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Extreme impacts in the European renewable electricity system as a result of climate variability

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With the need for clean energy that reduces greenhouse gas emissions, the coming decades will see a transition of our energy system towards a higher share of renewable energy sources. With this work we aim at gaining insight in meteorological conditions that lead to extremely low energy generation and extremely high residual load (difference between production and demand) in European countries. We constructed a simplified climate-energy modeling framework in which extreme impact events on the European energy system can be examined. We compute daily electricity demand and the supply from hydropower, wind and photovoltaic solar, based on 2000 years of simulated present and future weather conditions for countries in Europe. From this data the meteorological drivers with high impact on the current energy system were investigated for individual countries and larger regions. Atmospheric blocking in summer can result in heatwaves and droughts that in turn result in long-lasting periods of high energy demands in countries with large cooling capacities (southern Europe) and low energy production in countries that rely on hydropower. In winter, dry and cold periods with lower than normal windspeeds lead to high residual load in northern European countries, especially around the North Sea. These countries have a high share of offshore wind and high installed heating capacities. Dry seasons lead to a higher sensitivity to wind and solar variability due to a decrease in balancing potential of hydropower. Additionally, the co-variability of electricity shortage events between countries is investigated. The goal is to identify balancing potential of transmission between countries. Due to different demand profiles across Europe and the spatial variability of weather the potential of extreme event reduction through cross-border transmission is high.