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Coupled water-energy modelling to assess climate change impacts on the Iberian Power System

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Water resources systems and power systems are strongly linked; water is needed for most power generation technologies, and electricity is required in every stage of water usage. In the Iberian Peninsula, climate change is expected to have a negative impact on the power system: changes in runoff are expected to reduce hydropower generation and cooling water availability for thermal power generation; and higher temperatures are expected to increase (decrease) summer (winter) electricity demand, when water resources are already constrained. We use coupled hydrological and power system models to study the effects of climate change on the current Iberian power system.

The Iberian power system is a competitive power market where power price is determined by power supply and demand, and which can be simulated by a market equilibrium model considering the power demand function and the installed capacities and marginal costs of the power producers. Two effects of climate change on the power system were studied: changes in the hydropower production caused by changes in precipitation and temperature, and changes in the electricity demand over the year caused by temperature changes. A rainfall-runoff model was established to estimate the impact of precipitation and temperature changes on reservoir inflows. The model was calibrated using observed precipitation, temperature and river discharge time series. Potential evapotranspiration was estimated from temperature data, and snow accumulation/melt was modelled using a temperature index method. The delta change approach was used to generate synthetic precipitation and temperature data based on observations (1961-1990) and three regional climate models (2036-2065, CLM, RACMO and REMO). Because modelling generation on 1000+ hydropower plants is intractable, the capacities, inflows and minimum releases of all reservoirs were converted to energy and power units, and then aggregated into an equivalent energy reservoir. Irrigation water demands were also converted to power units and added to the minimum releases of upstream reservoirs and to power sinks of downstream ones. The water value method, an adaptation of stochastic dynamic programming, was used to estimate the marginal costs of hydropower as a function of the time of the year, the energy storage and the inflow state. The power system was simulated with estimated power demand, and the installed capacities and marginal costs of every generation technology, providing estimates of electricity prices and power production per technology under different climate scenarios.

The simulation results indicate that hydropower production is likely to decrease as a consequence of reduced inflows, causing higher electricity prices. Temperature changes will shift a portion of the electricity demand from winter to summer months, resulting in increased electricity prices. The reduction of water availability caused by climate change will increase the competition between irrigation and power production, leading to a sharper trade-off between electricity prices and agricultural benefits.