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SUPPLY of ELECTRICITY

Hydropower:
roadmap, status, and transition to phase II

Robert Boes, ETH Zürich

Annual Conference, 14.09.2017

In cooperation with the CTI

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Outline

- ES 2050: **Key questions** regarding hydropower
- **Merit of hydropower**
- **Swiss HP infrastructure**
- Selected **challenges**
- Selected **approaches** to tackle these challenges
- **Transition to SCCER Phase II**
- **Conclusions**

Energy Strategy 2050

Key questions with regard to hydropower

- Can we **increase** (e.g. by 10%) the present **hydropower electricity production** under changing demand, climate and operating conditions?
- Can we **maintain, improve and operate** a **cost-efficient hydropower infrastructure in the long-term future**?



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Merit of Hydropower (HP)

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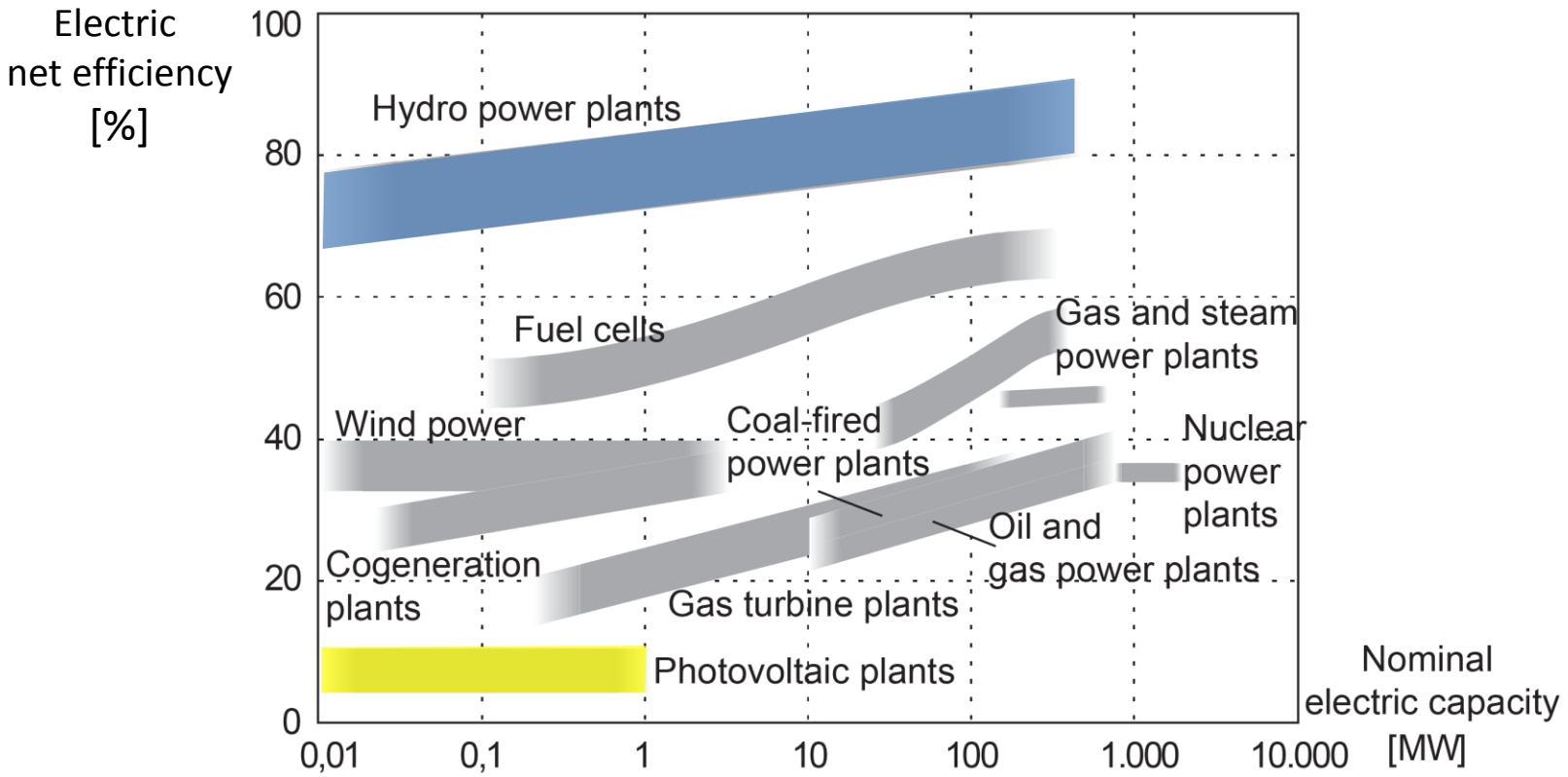
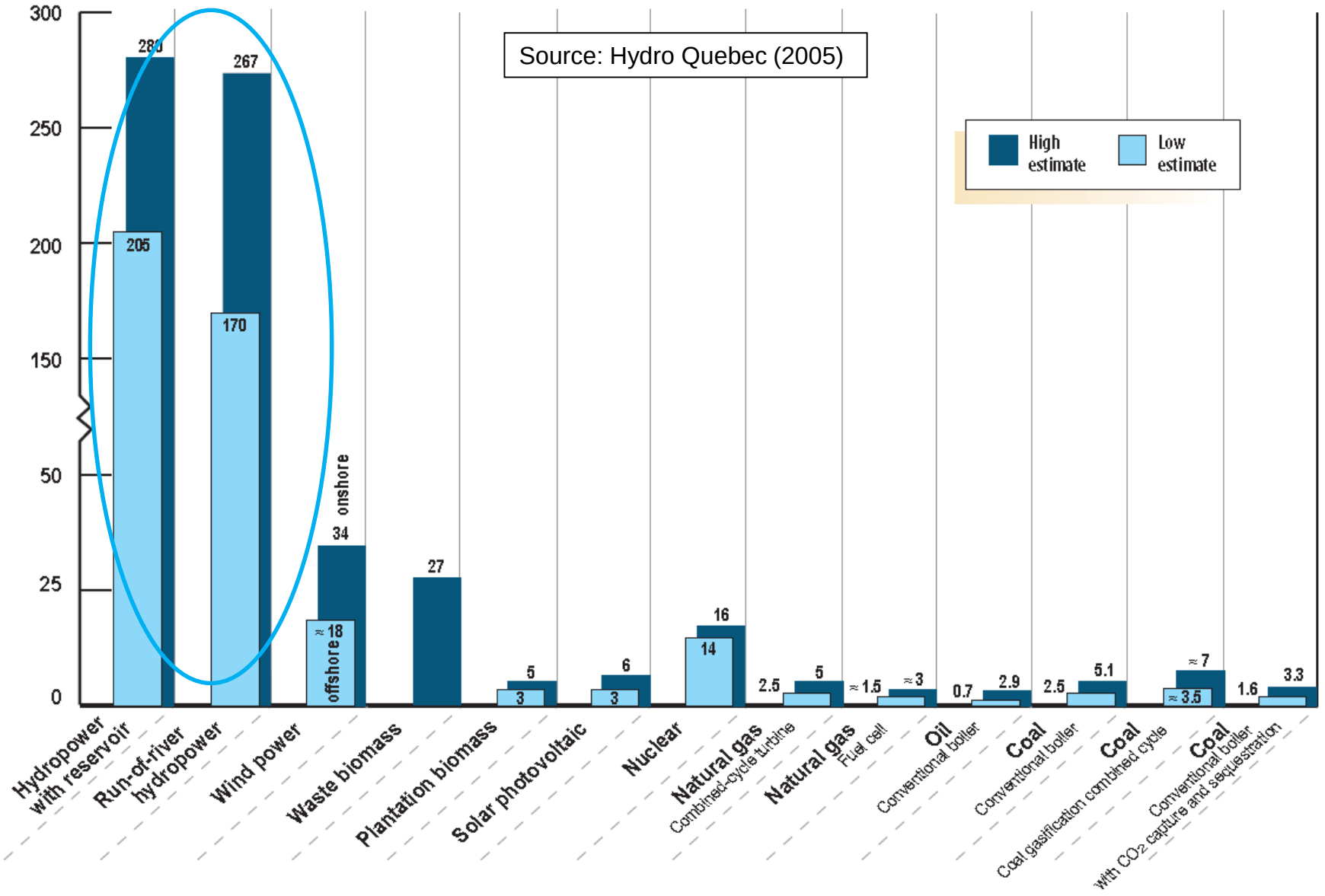
Energy efficiency

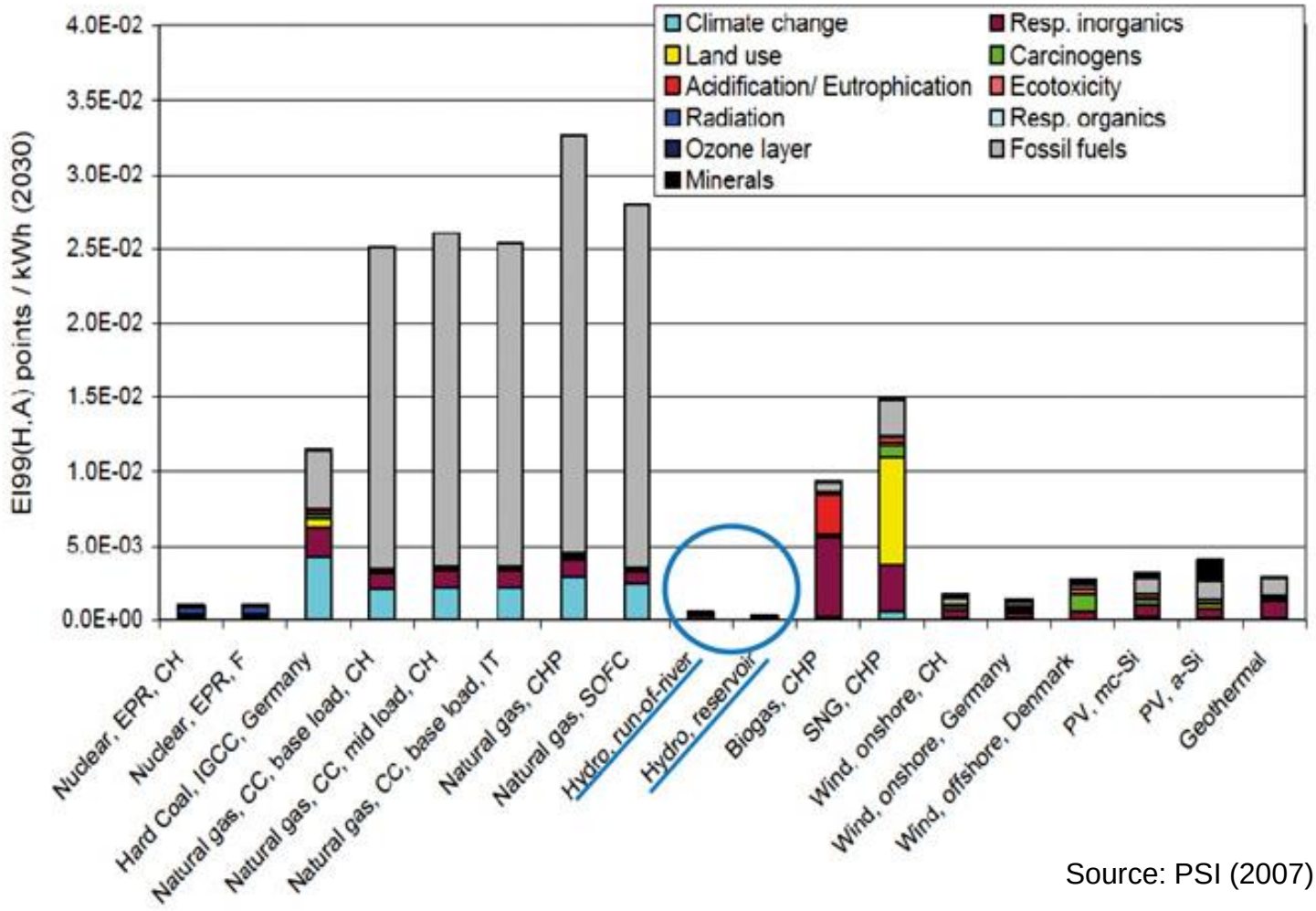


Source: after Giesecke *et al.* (2014)

Energy payback ratio

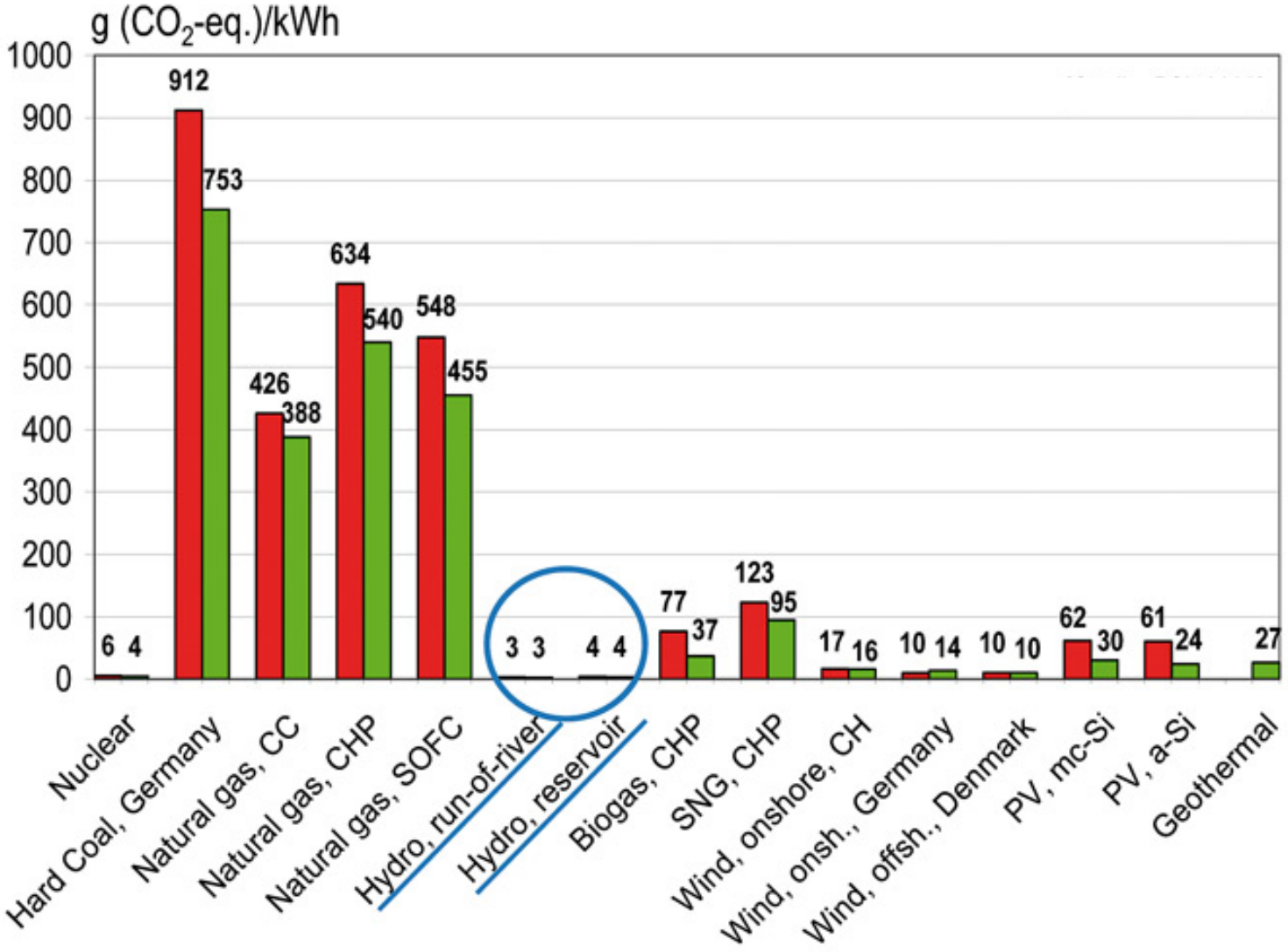


Ecological balance



Source: PSI (2007)

Balance of greenhouse gases



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Swiss HP infrastructure

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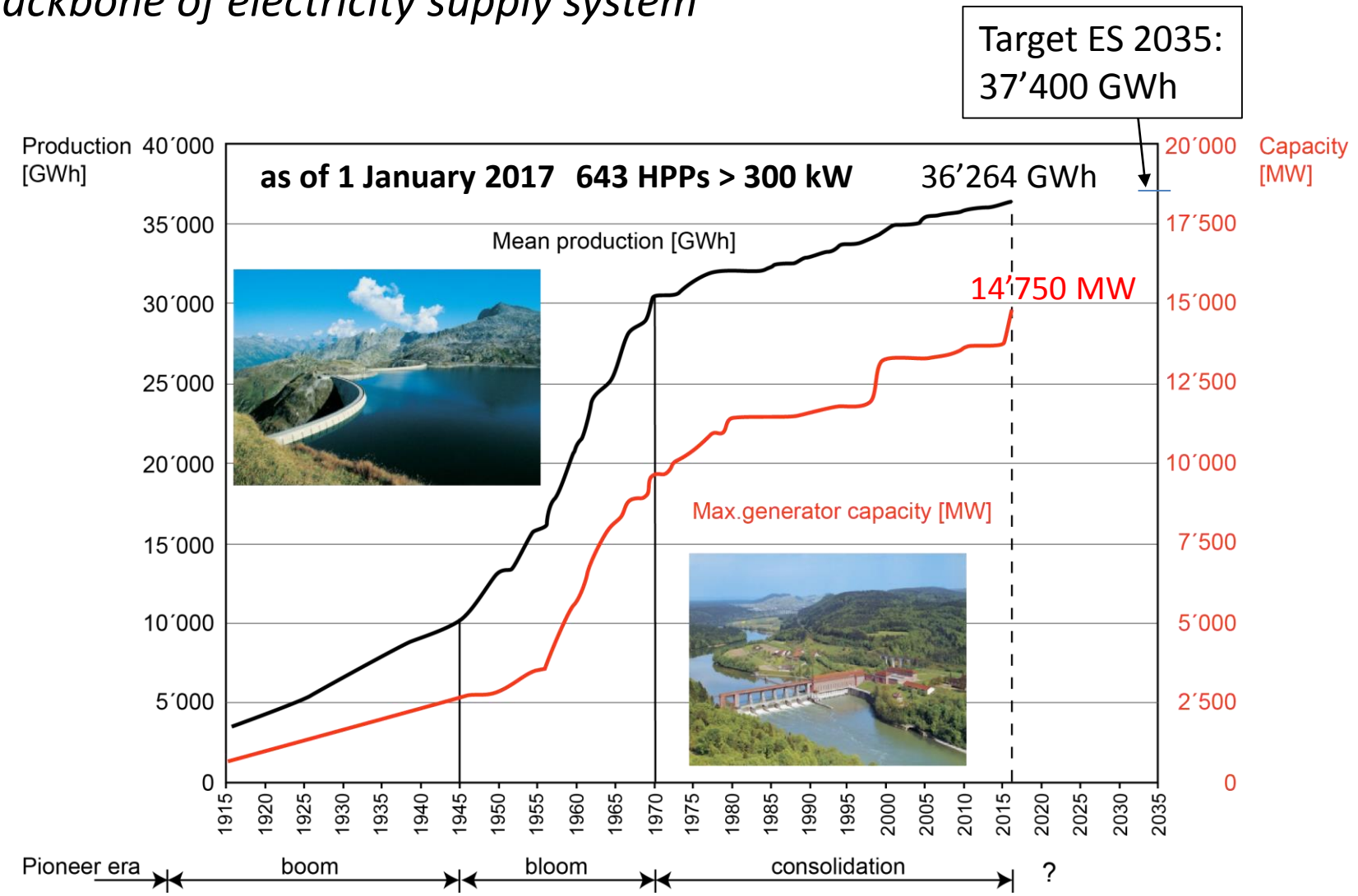
Development of Swiss hydropower

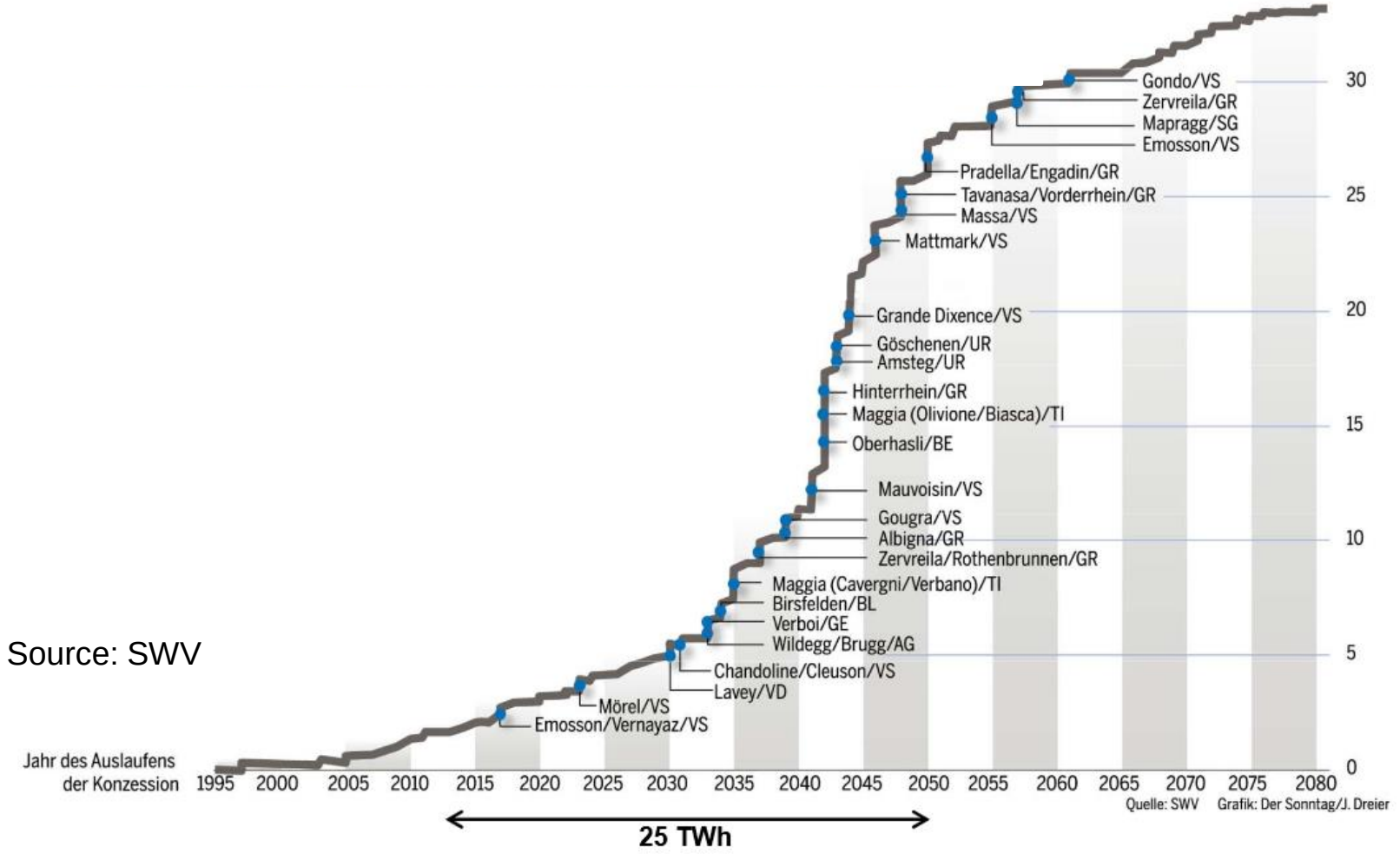
Backbone of electricity supply system



Source: adapted from Revaz, SFOE (2017)

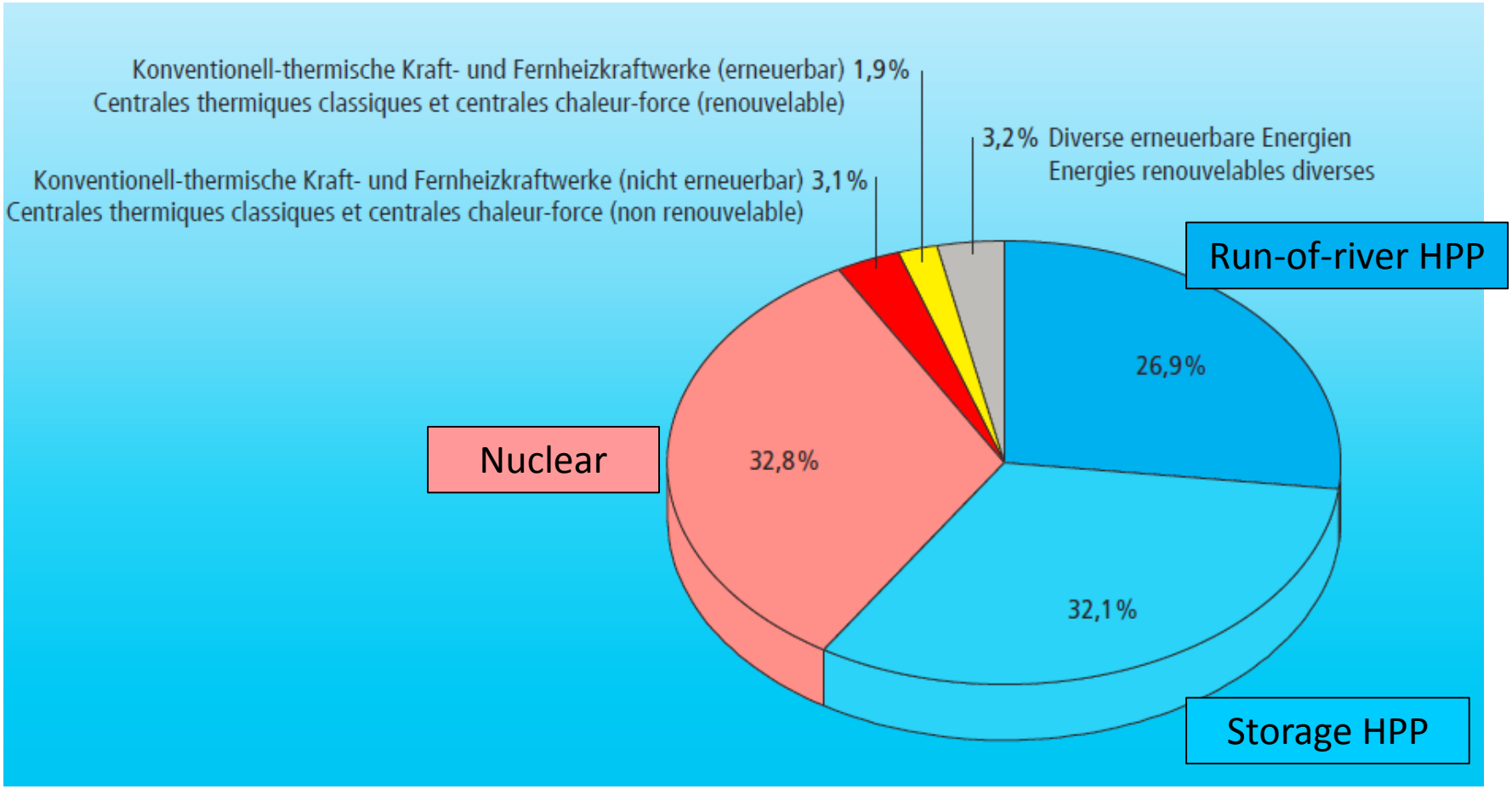
Development of Swiss hydropower

Concession renewals



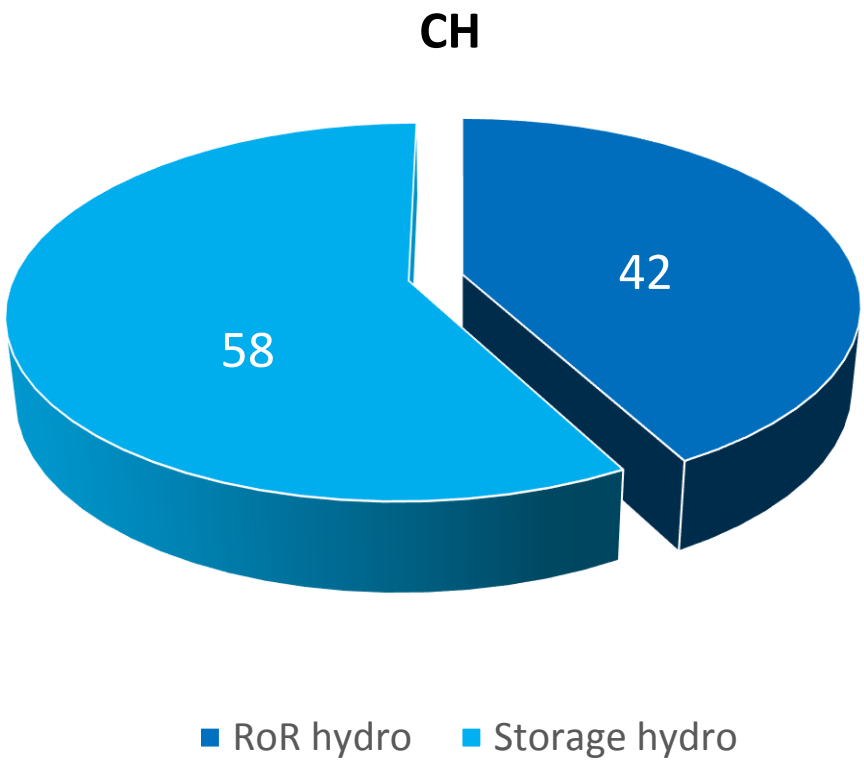
Source: SWV

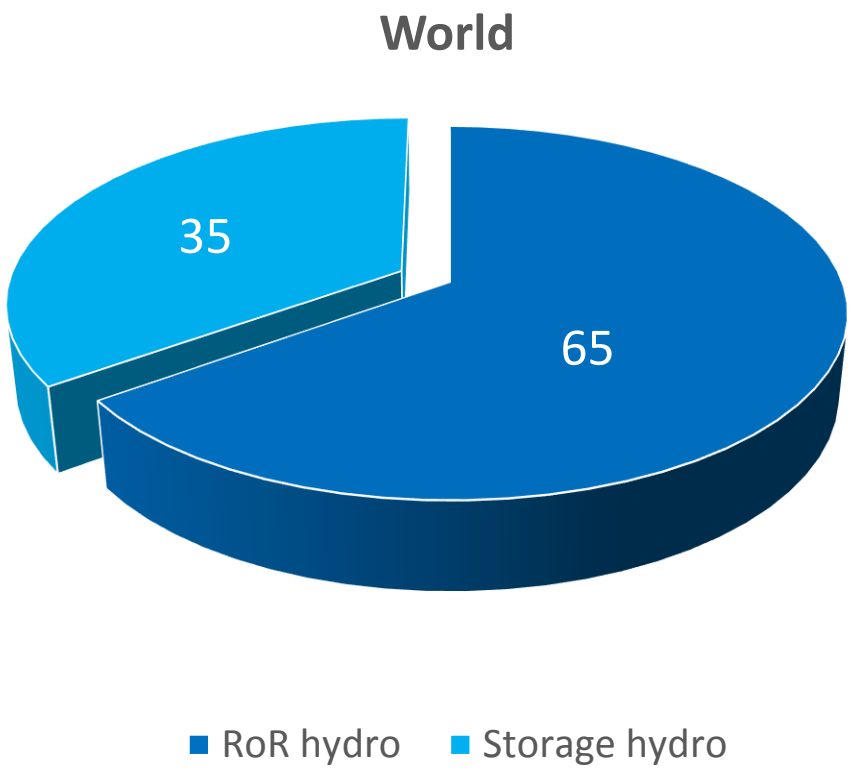
Swiss power plant category share 2016



Source: SFOE (2017)

HPP category share 2016





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Selected challenges

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Upcoming challenges for hydropower

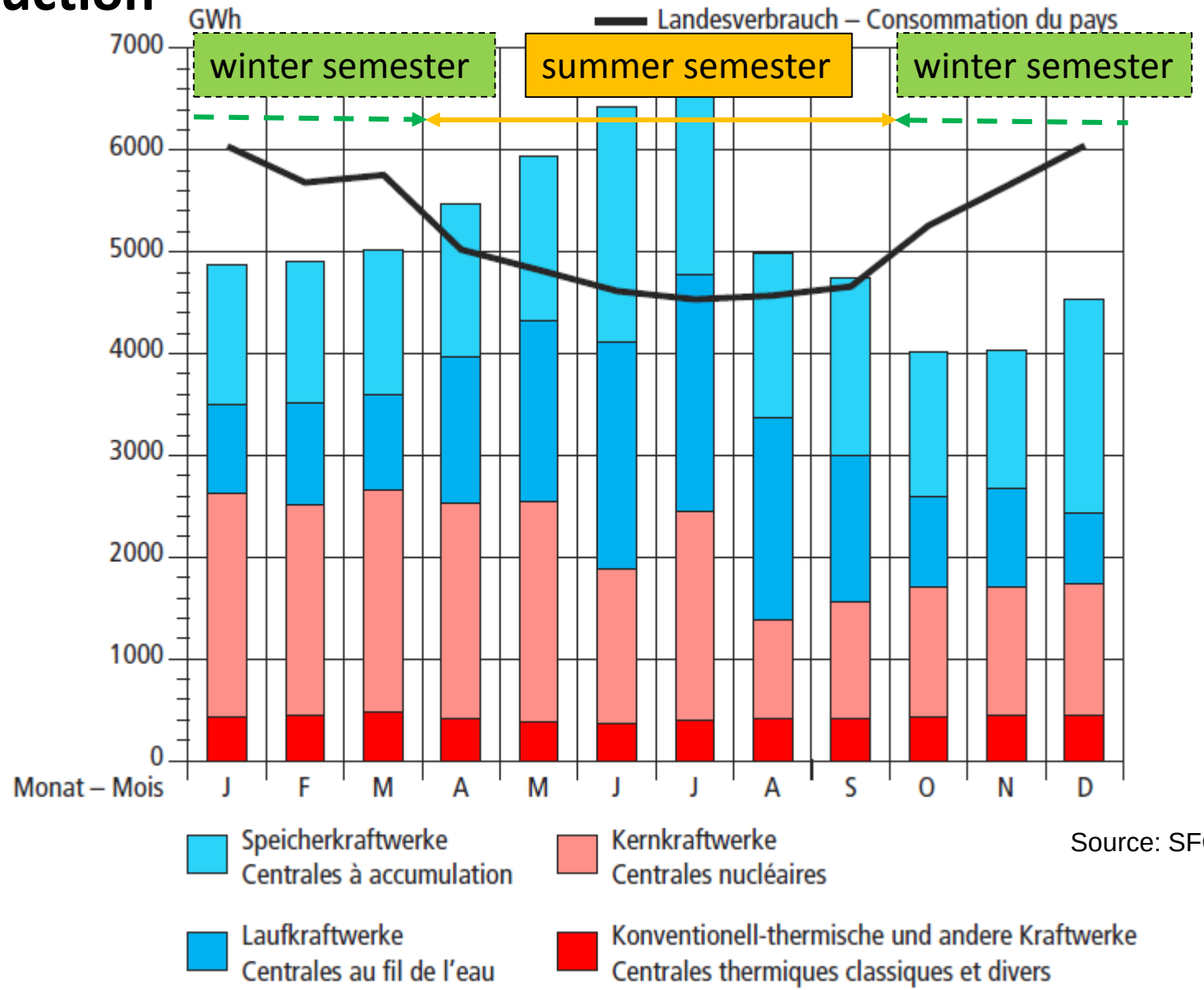
Can we **increase** (e.g. by 10%) the present **hydropower electricity production** under changing demand, climate and operating conditions?

- Increase **hydro production in winter** semester *(e.g. dam heightening)*
- Increase **storage volume** *(e.g. by periglacial hydro)*

Can we **maintain, improve and operate** a **cost-efficient hydropower infrastructure in the long-term future**?

- Improve **efficiency** *(e.g. counter negative effects of sediments)*
- Increase **flexibility** *(e.g. by new (pumped) storage schemes)*
- Make hydropower more **environmentally-friendly** *(e.g. improve fish migration across dams)*

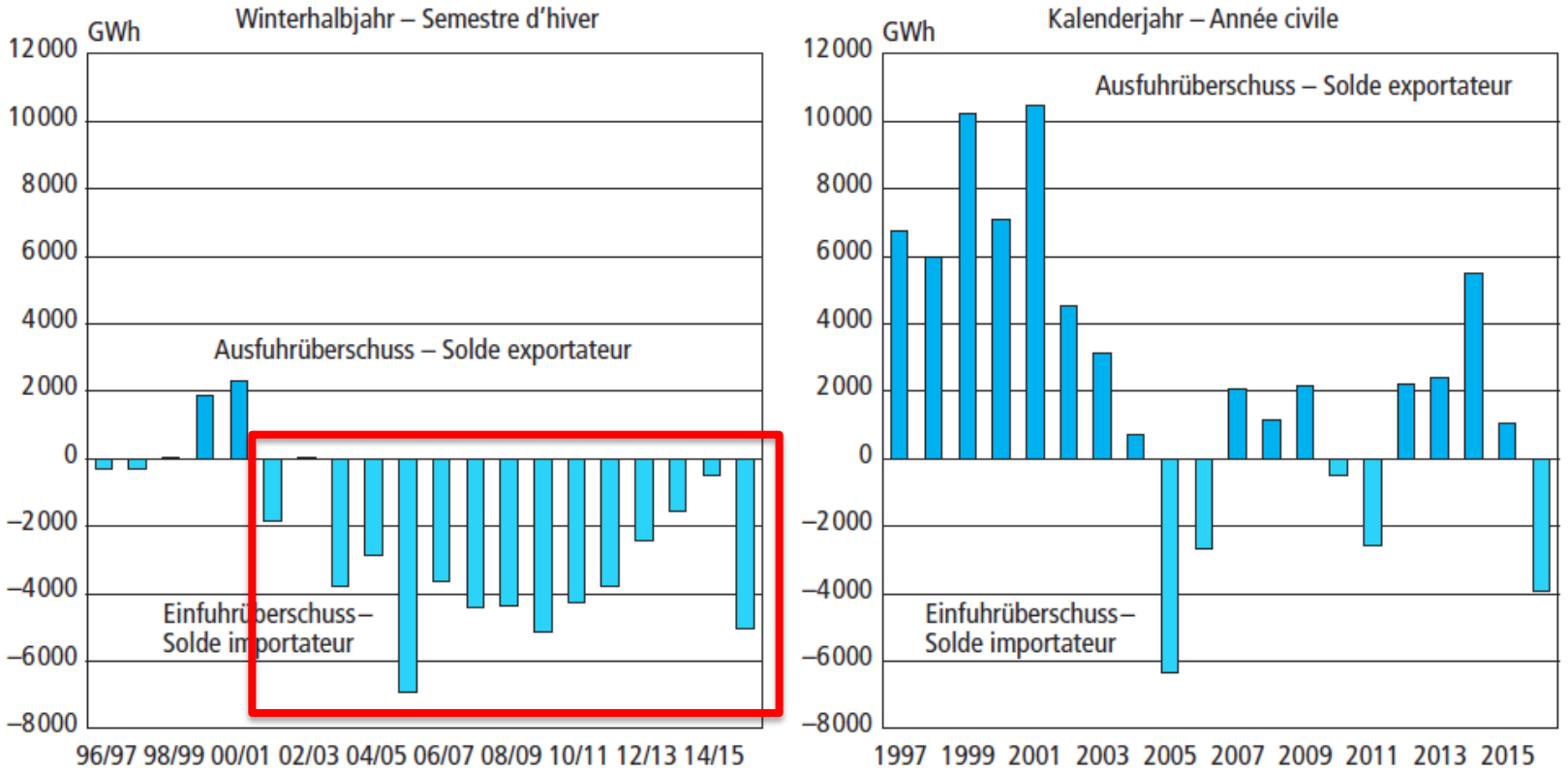
Monthly electricity consumption and production



Source: SFOE (2017)

Electricity shortage in winter semester

- Surplus of electricity import in winter semester for many years
- Today nuclear PPs produce 14 TWh of base load in winter semester
- New renewables shall produce 10.5 TWh in winter semester by 2050



Source: Piot (2014), SFOE (2016)

Electricity shortage in winter semester

Source:

- Current energy equivalent of Swiss storage reservoirs: 9 TWh
- **gap between consumption and production in winter semester** will amount to **between 3 and 7.7 TWh** (Source: Piot 2014) (depending on scenario)

→ close gap by

  - imports,
  - new combined cycle PPs,
  - additional seasonal storage reservoirs

Source: KWO (2016)

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Selected approaches to tackle these challenges

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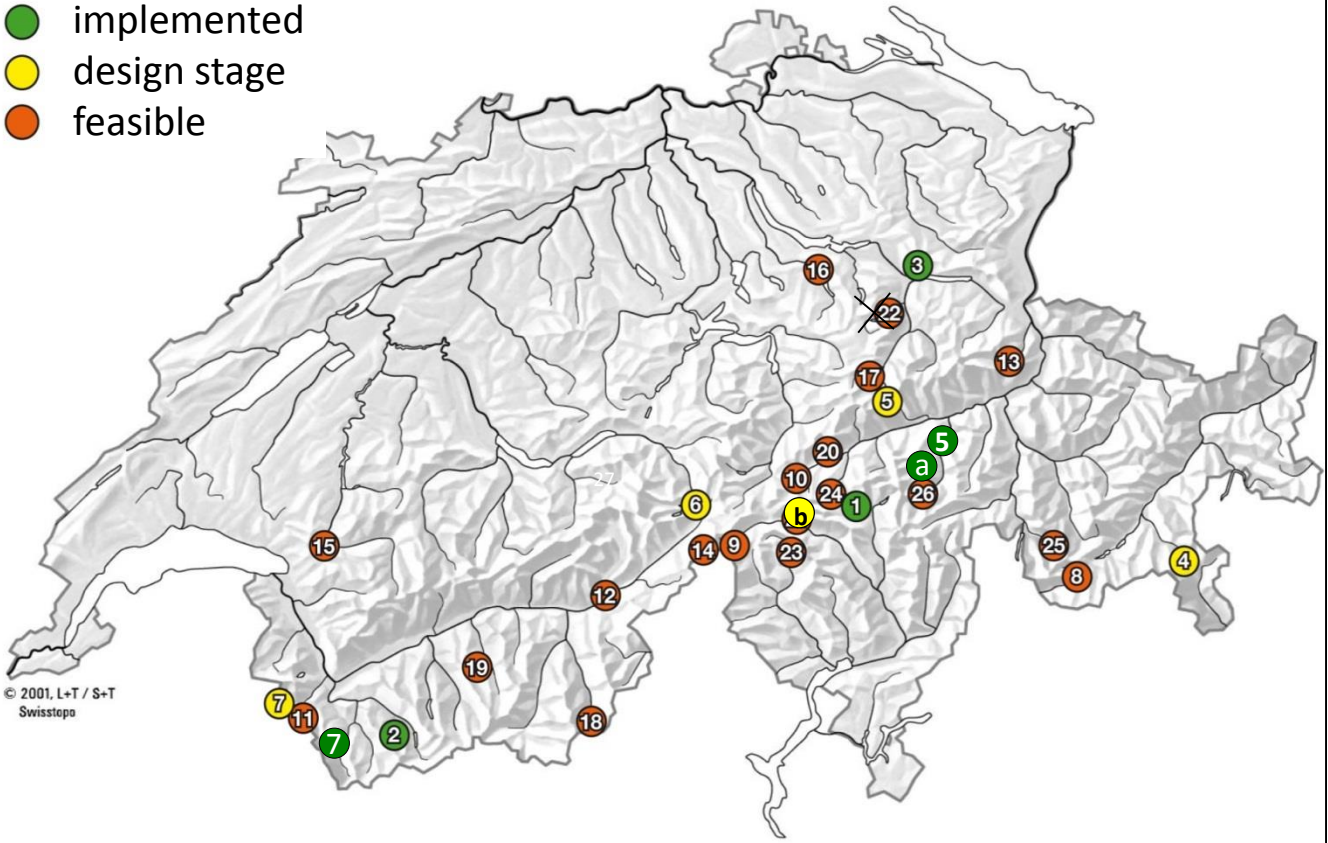
Dam heightening

- implemented
- design stage
- feasible



Map: SWV; Sources: SFOE (2004), EPFL (2012), VAW (2016)

→ **+370 hm³ of additional storage volume (+25%)**

→ **+ 2 TWh of additional winter semester and peak energy**

Implemented:
1 Luzzone (17 m)
2 Mauvoisin (13.5 m)
3 Muslen (5 m)
5 Muttsee (neu, 35 m)
7 Vieux-Emosson (20 m)
a Barcuns (5 m)

Design stage:
4 Lago Bianco N/S
6 Spitallamm/Seeuferegg (101 hm³)
b Göscheneralp (76 hm³)

Feasible:
8 Albigna (70 hm³)
9 Cavagnoli (29 hm³)
10 Curnera (40.8 hm³)
11 Emosson (227 hm³)
12 Gebidem (9.2 hm³)
13 Gigerwald (33.4 hm³)
14 Gries (18 hm³)
15 Hongrin (52 hm³)
~~16 In den Schlagen/ Hünermattdamm~~
17 Limmern (92 hm³)
18 Mattmark (100 hm³)
19 Moiry (77 hm³)
20 Nalps (44.5 hm³)
21 Piora (47.5 hm³)
22 Rhodannenberg (39.8 hm³)
23 Sambucco (64 Mio. m³)
24 Santa Maria (67 hm³)
25 Valle di Lei (197 hm³)
26 Zervreila (100 hm³)

Periglacial hydro

New reservoirs and schemes due to glacier retreat

Trift glacier 30 June 2004 (photo: VAW)

Trift glacier 3 July 2014 (photo: VAW)

Periglacial hydro

Technical potential of selected future hydropower plants

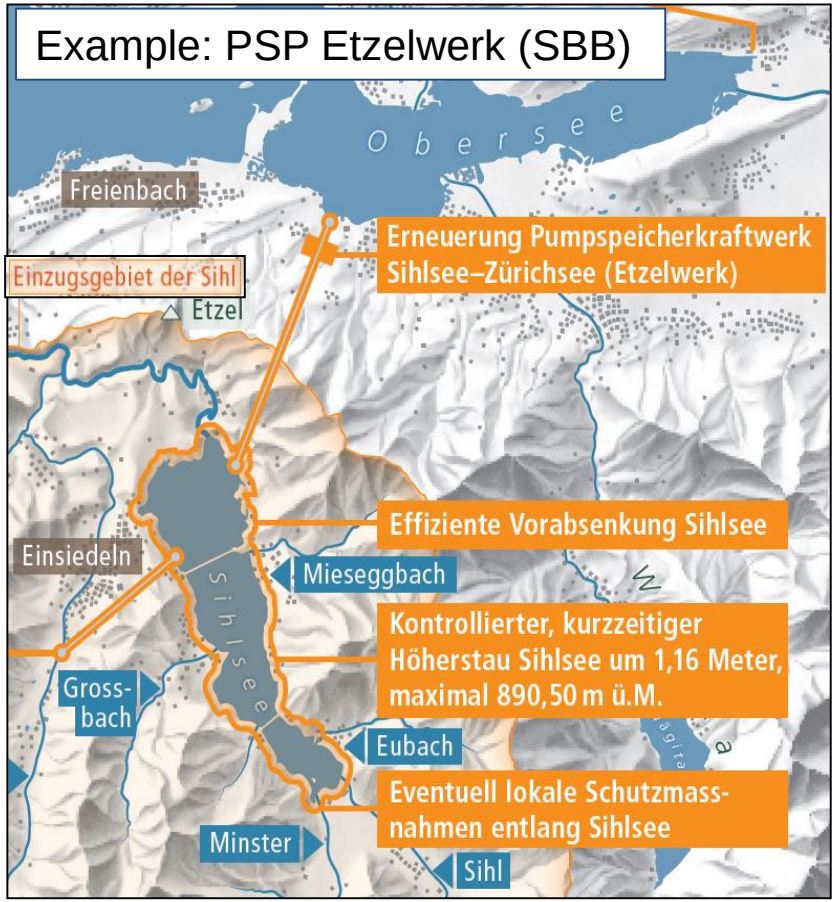
Location [name of nearest glacier] (Kanton)	Annual production [GWh/a]	Reservoir volume [hm³]	Stored energy equivalent [GWh]
Aletsch Glaciers (all) (VS)	180	106	211
Baltschieder Glacier (VS)	74	27	84
Gorner Glacier (VS)	119	34	88
Grindelwald (BE)	130	92	83
Hüfi Glacier (Maderan valley, UR)	171	60	181
Rhone Glacier (VS)	98	23	37
Roseg Glacier (GR)	253	89	210
Trift Glacier (BE)	146*	85*	215*
Total (% relative to 2016)	**1'171 (+3.2%)**	**516**	**1'109 (+12%)**

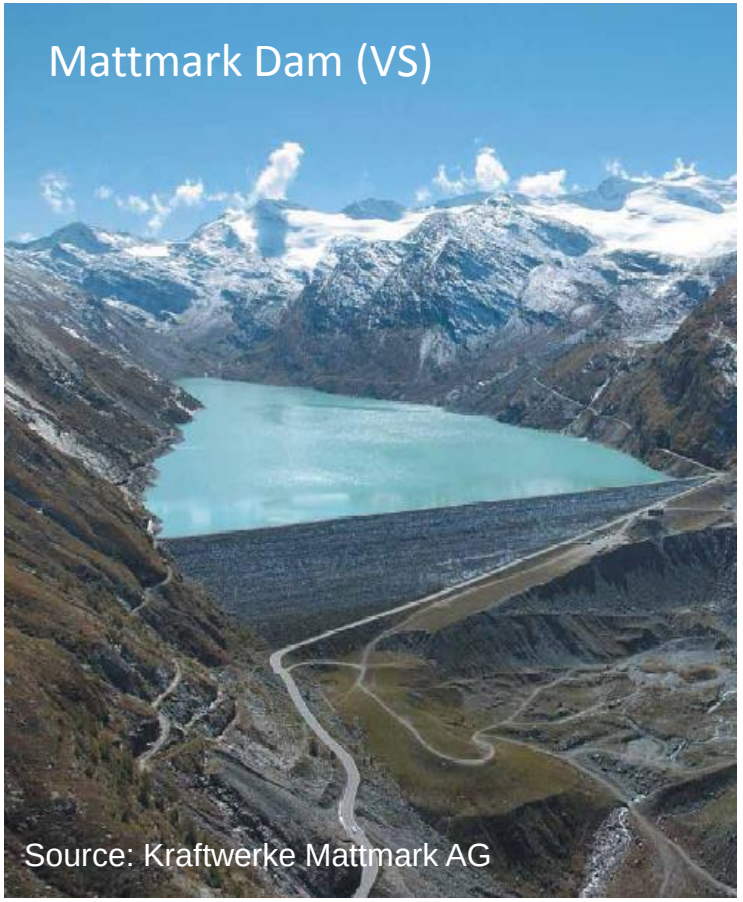
* http://www.grimselstrom.ch/ausbauvorhaben/projekt-speichersee-und-kraftwerk-trift

Source: Ehrbar et al. (2017)

Multi-purpose (pumped) storage schemes

- Combination with increase of **flood retention volume**
- Combination with **irrigation and drinking water needs**





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Key cont

HP under uncertainties (F. Oberrauch)

Fine sediment management (D. Felix)

Small HP & biodiversity (K. Lange)

Simulation of HP system operation (P. Burlando)

Task 2.1	*Task 2.2*	*Task 2.3*	*Task 2.4*
Morpho-climatic controls on future HP production	HP infrastructure adaptation to future requirements	Environmental impacts of future HP operating conditions	Integrated simulation of HP systems operation

Research directions

- **Increase of flexibility** in hydropower operation – structural and operation requirements
- Update of **climate change impacts** on HP production
- Extreme **natural hazards** and risk of HP operation
- Design of **new projects under uncertainties**
- **Reservoir sedimentation** and sustainable operation of storage hydropower plants

New: 3 Demonstrators

HP Demonstrators

Demo-5: Small Hydropower

Effect of short-term discharge fluctuations on downstream ecosystems

⇨ Presentation by C. Münch-Alligné tomorrow

Demo-6: Controlled fine sediment release from a reservoir by a hydrodynamic mixing device (SEDMIX)

Effect of fine-sediment venting through waterways on both reservoir sedimentation, hydraulic machinery and downstream ecosystems

⇨ Presentation by A. Schleiss tomorrow

Demo-7: Complex large hydropower scheme (FLEXSTOR)

Optimization potential of a large HP scheme as to intra-day and intra-annual operation

⇨ Presentation by P. Manso tomorrow

Conclusions

- **Hydropower** will remain **backbone of Swiss electricity supply**
- **HP faces new challenges** that need to be solved
- **HP targets for 2035 (as to annual production) and for 2050 (as to winter energy) can be met** with dam heightening and new periglacial storage schemes
- **SCCER-SoE aims at making HP more efficient, flexible, robust, safe, and cost-effective**
    - *Phase 1*: Number of challenges generally tackled, new approaches developped
    - *Phase 2*: Demonstrators included to show applicability of approaches; dissemination of findings and knowledge transfer are targeted
    - *Phase 3*: Still lots to do …. ☺

Thank you for your attention!

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