J D Ford, L G Giraudet, and D Reckien. 2021. 'When Adaptation Increases Energy Demand: A Systematic Map of the Literature'. *Environmental Research Letters* 16 (3): 033004. https://doi.org/10.1088/1748-9326/abc044.

Yalew, Seleshi G., Michelle T. H. van Vliet, David E. H. J. Gernaat, Fulco Ludwig, Ariel Miara, Chan Park, Edward Byers, et al. 2020. 'Impacts of Climate Change on Energy Systems in Global and Regional Scenarios'. *Nature Energy* 5 (10): 794–802. https://doi.org/10.1038/s41560-020-0664-z.

Zhang, Yi, Chuntian Cheng, Tiantian Yang, Xiaoyu Jin, Zebin Jia, Jianjian Shen, and Xinyu Wu. 2022. 'Assessment of Climate Change Impacts on the Hydro-Wind-Solar Energy Supply System'. *Renewable and Sustainable Energy Reviews* 162 (July): 112480. https://doi.org/10.1016/j.rser.2022.112480.