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Wind droughts and winter cold threaten Europe's future energy security

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To mitigate climate change a renewable energy transition is needed. Existing power systems will need to be re-designed to balance variable renewable energy production with variable energy demand. We investigate the meteorological sensitivity of a highly-renewable European energy system using large ensemble simulations from two global climate models. Based on 2×2000 years of simulated weather conditions, daily wind and solar energy yields and energy demand are calculated and events of high societal impact are selected: extreme low renewable energy production and extreme high energy shortfall (residual load, i.e. demand minus renewable production). Low energy production days are characterised by large-scale high pressure systems over central Europe, with lower than normal wind speeds. The events typically occur in winter when solar energy is limited due to short day lengths. Near-stationary high pressure situations occur that cause long lasting periods of low energy production, these longer lasting 7- and 14-days low production events peak late summer. High energy shortfall events occur due to comparable high pressure systems though now combined with below normal temperatures, driving up energy demand. In contrast to the low energy production events, 1-, 7- and 14-days high shortfall events all occur mid-winter, locked to the coldest months of the year. A spatial redistribution of wind turbines and solar panels cannot prevent these high-impact events, options to import renewable energy from remote locations during these events are limited. Projected changes due to climate change are substantially smaller than interannual variability. Future power systems with large penetration of variable renewable energy must be designed with these events in mind.