The hydropower potential of future ice-free basins worldwide

Vanessa Round, Matthias Huss, Daniel Farinotti

Swiss Federal Institute for Forest, Snow and Landscape Research WSL
Laboratory of Hydraulics, Hydrology and Glaciology (VAW)

Eidg. Forschungsanstalt für Wald, Schnee und Landschaft WSL

Versuchsanstalt für Wasserbau Hydrologie und Glaziologie

Introduction: new futures for glacial landscapes

New landscapes and new lakes

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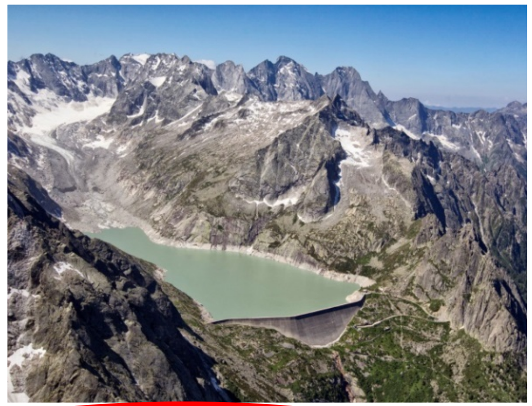
Hazards?

Tourism?



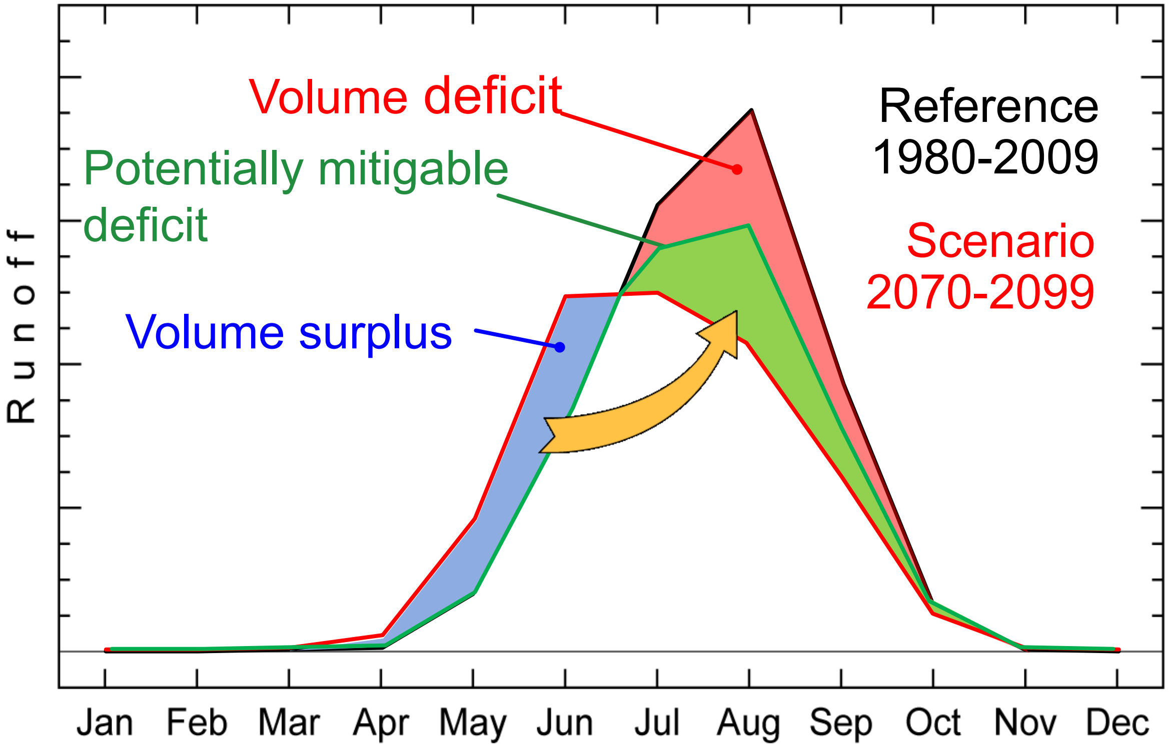
Hydropower?

Could the basins emerging through glacier retreat provide new locations for dams, for hydropower and water management?

Advantage: new periglacial environment has little established land-use and undeveloped ecosystems.

Introduction: preceding studies

Dams to mitigate projected changes in seasonal runoff (*Farinotti et. al, ERL,2016*).



→ 65% of projected summer glacier runoff deficit in Europe could be mitigable.

Dams for in place of glaciers for hydropower production - Trift Glacier

Introduction: aims of the study

- Quantify the theoretical hydropower potential of deglaciating areas
  - → potential hydropower production
  - → potential water storage capacity

  How does this potential evolve over time?

- Assess the feasibility of each location: taking into account environmental, technical, economic and social factors.

…for all glaciated regions worldwide

Methods: theoretical storage volumes

Dam simulated at the current terminus of each glacier.

Subglacial topography:

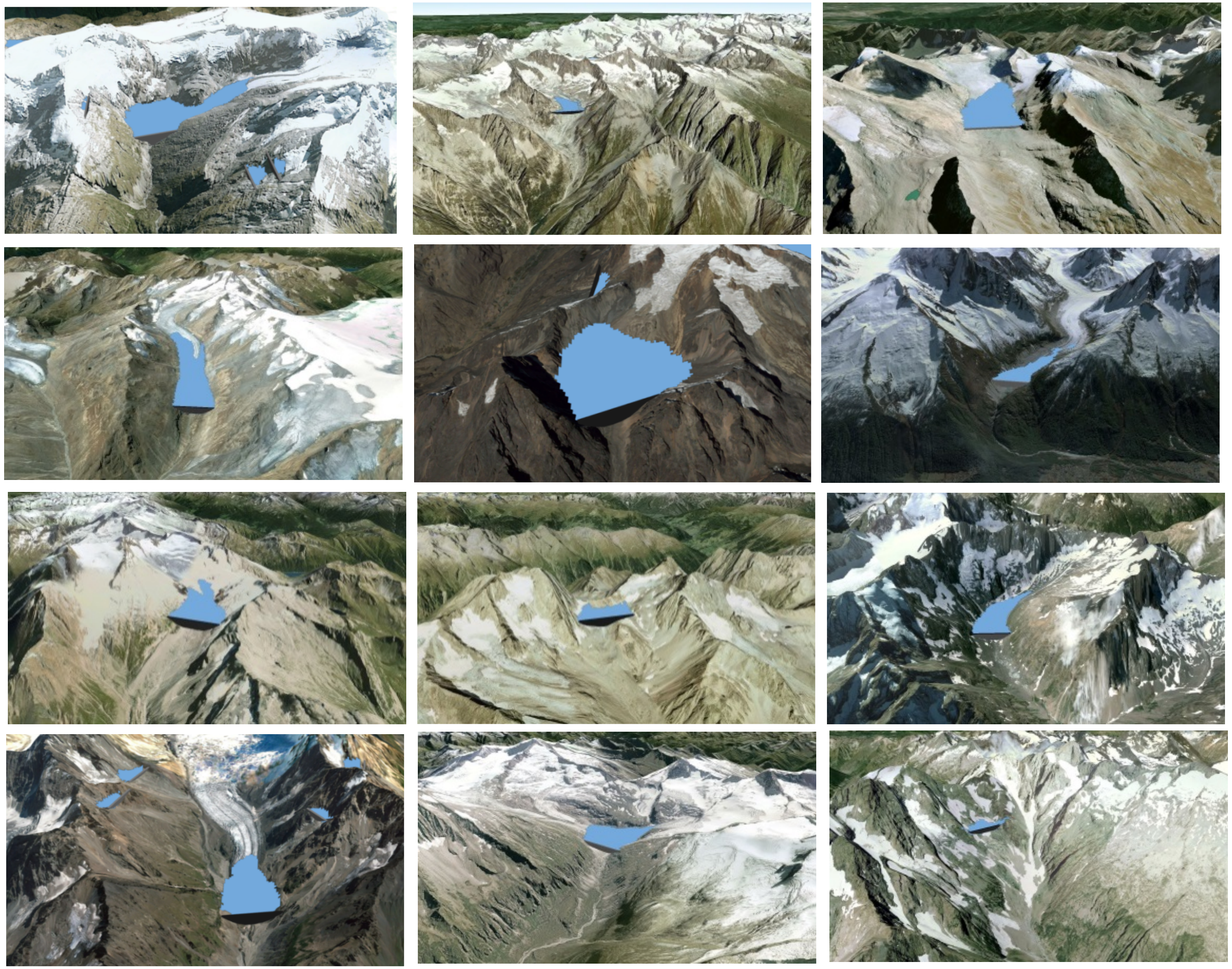
Global ice thickness model

(*Huss & Farinotti 2012*)

Reservoir optimization:

- Wall dimensions and angle providing minimum "wall area / lake volume" ratio
- Max. 300m high, 800m wide

Repeated for every Glacier



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Methods: theoretical power production

*Power = Hydraulic head * Runoff rate * gravity * density * efficiency*

Available hydraulic head

Maximum elevation drop from glacier terminus

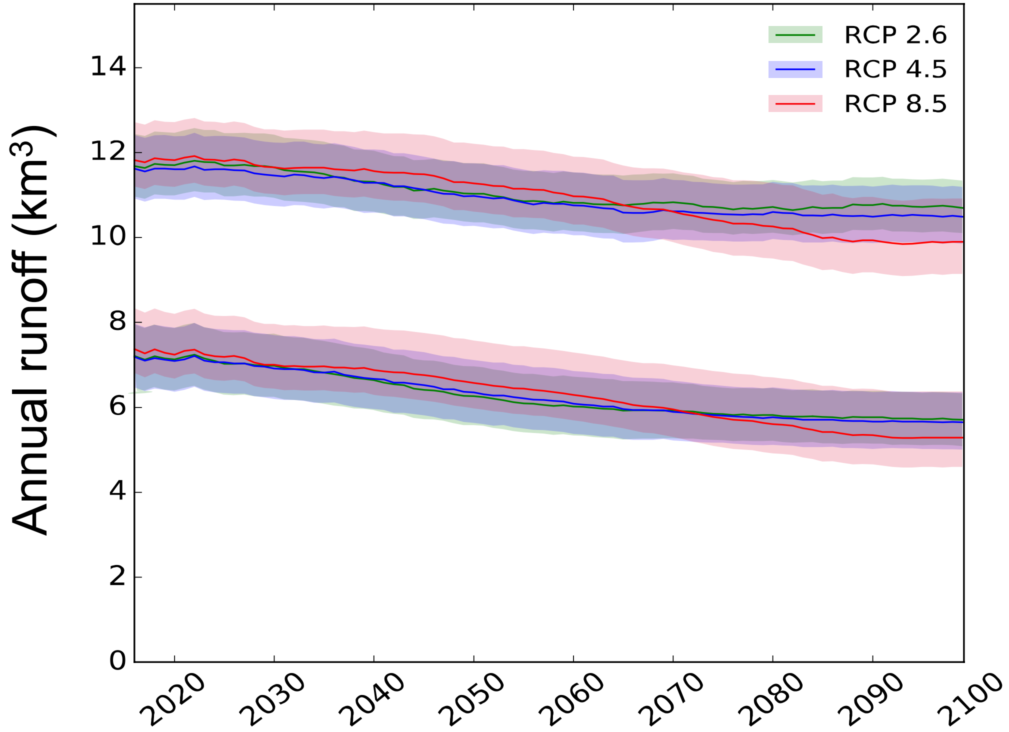
- various slope and distance limits

(Elevation data from ASTER global DEM)

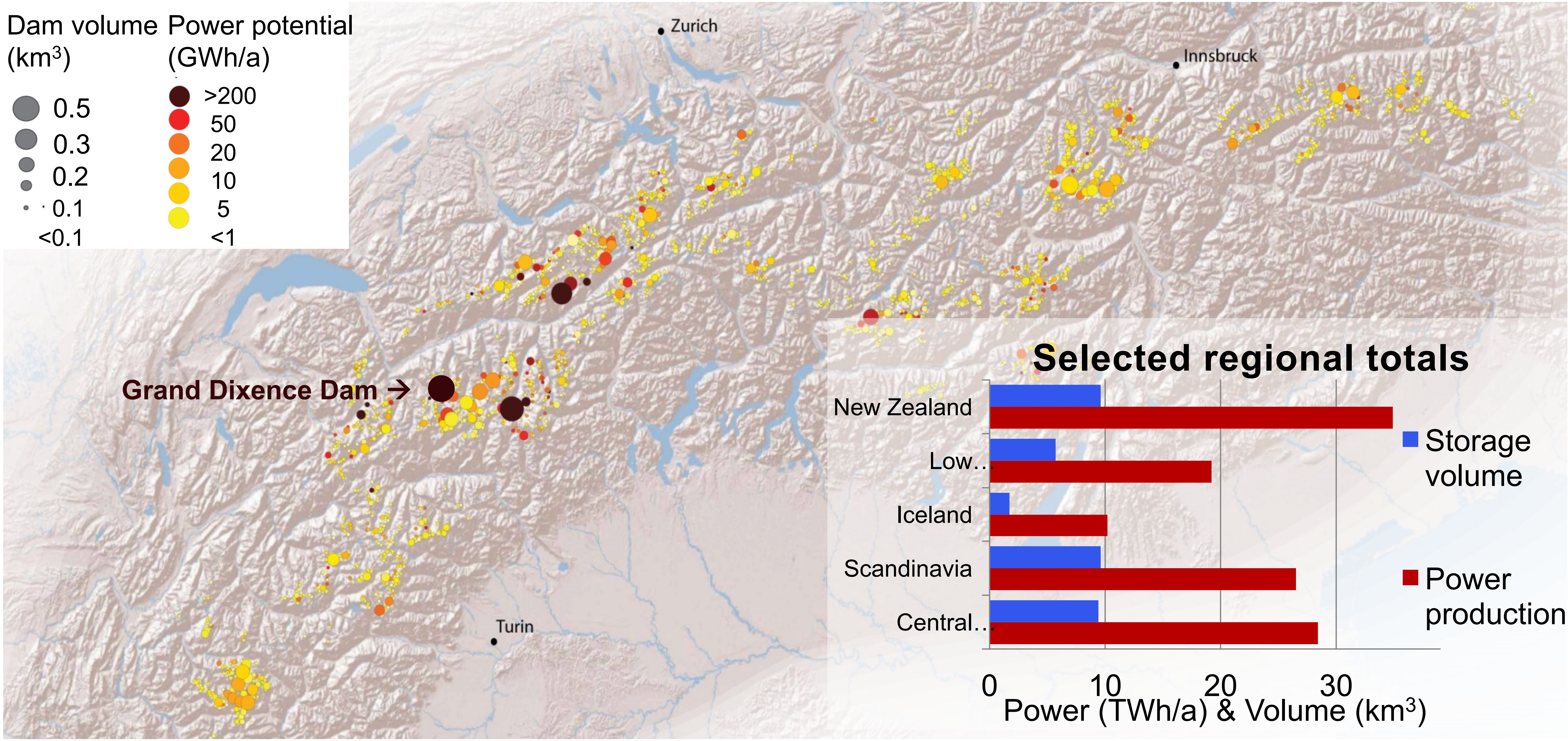
Runoff rate

Projected glacier runoff Global Glacier Evolution Model *(Huss & Hock, FRO, 2015)*

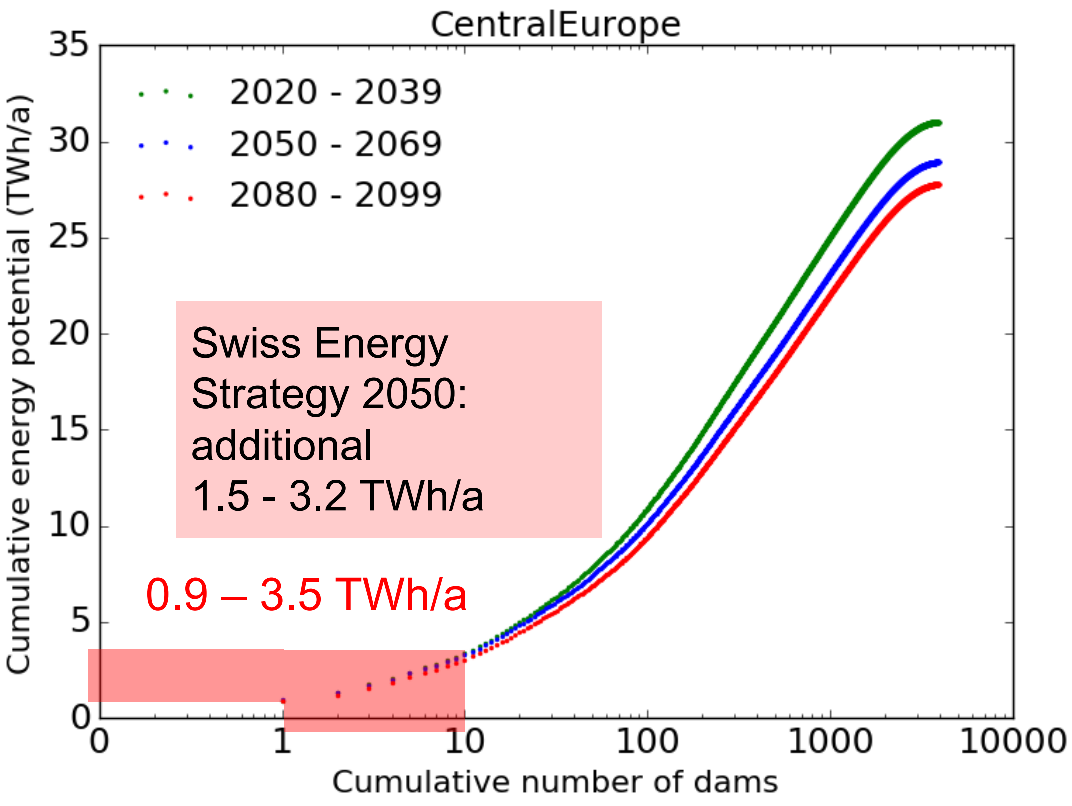
→ Precipitation runoff extrapolated to whole watershed



Results: theoretical potential European Alps example

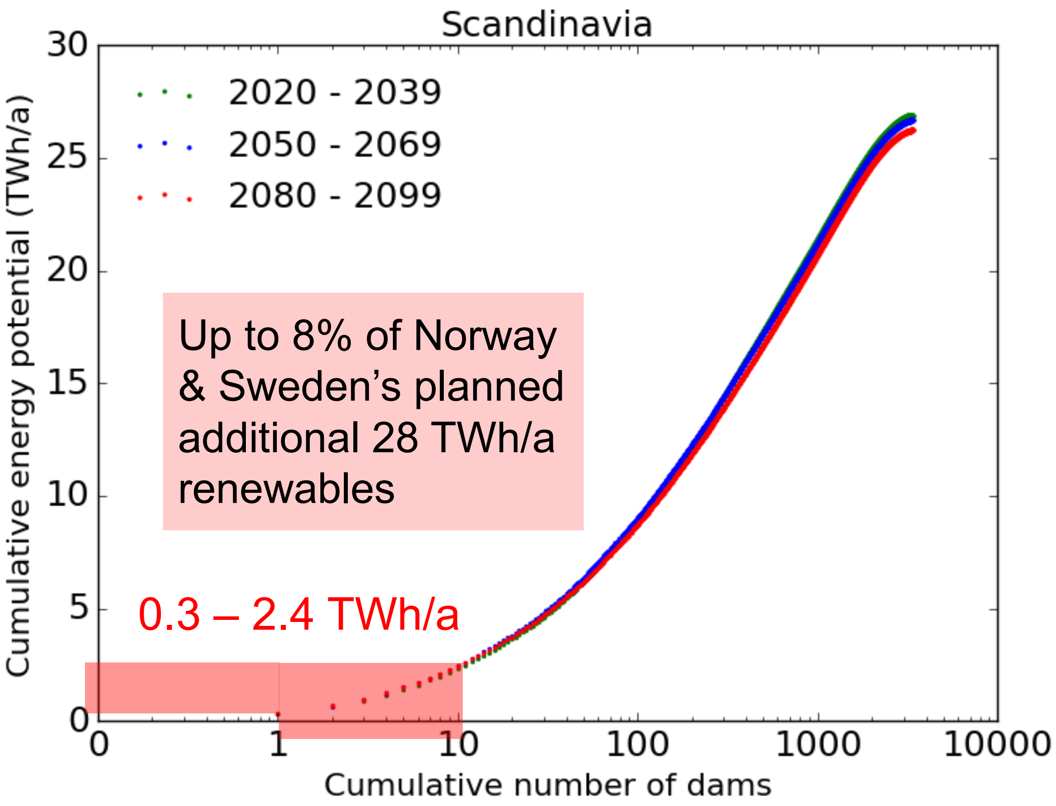


Theoretical potential: a realistic number of dams



Up to 10 largest dams

A small number of dams could be a significant contribution to renewable energy targets!



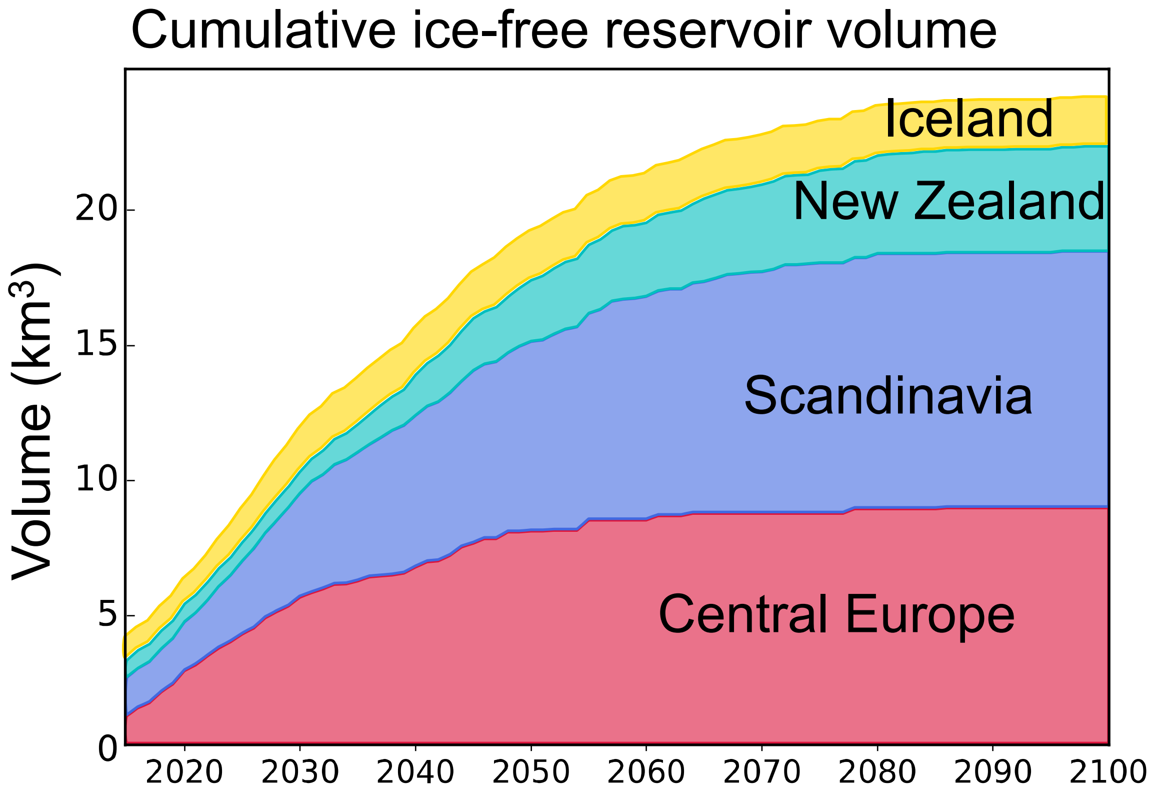
Up to 10 largest dams

Less significant potential from the largest dams
→ Partly due to less hydraulic head

Theoretical potential results: temporal evolution

When will the potential basins become ice free?

Ice-free year for each glacier:
Temporal evolution of minimum ice elevation comes from Global Glacier Evolution Model



Much of the potential volume becomes ice-free after mid century

Feasibility assessment: global parameters

Goal: Assess the feasibility of each site (each glacier) on the global scale

Hydropower Sustainability Assessment Protocol

Environmental and social indicators

- Density of endangered species
- UNESCO protected areas
- Demand: global gridded population density
- World Bank Development indicators:
  - political effectiveness and capacity
  - power production, usage, accessibility

Economic factors

- Accesses cost: Global "travel time" data
- Construction cost: dam dimensions
- Costs to benefit ratios

Technical

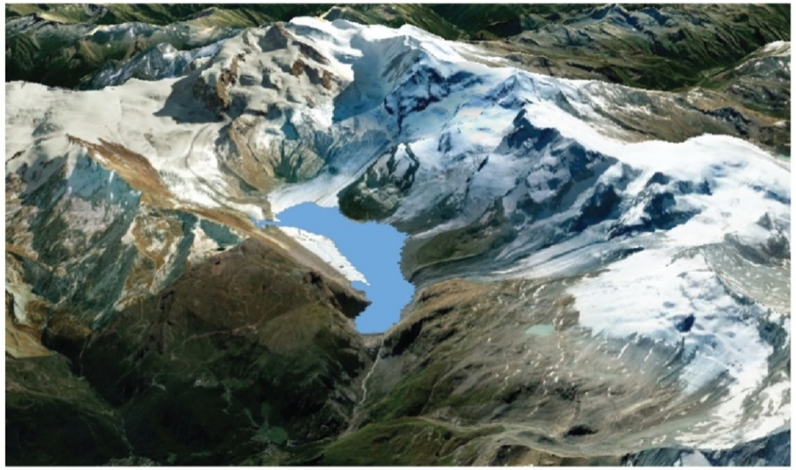
- Rock fall potential: average catchment slope
- Reservoir fill time (volume / runoff)
- GloGEM modelled ice retreat

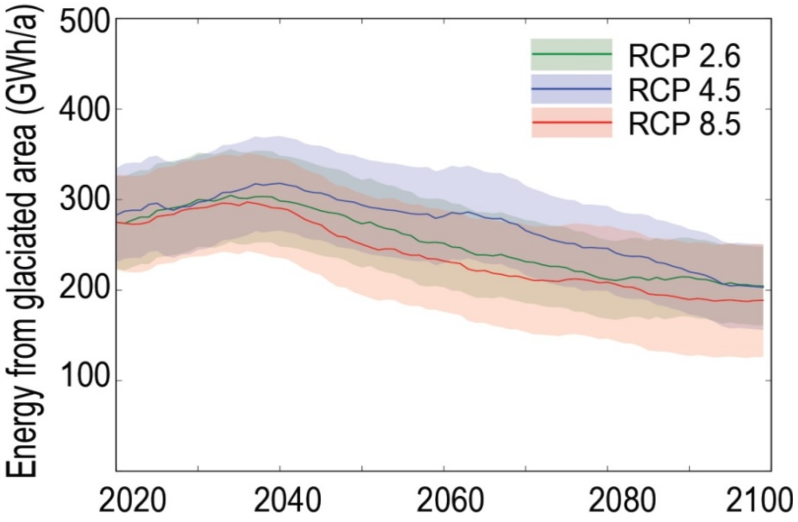
Challenge: combining and weighting all the parameters?

Which factors are the most important?

Results: site feasibility assessment

An individual example: Gornergletscher





Theoretical technical potential:

Mean power → 255 GWh/a

Dam volume → 385 mil. m^3

Time to fill → 1.5 years

Ice free basin → 2055

Feasibility indicators:

People supplied → 50,000

Endangered species → none

Accessibility → 171 minutes

World heritage → none

Watershed slope → 26°

For comparison:

Largest current dam in the European Alps

Volume ~ 400 mil. m^3

Power ~ 2 TWh/a

Large potential but not feasible:

- **1.8 TWh/a Iceland**
  (but no dam)

> 500 mio m3 (New Zealand)
(not becoming ice-free)

Conclusions and outlook

Glacier retreat exposes new landscapes with potential for artificial storage

✓ A first order quantification of the total hydropower potential (storage volume and power) of deglaciating basins

✓ Assessment of individual site potential and feasibility

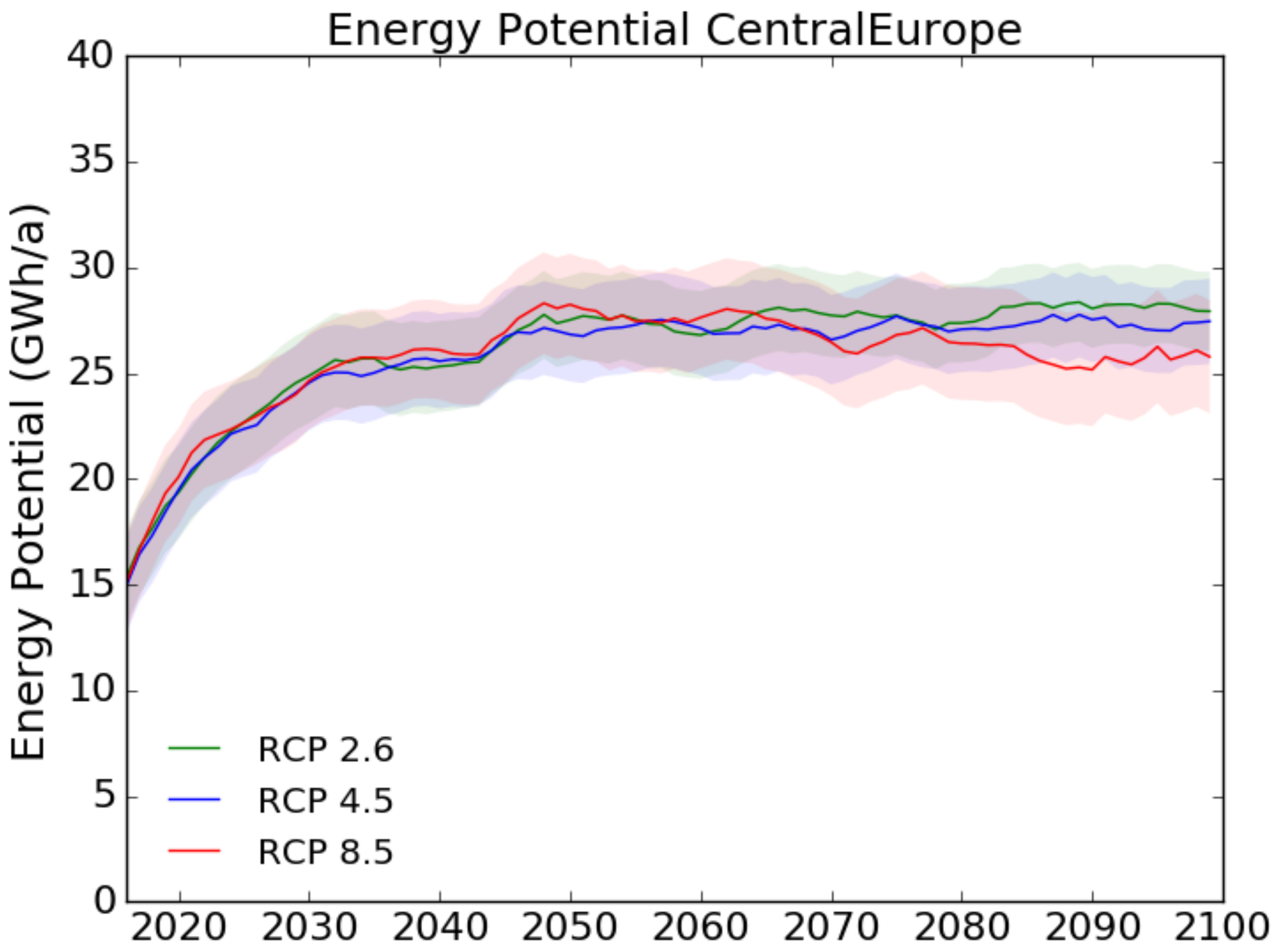
- Many potential storage sites becomes ice-free by 2050
- Just a small number of the ‘best’ dams could have a significant contribution to regional renewable energy targets
- Potential volume and power production similar to some of the largest existing alpine dams (>500 mio m^3, >2000 GWh/a).
- Many global datasets can provide an indication of feasibility

Outlook: Expansion to all glaciated regions globally is still underway

Combining feasibility factors still being finalized


Thank you for your attention!

Theoretical potential results: temporal evolution



Two temporal components:

- **Catchment runoff**
- **Locations becoming ice-free**

Technical potential limitations:

- Simplified technical construction parameters (dam and penstock)
- Not considering existing lakes or hydropower infrastructure
- Economic, environmental, social, technical feasibility??

→ Next step: assessing potential site feasibility