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Future Alpine hydropower production

Impacts of climate change, environmental flow and technical optimization on Run-of-River power plants in Switzerland

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Research questions

- **How will Run-of-River (RoR) power production in Switzerland change under climate change?**
- **What does the climate induced change in hydropower (HP) production mean compared to the potential increase by optimizing the design discharge or to losses due to environmental flow requirements?**

Method

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 (with the assumption of concerted mitigation efforts) and RCP8.5 (with the assumption of no climate change mitigation). Changes in HP generation under climate change are estimated for eleven RoR power plants based on differences in the flow duration curves (FDCs) between the reference period (1981–2010) and the future periods mid-century (2045–2074) and end of the century (2070–2099), assuming unchanged installed machinery and environmental flow requirements (Fig. 1).

The changes in HP production from RoR power plants depends mainly on the change in the usable water volume, which is controlled by the design discharge of the power plant and the environmental flow regulations. The potential of the design discharge is estimated in this study by assuming that it equals the flow which is exceeded at 80% percentile based on the mean FDC of the reference period (Fig. 1). The loss due to environmental flow regulations is compared with the scenario as if there were no environmental flow currently.

RoR plant Wildegg/Brugg – Aare
(a typical river of the Swiss plateau)

RoR plant Davos Glaris – Landwasser
(a typical alpine river)

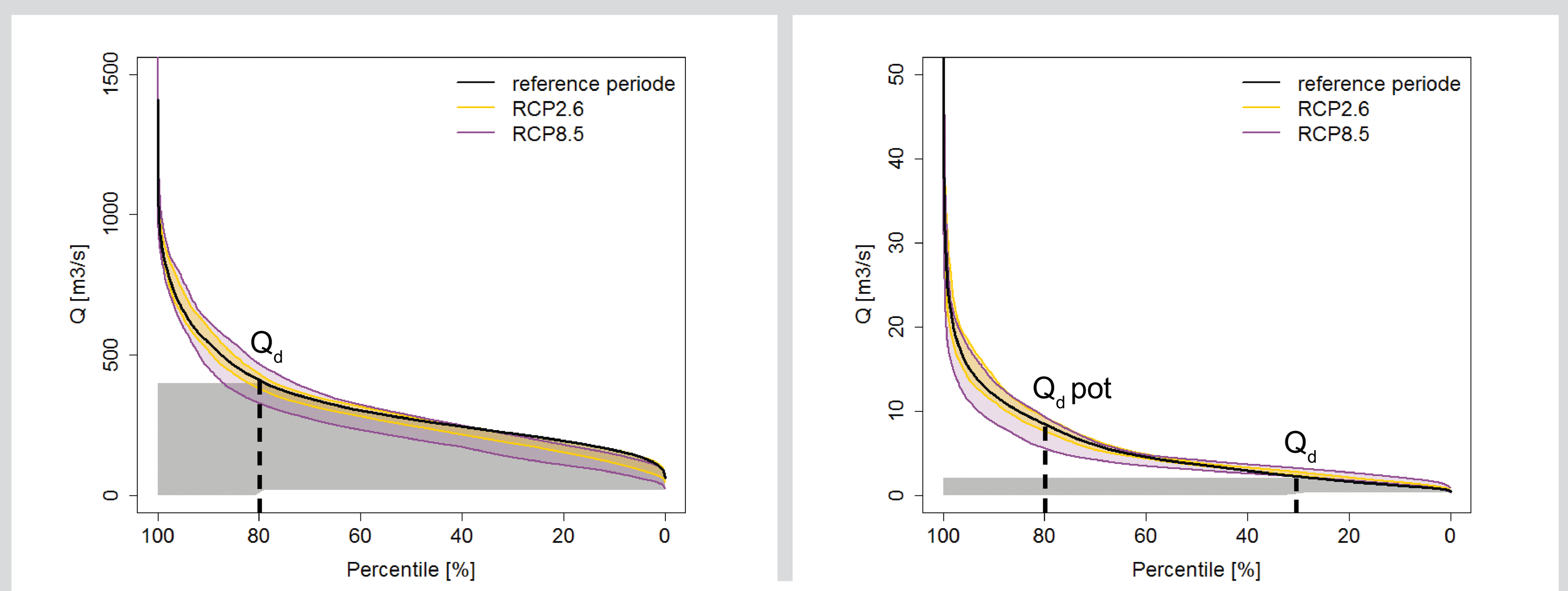


Fig. 1. Flow duration curves (FDCs) for the RoR power plants Wildegg-Brugg (Aare; left) and Glaris (Landwasser; right). The black line represents the reference period (1981–2010), the grey shaded area represents the usable water volume controlled by the design discharge and the environmental flow requirements. The areas bounded by yellow curves and purple curves represent the range of FDCs for the projected RCP2.6 and RCP8.5 emissions scenarios, respectively, for the end of the century. Q_d represents the current design discharge; $Q_d$pot the design discharge at the 80% percentile if it is not exceeded yet.

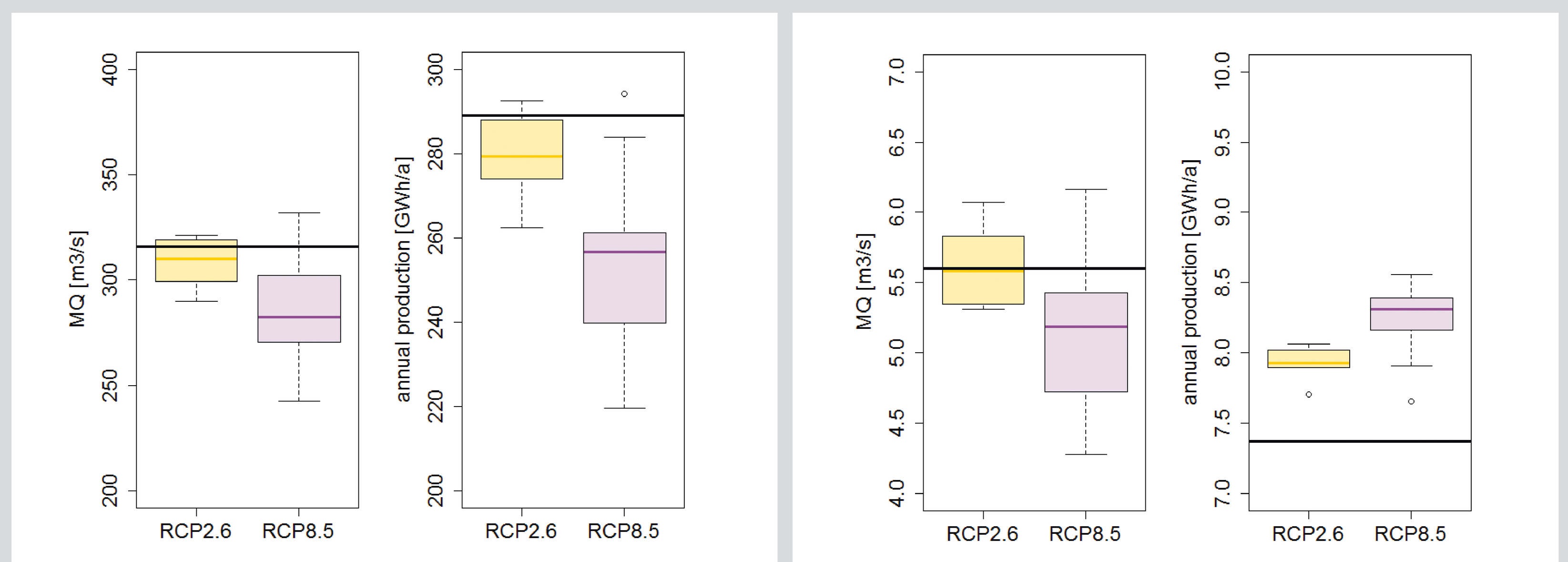
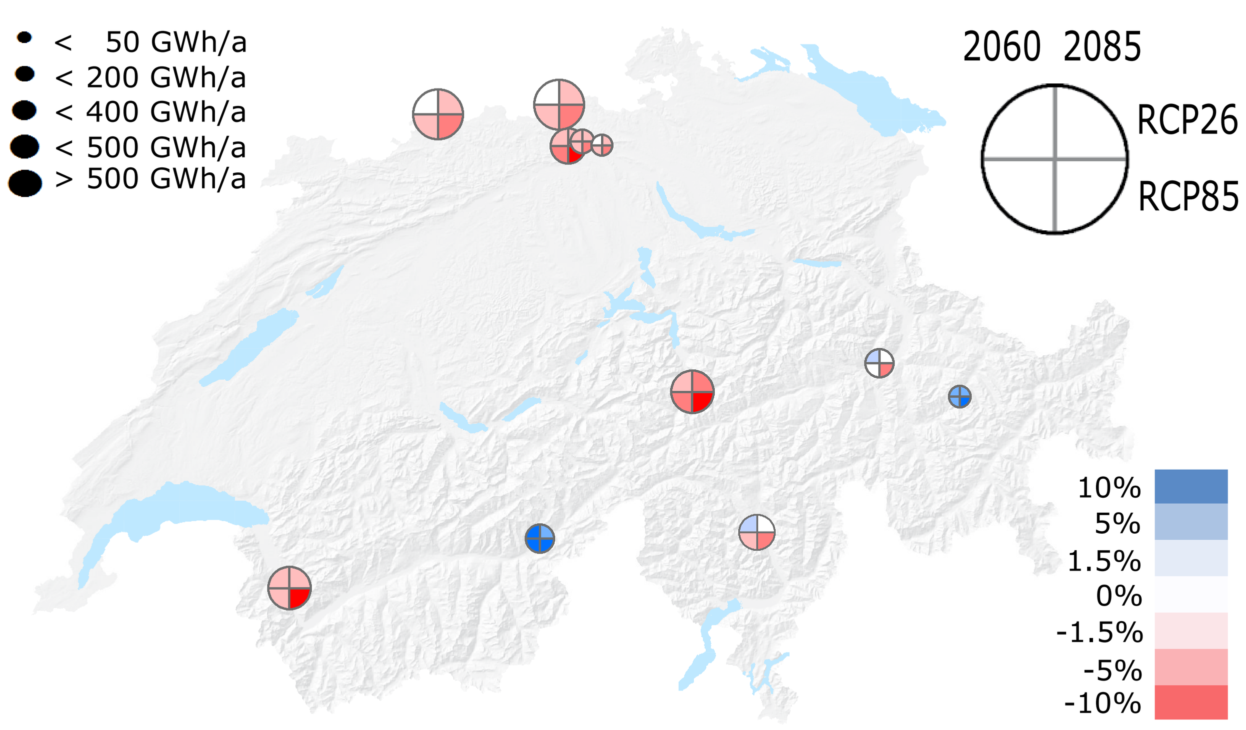


Fig. 2. The expected changes in the annual mean discharge [MQ] and mean production [GWh/a] at the Wildegg-Brugg power plant (left) and at the Glaris power plant (right) for the end of the century. The black line indicates the median value of the reference period. The yellow (RCP2.6) and purple (RCP8.5) boxplots represent the range of the different model chains under current design discharge and environmental flow requirements.

The water volume usable for HP production (shaded area – Fig. 1) depends mainly on low and medium water ranges. For the RoR power plant Wildegg-Brugg, the hydrological predictions indicate that both the average water supply and the annual production will decrease in the future (Fig. 2 left). For the RoR power plant Davos Glaris, which is heavily influenced by snow, the total water supply will decline by the end of the century; still, HP production is likely to increase due to the change in the lower and medium water range (Fig. 2 right).

Results

Change in mean annual production
for eleven selected RoR power plants



Change in mean winter production (Oct – Mar)

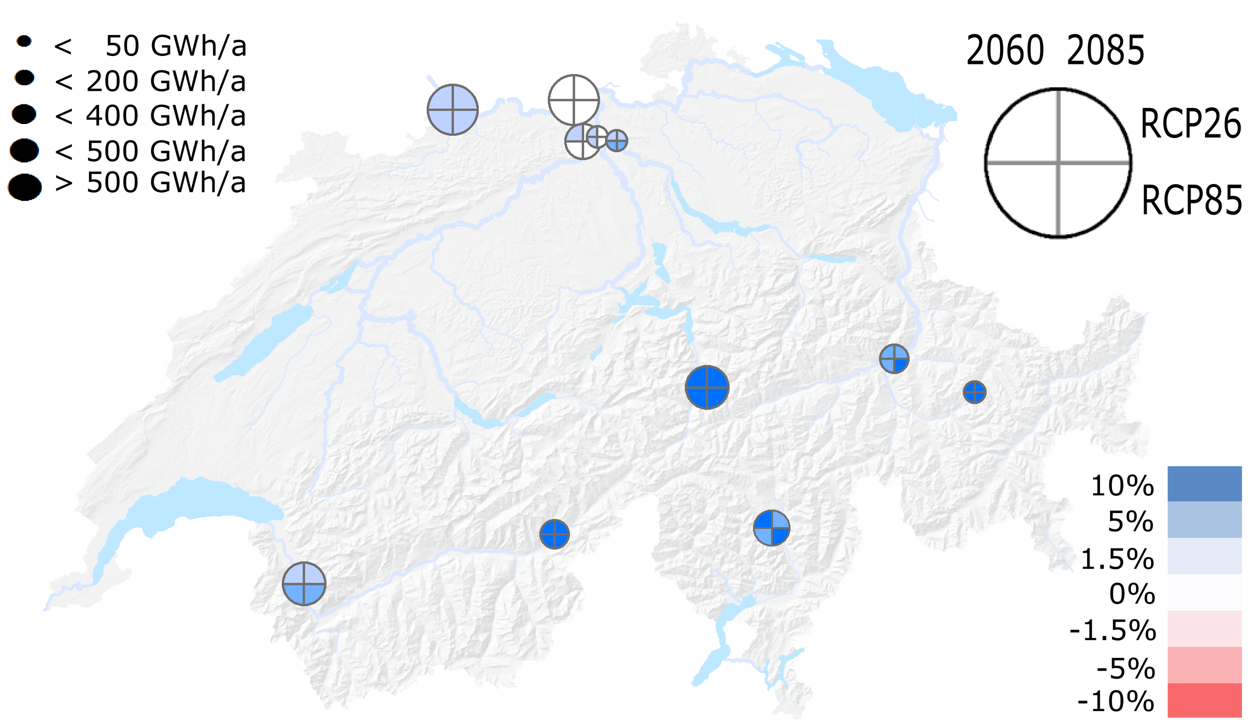
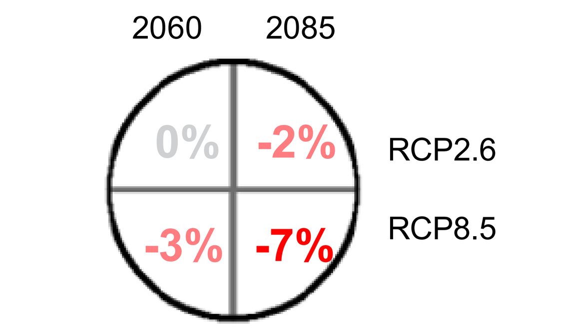


Fig. 3. Expected changes in annual (above) and winter (below) production of selected Swiss run-of-river power plants for the periods 2060 (mid-century, 2045–2074) and 2085 (end of century, 2070–2099). The calculations are based on the most recent Climate Change Scenarios CH2018 established by MeteoSwiss (21 climate models; two emission scenarios: with concerted mitigation efforts RCP2.6 and no climate change mitigation RCP8.5) and a state-of-the-art hydrological model (PREVAH), taking into account current installed machinery and environmental flow requirements.

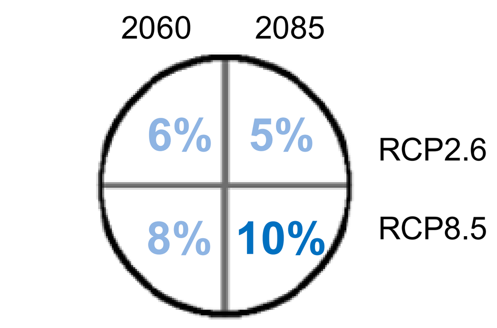
Overall projection for RoR power production in Switzerland

Climate induced changes in production 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. Climate change impact on production for the eleven considered RoR power plants (Fig. 3) means:

Future annual production



Future winter production



For the eleven RoR power plants under current hydrological conditions,

- the potential that could be achieved by optimizing the design discharge ($Q_d$pot = 80% percentile) is an increase of 6% in production.
- Compliance with legal constraints on environmental flow rates, compared to no residual flow, means a decrease of 4% in production.

Reference

SCCER-SoE, 2019: Climate change impact on Swiss hydropower production: synthesis report. Swiss Competence Center for Energy Research – Supply of Electricity. Zurich, Switzerland. 28 p.