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Untapped seasonal storage potential in Swiss hydropower schemes

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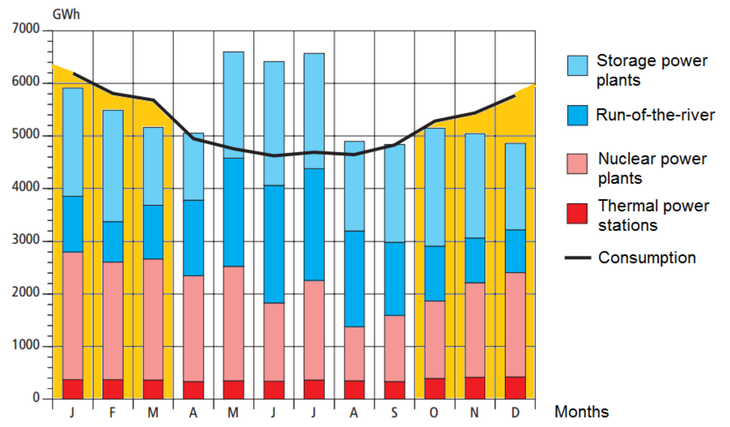
(1) Context and motivation

- CH's continued dependency on electricity imports, mainly in winter
- Growing need for additional capacity in seasonal energy storage
- Hydropower is expected to be the backbone of the energy transition
- Lack of common metrics to assess seasonal storage capacity



Since 2005, Switzerland has been importing electricity in winter, roughly from October to March, to compensate for the insufficient indigenous electricity production.

Fig. 1 Monthly electricity production and consumption (SFOE, 2015)

(2) Research questions

- What is the seasonal storage capacity in Swiss hydropower dams ?
- How could the untapped potential be captured?
- What is the impact on the Swiss energy transition ?

(3) Methodology to assess storage potential

Today's seasonal storage capacity (8.82 TWh) can be given by:

$$SSC = RLC * WEC$$

The untapped SS potential (SSP) is estimated with the help of the Water Turnover Ratio (WTR):

$$WTR = MAI / RLC$$

- **RLC** • reservoir live storage capacity [hm³]
- **WEC** • water equivalent coefficient [kWh/m³] or [GWh/hm³]
- **MAI** • mean annual inflows [hm³]
  It is the most robust hydrologic variable to estimate water resources in the context of Alpine watersheds where dam reservoirs are operated in intra-annual cycle.

For each given reservoir:

a) MAI is estimated based on all contributing catchment surfaces and cumulated inflows (SFOENV database of PREVAH modelled monthly flows) from the natural catchment and all diversions

b) WEC is estimated based on average annual WEC per powerhouse from the annual cumulated production and addition of all partial WECs to obtain a representative value for the entire cascade (the downstream limits coincide with the concession limits).

▶ **If WTR > 1 ⇔ RLC < MAI** the mean annual inflows are higher than the dam capacity → increasing the storage volume is an option (e.g. by dam heightening).
The seasonal storage potential is then **SSP = WEC*(WTR- 1)*MAI** [GWh] where MAI-RLC is the amount of water in excess of RLC

▶ **If WTR < 1 ⇔ RLC > MAI** the existing storage capacity is larger than natural inflows to the reservoir → more water can be diverted to this reservoir (e.g. by gravity or pumped diversion from neighboring catchments)
The seasonal storage potential is then **SSP = WEC*(RLC-MAI)** [GWh], where RLC-MAI is the unused reservoir volume.

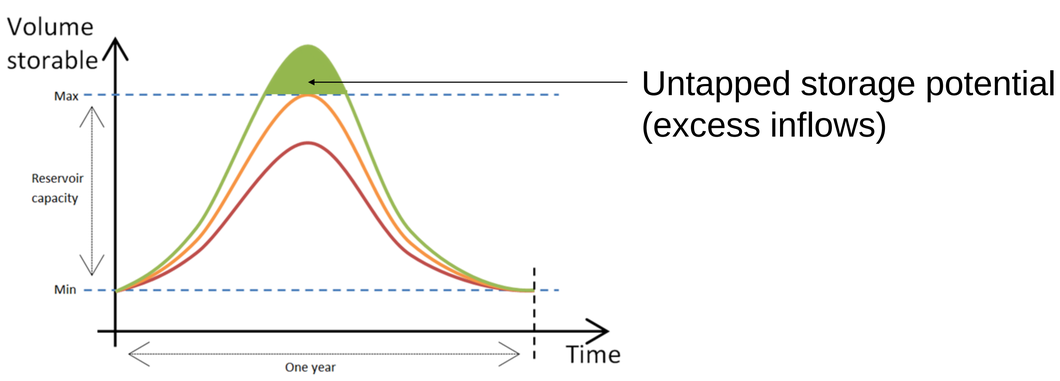


Fig.2 Typical curve of reservoir annual storage cycle (Akari 2016)

(4) Results

- We have analysed all Swiss hydropower reservoirs with a capacity above 1 million m³ [3]:
  - 63 reservoirs > 1 hm³
  - 40 reservoirs > 10 hm³
  - 29 reservoirs > 30 hm³
  - 36 reservoirs > 60 hm³
- These 168 dams represent 8778 GWh of storage capacity, which is over 99% of the total Swiss hydropower storage capacity.
- The results show that a significant number of dams could increase storage in a significant way:
  - 48 dams could capture existing excess natural inflows if their current storage capacity were to be increased (green dots in Figure 3 below).
  - 7 dams are sub-optimally used, and could catch additional inflows using existing infrastructure (red bubbles in the figure below).

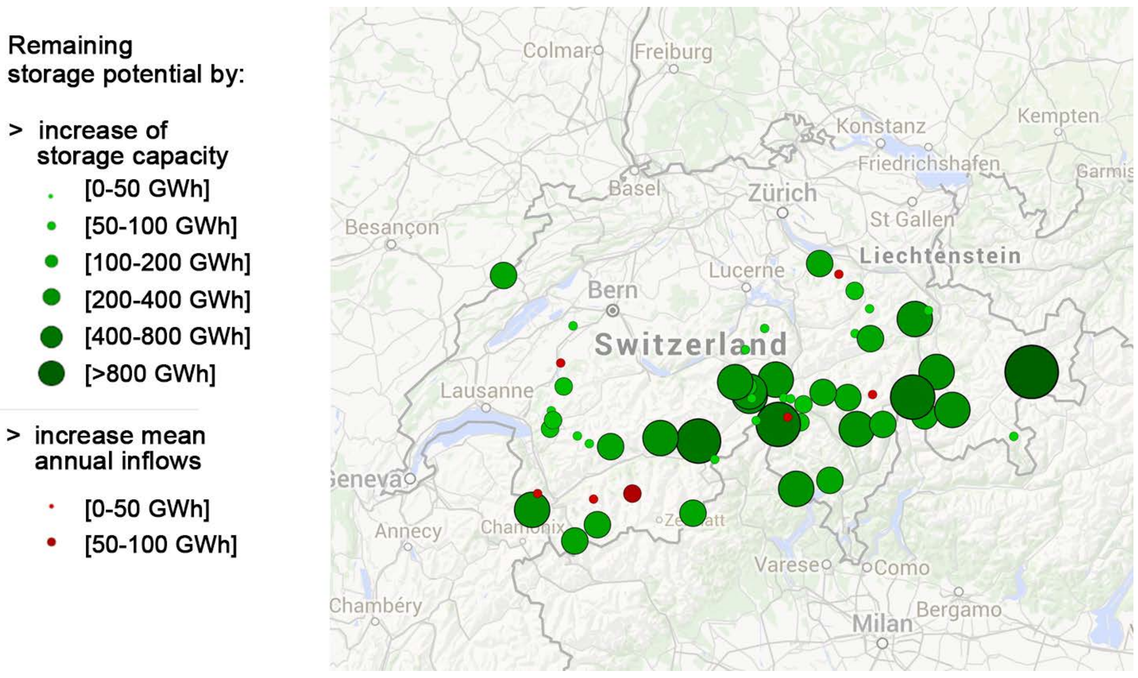


Fig. 3 Remaining hydropower storage potential per reservoir

(5) Conclusions

Based on our methodology and assumptions, 2 options exist to increase the seasonal storage capacity of Switzerland:

▶ **Increase storage capacity to capture excess natural inflows** (integrated river basin management by e.g. dam heightening, new dams, off-stream storage, reservoir interconnection) — **8000 GWh** (**98.5%** of potential)

▶ **Bring more water** (with additional inflows from pumping or gravity diversion from other basins) — **< 200 GWh** (**1.5%** of potential)

- The remaining storage potential of existing hydropower dams by catching additional inflows (through pumping or gravity diversions) into existing sub-optimal (oversized) reservoirs is less then **200 GWh**.
- Although relatively small, this contribution may increase in the future should the scenarios of glacier retreat and reduced annual inflows be confirmed as the result of climate changes in alpine catchments. This may help storing electricity from intermittent renewables (wind and solar).
- Based on the availability of excess natural inflows in several areas of Switzerland, the total remaining potential of hydropower storage is estimated to be about **8000 GWh**.
- Should this 8000 GWh potential be fully exploited, the seasonal storage capacity of hydropower in Switzerland would almost double. **Switzerland could then renew with electricity self-sufficiency, and thus avoid reliance on electricity imports in the winter season.**

References

1. Akari (2016), internship report, Energy Center, EPFL
2. SFOE, electricity statistics, 2015
3. SCD, Swiss Committee on Dams, Database of large Dams in Switzerland