



## Climate change impacts on Alpine hydropower in the context of environmental impacts and technical constraints

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Hydropower production affects different stakeholders, levels of administration and ecosystems, which makes the question of its sustainability complex. Hydropower delivers energy, storage capacity, jobs, economic value, but also involves altered streamflow, water temperature and sediment transport conditions, fractioning of aquatic habitats and modification of the landscape. Thus, an increasing demand for renewable and climate friendly energy from hydropower also results in more pressure on aquatic habitats, thereby potentially calling into question its sustainability.

In this work, we compare climate change impacts on the future energy production of 21 hydropower plants in Switzerland, to impacts related to environmental flow requirements and to site-specific technical optimisation potential. The simulation-based study corresponds to three future periods (2020–2049, 2045–2074 and 2070–2099) under three emission scenarios (RCP2.6, RCP4.5, RCP8.5), assuming unchanged environmental flow requirements and installed machinery. The results show an increase of winter production and a decrease of summer production, which in conjunction leads to an annual decrease. The simulated impacts strongly depend on the elevation and the plant-specific characteristics. The climate induced changes in production are of a similar order of magnitude as the production loss due to environmental flow requirements and the increase potential due to technical optimisations. A key result is that the climate induced reduction is not linearly related to the underlying streamflow reduction, but is modulated by environmental flow requirements, the design discharge and streamflow projections. Taken a step further, a change in production does not necessarily mean a linear change in financial revenue. The Water-Energy Nexus in terms of hydropower concerns more than just a  $\text{m}^3\text{s}^{-1}$ -kWh relationship: it is part of a complex framework that is namely sensitive to legal adjustments and to long lasting technical decisions taken in the past.