Complementing hydropower with PV and wind: Optimal energy mix in a fully renewable Switzerland

Jérôme Dujardin (1), Annelen Kahl (1), Bert Kruyt (1,2), Michael Lehning (1,2)
(1) Ecole Polytechnique Fédérale de Lausanne, Switzerland, (2) WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland

Context and Data

How do we replace the Swiss nuclear fleet? (Swiss Energy Strategy 2050)

- Annual solar irradiance [W/m²]
- Wind turbine location
- PV coverage [%]

Fig 1: Solar irradiance (2014) on PV panels (average of various orientations at 45° incl)
Fig 2: Scenario of PV and wind location
PV: Roof top, proportional to population density
Wind: Best location with available wind speed measurements

- Seasonal trends (environment)
- Strong daily variations in the demand (users)
→ Need for seasonal storage
→ Need for short term balancing

Methods
1. Short term storage applied to mismatch
2. Hydropower balancing
3. Import/export

Fig 4a: Distribution of power mismatch for different combinations of PV and wind. The color change along each vertical cross section represents a histogram (see Fig 4b) of mismatches for a given PV/wind mixing ratio indicated on the x-axis. Positive values correspond to overproduction, negative values to power deficits.

Fig 4b: Instantaneous mismatch

Results
- Most of the overproduction handled by currently installed pumps
- Current storage hydropower sufficient for power balancing and most seasonal storage
- Import level proportional to the share of PV
- More short-term storage does not help. Instead need for more seasonal storage

Fig 3: Demand and supply (2014) in a non-nuclear Swiss power system
Fig 6: Example of interplay between the various power sources

Conclusion
- Wind profile better addresses seasonal mismatch, thus reducing import
- A balanced PV / wind scenario reduces the need for short term storage
- Seasonal storage effectively reduces import

Fig 5: Energy balance throughout the year
Cumulative mismatch

Fig 10: Effect of increased reservoir capacity (hydro) on the required import

Other levers?
See side pages.