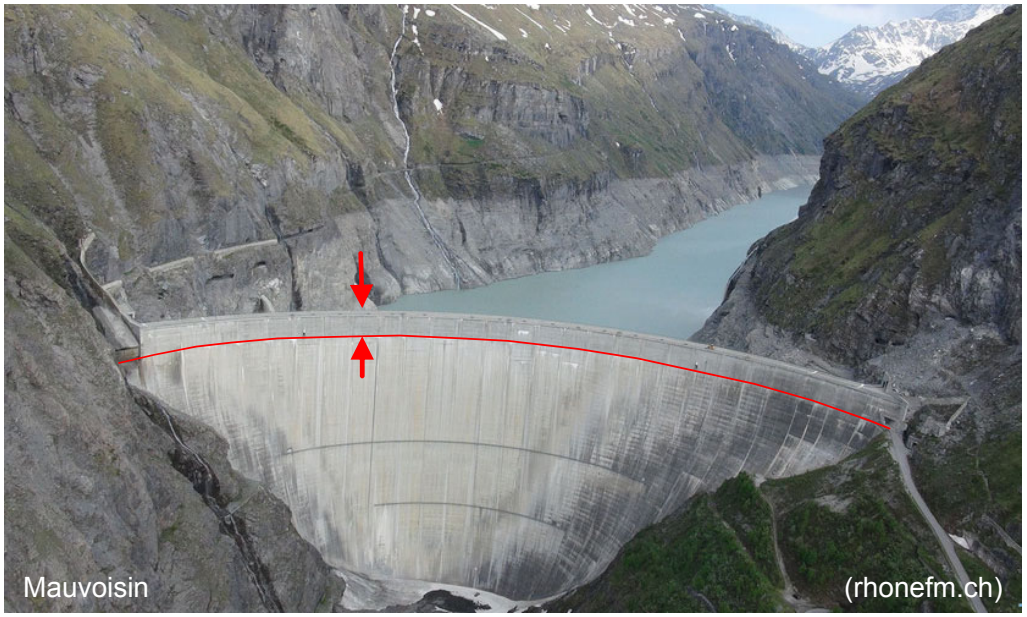
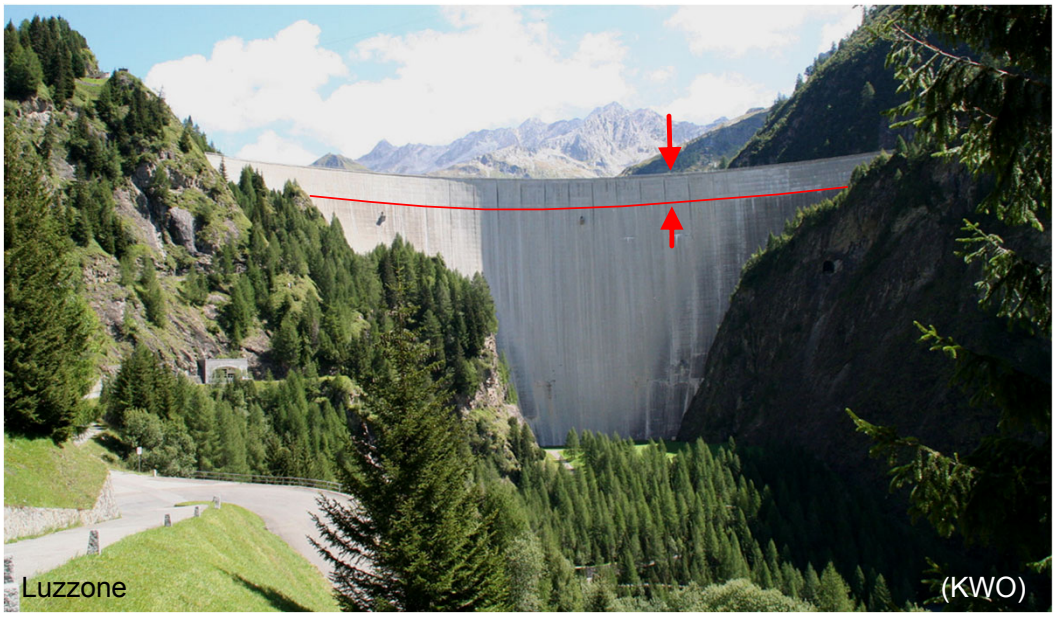
ETH zürich





Dam Heightening Options in Switzerland to increase Hydro Storage Capacity and Winter Production

SCCER SoE
SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

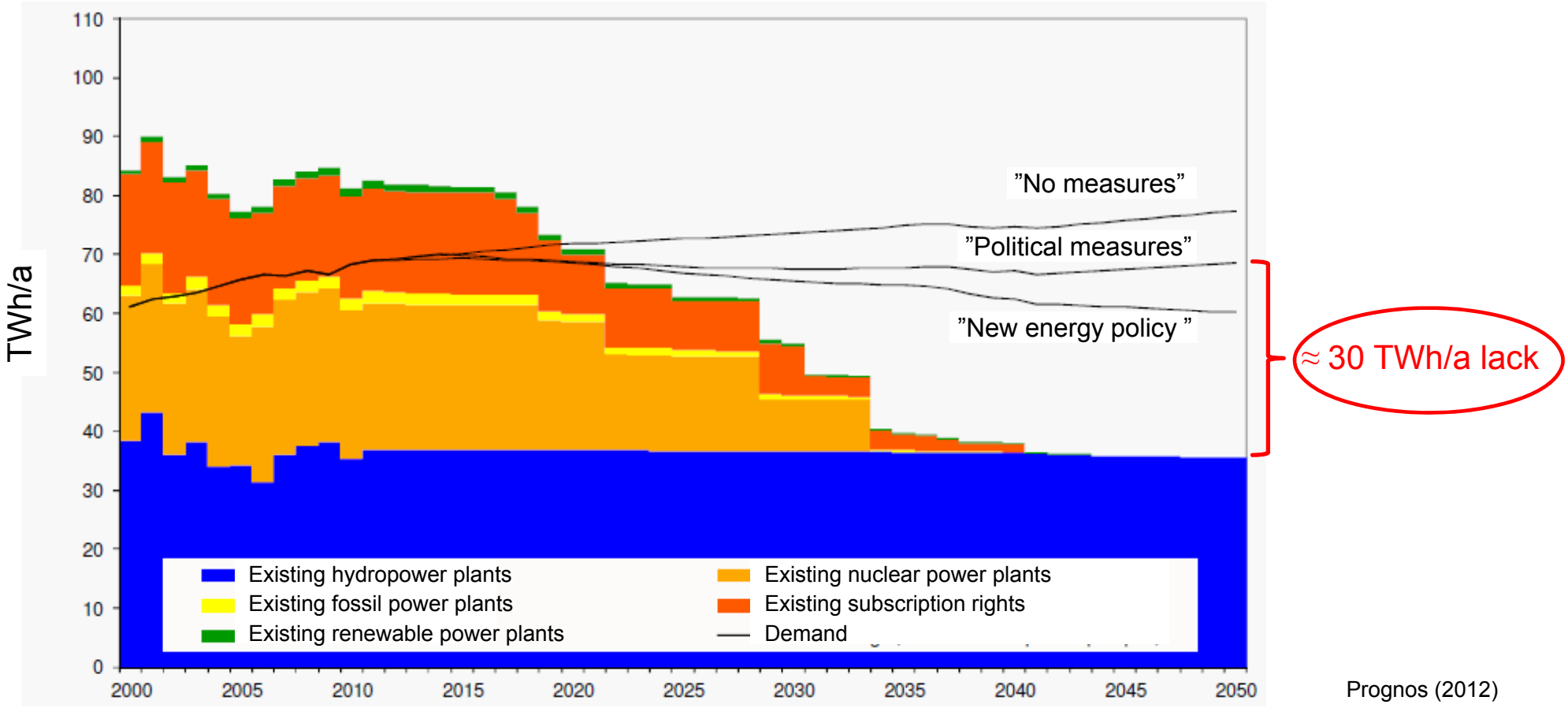
4 September 2019

Michelle Müller-Hagmann

SCCER-SoE Annual Conference 2019

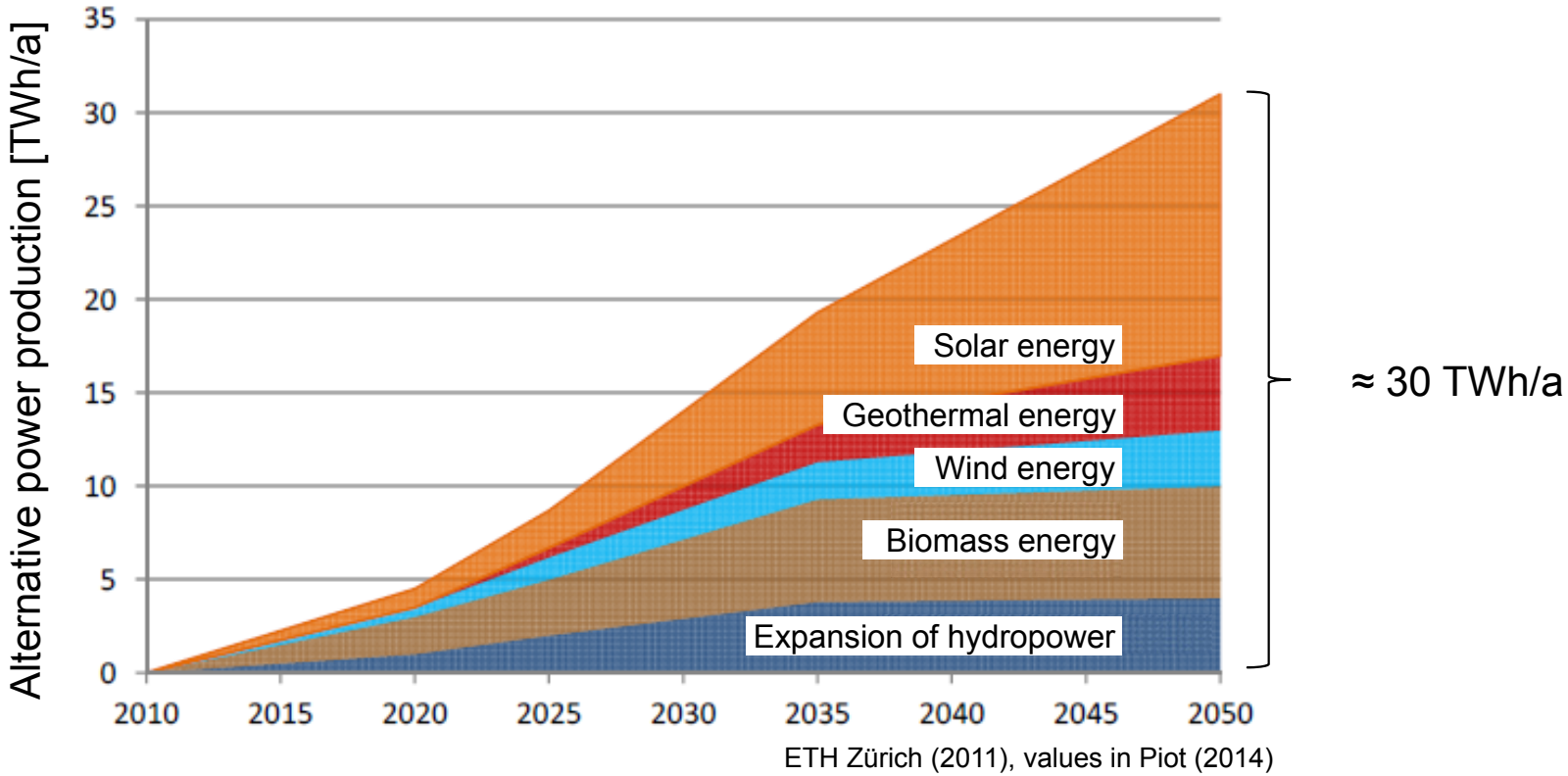
Laboratory of Hydraulics, Hydrology and Glaciology

Swiss Energy Strategy 2050 – Power supply and demand



Prognos (2012)

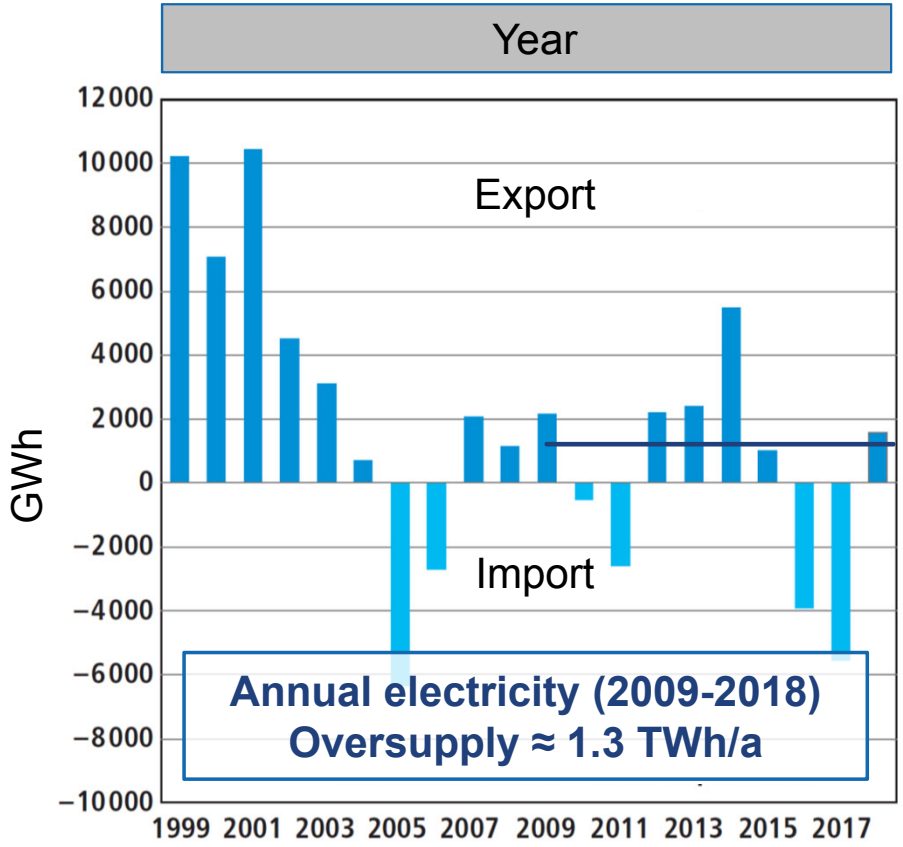
Swiss Energy Strategy 2050 – Alternative power production

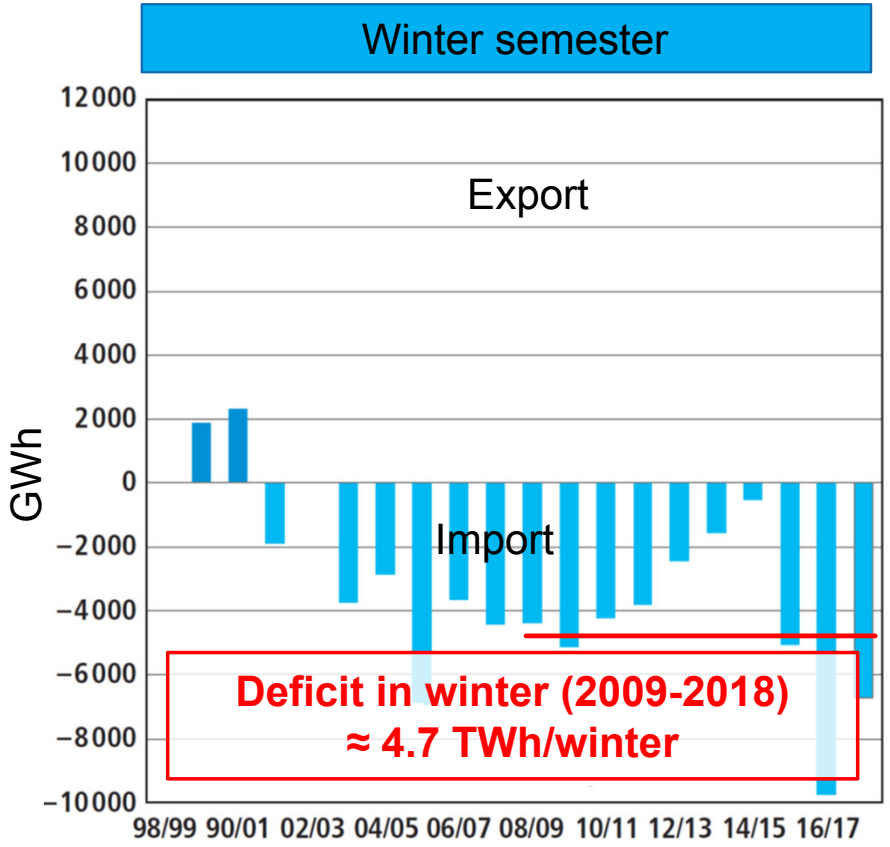


ETH Zürich (2011), values in Piot (2014)

Increasing alternative power production → Growing need for power storage capacity

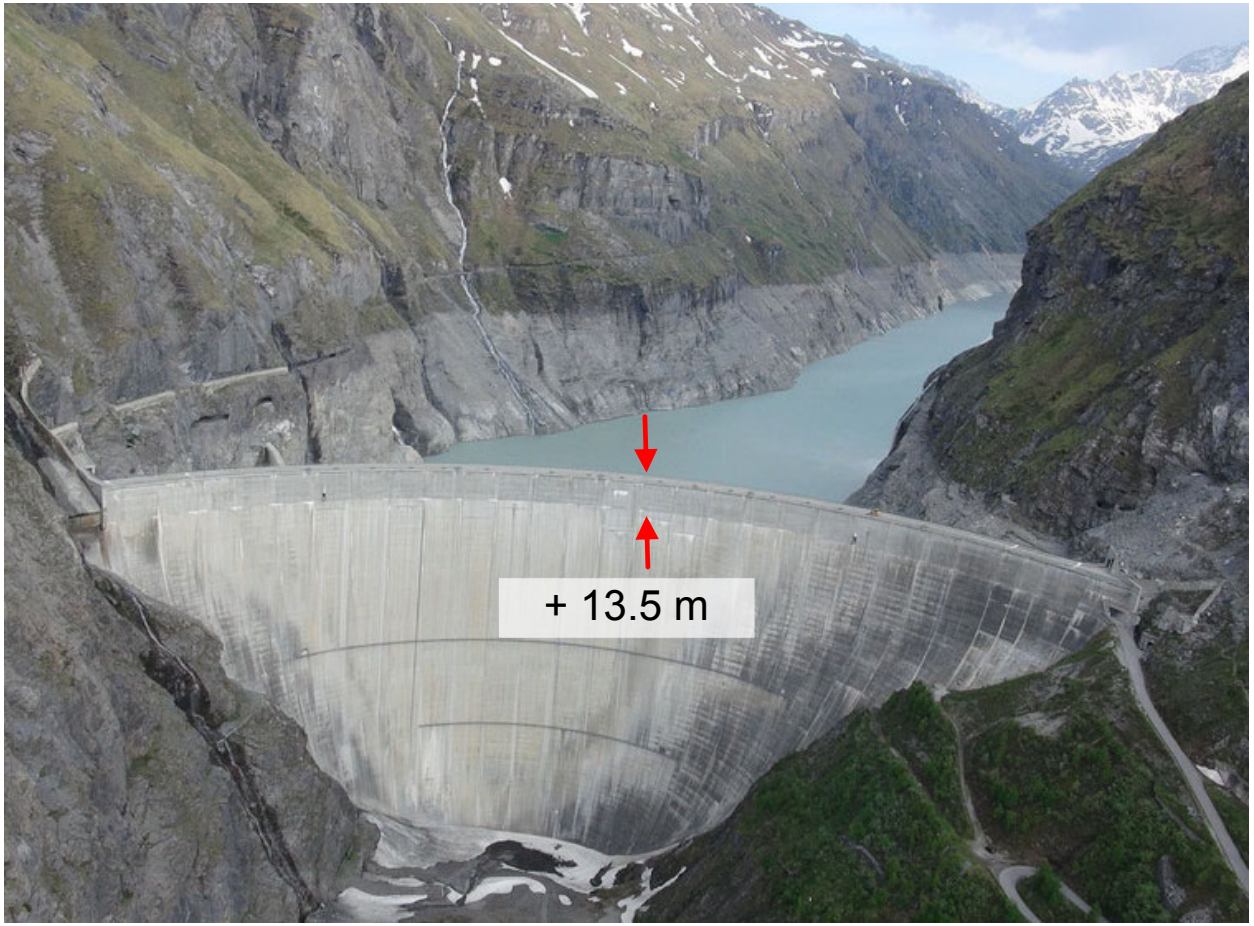
Electricity supply and demand





BFE, Schweizerische Elektrizitätsstatistik 2018

Dam heightening of Mauvoisin (1989 - 1991)



rhonefm.ch

Height H: 236.5 m → 250 m

$\Delta H/H = 6\%$

Volume V: 180 hm^3 → 210 hm^3

$\Delta V/V = 17\%$

Baublatt (1990)

Methodology

(1) Establishing an evaluation matrix

(2) Evaluation of 80 Swiss storage hydropower plants for

3 dam heightening options: $\Delta H/H = 5\%$ $\Delta H/H = 10\%$ $\Delta H/H = 20\%$

(3) Selection of preferable heightening degree

(4) Estimation of additional storage capacity and shifted electricity production (summer → winter)

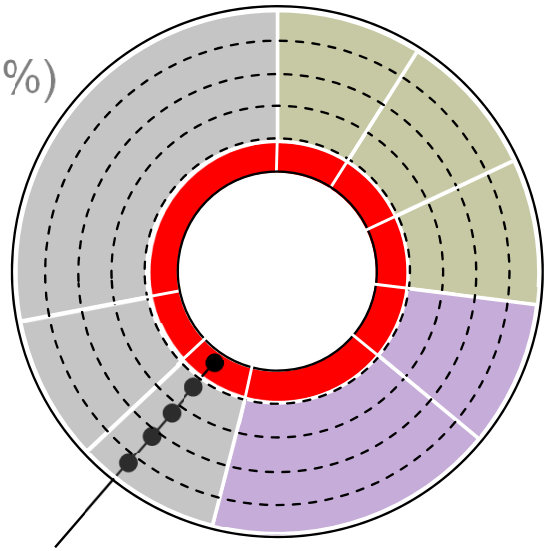
Evaluation matrix for dam heightening

POWER GENERATION SYSTEM (46%)

(F) Hydrology (9%)

(G) Modification of hydraulic systems (9%)

(H) Electricity production (28%)



FUTURE RESERVOIR AREA (27%)

(A) Protected areas (9%)

(B) Land use and buildings (9%)

(C) Infrastructures (9%)

DAM (27%)

(D) Structural suitability (9%)

(E) Relative effort (18%)

0 - 4 points

(0 points = knock-out-criterion)

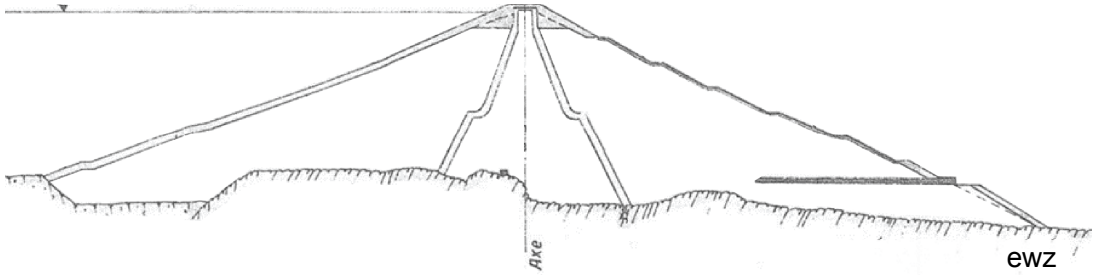
Evaluation – Case study Marmorera

Dam type: Earth core rockfill dam

Height: 91 m

Volume: 60 hm^3

Energy head: 1070 m (Cascade)



ewz

ETH Zürich

Marmorera – Evaluation: Future reservoir area (27%)

0 - 4 points (0 points = knock out criterion)

(A) Protected areas (9%)

- Reserves and areas of different protection degrees

→ Designated wildlife area slightly affected — 4 P.

(B) Land use and buildings (9%)

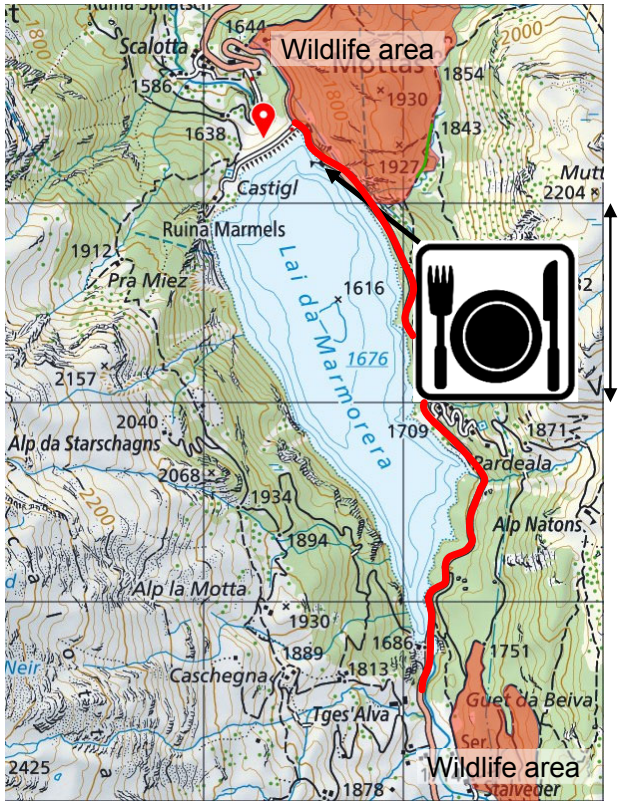
- Settlements, forests or agriculture land

→ Restaurant affected — 1 P.

(C) Infrastructures (9%)

- Embankments, traffic routes or supply and disposal lines

→ important mountain pass road affected — 1 P.



map.geo.admin.ch

Marmorera – Evaluation: Dam (27%)

0 - 4 points (0 points = knock out criterion)

(D) Structural suitability (9%)

- Rock fill dams: $\Delta H/H \leq 5\%$ well-suited, $\Delta H/H \leq 10\%$ suitable, $\Delta H/H > 10\%$ less suitable

$\Delta H/H = 5\% \rightarrow$	3 P.	$\Delta H/H = 10\% \rightarrow$	2 P.	$\Delta H/H = 20\% \rightarrow$	1 P.

(E) Relative effort (18%)

- Effort for dam and appurtenant structures, accessibility of construction sites
- No bottom and middle outlet modifications for heightening ≤ 10%
- Effort relative to additional storage capacity

$\Delta H/H = 5\% \rightarrow$	2 P.	$\Delta H/H = 10\% \rightarrow$	3 P.	$\Delta H/H = 20\% \rightarrow$	3 P.

Marmorera – Evaluation: Power generation system (46%) (I/II)

0 - 4 points (0 points = knock out criterion)

(F) Hydrology (9%)

- Capacity-inflow-ratio (CIR): CIR < 1 → sufficient inflow for summer and winter production
- No additional adductions or pumps required → 4 P.

$\Delta H/H$ = 5%: CIR=0.33 → 4 P. $\Delta H/H$ = 10%: CIR=0.36 → 4 P. $\Delta H/H$ = 20%: CIR=0.43 → 4 P.

(G) Modification of hydraulic system (9%)

- Whole hydraulic system incl. linked reservoirs and upstream located power houses
- Assumption: Energy head rise ≤ 10%: slight modifications at electro-mechanical equipment

- Slight modifications at adduction and intermediate water intake
- Surge tank modifications increases with heightening degree

$\Delta H/H$ = 5% → 3 P. $\Delta H/H$ =10% → 3 P. $\Delta H/H$ = 20% → 2 P.

Marmorera – Evaluation: Power generation system (46%) (II/II)

0 - 4 points (0 points = knock out criterion)

(H) Electricity production (28%)

- Additional energy power production in winter semester
- Considering all power plants of cascades

0 - 50 GWh/a: 1 P. 50 - 100 GWh/a: 2 P. 100 - 200 GWh/a: 3 P. > 200 GWh/a: 4 P.

$\Delta H/H$ = 5%: ≈17 GWh/a → 1 P. $\Delta H/H$ = 10%: ≈32 GWh/a → 1 P. $\Delta H/H$ =20%: ≈62 GWh/a → 2 P.

TOTAL SCORE OF MARMORERA:

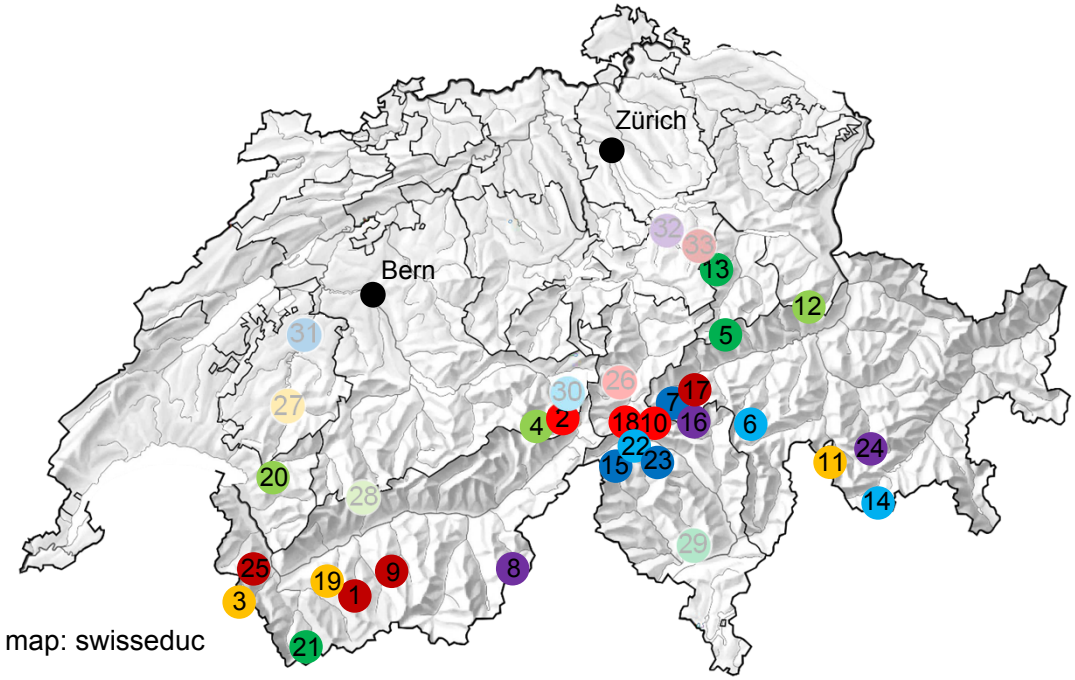
$\Delta H/H$ = 5% → 23 / 44 P. $\Delta H/H$ = 10% → 24 / 44 P. $\Delta H/H$ = 20% → 25 / 44 P.

Preferable (?) heightening degree

Dam heightening – Potential

- 80 Dams evaluated, whereof 33 large dams ($V \geq 20$ hm^3)
- 8 dams with knock out criteria

→ Additional winter production ≈ 2.3 TWh/a
(total energy equivalent of Swiss hydropower reservoirs: 8.8 TWh)

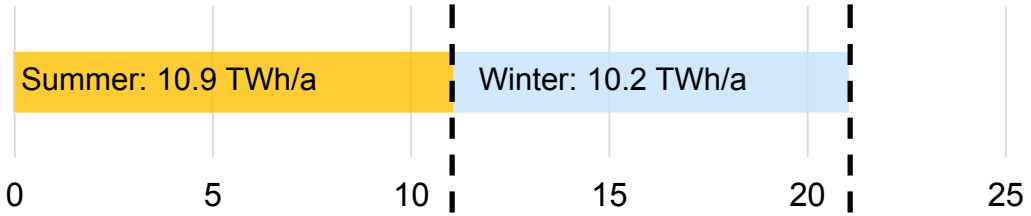


#	Name	Punkte	GWh
1	Lac des Dix +10%	39	546
2	Grimselsee +20%	35	233
3	Lac d'Emosson +10%	35	221
4	Oberaarsee +20%	34	154
5	Limmernsee +20%	33	125
6	Zervreilasee +5%	33	32
7	Lai di Curnera +20%	31	82
8	Mattmarksee +10%	30	68
9	Lac de Moiry +20%	29	167
10	Lago Ritom +10%	29	8
11	Lago di Lei +5%	28	101
12	Gigerwaldsee +5%	28	10
13	Klöntalersee +5%	28	5
14	Lago da l'Albigna +20%	28	73
15	Lago di Cavagnoli +10%	28	25
16	Lai da Sta. Maria +5%	27	30
17	Lai da Nalps +5%	27	19
18	Lago di Lucendro +5%	26	5
19	Lac de Cleuson +10%	26	16
20	Lac de l'Hongrin +20%	26	98
21	Lac des Toules +10%	26	19
22	Lago del Naret +20%	26	64
23	Lago del Sambuco +20%	25	96
24	Lai da Marmorera +20%	25	62
25	Lac de Salanfe +10%	24	48
26	Göscheneralpsee	0	-
27	Lac de Gruyère	0	-
28	Lac de Zeuzier	0	-
29	Lago di Vogorno	0	-
30	Räterichsbodensee	0	-
31	Schiffenensee +5%	0	-
32	Sihlsee +5%	0	-
33	Wägitalersee +5%	0	-

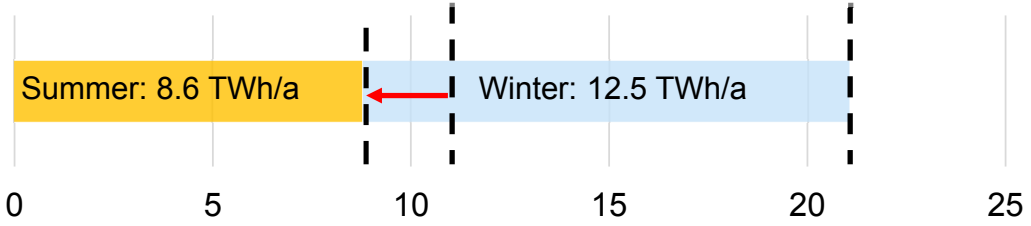
Dam heightening – Shifted energy production

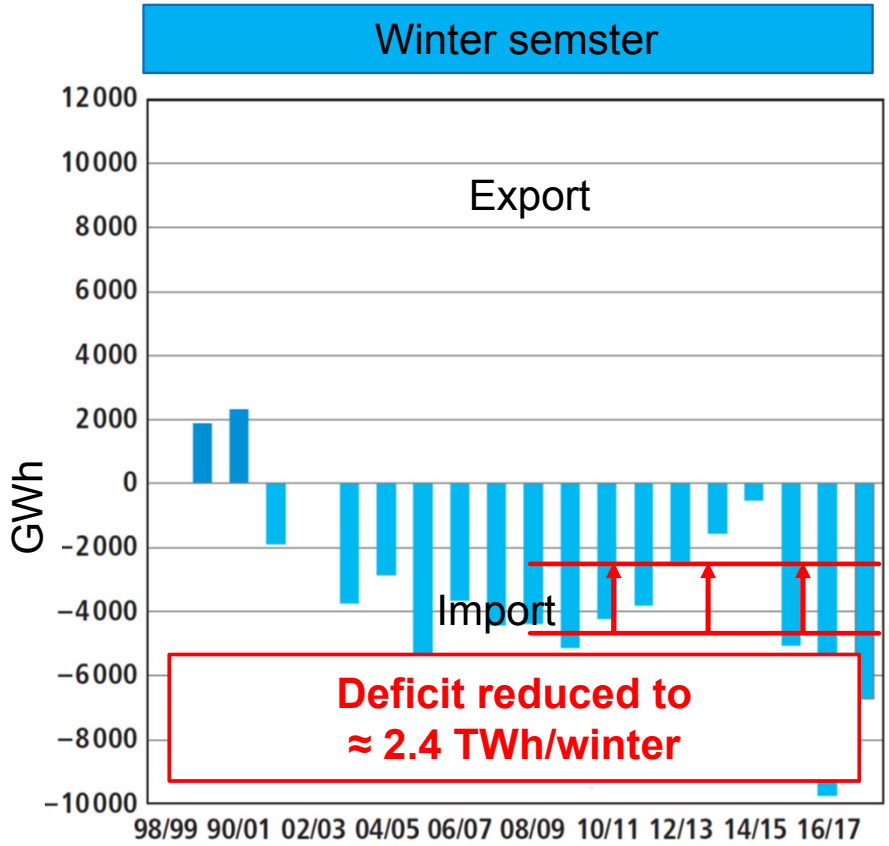
Existing storage power plants: 21.1 TWh/a

Values of BFE (2018): average of 2009-2018



After 25 dam heightenings: 21.1 TWh/a
Shift from summer to winter: 2.3 TWh/a



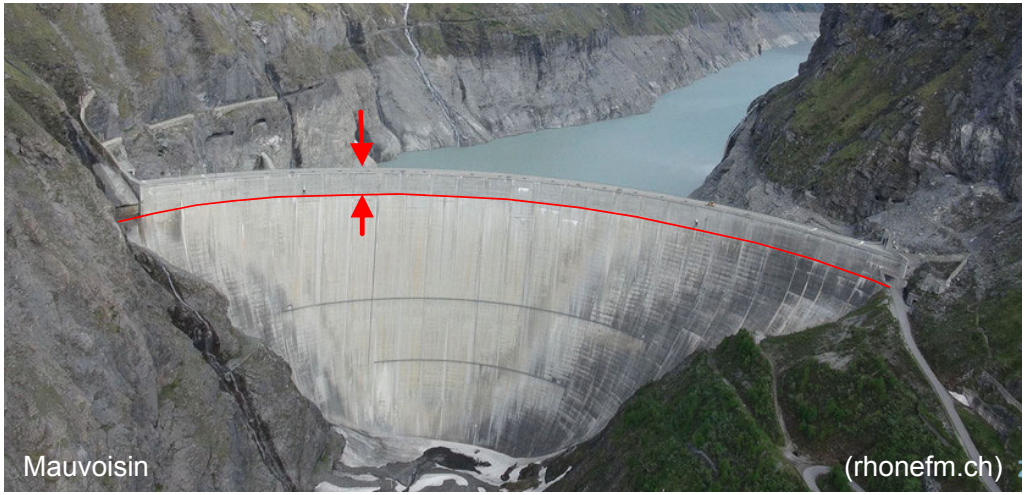


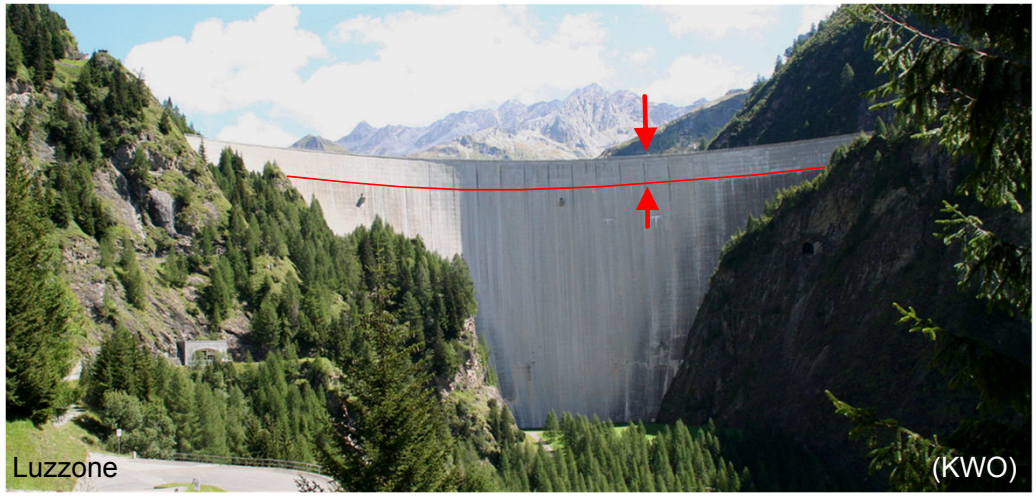
⟶ Winter deficit reduction ≈ 50% on average (data: 2009-2018)

BFE, Schweizerische Elektrizitätsstatistik 2018

Conclusions and Outlook

- Evaluation matrix
  - Suitable dams for heightening
  - Preferable heightening degrees
- Assessment of 80 dams in Switzerland
  - Heightening of 25 dams → 2.3 TWh additional winter production
  - Significantly higher independence of Swiss electricity supply
- Next step: analysis on feasibility of dam heightenings





Thank you for your attention

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