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NORWAY AS A BATTERY FOR THE FUTURE EUROPEAN POWER SYSTEM – COMPARISON OF TWO DIFFERENT METHODOLOGICAL APPROACHES

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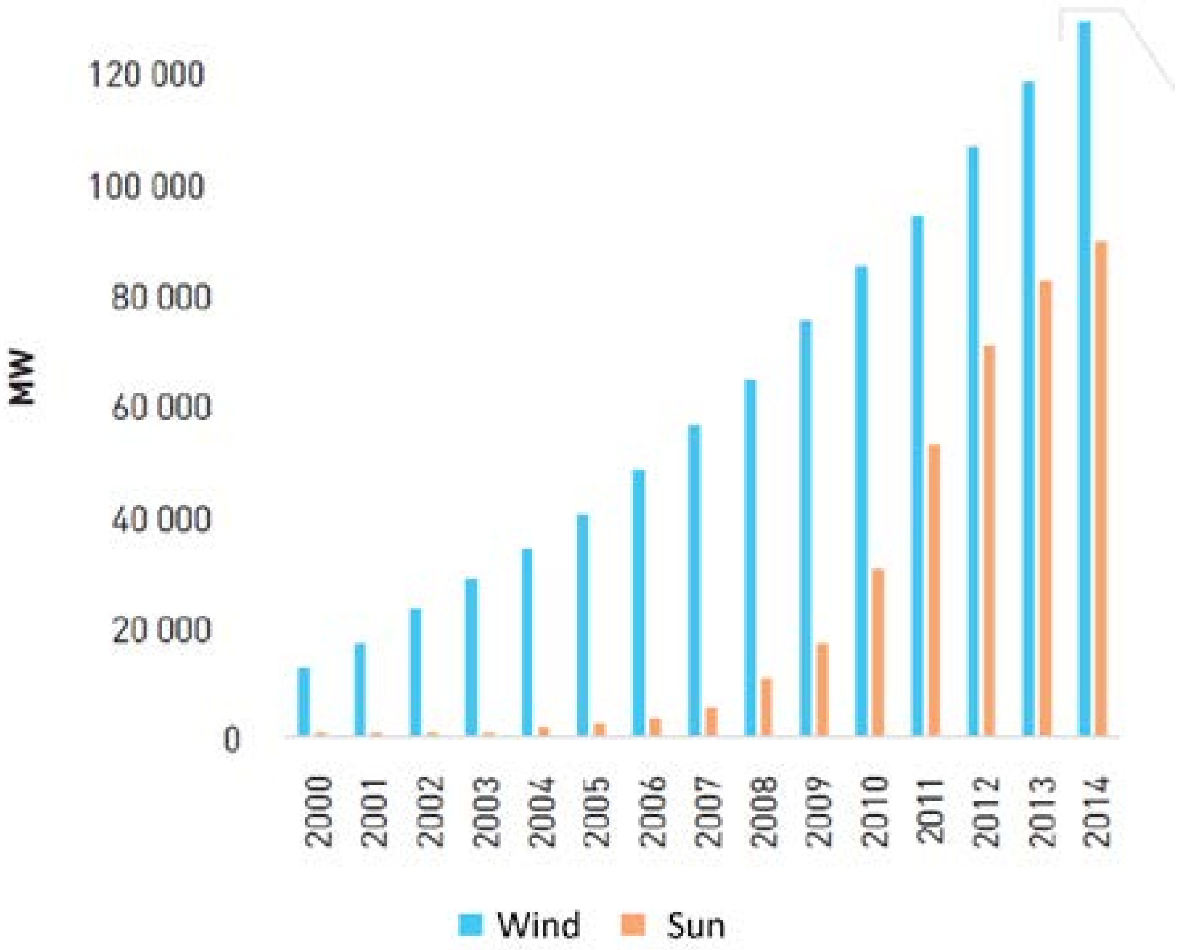
OUTLINE

- Background
- Objective
- The EMPS and the SOVN model
- Main assumptions
- Results
- Conclusions

Background

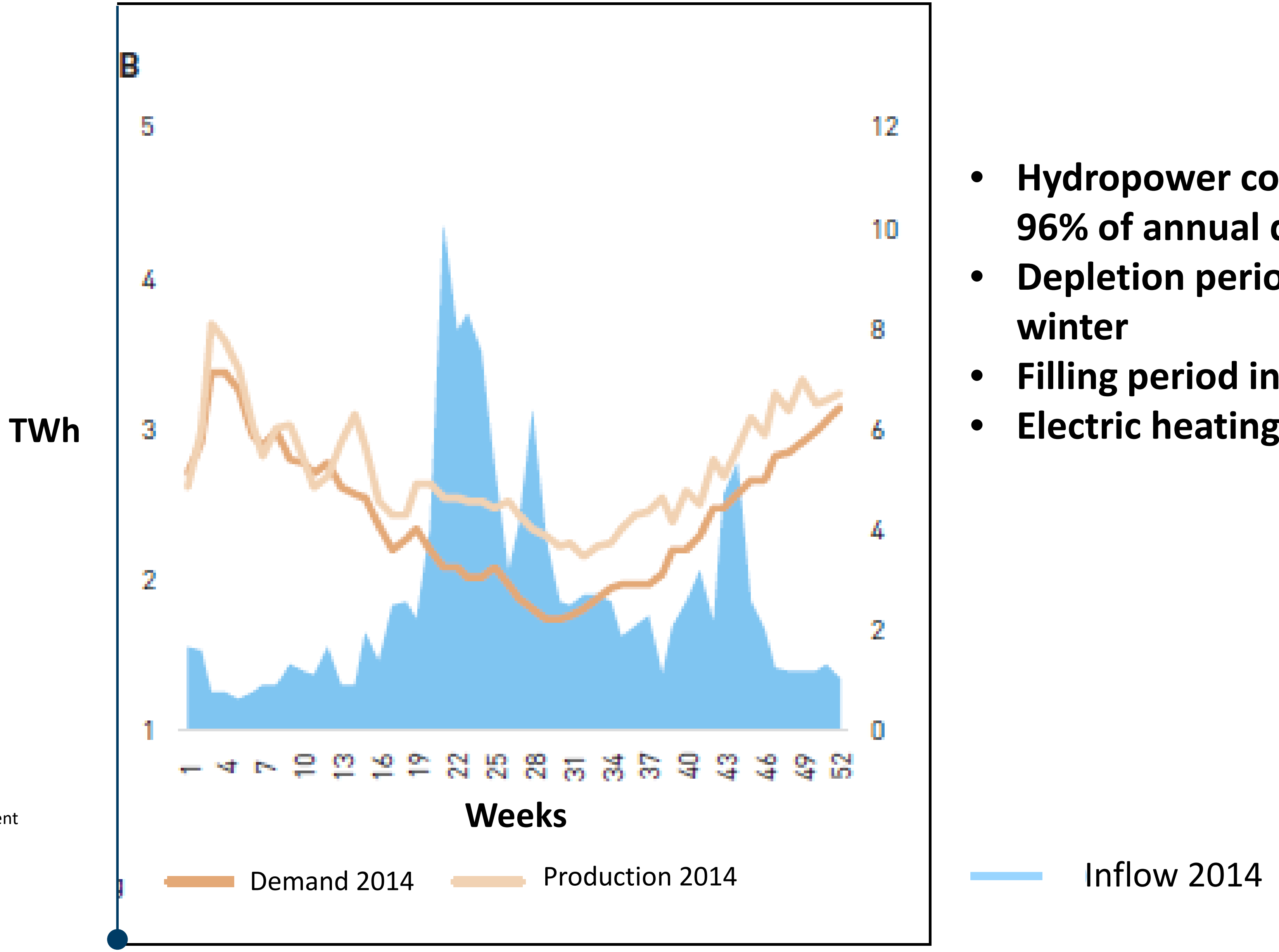
- EU aims to reduce greenhouse-gas emissions by 80-95% by 2050 compared to 1990
- Variable wind and solar power production will probably constitute a large share of the future electricity system
- Norway has nearly half of the hydropower storage capacity in Europe: ca 84 TWh



Development of wind and solar capacity in EU-28.

Source: OED. Meld.St 25. Kraft til endring. 2016

Inflow, demand and power production Norway 2014



- **Hydropower covers about 96% of annual demand**
- **Depletion period in the winter**
- **Filling period in the summer**
- **Electric heating**

Source: Det kongelige olje- og energidepartement
Meld.St.25 (2015-2016) Melding til Stortinget
Kraft til endring

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OBJECTIVE

Compare results from two stochastic optimisation models with different methodological approaches for a future power system in Europe with large shares of variable wind and solar resources

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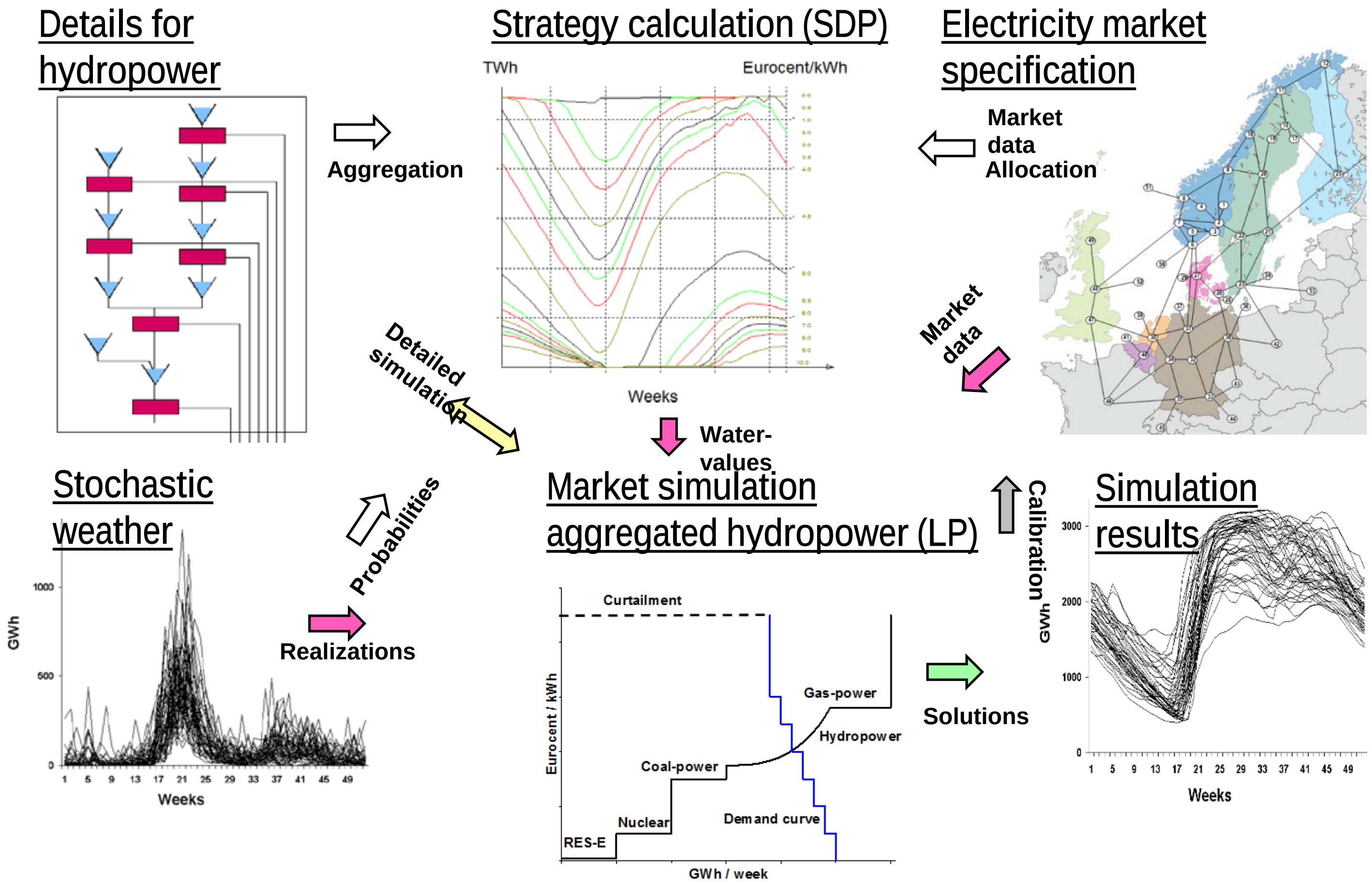
The EMPS model

EFI's Multi-area Power-market Simulator

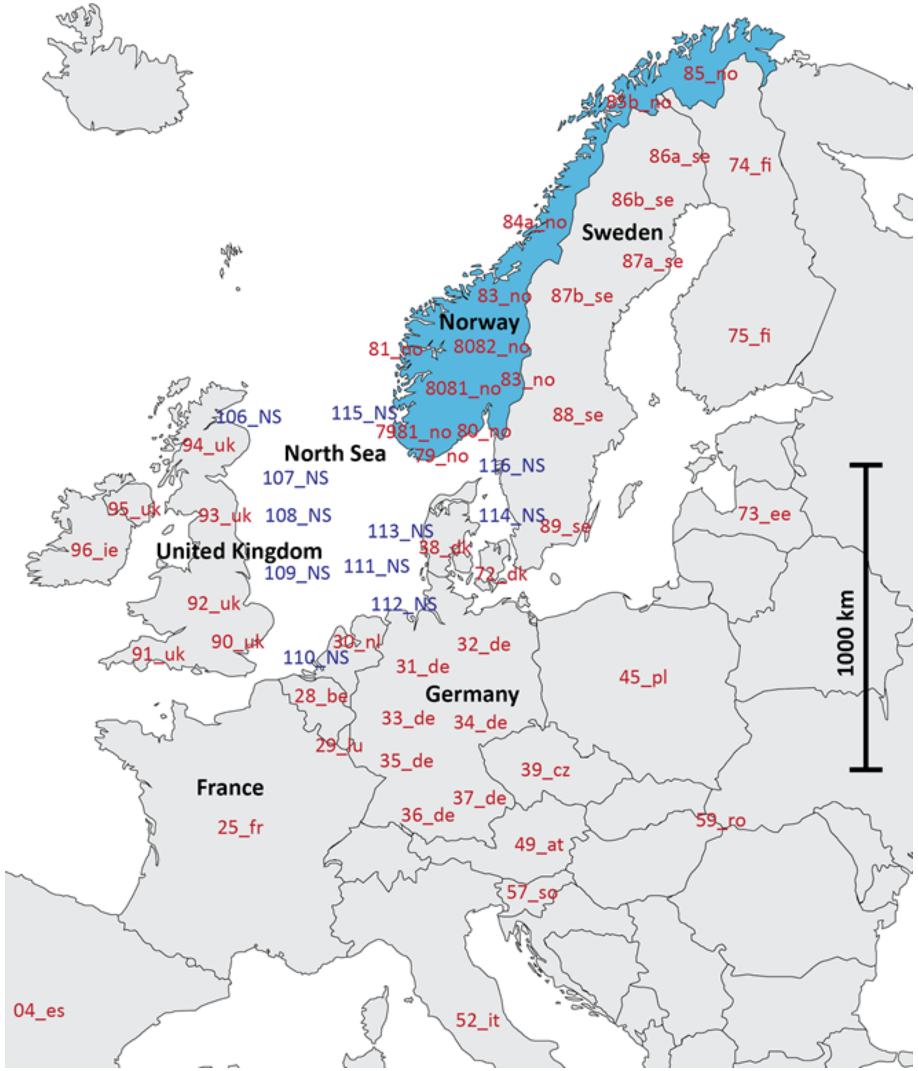


SOVN

Stochastic Optimisation model With individual water values and Net restrictions

- Power market optimisation and simulation model
- Operational decision problem: linear optimization including each plant and each reservoir
- No aggregation of hydropower
- This study uses water values from the EMPS model in both operational decision problems

EMPS and SOVN analyses 2050



59 nodes:
21 nodes in Nordic countries
7 nodes in Germany
6 nodes UK
11 offshore wind nodes in the North Sea

75 years with hourly historical wind, solar and inflow data

72 time periods per week (2 hours per weekdays 4 hours per weekends), serial simulations

Main assumptions

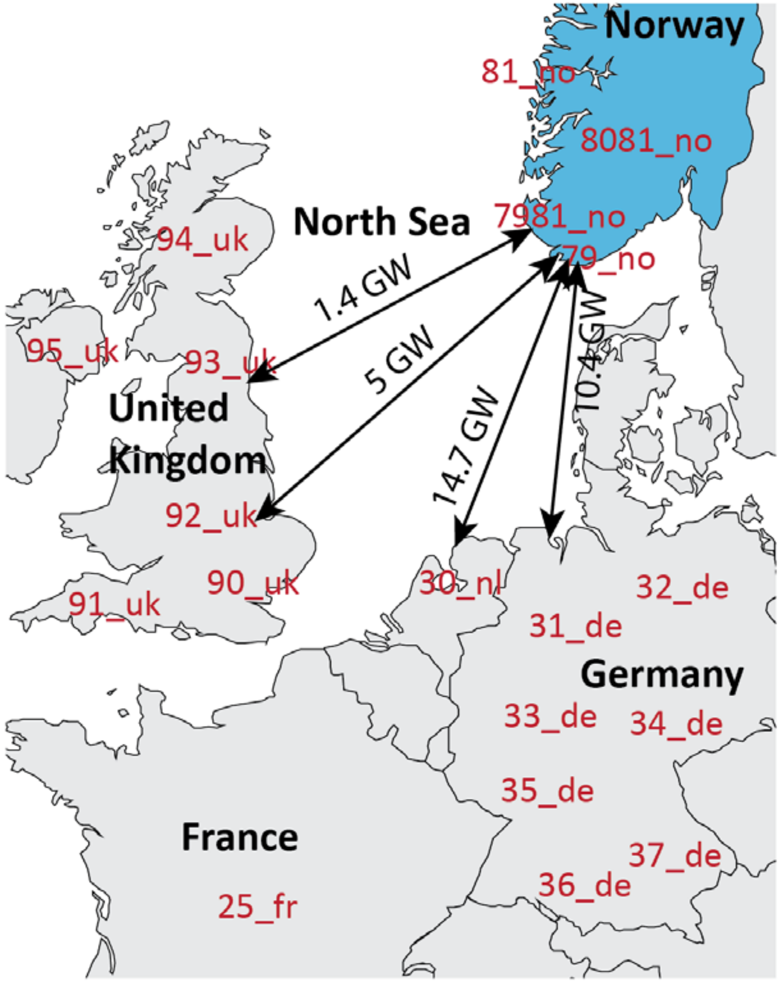
- From EU 7th Framework project eHighway2050: production and transmission capacities, annual demand, fuel prices,
- In addition: detailed modelling of every plant and every reservoir in the Norwegian hydropower system

- Inflow hydropower system: SINTEF Energy research data
- Historical hourly wind and solar series: Reanalysis data

- Wind and solar power production cover 61% of annual demand

Main assumptions increases Norwegian hydropower production

Name of EMPS region	Present capacity [GW]	New capacity [GW]	11 GW Increase [GW]	Pump capacity [GW]	New capacity [GW]	19 GW Increase [GW]	Pump capacity [GW]
SORLAND 79_no	4.1	7.6	**3.5**	**1.4**	8.3	**4.2**	**1.4**
VESTSYD 7981_no	3.6	7.8	4.2	2.1	10.1	6.5	3.4
VESTMIDT 81_no	5	7.9	**2.9**	**0**	**8.5**	**3.5**	**0**
TELEMARK 8081_no	2.1	3.1	1	1	6.3	4.3	4.4
TOTAL	14.8	26.4	11.6	4.5	33.2	18.5	9.2



Source: Solvang E, Harby A, Killingtveit Å, Increased balancing power capacity in Norwegian hydroelectric power stations. SINTEF Energi TR A7195 2012

Present capacity Norwegian hydropower about 30 GW

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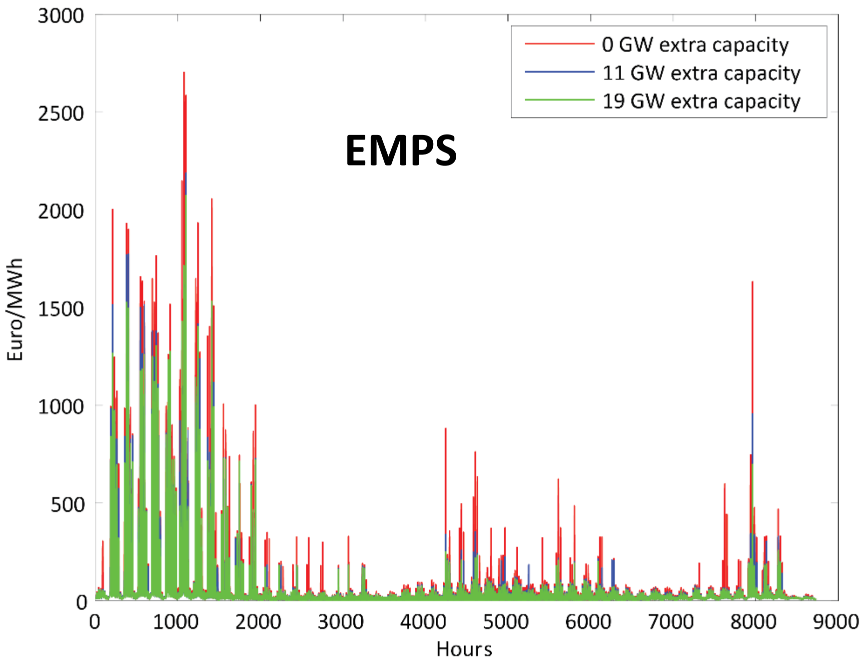
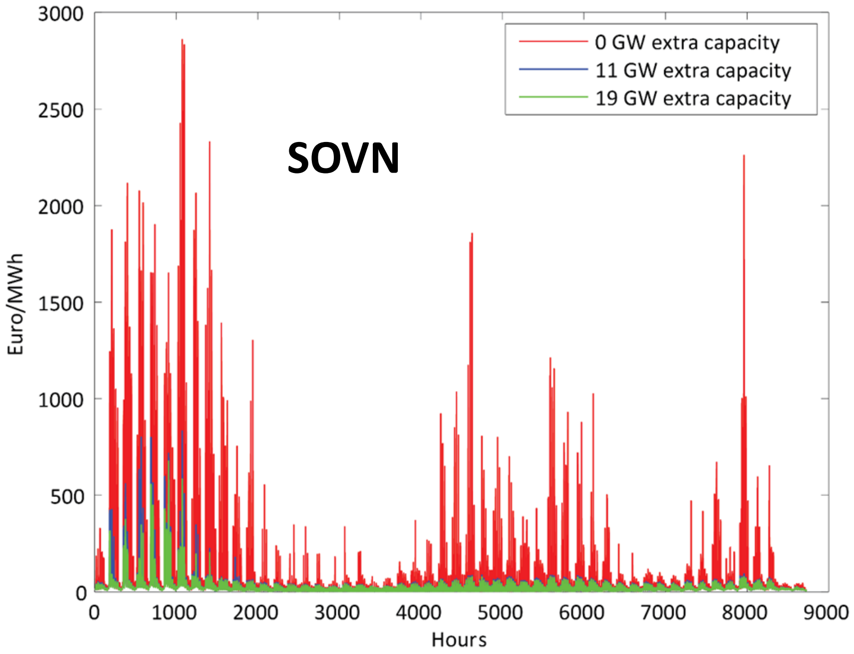
Impacts on the power prices in the Netherlands
"100% RES" scenario with extra nuclear





Prices hour-by-hour averaged for 75 years with stochastic weather data
Rationing prices of 10000 Euro/MWh sets the price in periods

Paper 6: I Graabak, M Korpås, S Jaehnert, M Belsnes. "**Balancing future variable wind and solar power production in Northern Europe with Norwegian hydropower**". Submitted to Elsevier Energy. 1st round of comments received.

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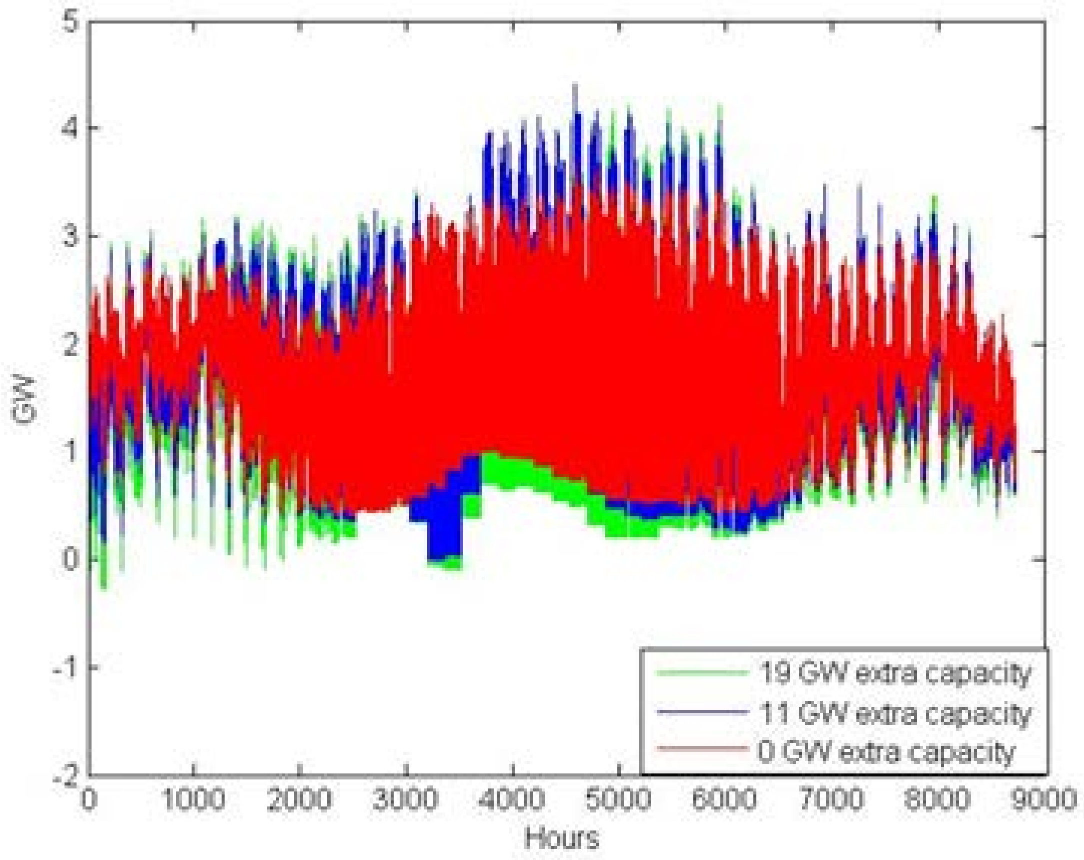
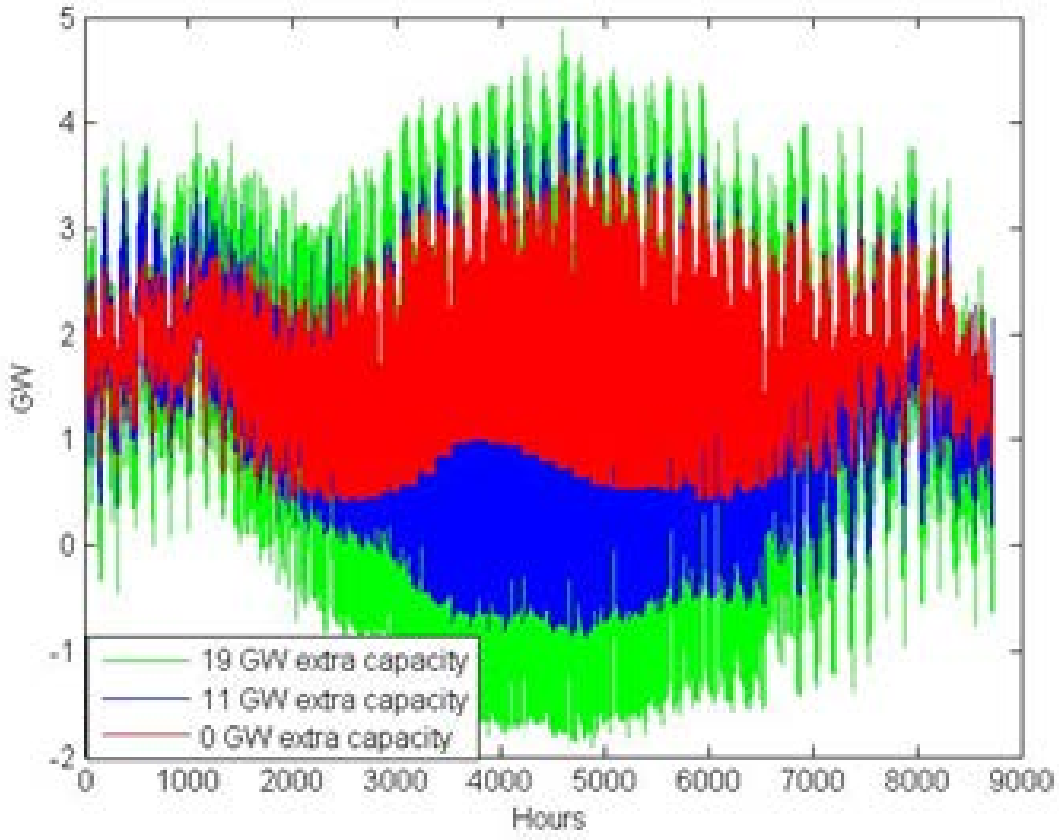
Production SORLANDET

hour-by-hour averaged for 75 years

EMPS

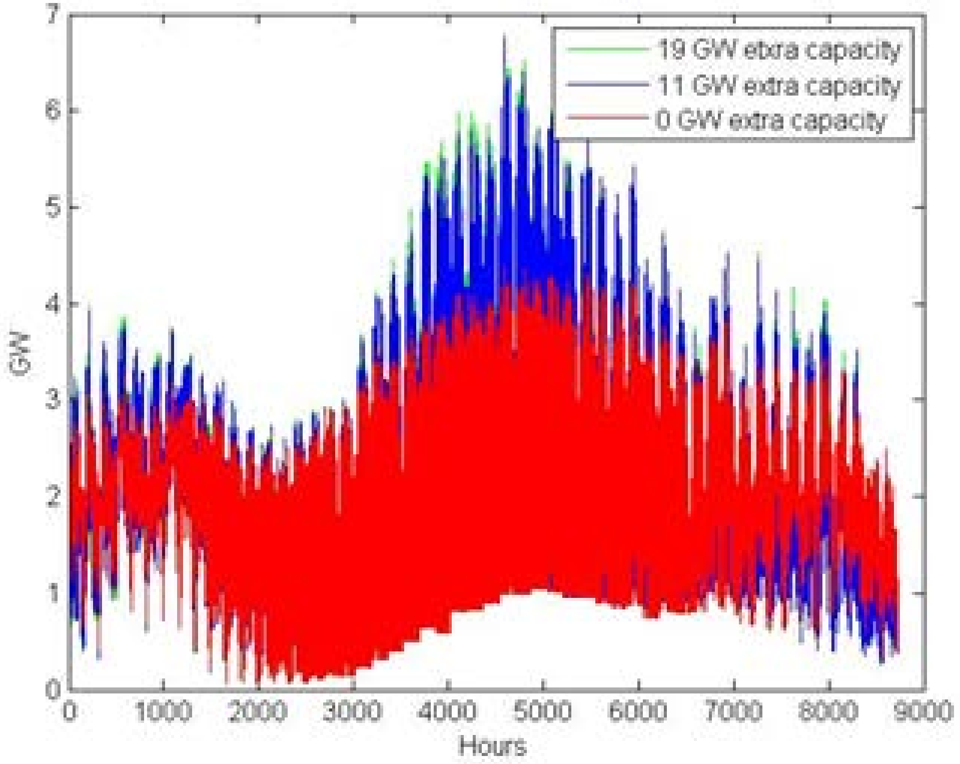


SOVN

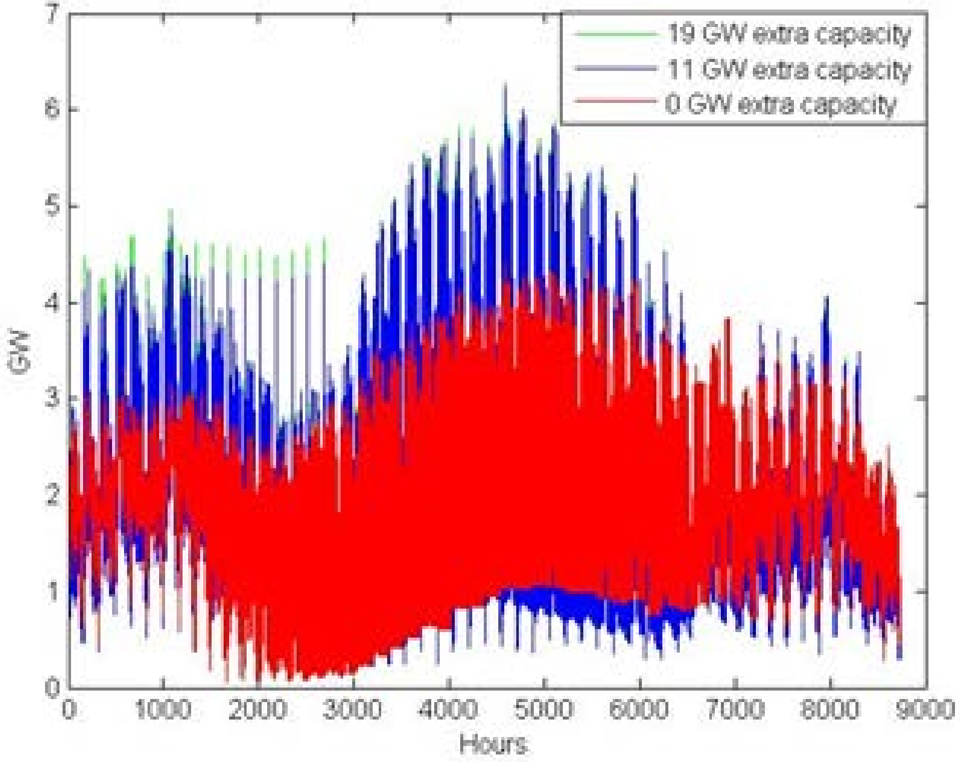


Production VESTMIDT hour-by-hour averaged for 75 years

EMPS



SOVN



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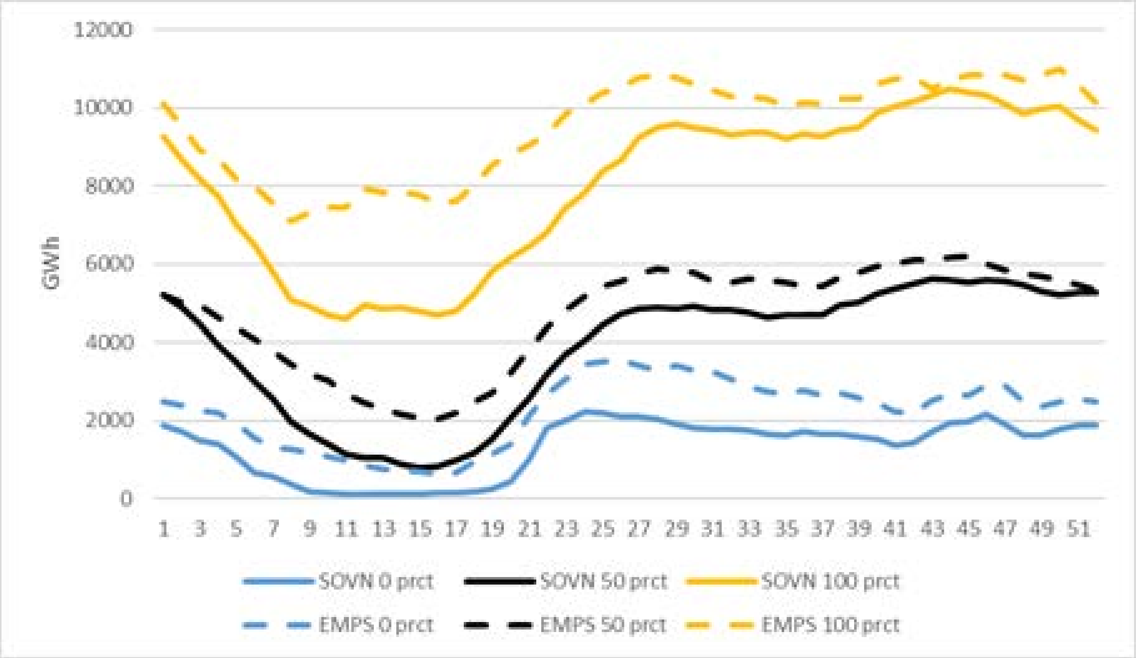
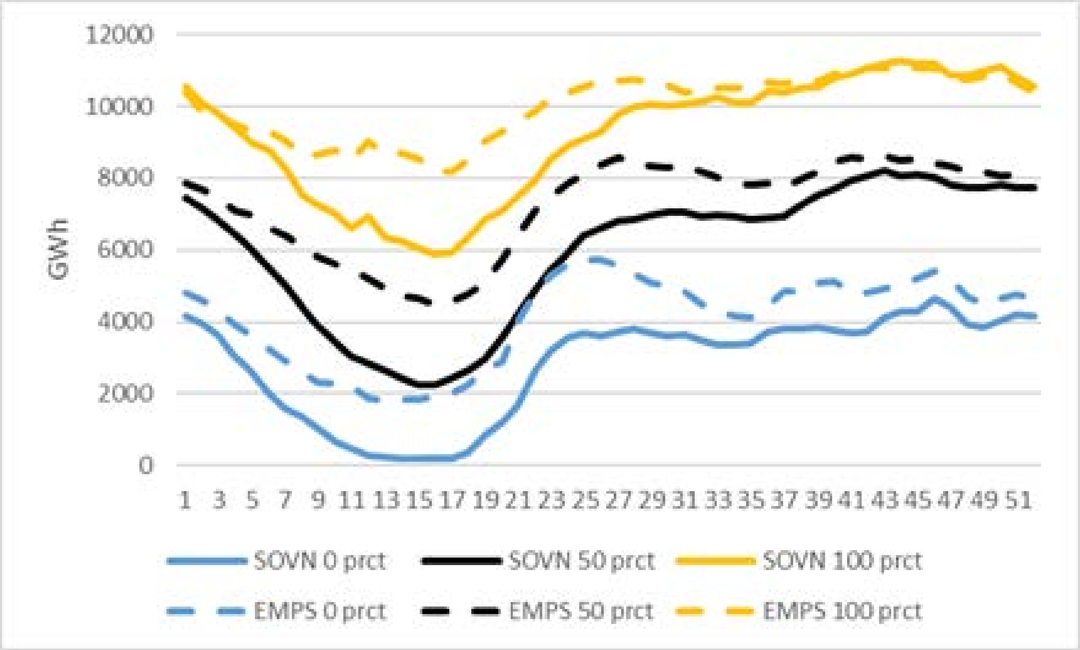
Average reservoir development SORLANDET

week-by-week for 75 simulations years

0 GW extra capacity



19 GW extra capacity in Norway, 4.2GW extra in SORLANDET, 1.4 GW pump capacity



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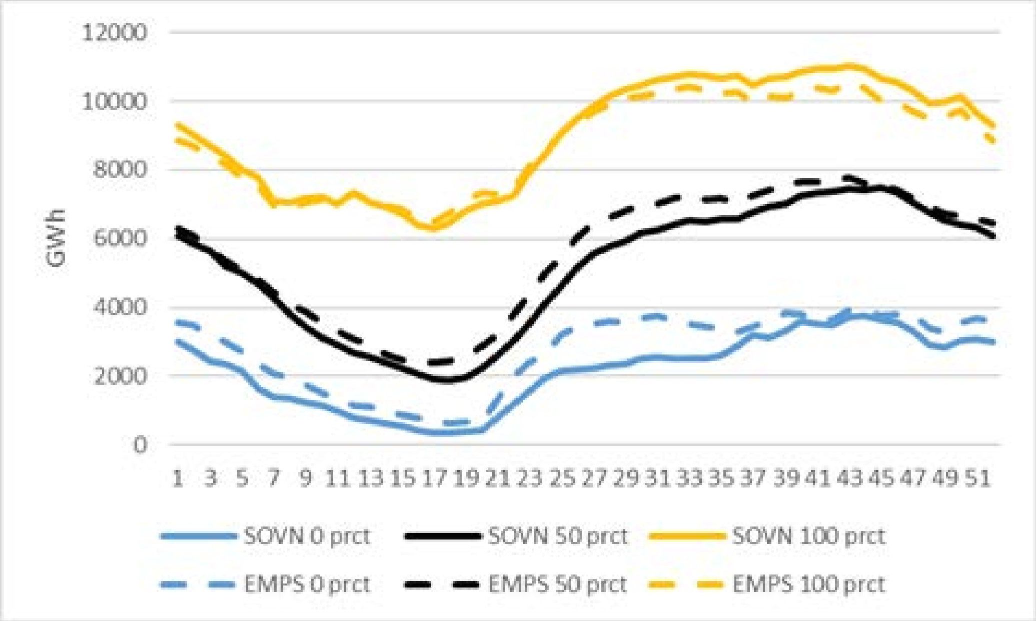
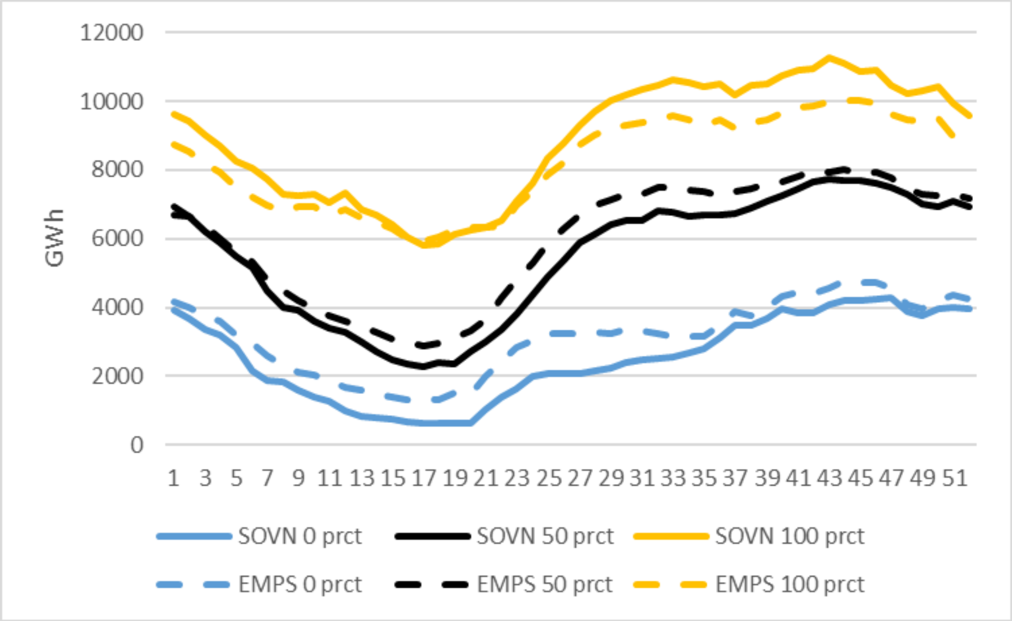
Average reservoir development VESTMIDT

week-by-week for 75 simulations years

0 GW extra capacity



19 GW extra capacity in Norway, 3,5 GW extra in VESTMIDT, no pumping



Conclusions

- SOVN to a larger degree than EMPS increase production in high price periods and pumping in low price periods
- Formal optimization (SOVN) /advanced heuristics (EMPS)
- None of the models manage to fully utilise the high price periods in the winter
- Pumping important for utilisation of increased capacity

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Teknologi for et bedre samfunn