The worldwide hydropower potential of periglacial environments

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SCCER-SoE annual conference – Horw
Glacier change: local effects

New landscapes

New glacier lakes

1977 - 2008

Hazards?  Tourism?  Hydropower?

Images © Glaciers online
Glacier change: downstream effects

Changes to seasonal runoff regime

Volume deficit
Potentially mitigable deficit
Volume surplus

Reference 1980-2009
Scenario 2070-2099

Idea: Use artificial storage reservoirs in place of glaciers to mitigate seasonal deficit?

→ What about the hydropower potential of such artificial storages?

Farinotti et al., ERL, 2016
Dams instead of glaciers?

The idea is not completely new... and has been implemented in the past.

Triftgletscher, Switzerland

Goal:
Quantify the theoretical hydropower potential of deglacierizing areas at the global scale.

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Subglacial topography
(from Huss & Farinotti, JGR, 2012)

Place a dam at the current glacier terminus

Reservoir optimization:
- wall angle providing minimum “wall area / lake volume” ratio
- max. 280m high, 800m wide
Theoretical storage volumes

- Place a dam at the current glacier terminus
- Reservoir optimization:
  - wall angle providing minimum "wall area / lake volume" ratio
  - max. 280m high, 800m wide
- Repeated for all 200,000 glaciers on Earth.

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

Power = hydraulic head \cdot \text{runoff rate} \cdot \text{gravity} \cdot \text{density} \cdot \text{efficiency}

Hydraulic head
Maximum elevation drop from glacier terminus (use ASTER global DEM and impose min slope)

Runoff rate
Glacier runoff projections from the Global Glacier Evolution Model (GloGEM) (Huss & Hock, FRO, 2015)
### Results: Theoretical potential

<table>
<thead>
<tr>
<th>Dam volume (km³)</th>
<th>Power potential (GWh/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>&gt;200</td>
</tr>
<tr>
<td>0.3</td>
<td>50</td>
</tr>
<tr>
<td>0.2</td>
<td>20</td>
</tr>
<tr>
<td>0.1</td>
<td>10</td>
</tr>
<tr>
<td>&lt;0.1</td>
<td>5</td>
</tr>
</tbody>
</table>

- **We are here**

**Swiss Energy Strategy 2050:** additional 1.2 - 3.2 TWh/a

- **2 – 10 of the largest dams**
Global total potential $\approx 1.4$ PWh/a

$\approx 1/3$ of today’s global hydropower production

ca. 20% of total
Global total potential $\approx 1.4$ PWh/a
What’s about suitability?

Remember: It’s about 200,000 sites.

Environmental and social indicators
- World Heritage and protected areas
- Density of endangered species
- Global population density (proxy for demand)
- World Bank Development indicators:
  • political effectiveness and capacity
  • power production, usage, accessibility

Technical
- Reservoir fill time (=volume/runoff)
- Timing of glacier retreat, and surging
- Catchment slope (proxy for gravitational hazards)

Economic factors
- Accessibility cost: Global travel time grid
- Construction cost: Dam dimensions
- Costs to benefit ratios
Suitability indicators

Combined suitability

World Heritage
WDPA protected areas
Endangered species
Glacier surging
Deglaciation year
Steepness
Dam capacity
Accessibility
Ocean terminating

~550 TWh/a “left”

Suitable realization barriers for ca. 60% of the sites.

Suitability: high moderate low excluded

Energy potential TWh a⁻¹
Everything combined, and put into context

Only high and moderate sites
Conclusions

- We provide the **first quantification of the hydropower potential from deglacierizing areas at the global scale** (ca. 200,000 potential sites).

- We estimate the **potential to be ca. 1.4±0.5 TWh/a**, of which about 40% passes a first-order suitability assessment.

- For some Countries, a **small number of large dams could have a significant contribution to the national electricity demand**.

- We acknowledge that our **analysis is not exhaustive, and stress that site-specific analysis is necessary**.
Thank you for your attention!
Top 10 sites* per country

* by energy potential

- United States (<1 %)
- China (<1 %)
- Canada (2.1 %)
- Nepal (>100 %)
- India (<1 %)
- Pakistan (7.7 %)
- Iceland (22.0 %)
- Bhutan (>100 %)
- Tajikistan (24.0 %)
- Switzerland (5.0 %)
- Chile (4.0 %)
- New Zealand (5.3 %)
- Kyrgyz Republic (19.0 %)
- Georgia (17.0 %)