The role of glacier retreat for Swiss hydropower production

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Introduction

Wide-spread glacier retreat since the development of hydropower production (HP) infrastructure
= depletion of long-term water storage that cannot be replenished by precipitation in the coming decades.

➔ Role of glacier mass loss for high elevation / high latitude HP ?

➔ Past & future share of Swiss HP from glacier mass loss

Reference: Schaefli et al., The role of glacier retreat for Swiss hydropower production, submitted to Renewable Energy

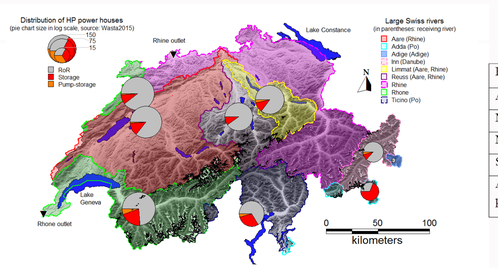
Case study

Switzerland produces over 50% of its electricity from hydropower (Fig. 1). Available water resources from precipitation are around 1300 mm yr^{-1} .

➔ Glacier mass change for all Swiss glaciers from 1980 to 2010
= – 620 mm yr^{-1} (relative to the glacier area in 2010, i.e. 944 km^2)

Source: Fischer et al., 2015

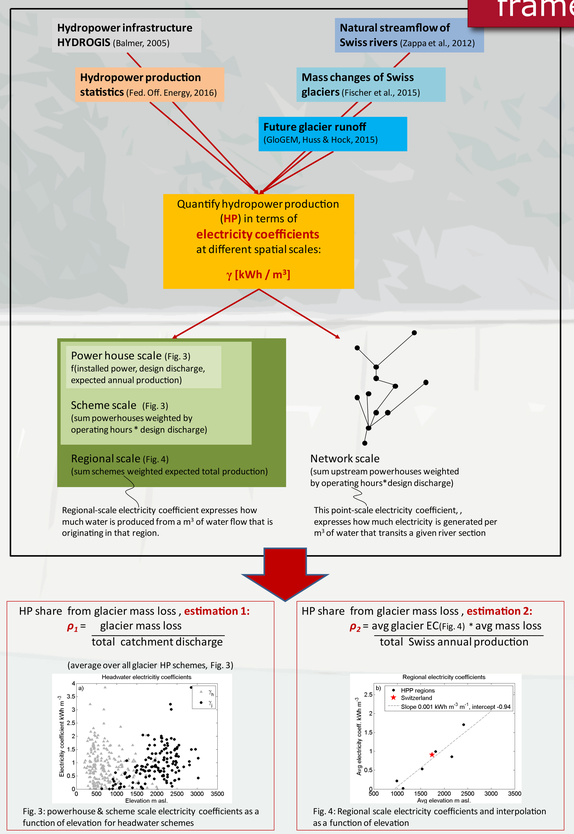
➔ Relative to Swiss area (41'285 km^2): –14 mm yr^{-1} .



Hydropower production	TWh yr^{-1}
Average production	35.7
Maximum (year 2001)	42.3
Minimum (year 1996)	29.7
Standard deviation	3.0
Average consumption for pumping	1.9

Figure 2: Left: Distribution of main types of HP powerhouses in the nine main Swiss river catchments; right: average HP (1980 – 2016); data source: Swiss Federal Office for Energy, 2015, 2016

Assessment framework



HP share from glacier mass loss , **estimation 1:**

$\rho_1 =$ glacier mass loss / total catchment discharge

(average over all glacier HP schemes, Fig. 3)

Fig. 3: powerhouse & scheme scale electricity coefficients as a function of elevation for headwater schemes

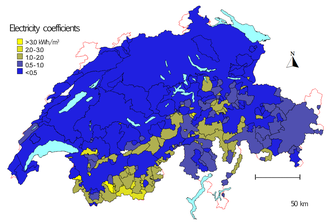
HP share from glacier mass loss , **estimation 2:**

$\rho_2 =$ avg glacier EC(Fig. 4) * avg mass loss / total Swiss annual production

Fig. 4: Regional scale electricity coefficients and interpolation as a function of elevation

Fig. 2: Assessment framework developed for the analysis of HP from glacier mass loss at different spatial sclaes, for the past (1980 - 2010) and for two future periods (2040-2060 and 2070 - 2090).

Results



Swiss-wide HP
from glacier mass loss
1980-2010 ρ_1 = 3.1 %
1980-2010 ρ_2 = 4.0 % (2.3% - 6.2%)
2040-2060 $\rho_{1,fut1}$ = 2.5%
2070-2090 $\rho_{1,fut2}$ = 1.2%

Figure 5: Left: Distribution of electricity coefficients of all hydropower production schemes. Catchments are nested, lowland RoR catchments contain upstream catchments. Right: estimated average production share from glacier mass loss (Swiss-wide).

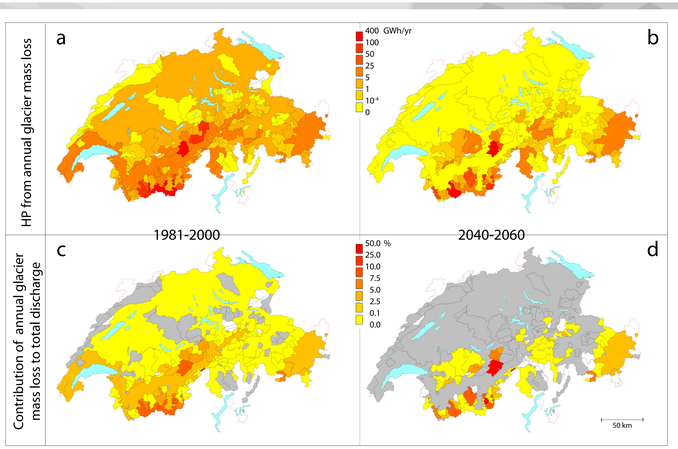


Figure 6 : Distribution of hydropower production from glacier mass loss; a) ratios ρ_1 for the period 1981-2000, b) ratios for the period 2040-2060 based on GloGEM simulations; c) hydropower production from glacier mass loss in GWh yr^{-1} for period 1981-2010, d) 2040-2060 based on GloGEM simulations.

Conclusion

➔ Since 1980, 3.0% to 4.0% (1.0 to 1.4 TWh yr^{-1}) of Swiss hydropower production directly provided by glacier mass loss

➔ For 2070-2090, a production reduction of 1.0 TWh yr^{-1} is anticipated, with general production decline starting before 2040 - 2060

➔ Exception: Rhone river with today 6.4% to 8.6% of HP from glacier mass loss and reduction expected only by 2070-2090.

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