

Energy Storage 2014

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Flexible generation and energy storage by Norwegian hydropower to balance variable renewable energy

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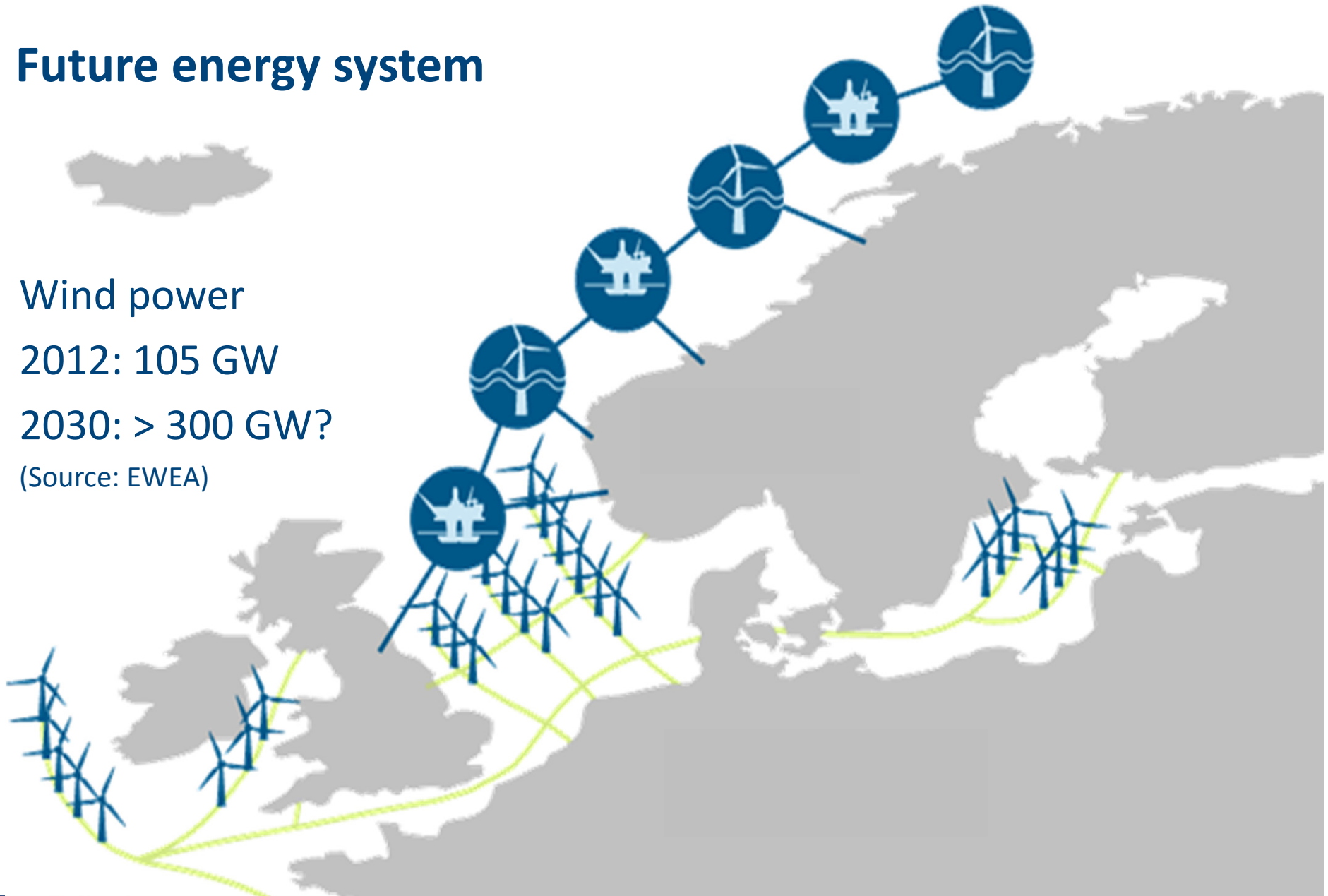
Future energy system

Wind power

2012: 105 GW

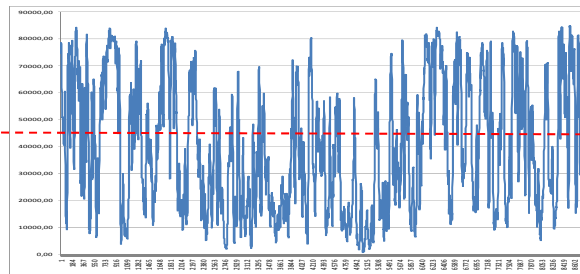
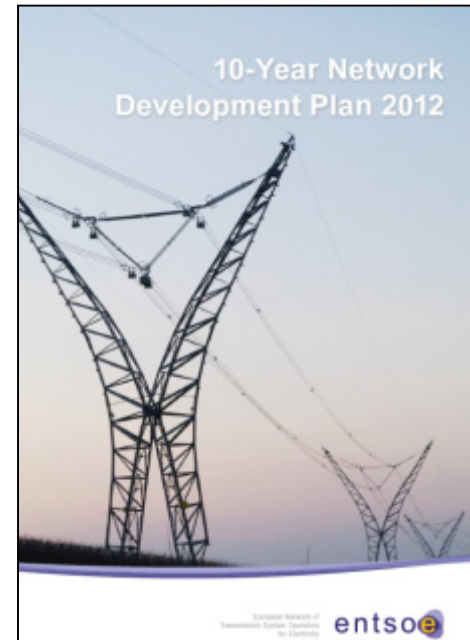
2030: > 300 GW?

(Source: EWEA)

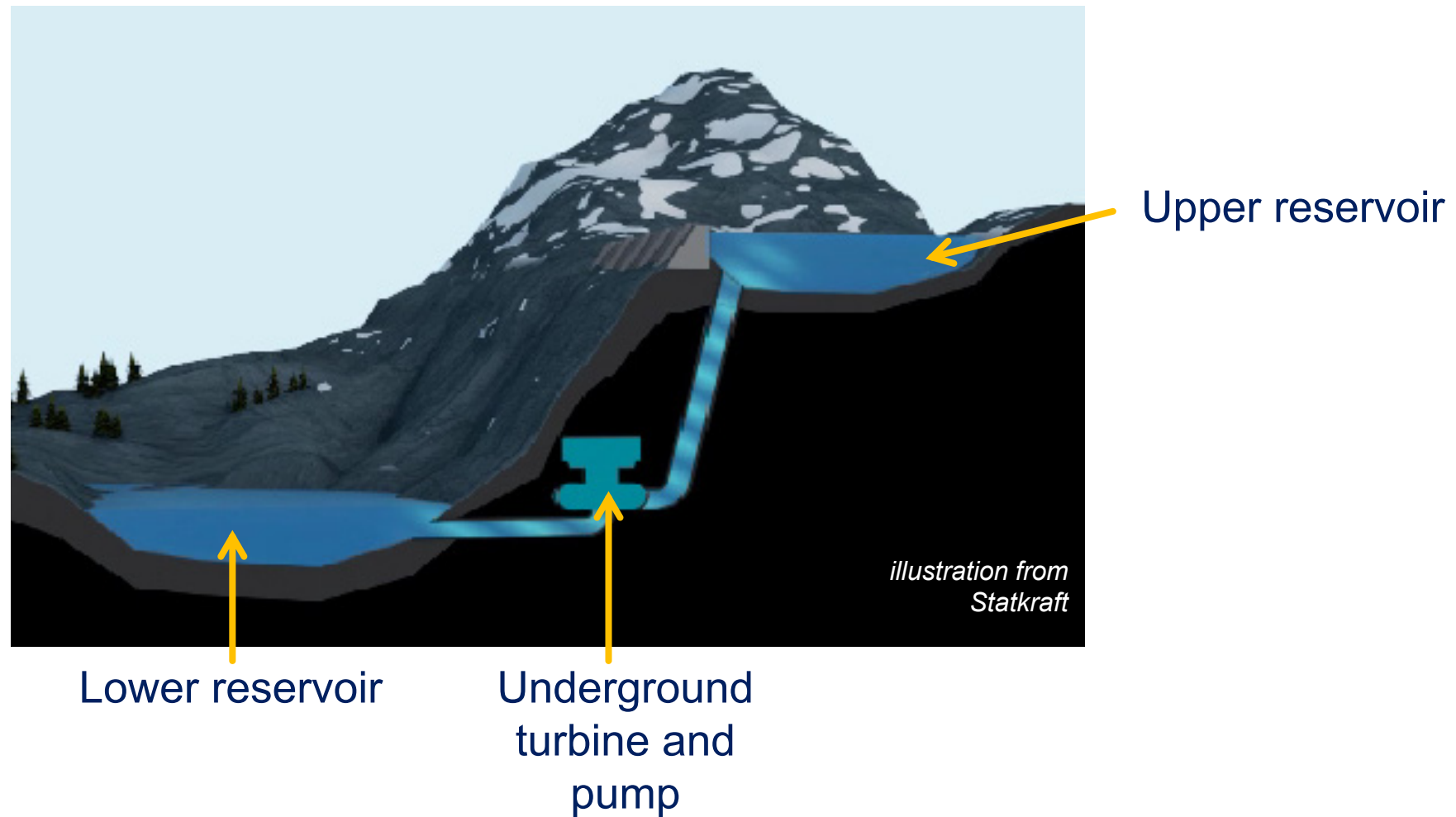


Integration of VRES

- Transmission and distribution grid expansion
- Demand side management
- Improved forecasting of resource availability
- Energy storage

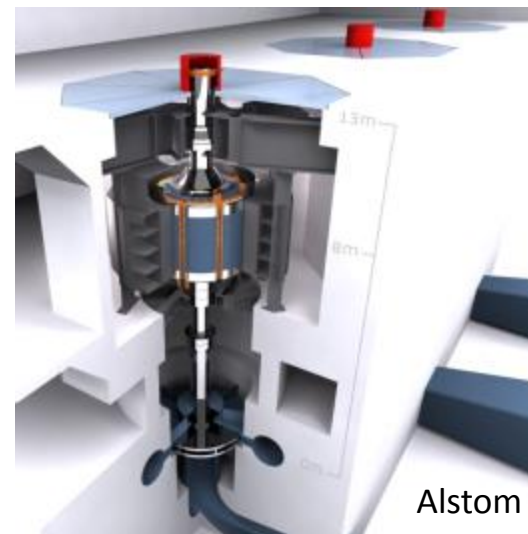
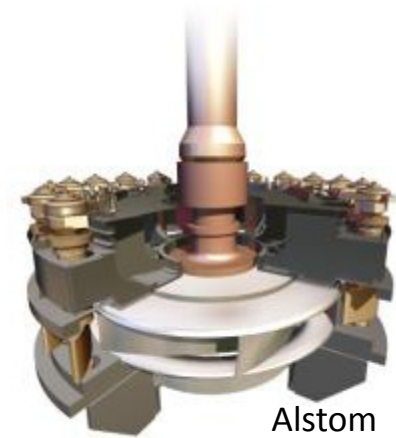


Energy balancing and storage by hydropower



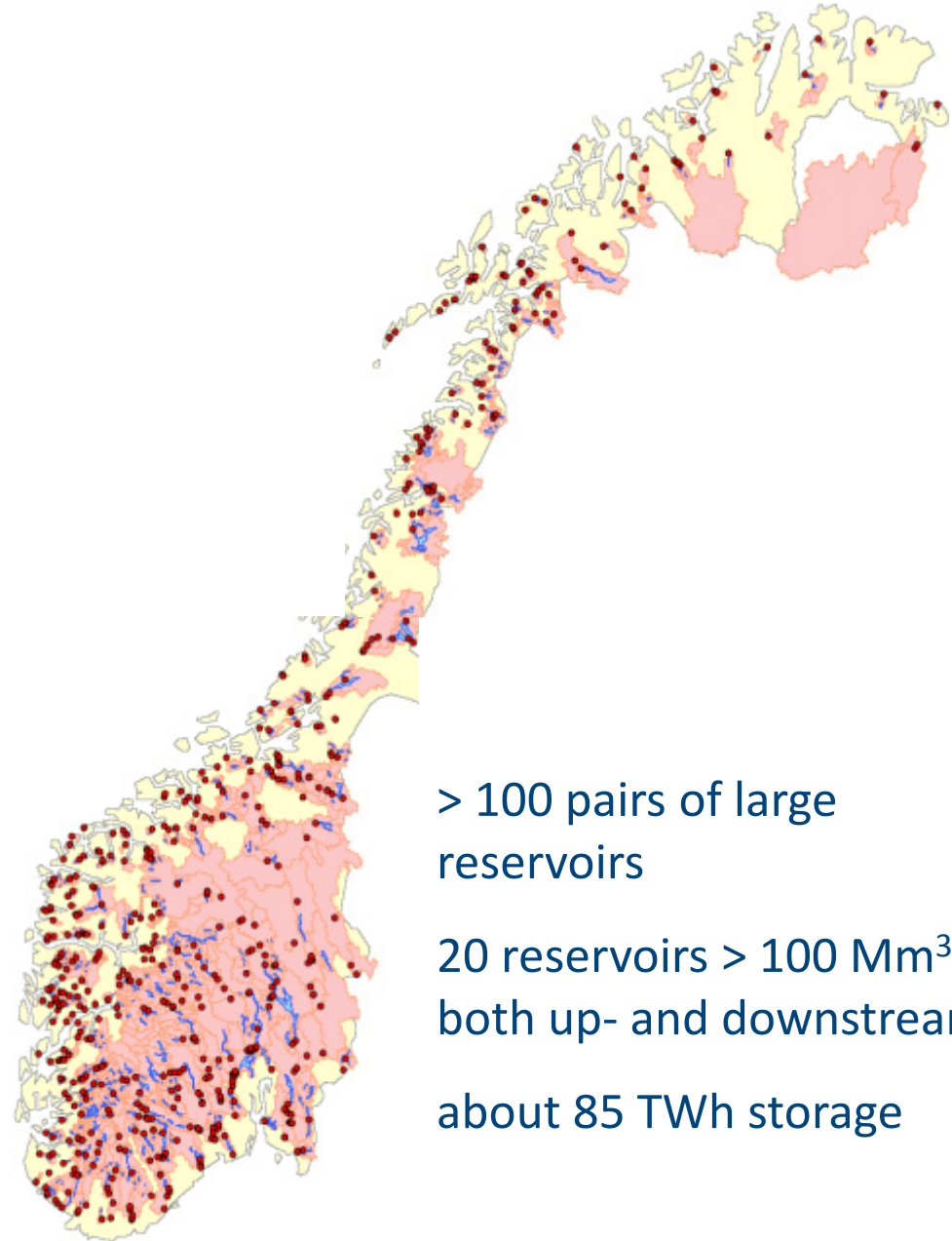
Hydropower's capability

- Closing the gap between generation and load
 - minutes to weeks
- Frequent and rapid start and stop
- Primary, secondary control and minutes reserve
- Frequency stabilization
- Voltage regulation
- Black start capability



Hydropower in Norway

- Number of reservoirs
- Storage capacity



> 100 pairs of large reservoirs

20 reservoirs > 100 Mm³
both up- and downstream

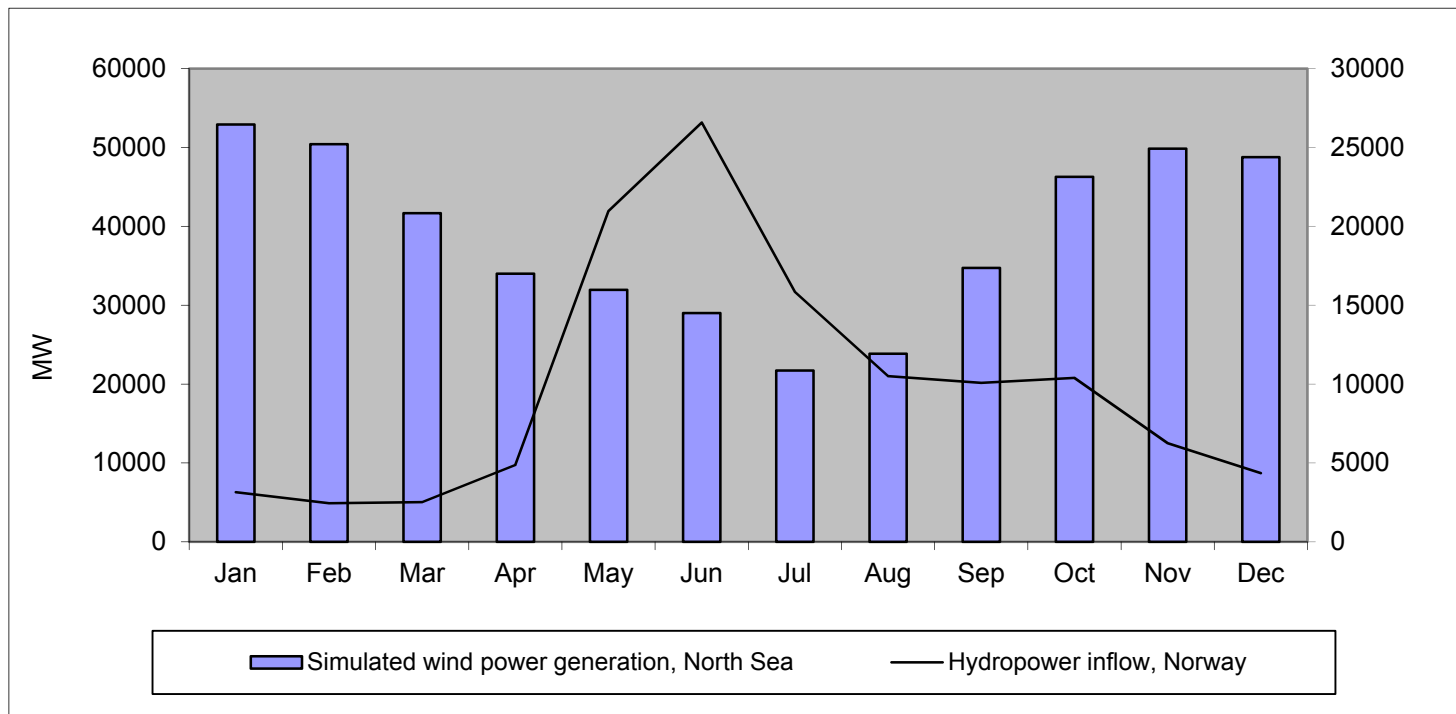
about 85 TWh storage



Hydropower in Norway

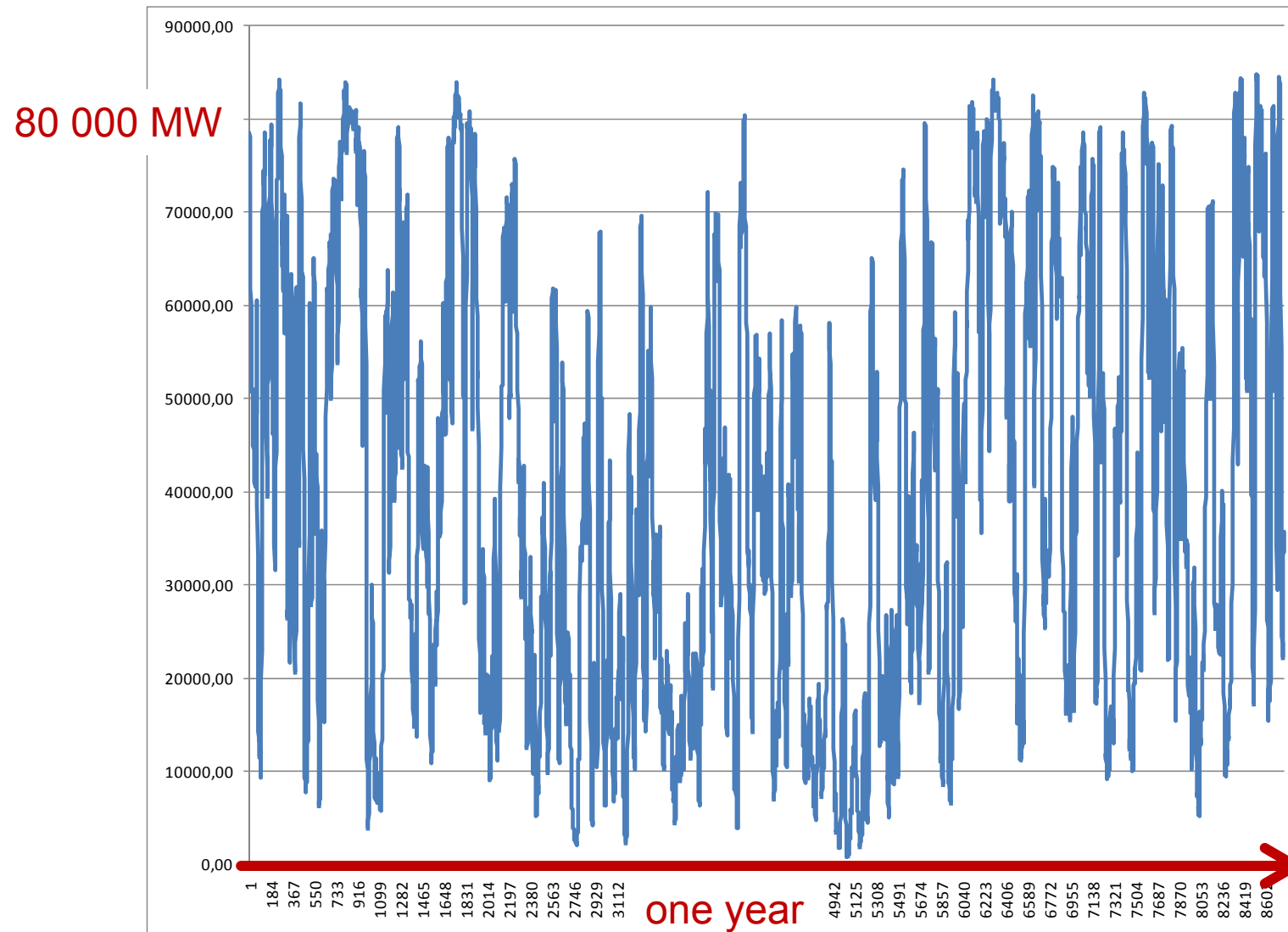
- Hydropower and wind power are complementary

Monthly average wind power generation and inflow to hydropower

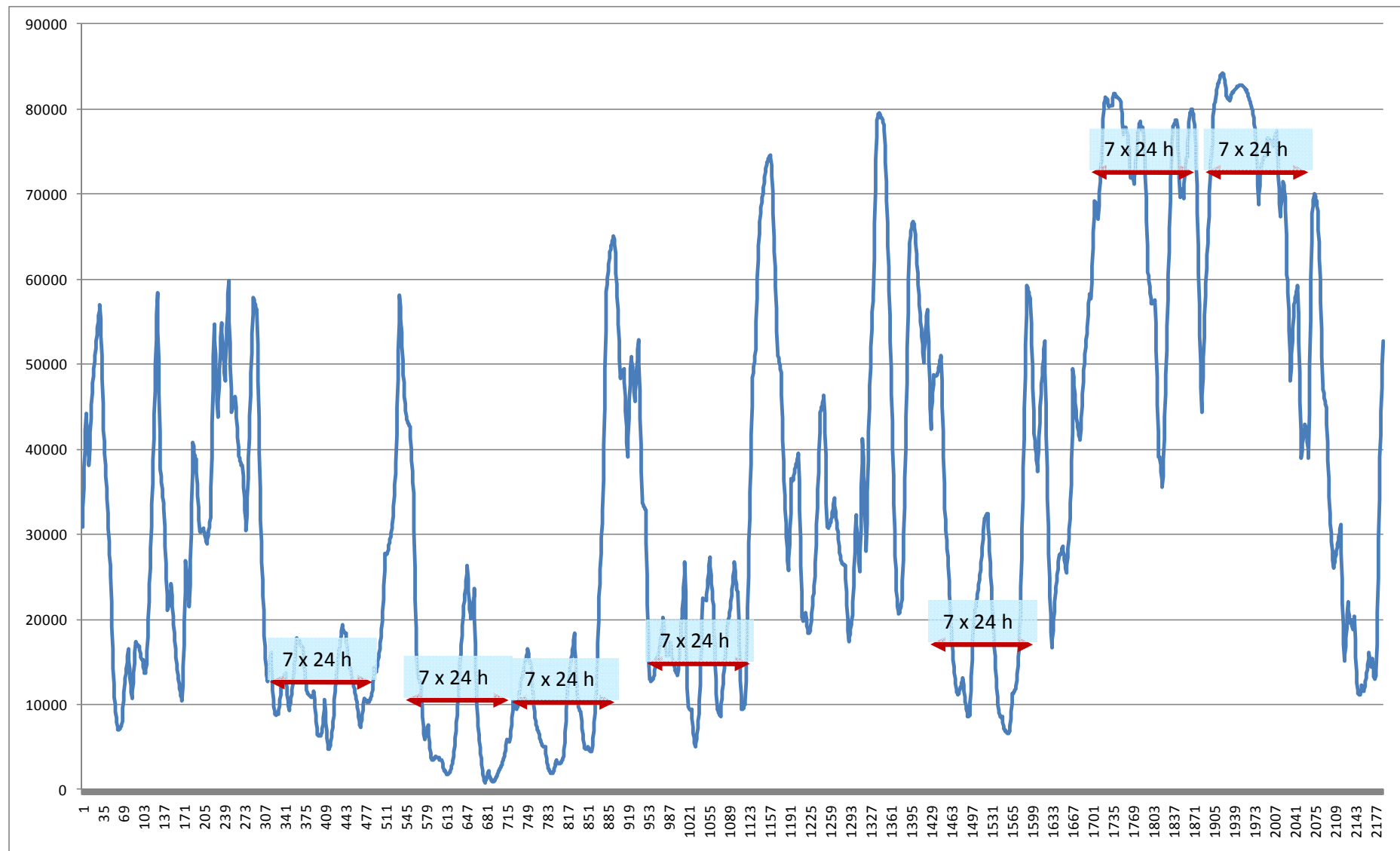


Simulated wind power production in the North Sea area in 2030

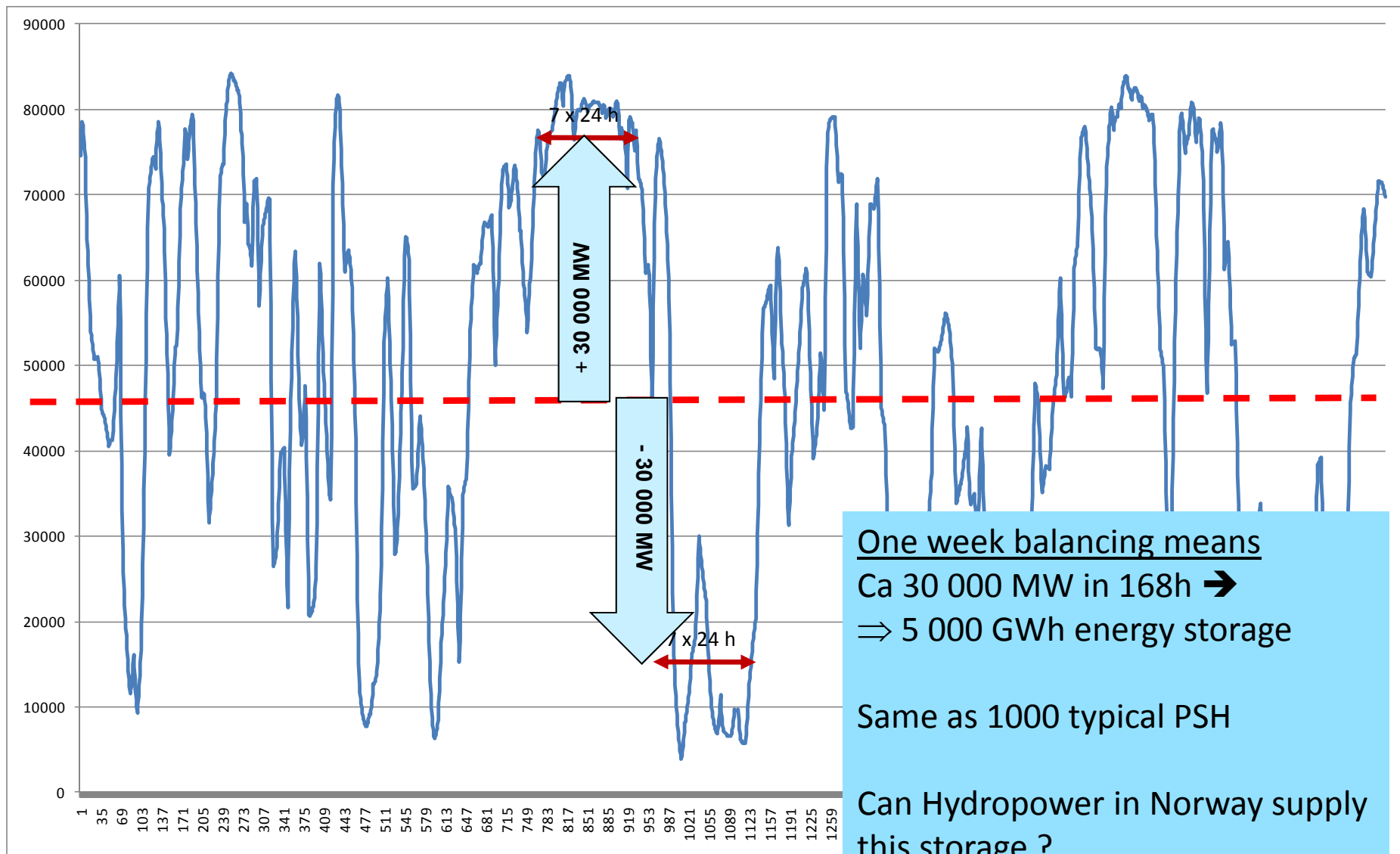
95 000 MW installed capacity



Wind power North Sea area – July-September 2001



Wind Power North Sea area – January-March 2001



One week balancing means
Ca 30 000 MW in 168h →
⇒ 5 000 GWh energy storage

Same as 1000 typical PSH

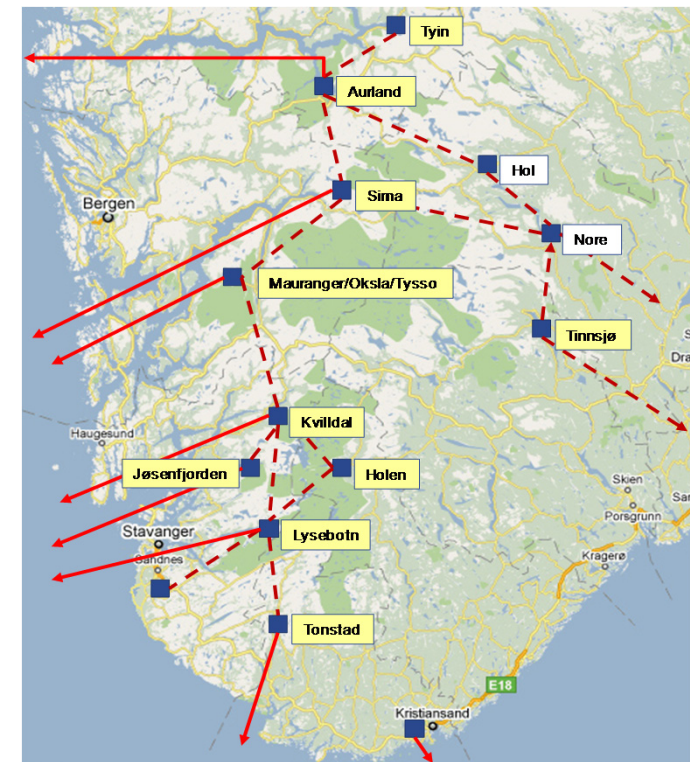
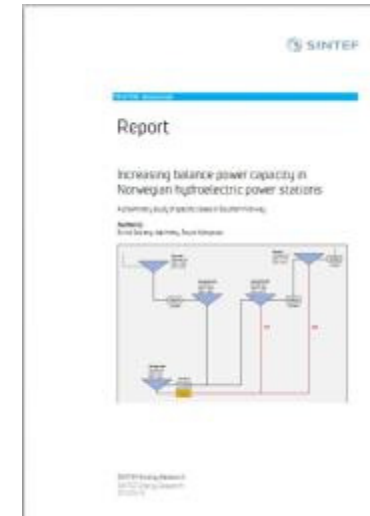
Can Hydropower in Norway supply
this storage ?

Potential in Norway

Increasing balance power capacity in
Norwegian hydroelectric power stations –
A preliminary study of specific cases in
Southern Norway

Solvang, E. et al. (2011)

- New power stations
- Hydro storage + pumped storage
- Existing reservoirs and dams
- Outlet into reservoir or fjord/sea
- 20.000 MW possible by 2030

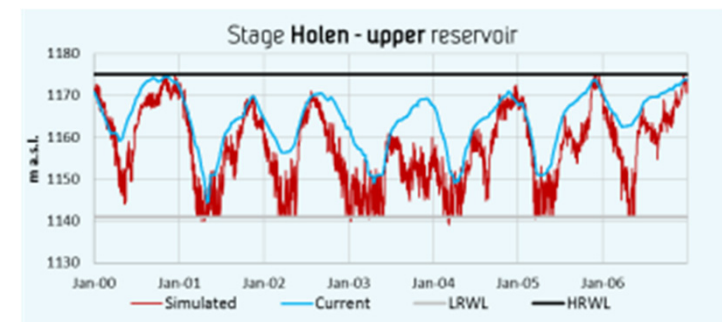
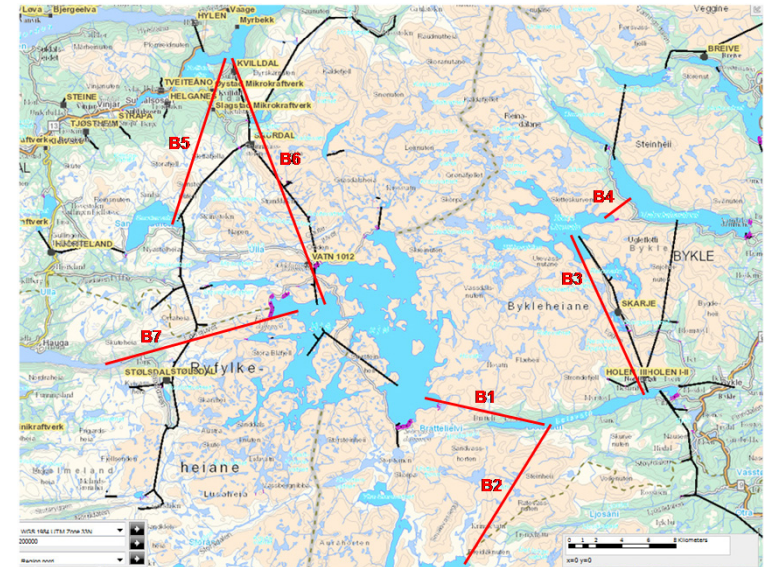


Potential in Norway

Norwegian hydropower for large-scale electricity balancing needs

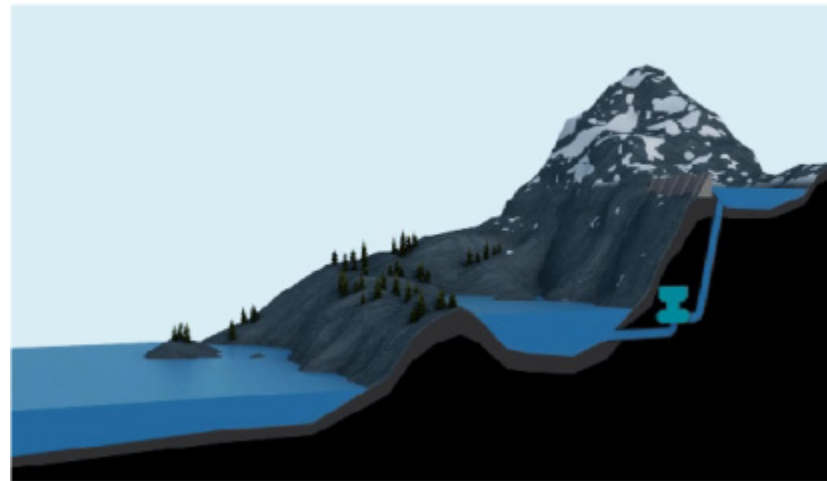
Solvang, E. et al. (2014)

- Implications for reservoir operation
- Water level fluctuations in reservoirs, three specific pumped storage cases
- Season, frequency, rate of change
- Analysis of public acceptance based on stakeholder interviews



Why using hydropower?

- Flexibility: Storage across entire time scale
- Most economic means of energy storage on large scale
- High efficiency (about 80 %)
- Various types of flexibility and balancing services
- Established technology

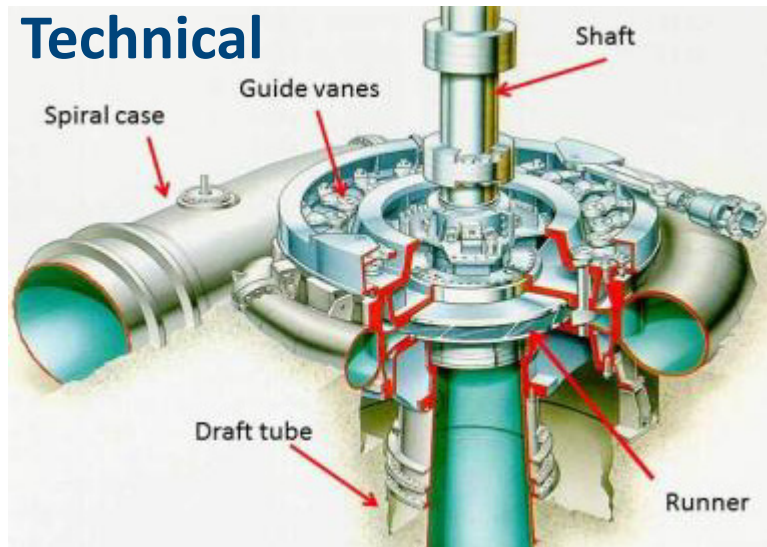


Hydro storage –
a renewable battery



Challenges

Technical



Economic



Environmental



Societal



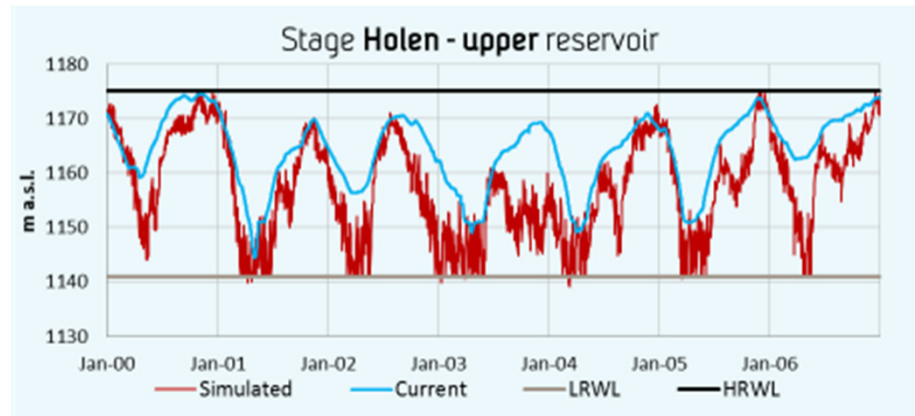
HydroBalance Project



- Scenarios for different futures of the Norwegian hydro system until 2050
- Analyses, simulations and case studies of
 - energy system
 - energy market
 - environmental impacts
 - regulatory framework and public acceptance

Environmental impacts

Water level fluctuations



Erosion



Water temperature

Ice



Aquatic life

Recreation

Societal and economic aspects

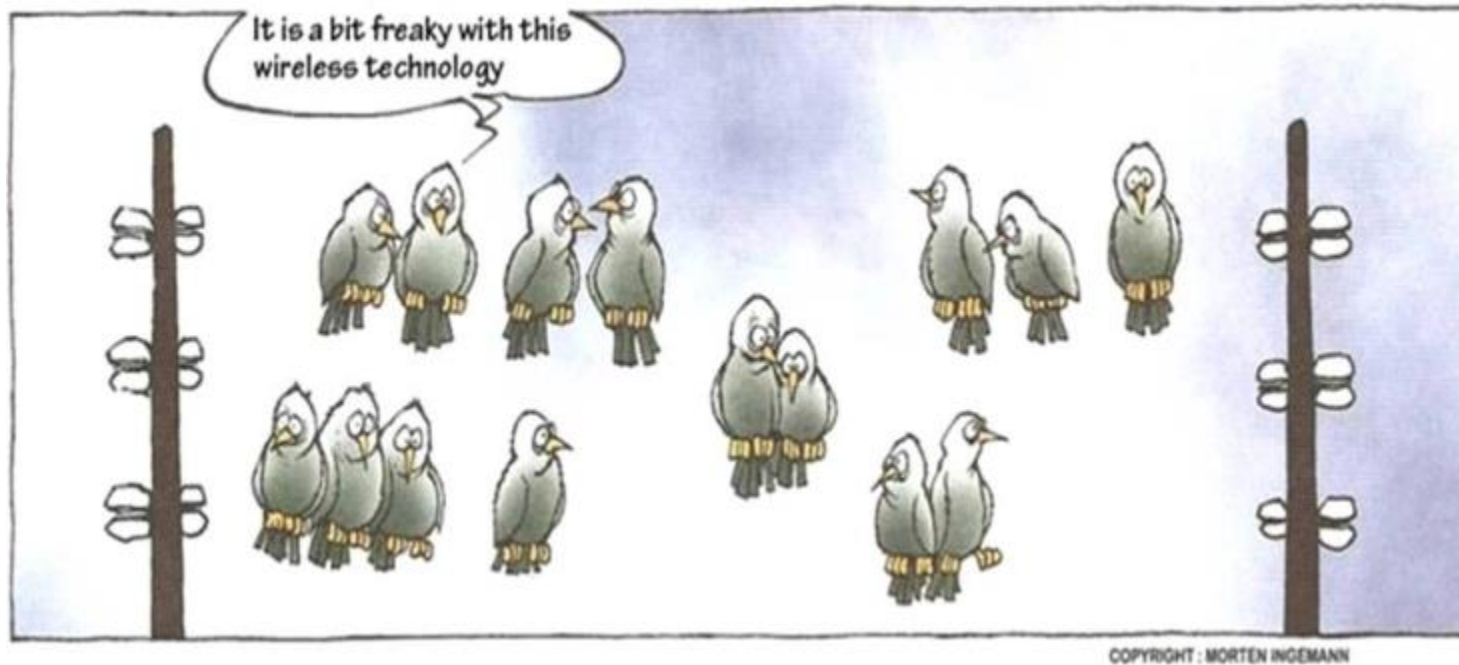
- Policy, regulatory framework
- Public acceptance
- Local value creation
- Job opportunities



Opposition against constructions and their impacts



Conclusions



- Uncertain future – many scenarios
- Rapid changes may come (...Fukushima...)
- Hydro reservoirs = excellent energy storage
- We probably need governmental agreements and new markets



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