THE IMPACT OF CLIMATE CHANGE ON ELECTRICITY DEMAND AND SUPPLY IN EUROPE

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Background and motivation

Climate change impacts electricity systems on the demand [1] and supply [2] side. Consequently, changing patterns and extremes of the different electric demand and supply components must be considered in electricity system planning and operation. This requires high-resolution data covering a range of climate scenarios in data formats suitable for energy system models to achieve a detailed representation of the impact of climate change on future energy systems. This paper presents the combination of state-of-the-art climate and energy modelling to generate a consistent open-access dataset for hourly electricity demand and generation components for all European countries until 2100, which can serve as input for energy system models. The set includes hydropower generation (run-of-river (RoR) and reservoir), which is highly relevant in the Austrian electricity system and makes the dataset more comprehensive than most available datasets.

Method

The methodological approach combines climate and energy system modelling [3]. Based on a high-resolution meteorological dataset (described in detail in [4], [5]) for two RCP pathways (RCP4.5 and RCP8.5[8]), weather-dependent electricity generation and demand profiles were derived. Temperature, wind speed, radiation, and precipitation were central parameters for calculating the profiles in hourly resolution for the whole of Europe until 2100. On the electricity generation side (wind, solar, hydro RoR, and hydro reservoir), technology-specific processing steps were conducted to generate electricity generation profiles from climate data. This approach included, e.g., matching hydropower plant sites with changing inflow profiles or combining wind speed levels with power turbine curves. On the electricity demand side, the impacts of electrification and changing temperature (e.g., demand regressions in temperature dependence for e-heating) were assessed.

The following weather-dependent generation and demand profiles were generated (encompassing NUTS3-NUTS0 level[9]) and will be provided as open-access datasets:

- PV generation (dependent on radiation, losses dependent on temperature)
- Wind generation (dependent on wind speed)
- Hydro RoR and reservoir generation (dependent on hydro inflow)
- E-heating, e-cooling, and e-mobility charging demand (dependent on temperature)

Results and conclusions

The hourly profiles for electricity demand and supply for all European countries can be used as inputs for the energy system modelling and analysed individually or as connected regions. While modellers can apply the generated dataset to various research questions, we focus on two exemplary countries and selected demand and supply components for the two assessed climate scenarios (RCP4.5 and RCP8.5) in the following. As an example, Figure 1 Panel (a) shows the distribution of the annual hydro RoR generation in Italy, while Figure 1 Panel (b) depicts the normalised electricity demand for e-cooling

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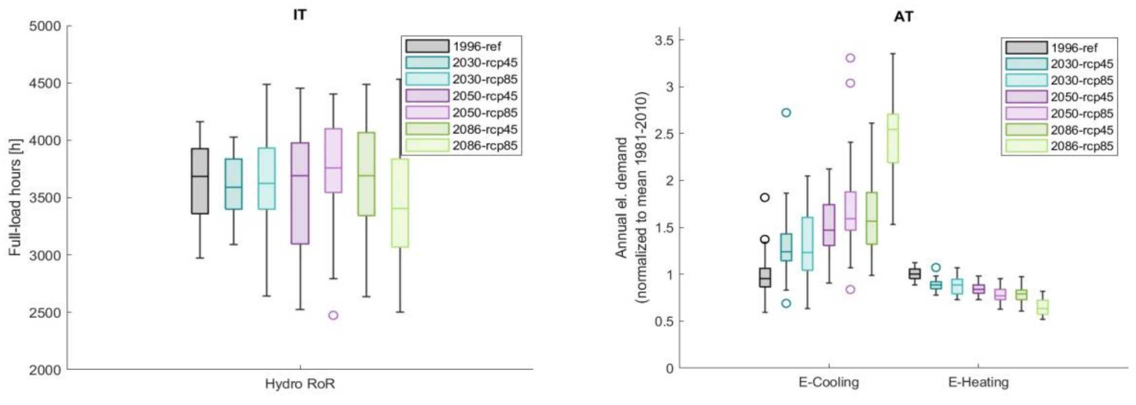
[8] CORDEX EUR-11 ICHEC-EC-EARTH rcp45/rcp85 r12i1p1 KNMI-RACMO22E v1
[9] Higher resolution for Austria

and e-heating in Austria. We compare the development in the climate scenarios to a reference period based on reanalysis data.



(a) **(b)**

Figure 1: Panel (a): Hydro run-of-river (RoR) full-load hours in Italy (IT); Panel (b): Annual electric cooling and heating demand in Austria (AT); each box represents the 30 weather years around the displayed year: 2030 (2015-2044), 2050 (2035-2064), and 2085 (2071-2100) in the analysed RCP4.5 and RCP8.5 scenario. The reference period 1996 (1981-2010) is based on ERA5-Land data.

In the exemplary applications of the dataset shown, no strong trend in full-load hours of RoR generation in Italy can be observed. Still, there is an increase in interannual variability with climate change. However, on the demand side, a substantial decreasing (heating) and increasing (cooling) trend is shown for Austria (in relative terms). Since, in absolute terms, heating demand is higher than cooling demand in Austria, a reduction in overall electricity demand from these two demand components is projected. This will modify the seasonal timing of climate stress events and reduce the need for seasonal storage.

Based on the work presented in this paper, the dataset was applied to systematically identify critical situations to analyse the security of supply and adequacy aspects [6] and flexibility needs in the Austrian and European electricity systems [7].

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