Model Application in the Otra River System

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Hydropower Scheduling User meeting 2025

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Sensitivity: Internal

Pumped Storage Power Plant

Vatnedalsvatn - Botsvatn

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Sensitivity: Internal

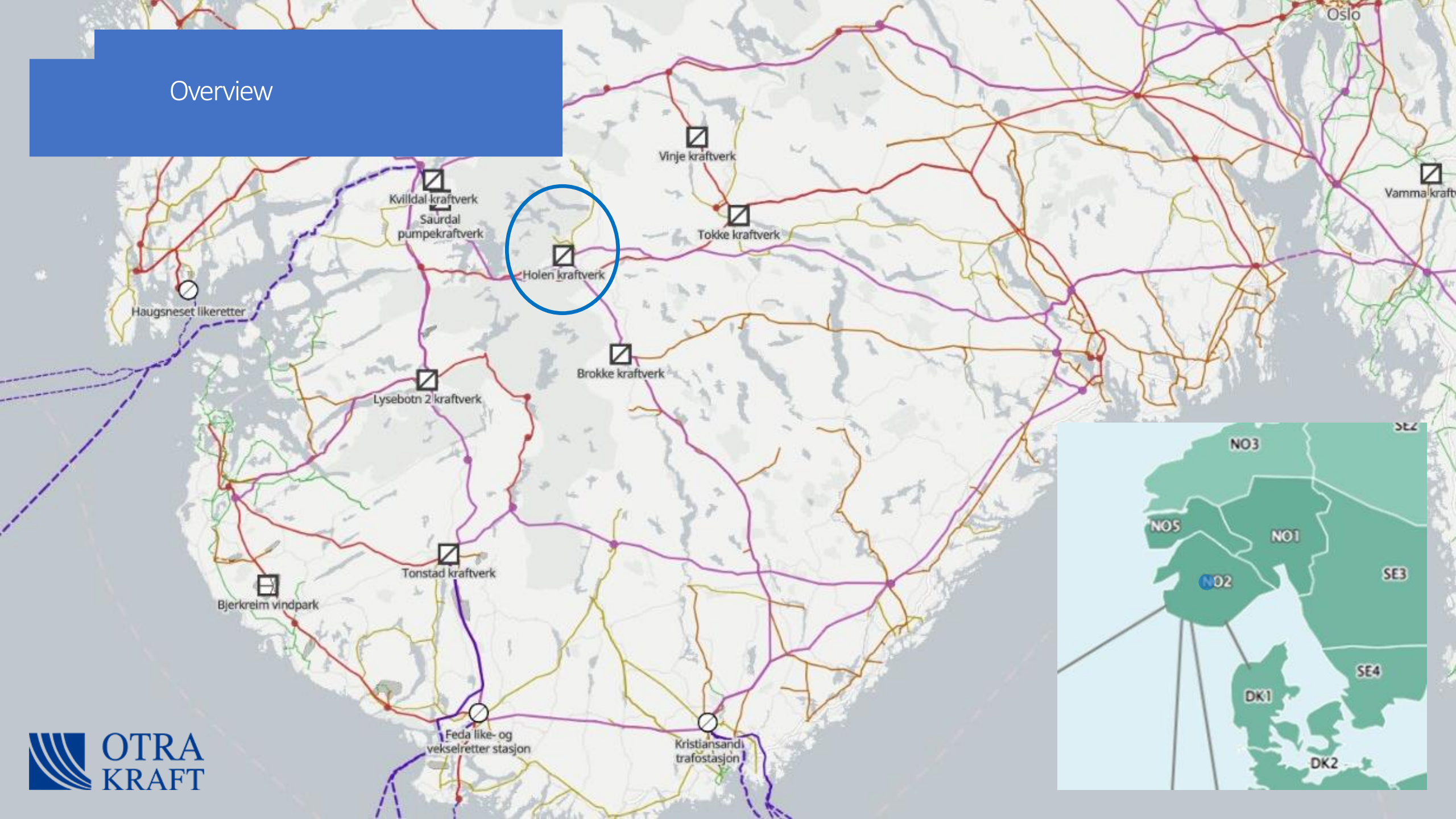
Outline

- Background/motivation
- Model application
- Model challenges
  - SINTEF support

Otra Kraft – Project Owner

- The excisting reservoirs and power stations in the area is owned by Otra Kraft DA.
- Otra Kraft DA is owned by Å Energi (68,6%) and Skagerak Kraft (31,4 %).
- Average production is 2.924 GWh. (Brokke, Holen and Skarg power station).

Overview



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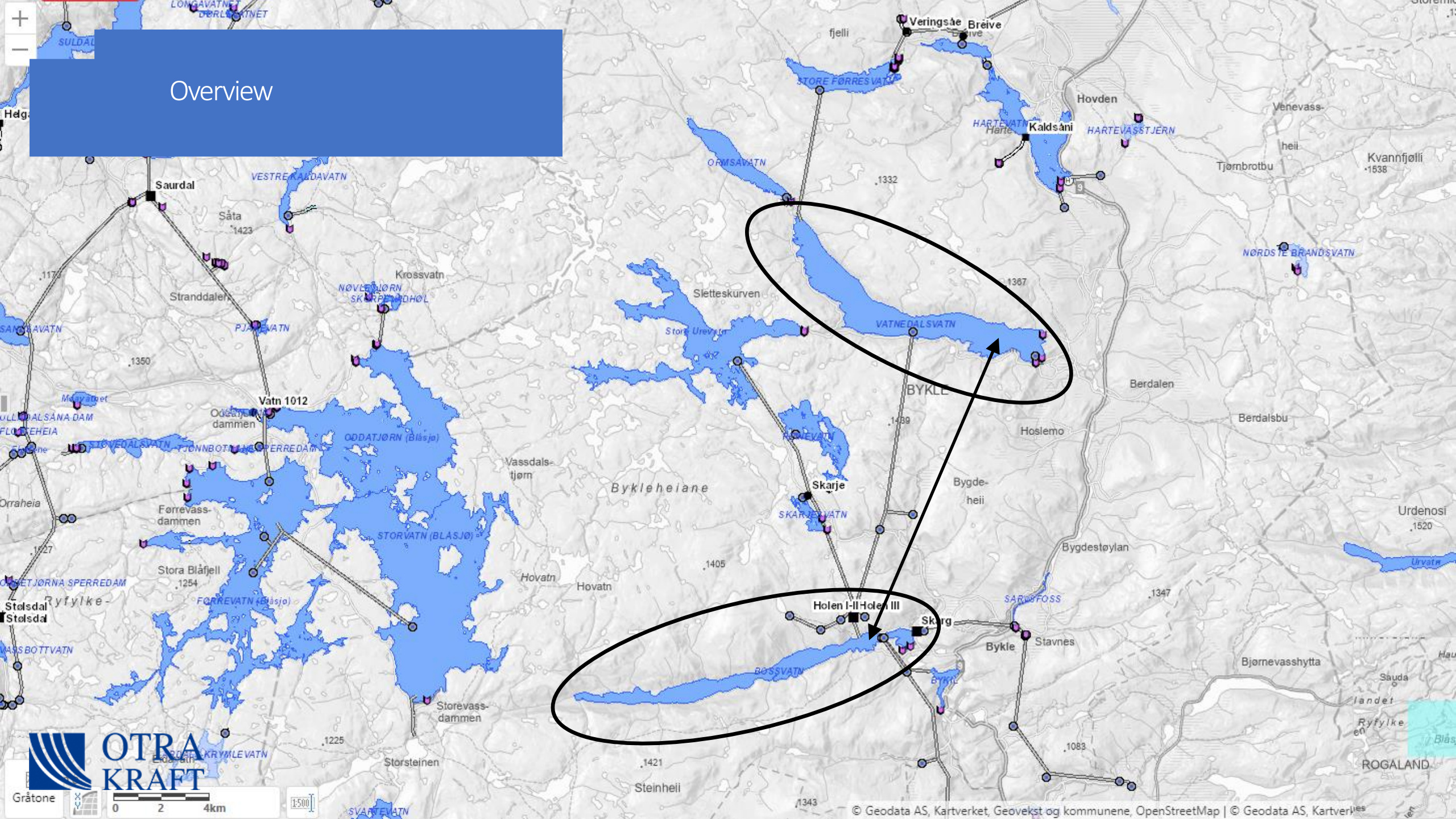
Overview



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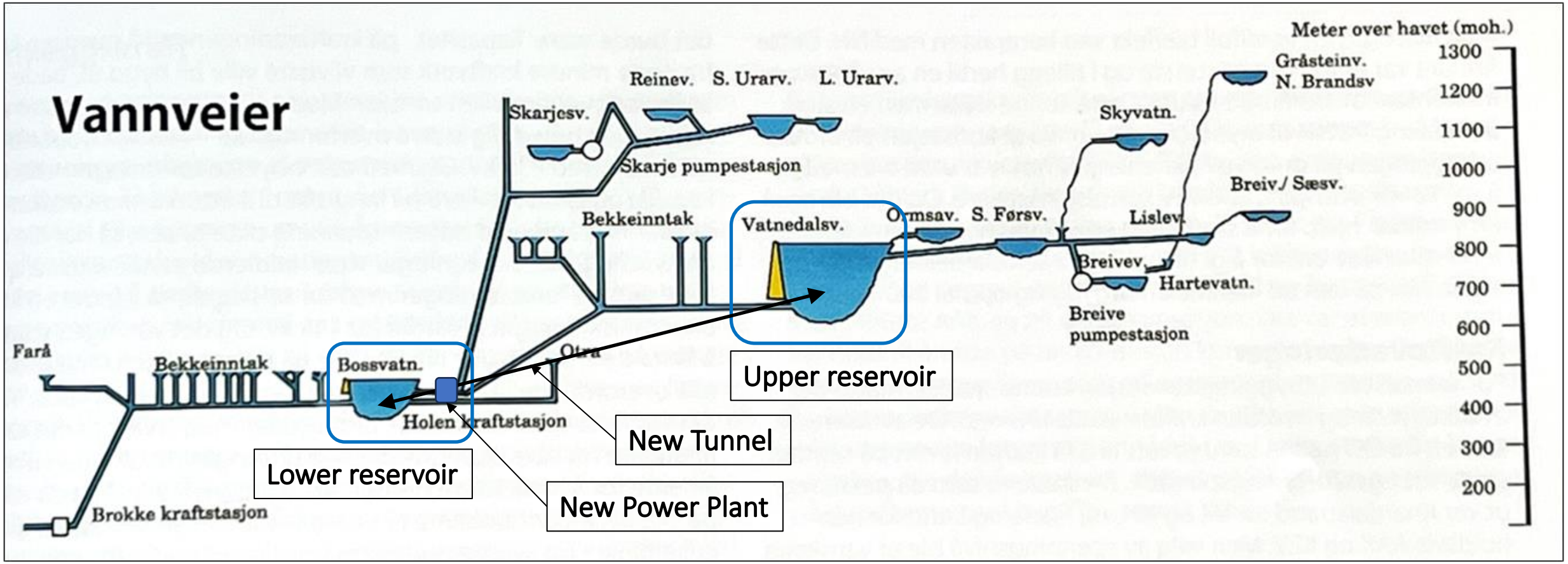
New Pumped Storage Power Plant



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Vatnedalsvatn

- Upper reservoir
- 1150 million m^3
- 840 – 700 masl.

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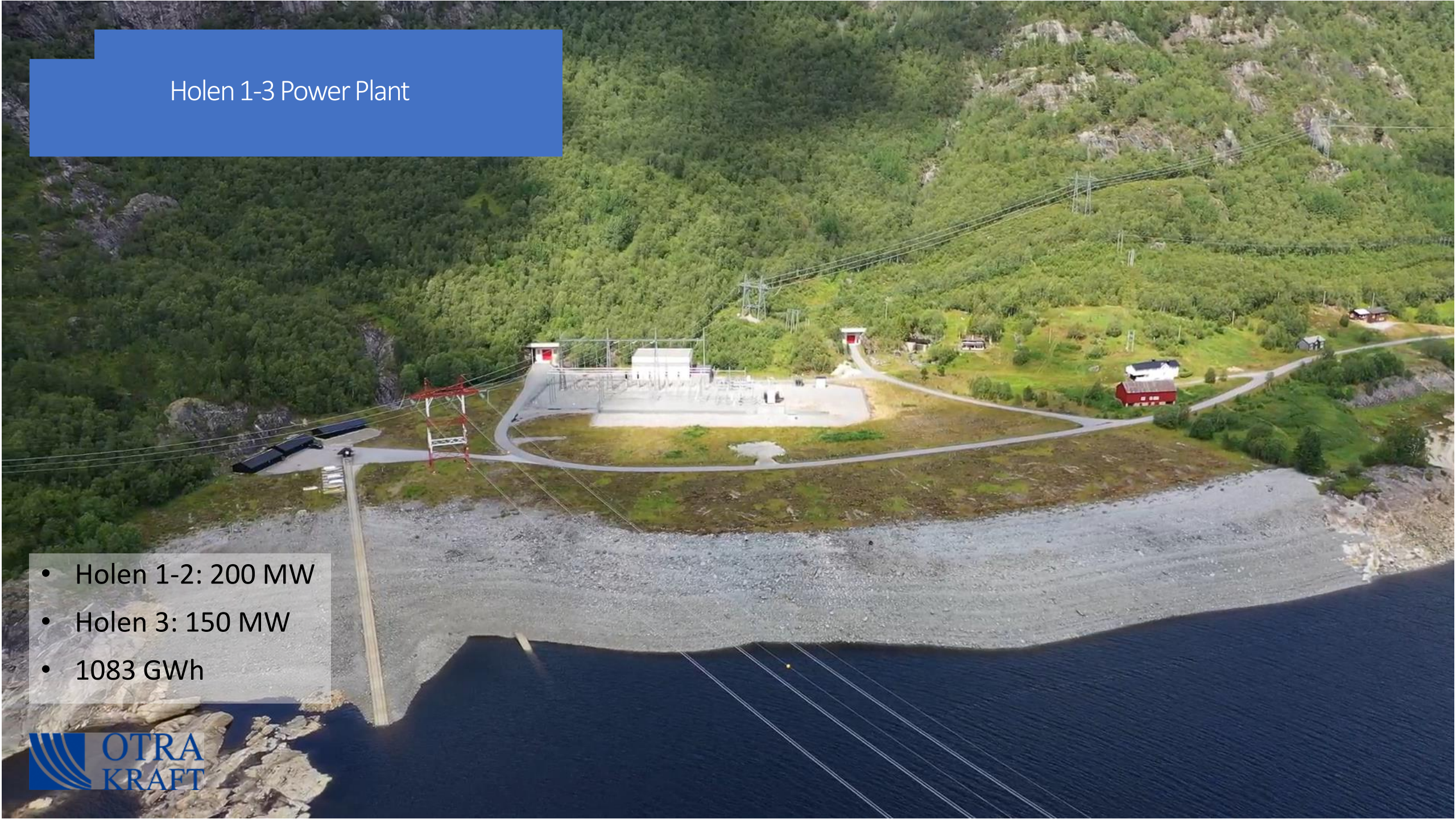
Botsvatn

- Lower reservoir
- 295 million m^3
- 551 – 495 masl.

Holen 1-3 Power Plant



- Holen 1-2: 200 MW
- Holen 3: 150 MW
- 1083 GWh

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Technical Information

- Upper reservoir – Vatnedalsvatn, 1150 million m^3, 840 – 700 masl.
- Lower reservoir – Botsvatn, 295 million m^3, 551 – 495 masl.
- **Head varying from 345 m to 149 m.**

- Holen 1-2 – 230 MW (96 m^3/s).
- Holen 3 – 150 MW (25 m^3/s).
- Brokke – 330 MW (136 m^3/s).

- New pumped storage power plant - 1000 MW at 280 m head (391 m^3/s).

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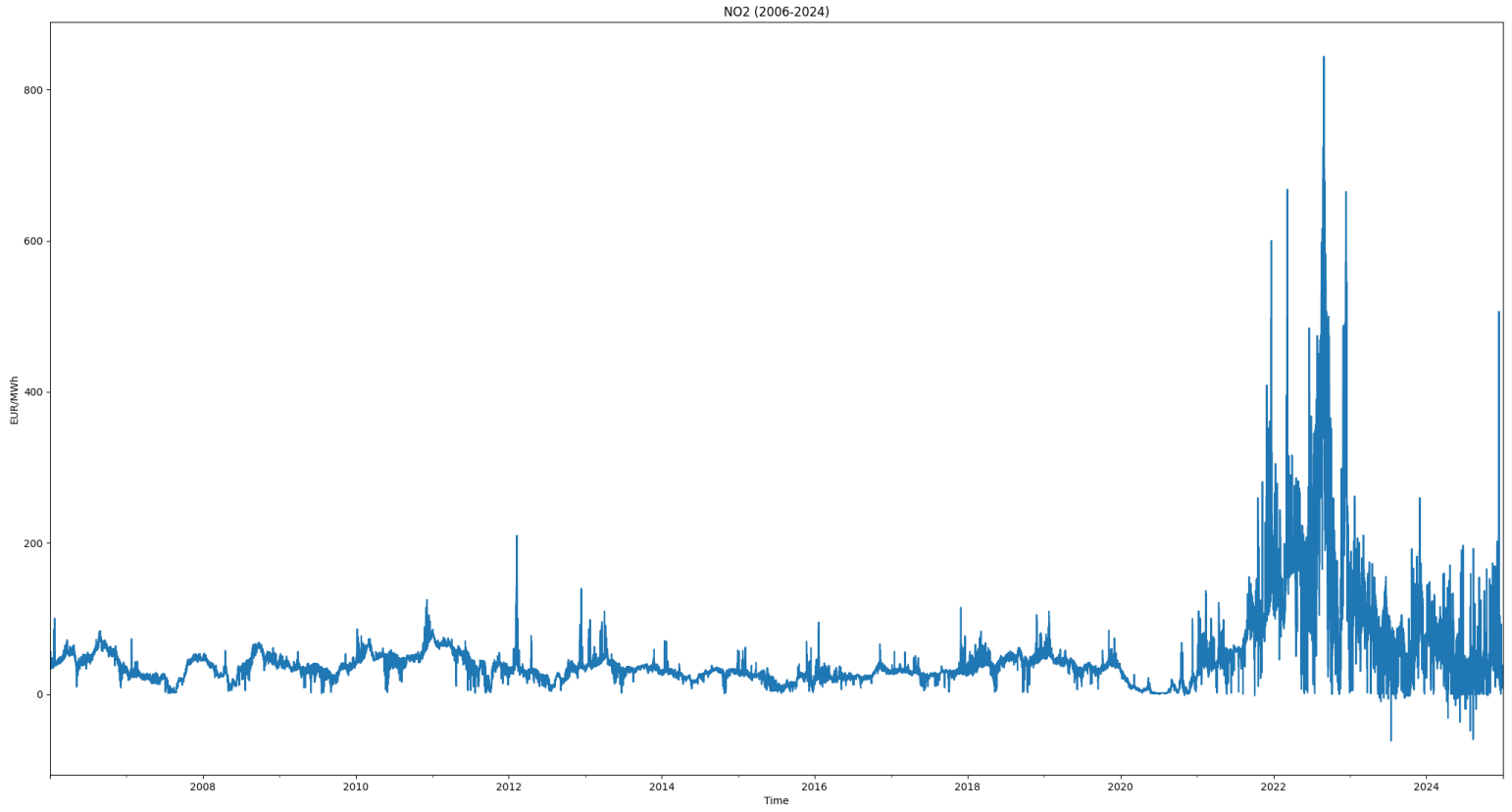
Motivation

- Analysed before



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External price prognoses (scaled to mean price 50 EUR/MWh)

- Duration curves
- Volatility measures

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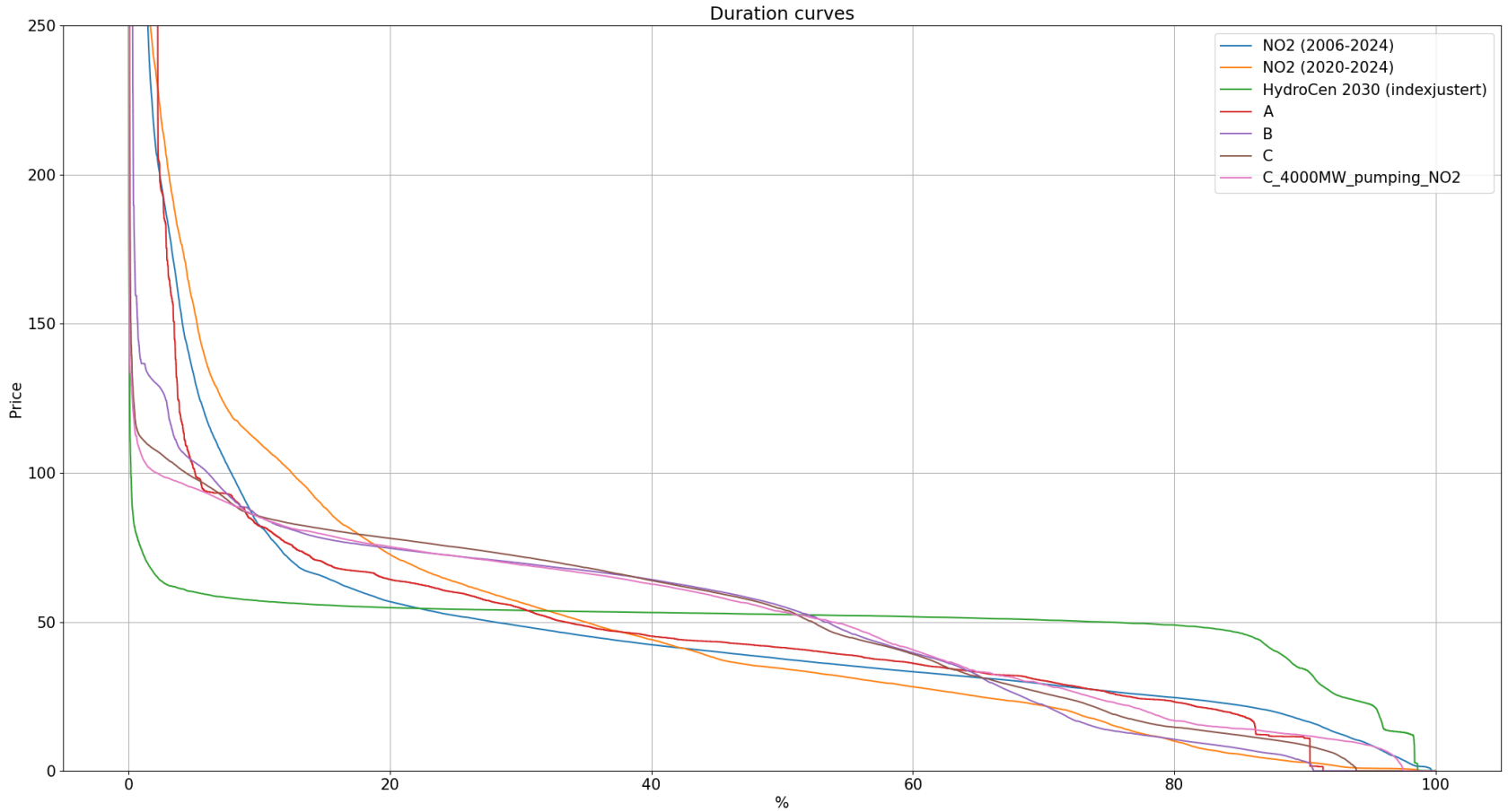
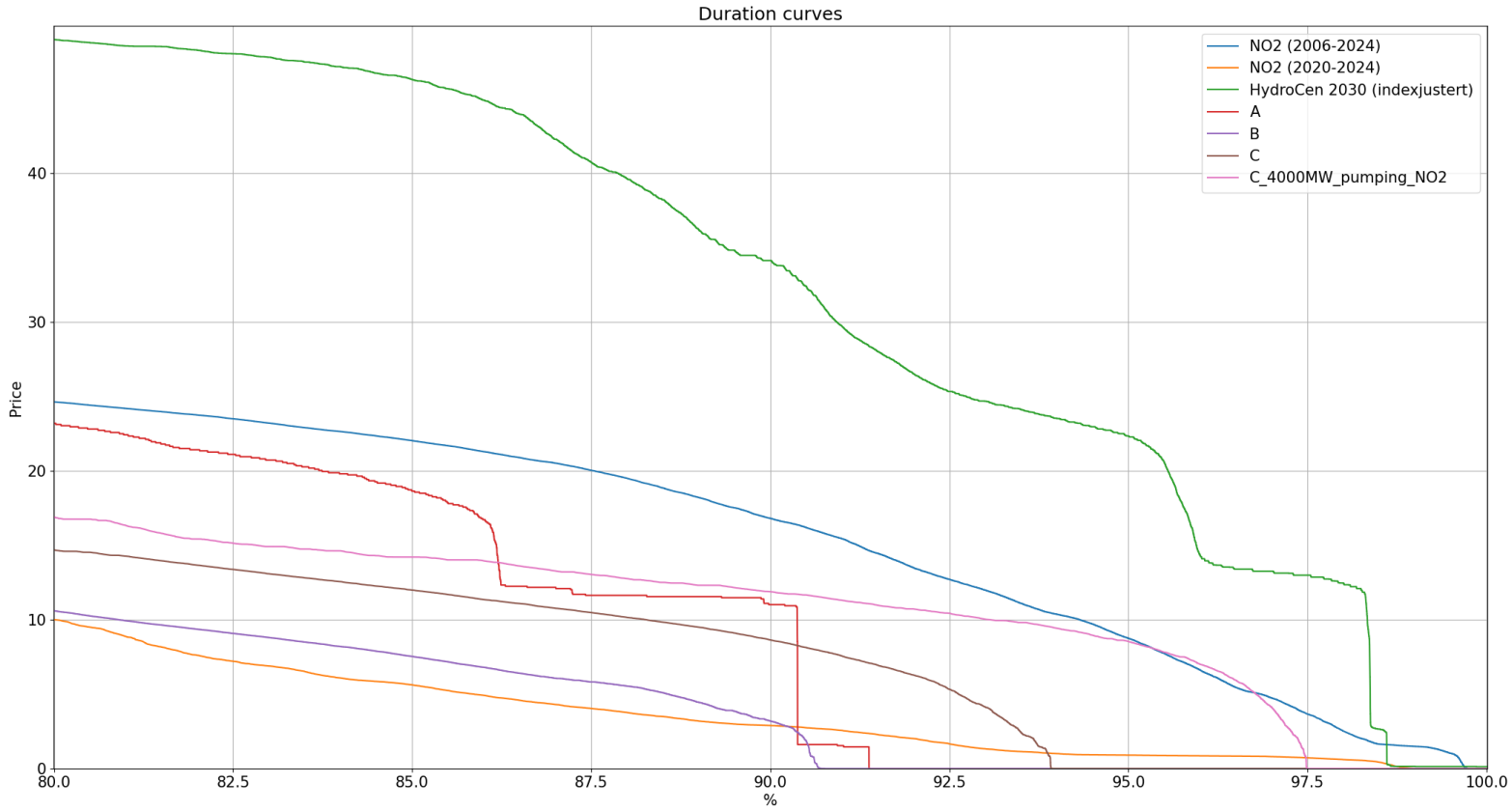
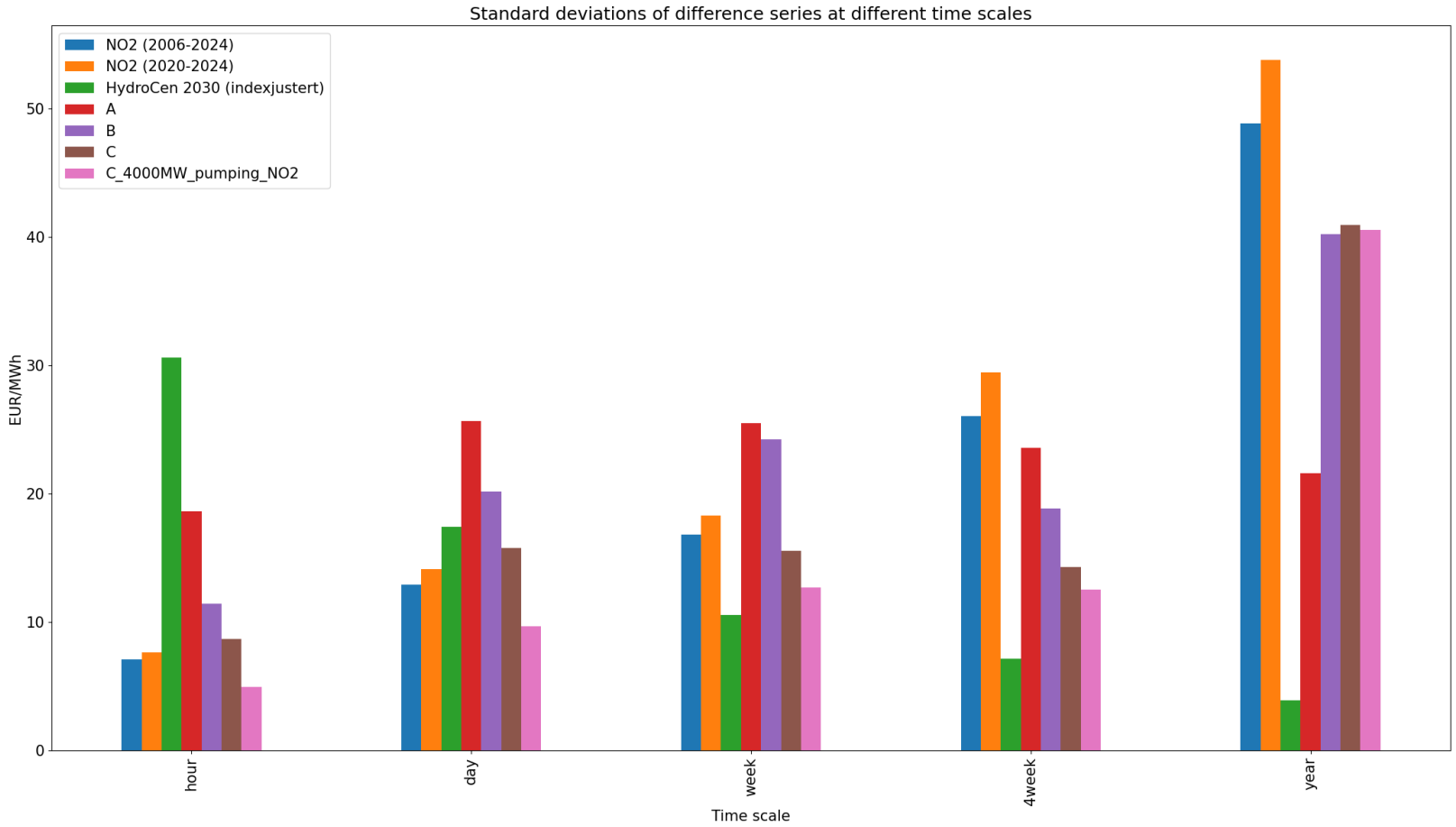
Duration curves



Duration curves (low prices)



Volatility


Standard deviations of difference series at different time scales
NO2 (2006-2024)
NO2 (2020-2024)
HydroCen 2030 (indexjustert)
A
B
C
C_4000MW_pumping_NO2
EUR/MWh
0
10
20
30
40
50
hour
day
week
4week
year
Time scale

Model application

- Simplified analysis
  - «Back of the envelope» python script
- Prodrisk - snipped model
- Prodrisk-SHOP simulator (TODO)

«Back of the envelope» python script

- Step through price series (5-55 weather years) with fixed step size
- For given step size (e.g. 168 hours):
  - Sort hours and pick pairs with high/low price above set threshold (e.g. 30% price difference)
  - Pump at low price (1000 MW, 300 m3/s)
  - Produce at high price (800 MW, 300 m3/s)
  - Example parameters match
    - 90 % plant efficiency (production and pumping)
    - 300 meter gross head

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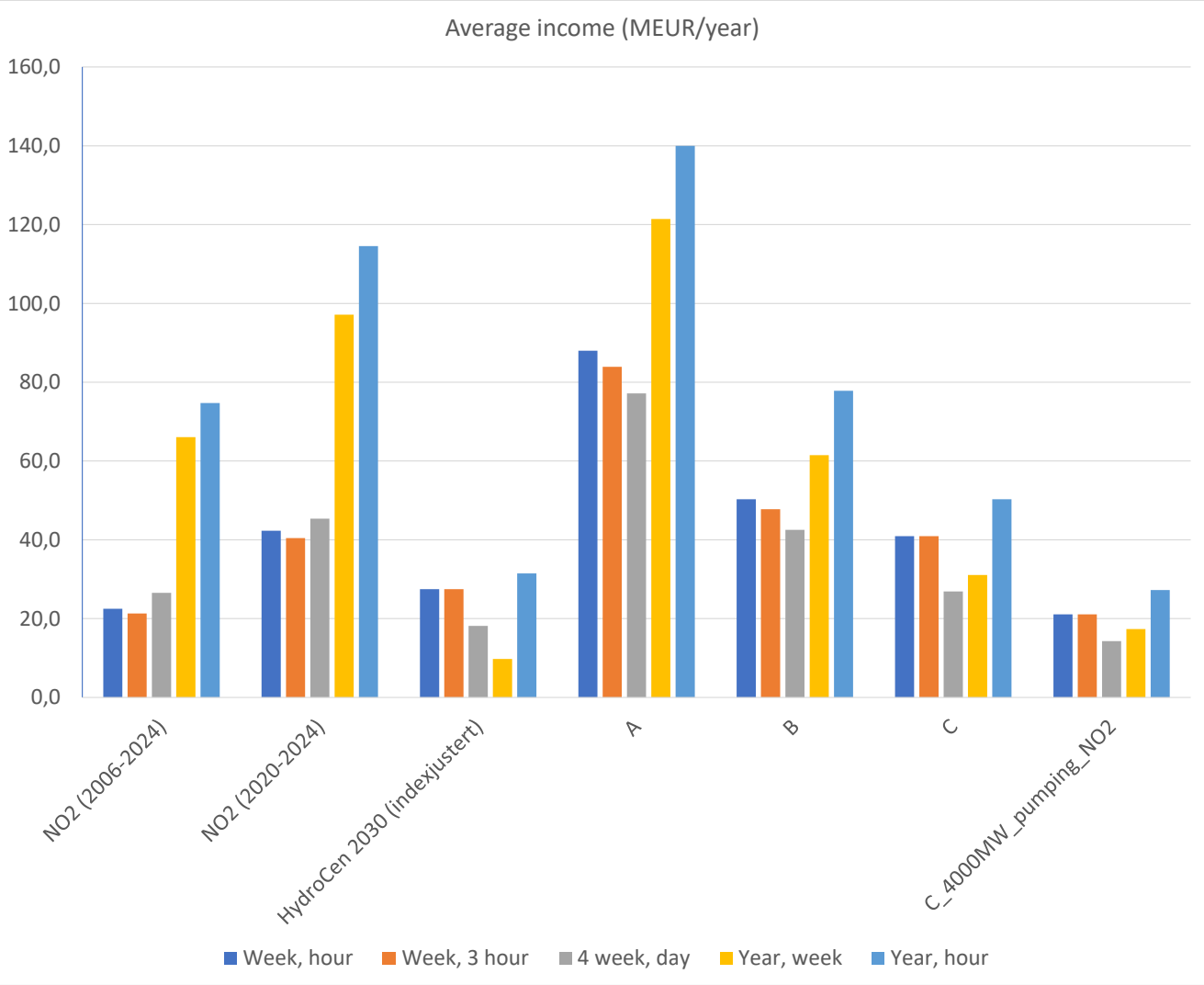
Required relative price difference = 30%



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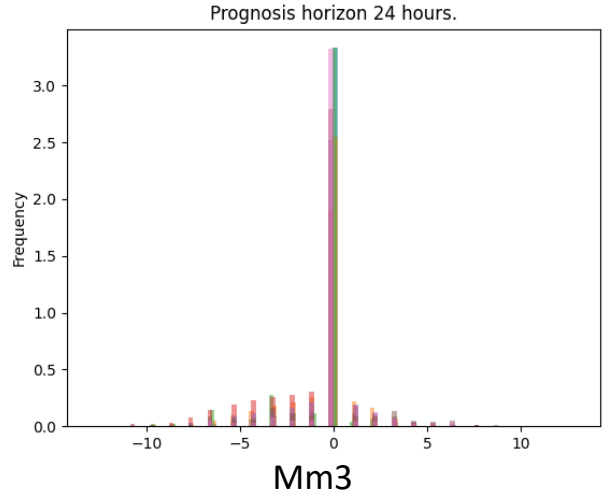
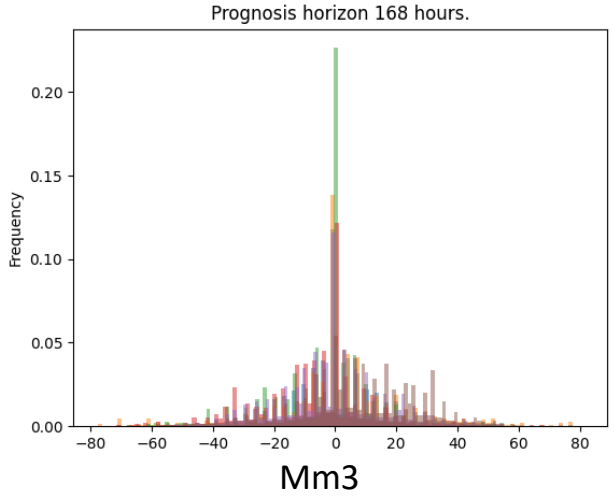
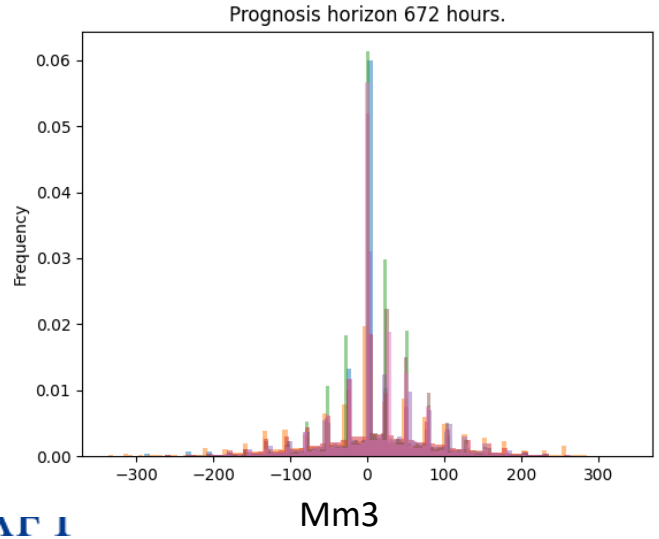
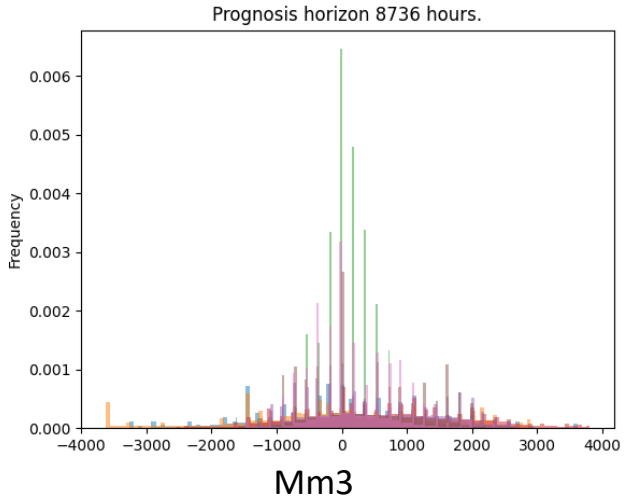
Reservoir utilization



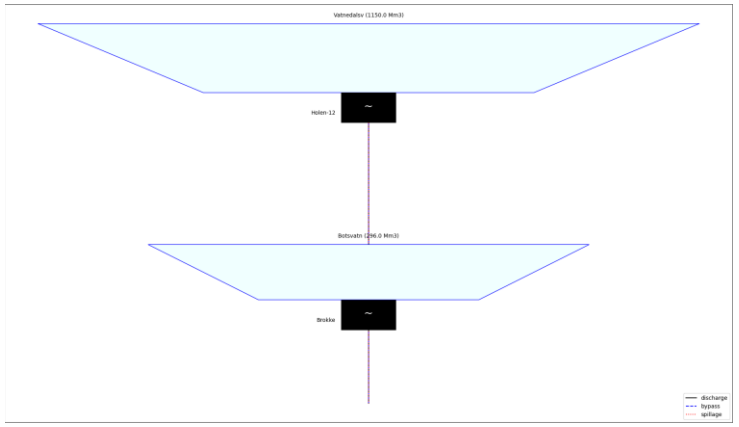


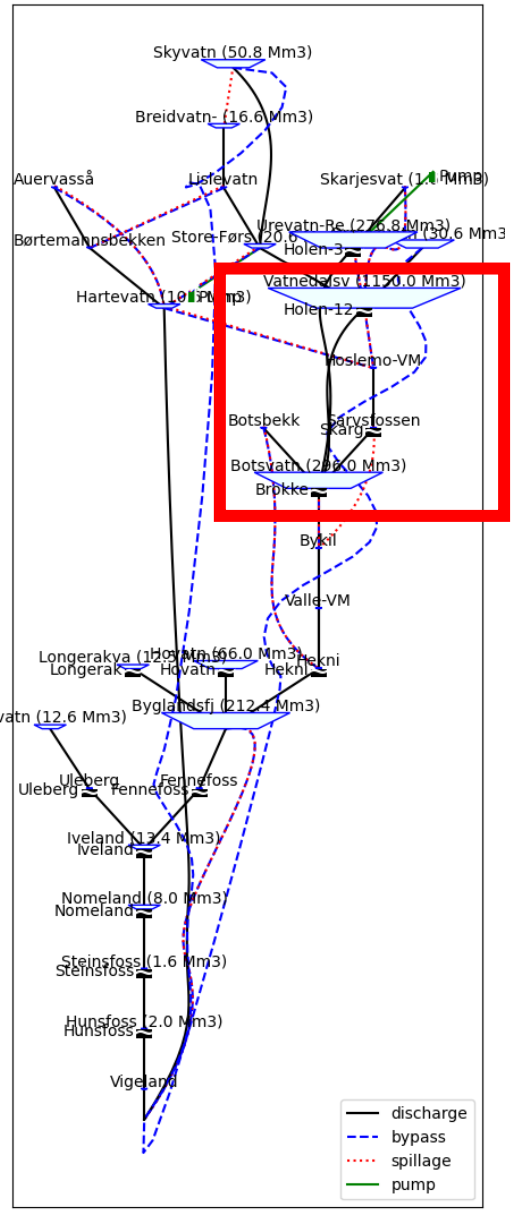




Prodrisk – snipped model

1. Run Prodrisk for the full system
2. Create a snipped/minimal model (2 reservoirs, 2 plants) by
   a) Remove all but 2 modules from the model dictionary
   b) Lock upstream decisions:
      I. Make new inflow series: local inflow + all upstream discharge/bypass/overflow from excluded modules
   c) TODO: Lock downstream decisions
      I. Use scenario dependent max/min discharge constraints





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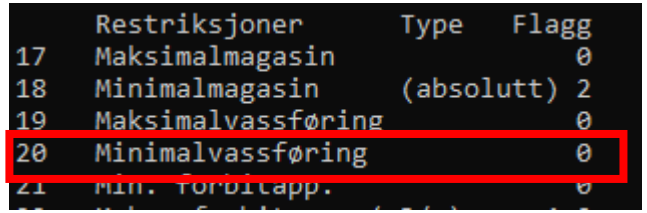
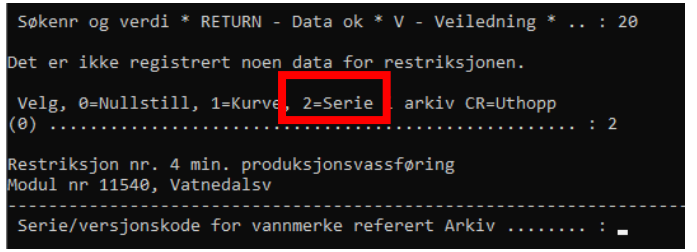
Model challenges

- Long calculation time
  - «Snipped system» method
- Head variation
- SINTEF support

SINTEF support

- Pmax constraint
- Scenario dependent max/min discharge using constraint-by-inflow-series functionality
  - Lock downstream decisions in «Snipped system»



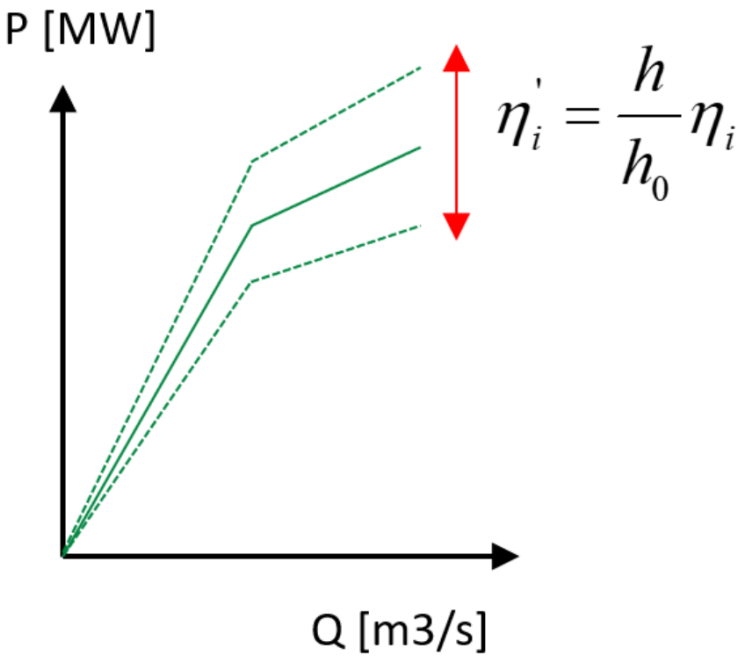


Head variation

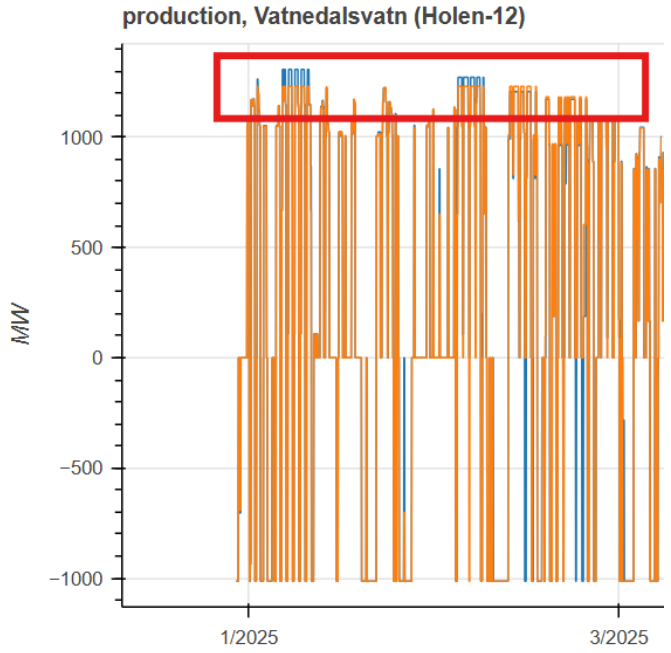
- P > Pmax
- Technical constraints
  - H_gross (max) / H_gross (min) <= 1.25, unless
  - Variable speed / Full converter solutions
- Simplified pump modelling in Prodrisk

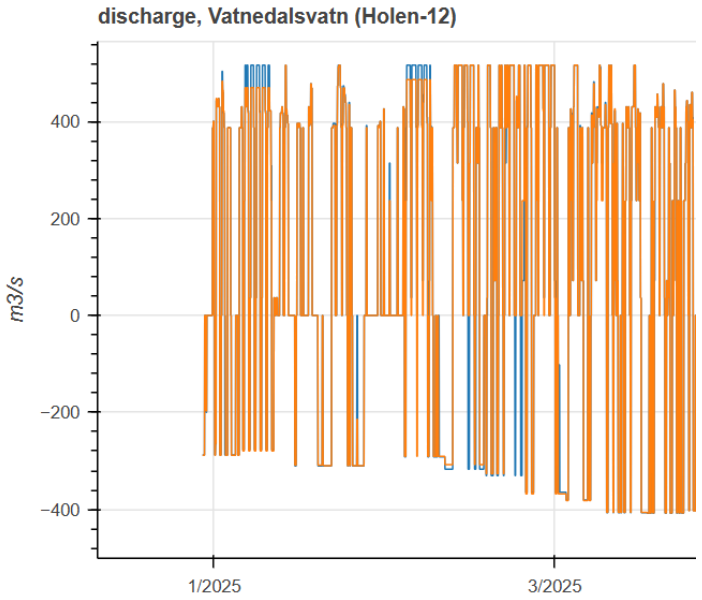
Pmax constraint

Forward simulation:



Prodrisk documentation





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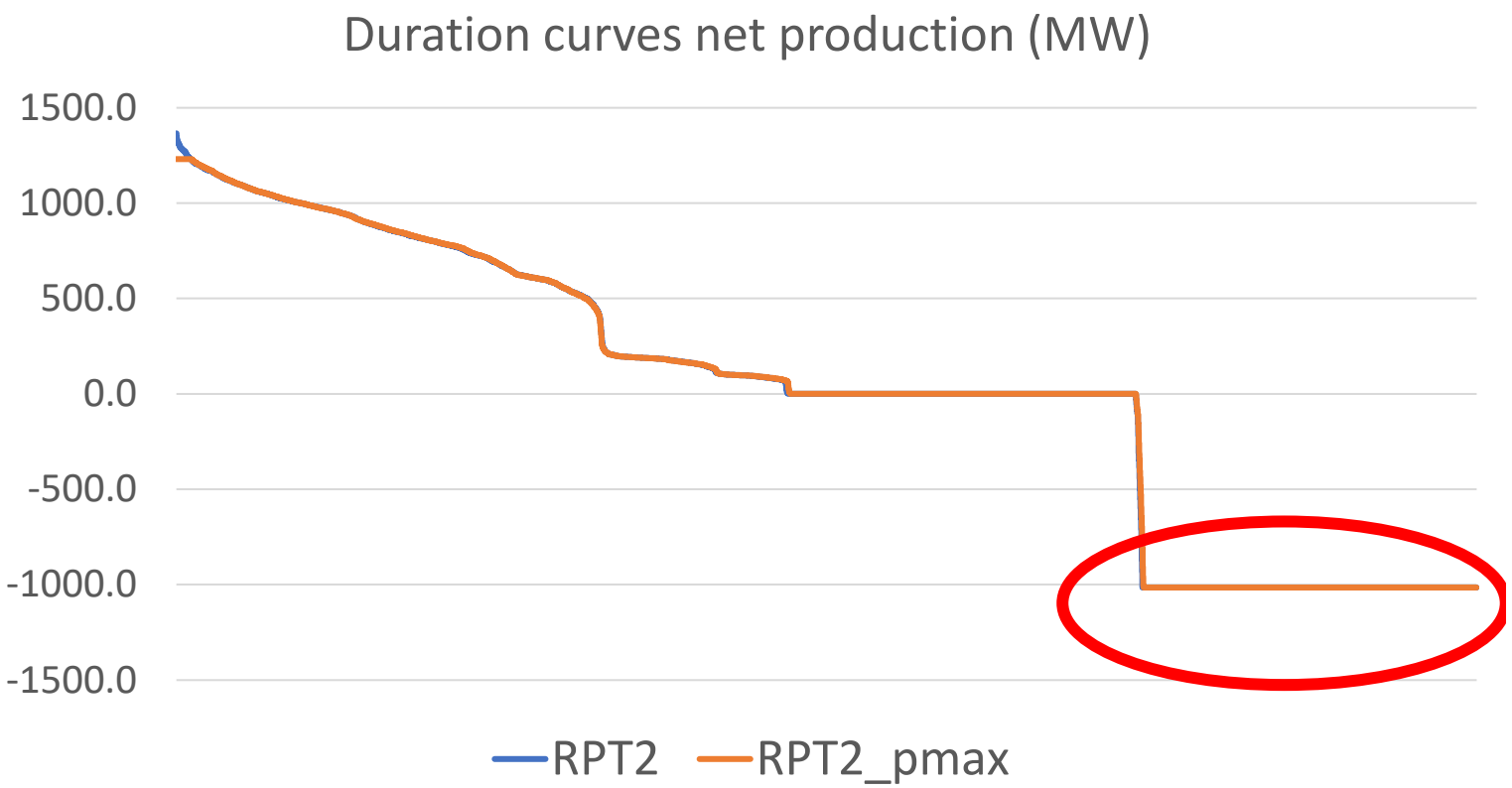
Technical constraints

- H_gross (max) / H_gross (min) <= 1.25, unless
  - Variable speed / Full converter solutions

- Prodrisk-SHOP simulator
  - Dynamically set upstream/downstream min/max on generators/pumps?

Simplified pump modelling in Prodrisk

- «Unphysical» pump modelling in Prodrisk
  - In particular for variable speed pumps
- Prodrisk-SHOP simulator



Summary

- Investment analysis – RPT in Otra river system
- Model application
- Model challenges

- Future work: Test Prodrisk-SHOP simulator (for snipped system)