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Analysis of the optimal allocation of wind and solar PV capacities in a decarbonized power system in Spain using PyPSA

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The Spanish energy roadmap aims at producing around 80% of electricity from renewable energy by 2030, while reducing nuclear energy in a scenario of increasing demand. To this end, the target for installed capacity is 50 GW for wind energy (30 GW in 2022), 39 GW for solar PV (20 GW in 2022) and 2.5 GW for battery storage. Plans underway suggest even more ambitious goals.
We present the results of an analysis of the optimal spatial distribution of new wind and solar capacities in Spain. The study is carried out using the electrical system model PyPSA-Eur, which allows analyzing the optimal allocation and sizing of new renewable plants, taking into account the variability of generation and demand, energy costs, integration and the transmission issues. Two main scenarios are explored: 1) capital costs and 2) operational nuclear power amount (0/3/7 GW). The study assumes a 20% increase of demand by 2030 and a maximum total installed power of 160 GW. The generation and distribution networks used in PyPSA-Eur includes 9 nodes, homogeneously distributed in the study region. The model is fed with the Spanish High Resolution Renewable Energy and Demand (SHIRENDA) open access database for energy system analyses. Both combined the generation and distribution networks and SHIRENDA allow adequately accounting for the very high spatial variability of the renewable resources in Spain.
The results show that the new capacities should be installed in up to four of the nine regions (nodes) considered, although this strongly depends on the amount of nuclear energy. In particular, for scenarios with low nuclear power (0/3 GW) wind capacities should be installed mainly in the Galicia (northwest of the study area) and Aragón (northeast) regions, and solar PV in the regions of Murcia (southeast) and Aragón. For scenarios with fully operational nuclear energy (7 GW), the region of Andalusia (south) was also selected both for wind and solar PV. The intermediate nuclear power amount scenario (3 GW) is best from the costs standpoint. The curtailment is high (about 10%), higher for wind, but reduces by 50% when nuclear energy is removed.
Overall, the results show that a homogeneous spatial distribution of new solar and wind capacities in the study region is far from optimal and that a better representation of the spatio-temporal variability of the renewable energy resources, as done in this study, is needed. Future work will explore the optimal ratio between solar PV and wind capacity, as well as the role of energy storage and demand management.