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THE IMPACT OF ENVIRONMENTAL CONSTRAINTS ON NORWEGIAN HYDROPOWER FLEXIBILITY IN POWER GRIDS WITH A HIGH SHARE OF RENEWABLES

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OUTLINE

Background

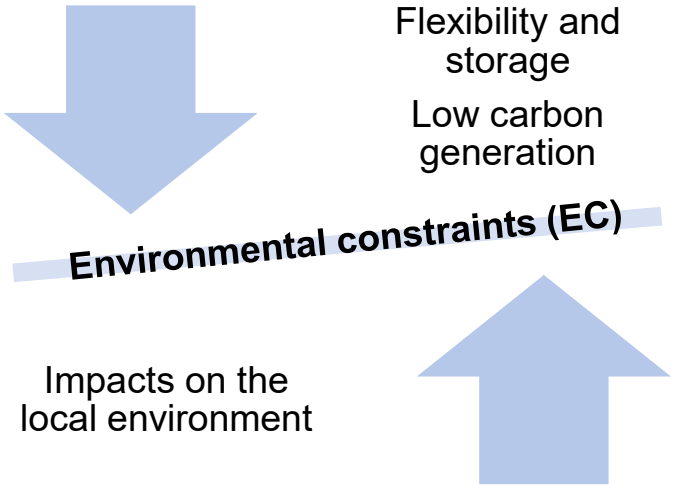
Method

Preliminary results

Conclusion

BACKGROUND

Hydropower lies in the middle of a complex environmental dilemma.



SumEffect project at SINTEF: global **impacts** on the **Nordic** power system by horizon **2030** of a **new set of ECs** applied to Norwegian hydropower

EC: **different impacts** on the power grid balance in the presence of a **high share of variable renewable energy (VRE)**

This study: impacts of **different** hydropower **ECs settings** on the **Nordic** power system in the presence of a **high share of VRE**

METHOD

A scenario fan simulator was used to perform the simulations.

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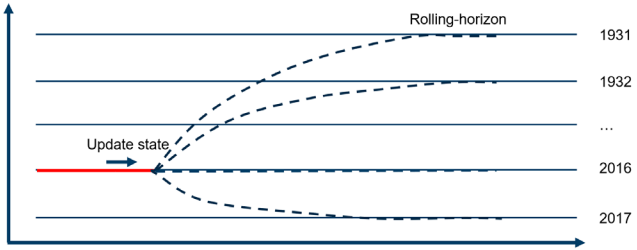


The FanSi model

- Scenario Fan Simulator developed by Sintef
- Simulates observed weather scenarios by solving a sequence of stochastic optimization problems

How the problem was defined

- 35 weather scenarios (load, water inflows, VRE production)
- 3-hour time step resolution, weekly stages
- Zonal model

How it works

- Two-stage stochastic problems solved with Benders decomposition
- Rolling horizon, fixed problem size
- Uncertainties are known in the 1st stage, resolved in the 2nd stage
- First-stage decision is implemented, and state variables are updated

We set the study in a 2050 horizon where a high increase in demand is supplied with VRE.

Assumed changes in the Nordic power system	2030	2050
Onshore wind capacity (GW)	41	65
Offshore wind capacity (GW)	8	65
Solar capacity (GW)	6	85
Annual energy demand (TWh)	459	845

Adjusted transmission

No new transmission between countries

Transmission within a country increased by calibration on

- Number of congested hours
- Price correlation between connected areas within a country

Approximately the same energy balance is maintained over the region (Norway, Sweden, Finland and Denmark).
Based on Statnett base case in its long-term market analysis 2022-2050.

A 2050 base case is compared to a case with revised environmental constraints.

Revised environmental constraints (*SumEffect project*)

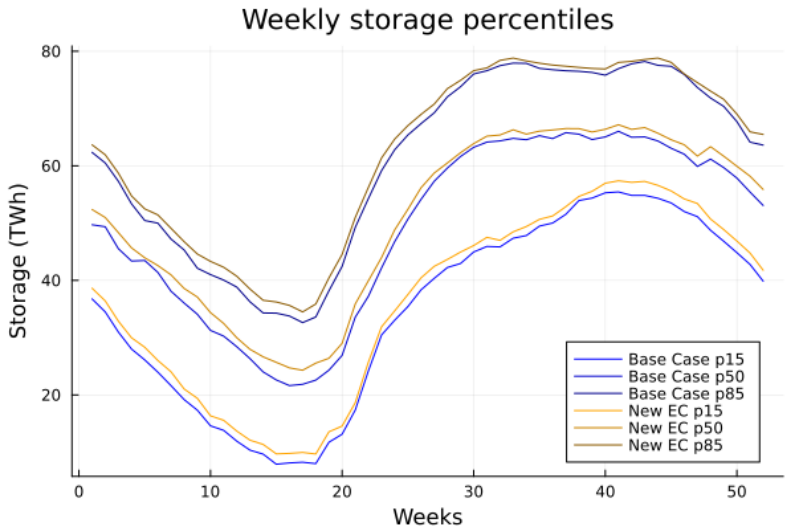
Minimum bypass flow, locally determined based on
- Preservation value of the local environment
- Gradient of the bypass
- Energy equivalent of the reservoir water content
- Natural inflow profile (Q95)

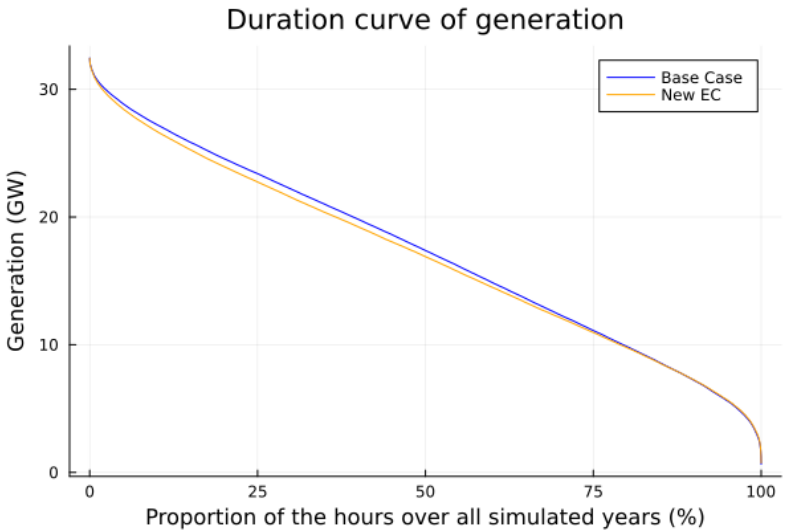
Reservoir filling period constraints

- ~400 impacted power plants (out of ~1700)
- Average increase of ~50% in the minimum flow

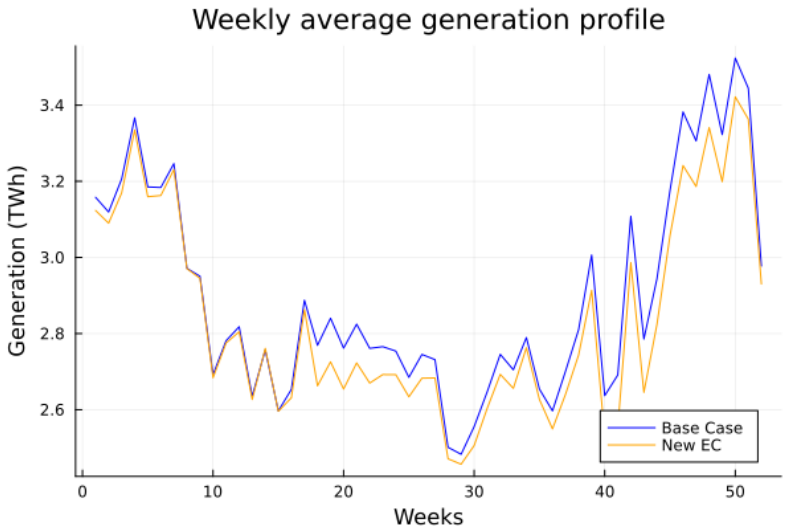
PRELIMINARY RESULTS

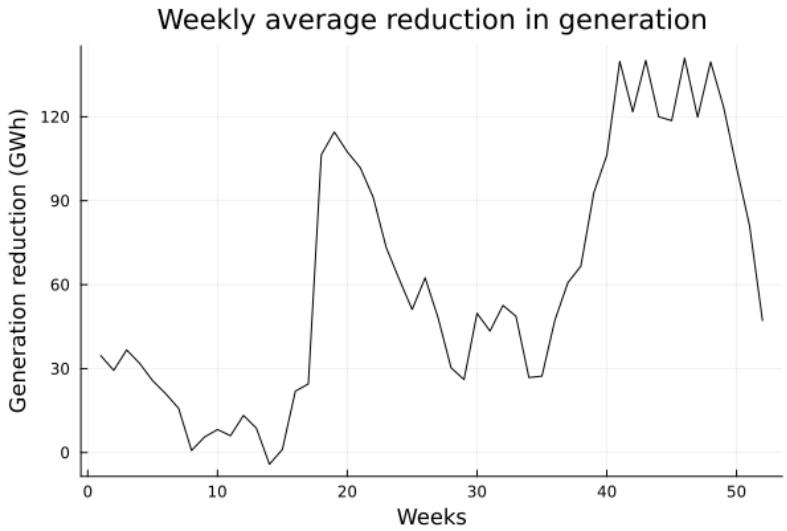
New EC lead to higher reservoirs levels and reduce high generation hours for Norwegian hydropower.



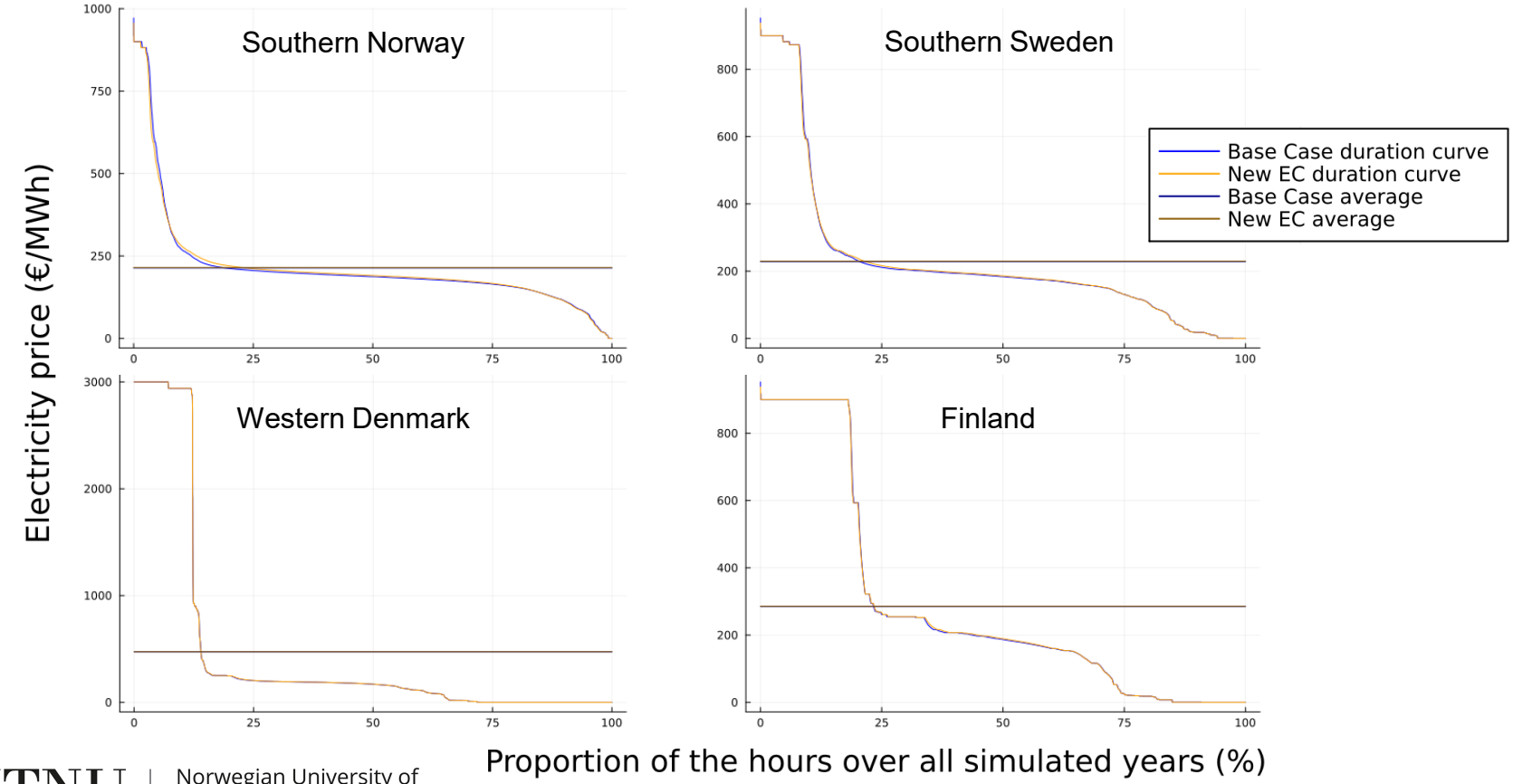


Norwegian hydropower produces less at the spring flood and at the end of autumn.





Prices are barely affected, especially outside Norway



Norwegian hydropower producers incur energy losses, but use flexibility to limit economic losses.

Average annual values	Base case	New set of EC	Difference
Production (TWh)	150,8	147,6	- 3,2 (- 2,1 %)
Revenues (G€)	33,8	33,7	- 0,15 (- 0,5 %)
Captured price (€/MWh)	224,3	228,1	+ 3,8 (+ 1,7 %)
Average price (areas weighted on hydro prod.) (€/MWh)	205,6	207,1	+ 1,5 (+ 0,7 %)
Flexibility factor (captured price/average price)	1,09	1,10	+ 0,01 (+ 0,9 %)

CONCLUSION

Takeaways

The presently considered new ECs lead to energy and revenue losses for hydropower.

Revenue losses remain limited as low-price sales are reduced.

Hydropower flexibility does not seem highly impacted by these ECs.

The high-VRE power system seems to cope with the new modelled ECs applied to hydropower, as the increase in simulated prices is low. This will be investigated further with sensitivity analyses.

→ Could there be room for more stringent ECs on hydropower without disproportionately affecting the power system?

Future work

Adjusting the power systems modeling of the rest of Northern Europe to Horizon 2050

Testing more stringent EC sets

Sensitivity analysis on energy mix (higher shares of VRE, 100% renewable?)

Sensitivity analysis on transmission capacity

Thank you for your attention!

Questions?