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

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Context and Data

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

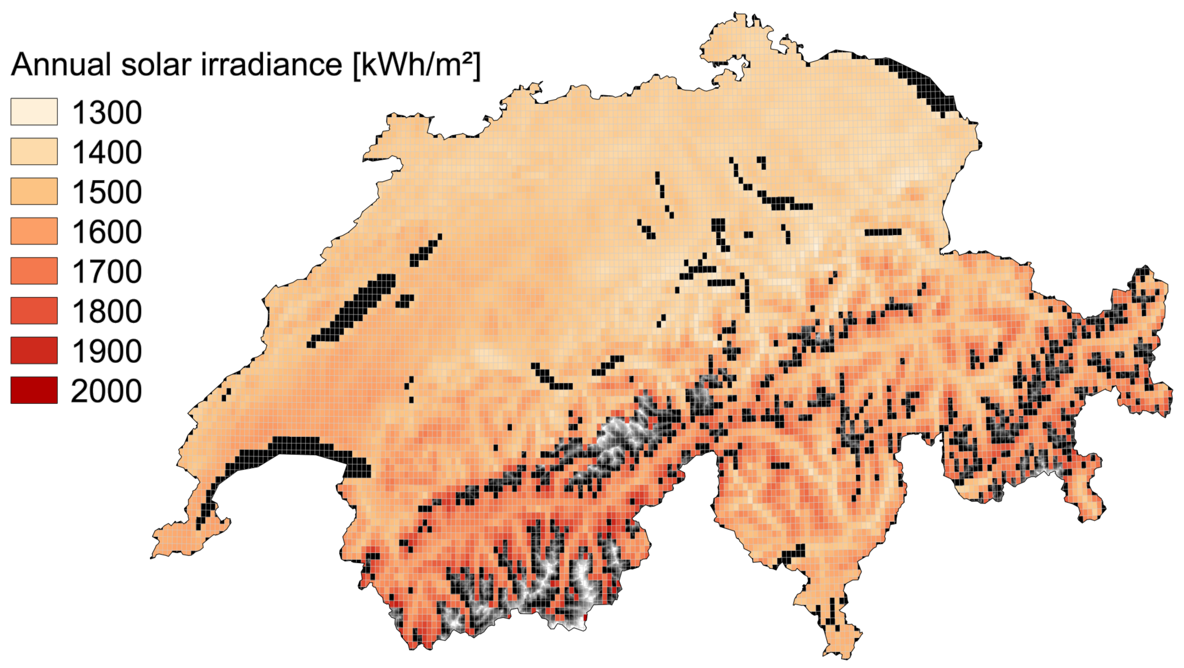

Fig 1: Solar irradiance (2014) on PV panels (average of various orientations at 40° tilt)

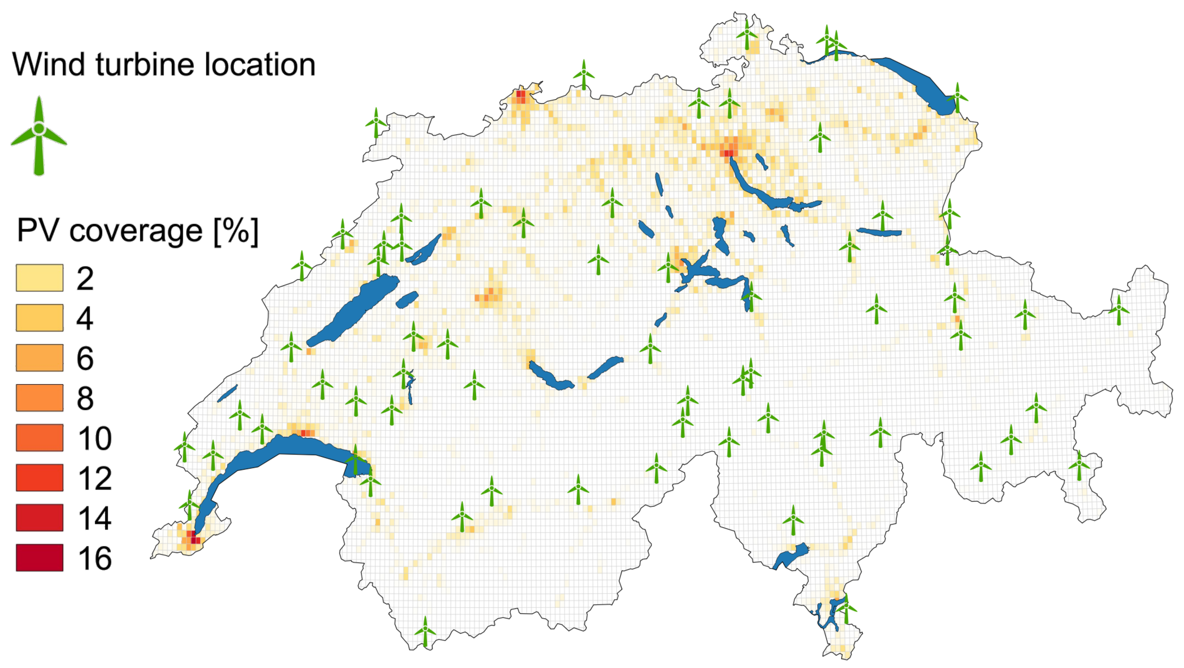

Fig 2: Scenario of PV and wind location
PV: Roof top, proportional to population density
Wind: Best location with available wind speed measurements

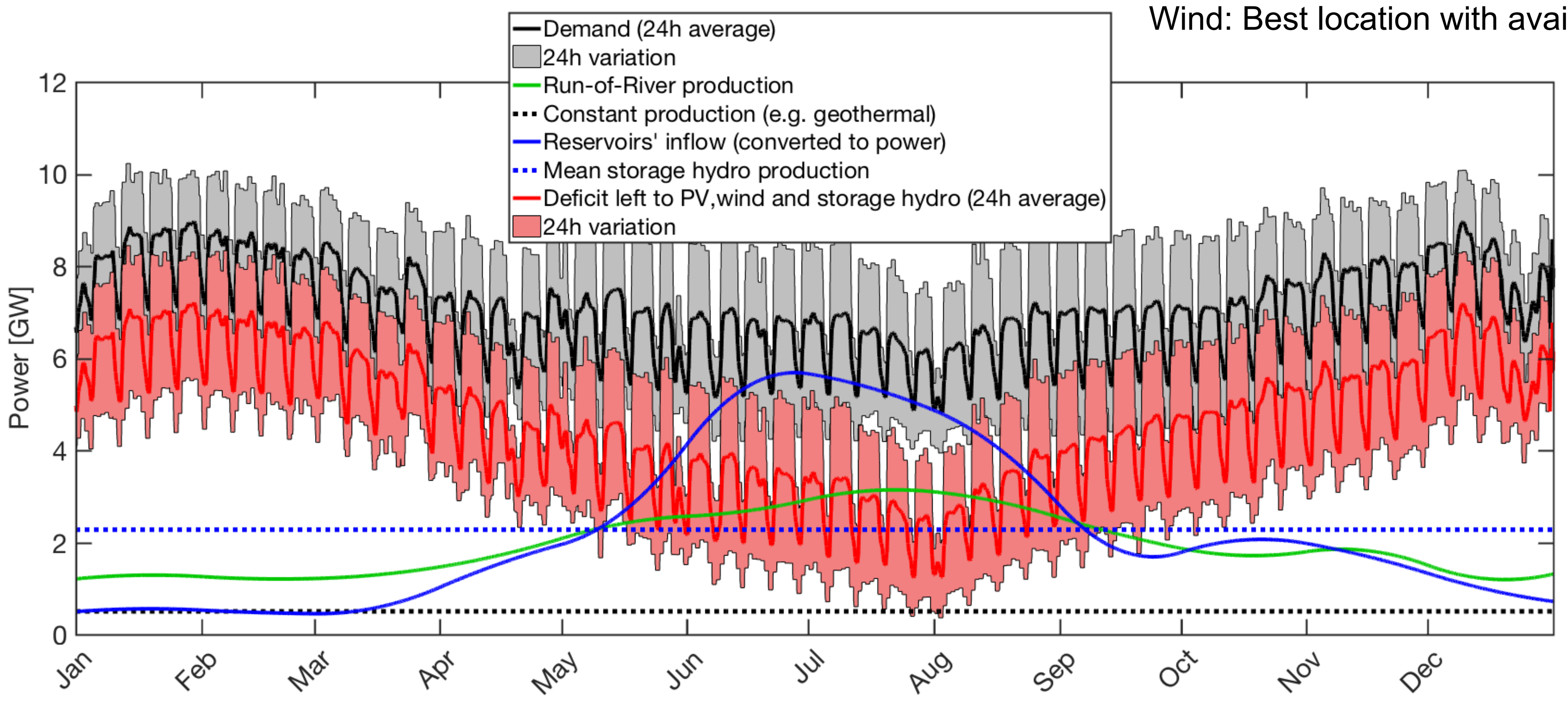

Fig 3: Demand and supply (2014) in a non-nuclear Swiss power system

- 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

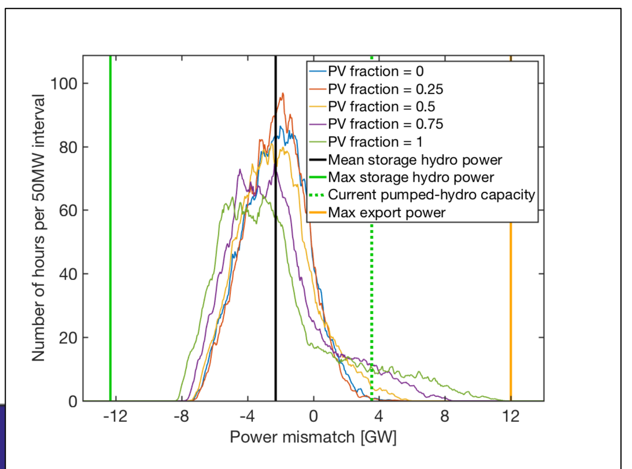

Fig 4b

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.

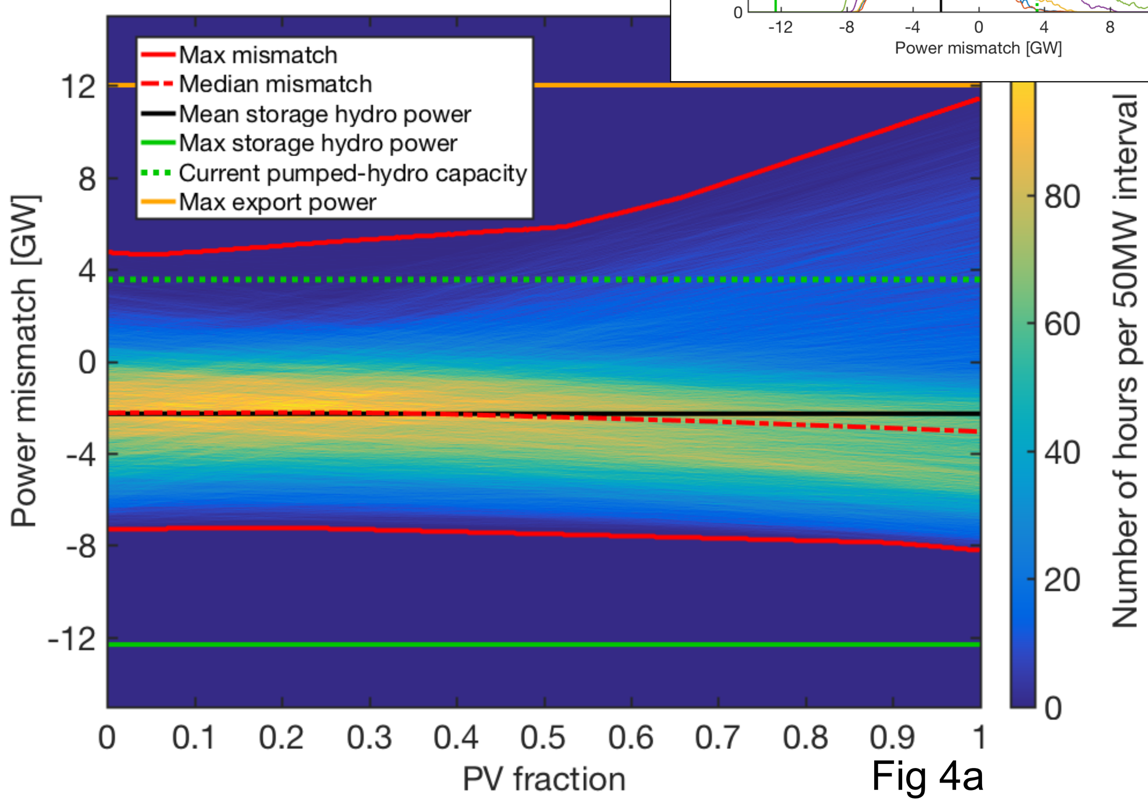

Fig 4a

Instantaneous mismatch

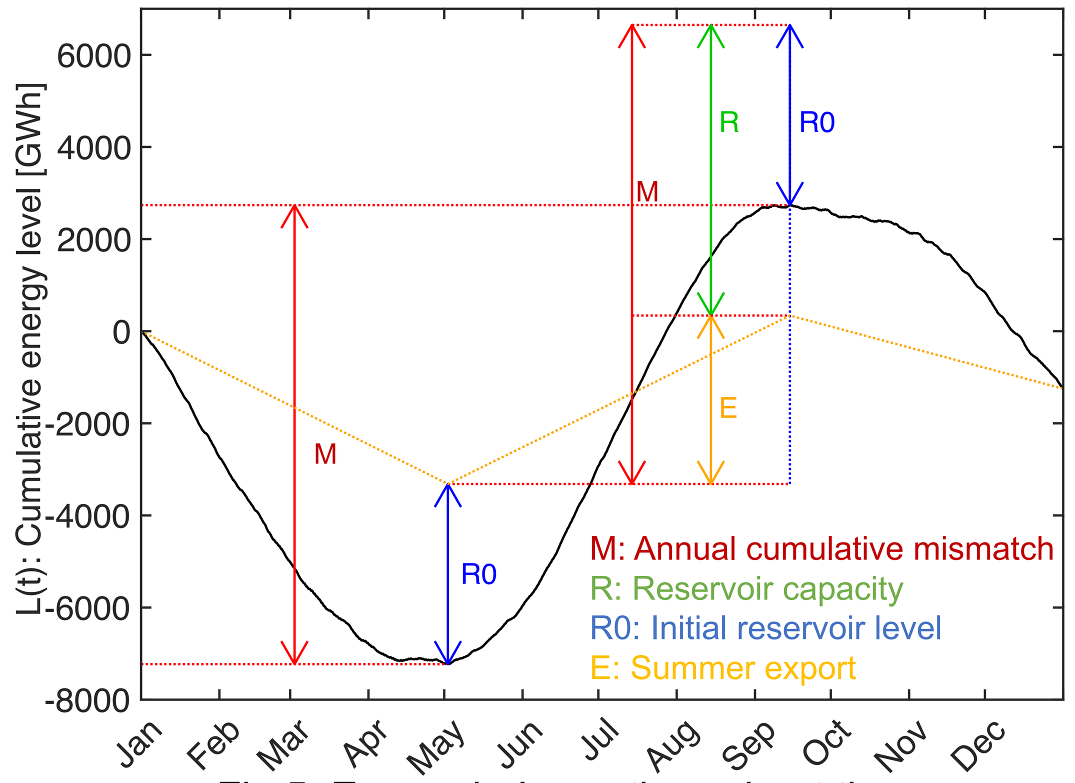

Fig 5: Energy balance throughout the year

Cumulative 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

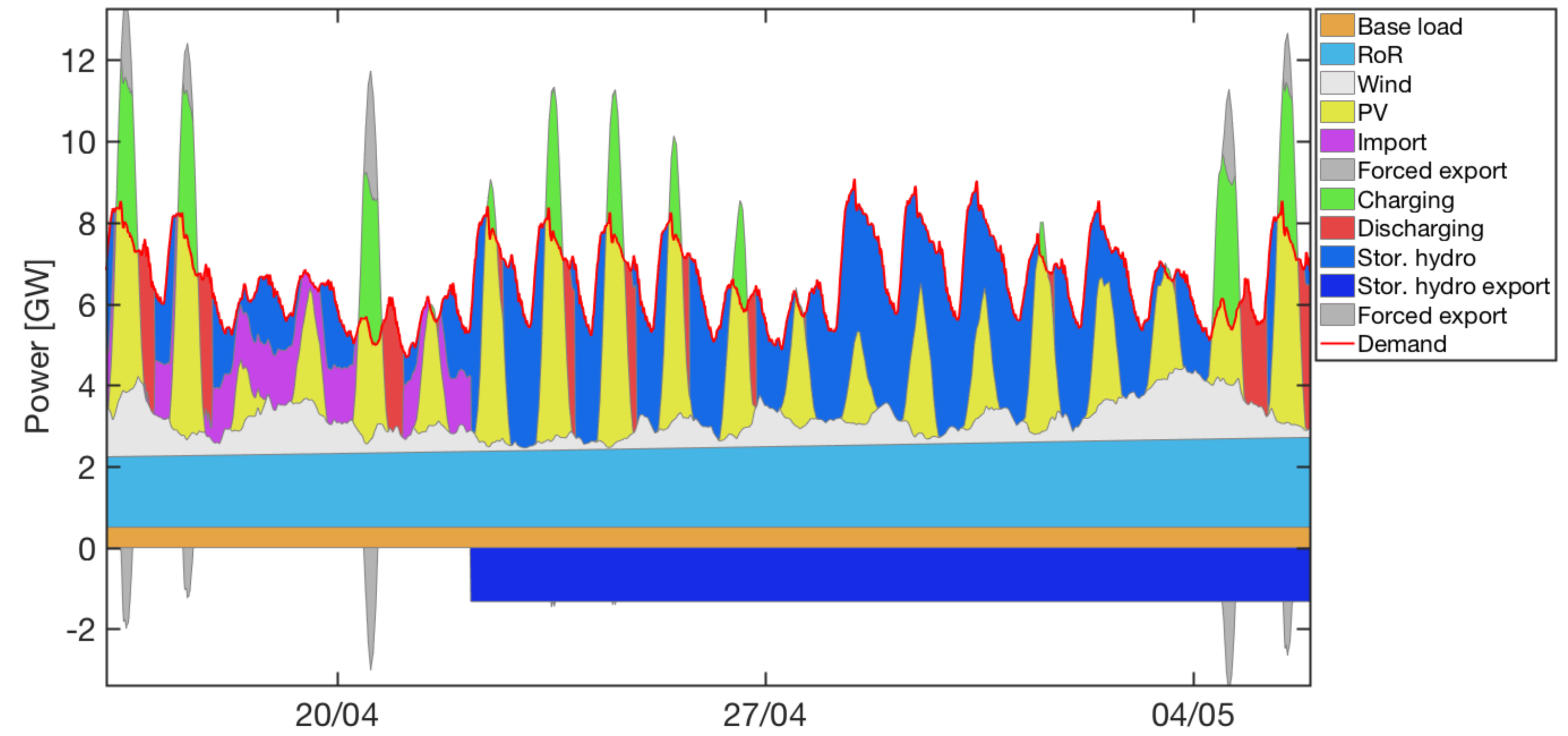

Fig 6: Example of interplay between the various power sources

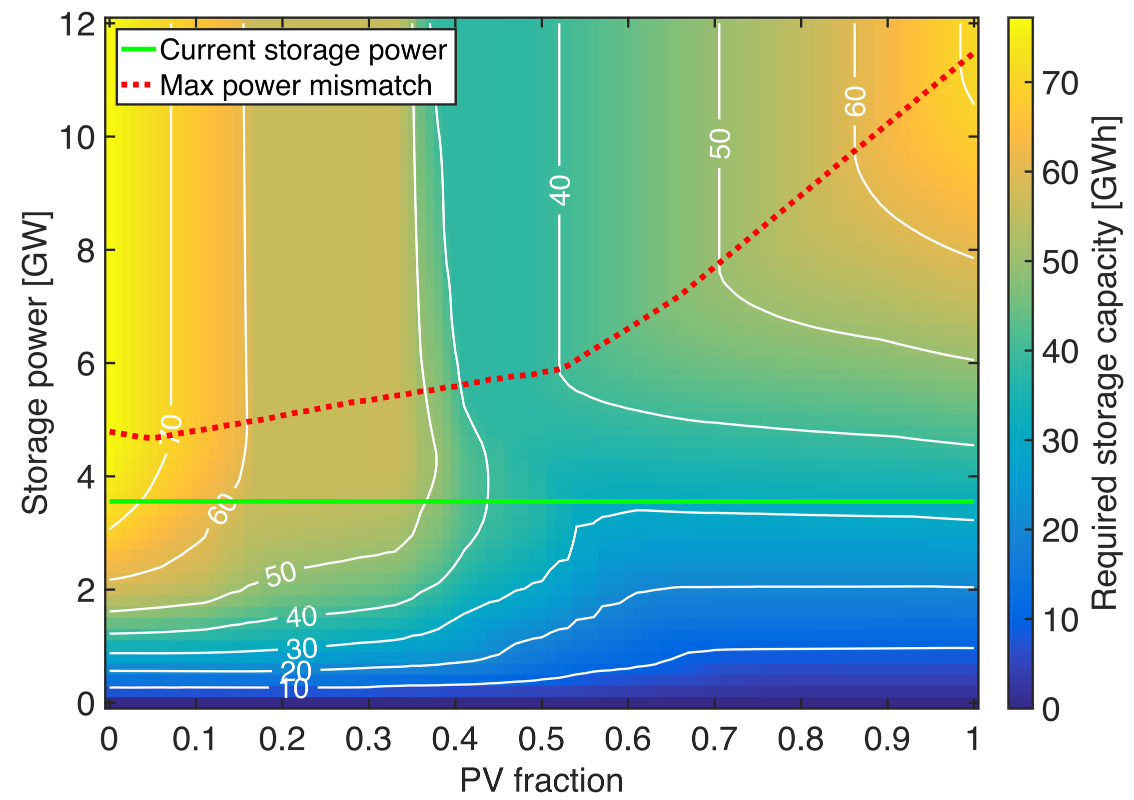

Fig 7: Required storage capacity for various combinations of PV / Wind / Storage Power

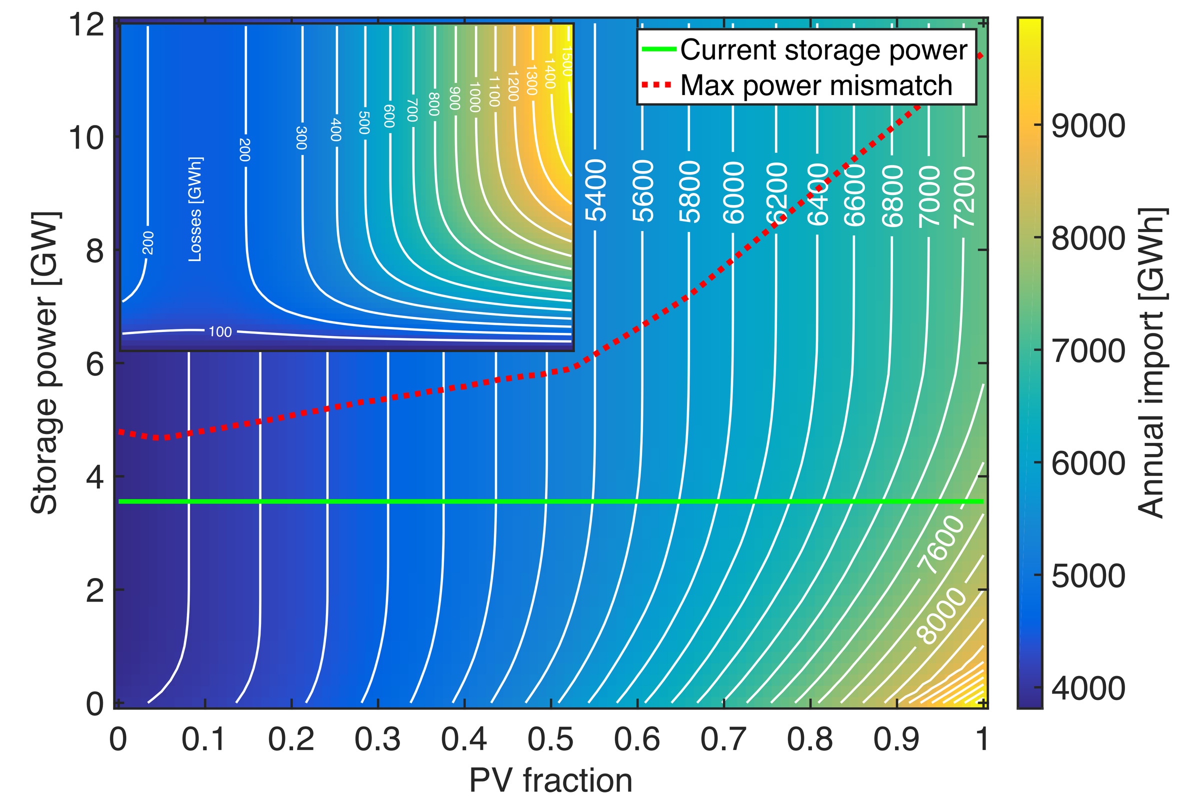

Fig 8: Required annual import to satisfy the demand for various combinations of PV / Wind / Storage Power

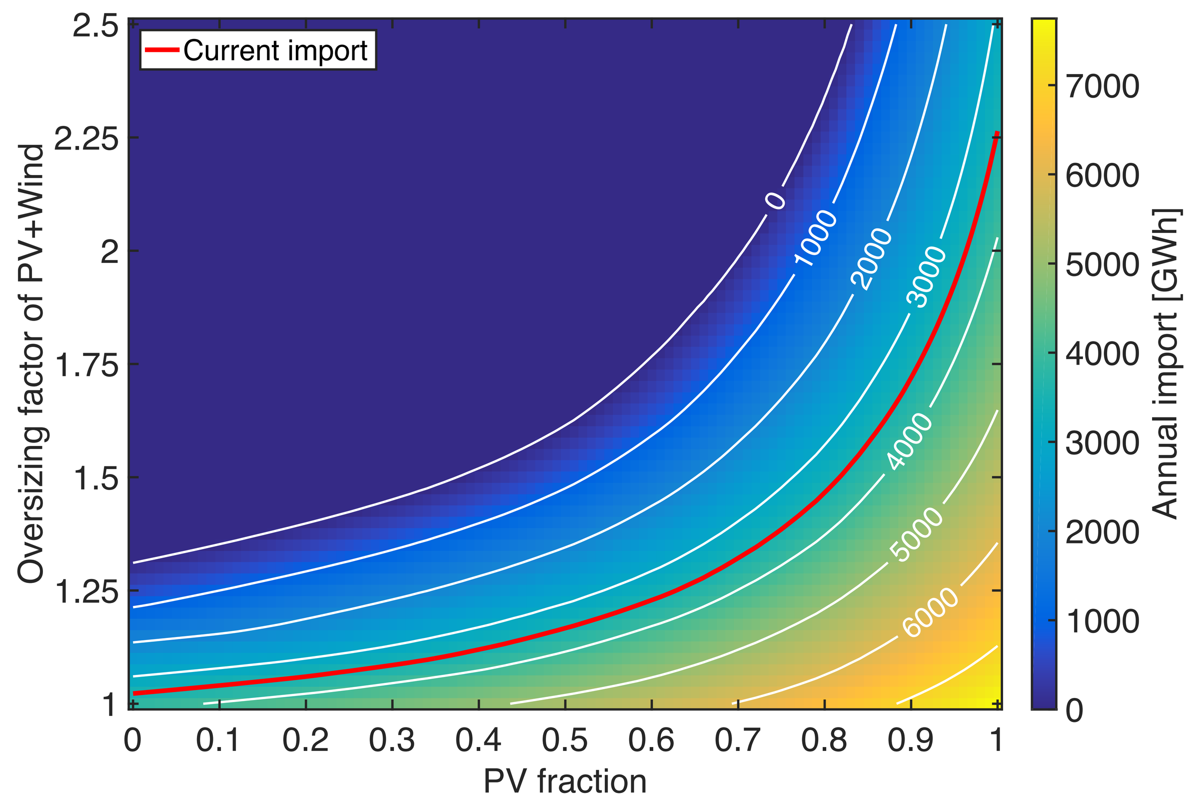

Fig 9: Effect of oversized PV/wind generation on the required import

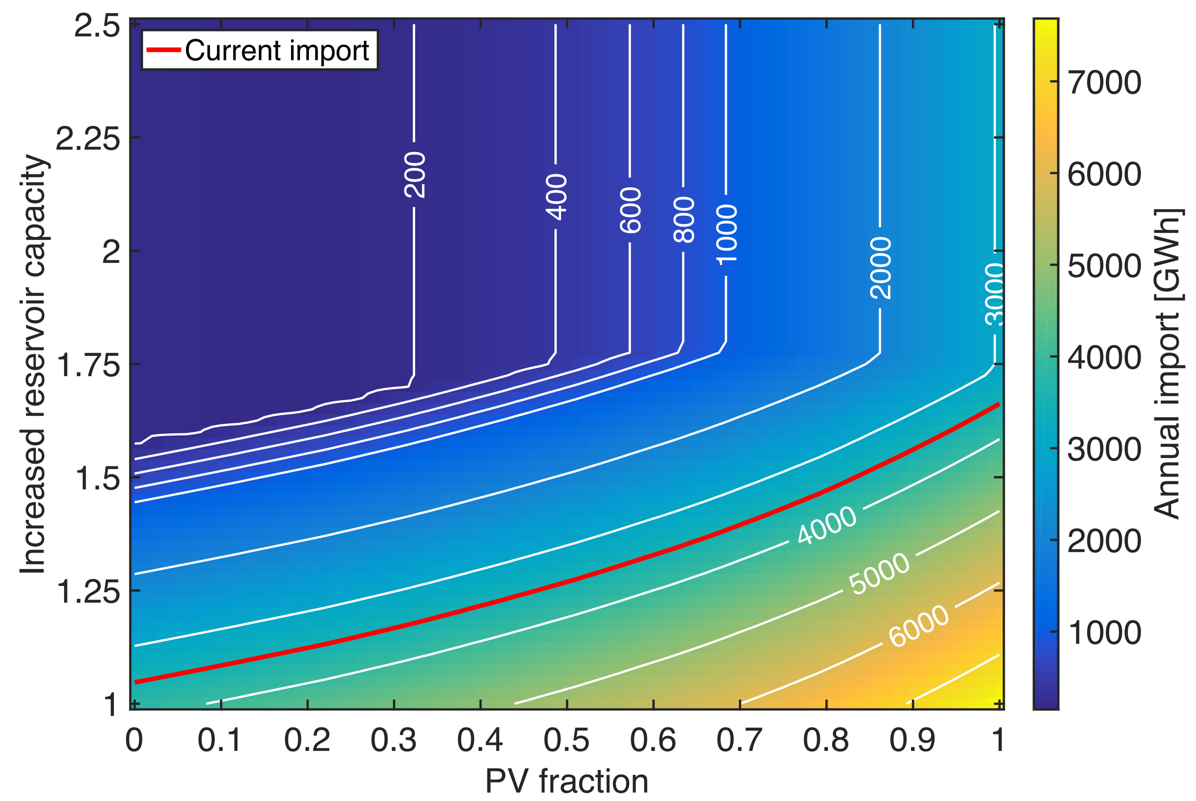

Fig 10: Effect of increased reservoir capacity (hydro) on the required import

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

Other levers ?

See side pages