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SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

Swiss Potential for Hydropower Generation and Storage

White paper

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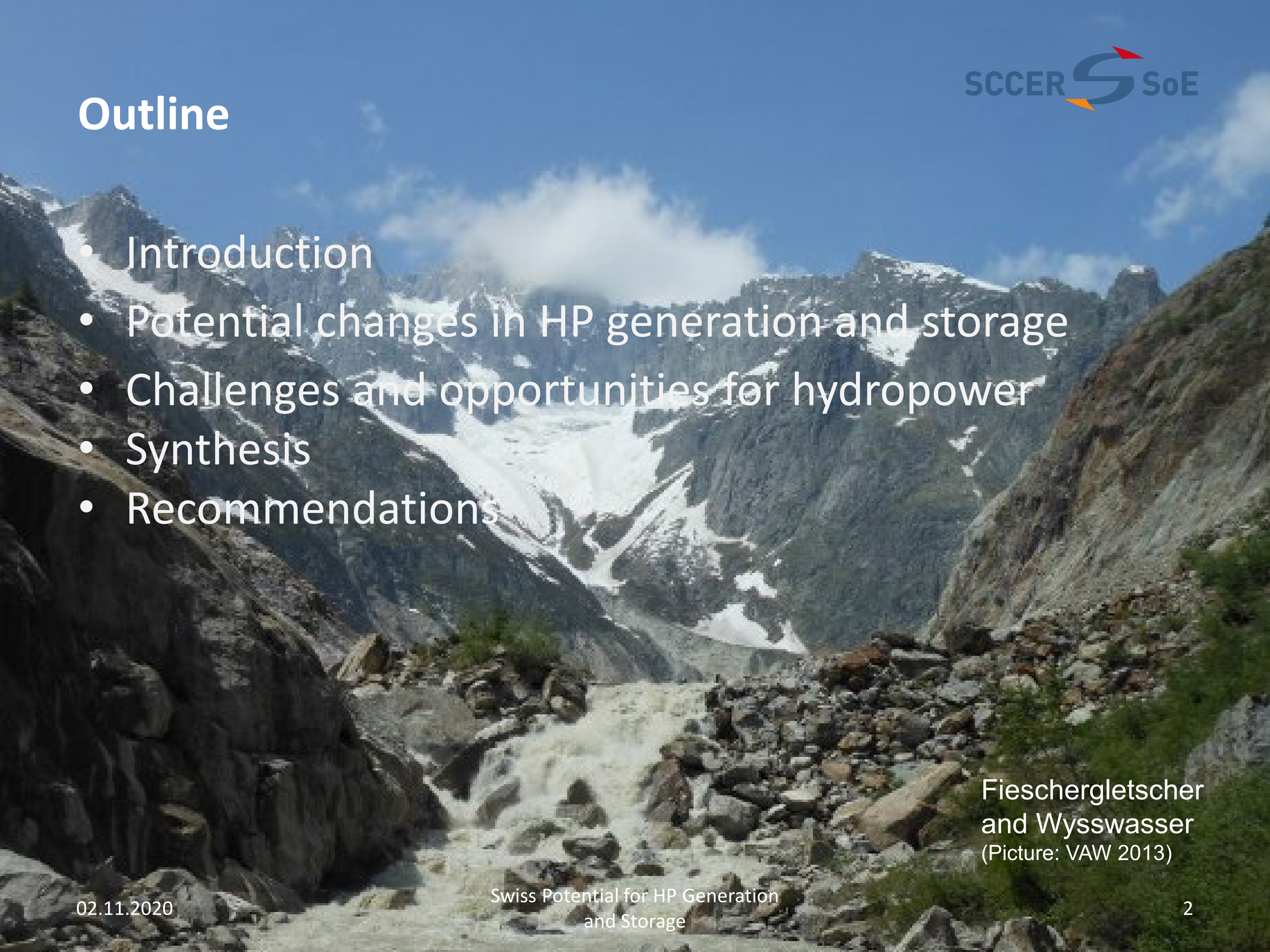
Outline

- 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:

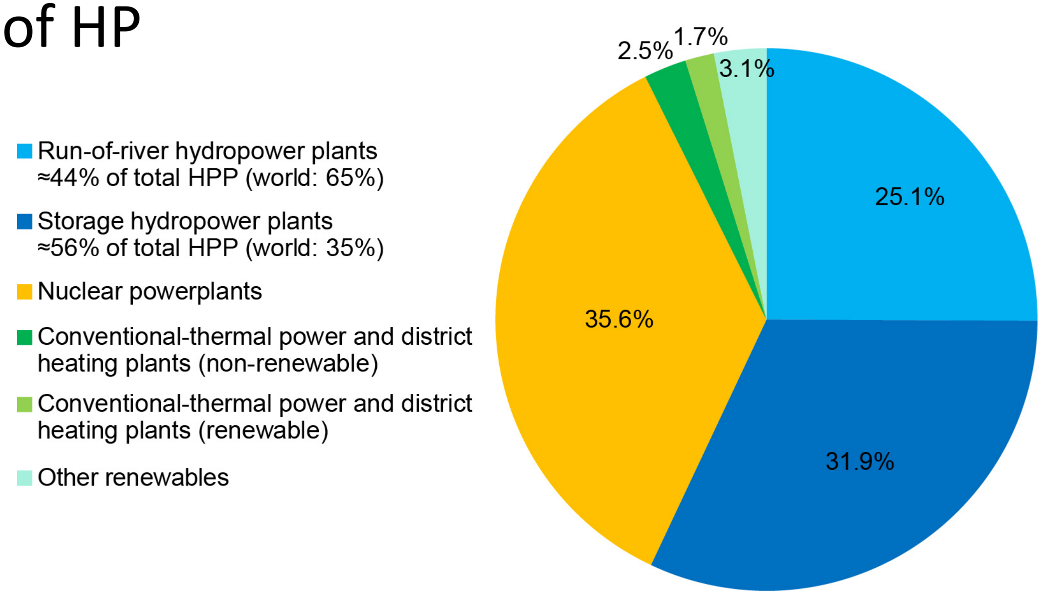
Central pillar of Swiss electricity generation portfolio

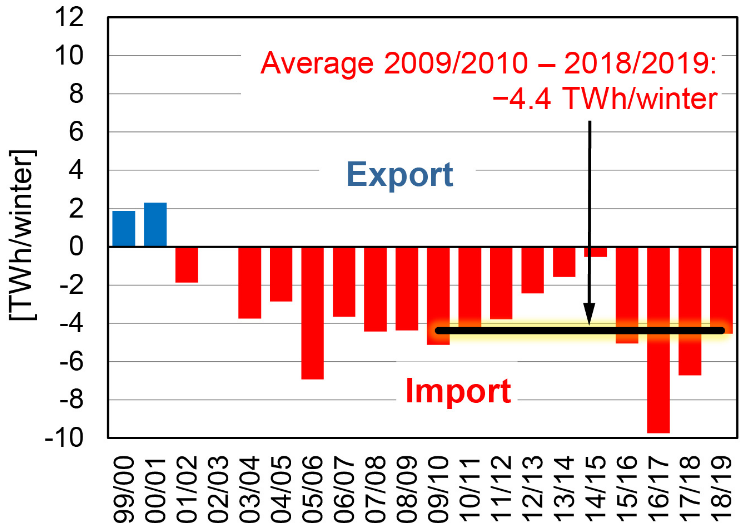
- ~57% of total electr. generation
- Electricity imports in winter half year

Future:

Swiss Energy Strategy (ES) 2050

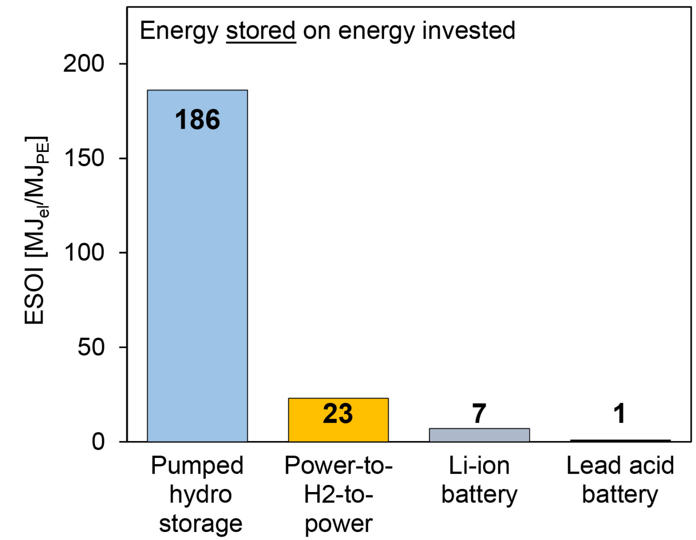
- Production targets
  - **≥ 37.4 TWh/yr in 2035** (Energy Act)
  - **38.6 TWh/yr in 2050** (Federal Council 2013)
  - **increase of ≥ 5 TWh/winter by 2035** (ElCom, 2020)
- Increasing need for regulating power





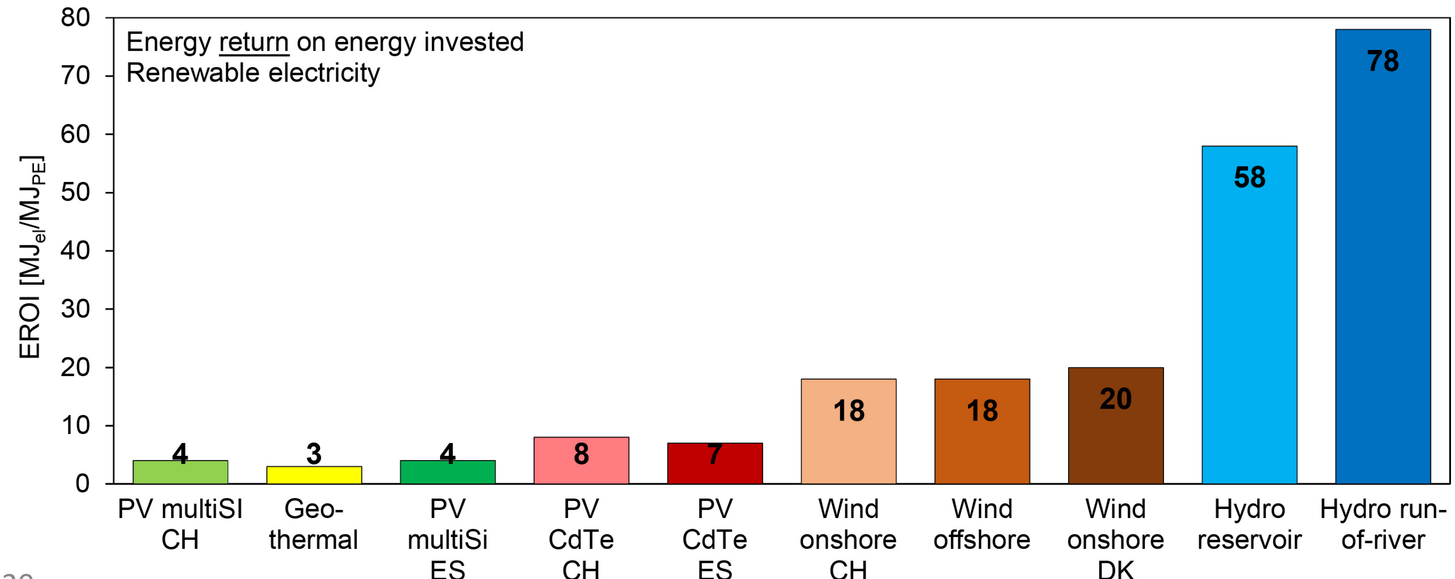
Introduction

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



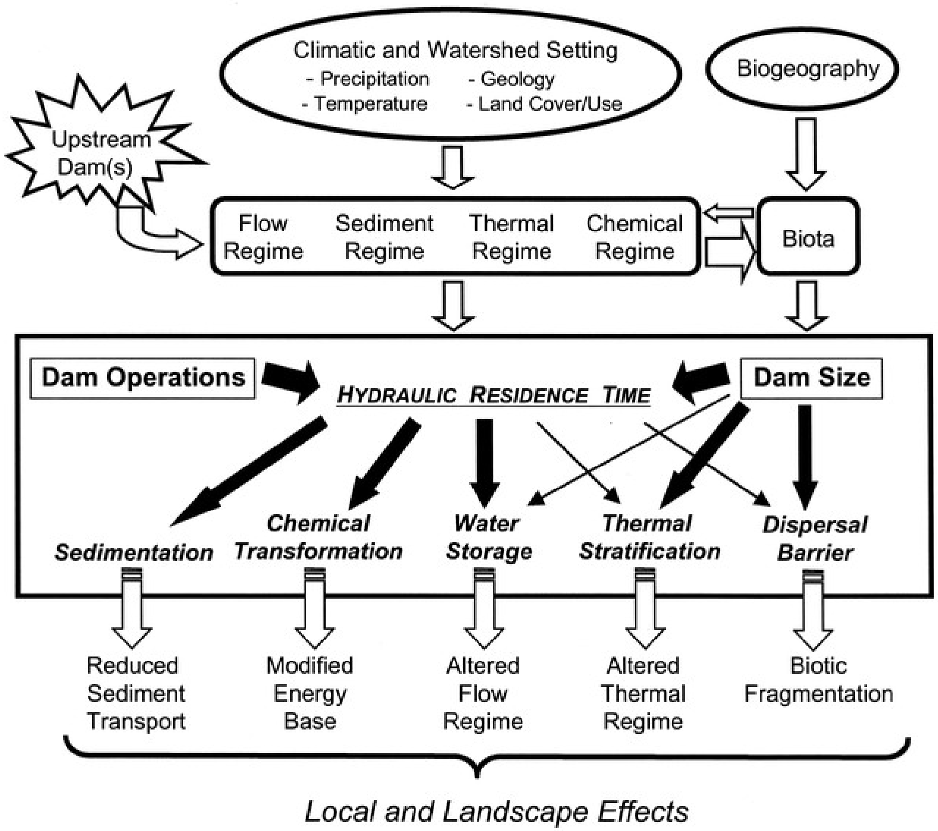
Source: adapted from Steffen *et al.* (2018)

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

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

→ Dam heightening may significantly contribute to winter production

Potential changes

Storage: periglacial HP and dam heightening

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

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

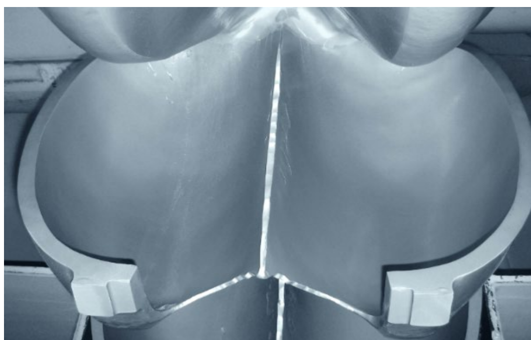
Periglacial reservoir Trift Glacier
145 GWh/year; 215 GWh of storage

Potential changes

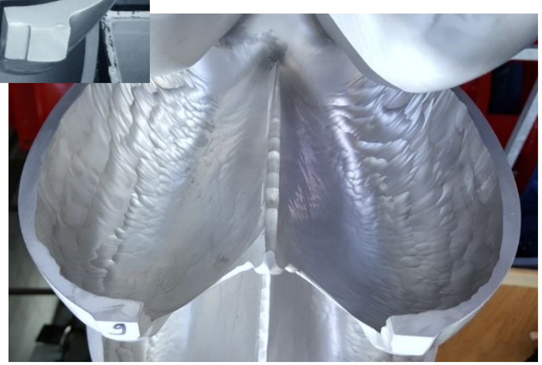
Improved operation

- 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

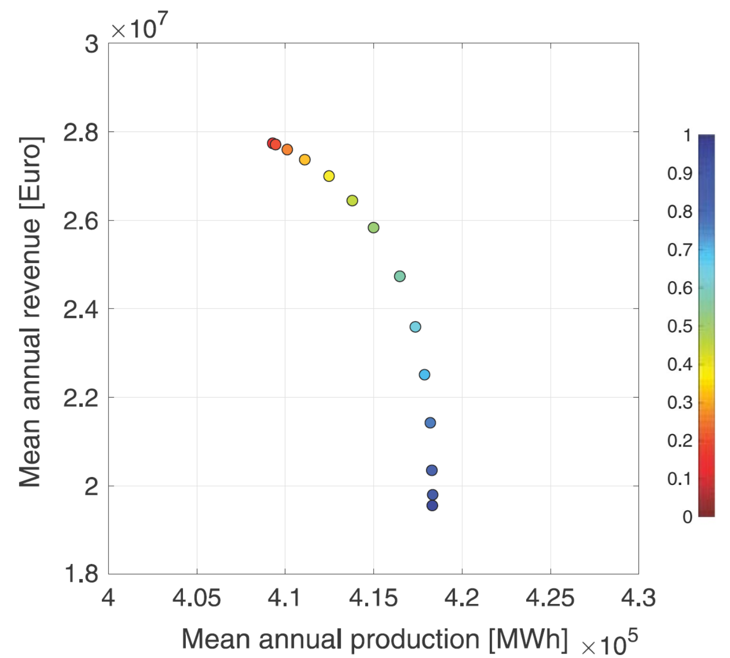
  → New incentives needed (e.g. flexible water fees)?



Felix (2016)



VAW (2018)



Anghileri et al. (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

	Annual generation [TWh/year]	**Winter semester generation [TWh/winter]**
Increased residual flow	−3.6 to −1.9	−1.5 to −0.8
Fish d/s migration measures	−1.0 to −0.2	−0.4 to −0.1

Potential changes
Climate change effects

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

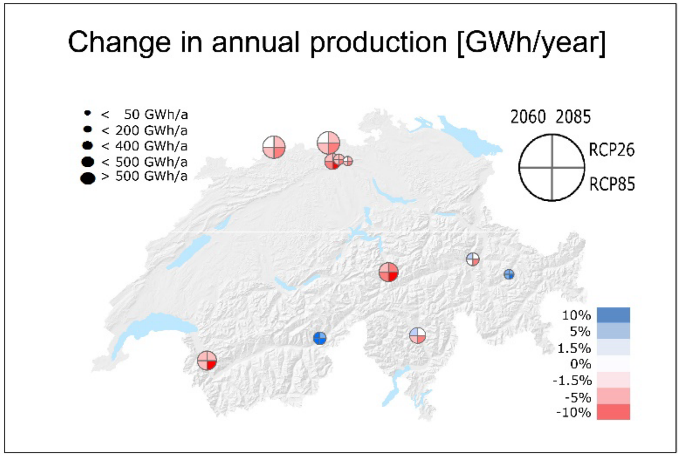
- affects annual and seasonal HP generation
- alters sediment input
- modifies the occurrence of natural hazards

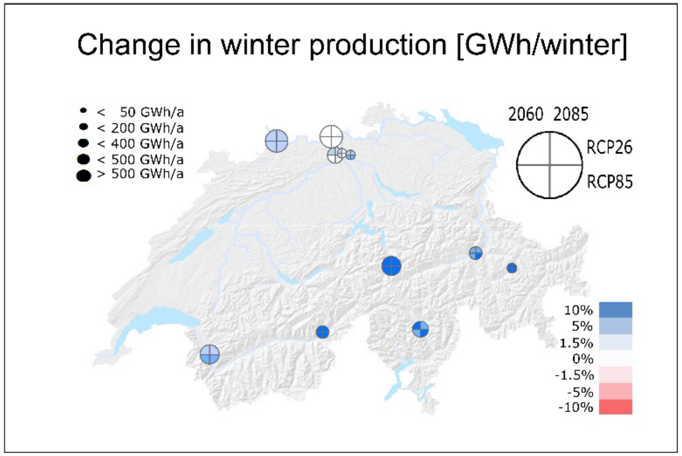
Run-of-river HP (values refer to 2060):

- 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

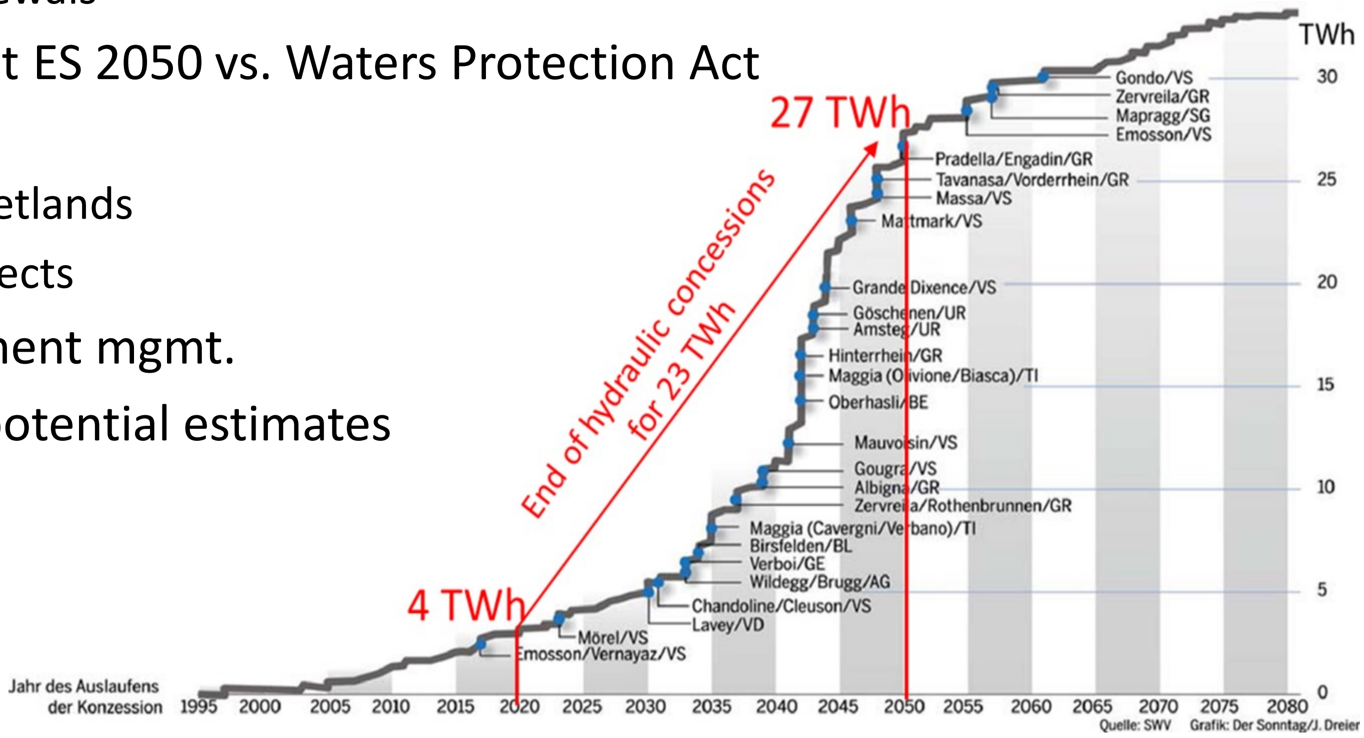
- Amortization treaties
- Concession renewals

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

Increased or reduced generation and storage (with reference to 2019) due to …	annual generation [TWh/year]			winter semester generation [TWh/winter]			stored energy / storage volume [TWh / Mio m^3]						Anno-tation
scenario	**lower**	**interm.**	**upper**	**lower**	**interm.**	**upper**	**lower**		**interm.**		**upper**		
… new small- and large-scale HP plants (except periglacial HP)	0.7	1.2	1.7	0.3	0.5	0.7	-	-	-	-	-	-	a)
… new HP storage plants in periglacial environment	0	0.4	0.8	0	0.2	0.5	0	0	0.5	200	1.0	400	b)
… upgrade and extension of existing HP plants	0.4	1.0	1.5	0.2	0.4	0.6	-	-	-	-	-	-	c)
… dam heightening	0	0.1	0.2	0.2	0.8	1.5	0.2	80	0.8	280	1.5	470	d)
… renewal and refurbishment of existing HP schemes	0.5	0.8	1.0	0.2	0.3	0.4	0.1	-	0.1	-	0.2	-	e)
… increased residual flow releases according to Waters Protection Act	-3.6	-2.5	-1.9	-1.5	-1.0	-0.8	-	-	-	-	-	-	f)
… fish protection and downstream migration measures at run-of-the-river low-head HP plants	-1.0	-0.4	-0.2	-0.4	-0.2	-0.1	-	-	-	-	-	-	g)
Total changes	**-3.0**	**0.5**	**3.1**	**-1.0**	**1.1**	**2.8**	**0.3**	**80**	**1.4**	**480**	**2.7**	**870**	

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

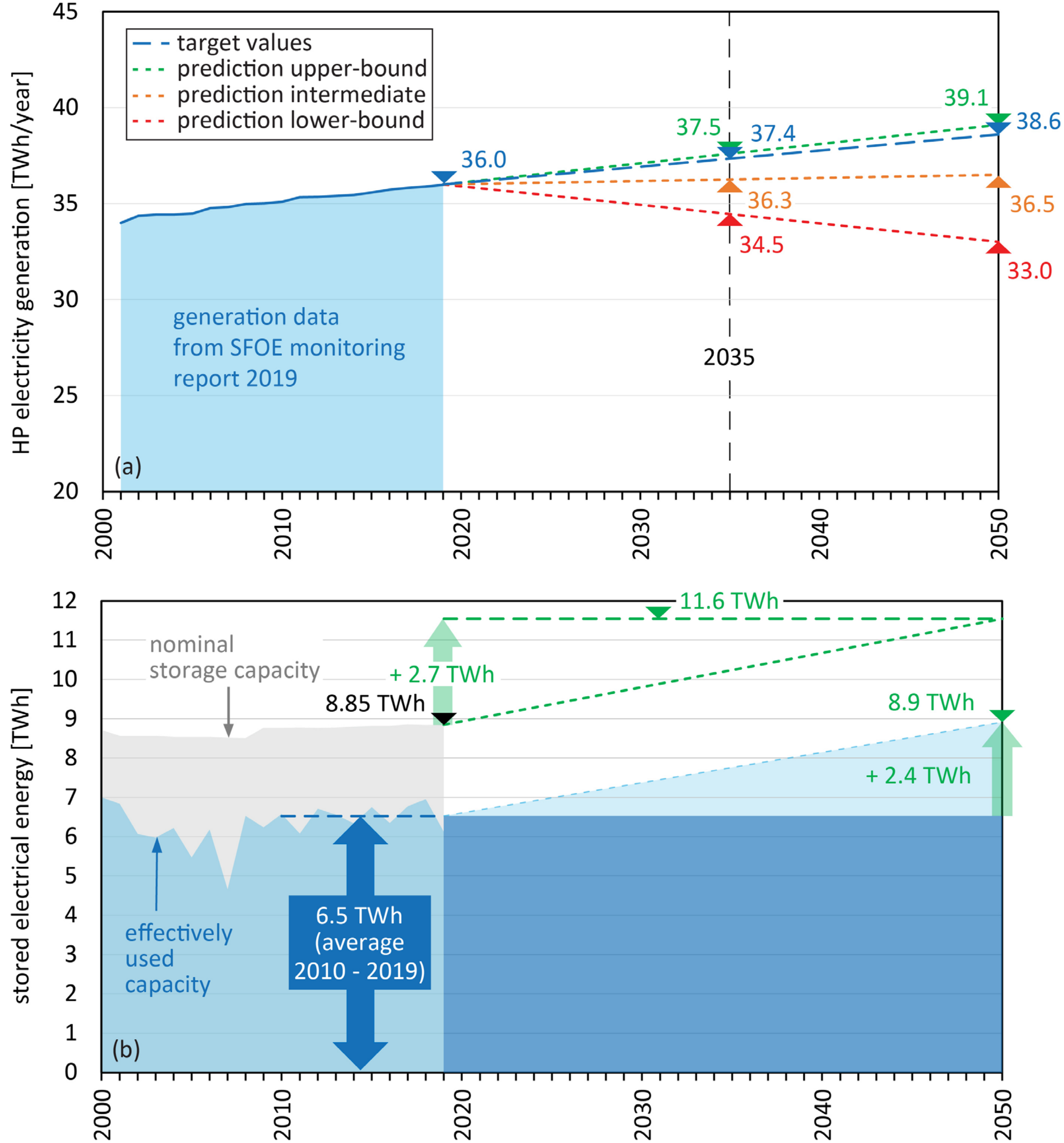
Synthesis

HP annual generation

- «on track» for «upper-bound»
- «flat line» for inter-mediate 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 !!

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