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Sensitivity of the Moroccan mix to the integration of Thermal and Battery Storage combined with Concentrated Solar Power and Photovoltaics: Design, Dispatch and Optimal Mix analysis

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Concentrated Solar Power (CSP) can shift electricity over time using cheap Thermal Energy Storage (TES). However, the cost of CSP is still high. Conversely, the cost of Photovoltaic (PV) systems have fallen. However, the Battery Energy Storage (BES) used to mitigate the generation variability is uneconomical to utilize as a grid-scale storage. Moreover, in order to increase the operating hours of both solar technologies, one has to increase both TES capacity and CSP solar field compared to the electricity-generating turbine, as measured by the Solar Multiple (SM), and increase the BES capacity and PV module size relative to a fixed inverter capacity, as measured by the Inverter Loading Ratio (ILR). This increase the investment costs although the Levelized Cost of Electricity tends to be lowered by the higher capacity factor (CF). These differences between solar technologies must be accounted when designing an optimal prospective power supply system based on renewable energies (RE). Particularly, the utilization of CSP and PV with storage is widely suggested within the Moroccan strategy that aims at deploying 20% of its electrical capacity from solar energy by 2030. However, the share between PV and CSP and the amount of storage associated is still to be found. This study discuss objectively scenarios for solar integration in the electricity mix by evaluating the impact of rental cost and storage of CSP [1] and PV on the optimal mixes together with the role of time-space complementarity in reducing the adequacy risk. To do so, we simulate hourly CFs and load curves adjusted to observations for the four Moroccan electrical zones. We analyze mixes along Pareto fronts using the Mean-Variance approach -implemented in the E4CLIM model - in which the total cost of a mix is constrained to be lower than that of the actual 2018 mix [1]. We find that wind gains a higher shares compared to solar technologies because wind is regular on average which involves less capacity to install. However, at low penetrations, the addition of TES to CSP decreases the risk – the more as SM is increased keeping the mean CF fixed – which makes CSP less variable than wind and favors its installation compared to PV. To prevent reaching the maximum-cost sooner at high penetrations, the share of CSP decreases compared to PV and wind. However, the larger the ILR, the larger the share of PV compared to wind and CSP-TES, particularly for SM<4 and CSP tends to replace PV with high ILRs at high penetrations. We also show that a strong RE variability reduction is achieved through spatial diversification and by taking into account correlations between PV and CSP capacities, but less so as the surplus of energy available for TES and BES is increased.

[1]: Bouramdane, A.-A.; Tantet, A.; Drobinski, P. Adequacy of Renewable Energy Mixes with Concentrated Solar Power and Photovoltaic in Morocco: Impact of Thermal Storage and Cost. Energies **2020**, 13, 5087.

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