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Challenges, trade-offs, and opportunities in the design of power transmission lines: a water-energy perspective

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High-voltage transmission lines provide the fundamental service of delivering electricity over long distances, connecting power plants to demand centers. Their role is particularly critical in energy systems characterized by the presence of hydropower, and other renewable resources, whose output exhibits trends and shifts in response to hydro-climatic variability. Yet, the design and operation of transmission networks is rarely placed within a broad water-energy context, often resulting in infrastructures unable to dispatch the available power during peak-production periods. The case in point is Laos: the country has attracted large investments in the hydropower sector, but their effectiveness is severely limited by the capacity of the high-voltage transmission facilities. Here, we show how such challenge could be tackled through the use of process-based models describing the interconnections between water, energy, and power transmission components. Specifically, we run our modelling framework over a broad range of hydro-climatic conditions, so as to identify the transmission lines severely limited by their capacity. With this information at hand, we then explore the potential of both design and management interventions. Potential solutions include the capacity expansion of a few transmission lines and the adoption of a wide area synchronous grid, which facilitates electricity exchange across Laos and Thailand. Results show that both solutions are cost-effective: they require limited investment costs and reduce reliance on fossil fuels, resulting in a significant abatement of CO_2 emissions.