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Future Alpine hydropower production: impacts of climate change, residual flow and technical optimization on Run-of-River power plants in Switzerland

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In Switzerland, around 57 % of electricity is generated by hydropower (HP), whereof around 25 % are produced by run-of-river (RoR) power plants. This share is expected to only slightly increase in the context of the Swiss energy strategy 2050, by about 10 % (in total 38'600 GWh/a). Nevertheless, growing energy demand coupled to growing ecological awareness is catapulting hydropower into a position of great expectation and responsibility. In this context, the present research project proposes to assess the impact of climate change and of evolving environmental flow constraints on RoR production in Switzerland. The obtained results are compared to the production increase that could potentially be achieved by technical optimization.

To assess climate change impacts, daily runoff until the end of the century was calculated with the hydrological model PREVAH, using a total of 26 climate model chains in transient simulation from the new Swiss Climate Change Scenarios CH2018, corresponding to the two different CO_2 emission scenarios RCP2.6 and RCP8.5. Changes in HP generation under climate change are estimated for 11 RoR power plants based on differences in the flow duration curves (FDCs) between the reference period (1981-2010) and the future periods (2045–2074 and 2070–2099), assuming unchanged installed machinery and residual water flow requirements.

The changes in HP production from RoR power plants are due to changes in precipitation, temperature and evaporation, which in turn have a strong impact on the dominant hydrological processes (snow accumulation and melt, glacier melt and runoff production), and show important spatial and temporal differences. By mid-century (2045–2074) and under concerted mitigation efforts (RCP2.6), annual production will remain roughly the same as during the reference period. Production will decrease slightly (about -3 %) without climate change mitigation (RCP8.5). Exceptions are power plants which are strongly influenced by melt processes. Due to reduced snowfall and increased winter precipitation and ensuing higher winter streamflows, winter production will increase at almost all RoR power plants considered in this study by mid-century, by about 5 % on average.

By the end of the century (2070–2099), a slight decline of the annual production (-1.5 %) is to be

expected under RCP2.6. Without climate change mitigation (RCP8.5), annual production will fall further (-7 %). Winter production will increase at virtually all studied RoR power plants. Depending on the emissions scenario, the average winter production increase will be between 5 % (RCP2.6) and 10 % (RCP8.5). However, this increase in winter production will not be sufficient to prevent annual production decline.

These climate change induced reductions of annual HP can be put into context by comparing the production losses that result from residual flow requirements. For the RoR power plants under consideration, compliance with legal constraints on residual flow rates, compared to no residual flow, means a difference of less than 4 %. We will discuss in detail the relevance of ecological constraints and of technical and thereby give a complete picture of emerging challenges and opportunities for Alpine hydropower production under climate and societal change.