NTNU – Trondheim
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# Norsk vannkrafts rolle i Europa

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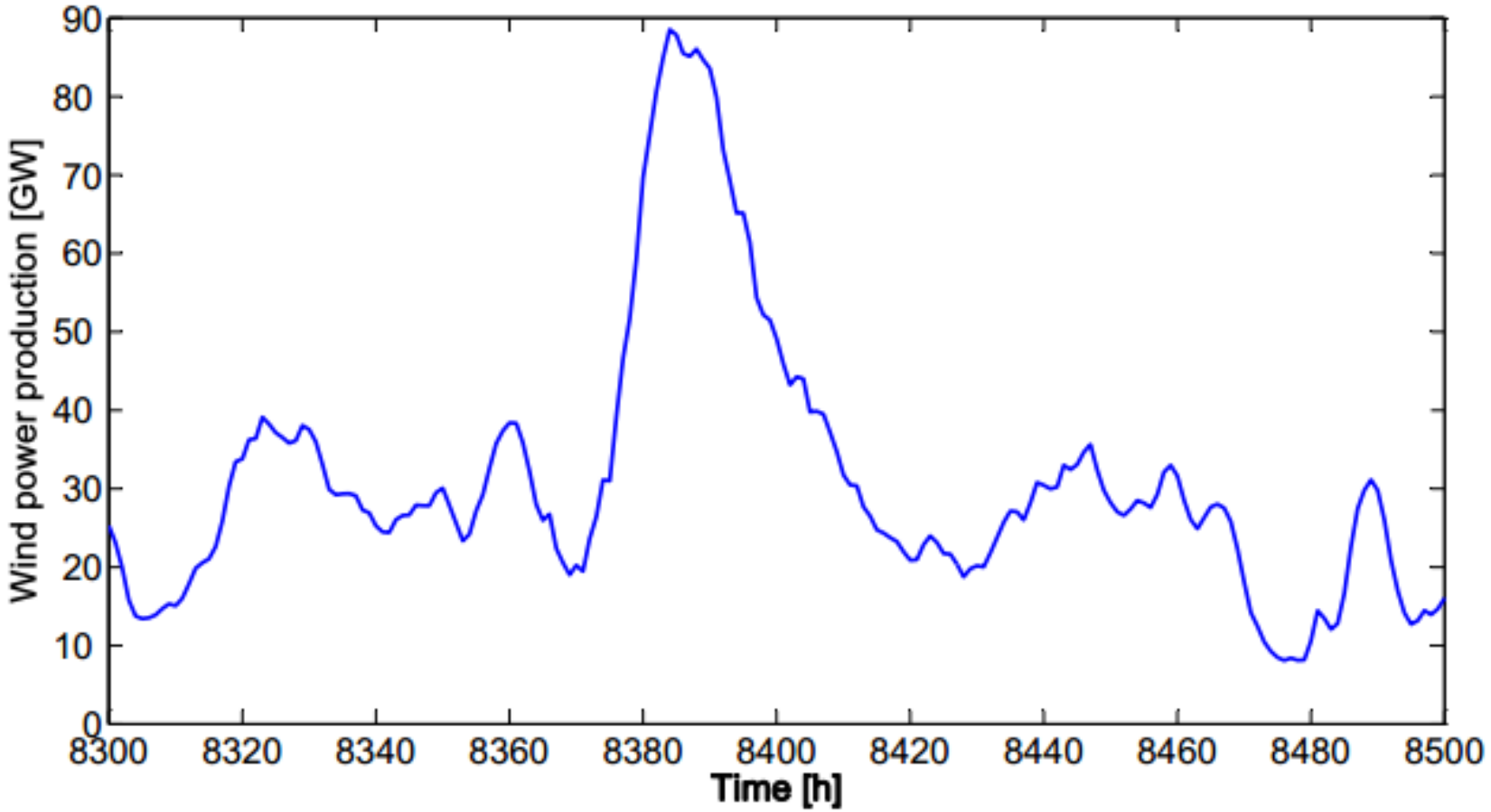
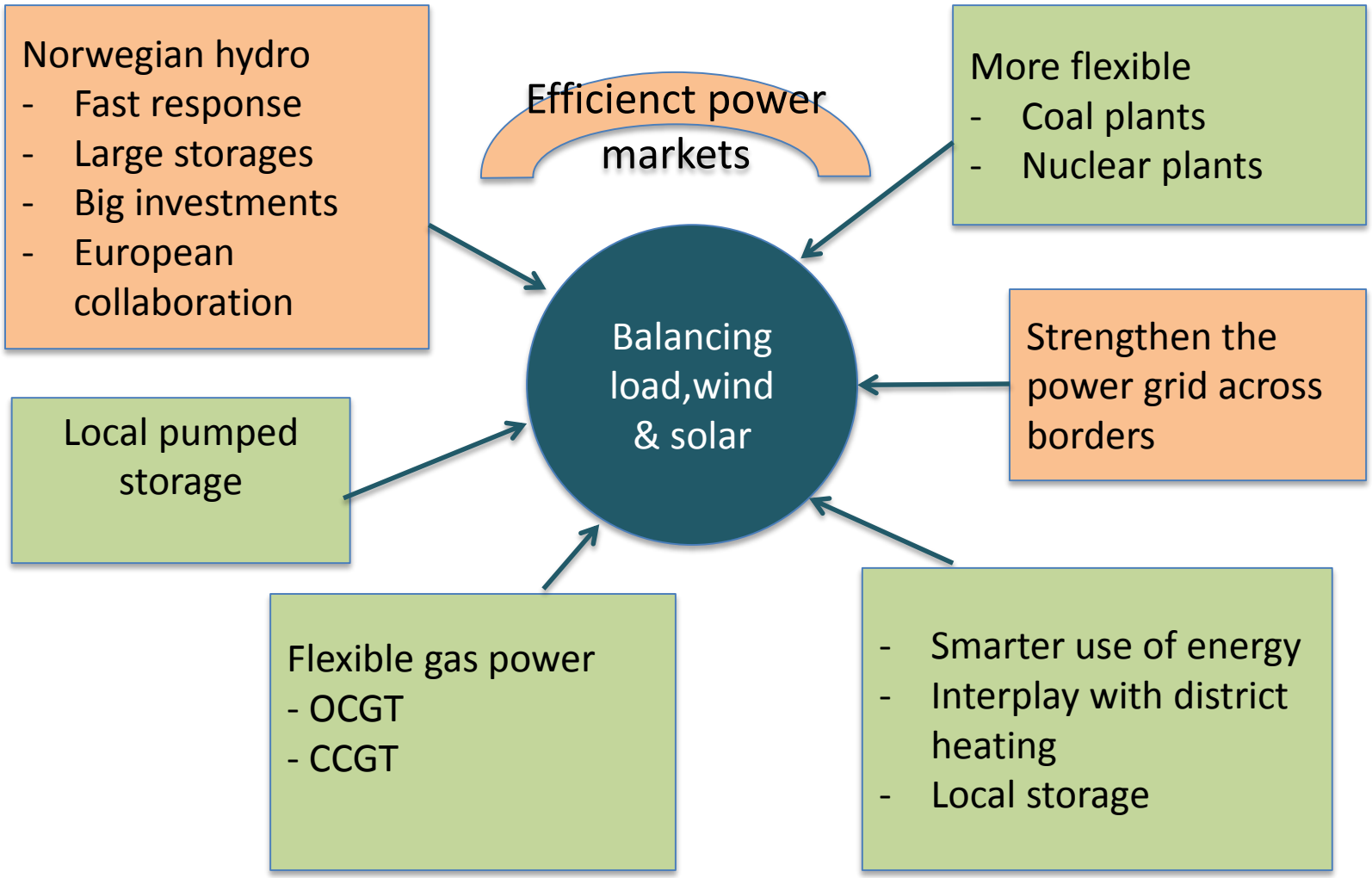
# Houston, we have a ~~problem~~ ..challenge!






*Source: Aigner (NTNU)*

# …and a whole lotta solutions!



# Norsk vannkraft har unike kvaliteter..

- Hurtig reguleringskapasitet for levering av effekt
- Store vannmagasiner for lagring av energi
- Store effekt- og pumpeutvidelser mulig i eksisterende vannkraftsystem

- Det er et sterkt økende behov for fleksibel kraft i Europa. Hva slags rolle kan norsk vannkraft spille?

20 Nyheter

Vil doble norsk vannkraft

Norsk vannkraft er billigst og kan dekke store deler av kraftbehovet i Tyskland på en vindstille kveld, ifølge NTNU og Sintef.

ENERGI

Ida Grieg Rilsnæs
Oslo

Vannkraft i Europa

Studien

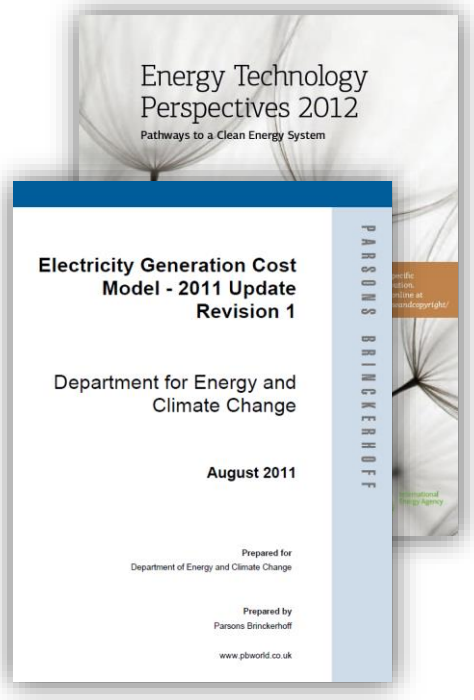
Kan doble

Monner mye

Tvinges fram

# 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

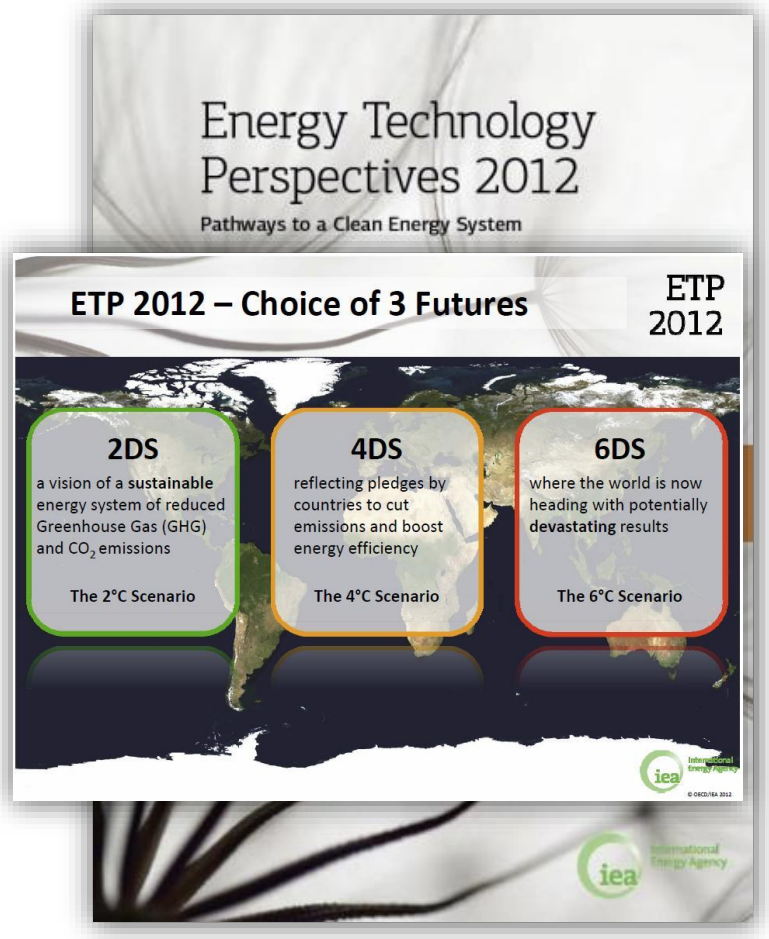


# Three scenarios
## 2025 – 2050 perspective

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

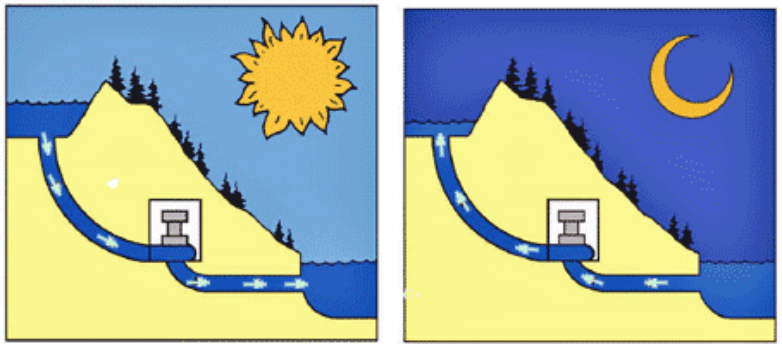
2. 4DS – IEA New Policy Scenario:
   - Gas price 34.8 €/MWh
   - $CO_2$ price 35.2 €/ton

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

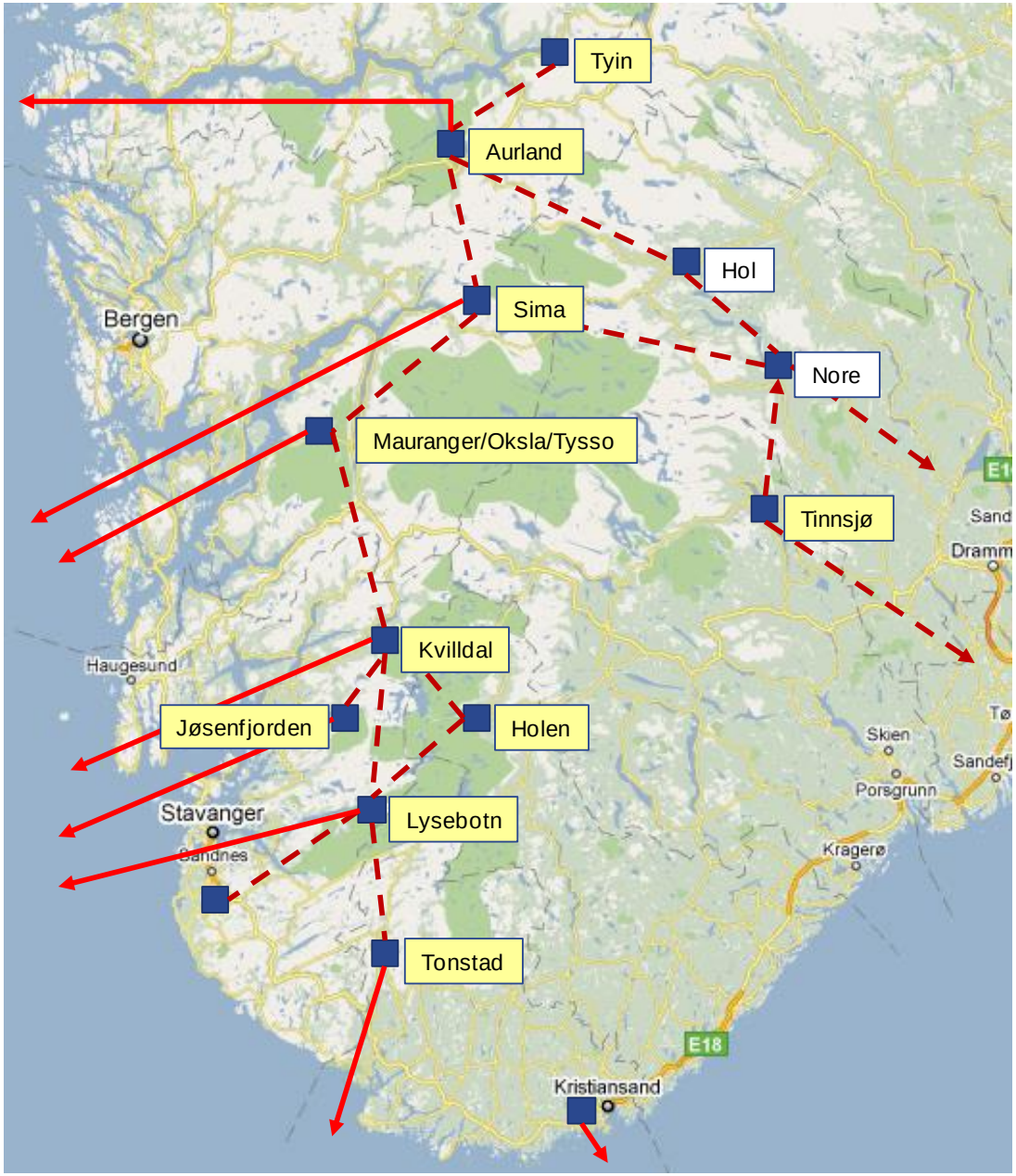


# Norwegian hydropower for balancing

- 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

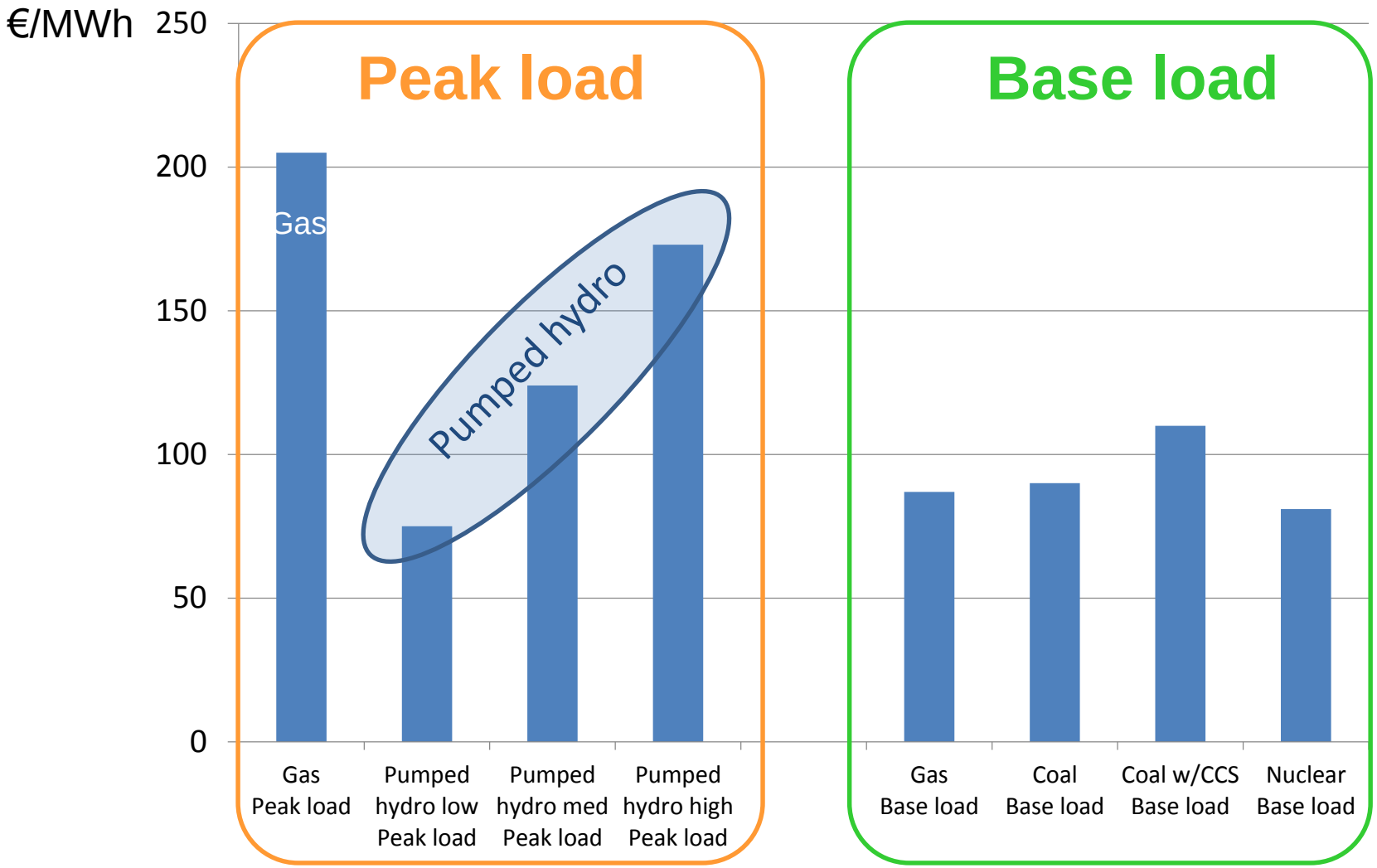


# CEDREN Case study 2030

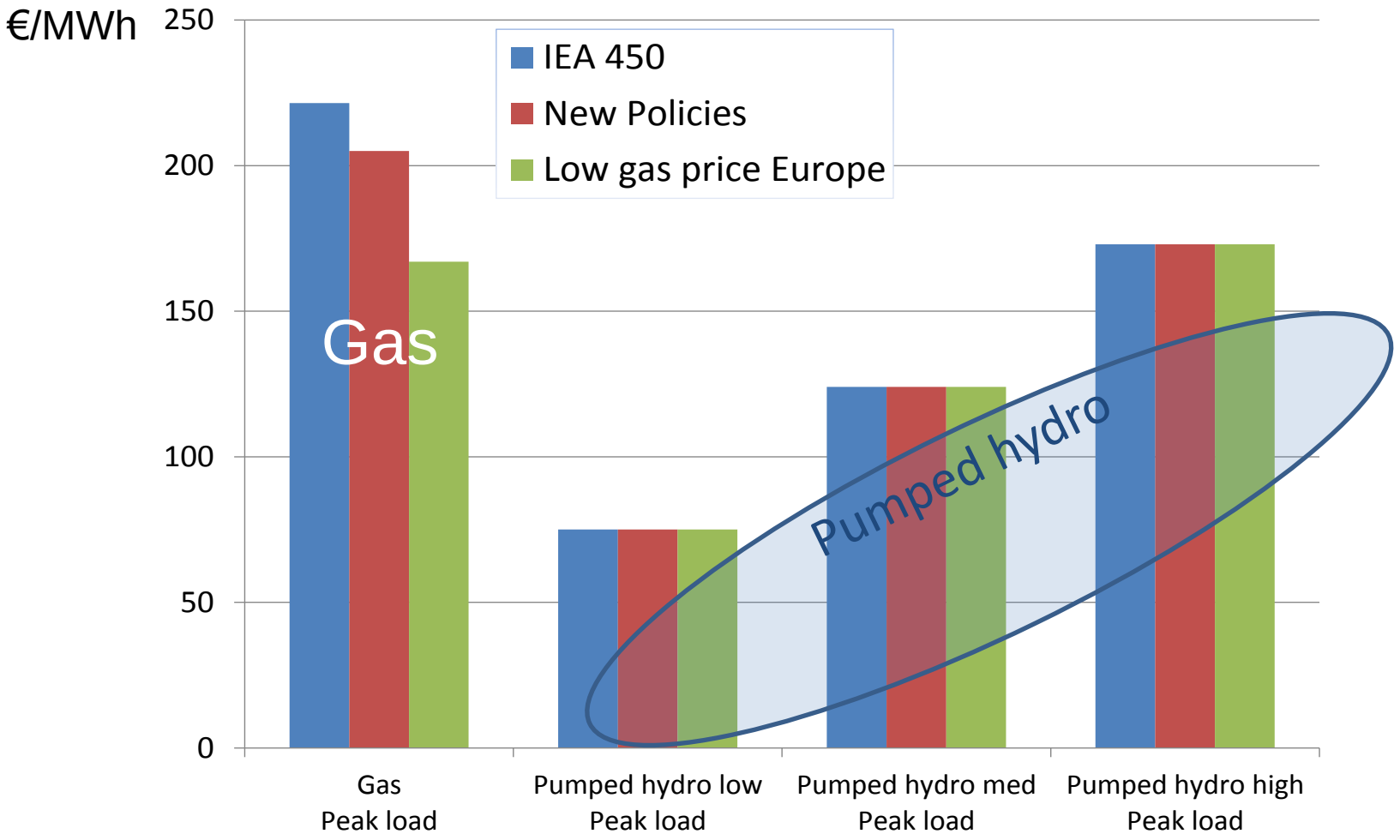



***10-20 GW new pumping and generation capacity using existing reservoirs***

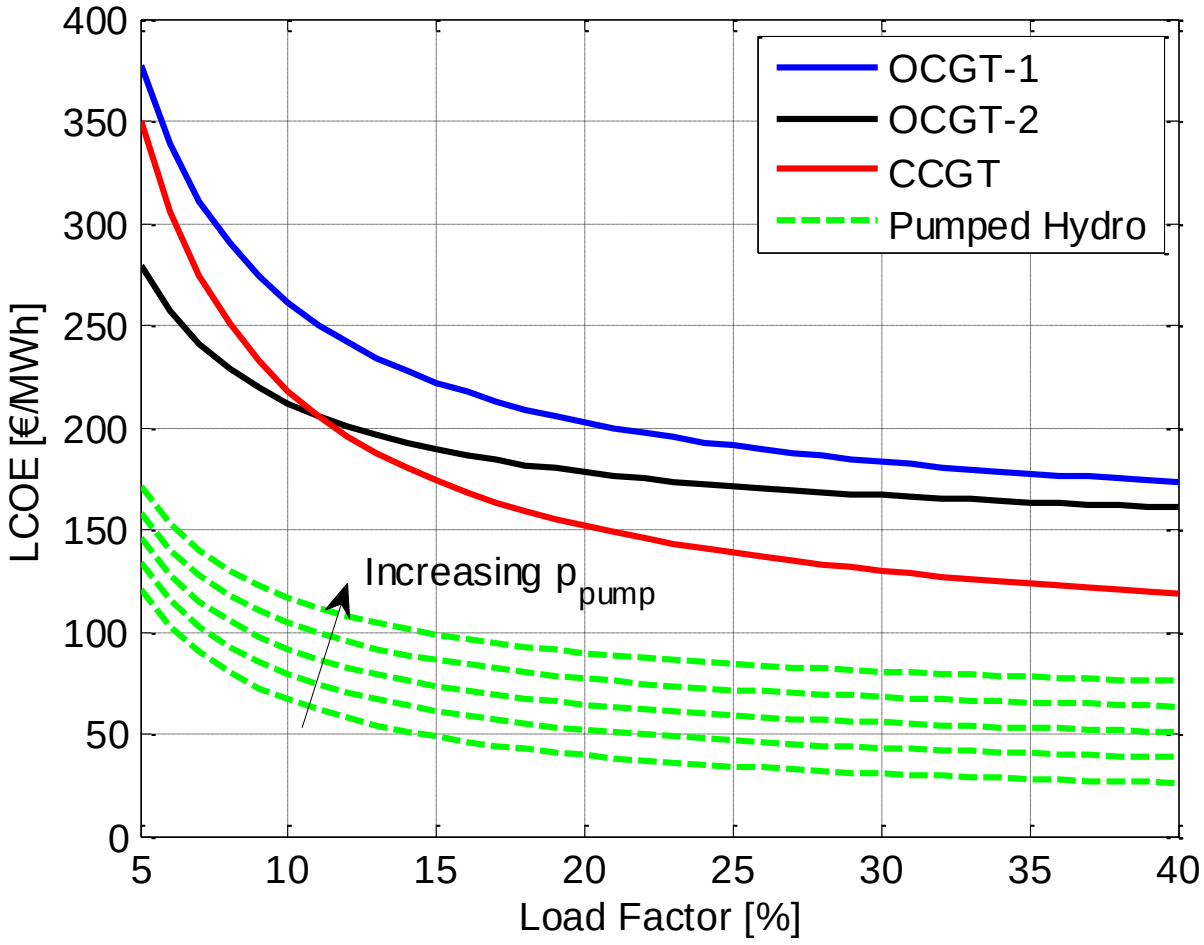
# Peak load and base load have different cost



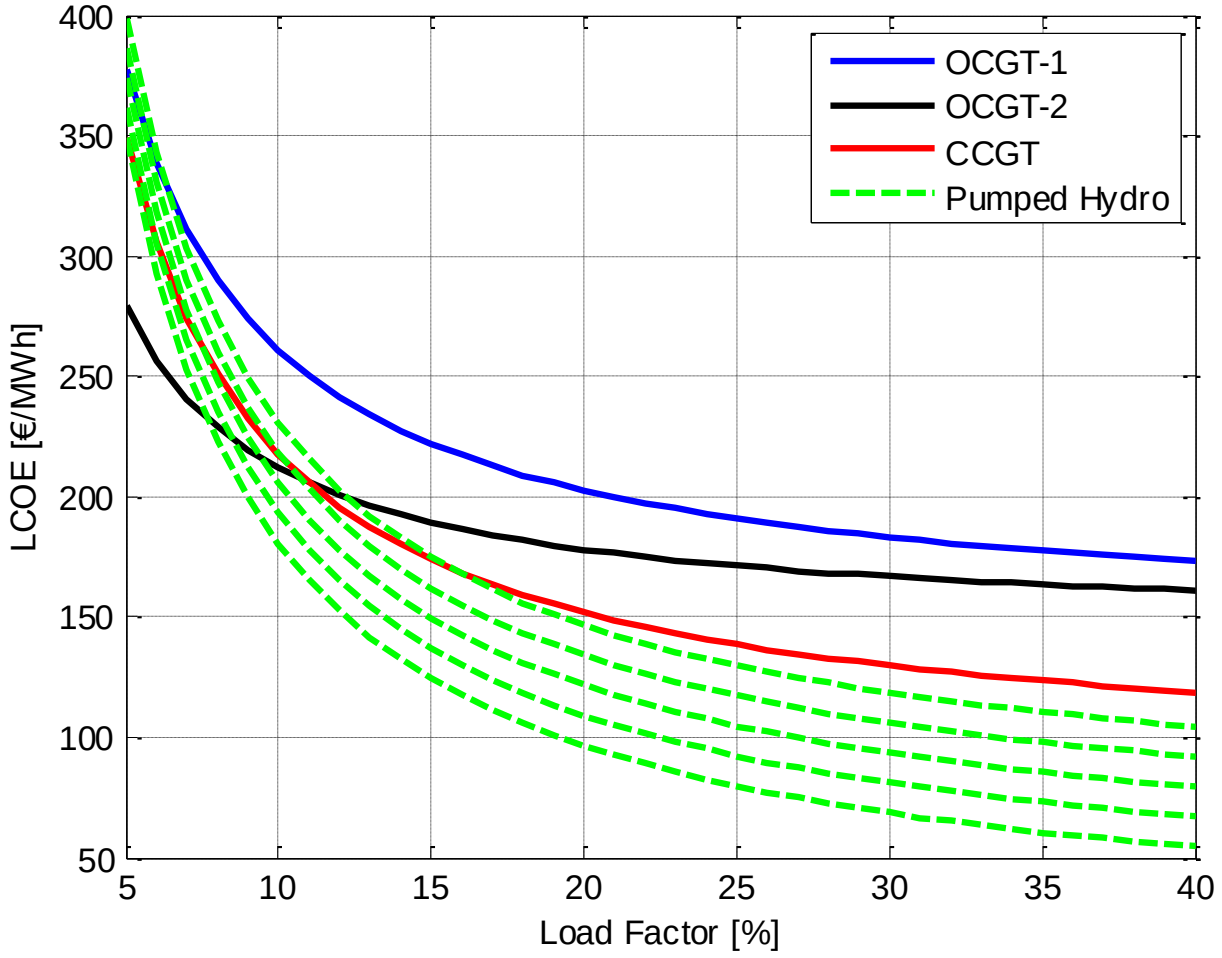
# Pumped hydro power is cost-effective for balancing in all scenarios



# Newest estimates confirms the competitivness of Norwegian pumped hydro



# Even when grid and cable costs are included



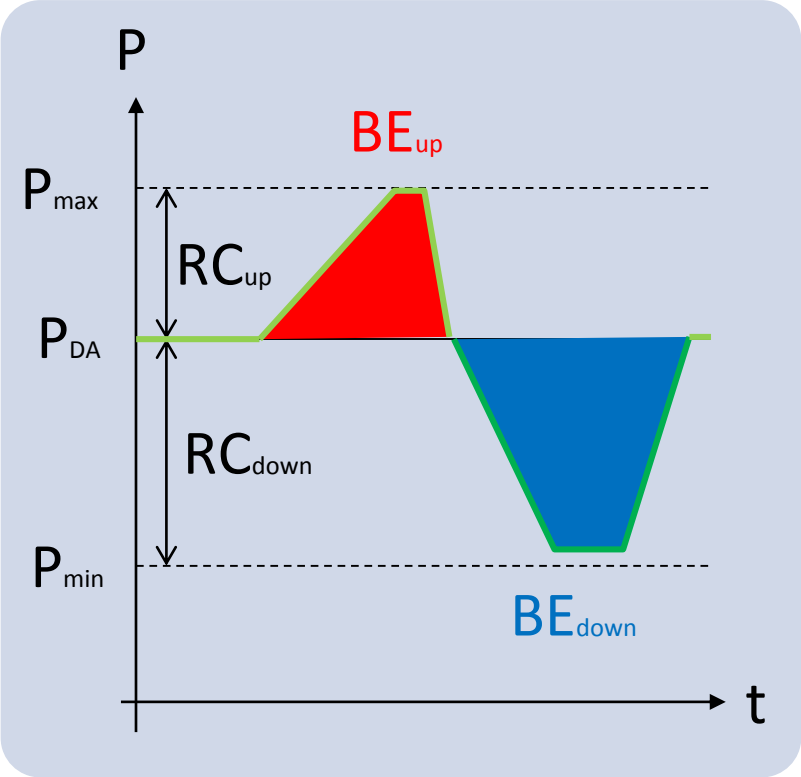
# Balancing Reserve Capacity vs Energy

**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)

# Study model 1 – Integration of balancing markets

**Fundamental model**

Detailed water course description
About 300 thermal power plants
Transmission corridors (NTC)

**Northern Europe**

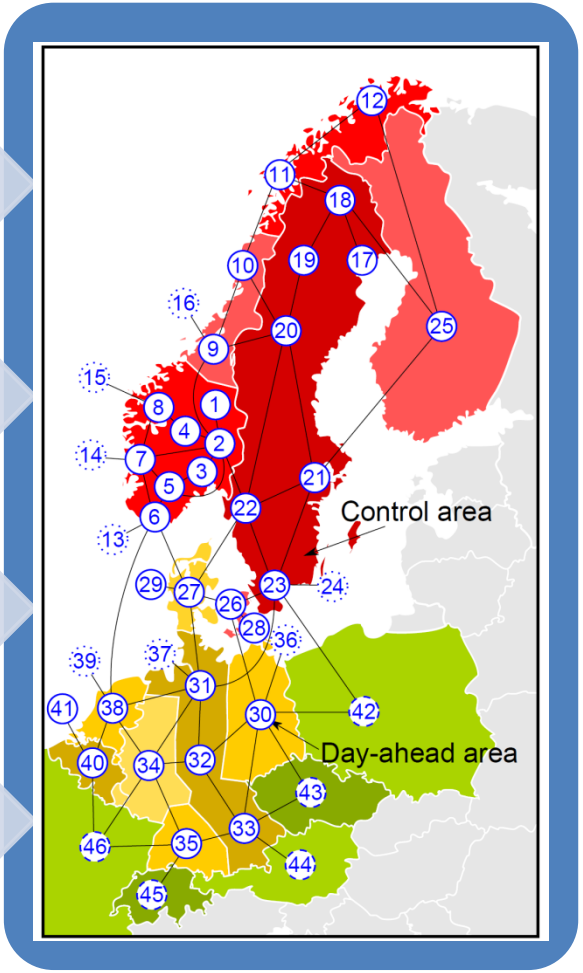
Denmark, Finland, Norway, Sweden
Germany, Netherlands, Belgium

**System scenarios**

2010 – current state of the system
2020 – a future state of the system

**Several climatic years**

Hydrology (Inflow)
Temperature
Wind speed



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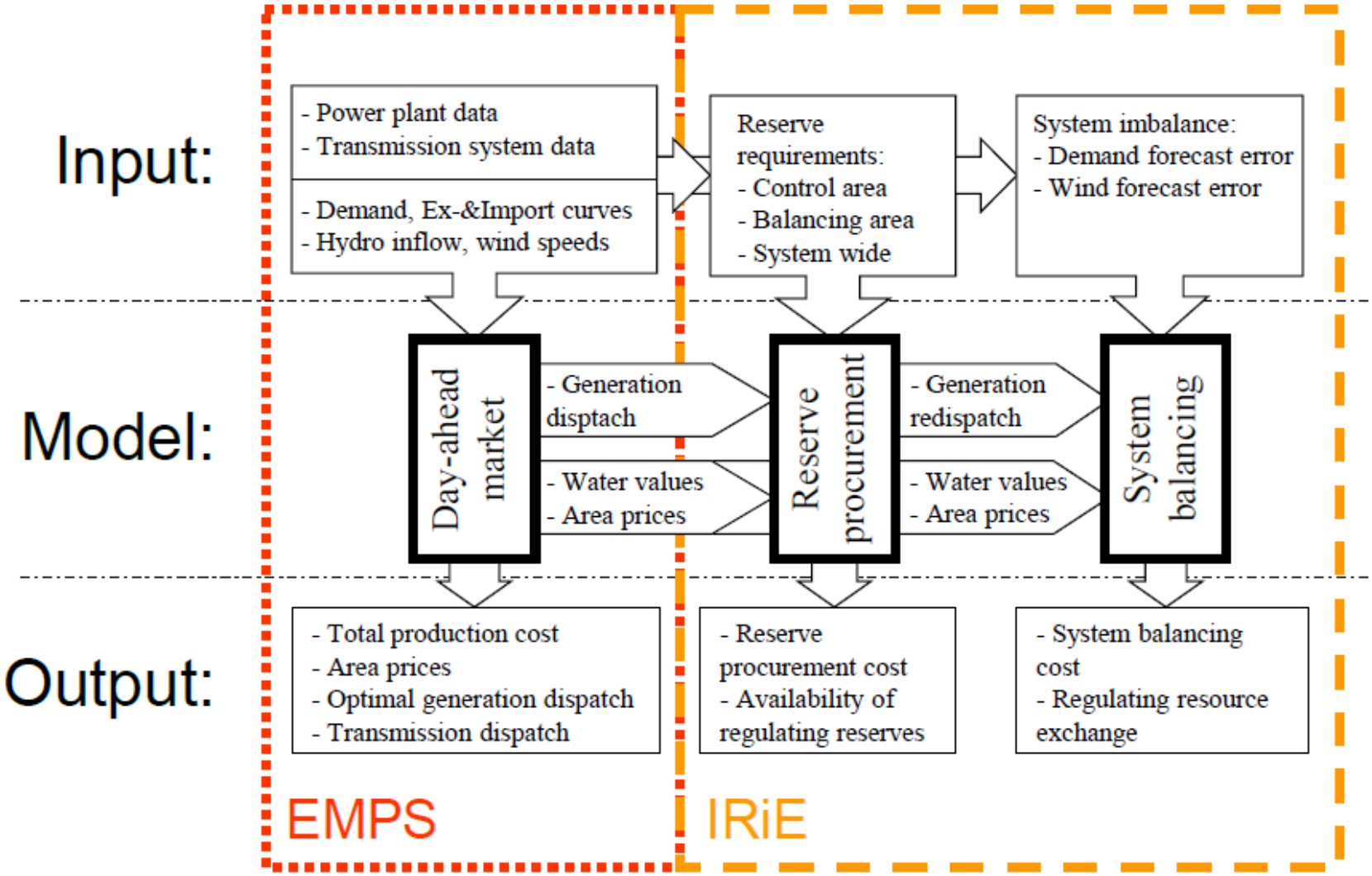
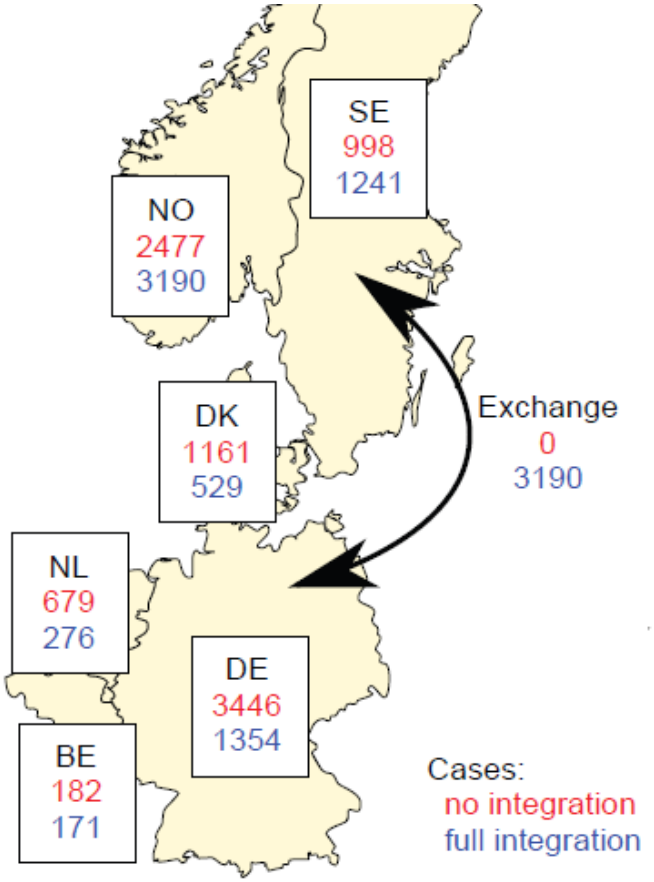


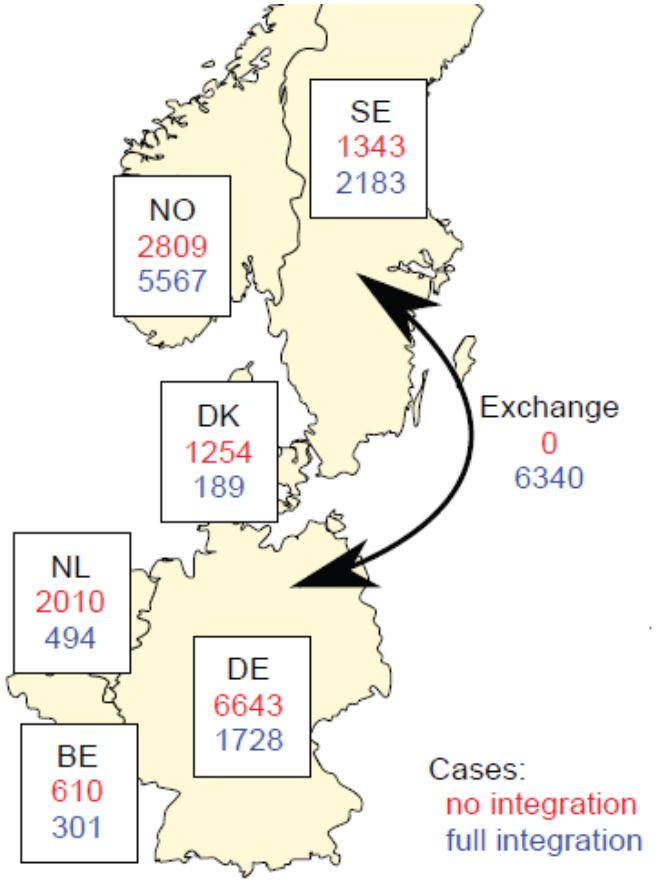

EMPS – EFI's Multi-area Power-market Simulator

IRiE – Integrated Regulating power market in Europe

# Country wise annual balancing reserve allocation (GWh/yr)




(a) 2010




(b) 2020

# Integration of balancing markets

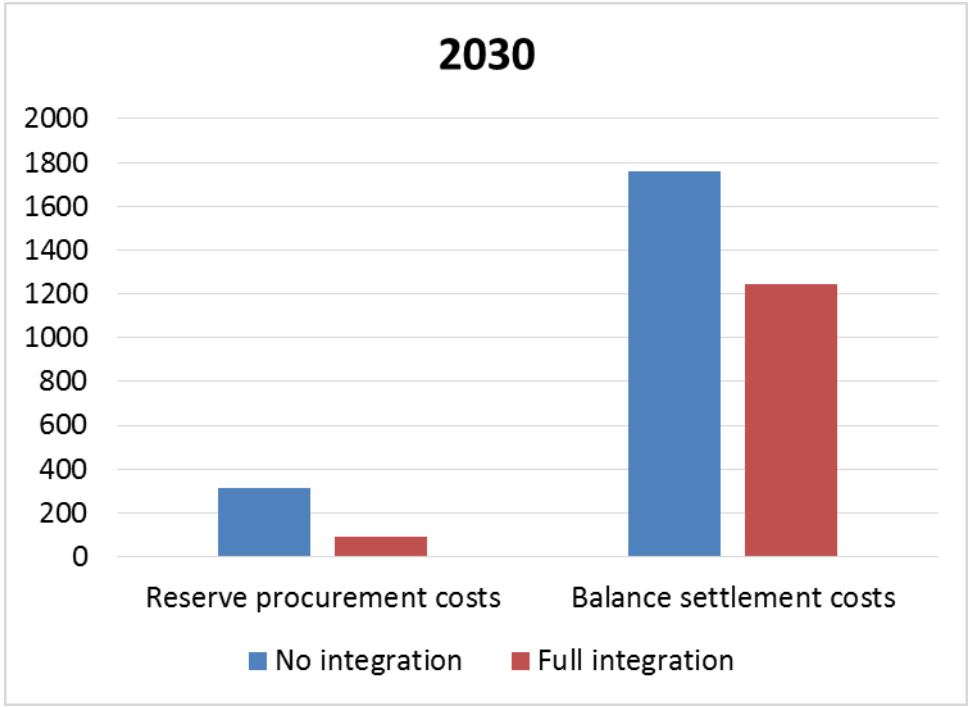
- Detailed European grid model based on DC power flow
- Representation of day-ahead, intra-day and balancing markets
- Co-optimizating day-ahead scheduels and reserve procurements based on forecasts
- Scenarios for load, generation and grid capacity year 2020 and 2030

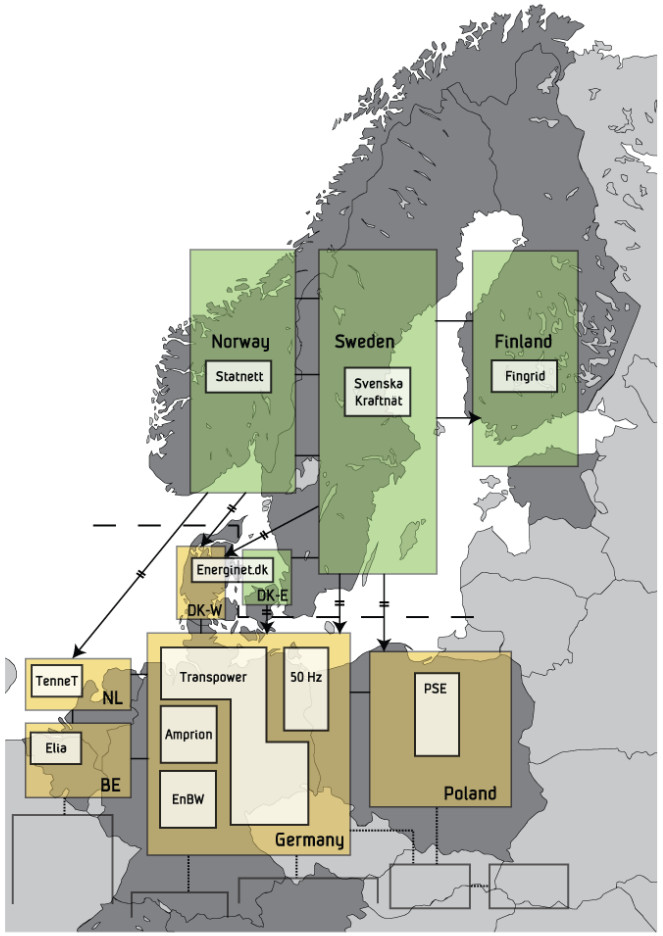



Source: Farahmand (NTNU/SINTEF)

# Large benefits of integrating the Northern and continental balancing markets

Total annual balancing cost savings (Mill.EURO)






Source: Farahmand (NTNU/SINTEF)

# Forskningsbehov?

- Dagens norske vannkraftsystem må oppgraderes for å dekke kommende behov og muligheter
- Mange anlegg går mot slutten av sin levetid
- (Re-)investeringer skal dekke behov fra nå til år 2100
  - Fra norsk «fastkraft» til fullt integrerte europeiske markeder

- *Optimistisk batteriscenario:*
  - *100 $/kWh*
- *Batterier tilsvarende norske magasiner:*
  - *60 000 Mrd NOK*

Energisalg/år

44 mrd

# 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