Outline

• Introduction
• Potential changes in HP generation and storage
• Challenges and opportunities for hydropower
• Synthesis
• Recommendations

Fieschergletscher and Wysswasser (Picture: VAW 2013)
Introduction
The present and future role of HP

Present:
Central pillar of Swiss electricity generation portfolio
• ~57% of total electr. generation
• Electricity imports in winter half year

Future:
Swiss Energy Strategy (ES) 2050
• Production targets
  – ≥ 37.4 TWh/yr in 2035 (Energy Act)
  – 38.6 TWh/yr in 2050 (Federal Council 2013)
  – increase of ≥ 5 TWh/winter by 2035 (EICom, 2020)
• Increasing need for regulating power
Introduction

HP *strengths* and weaknesses

Hydropower is favorable with respect to:

- Energy Return on Energy Investment (EROI)
- Energy Stored on Energy Invested (ESOI)
- Life-Cycle Assessment (LCA)
- Green-House Gas (GHG) emissions

Source: adapted from Steffen et al. (2018)
Introduction
HP strengths and weaknesses

Hydropower can have negative impacts on terrestrial & aquatic ecosystems

- Longitudinal connectivity (e.g. fish & sediment continuum)
- Residual flow reaches
- Hydro-/thermopeaking

Effects of dam-reservoir systems on fundamental riverine bio-physical processes

Source: Poff & Hart (2002)
Potential changes

*Generation*: new schemes, upgrades and renewals

- More than 90% of Swiss HP potential already exploited
- Multiple studies on HP potential by SWV, SFOE, SCCER-SoE

<table>
<thead>
<tr>
<th></th>
<th>Annual generation [TWh/year]</th>
<th>Winter semester generation [TWh/winter]</th>
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<tbody>
<tr>
<td>New small and large HP</td>
<td>0.7 – 1.7</td>
<td>0.3 – 0.7</td>
</tr>
<tr>
<td>Upgrades/extensions</td>
<td>0.4 – 1.5</td>
<td>0.2 – 0.6</td>
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<tr>
<td>Renewal/refurbishment</td>
<td>0.5 – 1.0</td>
<td>0.2 – 0.4</td>
</tr>
<tr>
<td>Periglacial HP</td>
<td>0.0 – 0.8</td>
<td>0.0 – 0.5</td>
</tr>
<tr>
<td>Dam heightening</td>
<td>0.0 – 0.2</td>
<td>0.2 – 1.5</td>
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</tbody>
</table>

→ Dam heightening may significantly contribute to winter production
### Potential changes

**Storage**: periglacial HP and dam heightening

<table>
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<tr>
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<th>Stored energy [TWh]</th>
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<td>Dam heightening</td>
<td>0.2 – 1.5</td>
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<tr>
<td>Periglacial HP</td>
<td>0.0 – 1.0</td>
</tr>
<tr>
<td>Renewal/refurbishment</td>
<td>0.1 – 0.2</td>
</tr>
<tr>
<td>New small and large HP</td>
<td>–</td>
</tr>
<tr>
<td>Upgrades/extensions</td>
<td>–</td>
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</table>

Heightening of Vieux Emosson dam (2012-2015) by +21.5 m (39%) → +93% in volume

Periglacial reservoir Trift Glacier
145 GWh/year; 215 GWh of storage
Potential changes

*Improved operation*

- Sub-seasonal runoff forecasts can reduce spillage and increase generation
- Real-time suspended sediment monitoring to reduce hydro-abrasion
- Dualism between maximized production and maximized revenue
  → New incentives needed (e.g. flexible water fees)?

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Swiss Potential for HP Generation and Storage

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Anghileri et al. (2018)

Felix (2016)

VAW (2018)
Potential changes
Environmental aspects

Swiss Waters Protection Act (WPA) requires (until 2030):

• Minimum residual flow
  – dynamic / non-proportional flows can be beneficial for ecology and HP system efficiency

• Limitation of hydro- and thermopeaking
  – see Whitepaper “Flexibility”

• Facilitation of up-/downstream fish migration
  – new technical solutions for d/s migration needed

• Limitation of bed load budget modification
  – flushing, bypassing, venting, dredging, replenishment
  → no estimates for production loss as measures are not yet defined

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<th>Annual generation [TWh/year]</th>
<th>Winter semester generation [TWh/winter]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased residual flow</td>
<td>−3.6 to −1.9</td>
<td>−1.5 to −0.8</td>
</tr>
<tr>
<td>Fish d/s migration measures</td>
<td>−1.0 to −0.2</td>
<td>−0.4 to −0.1</td>
</tr>
</tbody>
</table>

02.11.2020  Swiss Potential for HP Generation and Storage
Potential changes

*Climate change effects*

Energy transition coincides with a significant change in climate, which:

- affects annual and seasonal HP generation
- alters sediment input
- modifies the occurrence of natural hazards

Run-of-river HP (values refer to 2060):

- annual: −0.3% (RCP2.6), −2.9% (RCP8.5)
- winter: +6.4% (RCP2.6), +8.4% (RCP8.5)

Storage HP:

- No significant change in annual precipitation
- Significant losses in ice melt-dominated catchments
Challenges and opportunities

Challenges

Market situation & regulatory framework
- Amortization treaties
- Concession renewals

Conflict of interest ES 2050 vs. Waters Protection Act
- Residual flow
- Protection of wetlands
- Hydrological effects

Sustainable sediment mgmt.

Uncertainties in potential estimates
Challenges and opportunities

Opportunities

New glacier lakes
- Timeframe?
- Potential source of natural hazards

Multipurpose reservoirs – potential reduction in HP generation
- Irrigation (Aare catchment / Seeland, Val de Bagnes)
- Tourism

Natural hazard protection
- Flood protection
- Protection against mass movement

→ How to monetarize these incentives?
### Synthesis

#### Conclusions:

- **Target of ES 2050** will only be met in “upper-bound generation” scenario.
- In a more realistic “intermediate” scenario the generation gains from both extensions and new constructions are countered by reductions driven by environmental mitigation measures.
  - hardly any net increase in annual generation
  - ~1.1 TWh/winter increase in winter generation

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<table>
<thead>
<tr>
<th>Increased or reduced generation and storage (with reference to 2019) due to...</th>
<th>annual generation [TWh/year]</th>
<th>winter semester generation [TWh/winter]</th>
<th>stored energy / storage volume [TWh / Mio m³]</th>
<th>Annotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>scenario</td>
<td>lower</td>
<td>interm.</td>
<td>upper</td>
<td>lower</td>
</tr>
<tr>
<td>... new small- and large-scale HP plants (except periglacial HP)</td>
<td>0.7</td>
<td>1.2</td>
<td>1.7</td>
<td>0.3</td>
</tr>
<tr>
<td>... new HP storage plants in periglacial environment</td>
<td>0</td>
<td>0.4</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>... upgrade and extension of existing HP plants</td>
<td>0.4</td>
<td>1.0</td>
<td>1.5</td>
<td>0.2</td>
</tr>
<tr>
<td>... dam heightening</td>
<td>0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>... renewal and refurbishment of existing HP schemes</td>
<td>0.5</td>
<td>0.8</td>
<td>1.0</td>
<td>0.2</td>
</tr>
<tr>
<td>... increased residual flow releases according to Waters Protection Act</td>
<td>-3.6</td>
<td>-2.5</td>
<td>-1.9</td>
<td>-1.5</td>
</tr>
<tr>
<td>... fish protection and downstream migration measures at run-of-the-river low-head HP plants</td>
<td>-1.0</td>
<td>-0.4</td>
<td>-0.2</td>
<td>-0.4</td>
</tr>
<tr>
<td><strong>Total changes</strong></td>
<td>-3.0</td>
<td><strong>0.5</strong></td>
<td><strong>3.1</strong></td>
<td>-1.0</td>
</tr>
</tbody>
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02.11.2020

Swiss Potential for HP Generation and Storage

13
Synthesis

HP annual generation
• «on track» for «upper-bound»
• «flat line» for intermediate scenario
• decrease for «lower bound»

HP storage
• Figure for «upper-bound» scenario
• +2.4 TWh effective storage (~55% of winter imports 2010-2019)
Recommendations for policy makers

- Prioritize **renewals, upgrades and extensions of existing HP schemes** (including more storage by dam heightening)
- Consider **new HP storage schemes** in areas of retreating glaciers (periglacial sites) by weighing various interests
- **Act now!** – the planning, licensing and realization of major HP projects takes at least 15 years
- **Take additional actions** towards achieving the goals of the ES2050 (framework conditions and incentives)
- Realize potential projects on a **priority scheme based on sustainability criteria**
Thanks for your attention!

Thanks for all who contributed !!