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Winter electricity supply and seasonal storage deficit in the Swiss Alps

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Switzerland electricity production depends at 60% on hydropower, most of the remainder coming from nuclear power plants. The ongoing energy transition foresees an increase in renewable electricity production of solar photovoltaic, wind and geothermal origin to replace part of nuclear production; hydropower, in its several forms, will continue to provide the backbone and the guarantee of the instantaneous and permanent stability of the electric system. One of the key elements of any future portfolio of electricity mix with higher shares of intermittent energy sources like wind and solar are fast energy storage and energy deployment solutions. Hydropower schemes with pumping capabilities are eligible for storage at different time scales, whereas high-head storage hydropower schemes have already a cornerstone role in today's grid operation. These hydropower storage schemes have also been doing what can be labelled as "seasonal energy storage" in different extents, storing abundant flows in the wet season (summer) to produce electricity in the dry (winter) alpine season. Some of the existing reservoirs are however under sized with regards to the available water inflows and either spill over or operate as "run-of-the-river" which is economically suboptimal. Their role in seasonal energy transfer could increase through storage capacity increase (by dam heightening, by new storage dams in the same catchment). Inversely, other reservoirs that already store most of the wet season inflow might not fill up in the future in case inflows decrease due to climate changes; these reservoirs might then have extra storage capacity available to store energy from sources like solar and wind, if water pumping capacity is added or increased.

The present work presents a comprehensive methodology for the identification of the seasonal storage deficit per catchment considering todays and future hydrological conditions with climate change, applied to several landmark case studies in Switzerland. In some cases additional storage would allow mitigating negative impacts of climate change. In one of the tested cases the decrease in inflows is such that the reservoir will not fill up in the future; this reservoir will become a priority location for pumping capacity increase, for short-term or seasonal storage of excess solar/wind energy. Considering that the present average rate of glacier mass loss at the country scale is equivalent to the Grande Dixence reservoir per year (the largest Swiss reservoir, approx. 380 hm3), increasing artificial water storage might become mandatory to maintain the same level of security electricity supply in the future.