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Impact of strong climate change on balancing and storage needs in a fully renewable energy system

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We investigate the impact of strong climate change on a European energy system dominated by wind power. No robust trend can be observed regarding the change of the wind power yield for most countries in Europe. However, intra-annual variabilities in wind power generation robustly increase in most of Central and Western Europe and decrease in Spain, Portugal and Greece by the end of this century. Thus, the generation of wind power tends to increase (decrease) in the winter months compared to the summer months. Due to higher (lower) intra-annual variations, the probability for extreme events with long periods of low power production increases (decreases) in summer. This implies that more (less) energy has to be provided by backup power plants.
Our simulations are based on the results of five different Global Climate Models (GCMs) using the Representative Concentration Pathway scenario 8.5 (RCP8.5). These results are dynamically downscaled with the regional atmospheric model RCA4 by the EURO-CORDEX initiative (Coordinated Downscaling Experiment - European Domain). A comparison was made between historical data (1970-2000) and mid-century (2030-2060) and end-of-century (2070-2100) data, respectively. For all timeframes we made the assumption that a certain amount of energy is provided by wind power plants. This implies that changes in wind power potentials are neglected and only temporal effects are considered. Wind speed time series are converted to power generation time series using an extrapolation to hub height and a standardized power curve. Assuming a scenario for the future distribution of wind turbines, we obtain a wind power generation time series aggregated on a national level. The operation of backup power plants and storage facilities is simulated on coarse scales assuming an optimal storage strategy. Backup is required whenever the storage facilities are empty. The amount of change of the backup energy depends on the storage capacity – the higher the capacity, the higher the change as long as storage capacities do not allow for multi-year storage.