European grid development and hydro balancing potential
Increasing RES share needs

- System integration
- Flexible generation
- Grid extension (transmission and distribution)
- Energy storage (different scales)
Hydro storage

- Use of existing power stations
- Upgrade and re-licensing
- New hydropower equipment
- Environmental design
Pumped storage

Upper reservoir

Lower reservoir

Underground turbine and pump

Illustration from Statkraft
Installed PSH world-wide: ca. 140 GW

In operation

Project stage

Courtesy from Rioual, EdF

CEDREN Centre for Environmental Design of Renewable Energy
Goldisthal, Germany

1060 MW
12 Mio m³
8.5 GWh
Typical operational strategy
Indirect storage

Δ Generation - Δ load:
11 500 - 6 200 = 5 300 MW of balancing

Source: Jan Hystad, Statnett
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
- 11 200 MW possible by 2020
European grid development in the coming decade

- Larger and more volatile power flows over larger distances across Europe
- 100 Bottlenecks in 2020 (unless new transmission assets are built) due to
  - Market integration
  - Generation connection
  - Security of supply
- 80% due to RES integration
- Evaluation of investments into transmission line projects until 2022

Grid development until 2022

- 52,300 km high voltage routes:
  - 12 600 km HVDC (10,500 km subsea/inland cables)
  - 39 400 km HVAC (1,500 km subsea/inland cables)
  - 82 % new, 18 % upgrade

- Over-all investment costs:
  - 104 billion Euro, of which subsea cables 23 billion Euro
  - Highest in Germany (30 bill Euro) and the UK (19 billion Euro)
Transmission projects until 2016
Northern Europe

TYNDP 2012 - Projects of pan-European significance (2012 - 2016)
Legend
- Substation, Upgrade
- Substation, New
- DC line, New
- 150kV line, New
- 220kV line, New
- 220kV line, Upgrade
- 330kV line, Upgrade
- 330kV line, New
- 400kV line, New
- 400kV line, Upgrade

Source: ENTSO-E (2012) TYNDP
Transmission projects 2017-2022
Northern Europe

TYNDP 2012 - Projects of pan-European significance (2017 - 2022)

Legend
- Substation, Upgrade
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Source: ENTSO-E (2012) TYNDP
Transmission projects until 2016 – Southern Europe

Source: ENTSO-E (2012) TYNDP
Transmission projects 2017-2022 – Southern Europe

Source: ENTSO-E (2012) TYNDP
Transmission capacity abroad

- **NO-Sweden**
  - North/Mid-Norway: 1 100 MW
  - South-Norway: 2 050 MW

- **NO-Denmark**
  - SK1-3: 950 MW
  - SK4: 700 MW (2014)

- **NO-Netherlands**
  - NorNed1 (NL): 700 MW
  - NorNed2 (NL): 700 MW

- **NO-Germany**
  - NORD.LINK: 1 400 MW (2018)

- **NO-England**
  - 1 400 MW (2020)

Possible interconnection capacity in 2020:

4 800 + 4 200 = 9 000 MW

Sources: Statnett Nettutviklingsplan 2011, ENTSO-E, TYNDP 2012
Conclusions

- Tow main axes of power flow implicating grid development:
  - North-South (RES integration)
  - East-West (market integration)
- Hydro reservoirs = excellent resource for balancing and storage
- Grid extension required
- Main challenges in
  
  Environment
  - Climate, ecosystem

  Economy
  - Market, viability

  Social acceptance
  - Participation, transparency