Integrated modelling of the future energy system – results and challenges

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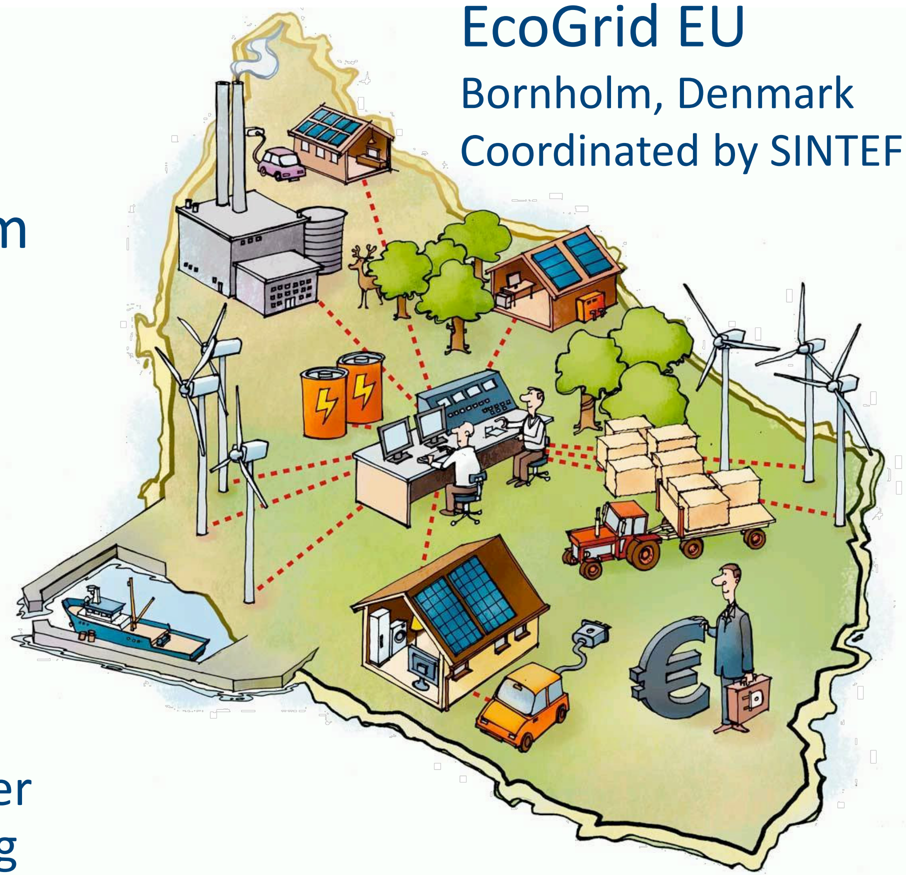
Contents

- The need for balancing wind power variations
- European power market model
- Benefits of integrated balancing markets
- Integrating different environmental requirements in hydro production planning

Challenges of wind power on the power system

- Wind power brings more variability and uncertainty
- Can impact reliability and efficiency of the power system
- Power system operation with wind power requirements:
  - Knowledge of wind power variability and predictability
  - Knowledge of wind turbine capabilities
  - Knowledge of future wind power installations for system planning



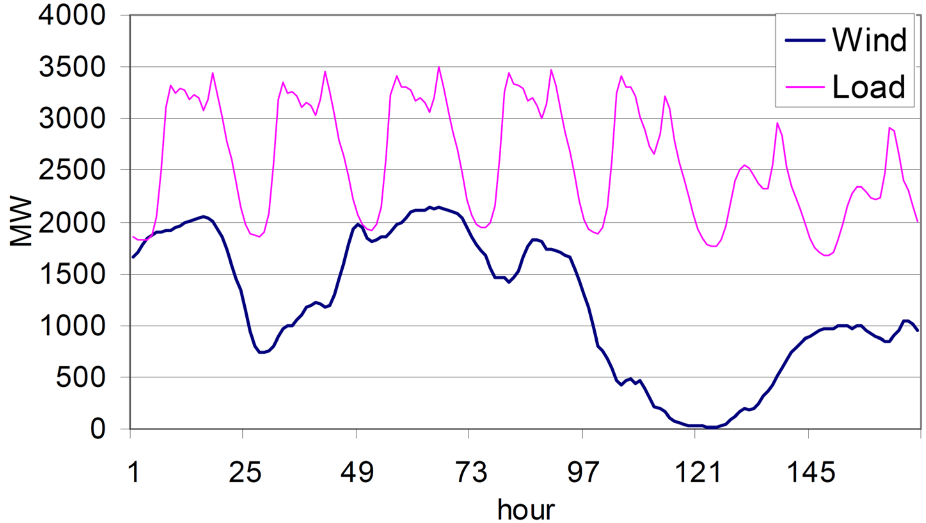
EcoGrid EU

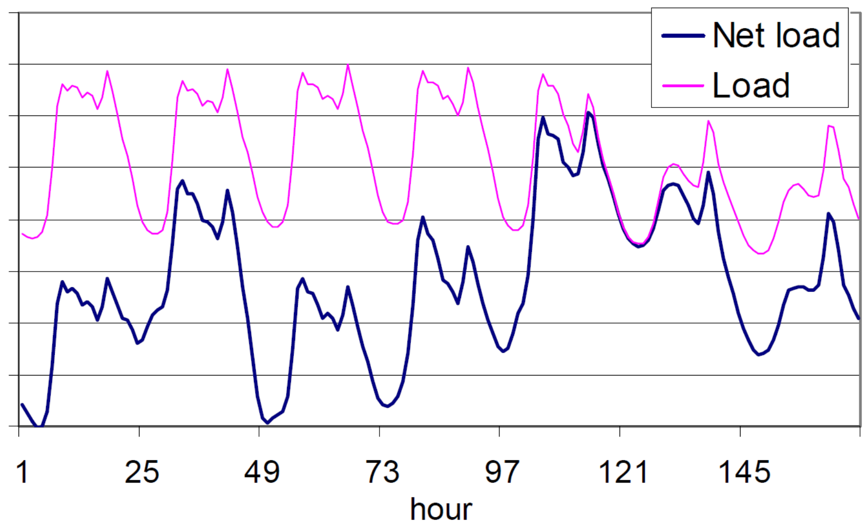
Bornholm, Denmark

Coordinated by SINTEF

Reserve requirements for wind power

- The system will see the aggregate net imbalance
  - Unforeseen variations in load and wind
  - Net load = Load – Wind - Solar





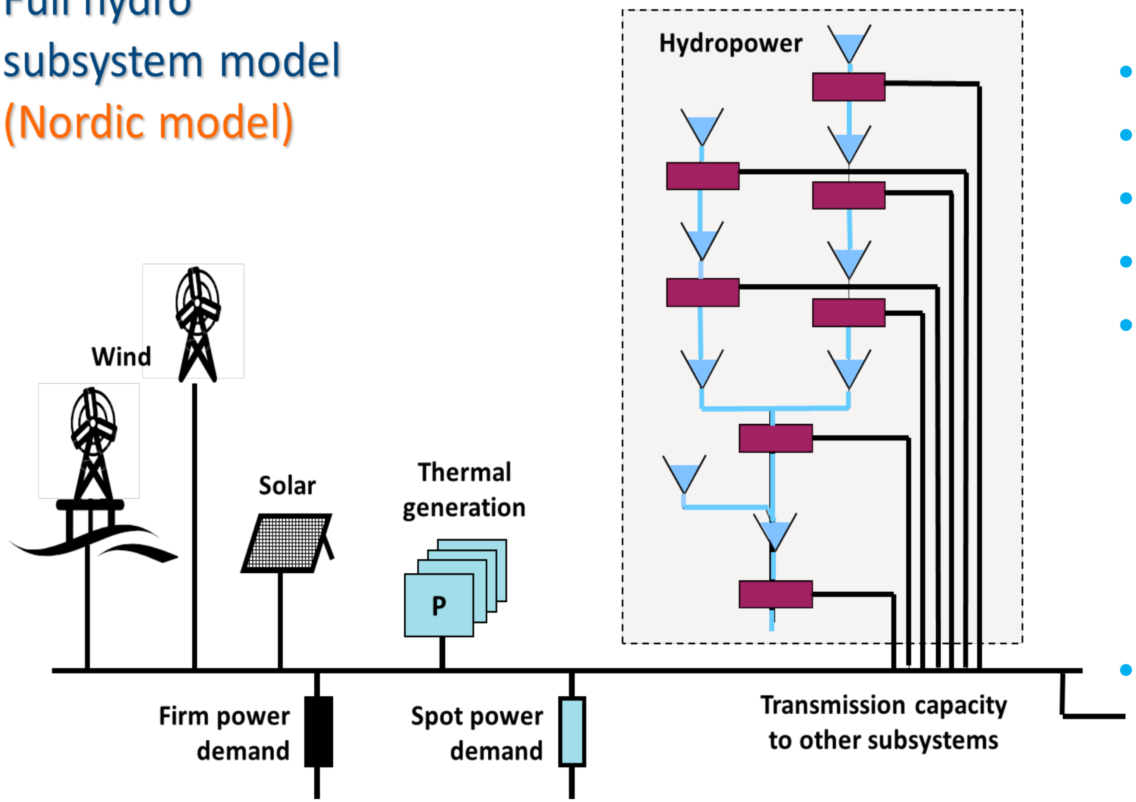
Challenges:

- Flexibility of thermal power plants (ramp rates, start/ stop operation)
- Wind can push thermal plants out of the market – security of supply has to be fulfilled

EMPS/Samkjøringsmodellen : A stochastic fundamental market model with hydro optimization

- Strategy for aggregate hydro models – Simulates detailed hydro

Full hydro subsystem model (Nordic model)

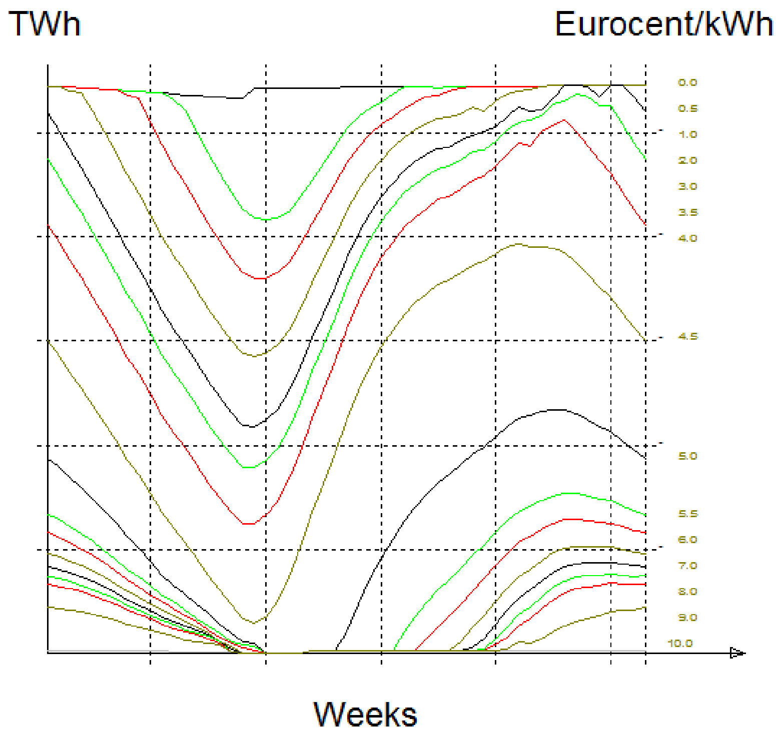


Features:

- Flexible demand modelling
  - Gradual adaptation to price
  - Optimizing adaptation
- Thermal unit start-up costs
- Reserves
- Wind power
- Parallel processing
- Advances in time resolution
  - Sequential blocks of hours per day
  - Daily inflow
  - Hourly wind power data
  - Daily pumped storage
  - Automatic calibration
- Detailed grid with load flow model
  - EPF/Samlast

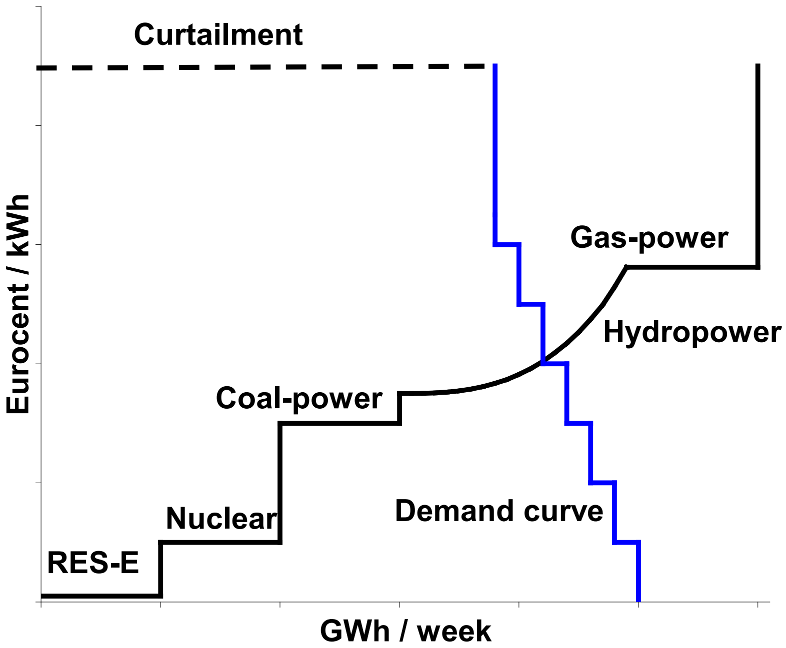
EMPS model: Optimization and simulation

Strategy hydro reservior calculation (SDP)



Water value tables

System/market simulation (LP)



The European Multi-area Power Market Simulator EMPS

Current EU model has 55 nodes/96 connections for 37 countries plus offshore nodes

Production units

- 10 thermal power plant types: Nuclear, oil, coal, gas etc
- CCS implemented in coal, gas and biomass
- RES plants deterministic: Biomass, geothermal
- RES plants stochastic: Hydro, wind, solar, wave
- 75 years of wind, solar and hydro resources simulated

Consumption

- Price dependent consumption per year from statistics, projected to a future year (2020-2050)
- 5-8 demand levels per week

Hydro power

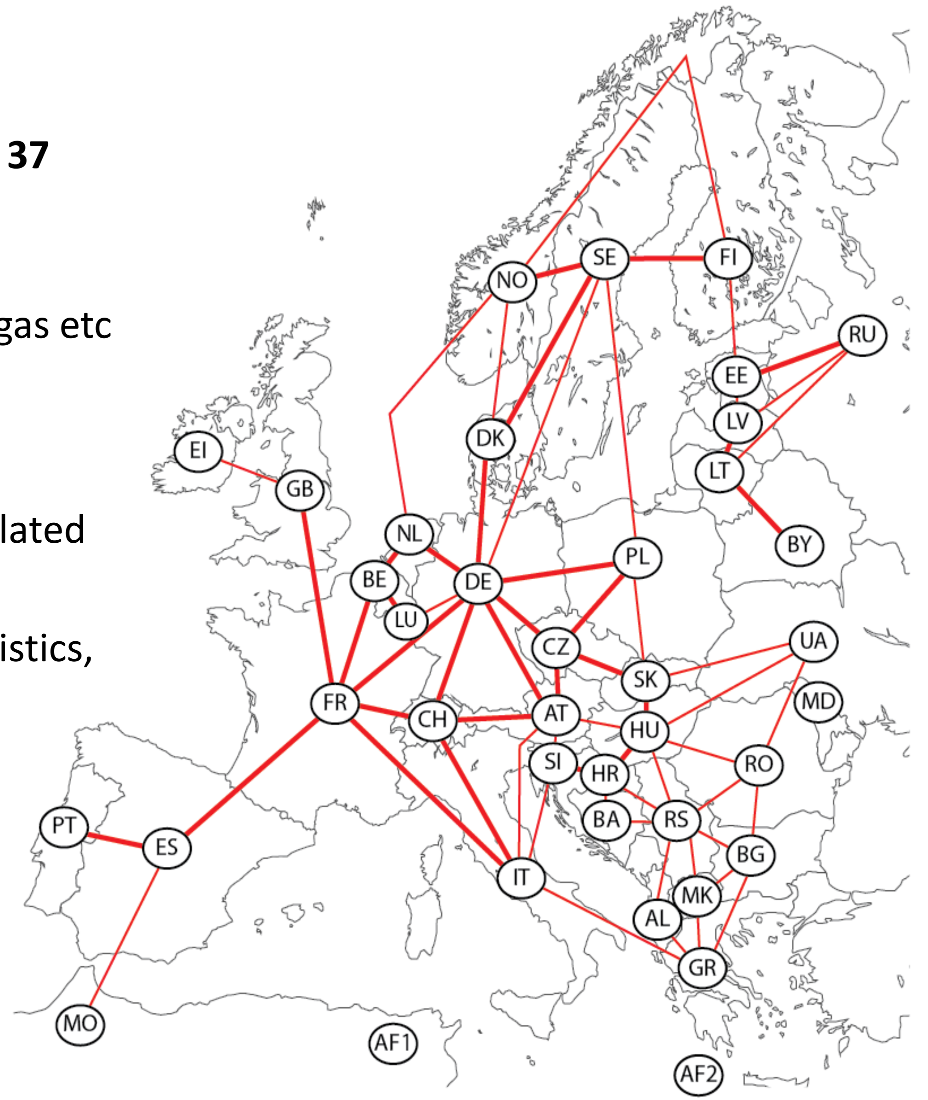
- Reservoir, Run-of-river, Pumped storage

Wind power

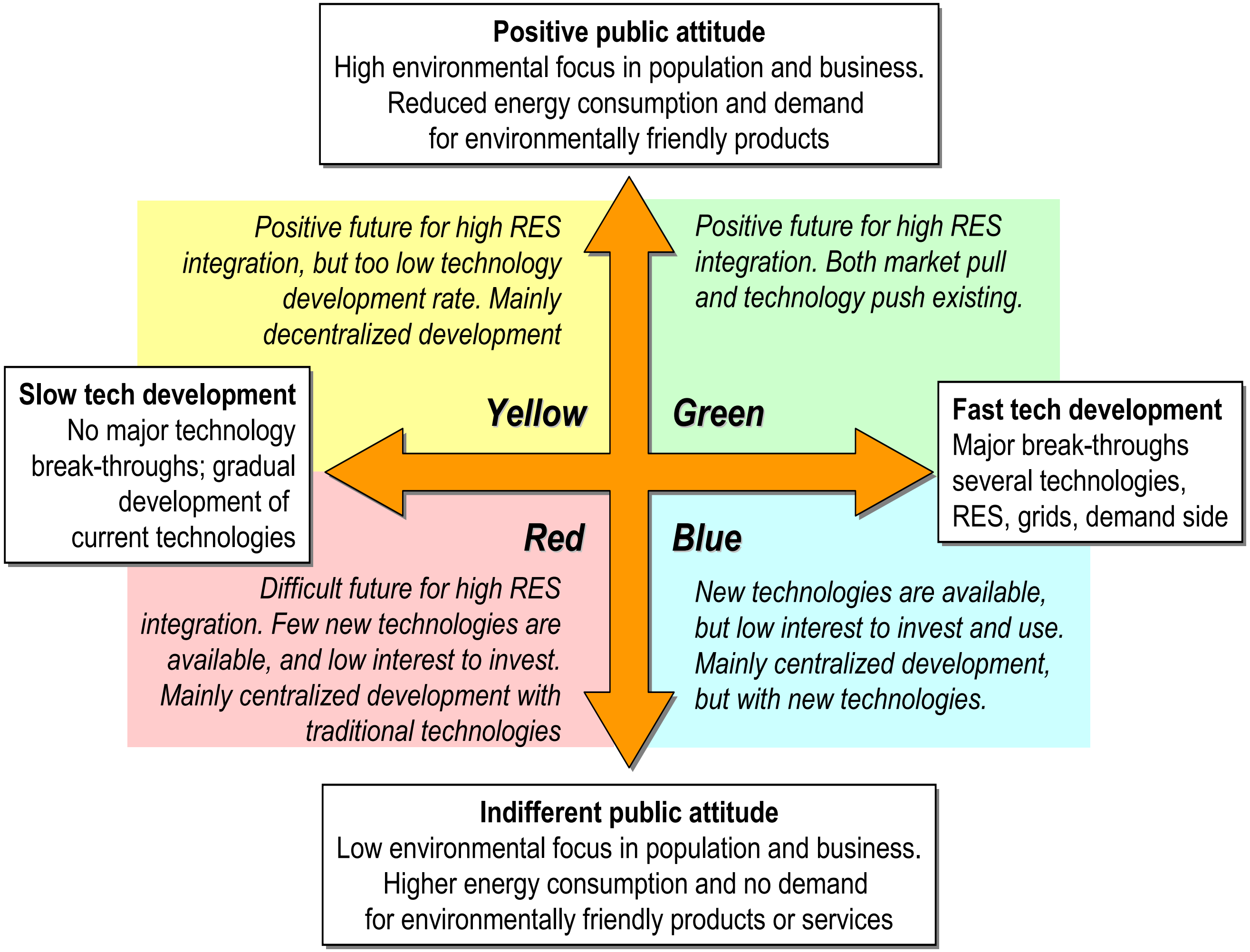
- Divided into onshore and offshore wind farms

Solar power

- Aggregated capacity of PV and CSP



Scenarios defined within the EU-SUSPLAN project

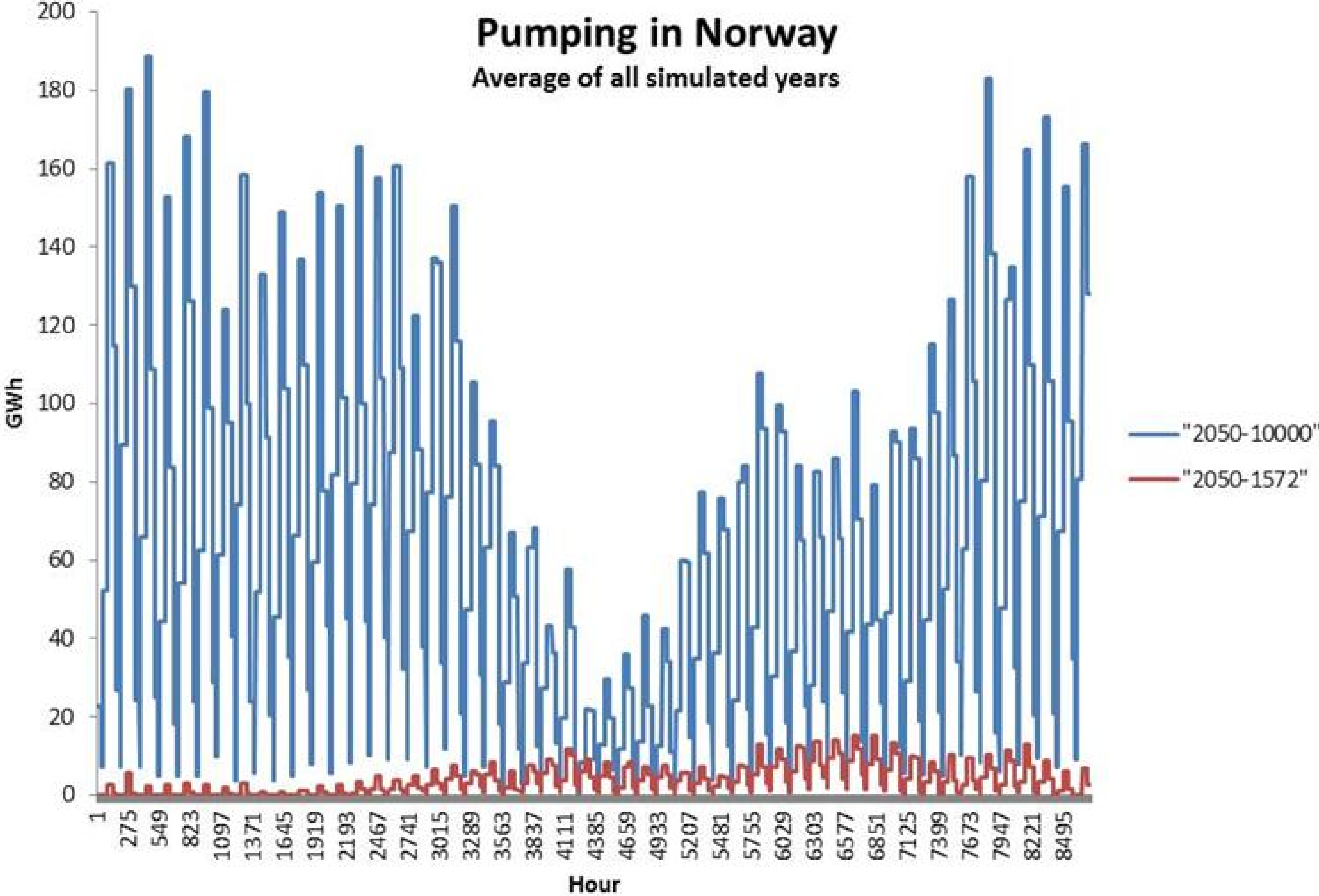


Large scale exchange of balancing power between Norway and Europe – case study

- 4 cases for Norway based on the "Blue" SUSPLAN scenario (70% renewable share in 2050).

  1. "2030-1572": Year 2030. Pump capacity of 1572 MW.
  2. "2030-10000": Year 2030. Production capacity of 40 GW + pump capacity of 11.5 GW. North Sea grid capacity of 20 GW.
  3. "2050-1572": Year 2050 . Pump capacity of 1572 MW.
  4. "2050-10000":Year 2030. Production capacity of 40 GW + pump capacity of 11.5 GW. North Sea grid capacity of 20 GW.

Results for CEDREN, 2012 (Graabak, Skjelbreid)



Results for CEDREN, 2012 (Graabak, Skjelbreid)

Case study results

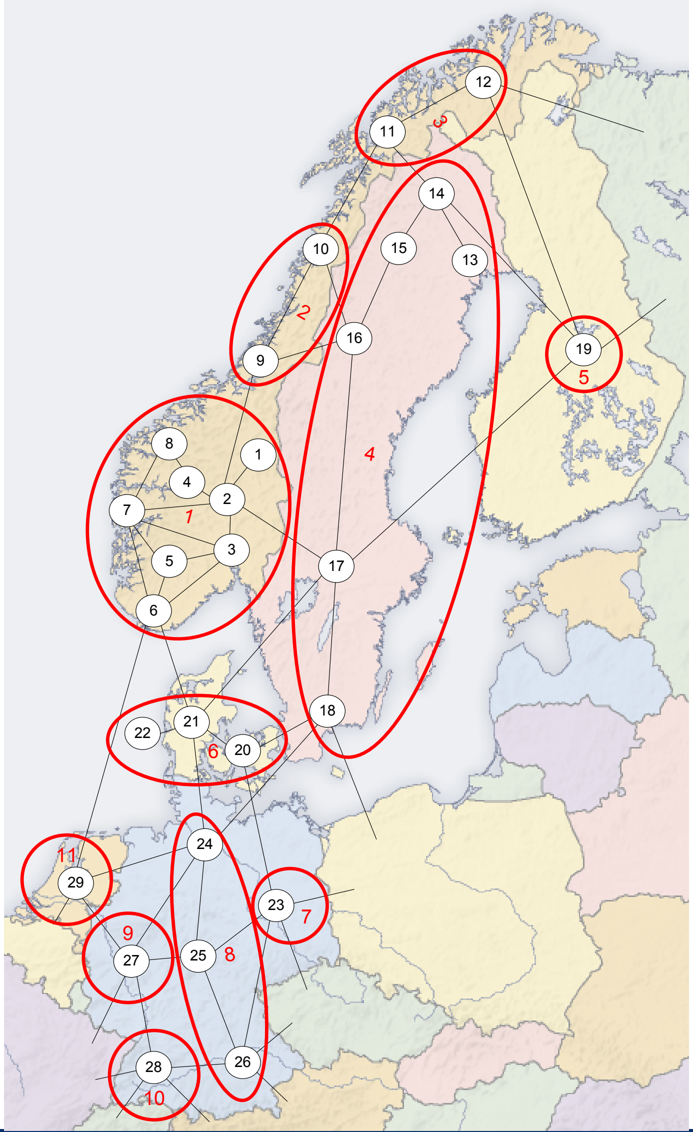
- All expected impacts on the European power system was observed:
  - Norwegian hydro power was used as pumped storage
  - CO_2-emissions in Europe were reduced
  - Higher prices in Norway – lower prices in Germany
  - Better utilization of wind- and solar power at the continent
  - Lower amount of energy not supplied at the continent

- NOTICE: More detailed analyses is required for better quantification of impacts
  - Grid- and hydro characteristics for Norway
  - Grid-, thermal- and wind characterisitcs for other countries

Results for CEDREN, 2012 (Graabak, Skjelbreid)

Model of an integrated regulating power marked

- Integrated regulating power market based on a common day-ahead market
- Detailed system description of nordic + Germany and Netherlands
- Purpose: Estimation of socio-economic benefit of integrating multinational regulating power markets



Results from PhD work by Stefan Janerth
Supervisor: Gerard Doorman, NTNU

Reserve and imbalance results

	No integration	Full integration	5% reservation	10% reservation
Reserve procurement costs	167 M€	44 M€	40 M€	36 M€
Balance settlement costs	119 M€	62 M€	54 M€	48 M€

- Large benefit of integration
- Decreased balancing costs due to interconnection capacity reservation

Results from PhD work by Stefan Janerth
Supervisor: Gerard Doorman, NTNU

Day-ahead results

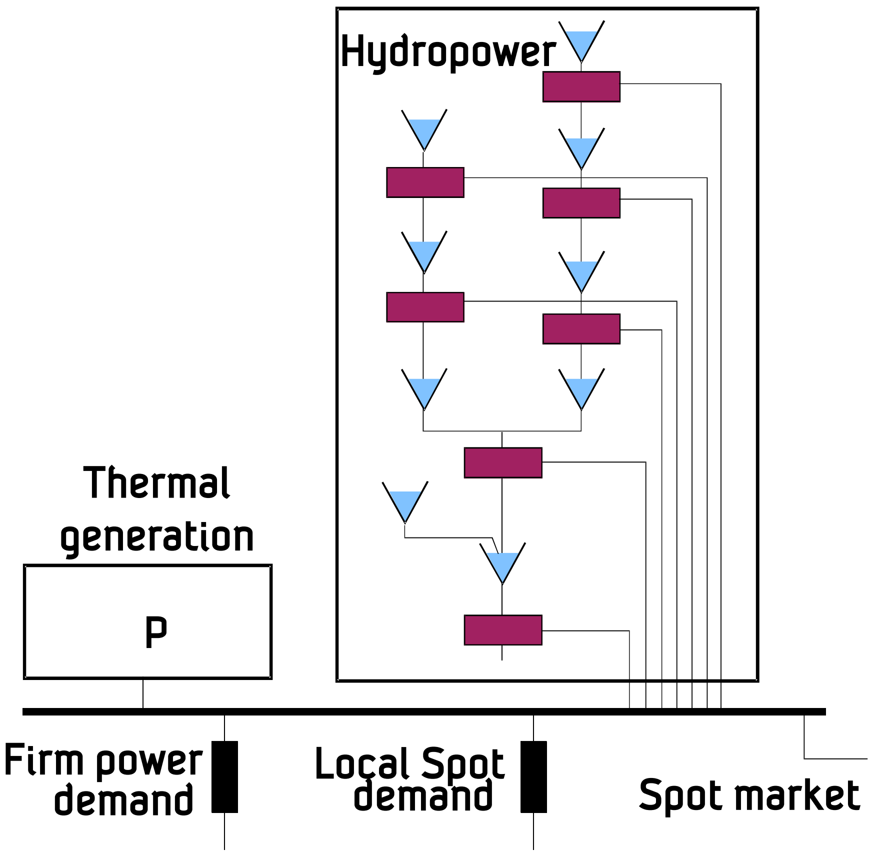
	Full integration	5% reservation	10% reservation
Gross exchange	17.42 TWh	16.85 TWh	16.26 TWh
Socio-economic outcome	-	-79.46 M€	-260.25 M€

- Simultaneous clearing of day-ahead and reserve procurement
- Perfect markets, no strategic bidding

Results from PhD work by Stefan Janerth
Supervisor: Gerard Doorman, NTNU

ProdRisk: Local Long and Medium Term Planning

- Exogenous stochastic market prices, endogenous market and combinations

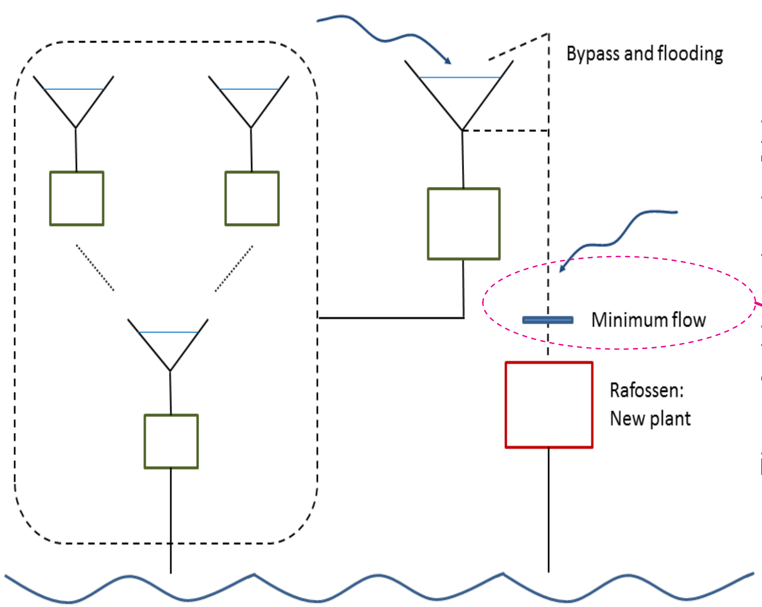


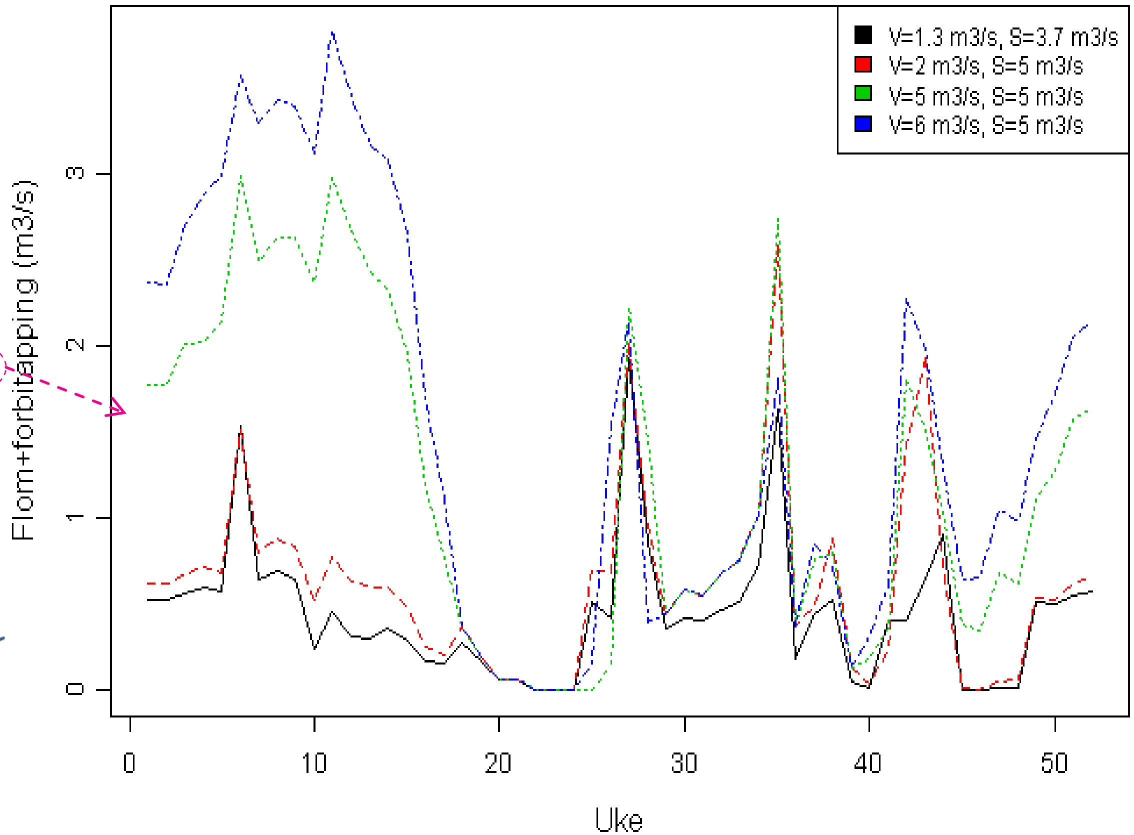
ProdRisk

Stochastic optimal scheduling

- SDDP solution algorithm – Optimization of detailed hydro system
- Supplement to EOPS/Vansimtap
- May include utility functions, futures trading
- Ideal for scheduling generation, maintenance
- Provides endpoint water values for short term scheduling
- Time consuming – Parallel processing used
- Flexible time resloution
- Flexible use of penalties
- Investment analysis

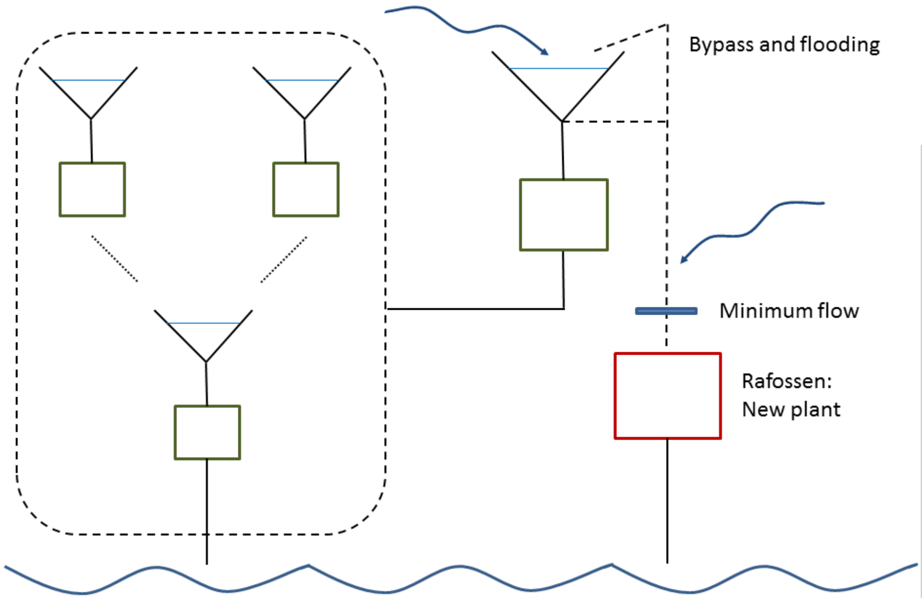
Estimating costs of environmental restrictions using ProdRisk

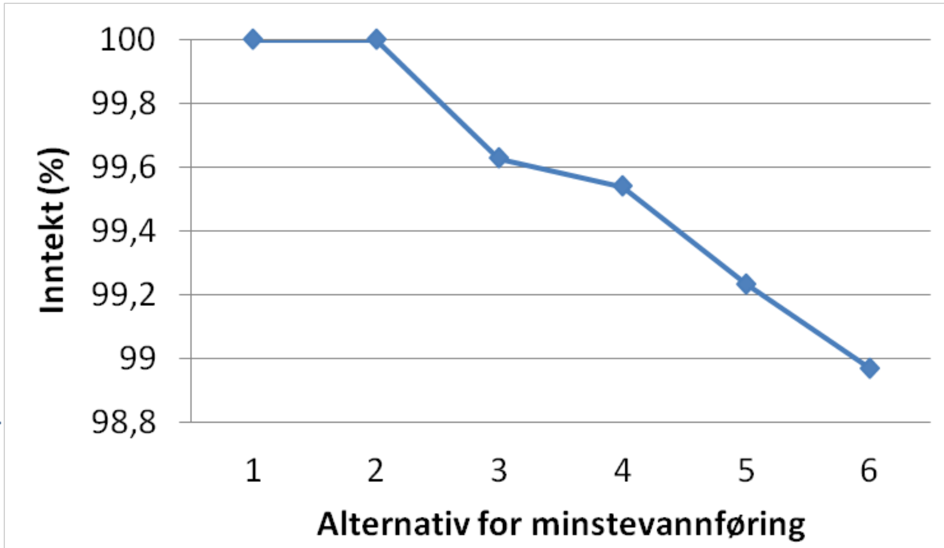




Project for Sira-Kvina 2012 (Follestad, Fjeldstad)

Estimating costs of environmental restrictions using ProdRisk





Summer (m3/s)	**1,3**	**2**	**5**	**6**	**7,5**	**9**
Winter (m3/s)	**3,7**	**5**	**5**	**5**	**7,5**	**7,5**

Project for Sira-Kvina 2012 (Follestad, Fjeldstad)

Summary

- The need for balancing wind power variations
  - Net load = Load – Wind – Solar
- European power market model
  - Large potential benefits of building interconnectors
- Integrated balancing markets
  - Large potential benefits of full cross-border integration
- Integrating different environmental requirements in hydro production planning
  - Simulating the effect on hydro production revenue using ProdRisk