HydroBalance User Meeting
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Practical examples on how Norwegian Hydro could be an enabler of increased RES in North West Europe

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Practical examples on how Norwegian Hydro could be an enabler of increased RES in North West Europe

- Lyse Production in brief
- New intermittent production and new flow patterns
- New interconnectors (NorthConnect)
- New operational requirements from the TSOs
- New solutions and designs (example from Lysebotn Power Plant)
- Concluding remarks

Hydro power in Lyse

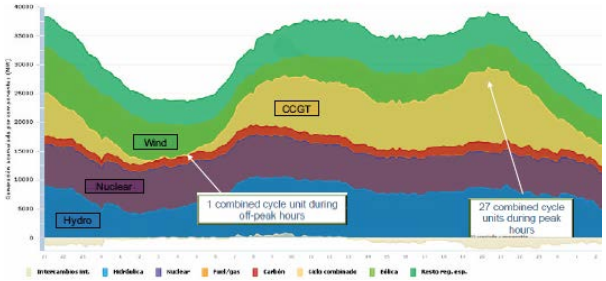
Annual Generation:	**6 032 GWh**
Storage Capacity:	**5 068 GWh**
Installed Power:	**1 599 MW**

Lyse Produksjon is part owner in Sira-Kvina (41%) and Ulla-Førre (18%), the two biggest Norwegian Power Plants

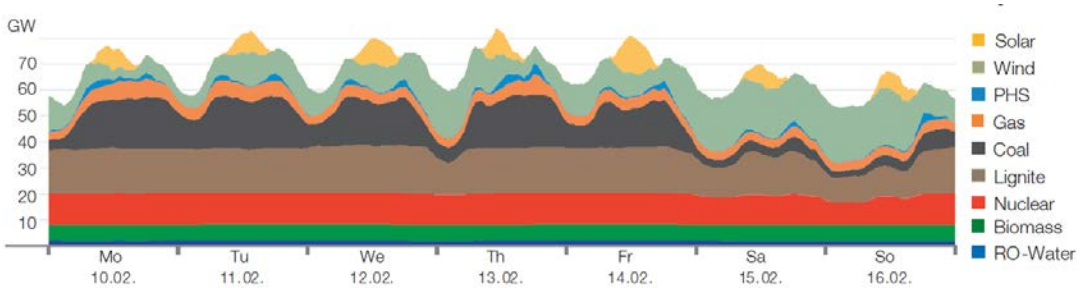
The Challenge: Thermal baseload production transformed to cover residual load

What flexibility actually means?

Example from the Spanish system
March 3rd 2010



Example from the German system
February 10th-16th 2014



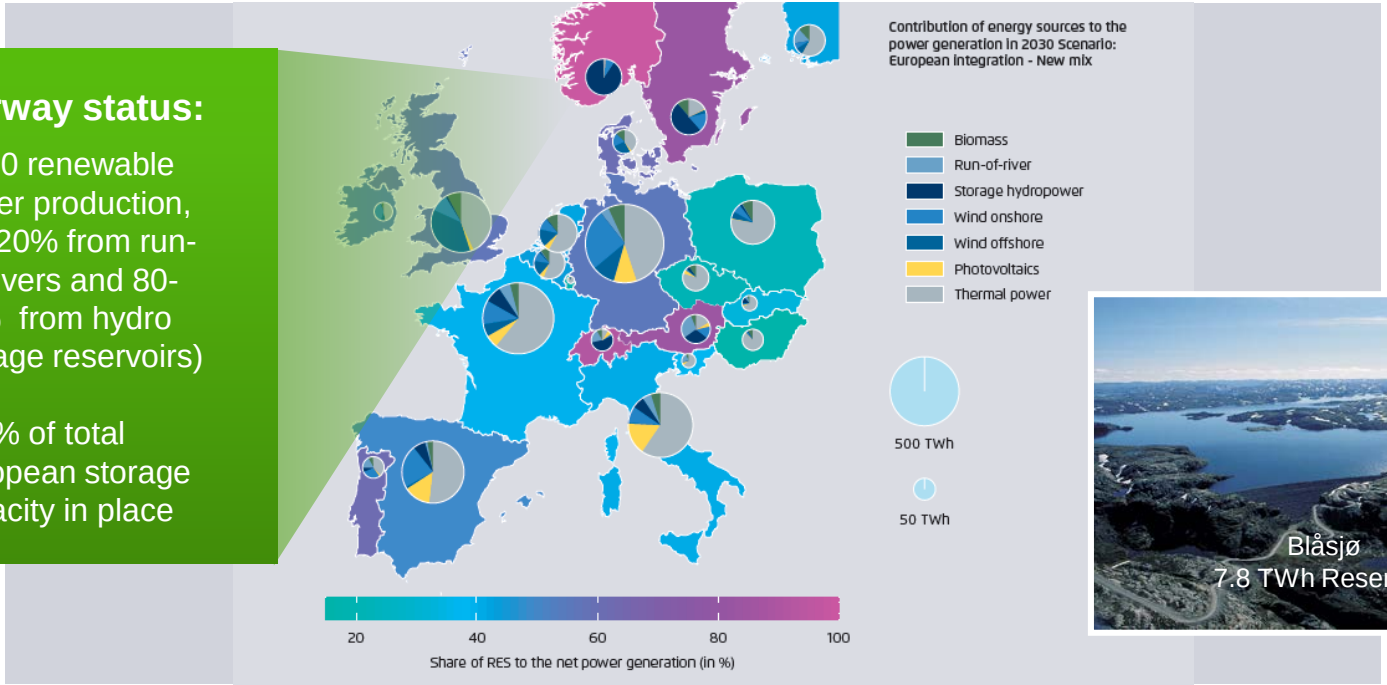
Gas plants (CCGT) (in Spain) and Coal fired plants (in Germany) now acting as balancing units – high costs, reduced operation hours and increased emissions

Estimated share and type of RES in national power generation by 2030 in Europe (source :Fraunhofer)

Norway status:

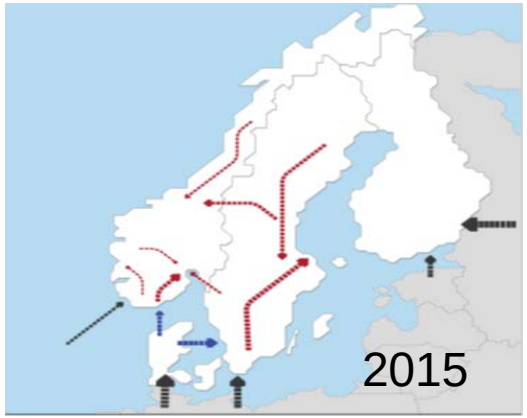
~ 100 renewable power production, (10-20% from run-off-rivers and 80-90% from hydro storage reservoirs)

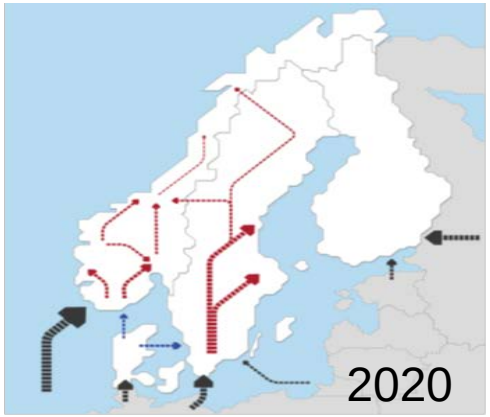
~50% of total European storage capacity in place



Flowpatterns more determined by intermittent RES production

Import





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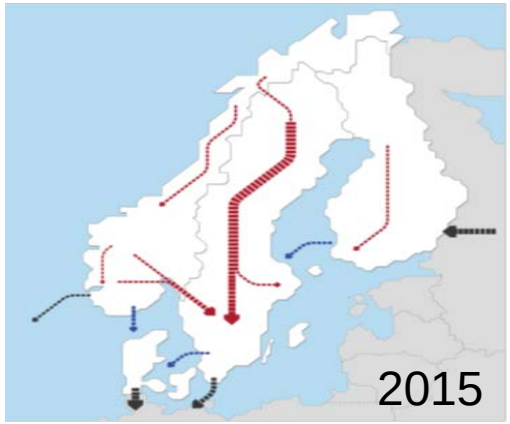
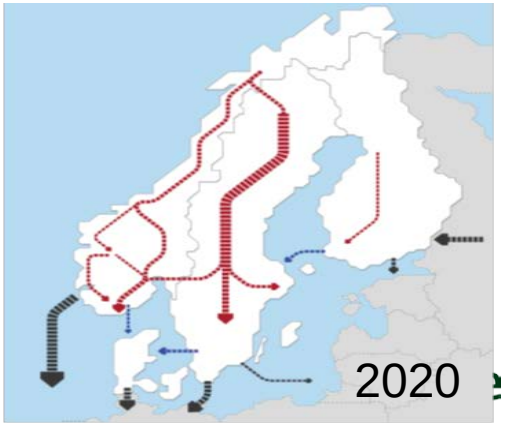
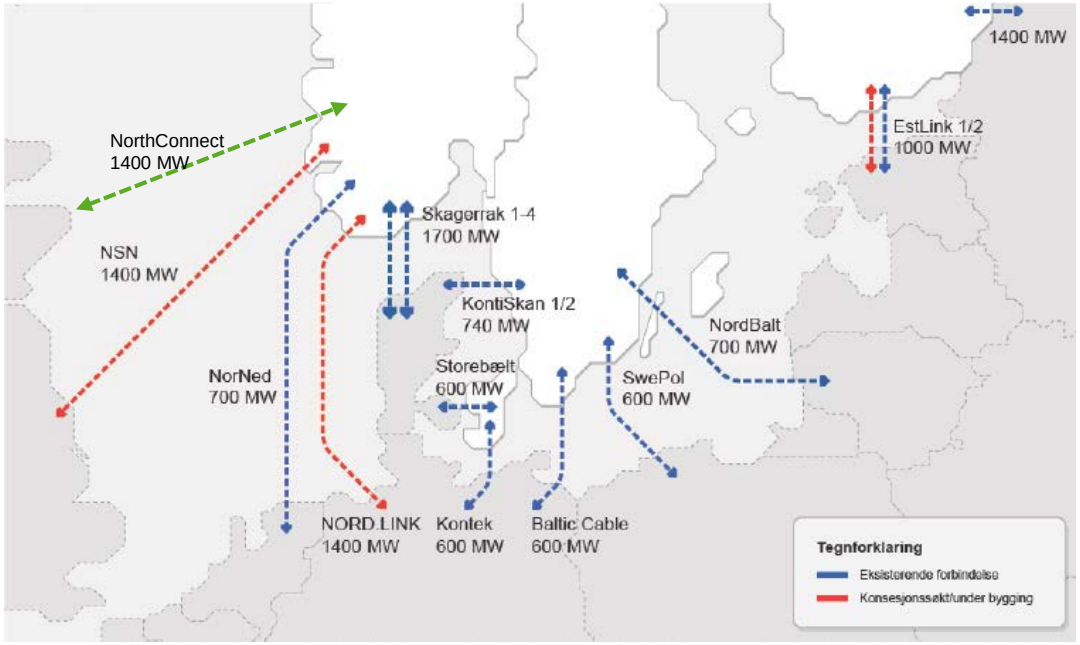




source:Statnett

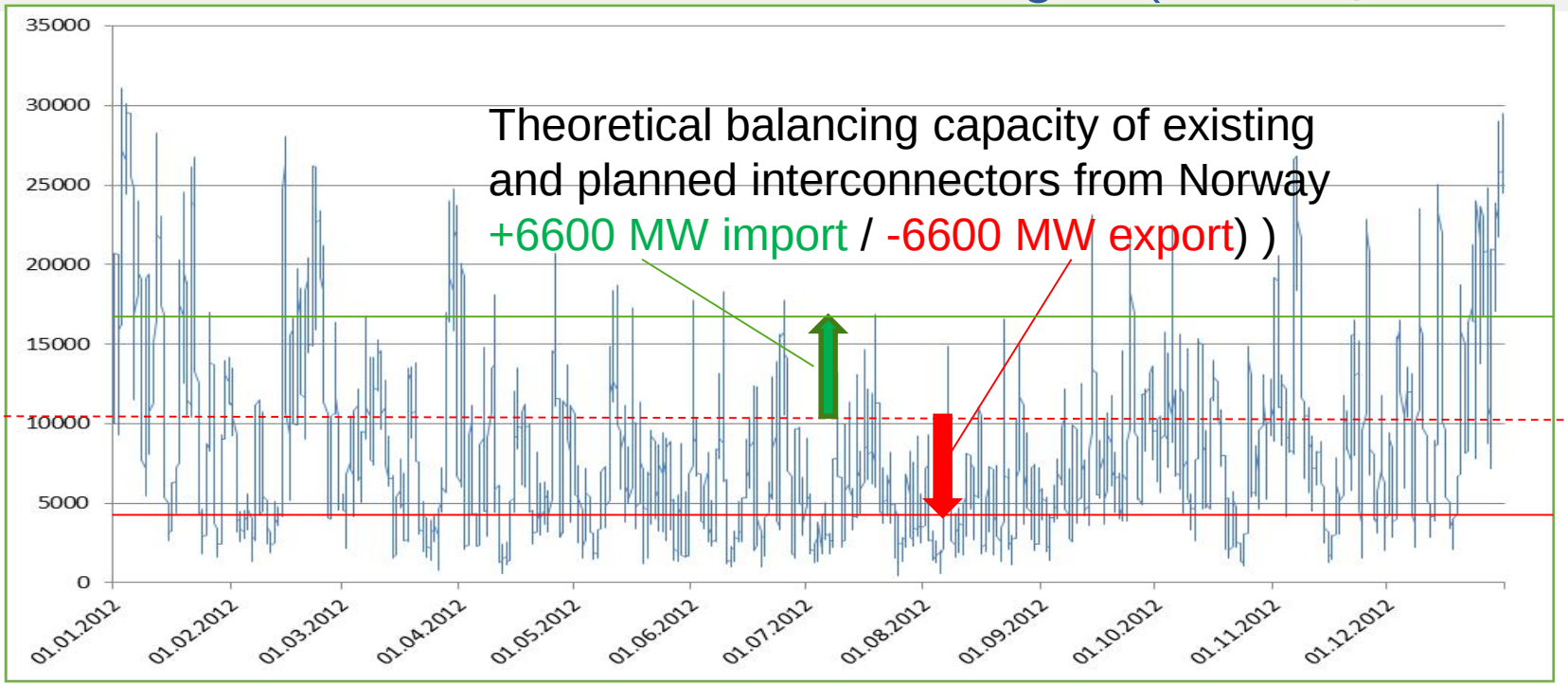
Existing and planned HV-DC interconnectors from the Nordics



NorthConnect new private interconnector under developing

Owners: Vattenfall AB, Agder Energi AS, E-Co Energi AS and Lyse AS

Wind Power Production in the North Sea Region (DE, DK, GB, IR) in 2012)



Observed Wind Energy Production in a system with **45600 MW** installed capacity (Stadium 2012)

Maximum: 31062 MW
Minimum: 419 MW
Typical: ca 10000 MW
Capacity Factor: **0.18**

Nordic production and demand in 2025

For a typical single year (weather as 1982) and night hours

Challenges and opportunities for the Nordic Power system

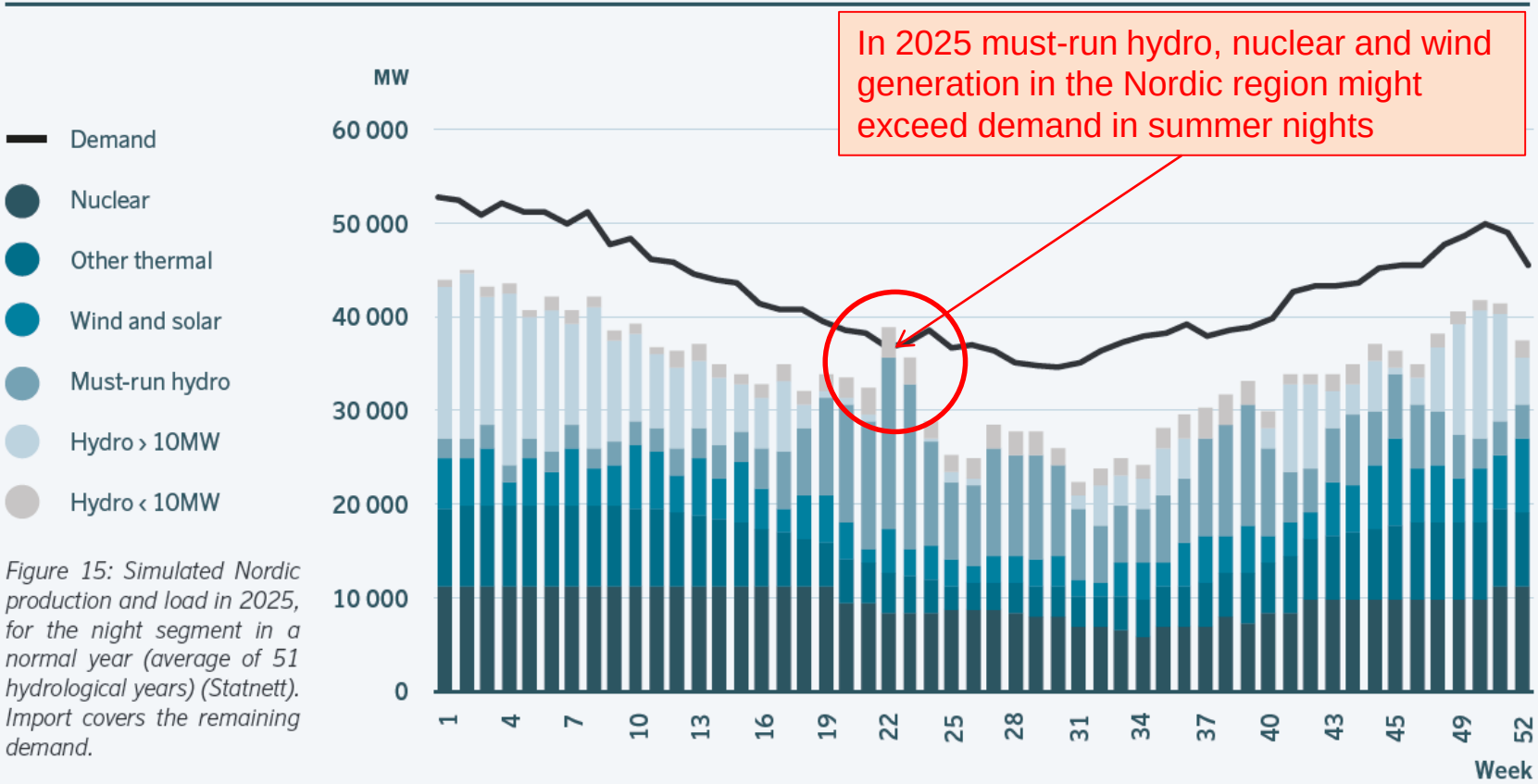
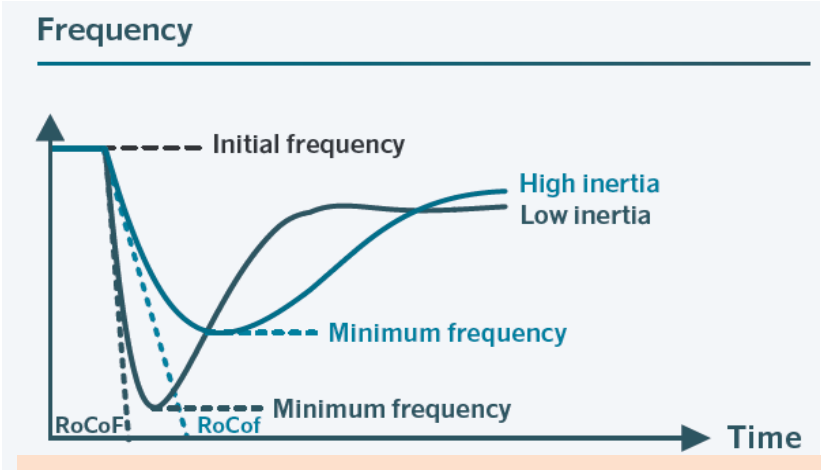


Figure 15: Simulated Nordic production and load in 2025, for the night segment in a normal year (average of 51 hydrological years) (Statnett). Import covers the remaining demand.

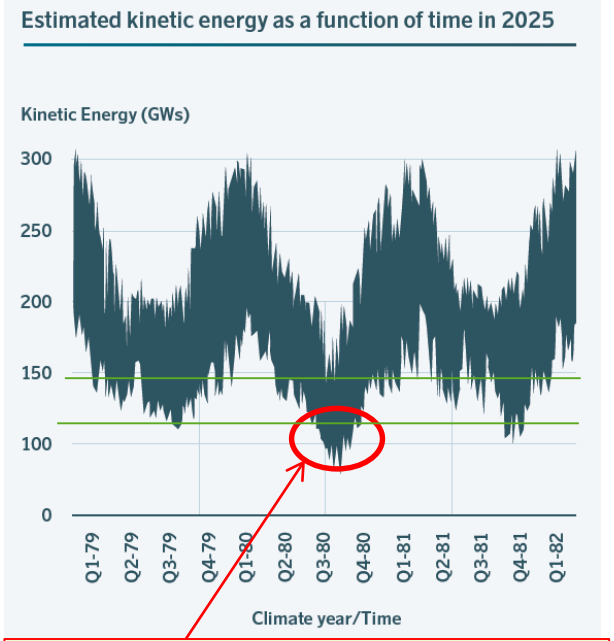
[9] *Must-run hydro: Production from power plants without reservoirs and power plants with reservoirs that are required to produce power at a specific time for various reasons, including full reservoirs, flow restrictions, reservoir targets etc. Includes all hydropower production with zero marginal costs.*

Future lower inertia in the power system represents a serious challenge



Two different problems occur when big production units are disconnected in «weak» power systems:

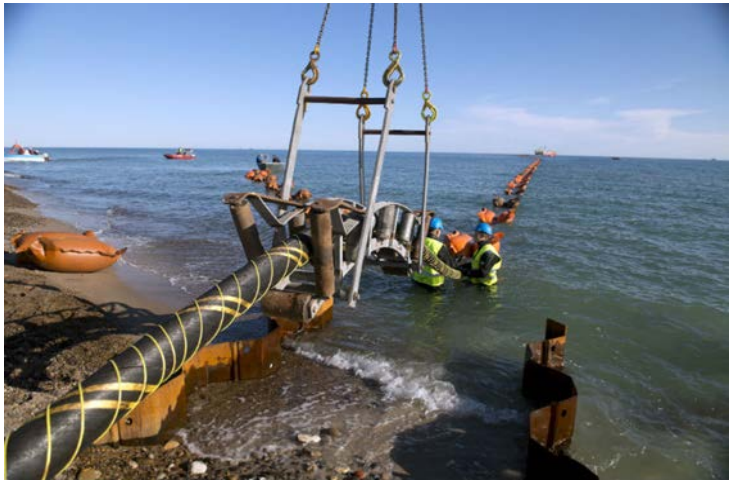
- The momentan change of frequency rate (RoCoF df/dt) increases
- The frequency drop (Δf) will increase - lower minimum frequency.



According to simulations by the Nordic TSOs the inertia will be below requirements (120-145 GWs) between 1- 19% of time in 2025

Deliveries of secondary reserves over SK4 interconnector to Danish TSO (Energinet DK)

- Trade of system services (secondary reserves) over an interconnector for the first time in Europe
- Up to now modest quantities (+/- 50 MW Lyse share)
- Demonstrates that the concept works satisfactorily, and could be extended to Germany and elsewhere as interconnection capacity increases.
- Commercially this concept seems viable based on our experience so far



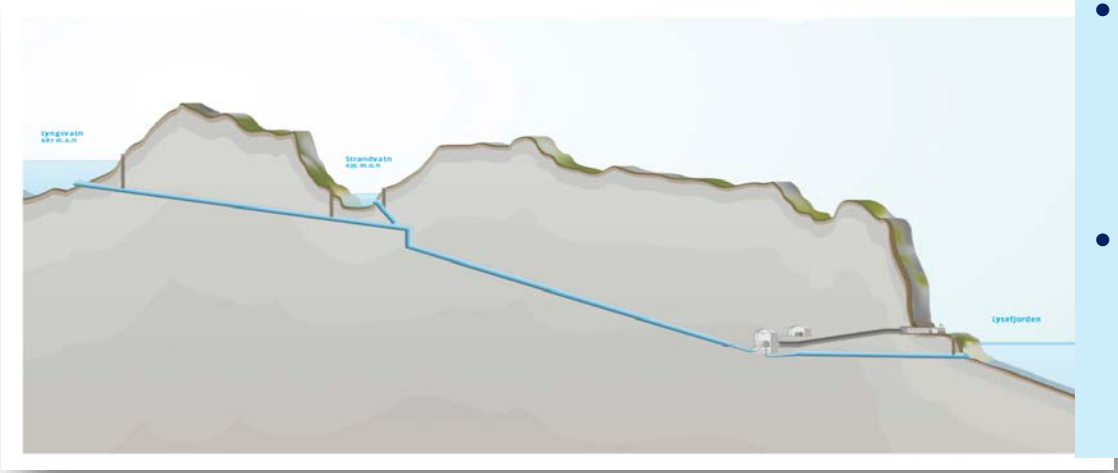
Lysebotn 1 Existing Hydro Power Plant
Main characteristics

- Installed capacity 210 MW
- 6 units (3 x 30 MW + 4 x 40 MW)
- Horizontal double pelton runners
- Annual generation 1320 GWh
- Licence granted in 1948
- Construction works started immediately
- Successively put into operation in the period from 1953 until 1964
- Europe's biggest power plant when put into operation

Lysebotn new Hydro Power Plant

Main technical characteristics

- Installed capacity 2 x 185 MW Francis
- Head 619 – 687 metres
- Consumption 2 x 30 m^3/s
- Generators 215 MVA , 13,8 kV
- Annual generation 1500 GWh
- Load factor 0,46
- Catchment area 316 km^2



- Installed capacity: +77%
- Storage capacity: +14%
- Loadfactor reduced: 0.72 to 0.46
- Lysebotn 2 is designed to run in condenser mode operation thus providing inertia and other system services.
- From condenser mode operation, Lysebotn 2 will be able to ramp up to full production (370 MW) within 1 minute!
- €200 mill upgrading project (Norway´s 11. biggest hydro power plant)

To summarize:

- If Norways conciderable storage hydro power installations shall underpin EU and national climate goals, increased interconnector capacity is an absolut prerequisite
- Increased interconnector capacity will however inevitably lead to increased import in particular in periods with high RES generation which will have a serious negative impact on system operation in particular when load in the Nordic system is low (during summer nights)
- The storage hydro power plants when restored and refurbished should if possible be redesigned to meet the new operational requirements from the TSO (similar to Lysebotn):
  - Higher power output (lower load factor)
  - Condenser mode operation capability
  - Shorter ramp up times
- Pumped Hydro Storage plants require higher price differencials and both development of markets and business models that will underpin such development


Lyse