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New environmental constraints – Impacts on the power system

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Introduction

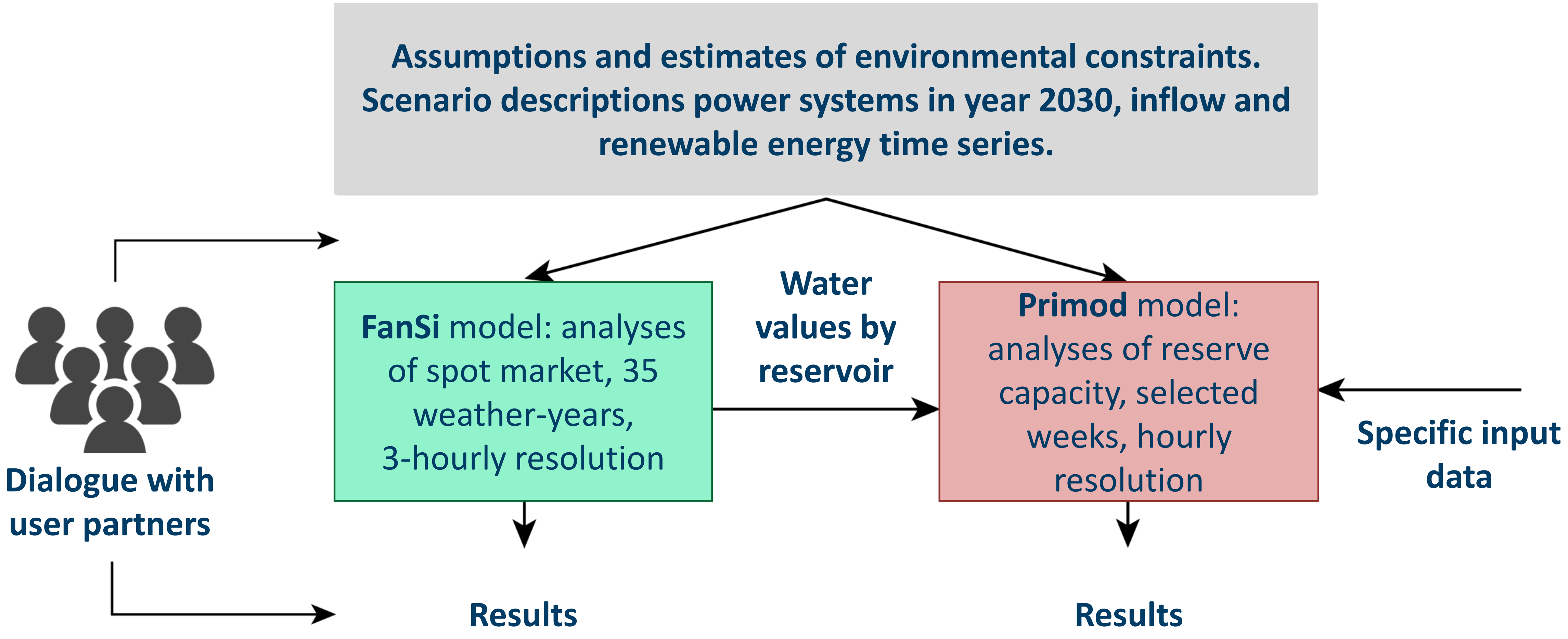
- Many concessions for hydropower are undergoing revision, introducing more environmental restrictions
- There are concerns this will result in power loss and reduced flexibility
- Project "Nye miljørestriksjoner – samlet innvirkning på kraftsystem" ("SumEffekt")
- SumEffekt's main aim is to provide new understanding of the effects of new environmental restrictions on the power system

https://www.miljodirektoratet.no/globalassets/publikasjoner/m49/m49.pdf

The project

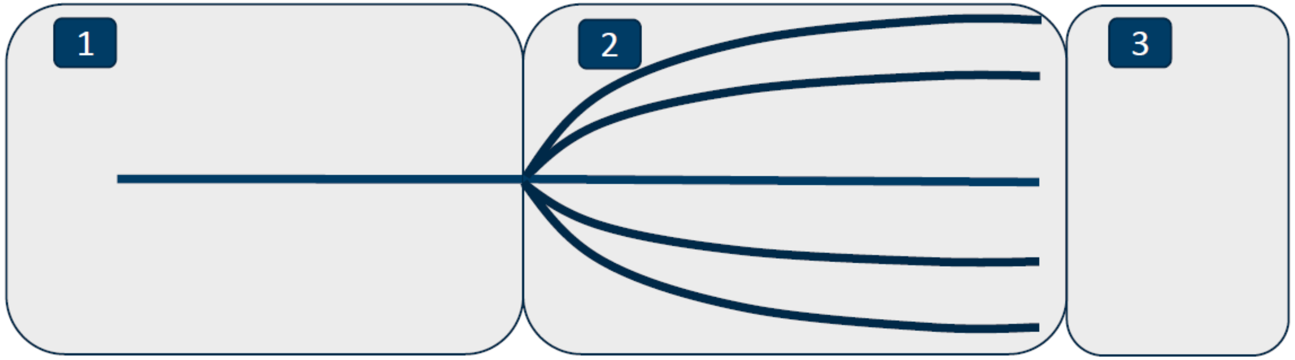
- IPN Innovation Project (2020-2023)
- Project lead: Fornybar Norge (Solgun Furnes)
- User partners: Fornybar Norge, Statkraft, Å Energi, Hydro Energi, Hafslund-Eco, Eviny, Energiforsk, Energiforetagen, SFE Produksjon, Sira-Kvina Kraftselskap, Trønderenergi, Skagerak Kraft, NTE Energi, Statnett, NVE
- SINTEF Energy Research: Ingeborg Graabak (lead), Mari Haugen, Lennart Schönfelder, Atle Harby, Birger Mo, Anders Arvesen

Overall project method



FanSi model

- Fundamental long-term market model
- Detailed treatment of hydropower
- Simulates each week for historical weather years
- Solves sequences of stochastic optimization problems
- Formal optimization, individual water values per reservoir

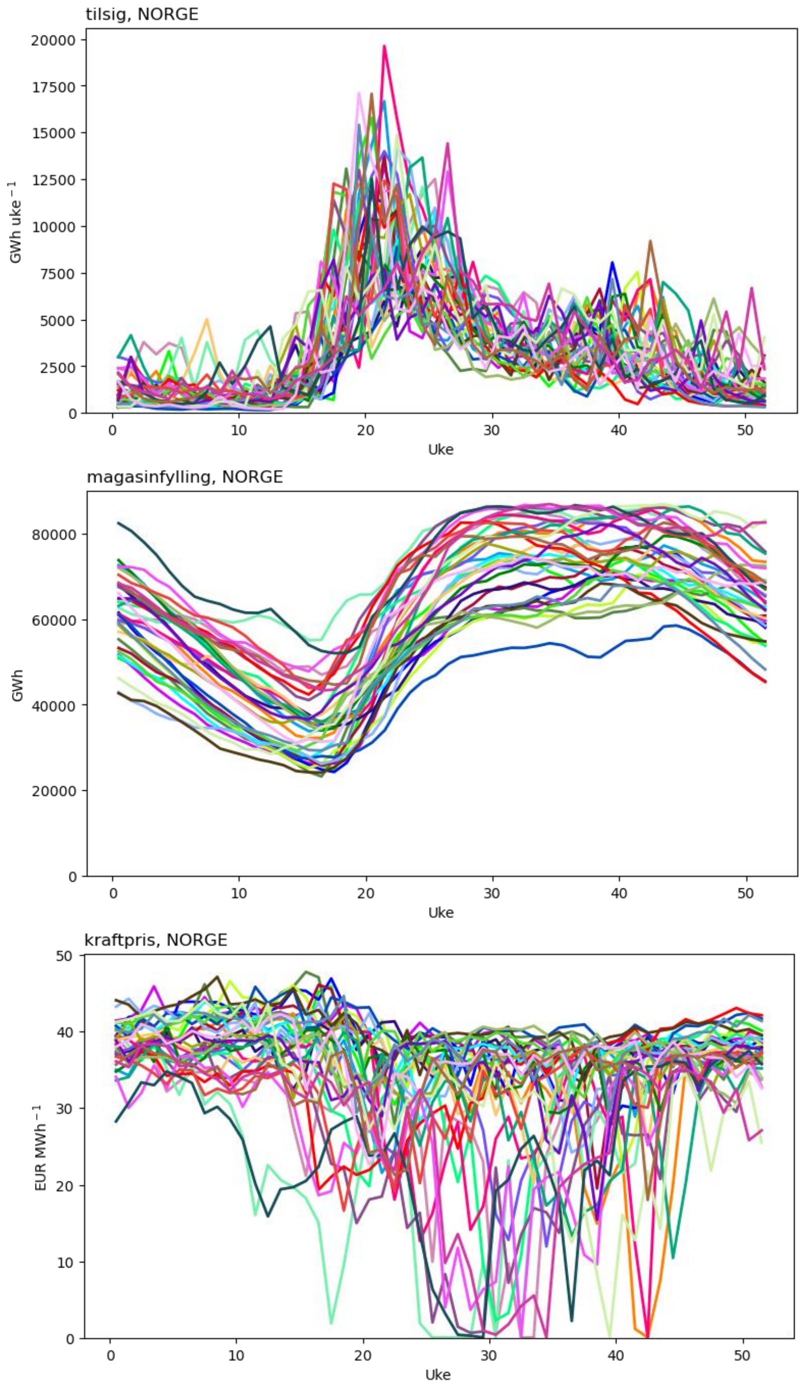


Simulation
Horizon: Week
Time resolution: 3 hours

Water values (scenario fan)
Horizon: 52 weeks
Number of scenarios: 9
Time resolution: Weekly

End-values from EMPS

Credit bottom figure: Arild Helseth, SINTEF Energi

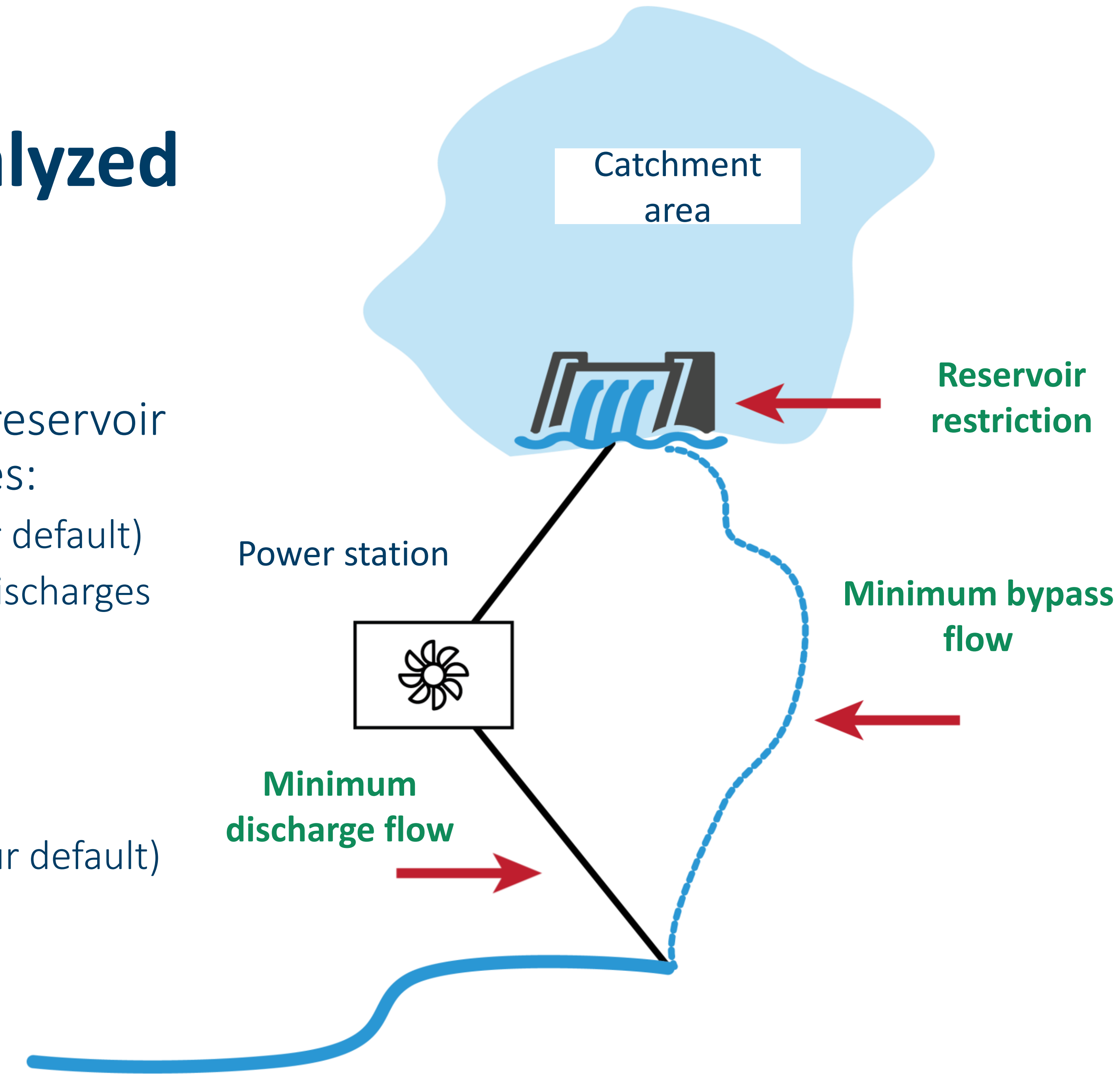


Environmental restrictions analyzed

- Reservoir restriction (108)

  Inflow must be used for filling up reservoir in summer period. Two approaches:
  - Restricted use of local inflow only (our default)
  - Restricted use of all inflow including discharges
- Minimum bypass flow (148)

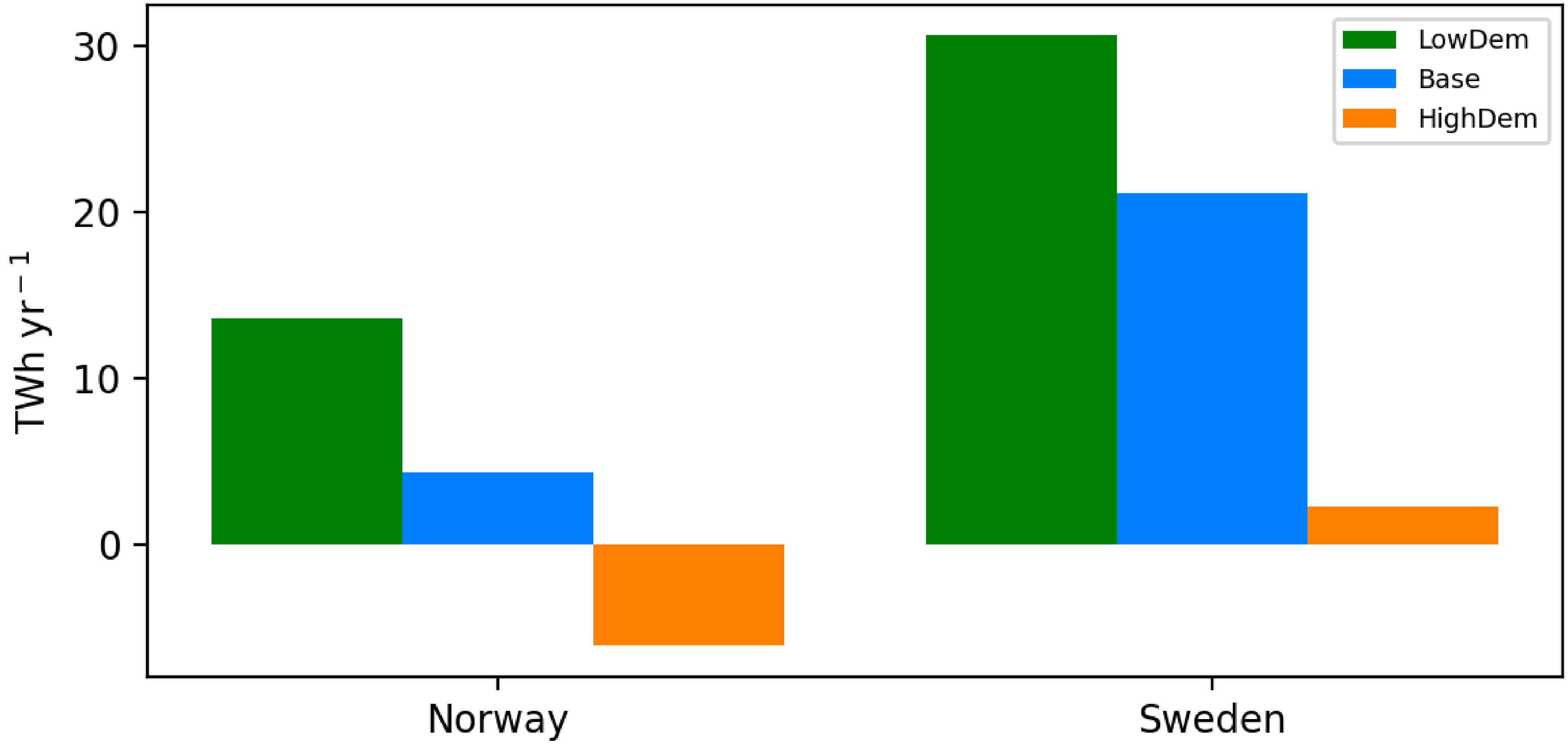
  Two methods:
  - Q95
  - Q95 with site-specific adjustments (our default)
- Minimum discharge flow (29)



Scenarios analyzed

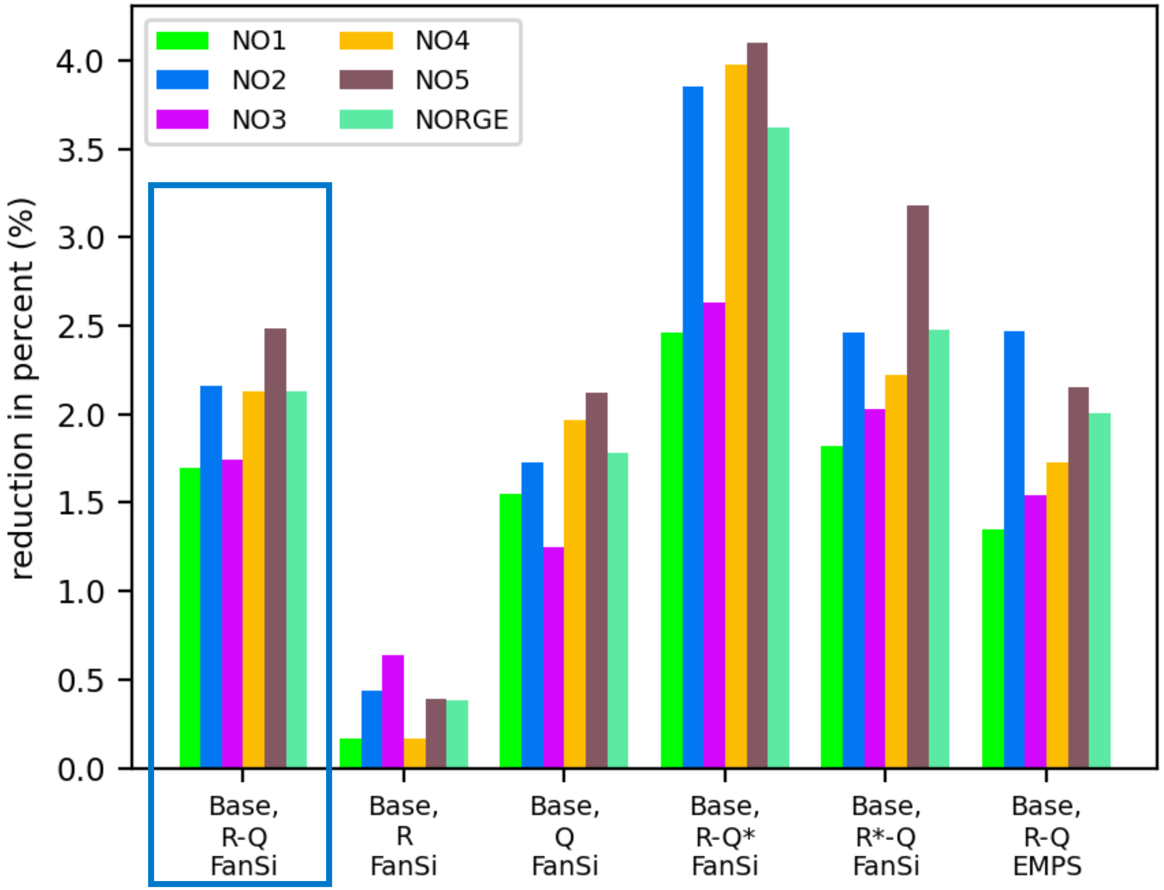
Scenario name	Environmental constraints	Scenario characteristics
Base		
Base_R-Q	Reservoir, flow	
Base_EMPS		EMPS model (replacing FanSi)
Base_EMPS_R-Q	Reservoir, flow	EMPS model (replacing FanSi)
Base_R	Reservoir	
Base_Q	Flow	
Base_R*-Q	Reservoir (strong), flow	
Base_R-Q*	Reservoir, flow (strong, Q95)	
LowDem		Low demand
LowDem_R-Q	Reservoir, flow	Low demand
HighDem		High demand
HighDem_R-Q	Reservoir, flow	High demand
HighDem_HighSolar		High demand, high solar production
HighDem_HighSolar_R-Q		High demand, high solar production
HighPrice		High fuel and CO_2 prices
HighPrice_R-Q	Reservoir, flow	High fuel and CO_2 prices
LowTransm		Low transmission
LowTransm_R-Q	Reservoir, flow	Low transmission

National power balance in three scenarios



Reduction in average annual hydropower

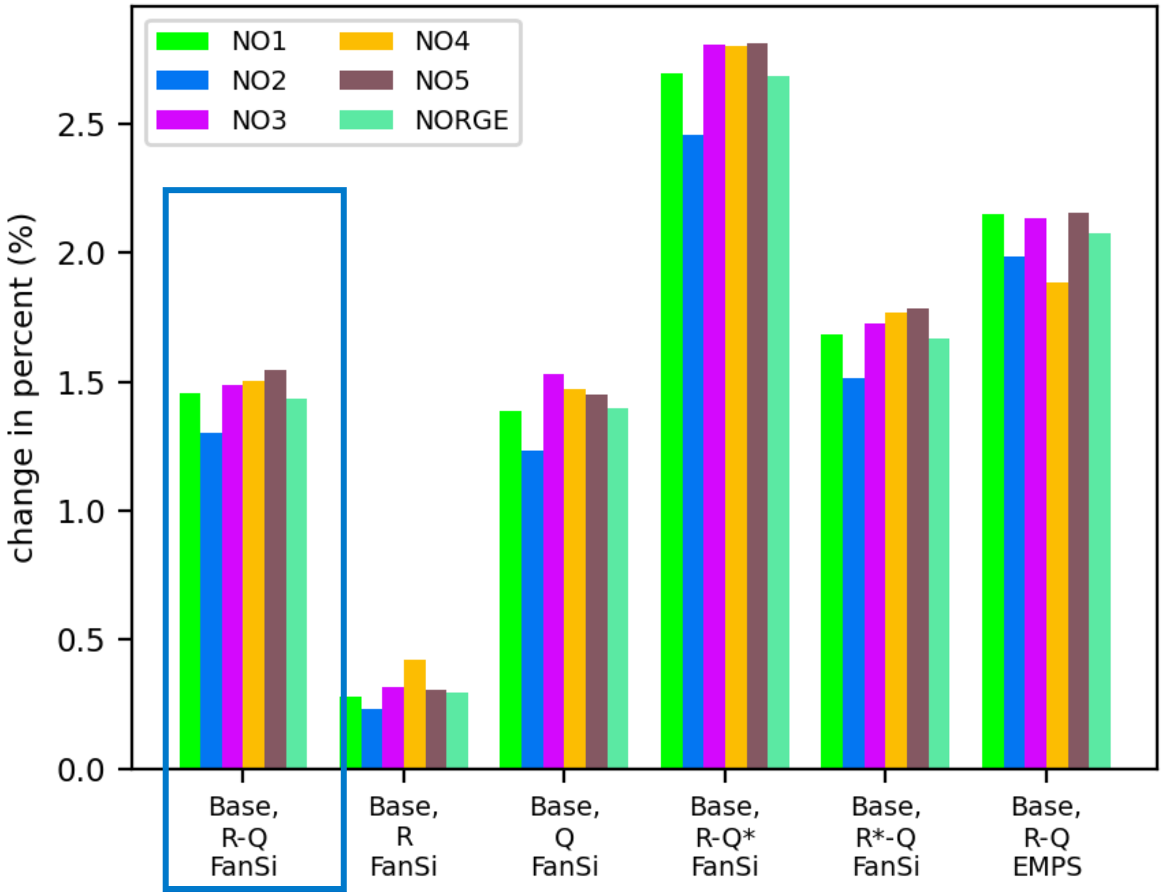
Average annual reduction in hydropower (%) :



- We estimate average annual reduction 3 TWh (2%)
- Primarily because of minimum bypass flow requirements
- Estimate is consistent across scenarios for the power system

Increase in average annual power price

Change in average annual power price (%)

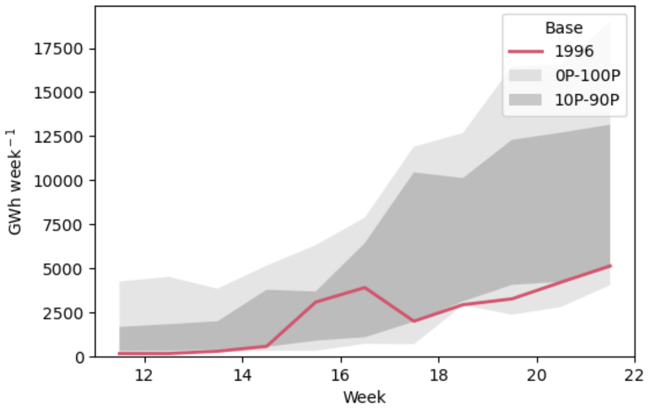


- We estimate average increase in power price of 1-2% (1-2 EUR MWh^{-1})
- Primarily because of minimum bypass flow requirements
- This estimate is consistent across scenarios for the power system

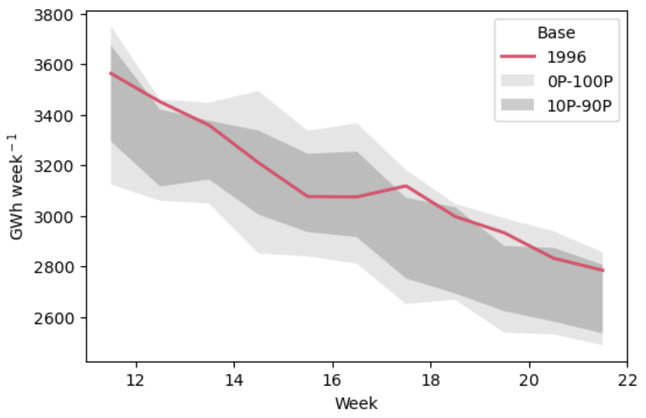
Some individual periods show marked price increases (example shown for 1996)

- Simulations show incidents of price increases in weeks 18-22
- Effect is mainly attributable to reservoir restrictions
- Such events are relatively few in the results, but at the same time probably underestimated by FanSi

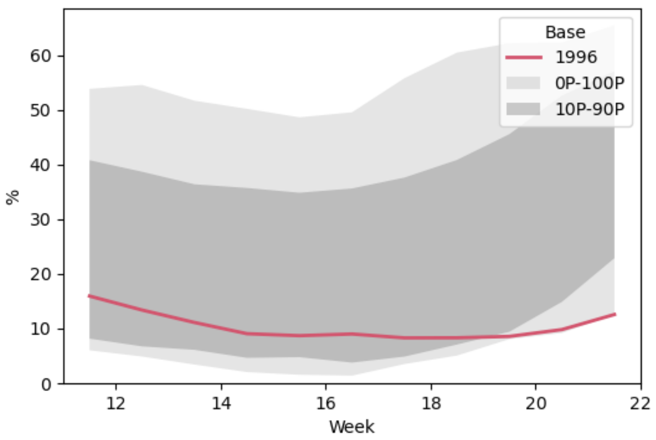
a) Total inflow, Norway, weeks 12-22, Base



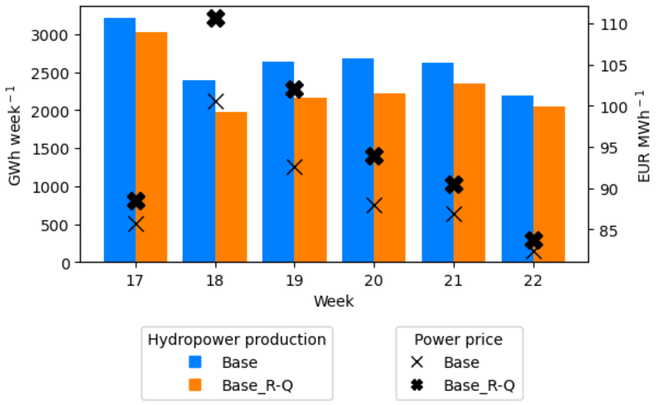
b) Temperature-dependent demand, Norway, weeks 12-22, Base



c) Total reservoir filllings, Norway, weeks 12-22, Base



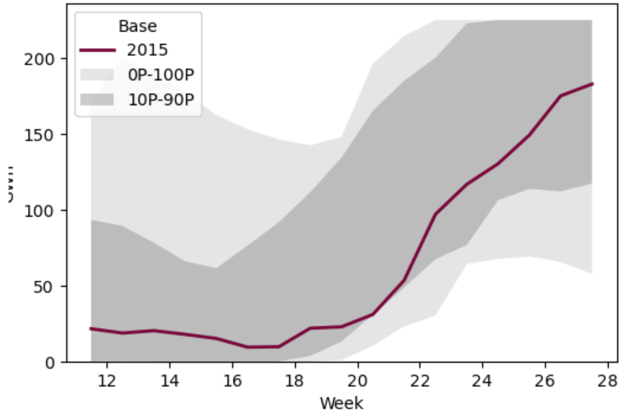
d) Hydropower production, power price, 1996, Norway, Base_R-Q



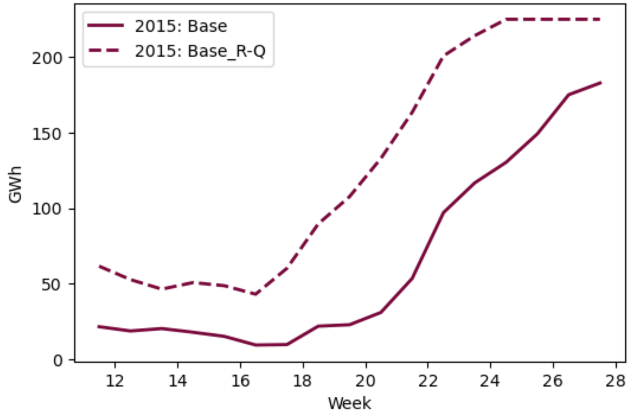
Some periods show increase in flooding (example for 2015, Gråsjøen)

- Reservoir restrictions lead to accelerated increases in simulated reservoir fillings from week 18
- This can result in flooding during summer and fall
- Example shown for Gråsjøen, which is assigned a new reservoir restriction in our analysis

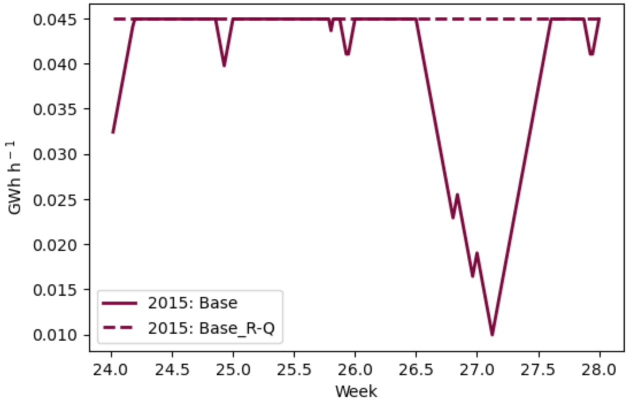
Reservoir fillling, module "Graasjoe", weeks 12-22, Base



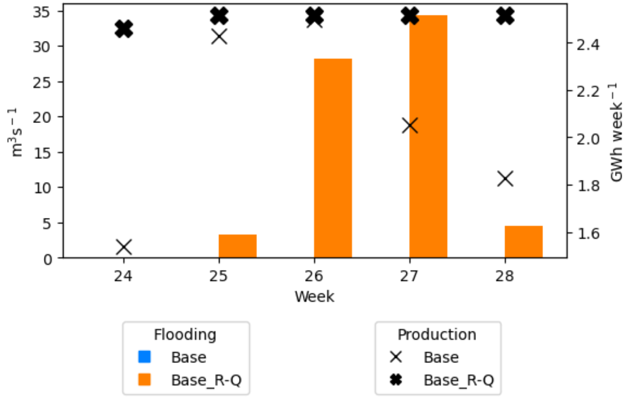
c) Reservoir filllings, "Graasjoe", weeks 12-22, 2015



e) Hydropower production, "Graasjoe", at three-hourly time resolution, week 25-28, Base and Base_R-Q



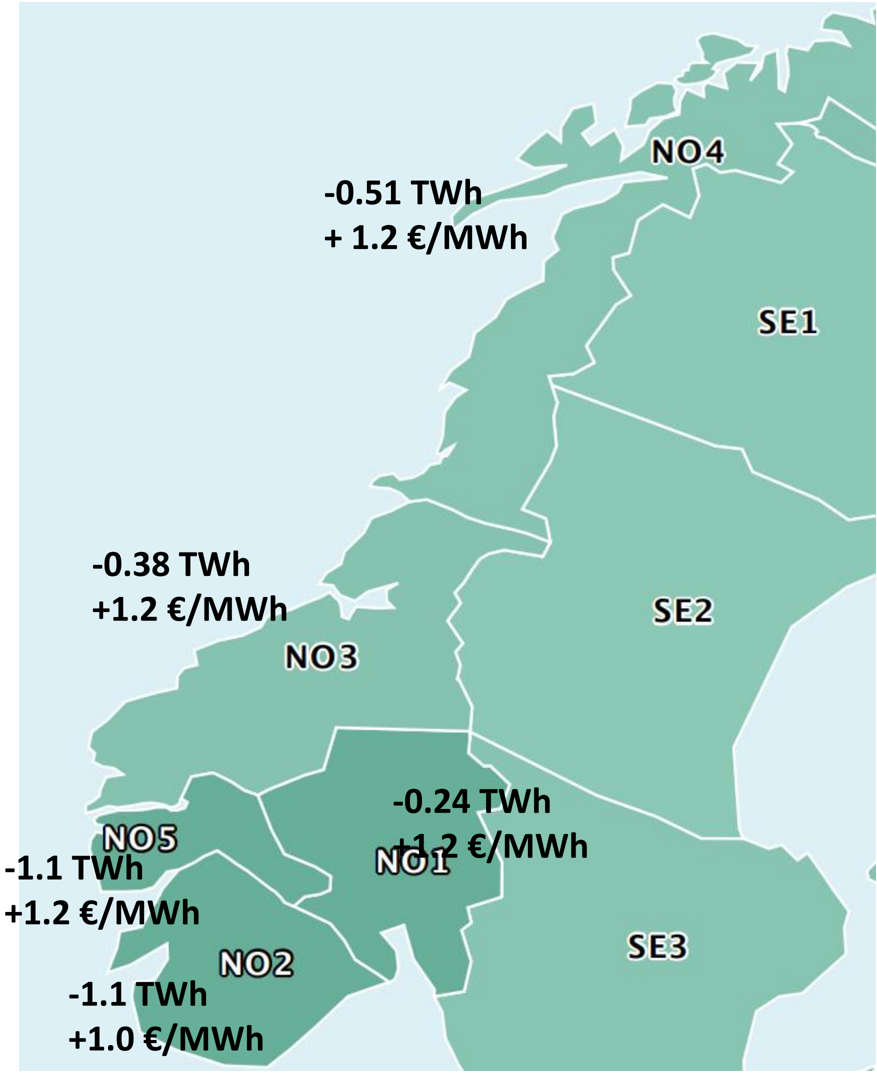
f) Flooding for "Graasjoe" and power price for "Norgemidt", 2015, week 25-28, Base and Base_R-Q



Conclusions and additional remarks

- We estimate average **hydropower reduction 3 TWh** and average **power price increase 1-2%**
- **Two types of effects in single periods**:
  1) Marked price increases in weeks 18-22
  2) Flooding increases in summer-fall
- Loss of flexibility due to restrictions result in **greater need to utilize other sources of flexibility**
- Additional simulation results from Primod show **lower availability of spinning reserve capacity in weeks 18-24**
- **There is uncertainty**
  - From assumptions and estimates about environmental constraints
  - From aggressive reservoir scheduling in FanSi simulations

Annual average, FanSi, scenario Base:



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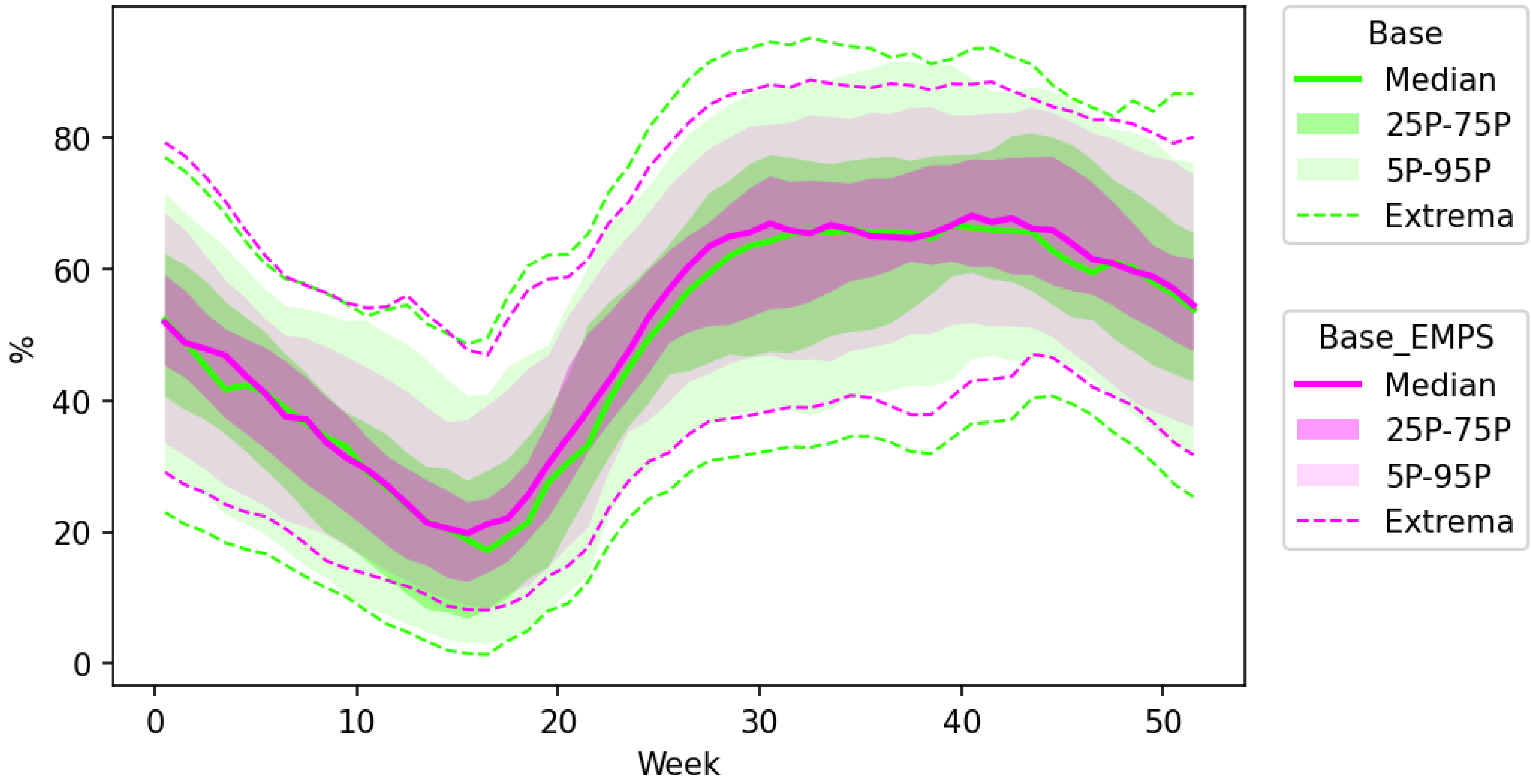
Reservoir fillings with FanSi and EMPS



Reservoir fillings with and without restrictions (FanSi)