HydroBalance Kick-off Meeting

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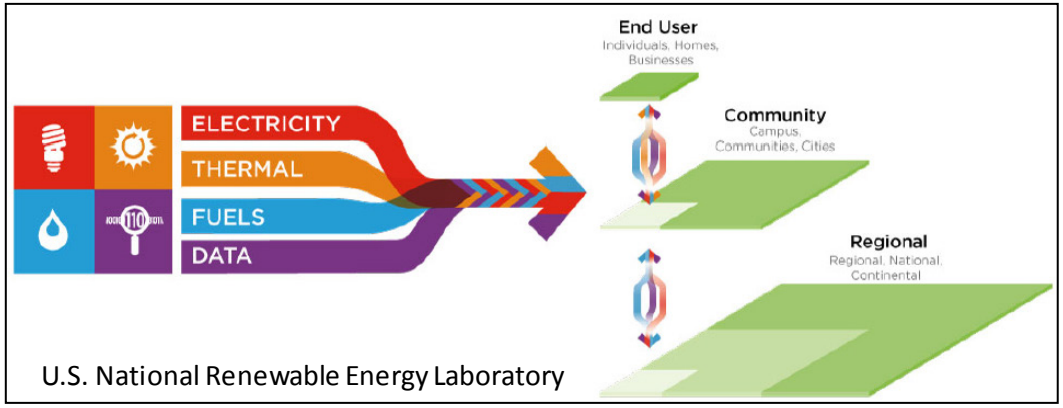
Trondheim, 23/10/2013

European grid development and hydro balancing potential

Increasing RES share needs

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



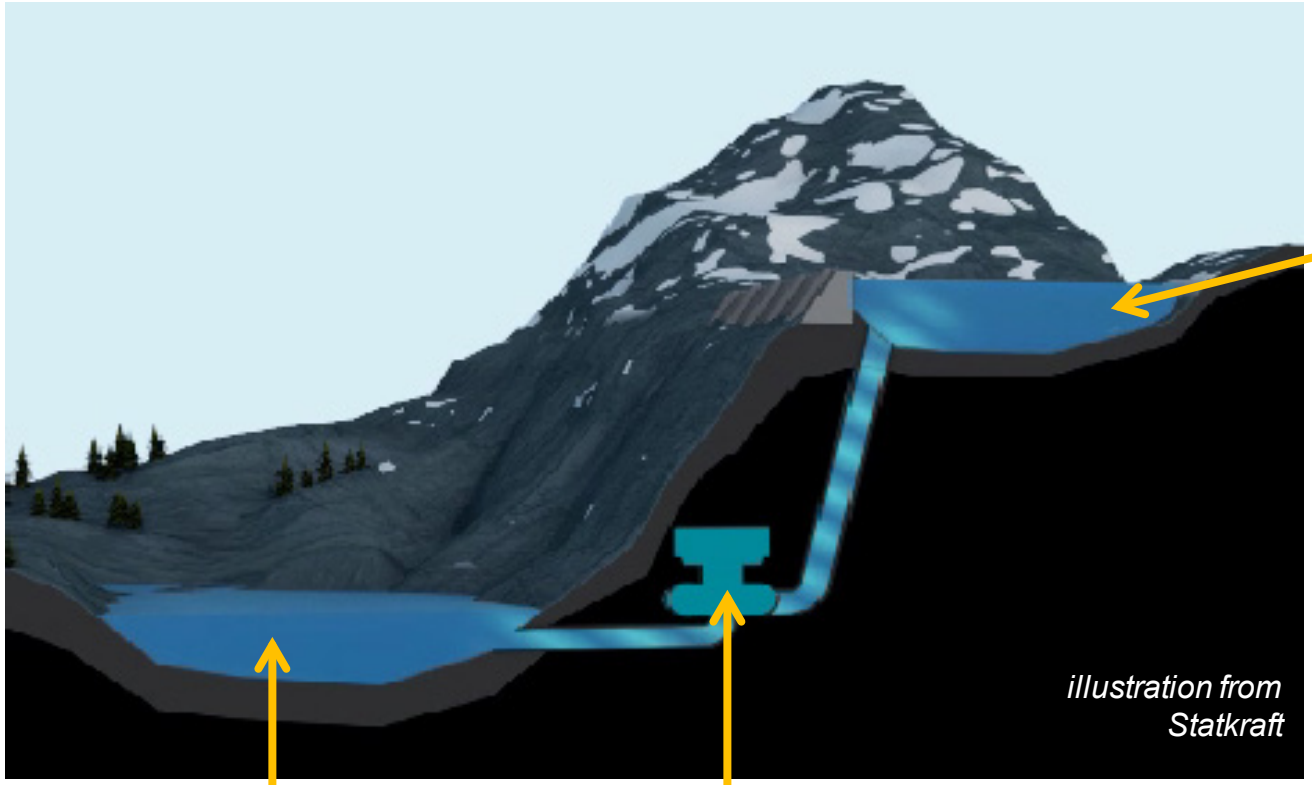
U.S. National Renewable Energy Laboratory

Hydro storage

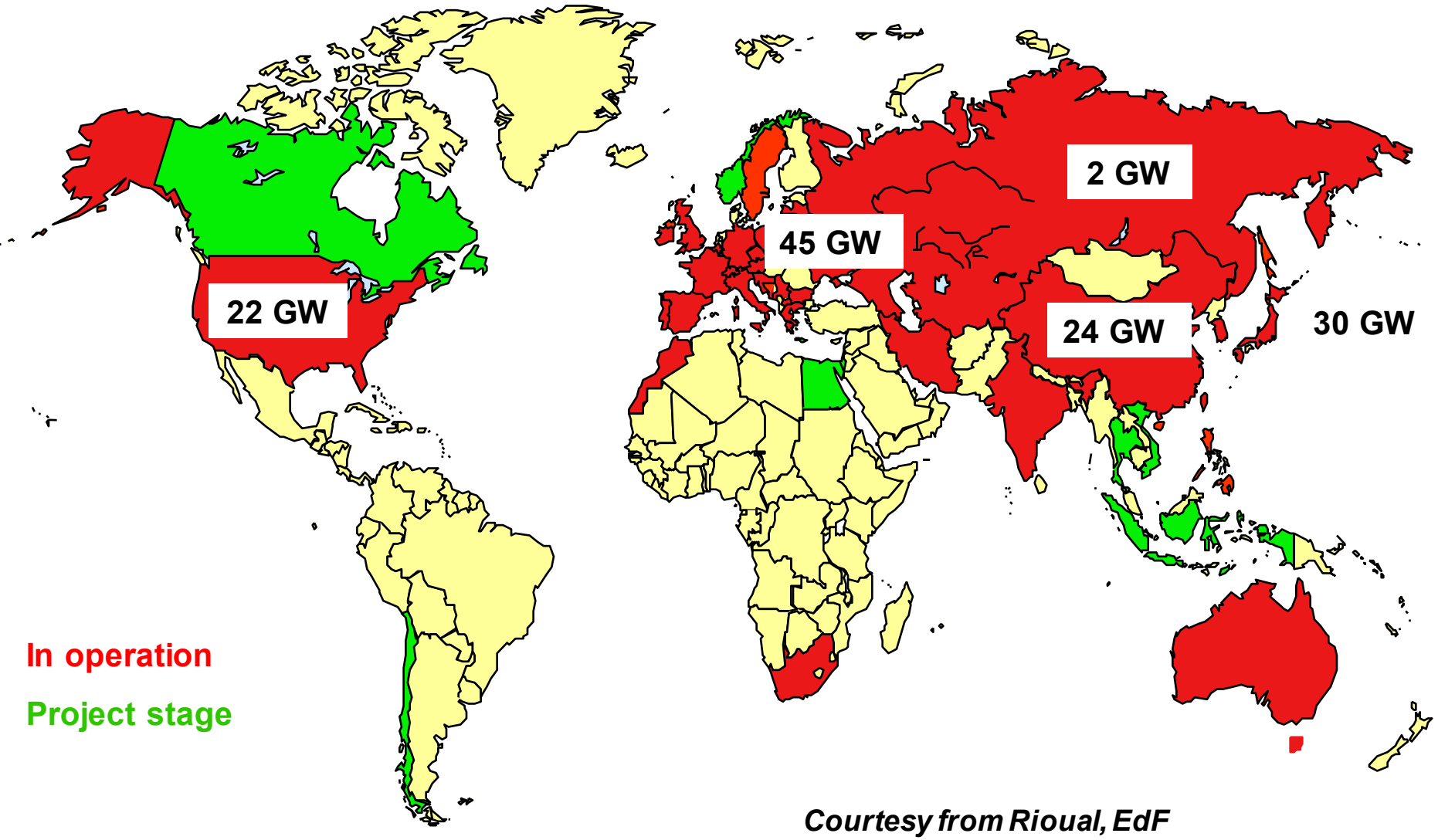
- Use of existing power stations
- Upgrade and re-licensing
- New hydropower equipment
- Environmental design

Photo: Statkraft

Pumped storage

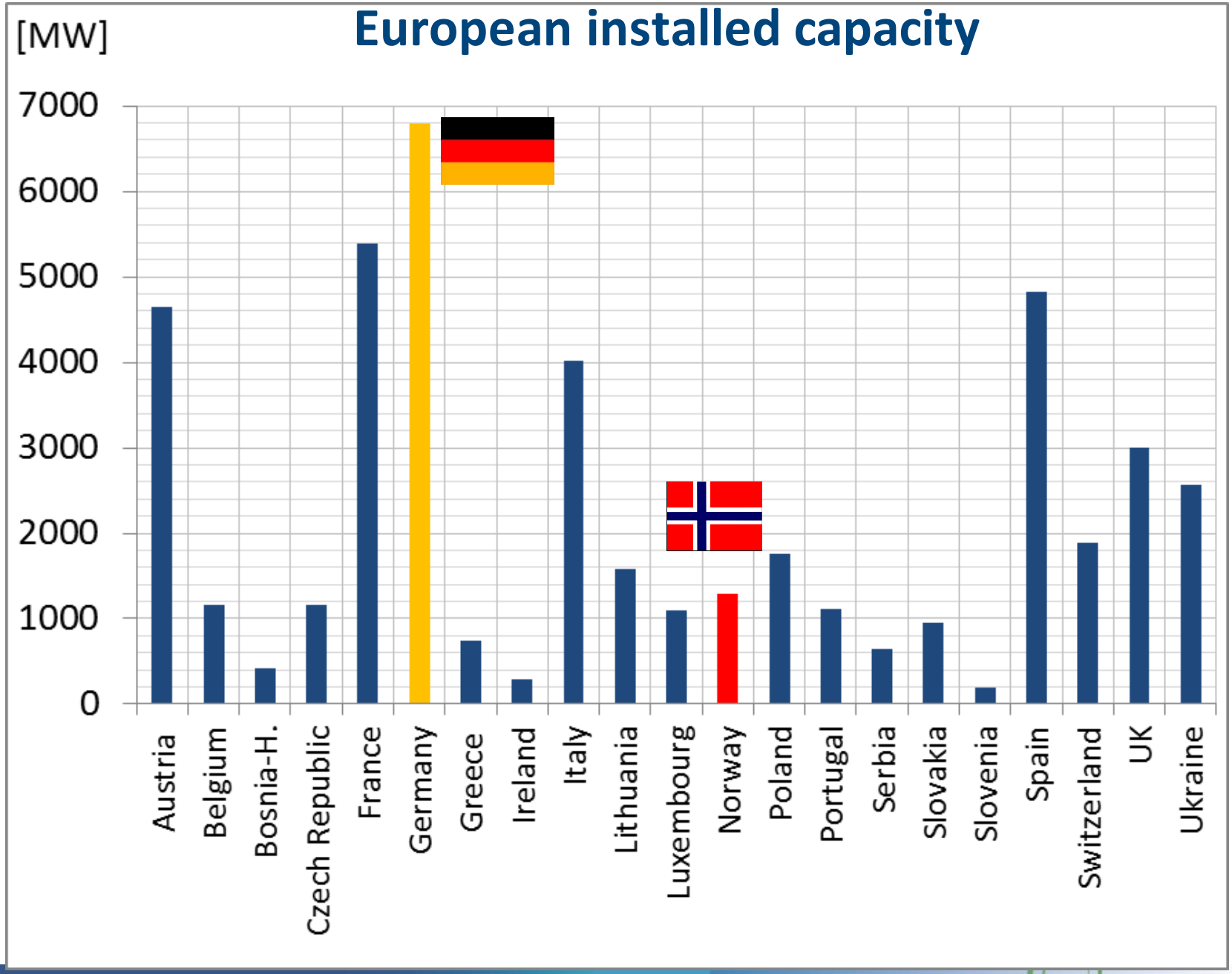


Installed PSH world-wide: ca. 140 GW



Courtesy from Rioual, EdF

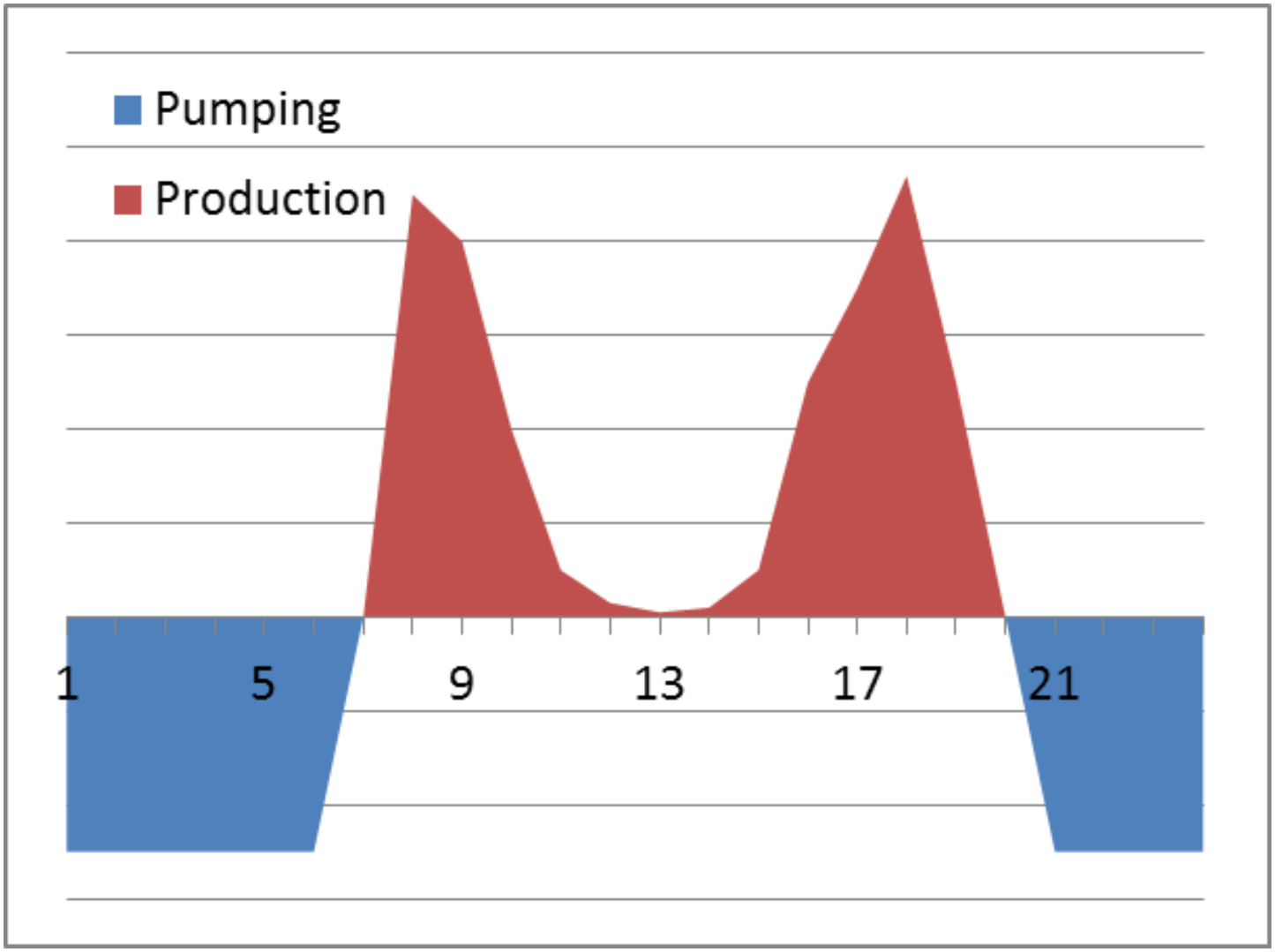
European installed capacity



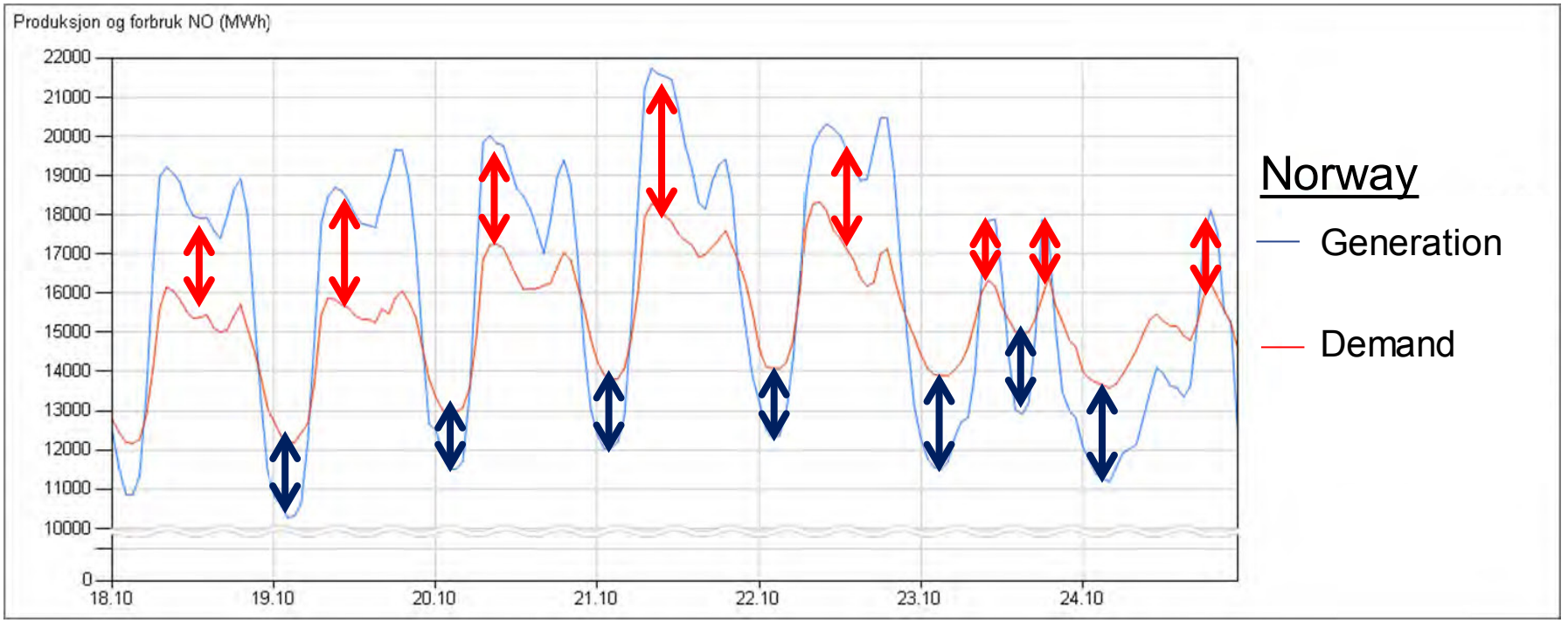
Goldisthal, Germany

1060 MW
12 Mio m^3
8.5 GWh

Typical operational strategy



Indirect storage



Source: Jan Hystad, Statnett

Export

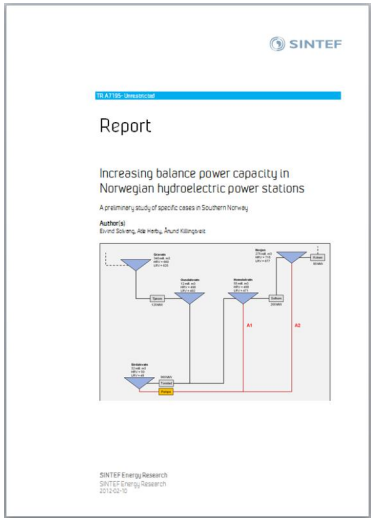
Import

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

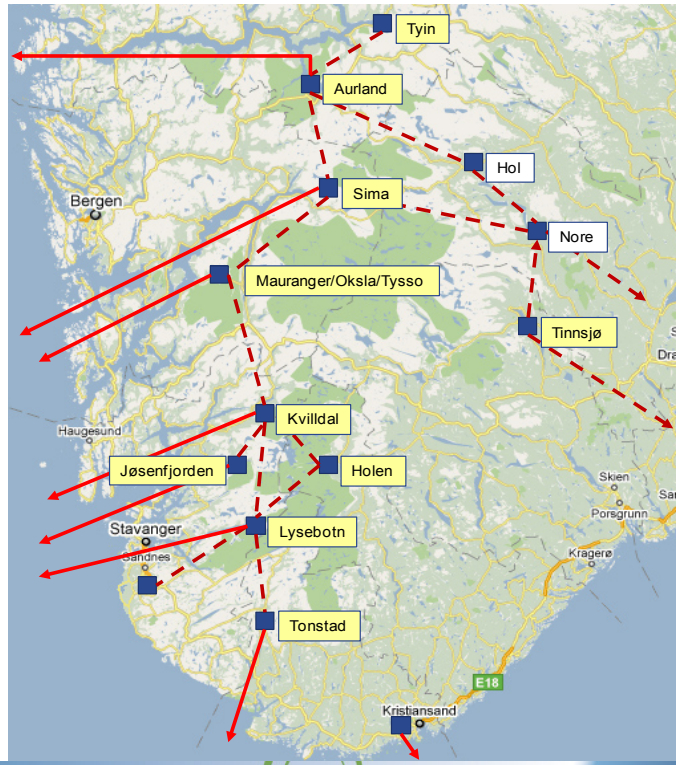
Potential in Norway

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

Solvang, E. et al. (2011)

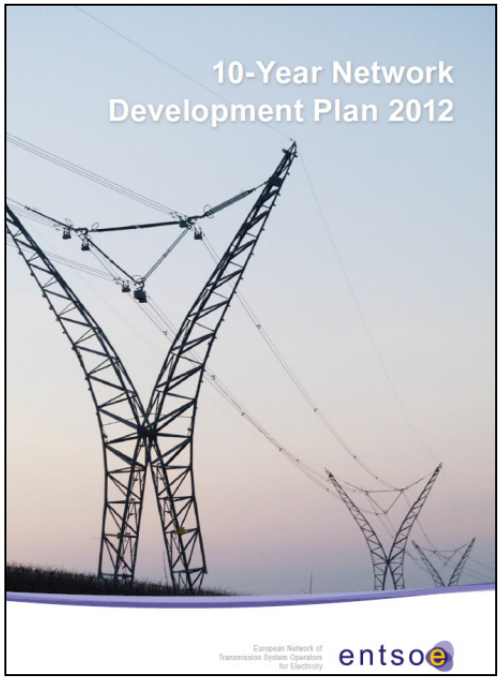


- New power stations
- Hydro storage + pumped storage
- Existing reservoirs and dams
- Outlet into reservoir or fjord/sea
- 11 200 MW possible by 2020



European grid development in the coming decade

- Larger and more volatile power flows over larger distances across Europe
- 100 Bottlenecks in 2020 (unless new trans-mission 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



Source: ENTSO-E (European Network of Transmission System Operators for Electricity, available at https://www.entsoe.eu/major-projects/ten-year-network-development-plan/tyndp-2012/

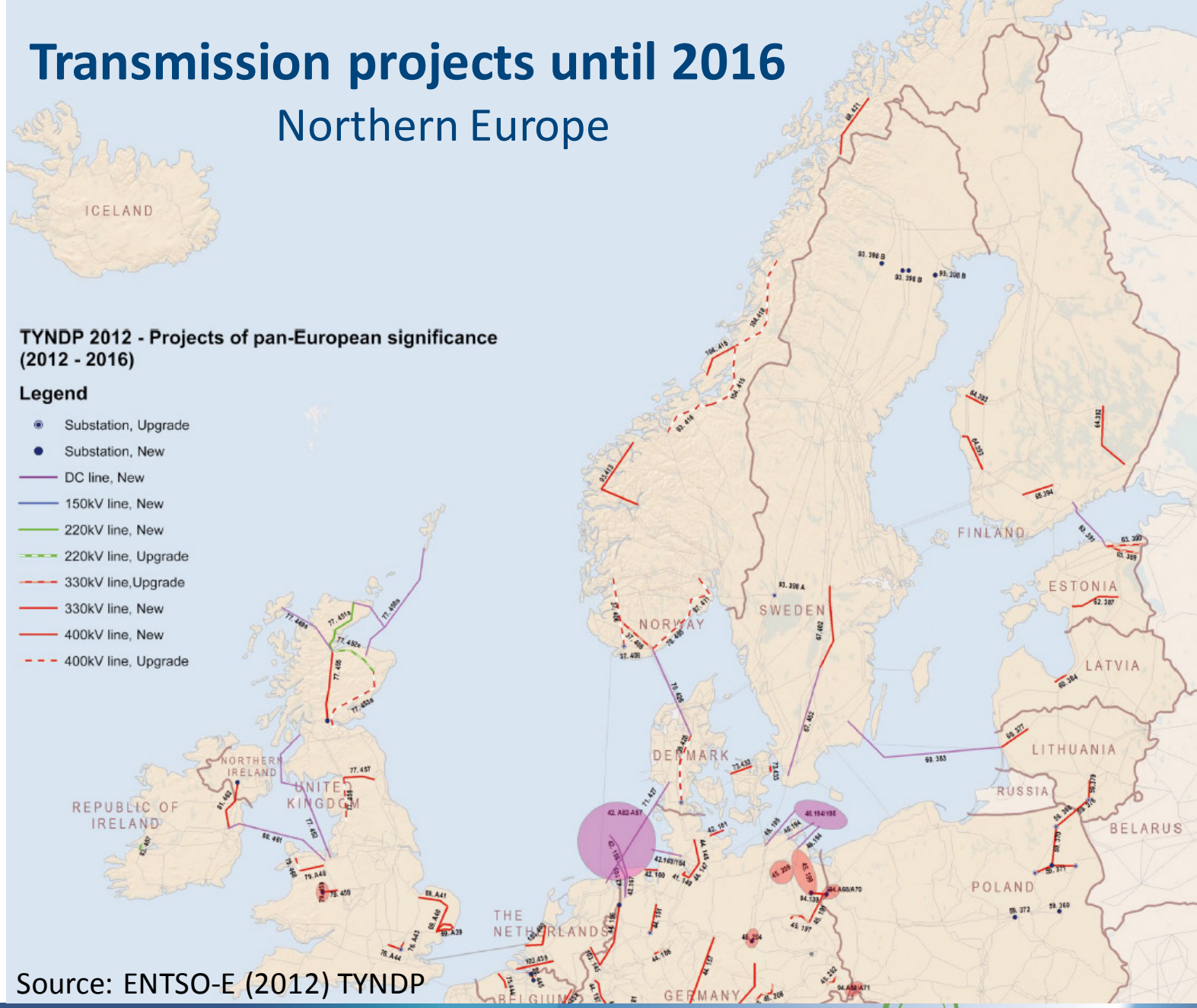
Grid development until 2022

- 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

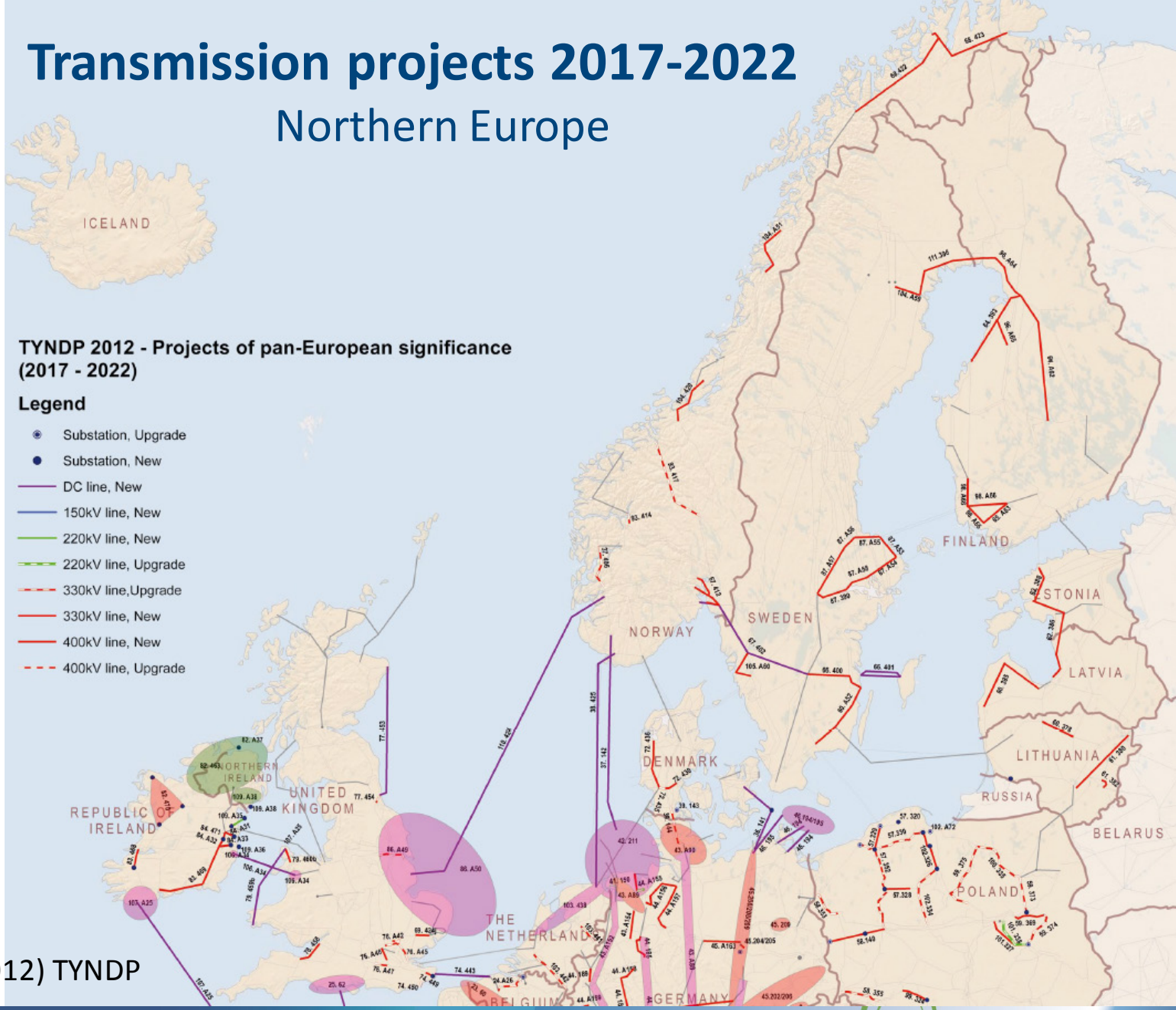
Northern Europe



Source: ENTSO-E (2012) TYNDP

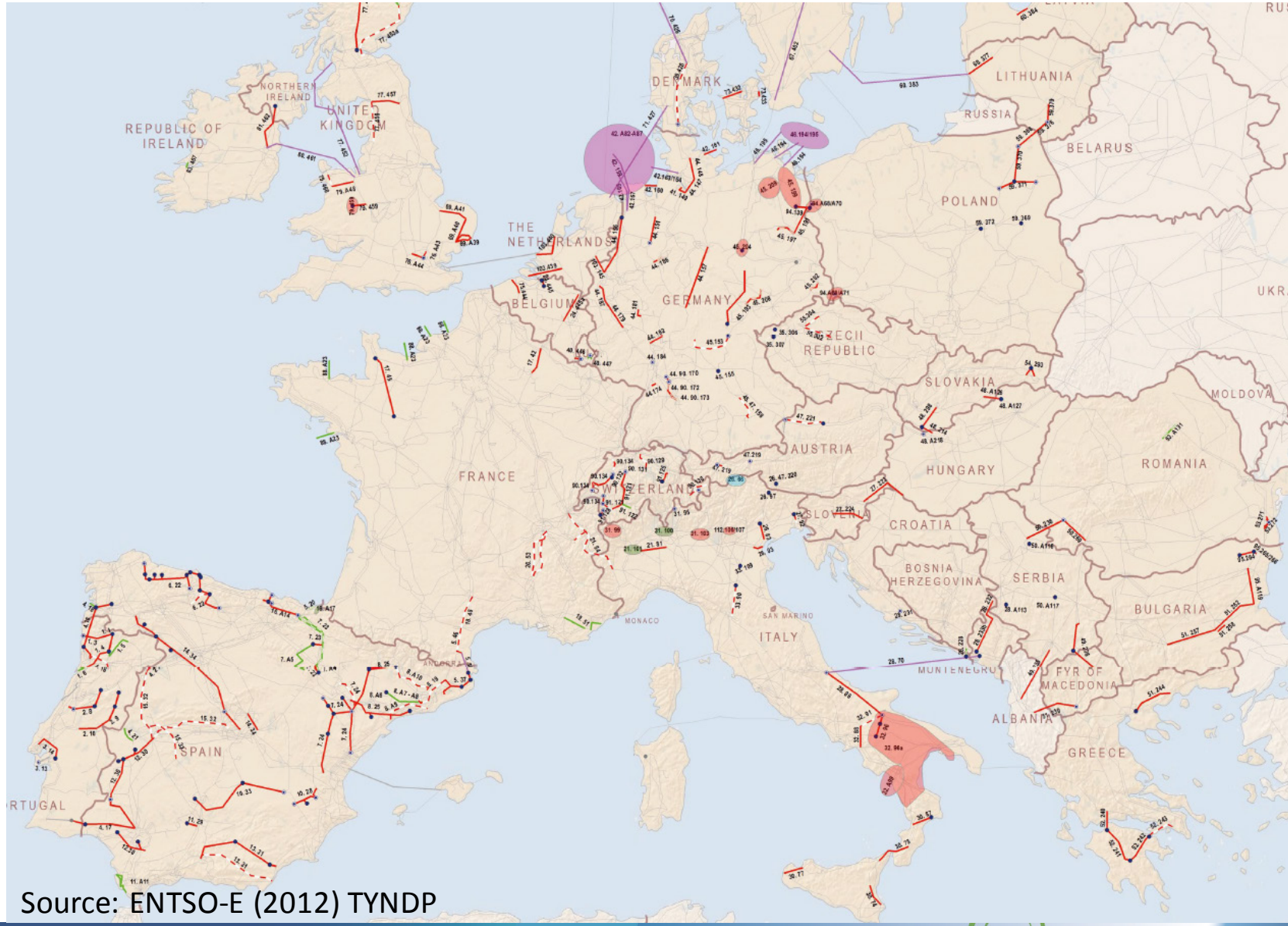
Transmission projects 2017-2022

Northern Europe



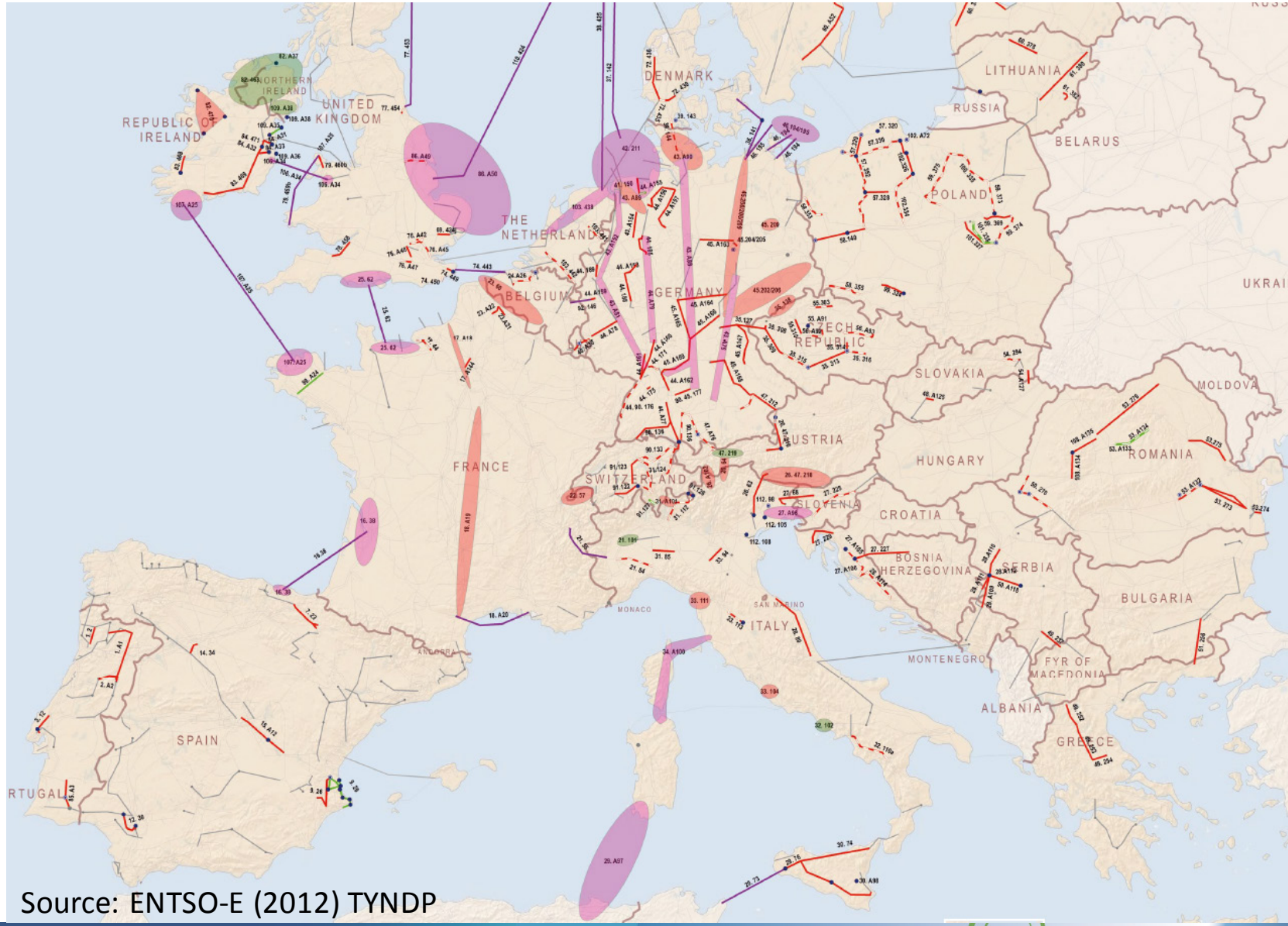
Source: ENTSO-E (2012) TYNDP

Transmission projects until 2016 – Southern Europe



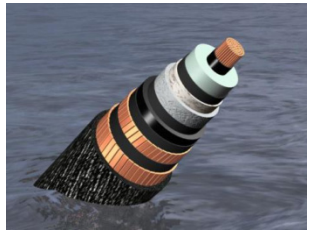
Source: ENTSO-E (2012) TYNDP

Transmission projects 2017-2022 – Southern Europe



Source: ENTSO-E (2012) TYNDP

Transmission capacity abroad

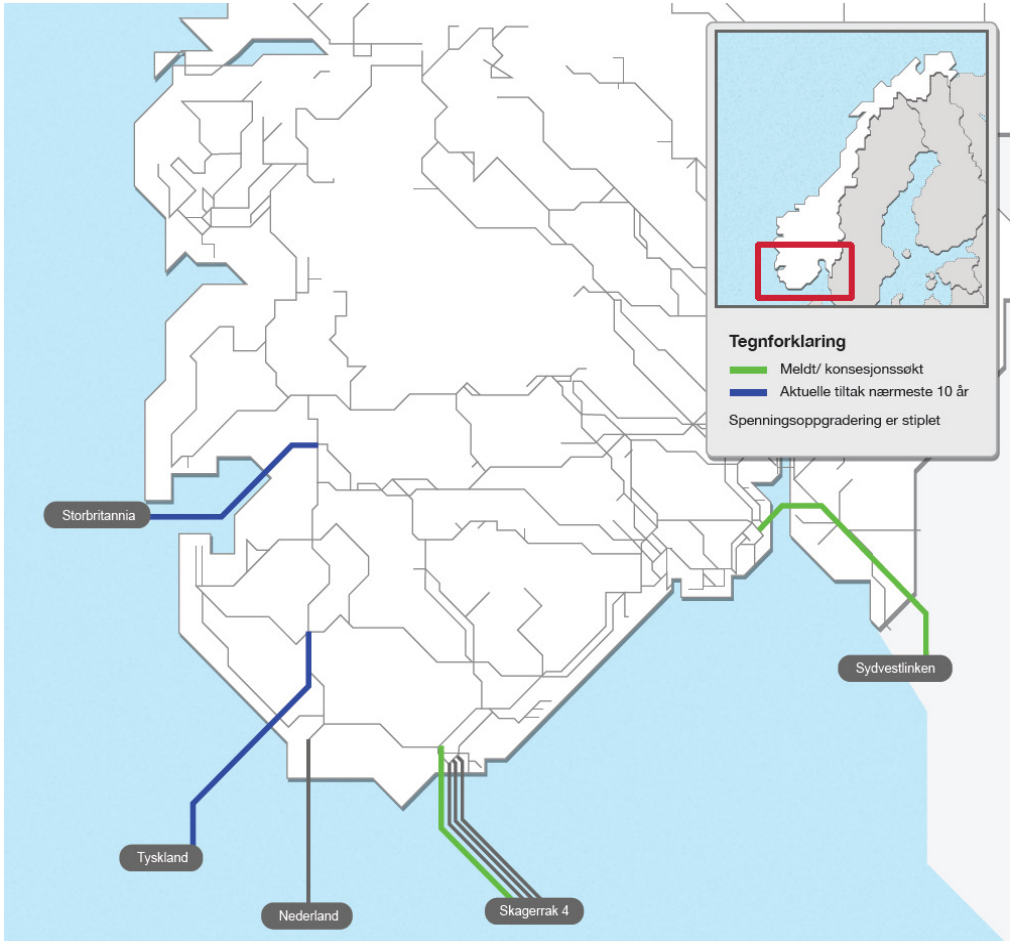


- NO-Sweden
  - North/Mid-Norway: 1 100 MW
  - South-Norway: 2 050 MW
- NO-Denmark
  - SK1-3: 950 MW
  - SK4: 700 MW (2014)
- NO-Netherlands
  - NorNed1 (NL): 700 MW
  - NorNed2 (NL): 700 MW
- NO-Germany
  - NORD.LINK: 1 400 MW (2018)
- NO-England
  - 1 400 MW (2020)

Possible interconnection capacity in 2020:

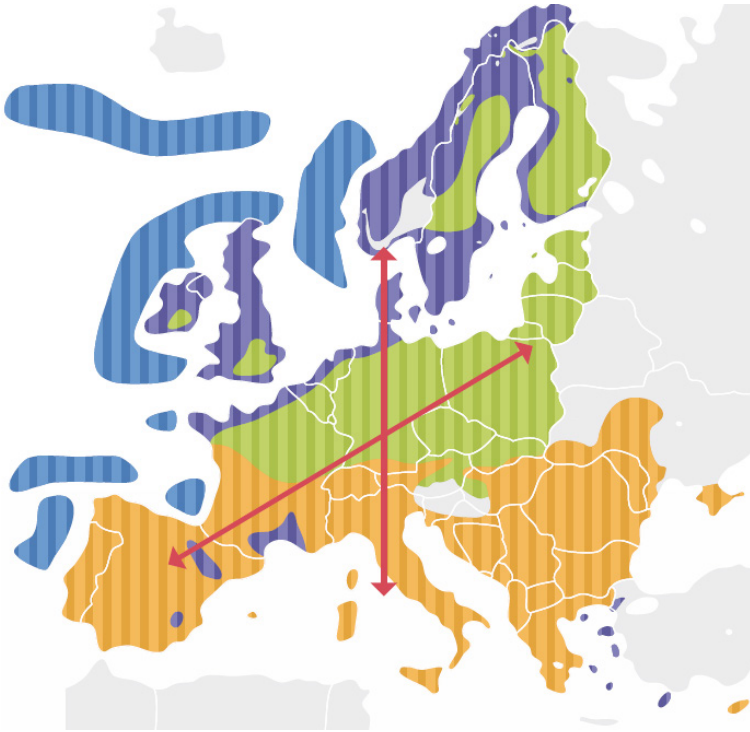
4 800 + 4 200 = 9 000 MW

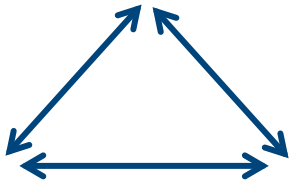
Sources: Statnett Nettutviklingsplan 2011
ENTSO-E, TYNDP 2012



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





Economy
Market, viability

Environment
Climate, ecosystem

Social acceptance
Participation, transparency