NTNU – Trondheim
Norwegian University of
Science and Technology

Norge er Europas billigste batteri

Gløshaugen Akademiske Klub, 5. Feb. 2015

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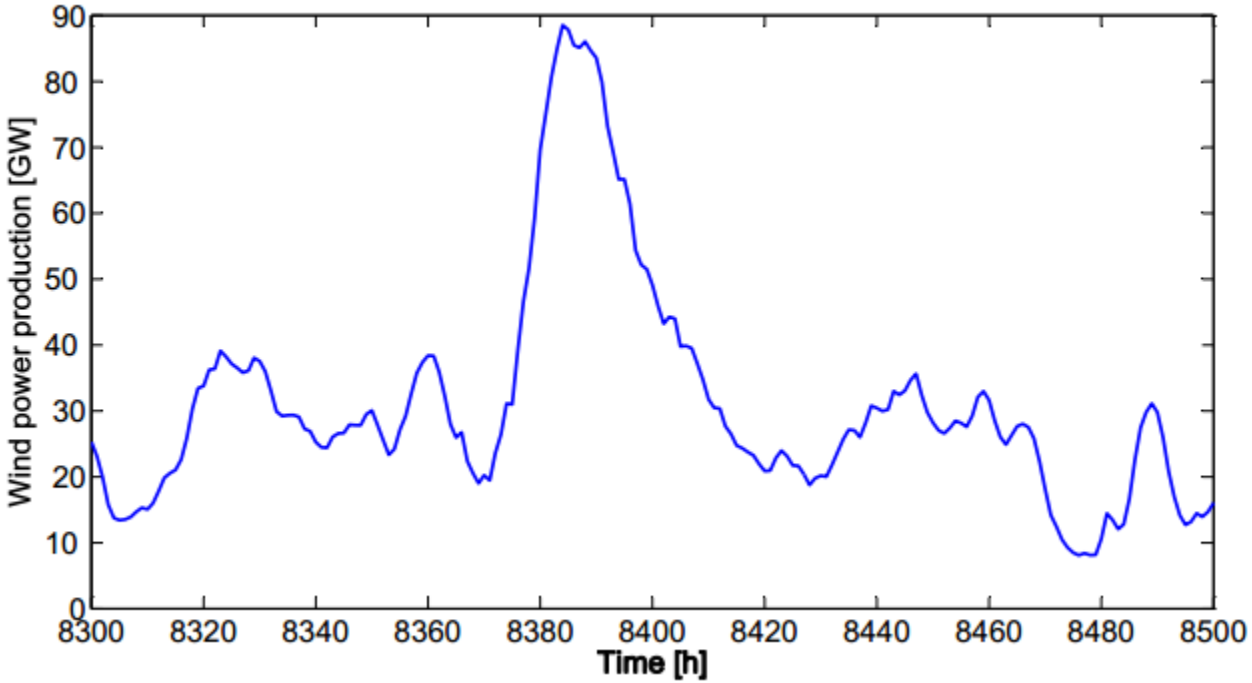
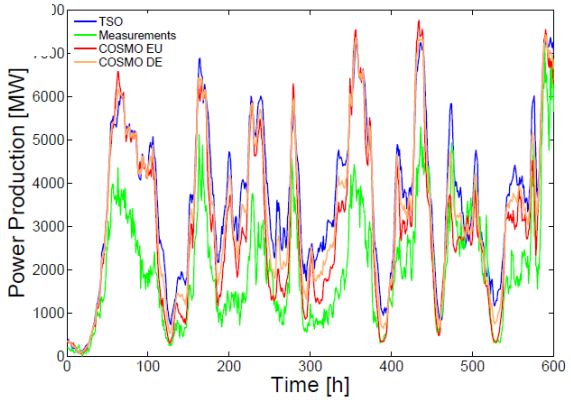
Inst. for elkraftteknikk

Simulated 2030 North Sea wind power during the storm front of «Carmen»…

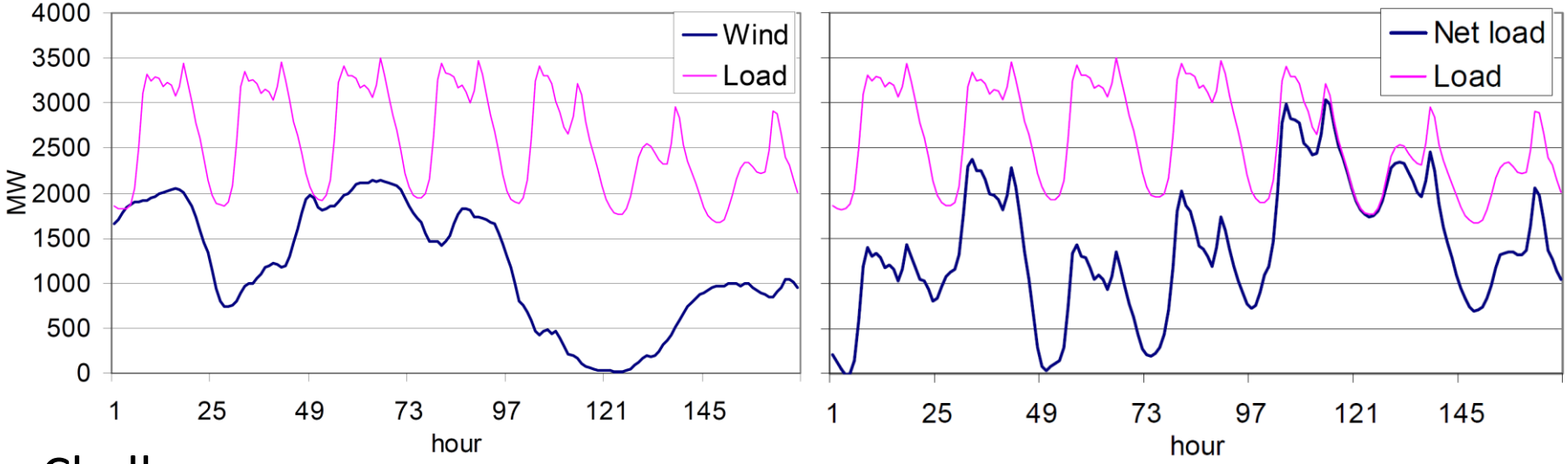




Source: Aigner (NTNU)

…but it is the Net Load that matters

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

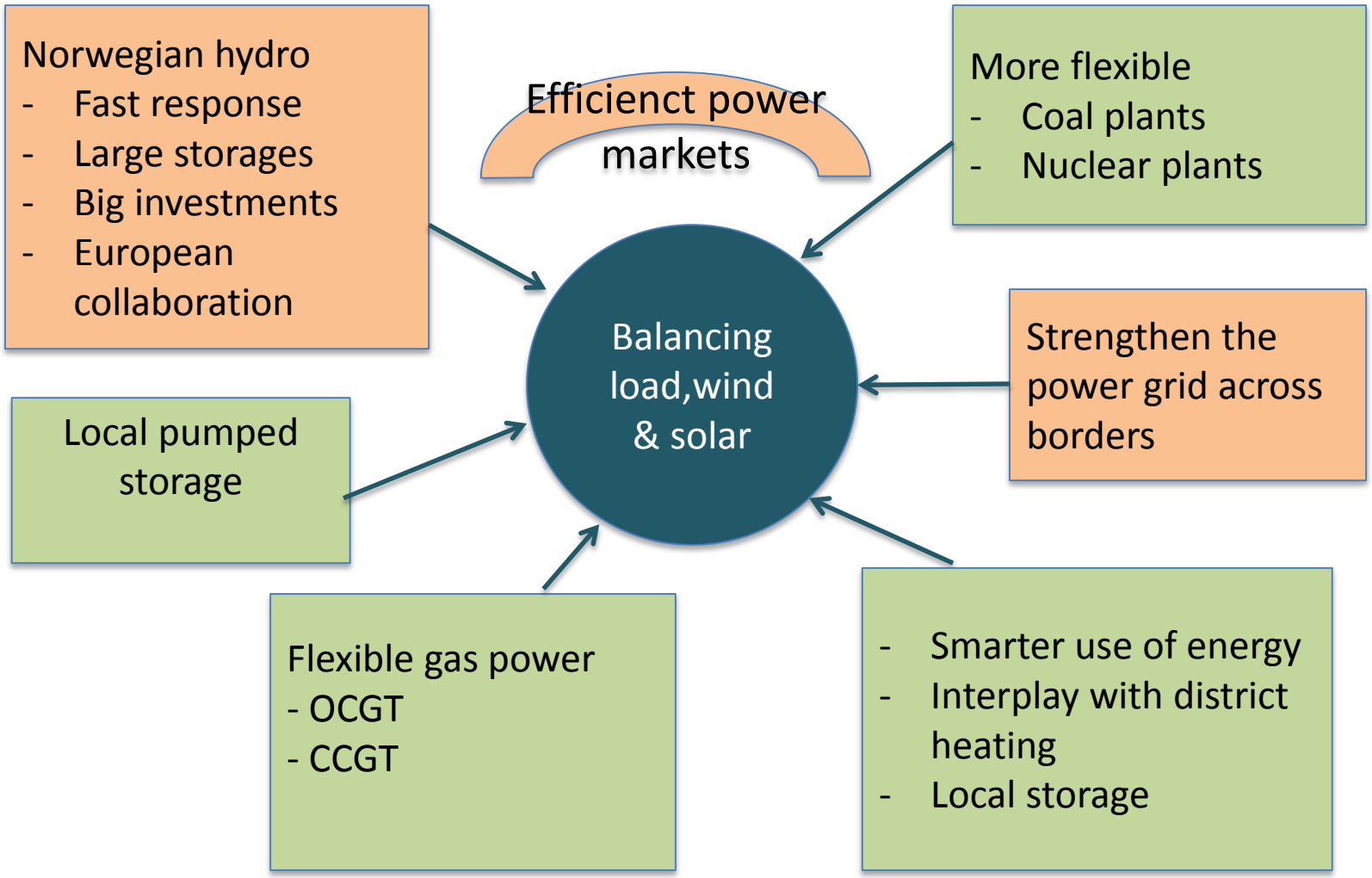


Challenges:

- Flexibility of thermal power plants (ramp rates, start/ stop operation)
- With very high RE share, thermal plants can be pushed out of the market – security of supply has to be fulfilled

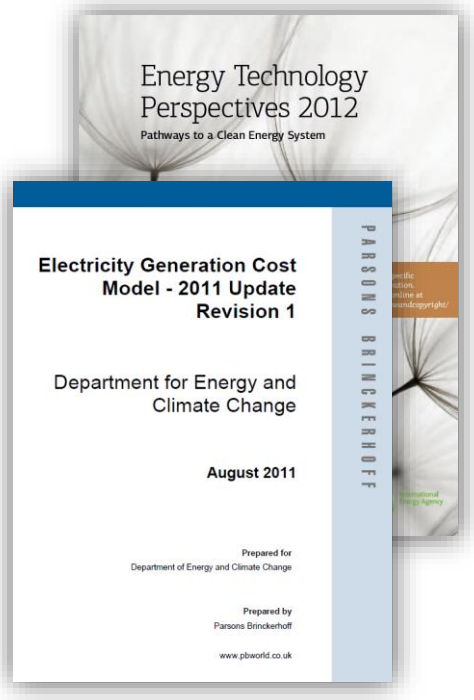
Sources: NREL, Holttinen (VTT)

Balancing of renewables in Europe



Study of power production cost in Europe

- Only cost is considered
  - Market simulation not included
  - Assessment of the most cost-effective solutions in the near term
- In-house study
  - Time period 2030-2040
  - Based on IEA WEO scenarios and figures
  - Gas plant models and costs according to report for UK Dept. of Energy and Climate Change
  - Pumped hydro storage and grid data based on Norwegian figures; CEDREN, NVE and Statnett

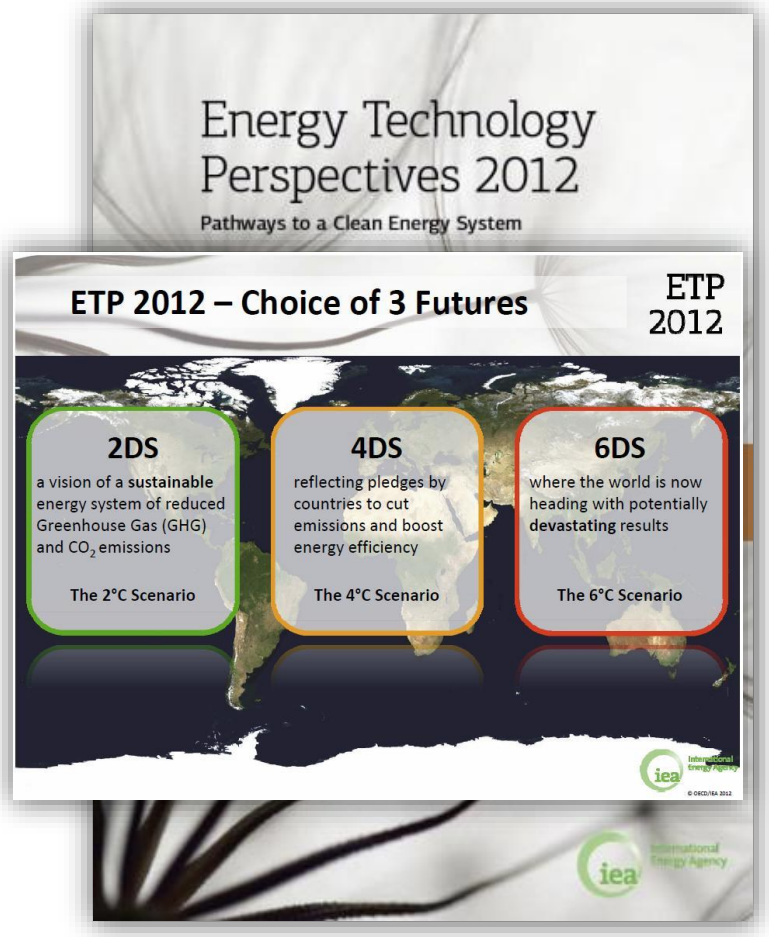


Three scenarios
2025 – 2050 perspective

1. 2DS – IEA 450 Scenario:
   - Gas price 29.5 € /MWh
   - CO_2 price 93.9 €/ton

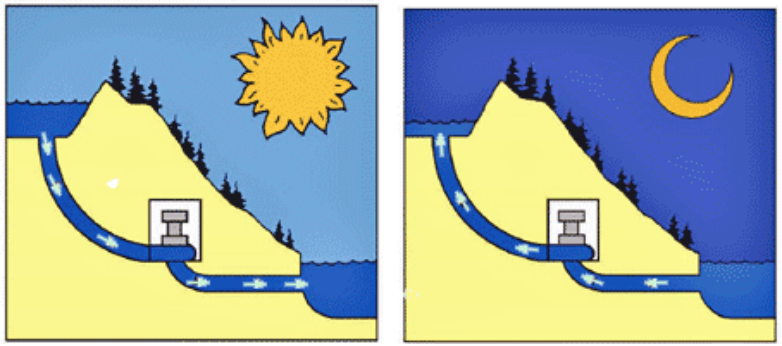
2. 4DS – IEA New Policy Scenario:
   - Gas price 34.8 €/MWh
   - CO_2 price 35.2 €/ton

3. Low Gas price Europe:
   - Gas price 19.7 €/MWh (USA level)
   - CO_2 price 35.2 €/ton (as 4DS)

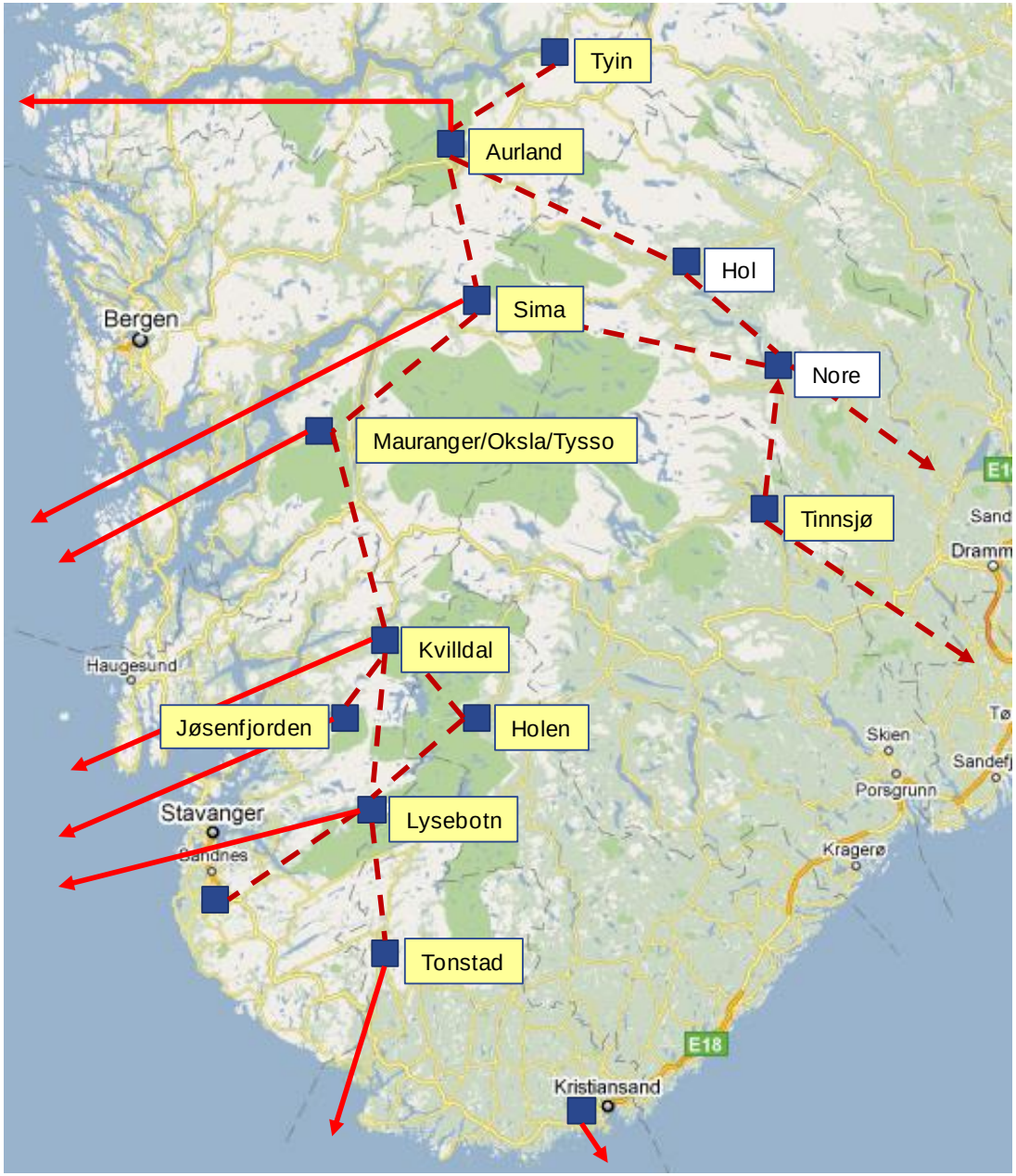


Norwegian hydropower for balancing

- 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

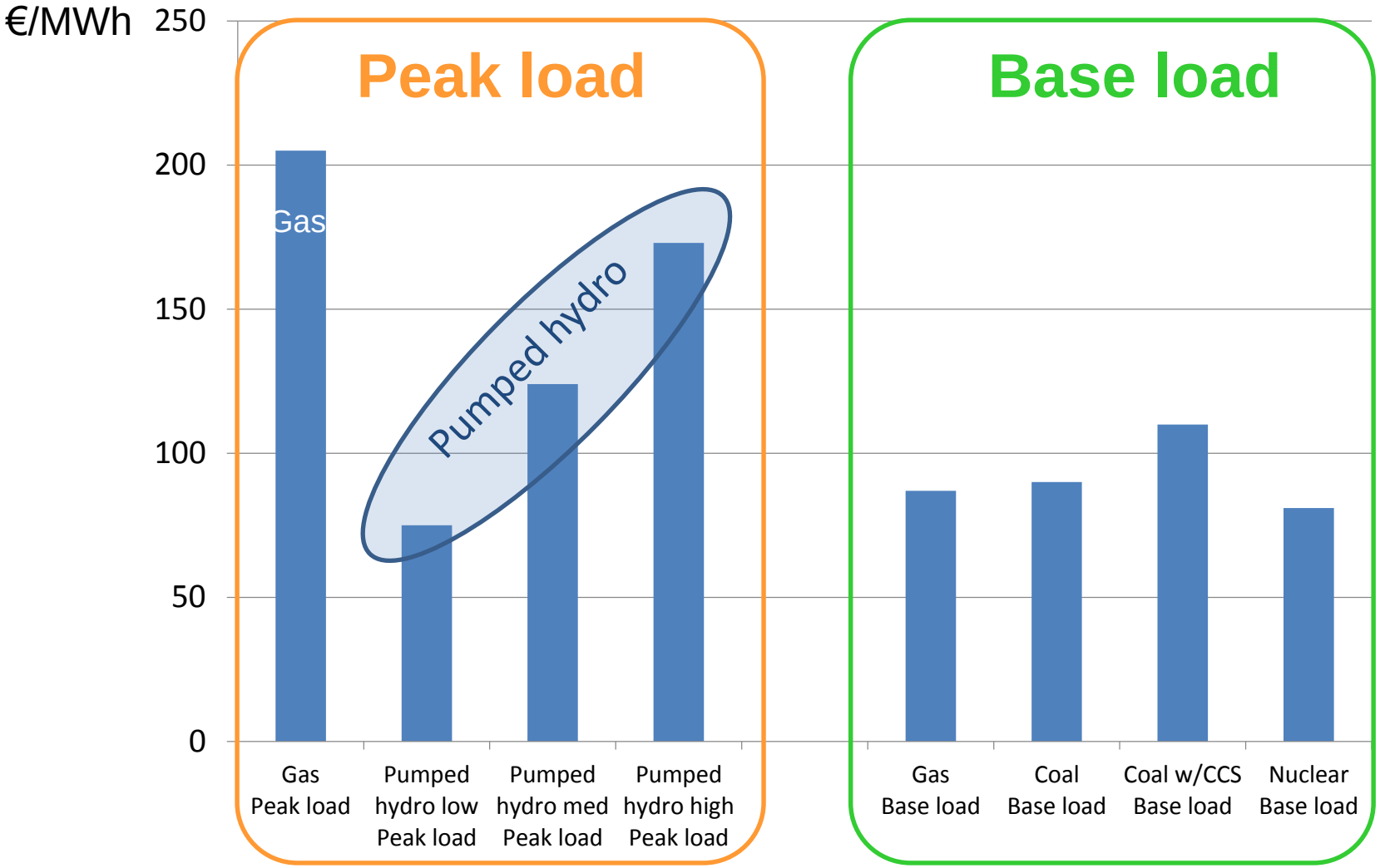


CEDREN Case study 2030

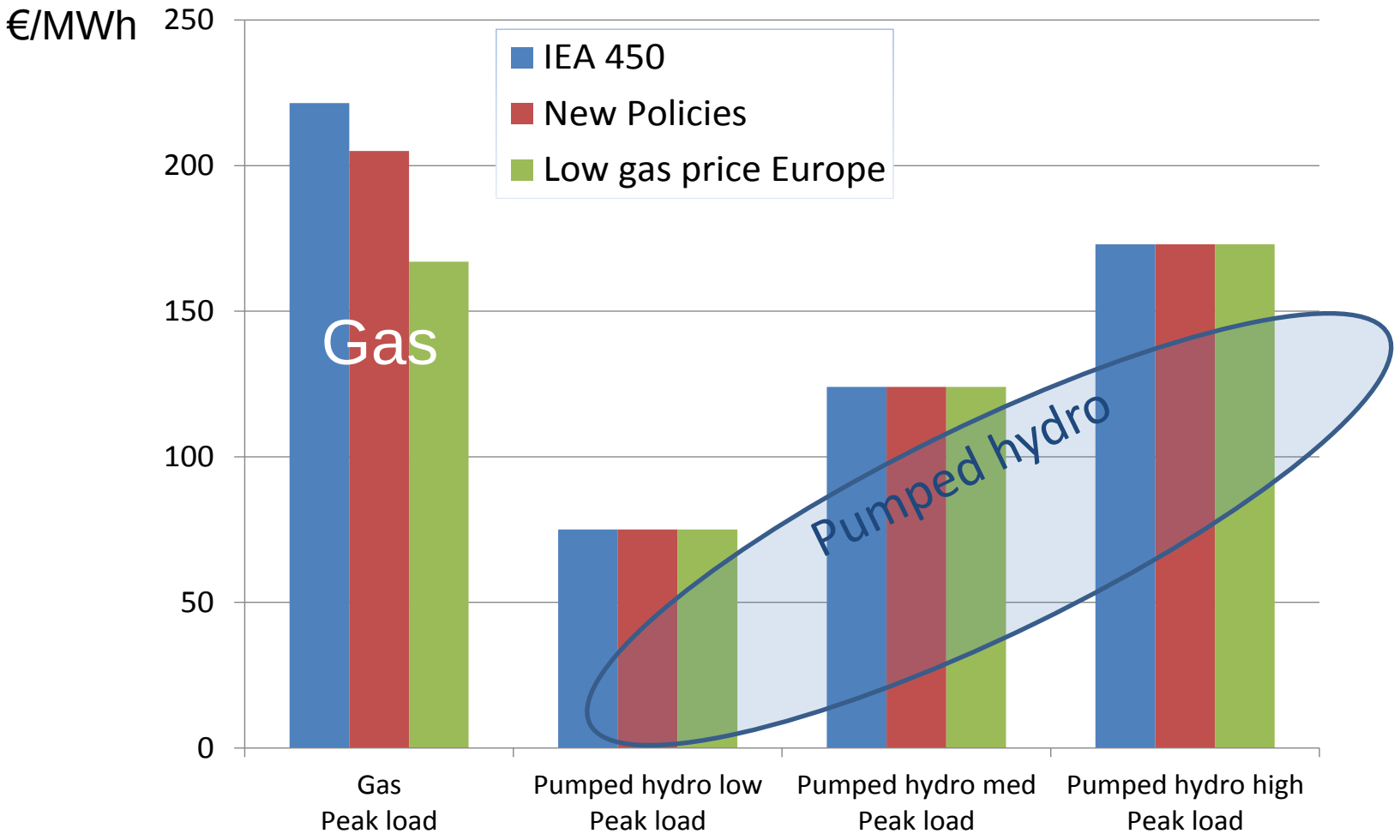


10-20 GW new pumping and generation capacity using existing reservoirs

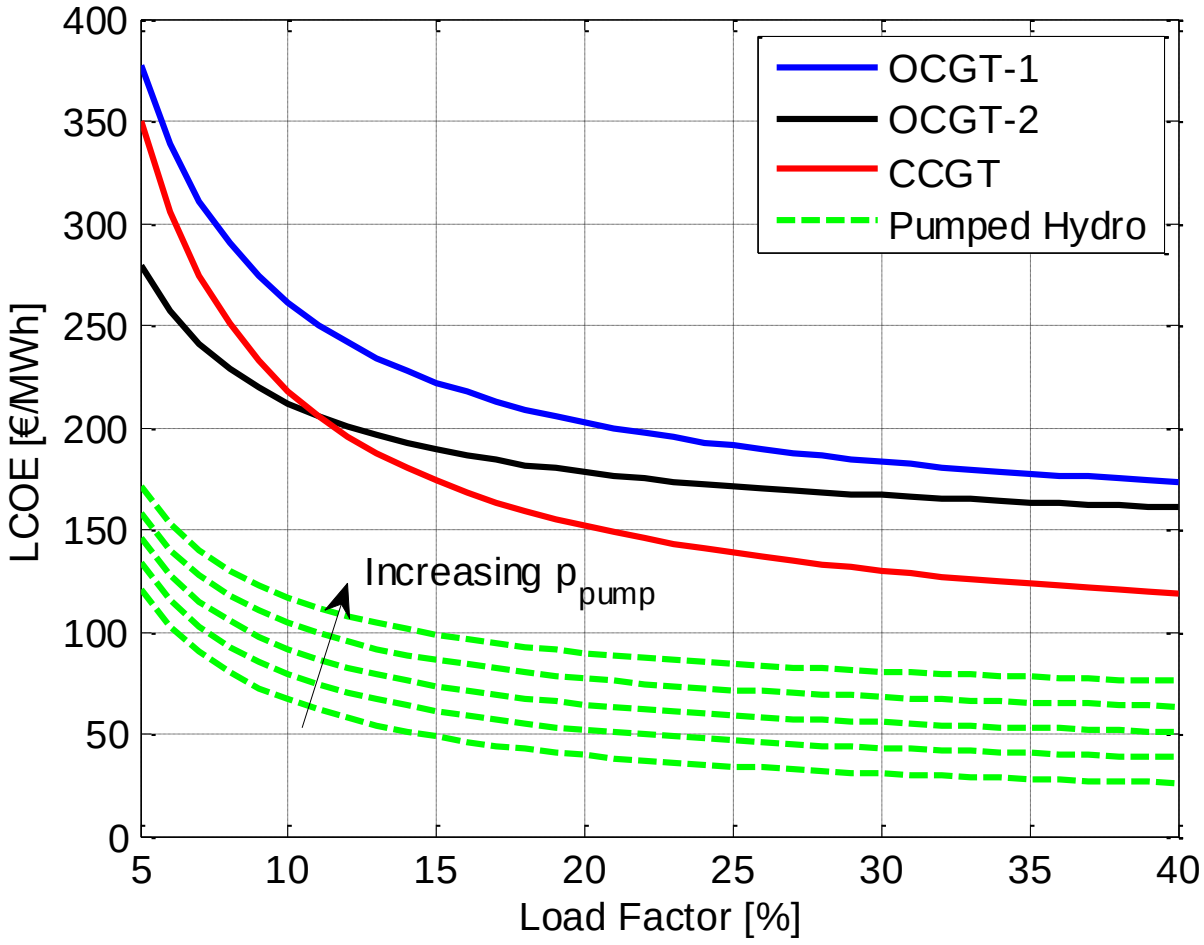
Peak load and base load have different cost



Pumped hydro power is cost-effective for balancing in all scenarios



Newest estimates confirms the competitivness of Norwegian pumped hydro



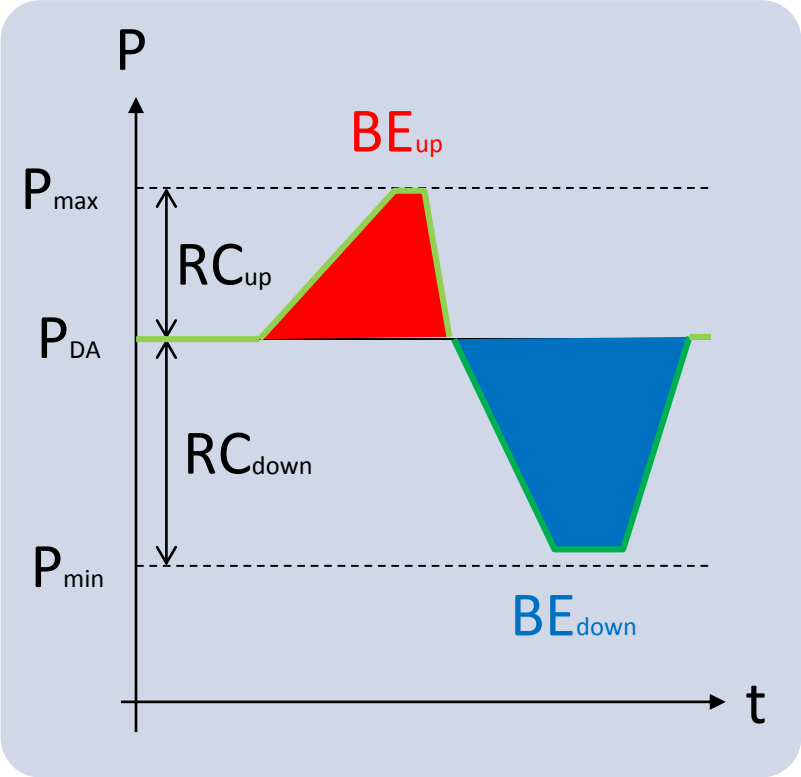
Balancing Reserve Capacity vs Energy

Reserve procurement

- Reserve capacity (RC) [EUR/MW]
- TSOs ensure sufficient reserves in the system during operation

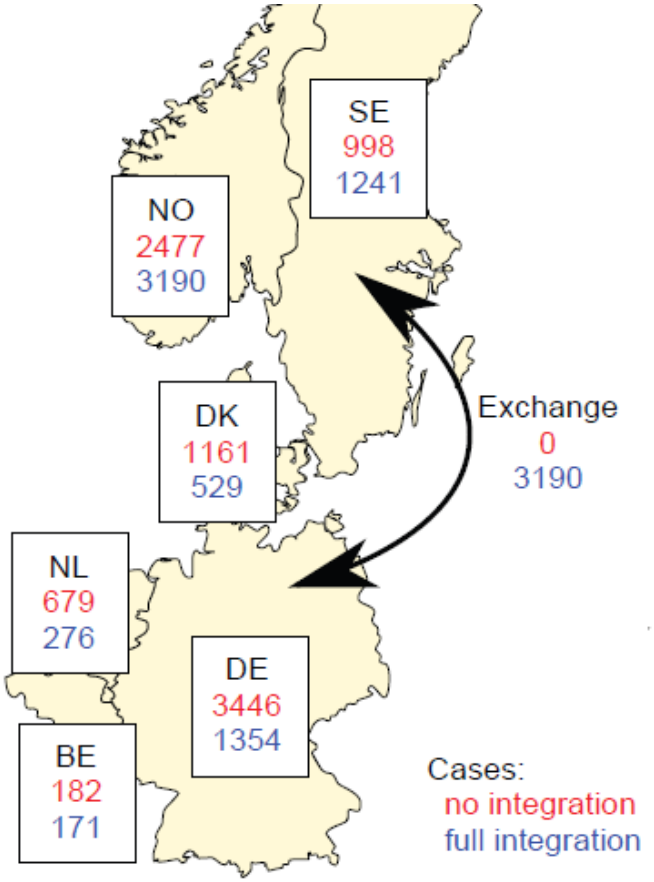
System balancing

- Balancing energy (BE) [EUR/MWh]
- TSOs activate reserves to counteract system imbalances

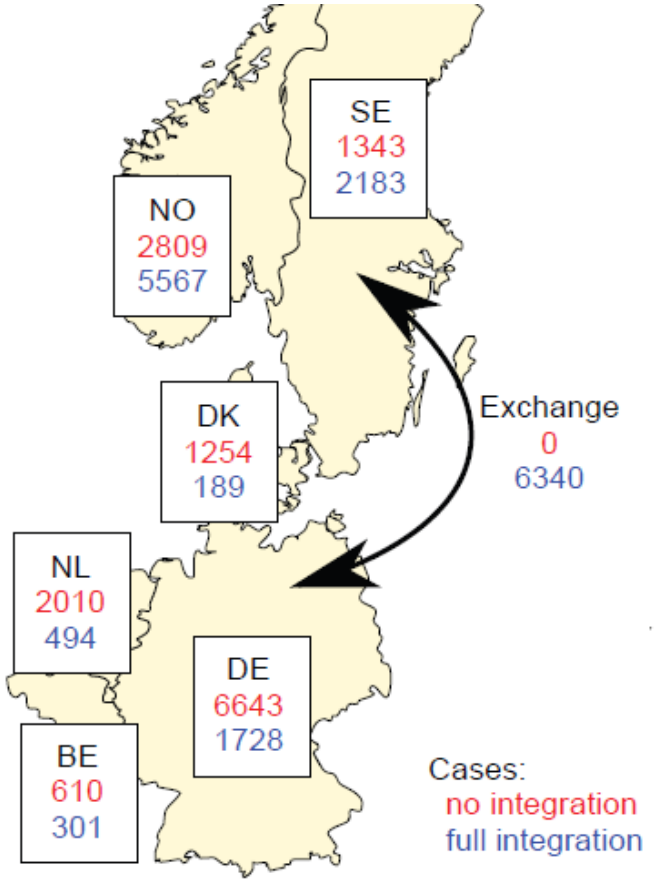


Source: Doorman (NTNU)

Country wise annual balancing reserve allocation (GWh/yr)



(a) 2010



(b) 2020

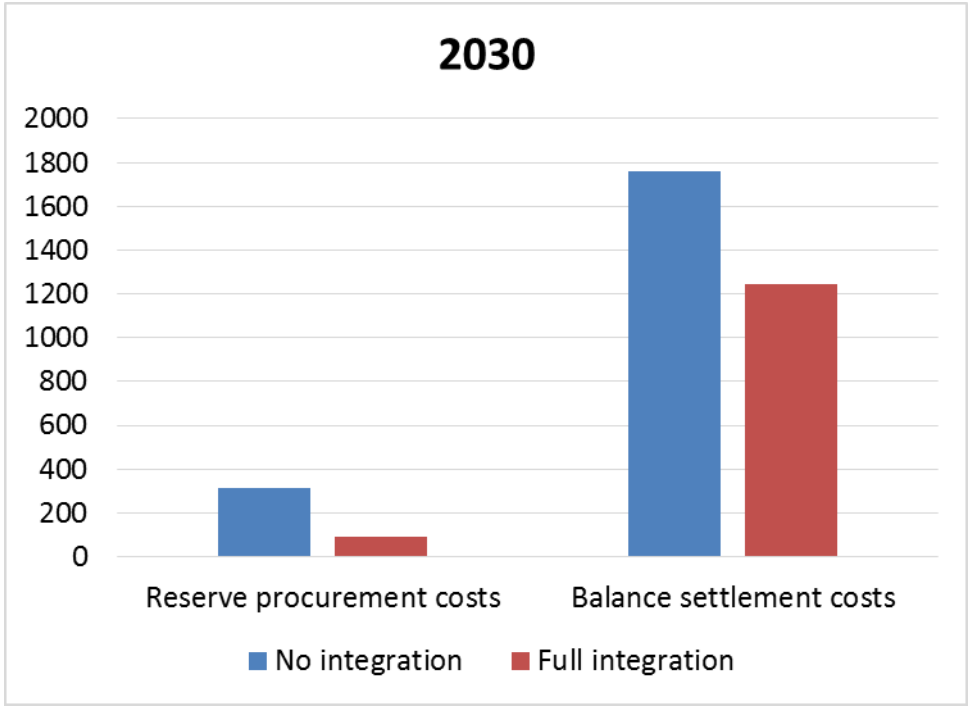
Integration of balancing markets

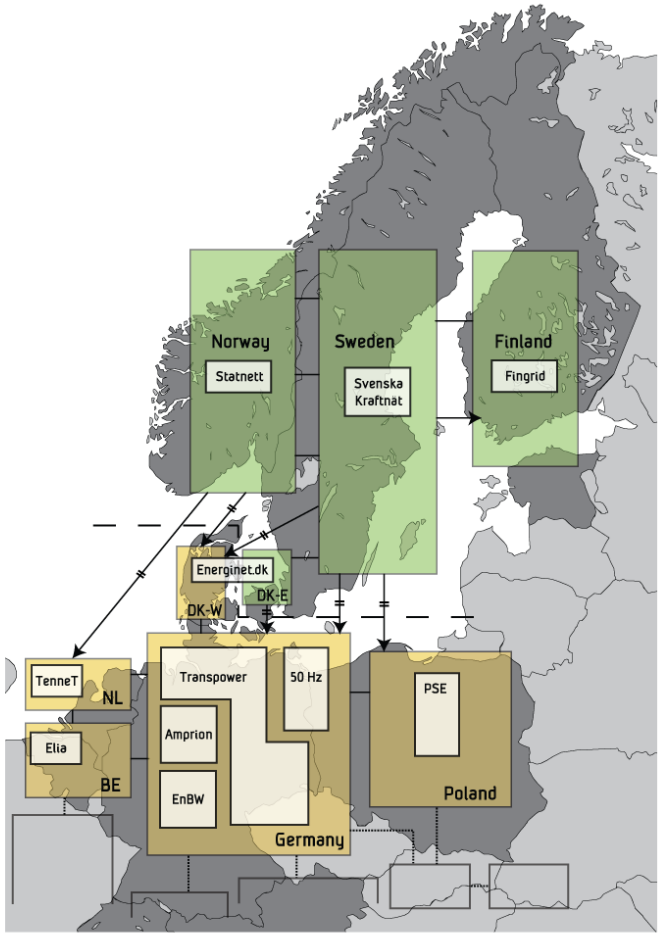
- Detailed European grid model based on DC power flow
- Representation of day-ahead, intra-day and balancing markets
- Co-optimizating day-ahead scheduels and reserve procurements based on forecasts
- Scenarios for load, generation and grid capacity year 2020 and 2030

Source: Farahmand (NTNU/SINTEF)

Large benefits of integrating the Northern and continental balancing markets

Total annual balancing cost savings (Mill.EURO)

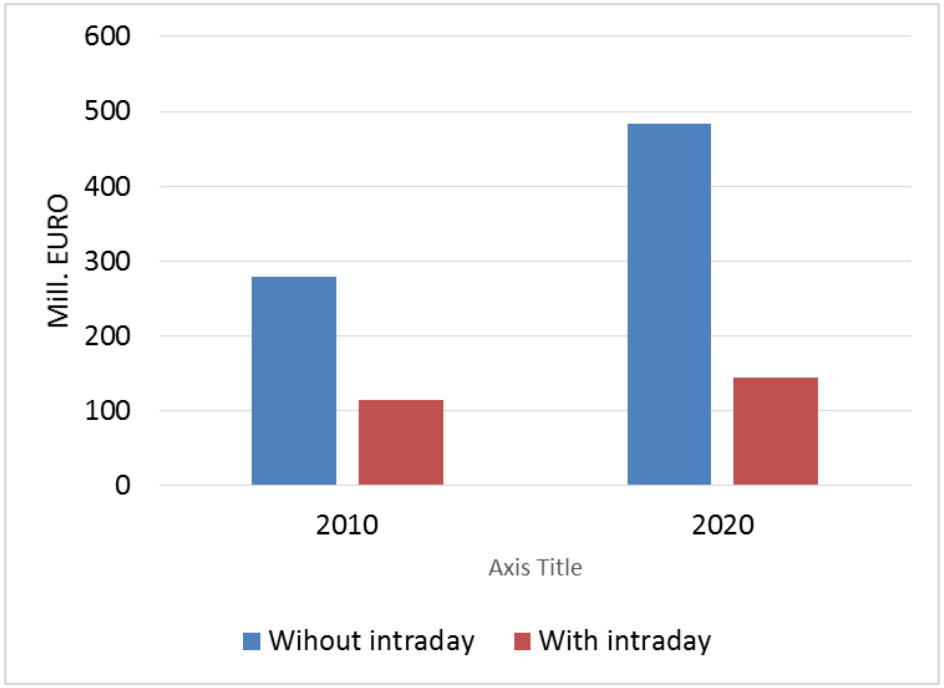




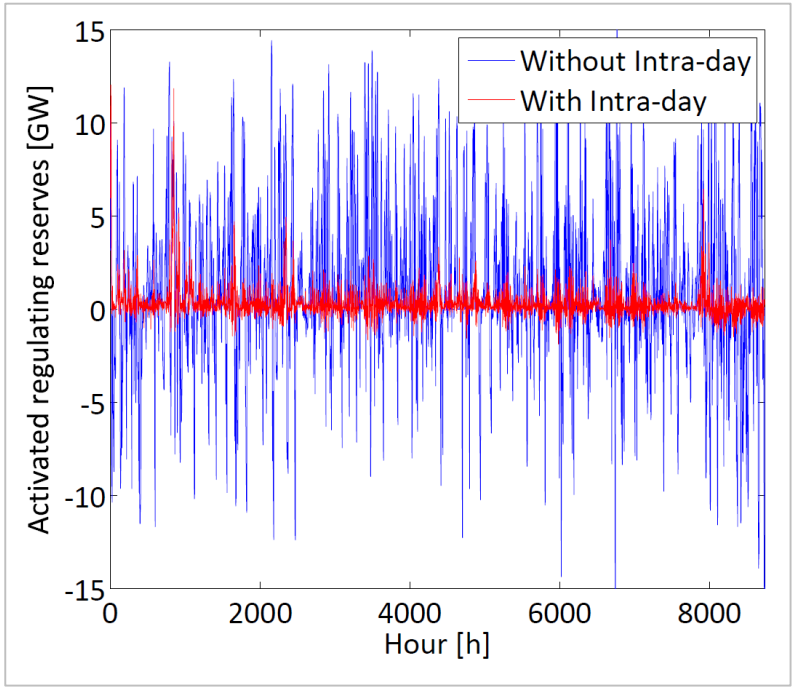
Source: Farahmand (NTNU/SINTEF)

Significant additional savings are achieved with intra-day markets

Total annual balancing cost savings



Activated reserves



Source: Aigner (NTNU)

Summary

- Norwegian pumped hydro is cost-effective for balancing
  - Large potential
  - Large flexibility and multiple uses
  - Requires European collaboration
- An efficient and integrated power market is an enabler for high RE penetration
  - Reduces the need for expensive storage
  - Reduces the need for expensive reserves
- Comprehensive studies of balancing markets in Northern Europe
  - Large benefits of integrated markets for balancing resources
  - Large benefits of integrated markets for intra-day trading