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From multi-decadal energy planning to hourly power dispatch: evaluating the reliability of energy projections in the Southern African Power Pool

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Development pathways for Sub-Saharan Africa project a substantial increase in population and living standards and, correspondingly, in the regional energy demand. To accommodate future energy needs, power and energy system communities have been developing least-cost optimization models to support long-term transformational energy system planning and the transition to carbon neutrality at the African continental scale.

However, these models usually focus on annual or seasonal energy balances and overlook higher time resolution dynamics that can actually lead to short but impactful events when considering the expansion of renewable energy share. Indeed, the variability of renewable generation and power demand can lead to significant risks, including elevated electricity prices, transmission line overload, and power generation deficits.

In this work, focusing on the Southern African Power Pool, we couple an energy system planning model, OSeMOSYS-TEMBA, and a power system model, PowNet, to obtain higher temporal resolution characterization of the energy system evolution in the future.

OSeMOSYS-TEMBA is a long-term energy system planning model producing cost-optimal trajectories of capacity expansion for different technologies for all the countries in continental Africa with a seasonal resolution from 2015 to 2070. Yet, OSeMOSYS-TEMBA is not resolved enough to account for power grid reliability under high penetration of renewables, where flexible operations and power grid reliability are crucial, and might substantially affect model projections.

PowNet is a least-cost optimization model running on an annual horizon with hourly resolution and optimizes the dispatch of power from each source as well as the usage of transmission lines, constrained to the power capacity available according to the long-term energy planning provided by the OSeMOSYS-TEMBA model. We assess the difference in generation mix, the impact on transmission lines overloading, power generation deficits in 2030 under three climate policy scenarios: no climate policy, and constrained to 2.0°C and 1.5°C warming constraining emissions to a consistent pathway.

Results indicate power generation deficits and transmission lines overloading are observed in many countries, especially during the night. These impacts are to be associated with insufficient total power system capacity to meet power demand due to the low time and spatial resolution of the energy system model. Indeed, the increased dependency on variable renewable resources, and a higher resolution demand profile emphasize the need to further expand total capacity, the importance of flexible generation adopting a diverse energy portfolio, and the potential benefits of increasing transmission lines' capacity. Finally, the storage of unused water for future power generation within the available reservoirs might potentially reduce the power deficit. These results show the importance of the assumptions embedded in the energy system model and motivate methodological improvements to design coupled energy and power system pathways that remain reliable at high spatial and time resolution.