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Promising future for sustainable hydropower development in the Upper Indus basin

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Hydropower is developing rapidly in Asia with limited concerns for long-term sustainability of hydropower plants. In the Indus, a four-fold increase in the 2020 hydropower capacity is envisioned by 2040 in Pakistan alone. Using the Hydropower Potential Exploration (HyPE) model, we investigate the future of hydropower potential in the Upper Indus basin (UIB) to inform such rapid expansion. HyPE uses a spatial cost-minimization framework to evaluate theoretical, technical, financial and sustainable hydropower potential considering the impact of natural, technical, financial, anthropogenic, environmental, and geo-hazard constrains on hydropower development. The model performs optimal siting and sizing of two run-of-river hydropower plant types under these varied constrains to minimize the unit cost of production at both the individual site and the basin scale. HyPE is run with current and future hydrology simulated using a cryosphere-hydrology model to understand the implication of climate change on the available potential in the UIB. Future hydrology is simulated using ensembles of spatially downscaled CMIP6 general circulation models (GCMs) covering a wide range of possible climatic futures under three combinations of the Shared Socio-economic Pathways (SSP) and the Representative Concentration Pathways (RCPs): SSP2-RCP4.5, SSP3-RCP7.0 and SSP5-RCP8.5.

The majority of the projections suggest an increase in annual average discharge. Over 50% increase in average annual discharge and subsequently theoretical potential is seen by the end of the century in the warm-wet corner under SSP5-RCP8.5. Increases in technical, financial and sustainable potential are slightly lower than that for theoretical potential. Some decline as much as -9% is seen only in the cold-dry corner under SSP2-RCP4.5. Higher increases in potential of all classes are seen in the western parts of the basin than in the eastern parts. Also, changes in low flows (-36 to 190%) are more extreme than in high flows (-52 to 109%) resulting in a boom in small projects in the future hydropower potential portfolios. Consequently, the cost curves at the sub-basin scales shift as the nature of hydropower plants vary more across the sub-basin. Furthermore, simulating the actual energy generation of historical and future hydropower portfolios under future hydrology reveals the robustness gained by considering climate change from the initial stages of hydropower design.

Promisingly, even the sustainable potential remains sufficient to establish energy security with intra-basin energy sharing in the UIB in the future. Fulfilling energy security in the downstream regions of the UIB countries, however, will require closer evaluation of how the spatial variation in sustainable hydropower across the UIB may be best leveraged. Sustainable hydropower development should be combined with other renewable energy sources to balance water utilization for hydropower versus other usage throughout the Indus for simultaneous fulfilment of the sustainable development goals (SDG) for water, energy and food security. Most importantly, the positive future of hydropower potential demonstrates that there is already enough leeway to consider factors beyond technical and financial criterion to also incorporate energy justice in sustainable hydropower development.