Balancing New Renewables in Europe - Norwegian Contributions and Research Challenges

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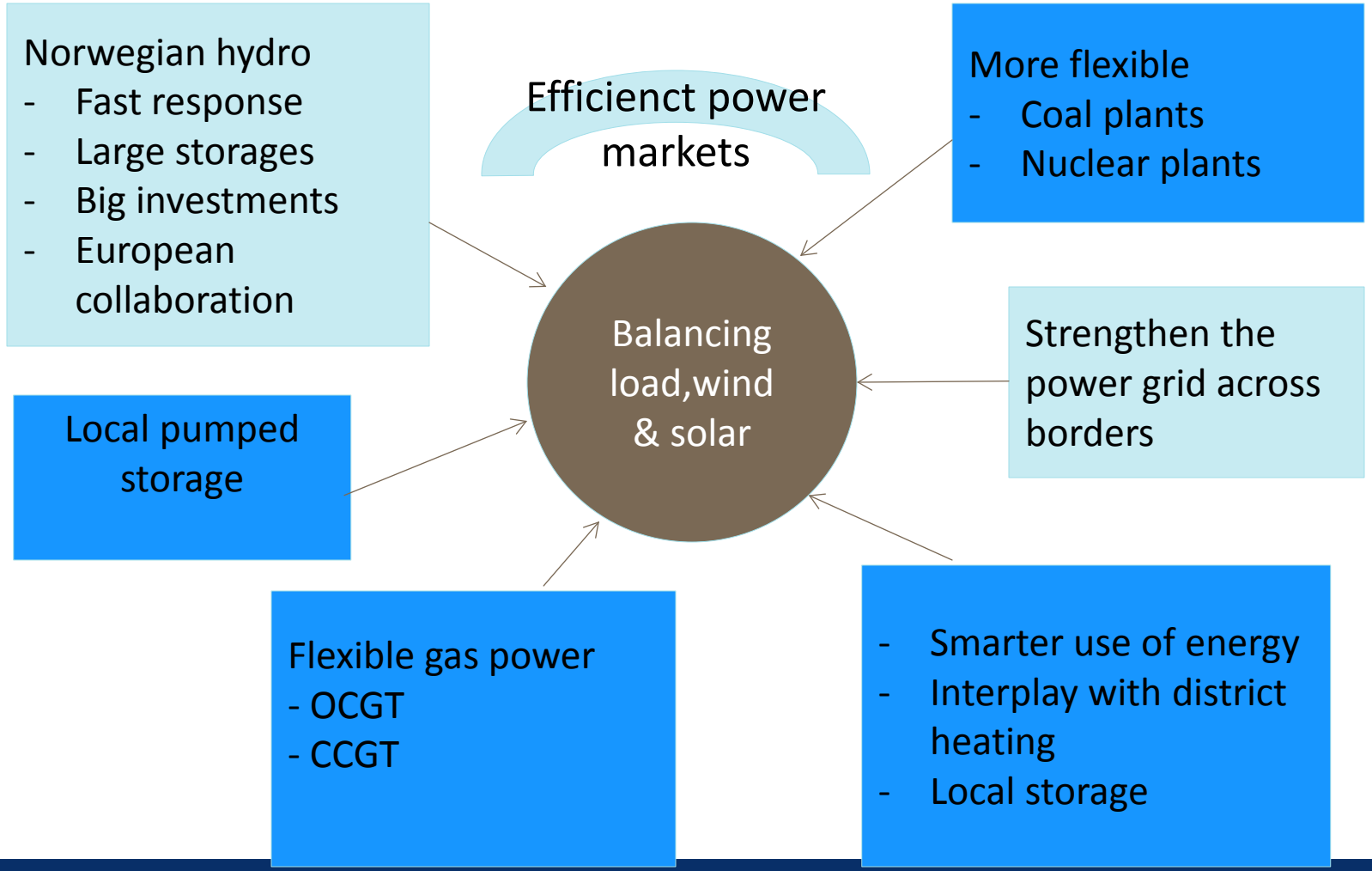
Content

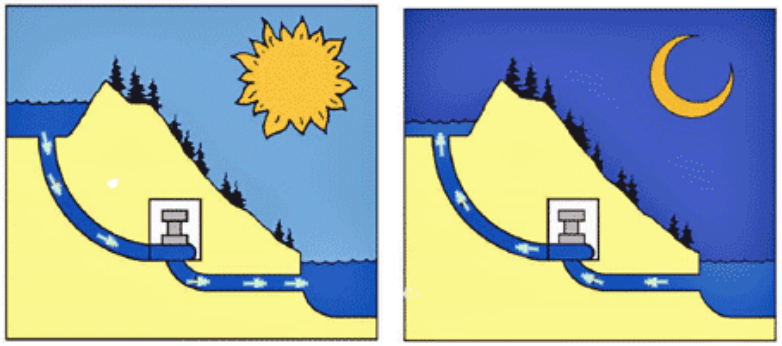
- Overview of balancing options and in particular Norwegian hydro power
- Research challenges related to balancing and storage optimization
- Example of model results
- Application to distributed energy management systems

Balancing of renewables in Europe

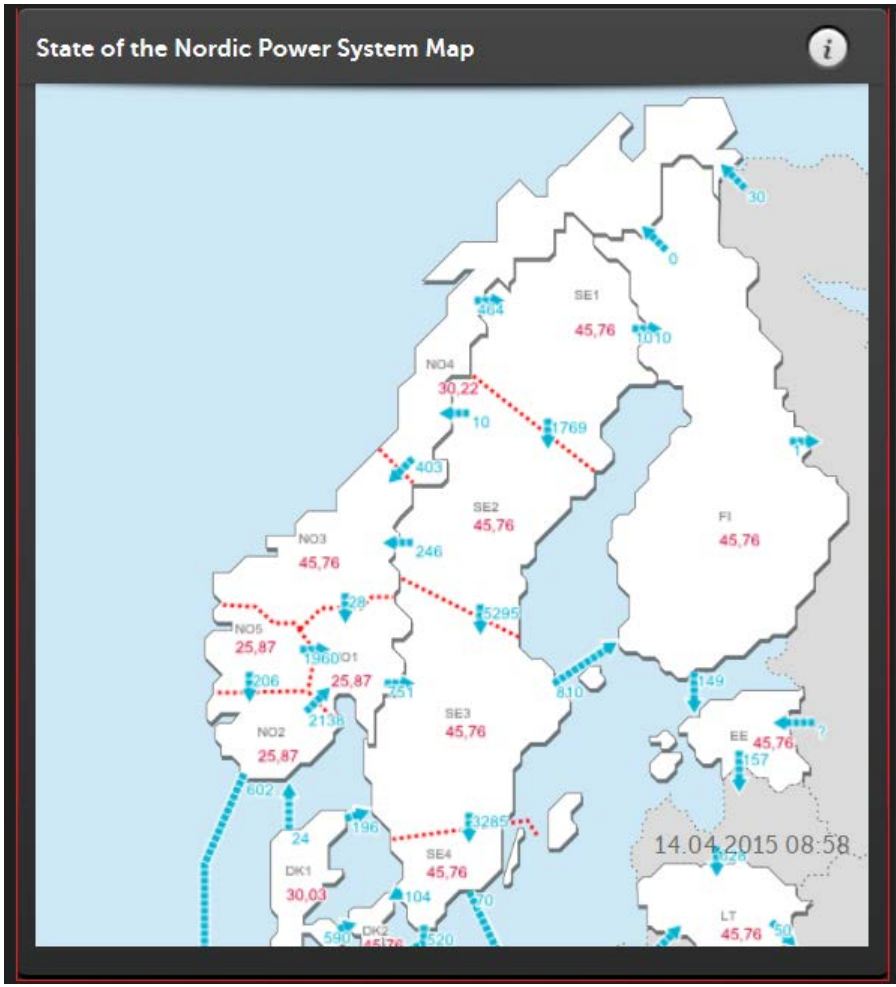


Norwegian hydropower for balancing

- The reservoirs are natural lakes
  - Multi-year reservoirs
  - Largest lake stores 8 TWh
  - Total 84 TWh reservior capacity
- Balancing capacity estimates 2030
  - 29 GW installed at present
  - + 10 GW with larger tunnels and generators
  - + 20 GW pumped storage
  - 30 GW total new capacity
    - Within todays environmental limits
  - Requires more transmission capacity



Norwegian figures



Source: http://www.statnett.no/en/Market-and-operations/

Problems that are best addressed using optimization and simulation models

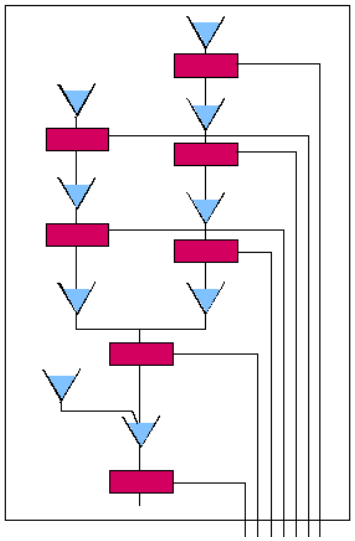
- Investments (how much, where and when)
  - New transmission (TSOs)
  - Exchange capacities between countries (several TSOs, governments)
  - New pumped storage plants (Producers)
  - Fundamental based optimization and simulation models of the whole system (e.g. Northern Europe)
- Operation of existing system
  - Price forecasting
  - Scheduling of flexible production and storages
  - Local optimization and simulation models with market input
  - Fundamental based optimization and simulation models of the whole system
- Simulating operation of the existing or a future system

Large scale stochastic dynamic optimization

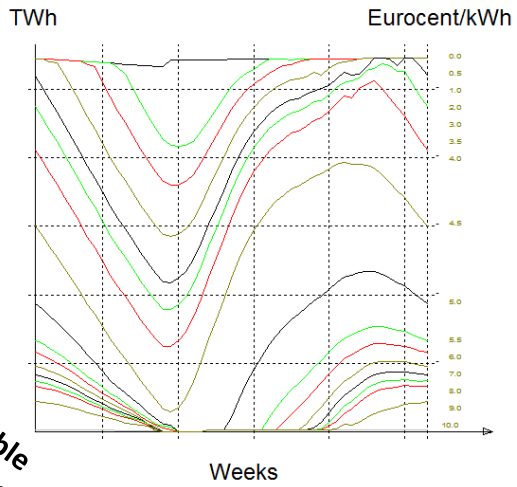
- Multi state
  - Typical more than 1000 different storages in an fundamental market model
    - Very varying storage size (from about three years to hours)
- Stochastic multidimensional
  - Inflow, wind, radiation
    - Correlated in time an space
      - Historical observations
      - Short-term forecast, snow pack information
  - Exogenous prices
- Multi stage
  - Weekly (split into intraweek time step)
  - Several year long planning horizon
- Transmission constrained
  - Several thousand nodes

Simulation of markets with storages an weather uncertainty

Storage possibilities



Strategy by (SDP/SDDP)

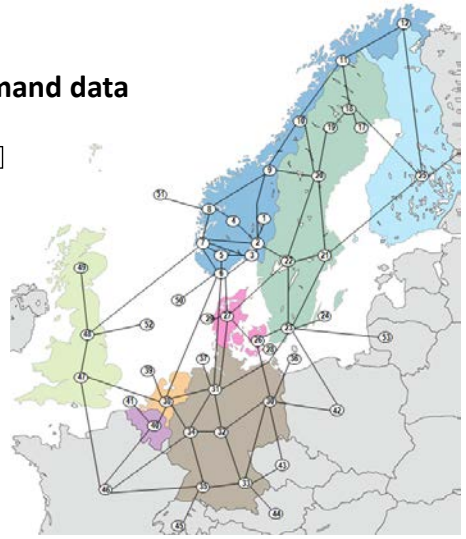


Feasible solution

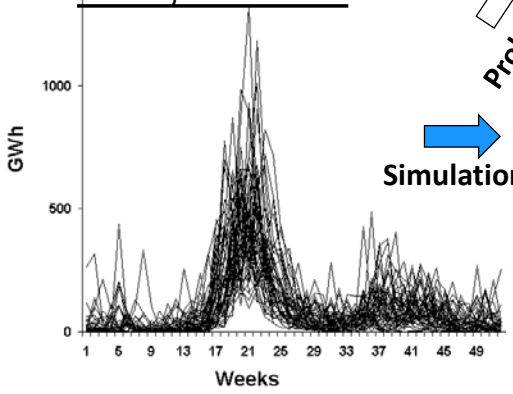
Vannverdi

Markets and prices

Supply/demand data



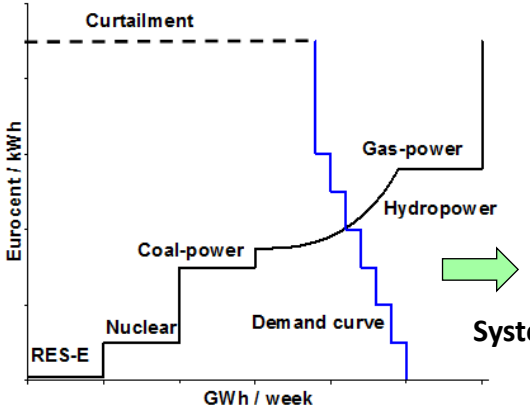
Stochastic, inflow solar, wind etc



Probability

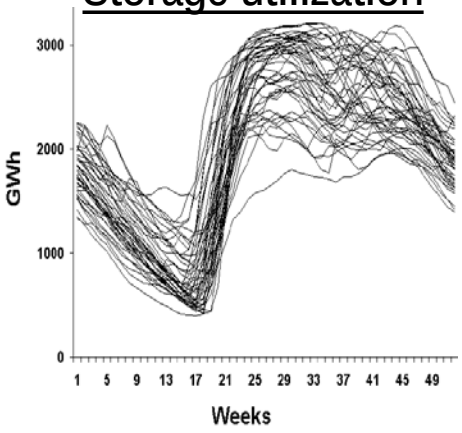
Simulation

Simulating markets (LP)



System operation

Storage utilization



Methods and tools

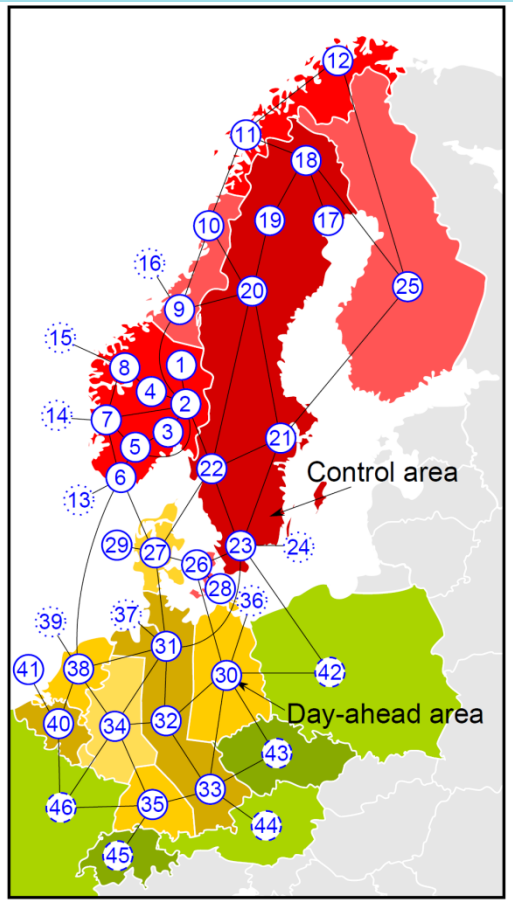
- To complicated to be solved in one large optimization
  - Decomposition
  - Aggregation and disaggregation
  - Optimization vs simulation

- Different formal stochastic dynamic optimization problems (SDP, SDDP, multi deterministic etc)
- Stochastic multi state multi stage optimization tools are used for daily decision making by most major Scandinavian market players
- Continuous research
  - Currently 4 research projects at my research group at SINTEF funded partly by the Norwegian Research Council and the market players.

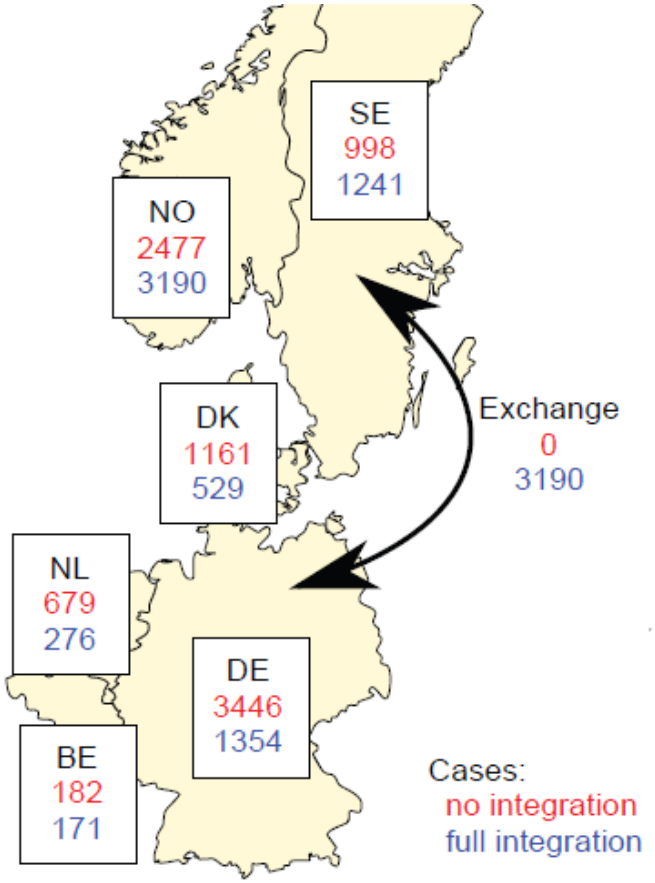
Study– Integration of balancing markets

(PhD study by Stefan Jaehnert (NTNU/SINTEF)

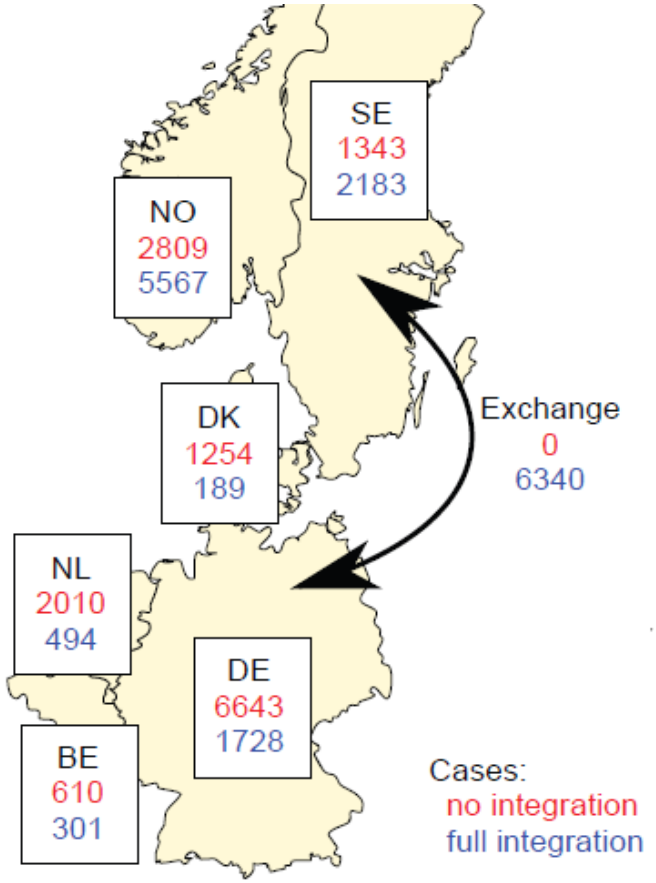
Fundamental model	Detailed water course description About 300 thermal power plants Transmission corridors (NTC)
Northern Europe	Denmark, Finland, Norway, Sweden Germany, Netherlands, Belgium
System scenarios	2010 – current state of the system 2020 – a future state of the system
Several climatic years	Hydrology (Inflow) Temperature Wind speed



Country wise annual balancing reserve allocation (GWh/yr)

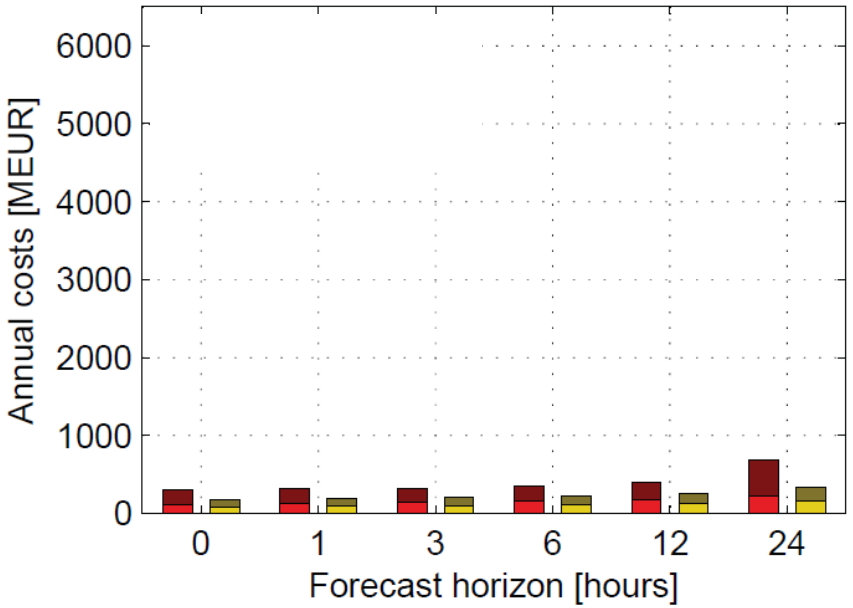


(a) 2010

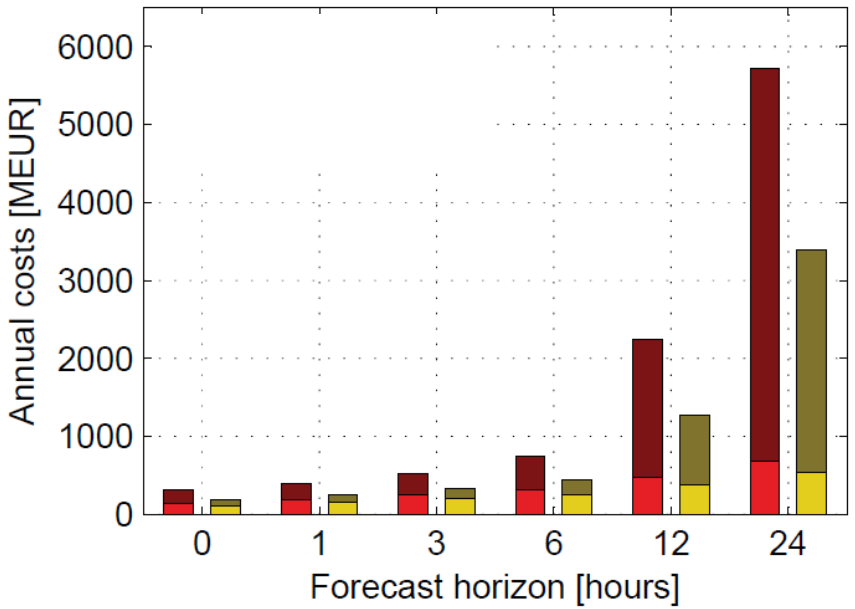


(b) 2020

Total balancing market costs for different wind forecast horizons



(a) 2010



(b) 2020

No integration : Reserve procurement
No integration : System balancing
Full integration: Reserve procurement
Full integration: System balancing

Application of competence and methods to distribution networks

- Similarities
  - Weather related uncertainties in end use and local production (stochastic problems)
  - Use of local storages (dynamic problems)
  - Smaller storages but multi stage problems
- Difference
  - Distribution network modelling vs transmission system modelling
    - Linear approximation better for higher voltages
  - Different time resolution
  - Market setting and environment - normally stronger couplings