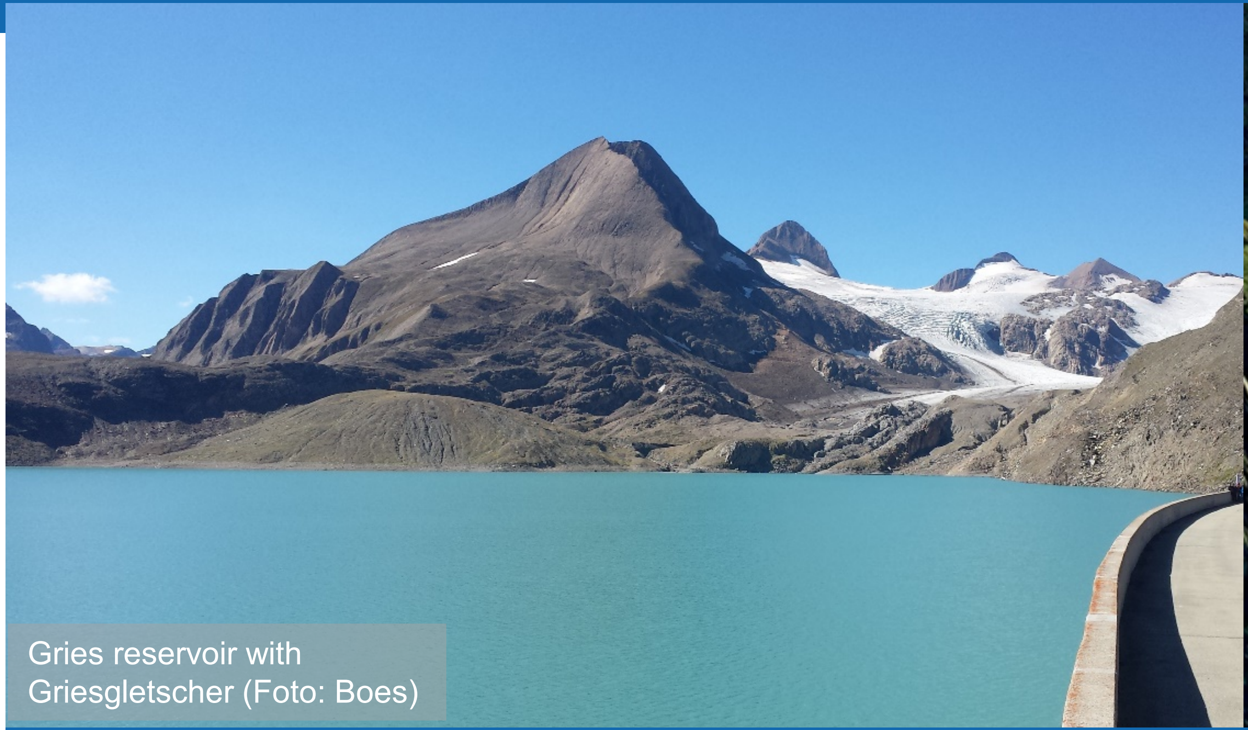
Gries reservoir with Griesgletscher (Foto: Boes)


Trift reservoir (visualization) with Triftgletscher (Source: KWO)

Retreating glaciers and new multipurpose schemes

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SCCER SoE
SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

Outline

Retreating glaciers and new multipurpose schemes

- Glacier retreat
- Opportunities for new HP sites
- Systematic study of HP potential after glacier retreat
- Conclusions

Glacier retreat: example of Rhonegletscher

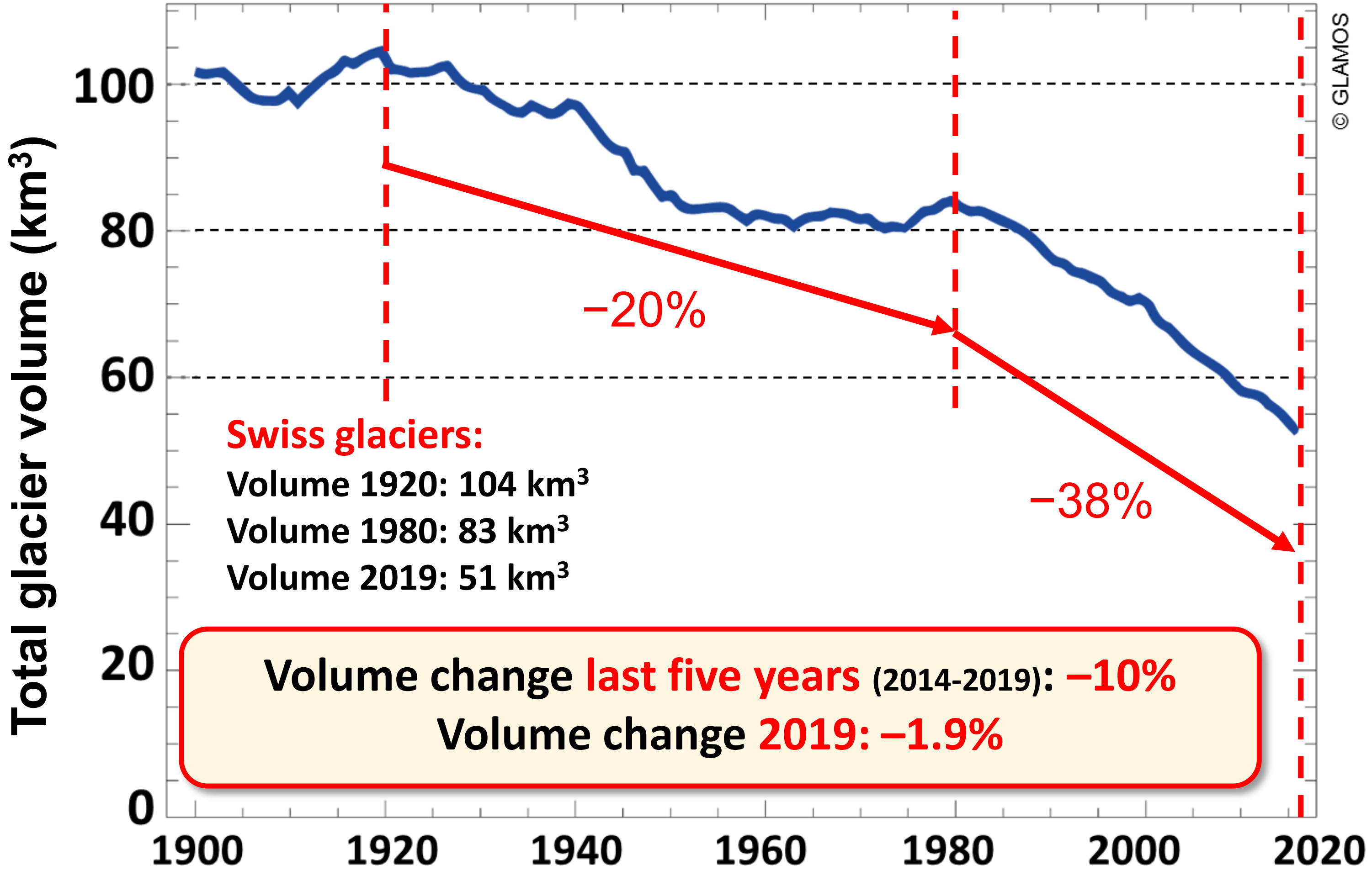
Large areas become ice-free, proglacial lakes may form

Rhonegletscher around 1900

Prediction of Rhonegletscher in 2050

Source: VAW, ETH Zürich

Glacier retreat CH in the past and in the future



Source: adapted from Farinotti (2019), presentation at ETH-Klimarunde

Model projections of glacier change in the Alps

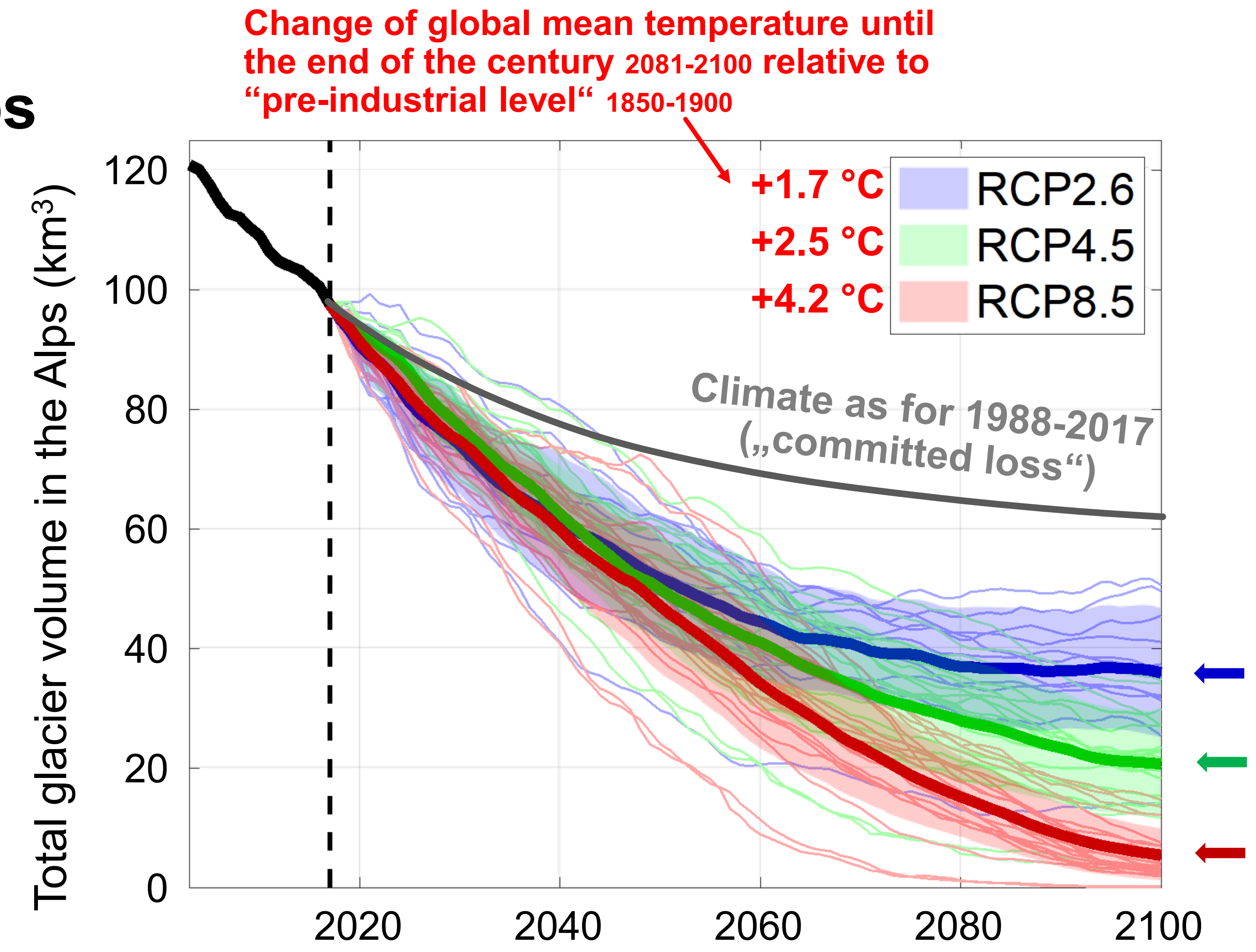
changes **until 2100:**

80±10% loss for RCP 4.5

quasi **ice-free** for RCP 8.5

40% remain for RCP 2.6

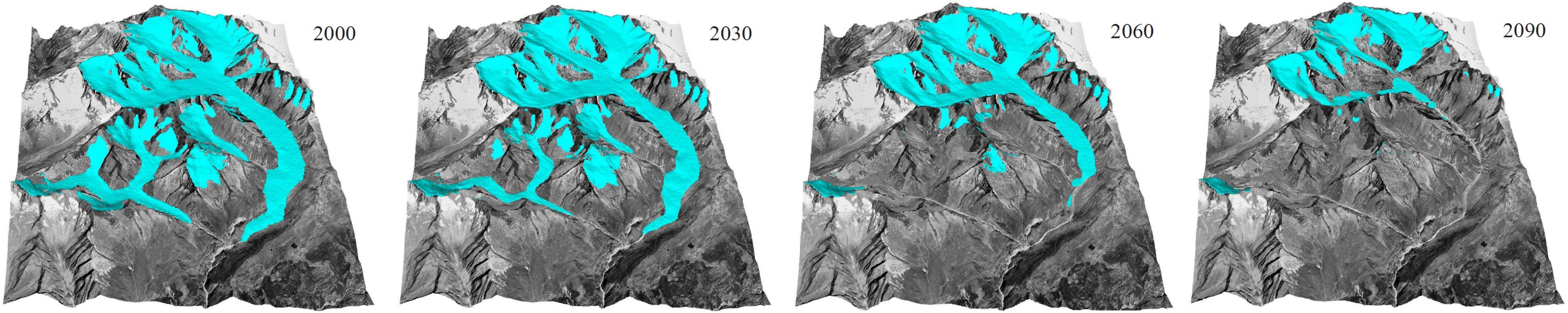
Glaciers are some **40% too large for „today's climate"**

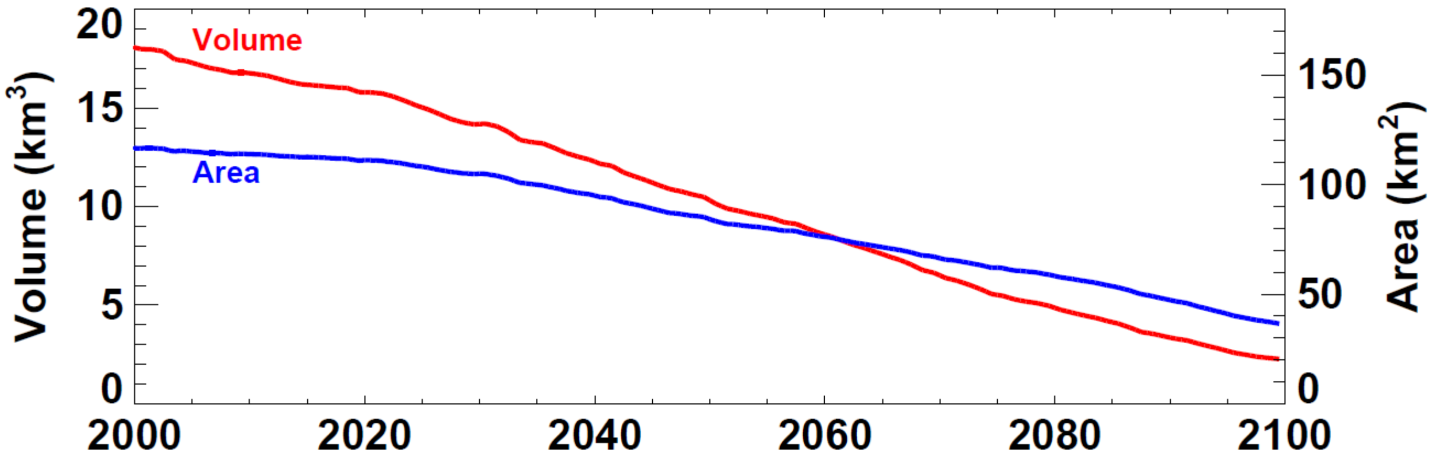


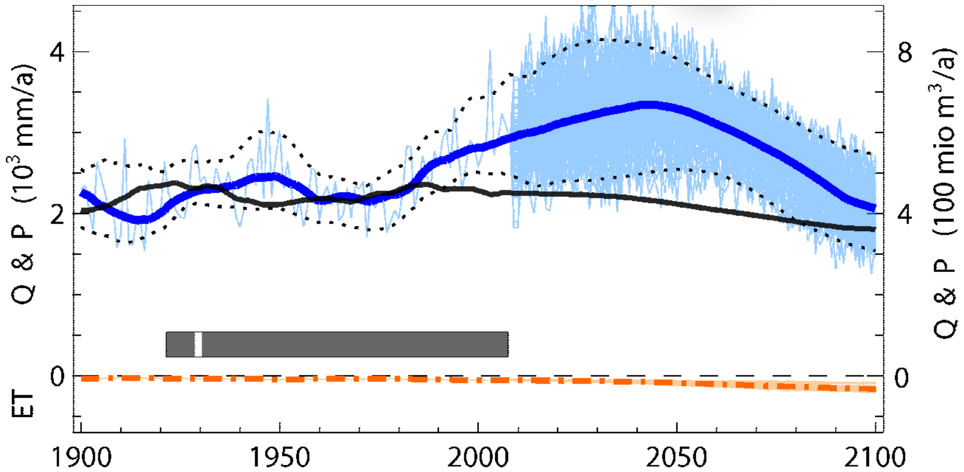
Source: Zekollari et al. (2019), DOI: 10.5194/tc-13-1125-2019, adapted from Prof. Daniel Farinotti, ETH Zürich

Temporal development of glacier change

Example of Massa catchment (Aletsch area)



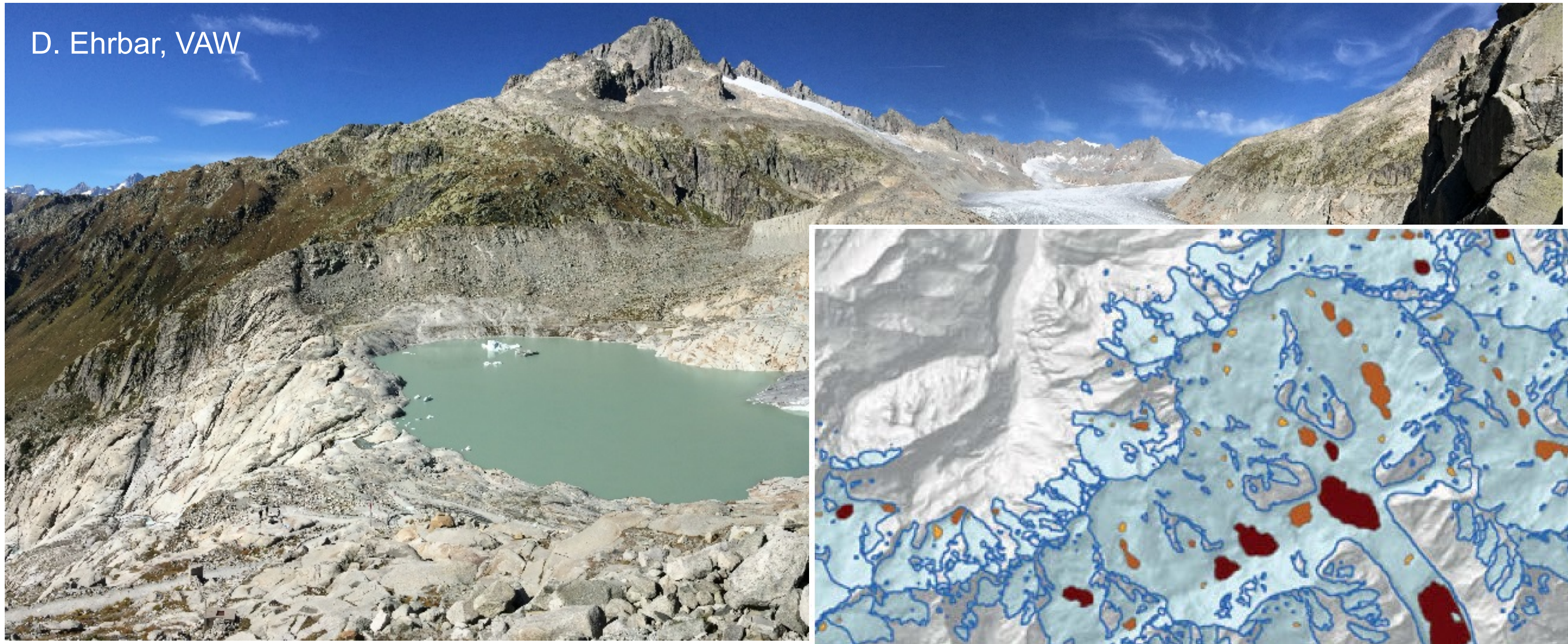




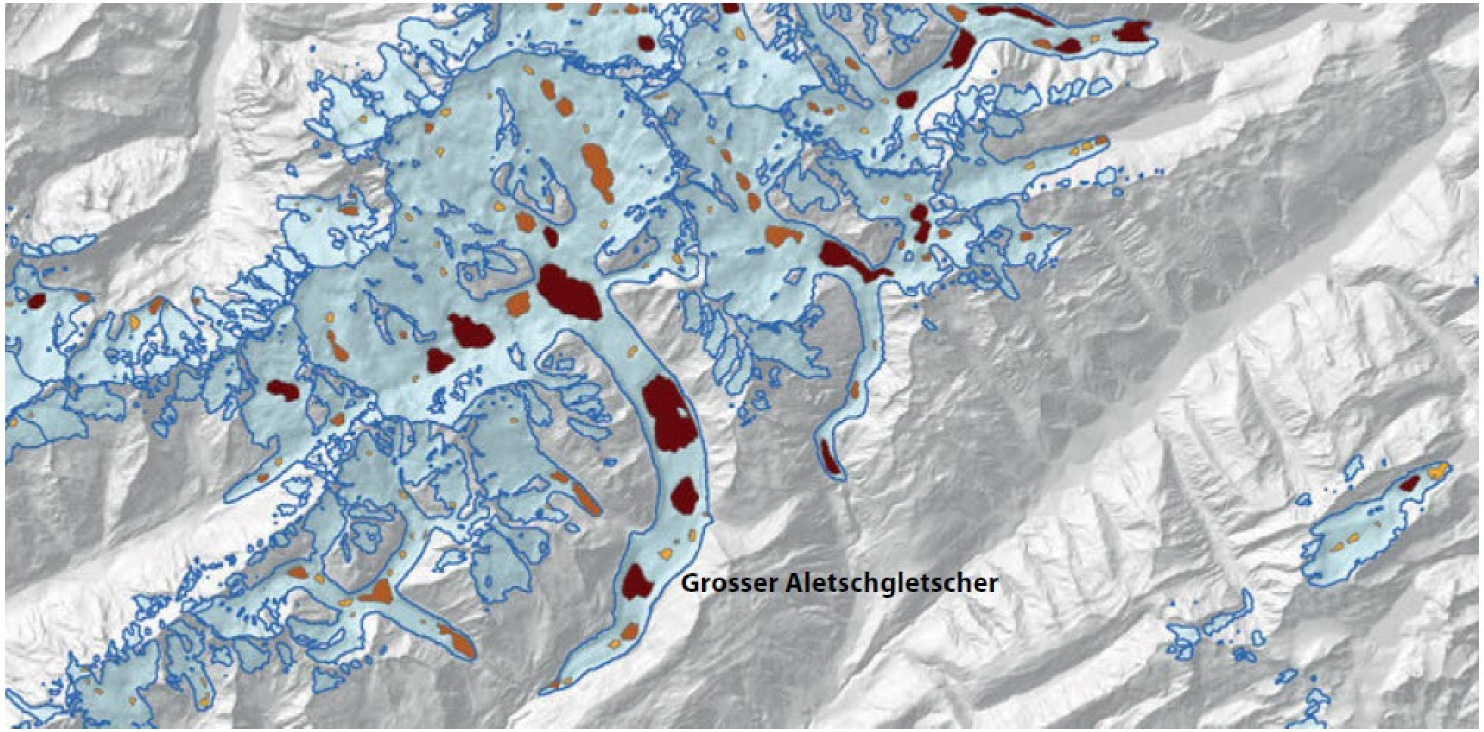
Source: Farinotti et al. (2011)

Periglacial lakes and glacier forefields

Lakes form at glacier-bed depressions



Proglacial lake at snout of Rhone glacier in 2016



New future natural lakes at Aletsch glacier (Source: NELAK 2013)

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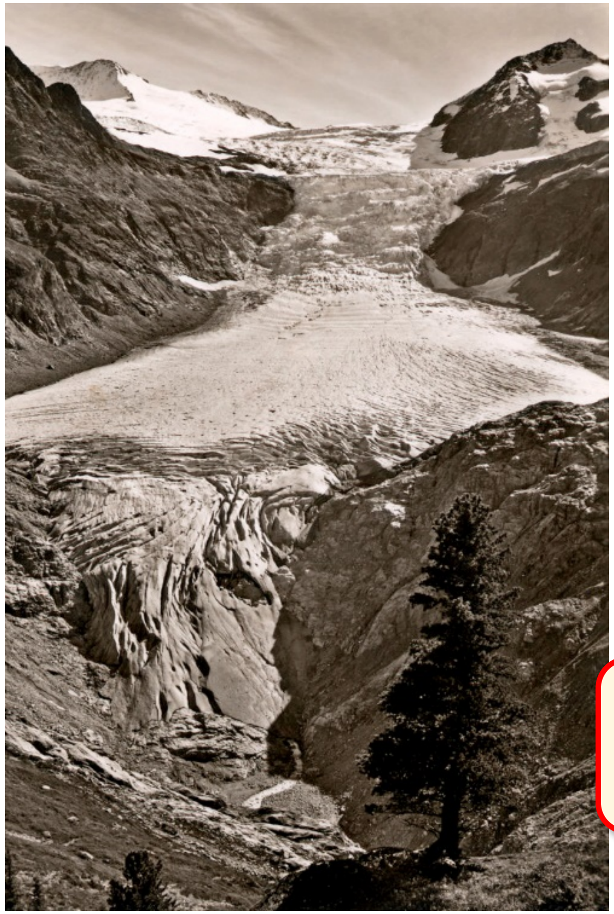
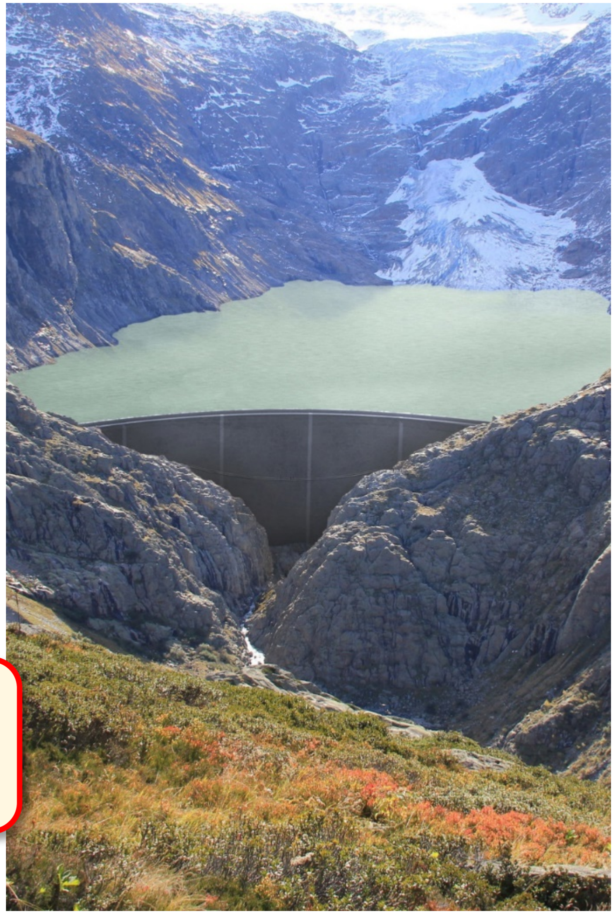
Periglacial lakes and glacier forefields

Feasibility of new reservoirs and hydropower schemes



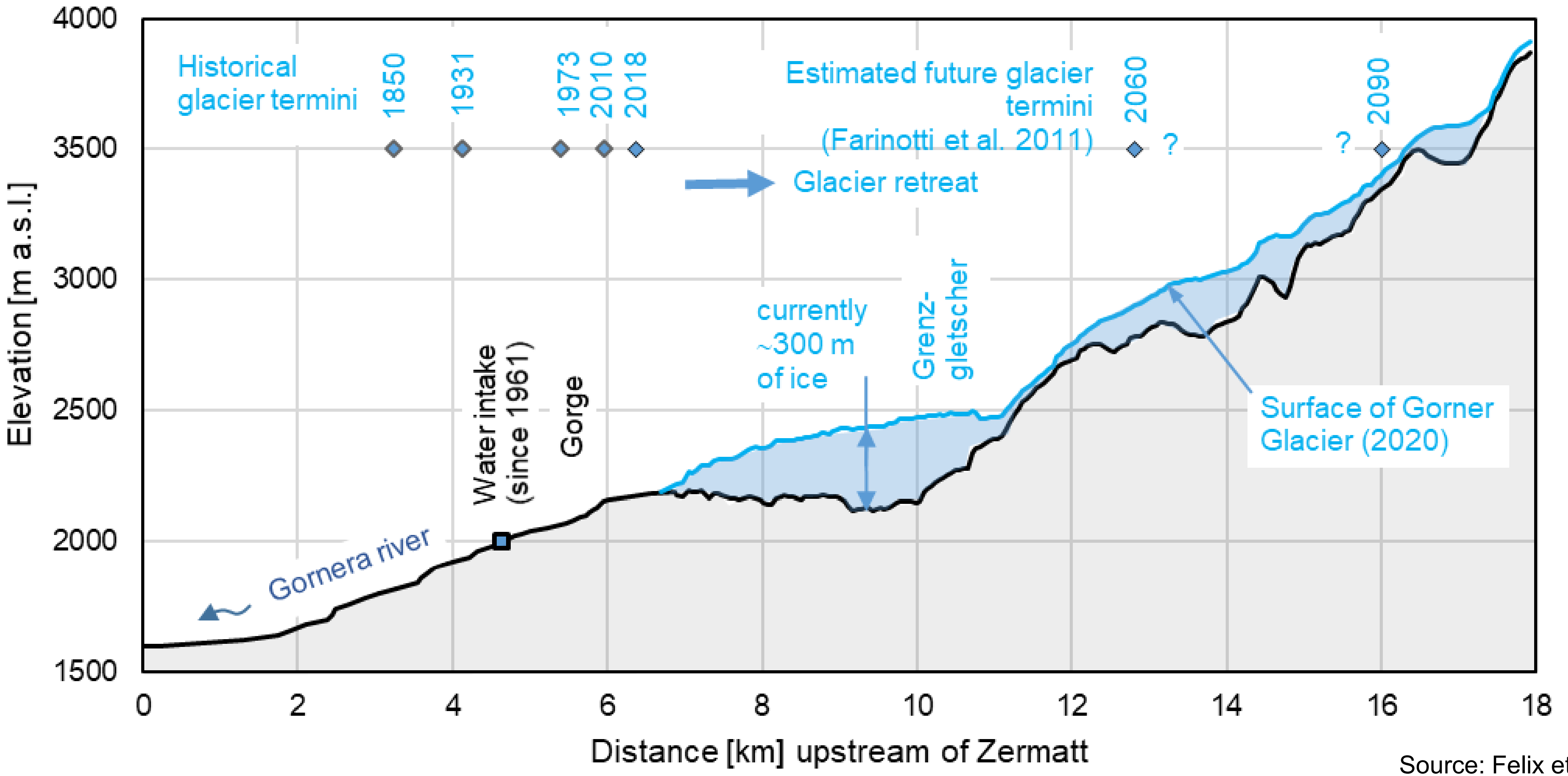


→ potental sites for new storage HP nationwide

Source: KWO

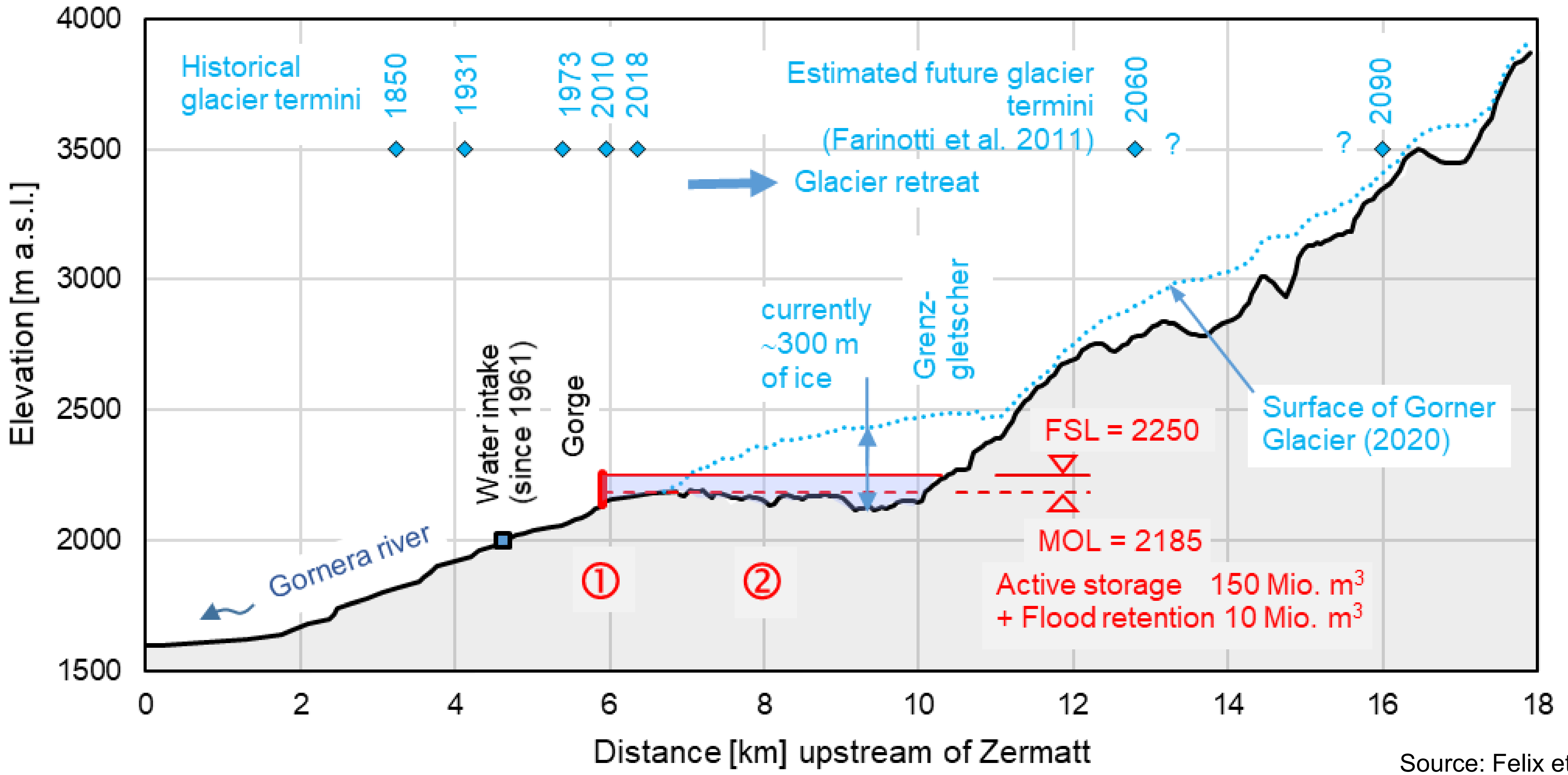
Trift Glacier 1948 **2008** **2032**

Example of Gornergletscher (longitudinal section)



Source: Felix et al. (2021), submitted

Example of Gornergletscher: new multipurpose scheme



① Potential new dam

② New reservoir

Source: Felix et al. (2021), submitted

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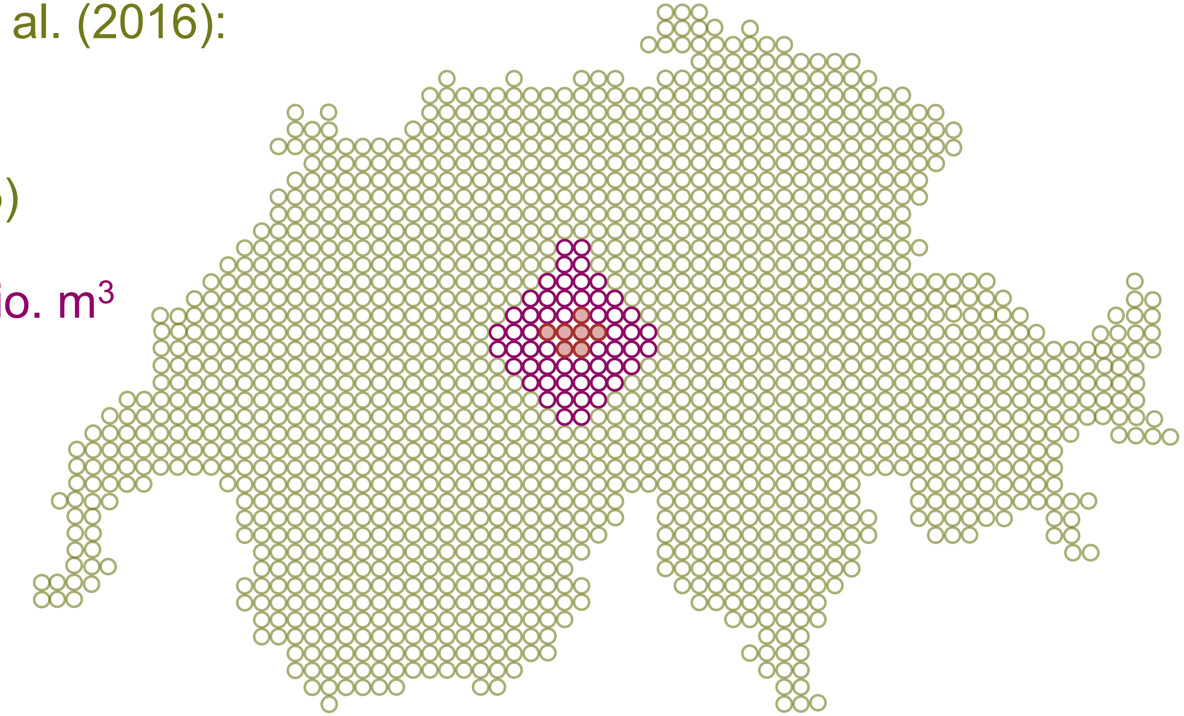
Swiss periglacial HP potential: Methodology

① evaluate runoff projections (until 2100) from Farinotti et al. (2016):
- 1576 glaciers in Switzerland
- 14 global circulation models (GCM)
- 3 emission scenarios (RCP2.6, RCP4.5 and RCP8.5)

② select sites with annual runoff volume larger than 10 Mio. m^3 averaged over period 2017-2035

③ consistently rate all remaining 62 **sites that will be ice-free at potential dam locations by 2035** with an evaluation matrix

④ estimate hydropower potential of best-rated sites and compare with targets of Swiss Energy Act / Strategy



Site rating criteria – evaluation matrix

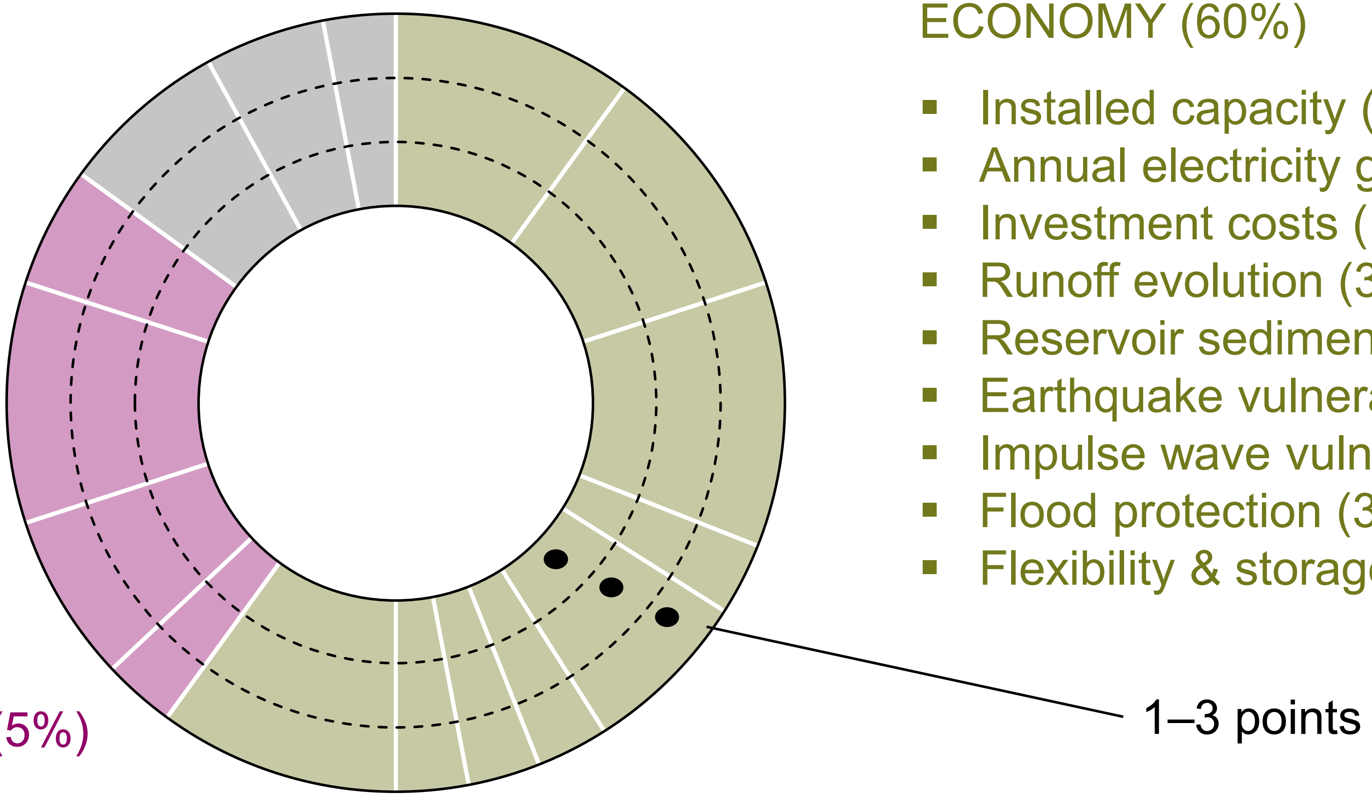
1 - 3 point(s) per criterion, with varying weighting factors (here: Model A)

SOCIETY (15%)

- Protected areas (7%)
- Land use (5%)
- Tourism (3%)

ENVIRONMENT (25%)

- Visibility (3%)
- Environmental flow (7%)
- Sediment continuity (10%)
- Hydro- & thermo-peaking (5%)

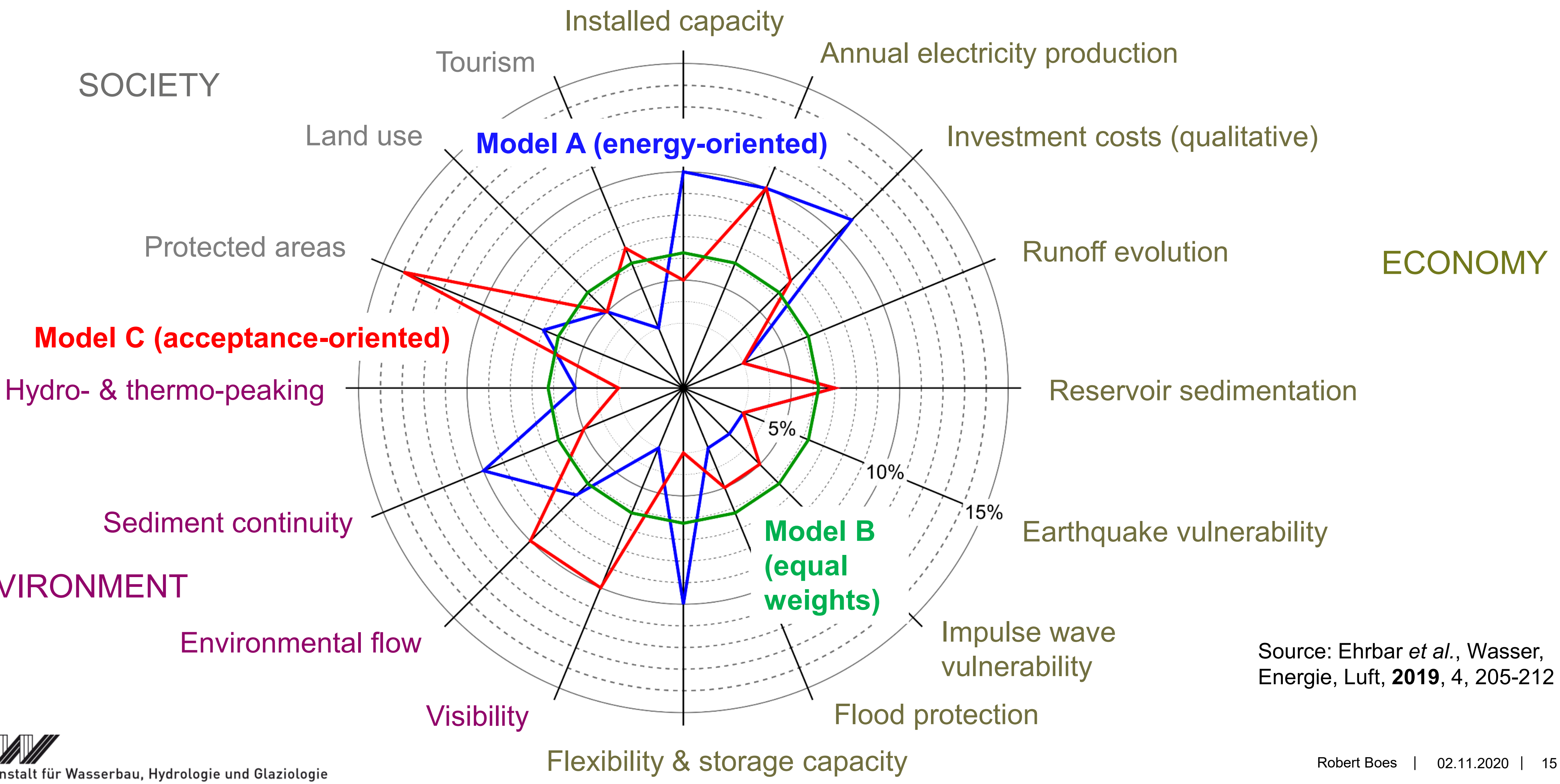


ECONOMY (60%)

- Installed capacity (10%)
- Annual electricity generation (10%)
- Investment costs (11%)
- Runoff evolution (3%)
- Reservoir sedimentation (7%)
- Earthquake vulnerability (3%)
- Impulse wave vulnerability (3%)
- Flood protection (3%)
- Flexibility & storage capacity (10%)

Source: adapted from Ehrbar *et al.*, Sustainability, **2018**, 10(8), 2794

Weighting and sensitivity analysis



Source: Ehrbar *et al.*, Wasser, Energie, Luft, **2019**, 4, 205-212

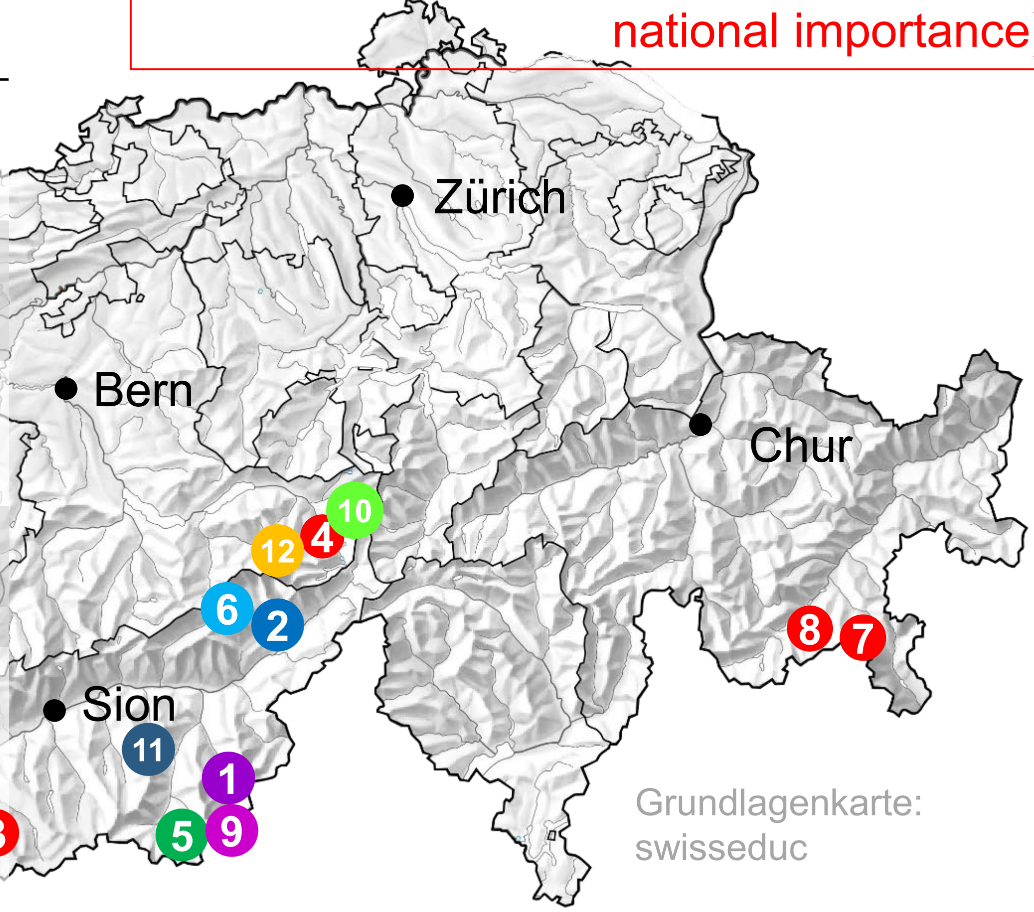
Example of sensitivity analysis

	Model A (energy-oriented)		Model B (equal weights)		Model C (acceptance-oriented)	
Site (glacier)	Points	Rank	Points	Rank	Points	Rank
Aletschgletscher	211	3	200	6	198	8
Gornergletscher	204	7	187.5	10	192	9
Triftgletscher	210	4	206.25	3	211	2

New periglacial HP: Potential of the «top 12» sites

	Glacier (alphabetical order, Canton)	**Annual generation [GWh/a]**	**Stored energy [GWh]**	**Reservoir volume [Mio. m³]**
1	Allalin (VS)	32	47	20
2	Aletsch (VS)	200	216	106
3	Corbassière (VS)	57	33	16
4	Gauli (BE)	16	75	41
5	Gorner (VS) *	220	550	150
6	Oberaletsch (VS)	105	60	30
7	Palü (GR)	14	19	9
8	Roseg (GR) **	95	159	71
9	Schwarzberg (VS)	19	41	19
10	Trift (BE) ***	145	215	85
11	Turtmann (VS)	36	78	36
12	Unt. Grindelw. (BE)	112	150	84
	Total (w/o 3,4,7,8)	**1051 (869)**	**1643 (1357)**	**667 (530)**

in red: Sites with glacier forefields in federal inventory of wetlands (biotopes of national importance)



Source: adapted from Ehrbar *et al.*, Sustainability, **2018**, 10(8), 2794

* from Lehmann (2020) ** from Baumann (2020) *** https://www.grimselstrom.ch/ausbauvorhaben/zukunft/kraftwerk-trift/

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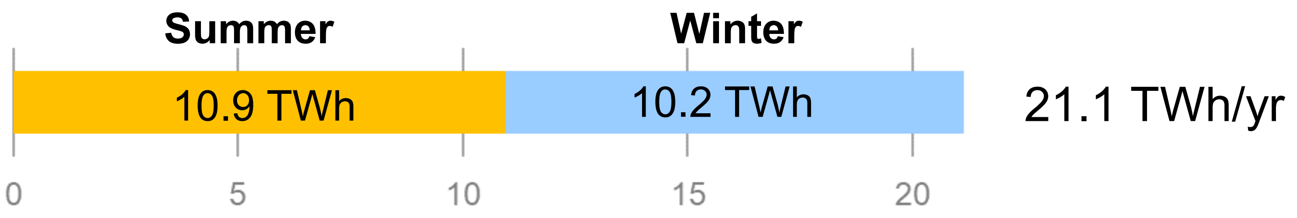
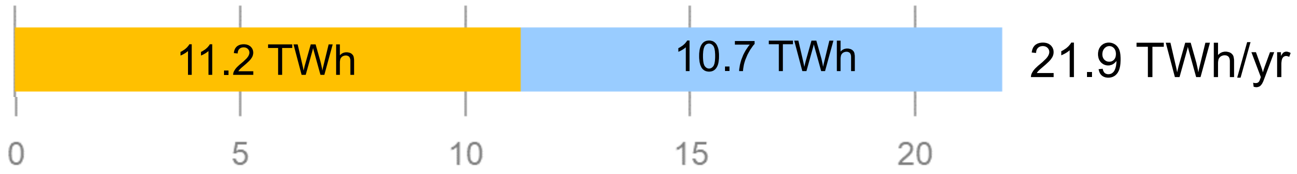
Increase of <u>winter generation</u> by periglacial HP

current winter semester generation of Swiss storage Hydropower

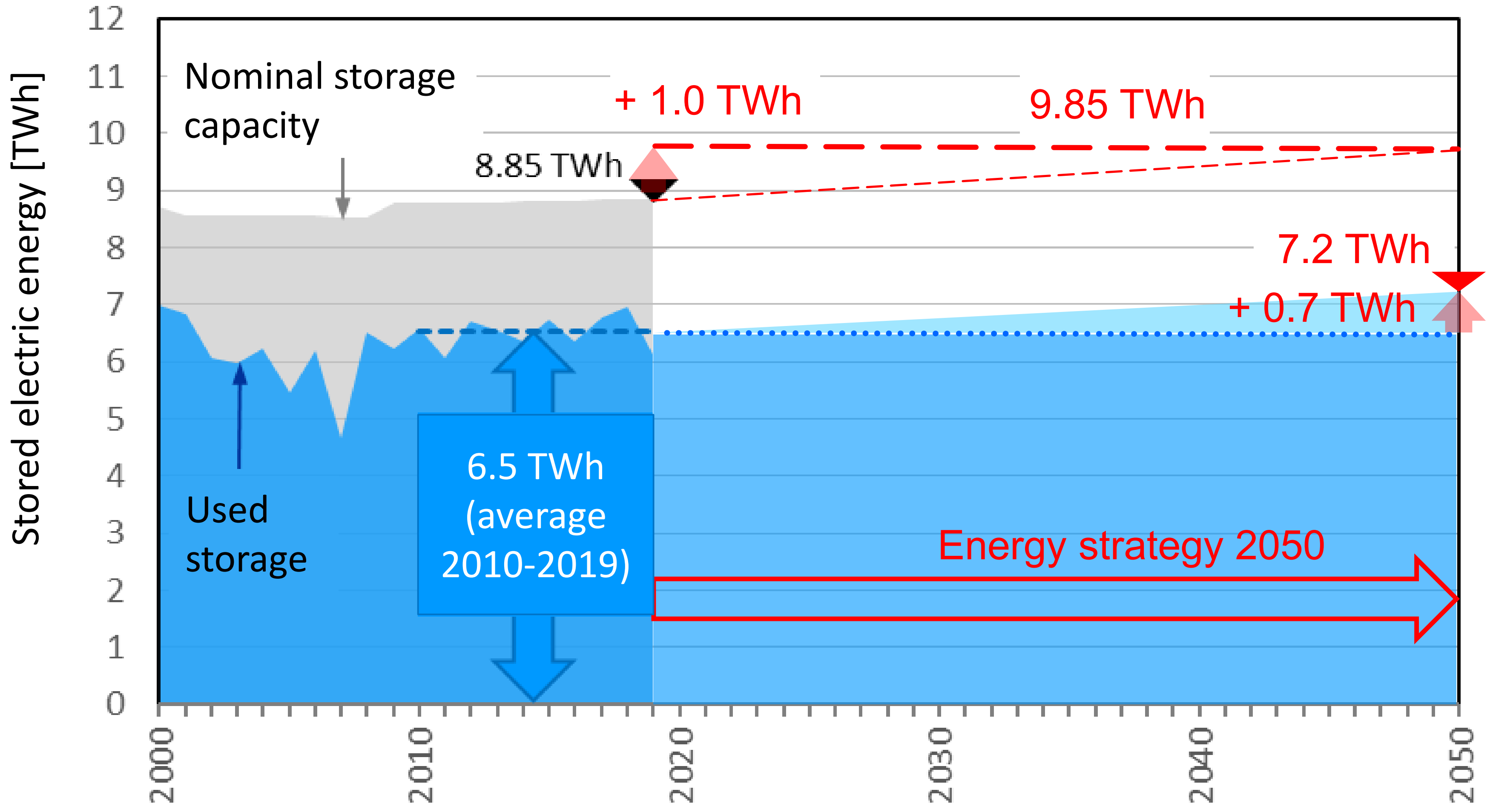
SFOE (2020), decadal mean 2010-2019



with ~12 new periglacial HP storage plants **(w/o sites in protected wetlands):**
up to 0.8 TWh/yr of additional annual generation, of which 0.5 TWh in winter



Increase of stored energy by periglacial HP reservoirs



Source for past storage capacity and use: Electricity statistics of SFOE

By new periglacial multipurpose reservoirs * up to +1.0 TWh

(of which +0.7 TWh used on average)

Increase of yearly electricity storage by up to ~11%

* w/o sites in protected wetlands

Conclusions

Swiss hydropower potential in glacier retreat areas

? How can we **increase electricity production from hydropower**?

! **New storage hydropower plants in the Swiss periglacial environment** can produce an additional 0.8 TWh/year (57% / 31% of 2035 / 2050 target values) and provide up to 1.0 TWh of additional storage (~11% of current HP storage)

… **Upgrade and extension of existing schemes** (efficiency increase and dam heightening) may be more feasible → see today's presentation on dam heightening

But: **Generation reductions due to environmental mitigation measures at the existing HP fleet** (e.g. increased environmental flow releases) **have to be accounted for** separately → see today's presentation on White paper on hydropower generation and storage

Thanks for your attention!

Ehrbar D., Schmocker L., Vetsch D. F., Boes R. M. (2018). Hydropower Potential in the Periglacial Environment of Switzerland under Climate Change. *Sustainability* 10(8): 2794. doi:10.3390/su10082794

Ehrbar D., Schmocker L., Vetsch D., Boes R. (2019). Wasserkraftpotential in Gletscherrückzugsgebieten der Schweiz. *Wasser, Energie, Luft* 111(4): 205-212.