Application of portfolio theory to the wind-solar energy mix in Spain: climate-related risks and opportunities

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Non-hydroelectric renewable energy sources (RES) are the fastest growing energy generation technologies in terms of new capacity and their penetration is expected to double in the next 20 years. More than half of this growth is expected to come from wind power. However, given the variable nature of RES production linked to climate variability and the need for a constant supply-demand balance, increasing penetration of renewables raises structural, technological and economical issues. In Spain, the correlation of solar and wind climate potential with the seasonal fluctuation of electricity consumption, associated mostly with tourism activity, allows for some ambitious renewable penetration scenarios. This work aims at identifying optimal energy mix scenarios that maximize RES penetration while minimizing distribution risk, using the Markowitz modern portfolio theory as a starting point. We apply the e4clim model to the Spanish electricity system, using reanalysis and electricity data in order to produce scenarios for optimal geographical and technological distribution of RES installed capacity. We conduct a mean-risk analysis and discuss the geographical distribution for the most relevant optimal scenarios. We also provide an interpretation of the optimal RES penetration results in terms of the regional climatic characteristics of Spain. Beyond the large potential of the regional climates of Spain to exploit RES technologies, optimal scenario results reveal interesting regional differences with respect to the current installed capacities, which can be linked to economic and regulatory regional contexts.