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The albedo-climate penalty of hydropower

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Limiting global warming to less than 2°C relative to preindustrial times by the end of this century requires a rapid and long-lasting decarbonization. In contrast to the other major renewable energy sources, solar and wind, hydropower reservoirs allow storing energy and releasing it when required, a significant advantage for stabilizing electrical grids. The establishment of hydropower reservoirs typically involves a land-use change when formerly terrestrial ecosystems are inundated. One, hitherto overlooked, consequence of this land-use change is a decrease in surface albedo, as waterbodies are characterized by a lower albedo compared to most terrestrial ecosystems. The main objective of this study is to quantify the positive radiative forcing resulting from this albedo change and to oppose it with the negative radiative forcing resulting from the fossil fuel displacement by the hydropower electricity generation. To that end, we compiled, on the basis of publicly available datasets, a global database of hydropower reservoirs. The hypothetical change in albedo associated with their construction was assessed on the basis of the difference in remotely sensed albedo (MODIS MCD43A1) between the hydropower reservoir and the surrounding landscape. We then calculated the break-even point, that is the time required for the time-integrated negative radiative resulting from the fossil fuel displacement to offset the positive radiative forcing from the albedo difference. The major result from this study is that break-even times range from less than a year up to several years and even a few decades. The key metric governing these differences is the annual electricity generation to reservoir surface area ratio, low ratios resulting in unfavorably long break-even times. Additional influence factors having a modulating influence are latitude, governing the incident solar radiation, and the magnitude of the albedo difference. We conclude that the displacement of fossil fuels by hydropower wins over the albedo penalty in the long-term. In the short-term, and thus for contributing towards the goal of a rapid decarbonization, the albedo penalty may be dominating and needs to be considered in the design of hydropower plants.