Virtual energy storage-gain due to spatiotemporal coordination of wind-, solar- and hydropower over Europe

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The functionality of a renewable electricity system in Europe depends on long-term climate variations, uneven spatiotemporal distribution of renewable energy, and constraints of storage and electric transmission. In particular, hydropower offers a large capacity for energy storage and production flexibility, but only stands for a minor part of the total energy potential. Here we explored the spatial and temporal power variance of a combined system consisting of wind-, solar- and hydropower availability for a 35-year period based on historical hydro-meteorological data from large parts of Europe. A spectral analysis of these historical time-series shows that spatiotemporal coordination within the power system can potentially contribute with a “virtual” energy storage capacity that is many times higher than the actual energy storage capacity contained in the existing hydropower reservoirs in Europe. Such virtual energy storage capacity implies reduced water storage demand, hence, indirectly contributes to reduced constraints of the food-water-energy nexus also in a wider system perspective. This study focused on the theoretical maximum potential for virtual energy storage, but the feasibility of this potential is limited by the uncertainty associated with production optimization and the meteorologic forecasts of future energy availability.