

SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

with storage Hydropower plants!

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Energy funding programme

Swiss Competence Centers for Energy Research



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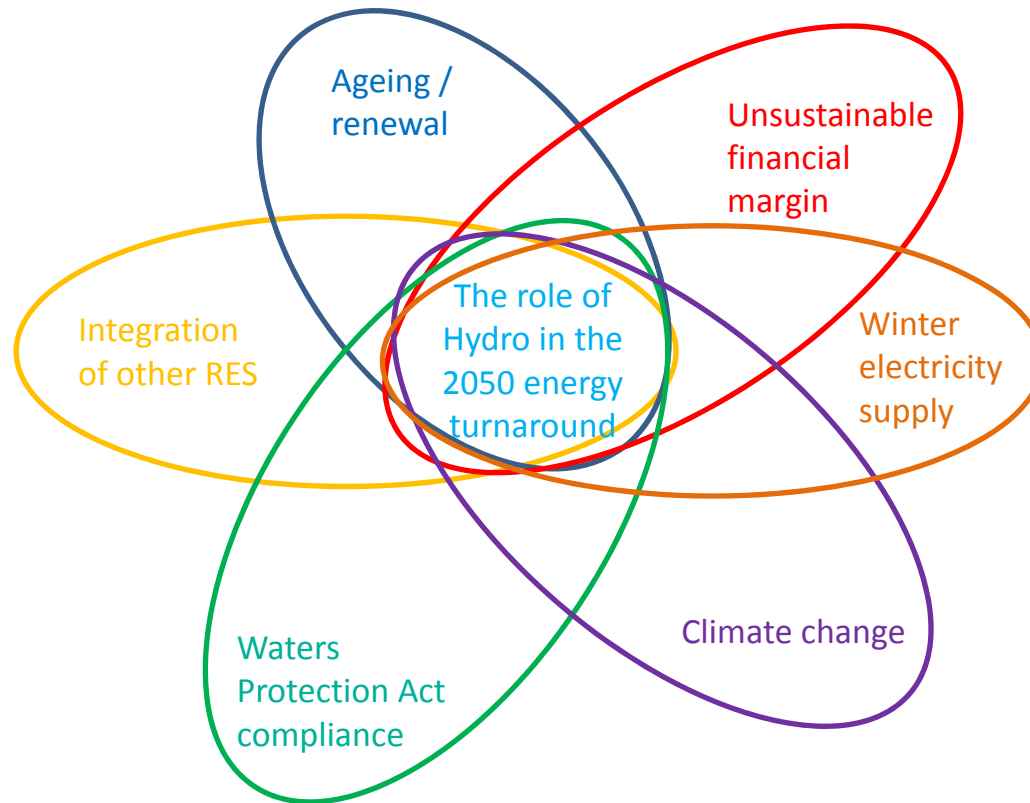
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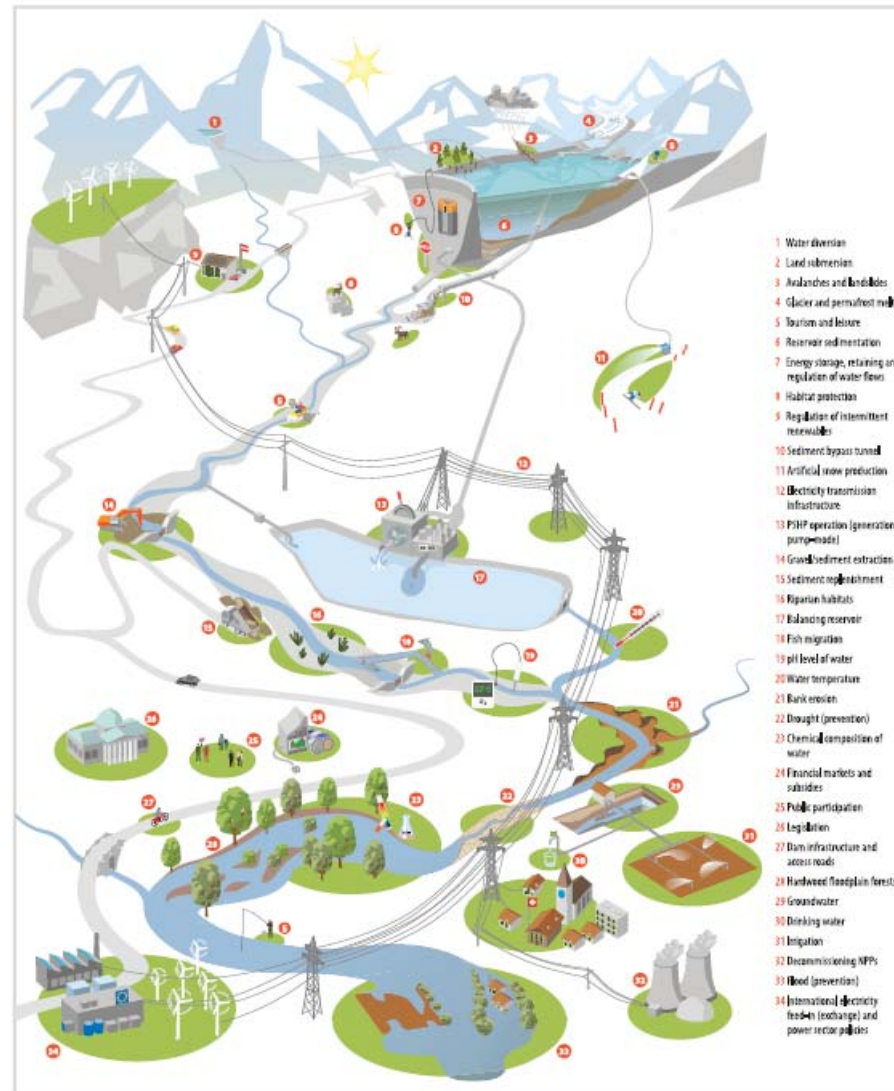
Commission for Technology and Innovation CTI



Goescheneralp, Uri, 155 m

Hydropower @ crossroads





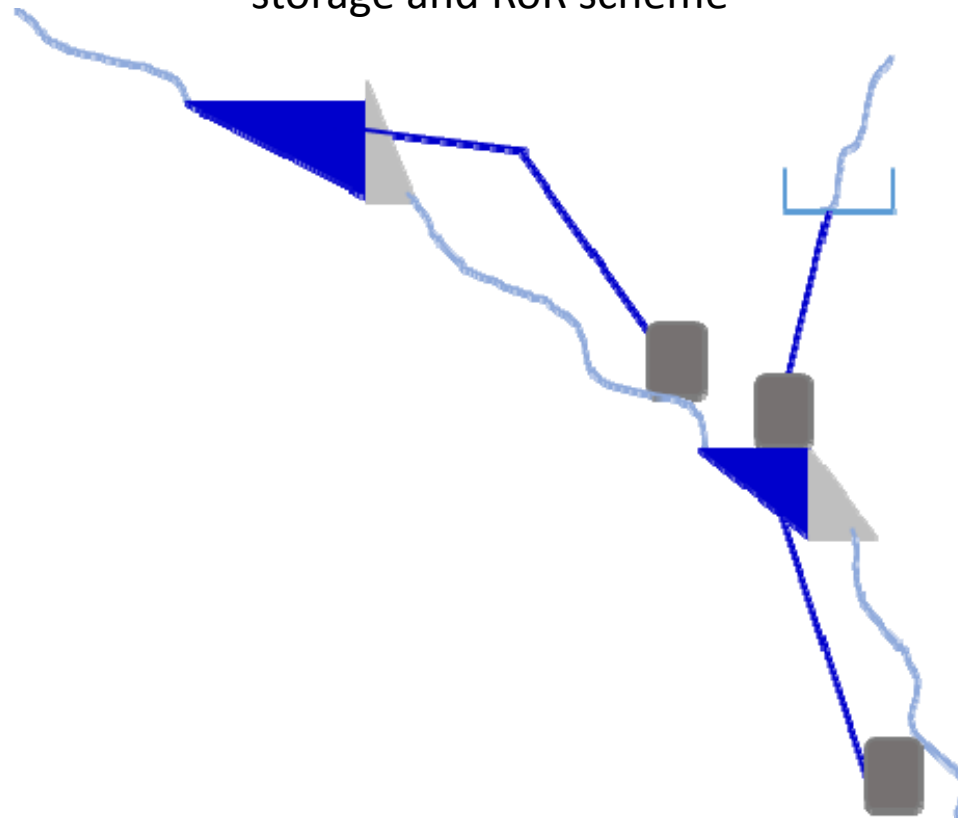
Rethinking Pumped Storage Hydropower in the European Alps

Astrid Björnsen Gurung, Axel Borsdorf, Leopold Füreder, Felix Kienast, Peter Matt, Christoph Scheidegger, Lukas Schmocker, Massimiliano Zappa, and Kathrin Volkart

MRD 2016

Fluid diagram view

Typical high-head mixed storage and RoR scheme



Hydropower

- $P(t) = \eta(H_n, Q) * \rho * g * H_n(t) * Q(t)$

- $P = \rho * g * \eta * Q_n * \Delta H / 10^6$ [MW]

- $E = P * 1 h = \eta * \rho * g * H_n * \frac{V}{3600}$

- $E = \rho * g * \eta * Q * \Delta H / (10^9 * 3600)$ [GWh]

- Water energy content (energy yield estimators):

- $\widehat{WEC}_H \approx H_n / 400$ [kWh/m³]

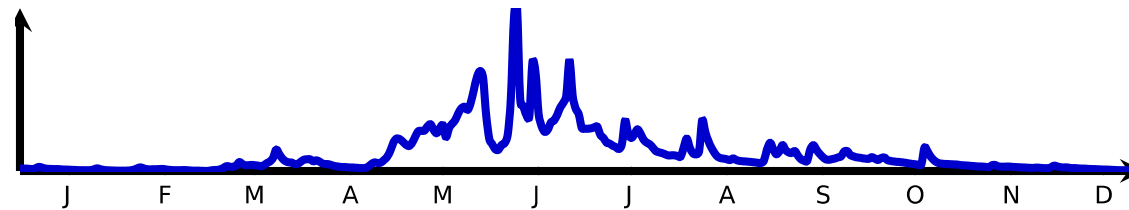
- $\widehat{WEC}_T \approx \frac{\text{Annual energy output}}{\text{Rated } Q \times \text{working hours} \times 3600} = \frac{\text{Installed capacity (MW)}}{\text{Rated } Q \text{ (cms)} \times 3600}$

Why do we need water storage?

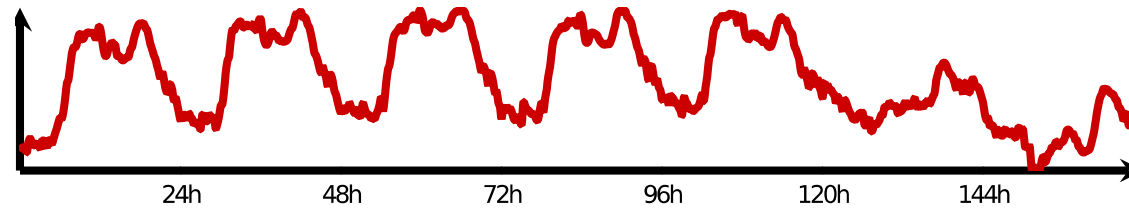
And why does it matter for energy purposes....

Matching

Annual distribution of inflows with clear seasonal pattern



Electricity demand variability
(intra-hourly/daily/weekly/monthly/annual)



Water Storage – A Definition

In general, water storage is the natural or artificial accumulation of water for imminent protection or for later use.

- **Flood attenuation** (i.e. reservoir flood routing)
- **Store-to-provide** : storage of abundant inflows (in short periods) for subsequent use at lower flow rates (in longer periods): **seasonal energy transfer**, dry season support, water supply, navigation, fisheries, irrigation
- **Store-to-peak**: storage during long periods of low flows for subsequent use with high flow rates in short periods: peak water consumption, fire protection, **peak power production or ancillary services to the electrical grid**

** In red, energy applications*

Key words are:

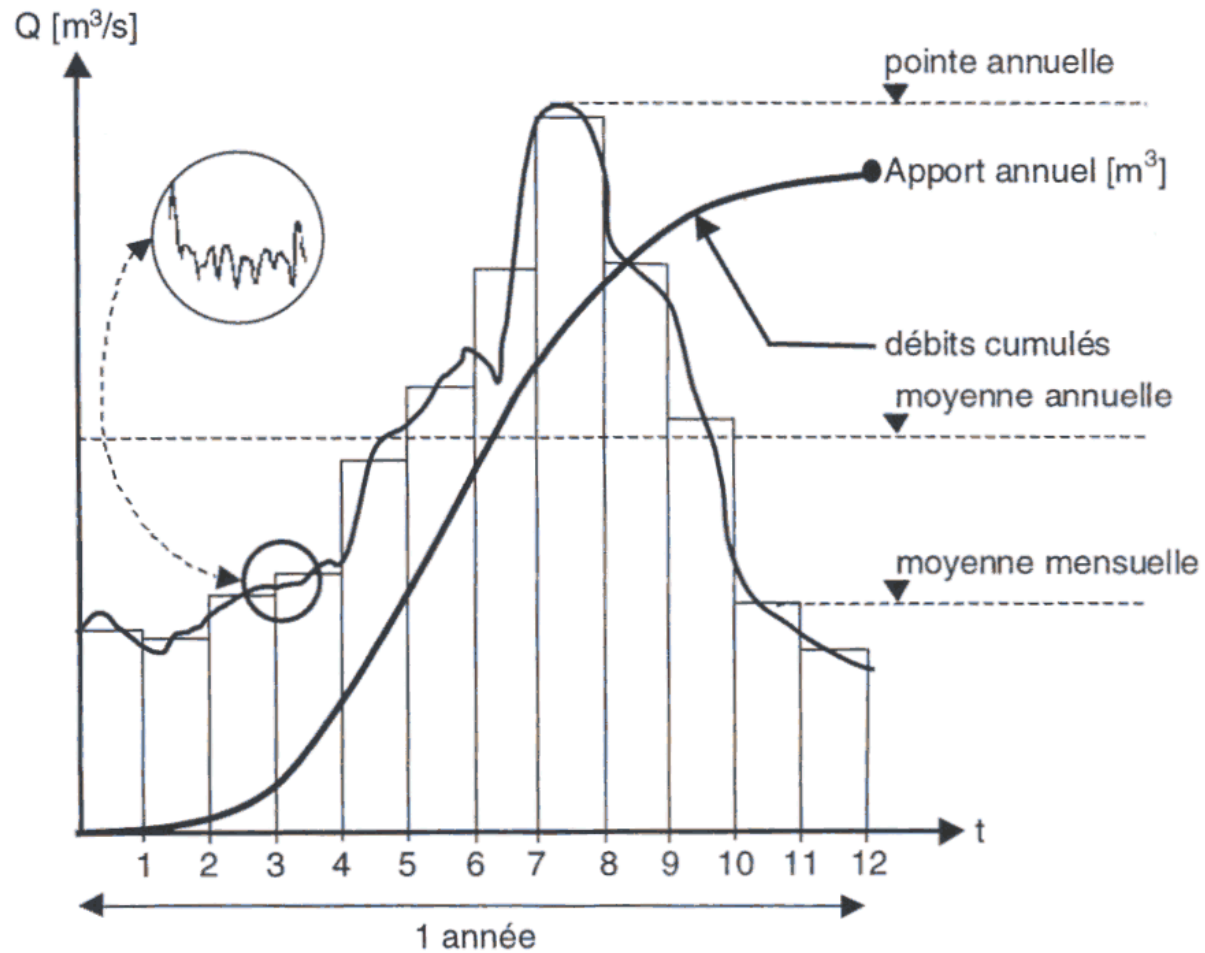
Time shift

Attenuation

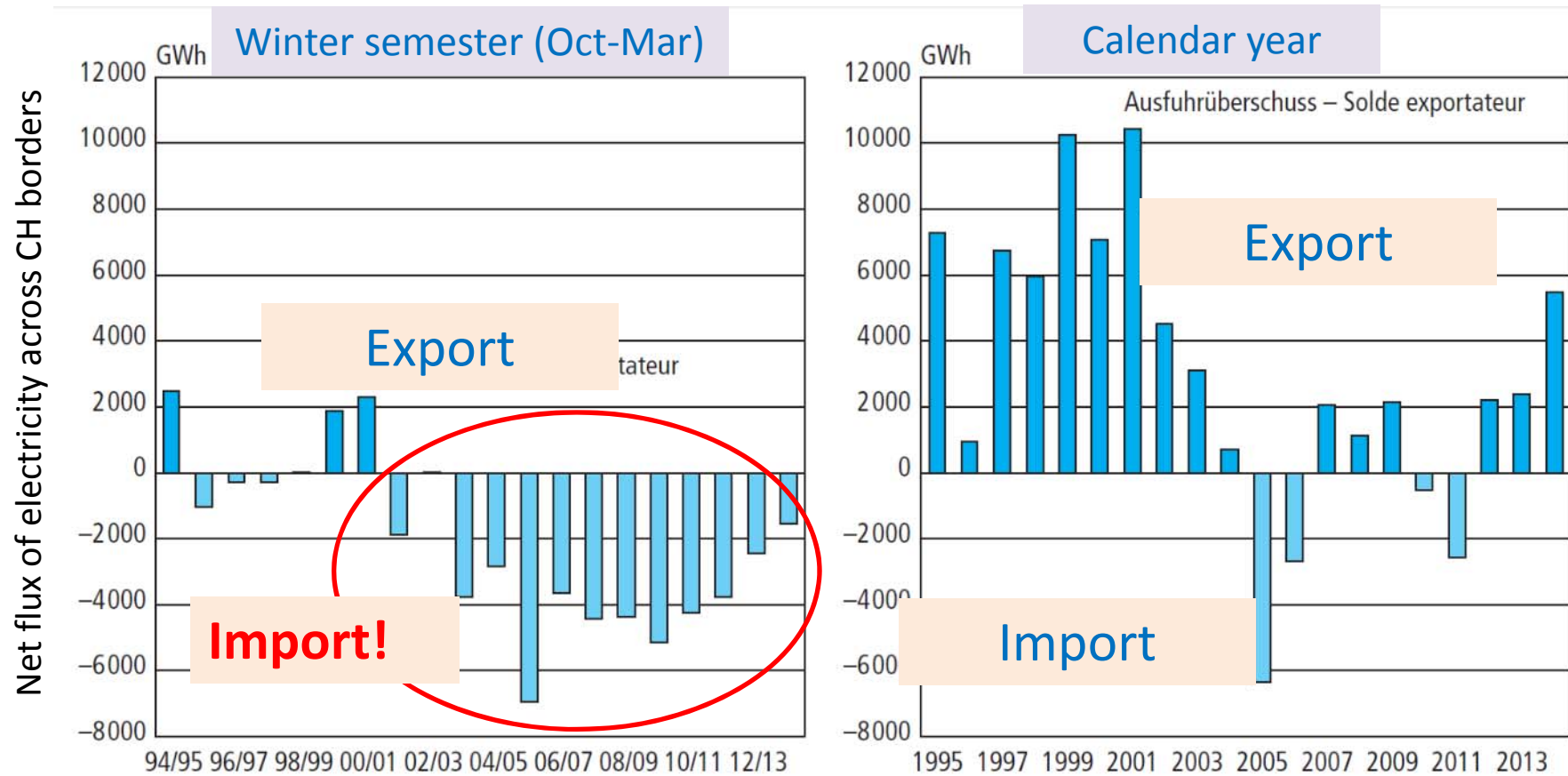
Regulation

Matching resource availability & demand

Streamflow time series & cumulated



Winter Electricity supply (I)

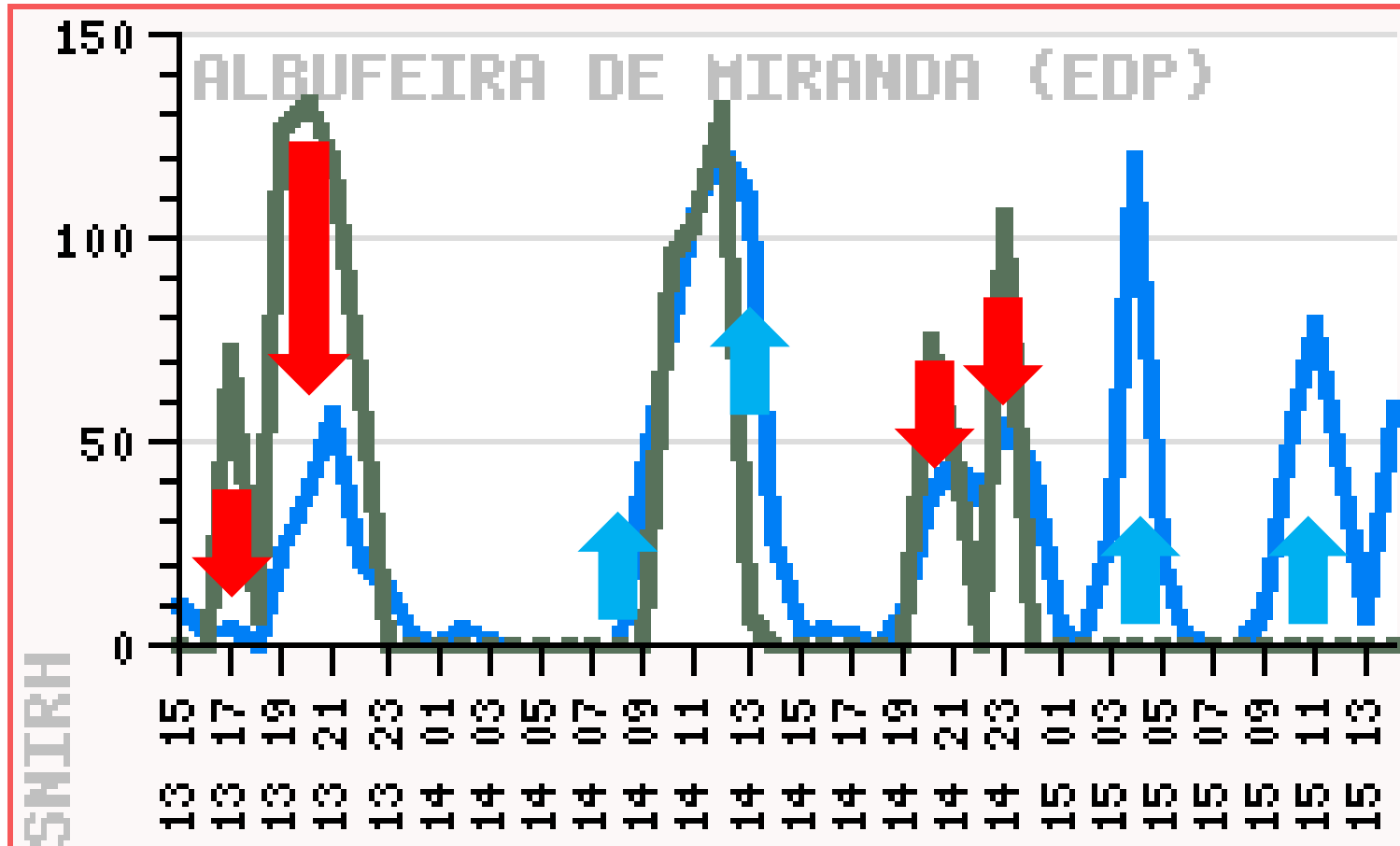


Source: Electricity Statistics SFOE 2014

HPPs operating in dry times

- Rhône/Branson:
<https://www.hydrodaten.admin.ch/fr/2024.html>
- Inn/Martina:
<https://www.hydrodaten.admin.ch/fr/2067.html>
- Aare/Brienzwiler:
<https://www.hydrodaten.admin.ch/fr/2067.html>
- Sarine/Fribourg:
<https://www.hydrodaten.admin.ch/fr/2119.html>

Storage



Miranda I+II HPP

River Douro

318 MW

3 x 128 cms

1 x 386 cms

0.9 to 1.1 TWh/a

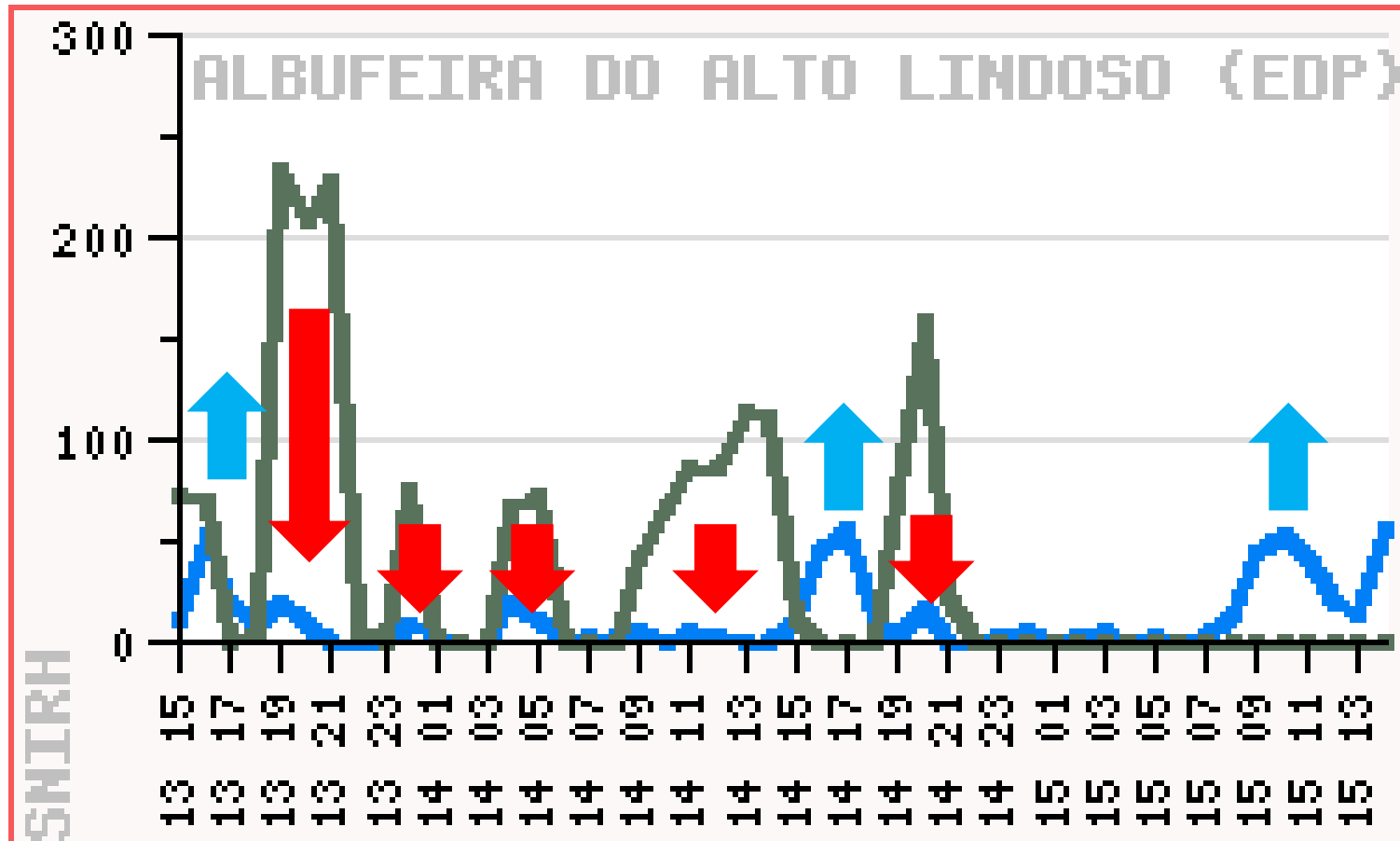
28 hm³ TS

6.6 hm³ LS

BLUE => Qin

GREEN => Qout

Lindoso PSP 600 MW



BLUE => Qin

GREEN => Qout

Storage < > Options