Hydropower in future market scenarios

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Annual Conference 2020

In cooperation with the CTI

Energy
Swiss Competence Centers for Energy Research

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Task 4.2: Global observatory of electricity resources

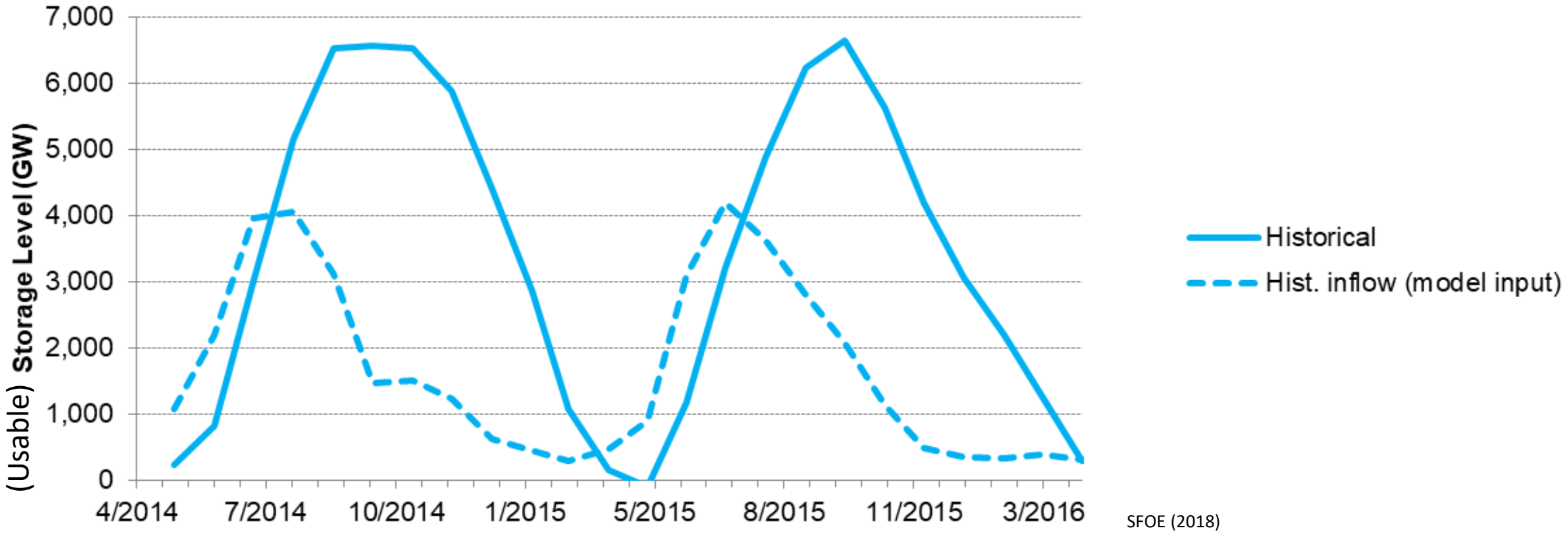
- Models & Scenarios:
  - Electricity markets (CH + surrounding countries)
  - European electricity system, global energy system
- Review of Swiss Electricity Scenarios
- etc.

(Stored) hydropower:

- Challenges in modeling of stored hydropower
- Profitability in future market scenarios

How to model stored hydropower?

2 years of stored hydropower in Switzerland (monthly):

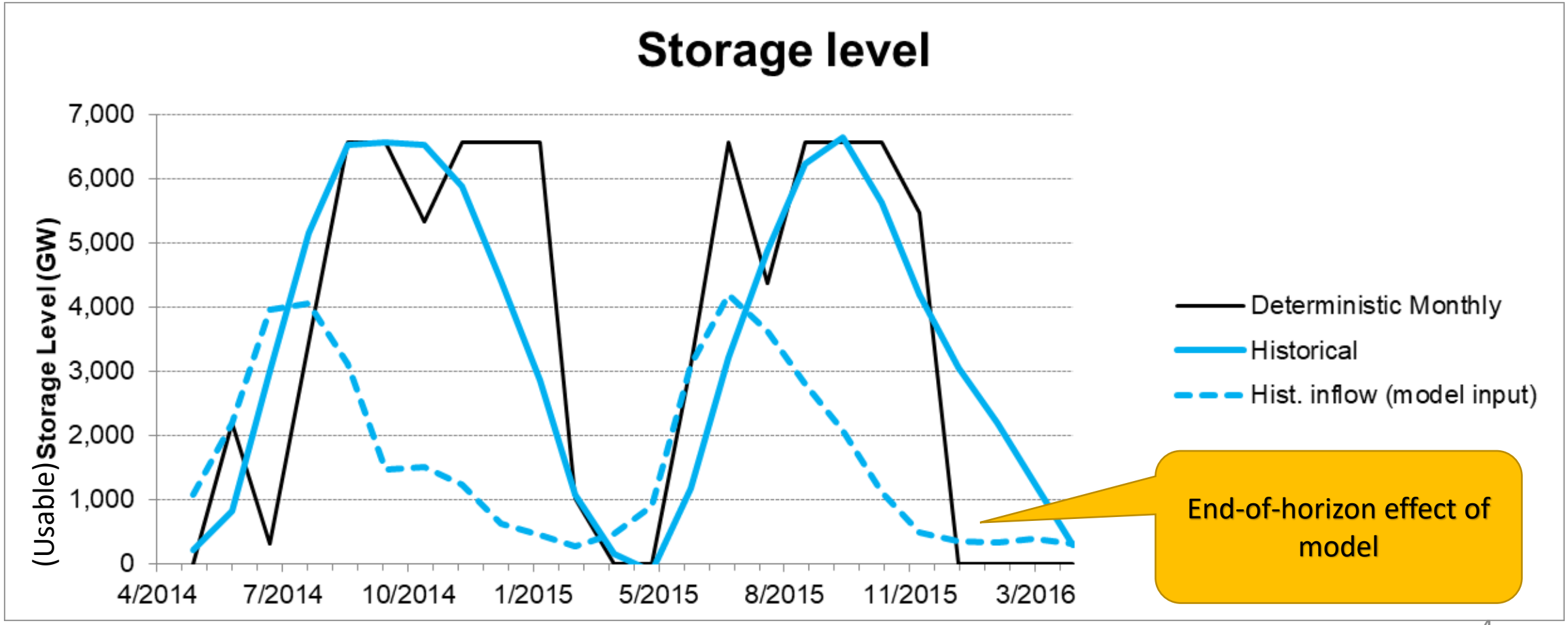


SFOE (2018)

- Test of economic dispatch model: Can historical patterns be replicated? – Tests not common!

Modeling: Monthly (24 time-steps)

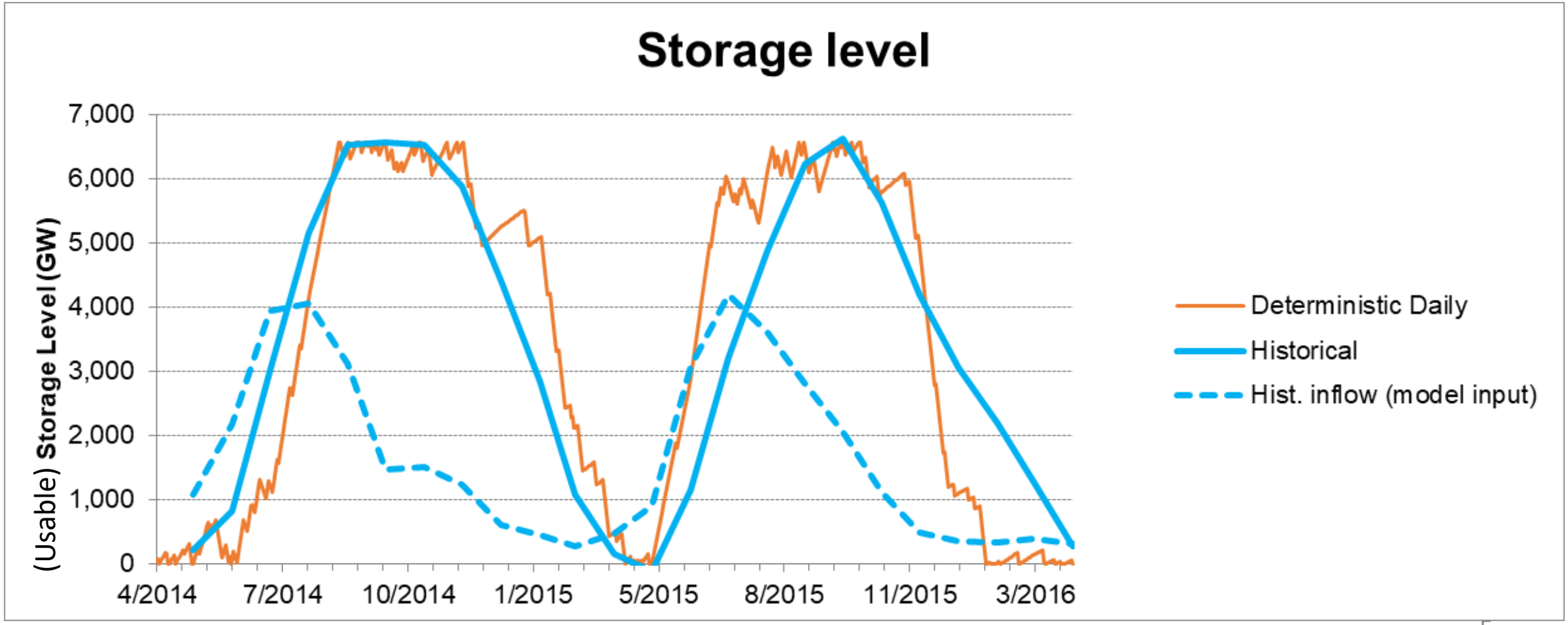
- Deterministic optimization model with monthly averaged wholesale electricity prices; no pumping



Densing (2020); SFOE (2018)

Modeling: Daily (730 time-steps)

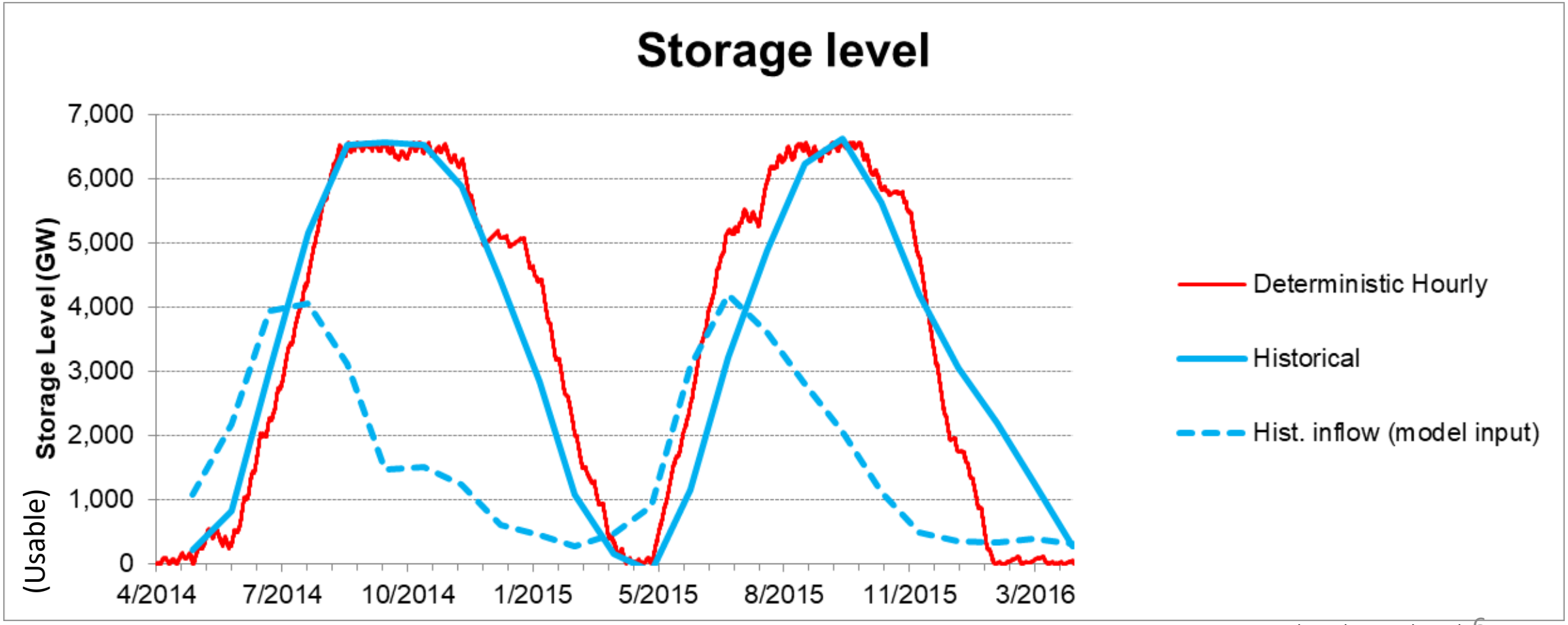
- Deterministic optimization model with daily averaged wholesale electricity prices



Densing (2020); SFOE (2018)

Model: hourly (17,520 time-steps)

- Deterministic optimization model with hourly wholesale electricity prices

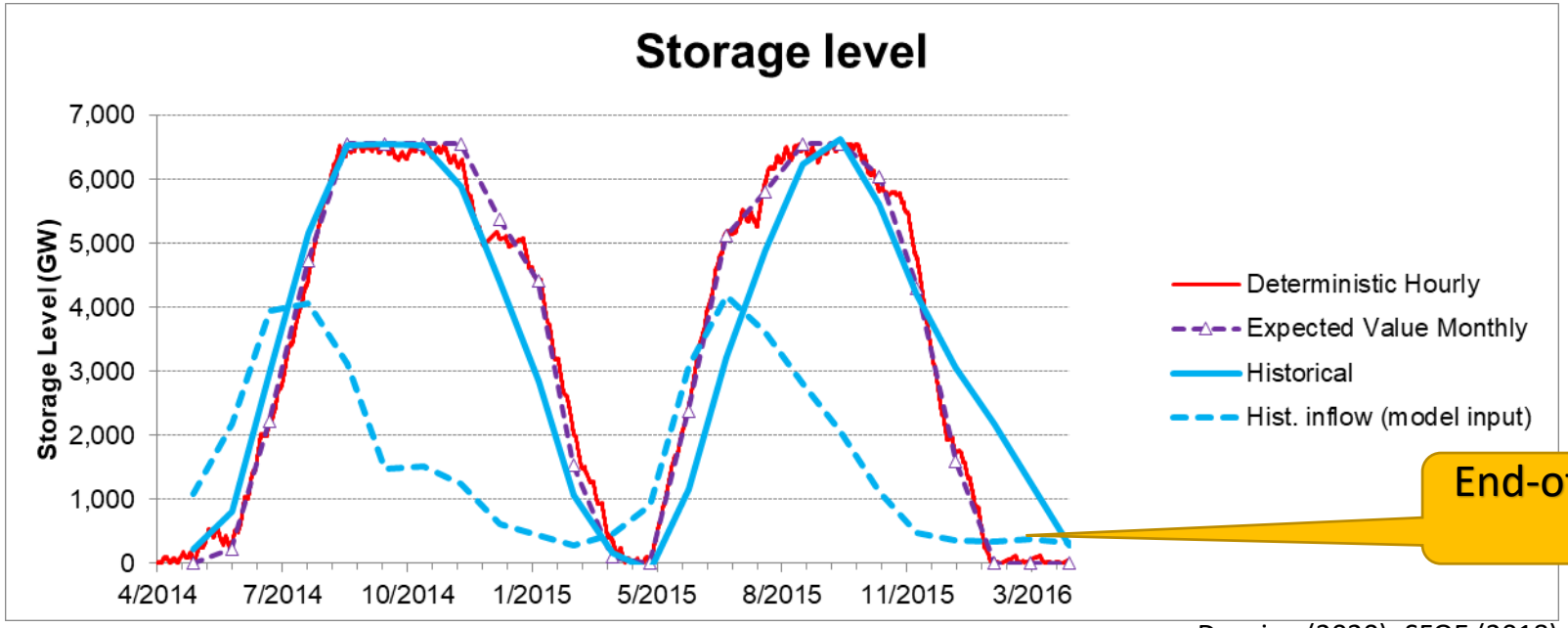


- Caveat: ca. 100 storage reservoirs, multiple actors, etc.

Densing (2020); SFOE (2018)

Probabilistic model: 24 time-steps

- Probabilistic model: Dispatch depends on statistical price distribution of current month; storage level fulfilled on “average” only; inflow still deterministic



Densing (2020); SFOE (2018)

Advantages:

- No artefact patterns (caused by (too) detailed time-steps)
- Numerical: Small problem size, quick solve time
- Yields dispatch-thresholds
- Extension to: Optional production for spinning reserve

Disadvantages: Model is non-linear; dispatch-thresholds in fact only on «average» correct

Future electricity price scenarios

Scenarios from two studies:

«PowerDesign»
(SFOE)

Price model: Fundamental agent-based model by KIT (Karlsruhe)
Hydropower model: previous probabilistic modeling approach
Scenarios:

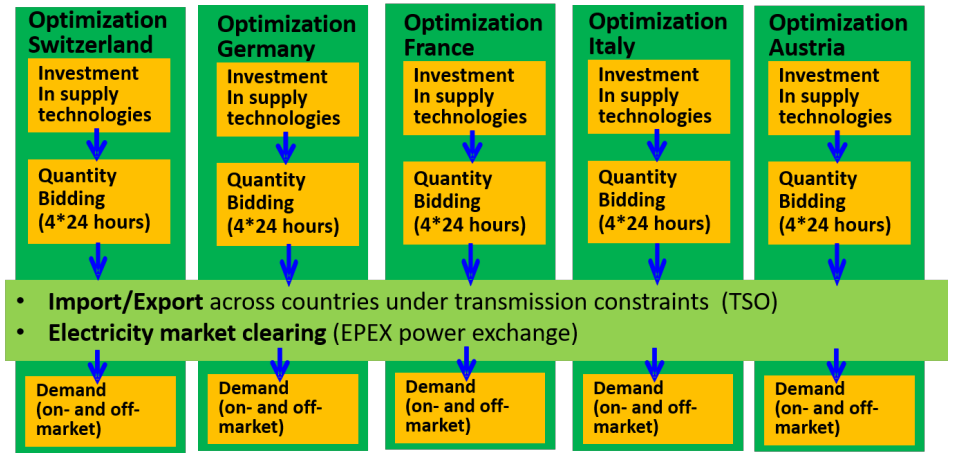
- «CRM»: Some capacity remuneration mechanisms present → less price peaks
- "EOM": Energy only markets (i.e. without CRM) → high peaks

«SwissHydro»
(VSE & EWZ)

Price model: Cross-Border Electricity Market model **BEM**; fundamental; Nash-equilibrium with conjectural variations.
Hydropower model: BEM
Scenarios:

- Low CO_2 scenario (NEP+E, Europe: EUCO scenario)
- No annual imports
- Today's fuel + CO_2 price

BEM: cross-Border Electricity Market model

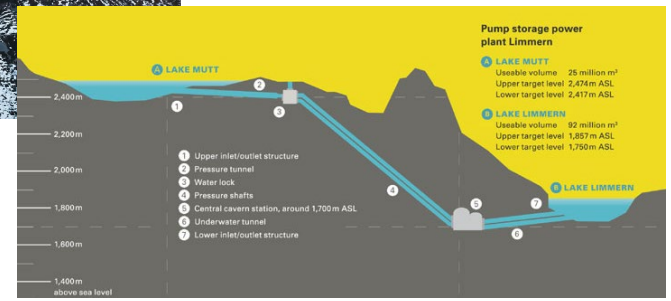


Densing, M., Kannan, R., Panos, E., & Kober, T. (2018). Long term role of Swiss hydropower from an energy systems and market perspective. Zukunftspotenzial der Schweizer Wasserkraft durch Synergien im Energiesystem und Markt Perspektiven. Villigen PSI, Switzerland: Paul Scherrer Institute. Final Report. https://www.dora.lib4ri.ch/psi/islandora/object/psi:25854

Zimmermann, F., Densing, M. et al. (2018). *Impact of different market designs in the CWE market area on electricity prices and on the competitiveness of Swiss hydropower (PowerDesign).*, *ARAMIS Swiss Federal Research Database* https://www.aramis.admin.ch/Dokument.aspx?DocumentID=50031

Panos, E., Densing, M. (2019). The future developments of the electricity prices in view of the implementation of the Paris Agreements: Will the current trends prevail, or a reversal is ahead? *Energy Economics*. DOI: 10.1016/j.eneco.2019.104476

Future price scenarios: Cycling

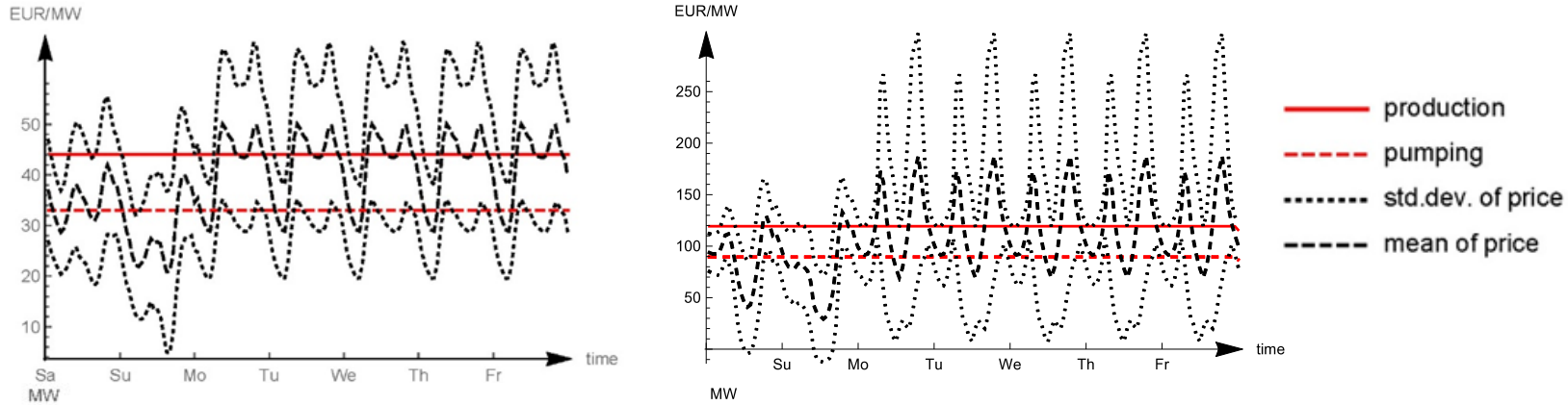


Example: 1 GW PSP, no natural inflow, large lower reservoir, time horizon: a week

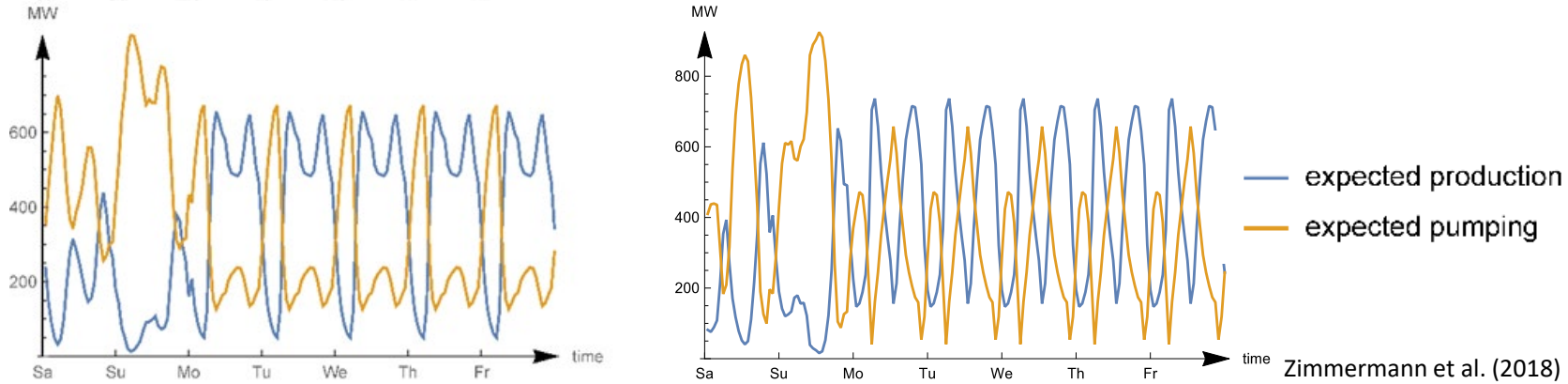
Price distribution 2015-16

Price distribution in (extreme) scenario "EOM" 2050

Thresholds (EUR/MWh)



Optimal Production and Pumping (MW)



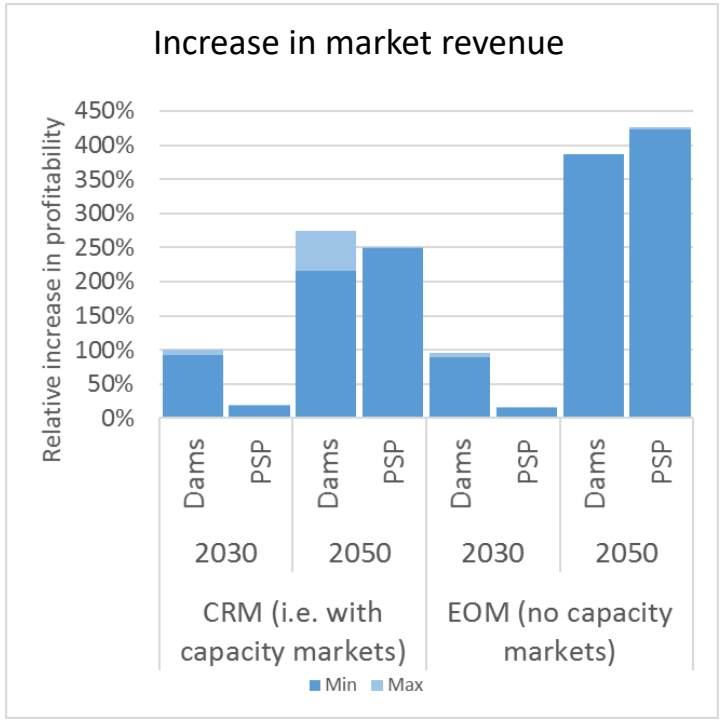
Zimmermann et al. (2018)

More volatile electricity prices in 2050 leads to more cycling

→ Operational challenges of more frequent switches without efficiency loss (here not considered)

Future price scenarios: Profitability

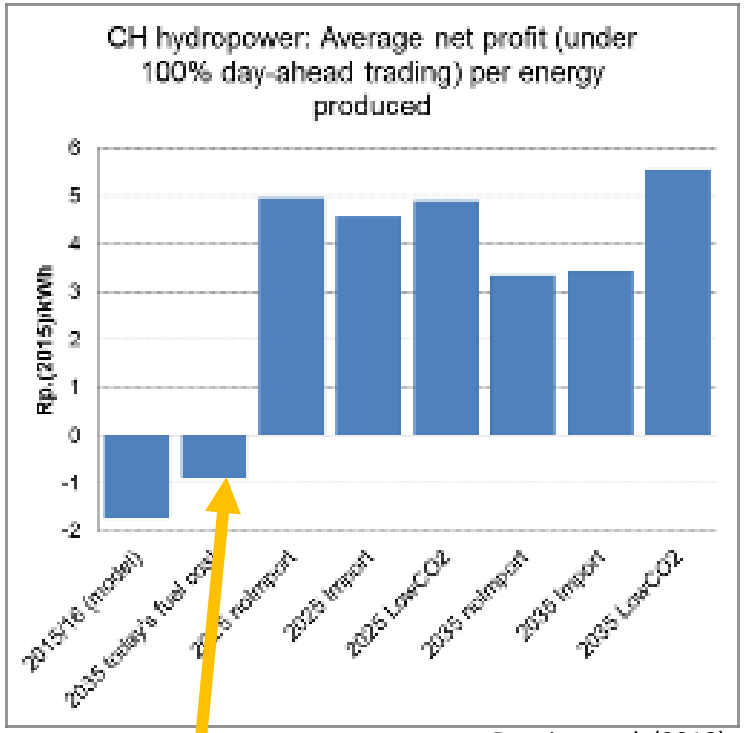
Study «PowerDesign»



Zimmermann et al. (2018)

- High price-level increase caused by CO_2- and natural-gas-price increase (a common assumption in many energy scenarios)
- Price variations (PSPs need that) increase later (2050)

Study «SwissHydro»



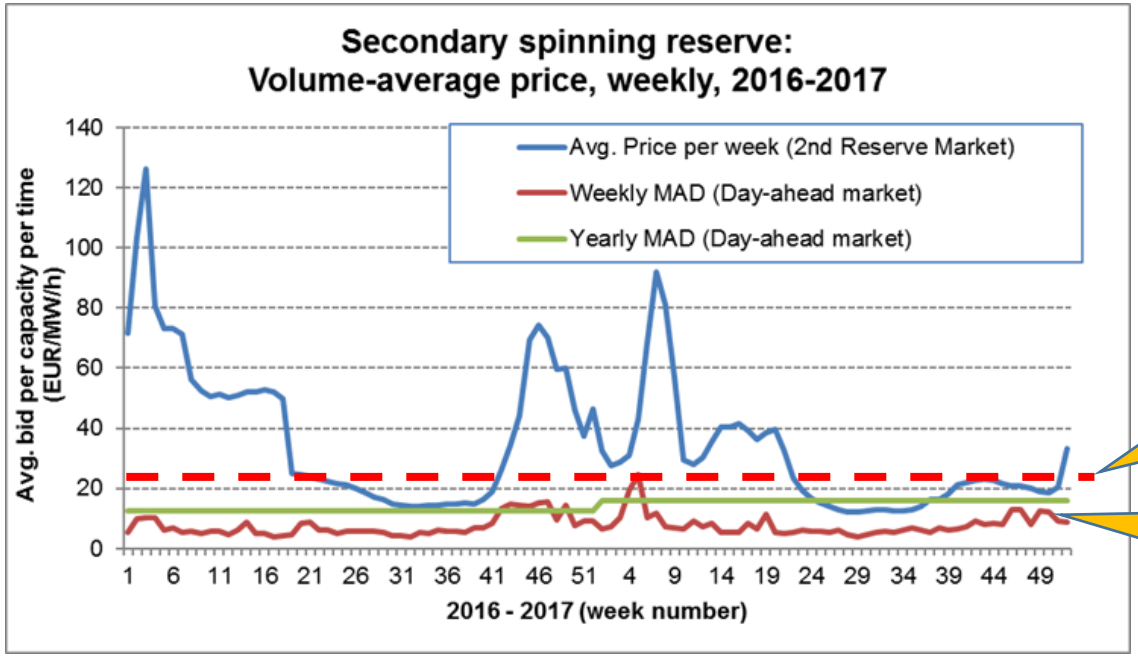
Densing et al. (2018)

- Under "today's" fuel and CO_2 price in year 2035+, average profitability may still be low

(…CO_2 price in ETS increased slightly in 2017-2020)

Can spinning reserve save hydropower?

- Derivation of (fair) price bounds for spinning (secondary) reserve power
  - E.g. lower bound: Capacity payment (per time unit, per MW) >= Mean absolute deviation from median (MAD) of electricity prices



Upper bound (incl. scarcity of storage)

Lower bound (MAD)

Densing (2020): Swissgrid (2018)

→ If reserve markets become more liquid, some historical service-price levels may be difficult to maintain

Densing, M. (2020). The value of flexible selling: Power production with storage for spinning reserve provision. *European Journal of Operational Research*. DOI: 10.1016/j.ejor.2019.08.012

Conclusions & Outlook

- Economic storage modeling
  - Non-trivial to balance: accuracy and solvability (despite increasing computing power)
  - Probabilistic (not fully stochastic) model allows time-step reduction (e.g. 8760 → 12)

- Prospects of Swiss (stored) hydropower
  - Spinning reserve?
    - Service price linked to energy price volatility (opportunity cost of not going to energy market)
    - Improvement of wind & solar forecasts technically still possible
  - What drives future market prices in Switzerland?
    - Prices likely still to be influenced by load-periods with (gas) peak plants, despite new renewables
    - Hence, CO_2- and gas-price will still (partially) drive revenues of hydropower

- Research beyond SCCER (2 PhD thesis until 2023/24):
  - **Risk-averse decision-making** in electricity markets with storage
  - Profitability of small **decentralized storage** (battery, hydrogen)