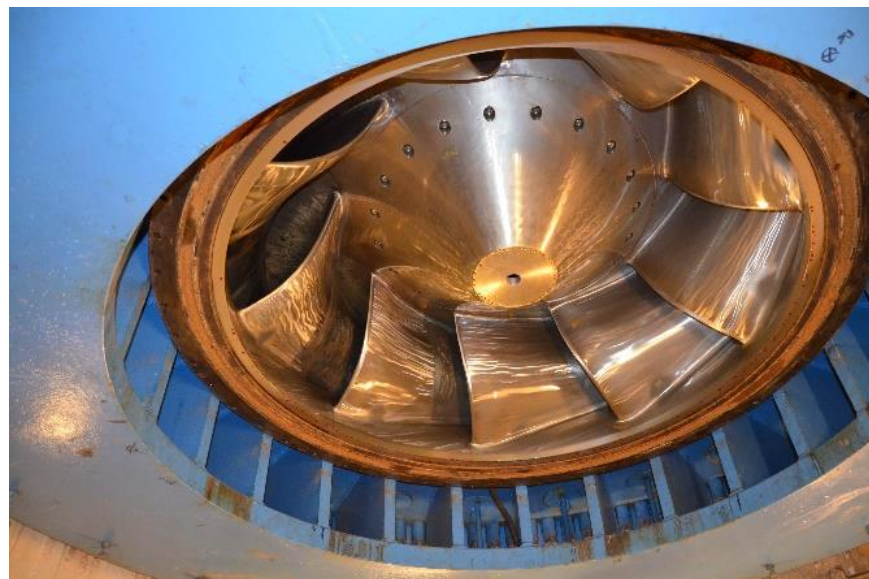


Hydropower Summit 2020 USA-Norway

Strategy for pump storage projects – Where are we going no? Balancing between optimism and realism?

Leif Lia, Professor NTNU
Kaspar Vereide, Sira-Kvina/NTNU



Pump Storage Projects - PSP

- **Norway as a case**
 - **12 PSP constructed mainly for seasonal pumping**
 - **Utilization of flood water and low prices**
 - **Number of reservoirs is reduced**
 - **Complicated start-up procedures**
 - **Normal operation in full capacity**



Pump Storage Projects - PSP

Name	Commissioned	Nominal Head	Pumping capacity	Upper reservoir capacity	Lower reservoir capacity
	Year	m	MW	mill. m ³	mill. m ³
Saurdal	1985	437	320	3100	238
Aurland III	1979	400	270	448	10
Duge	1979	220	200	1400	926
Nygaard	2005	450	56	103	43
Øljusjøen	1974	212	50	161	27
Tevla	1994	165	50	204	5
Jukla	1974	200	40	236	31
Herva	1962	257	33	109	21
Brattingfoss	1955	118	11	107	8

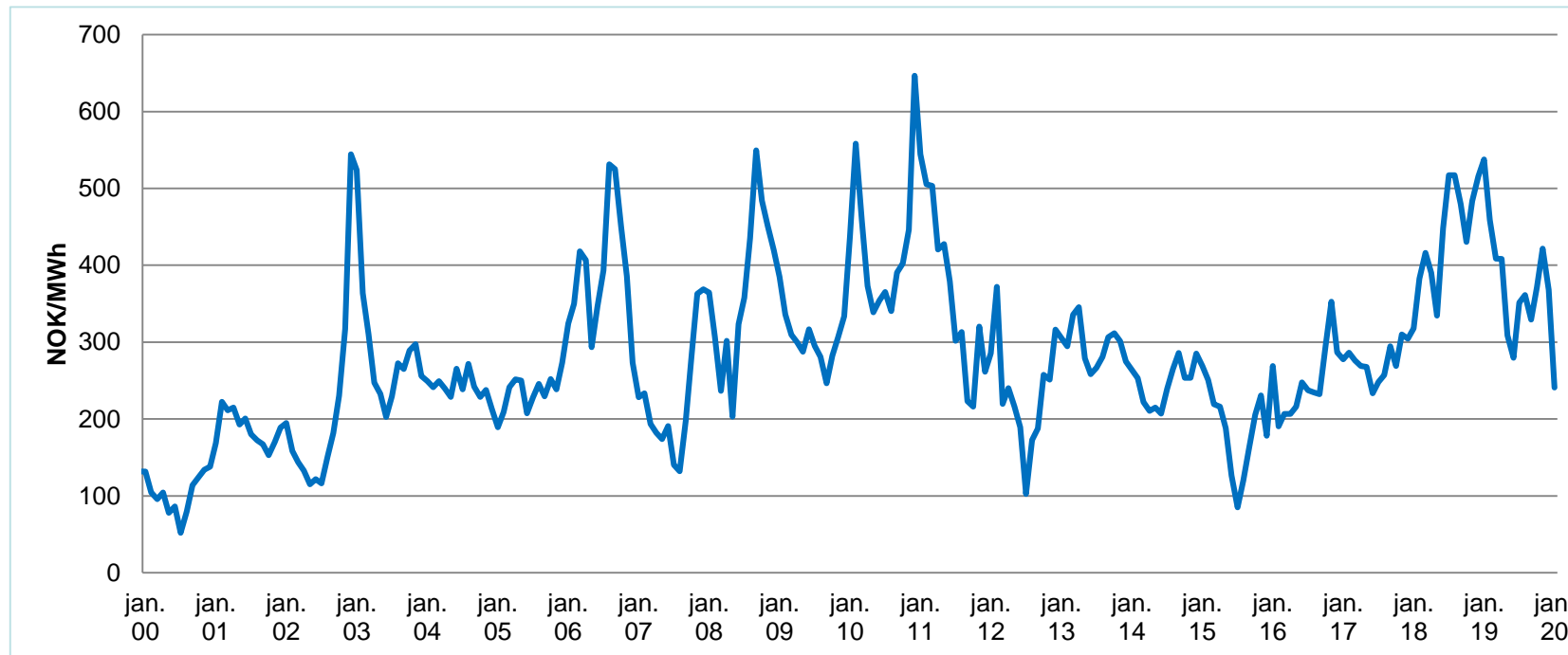
Strategy 5 – 10 years back

- Large scale PSP – Green battery for Europe
 - 10 000 – 20 000 – 30 000 mentioned as feasible
- Available reservoir capacity of 85 TWh
- Time duration 1 – 2 weeks for balancing “black holes” caused by lack of wind and/or sunshine
- Full incorporation of other renewable sources



Current market situation

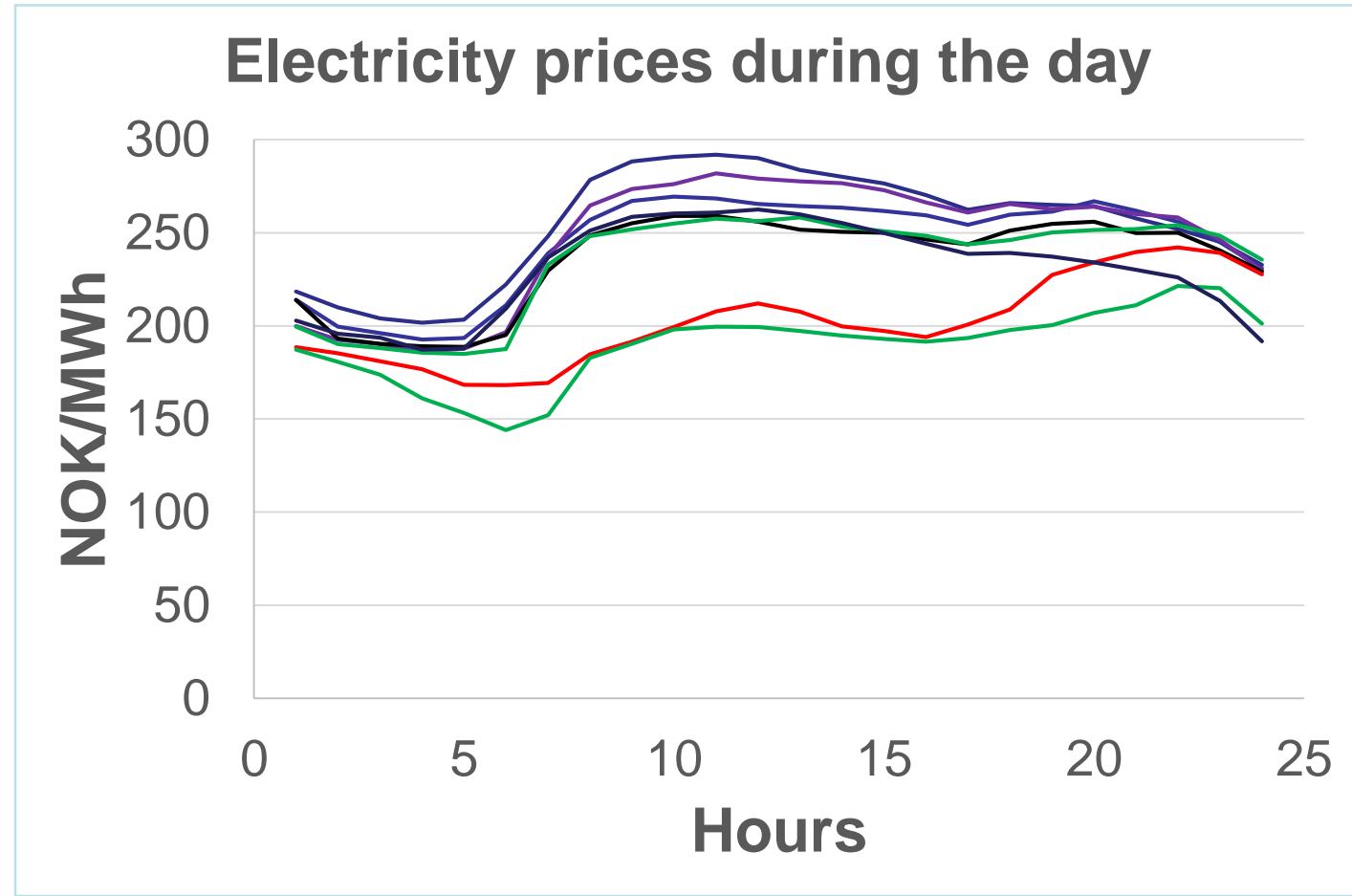
- **Low electricity prices in Europe**
- **Large scale PSP implemented in Austria and Switzerland**
- **Limited bi-lateral transfer capacity**
- **More capacity to be implemented**
- **In Norway: 17 TWh waiting to be constructed**



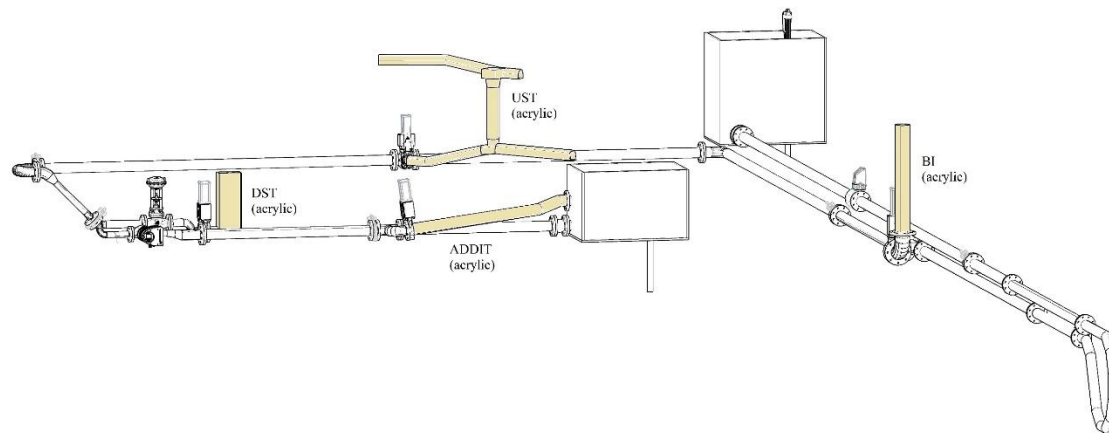
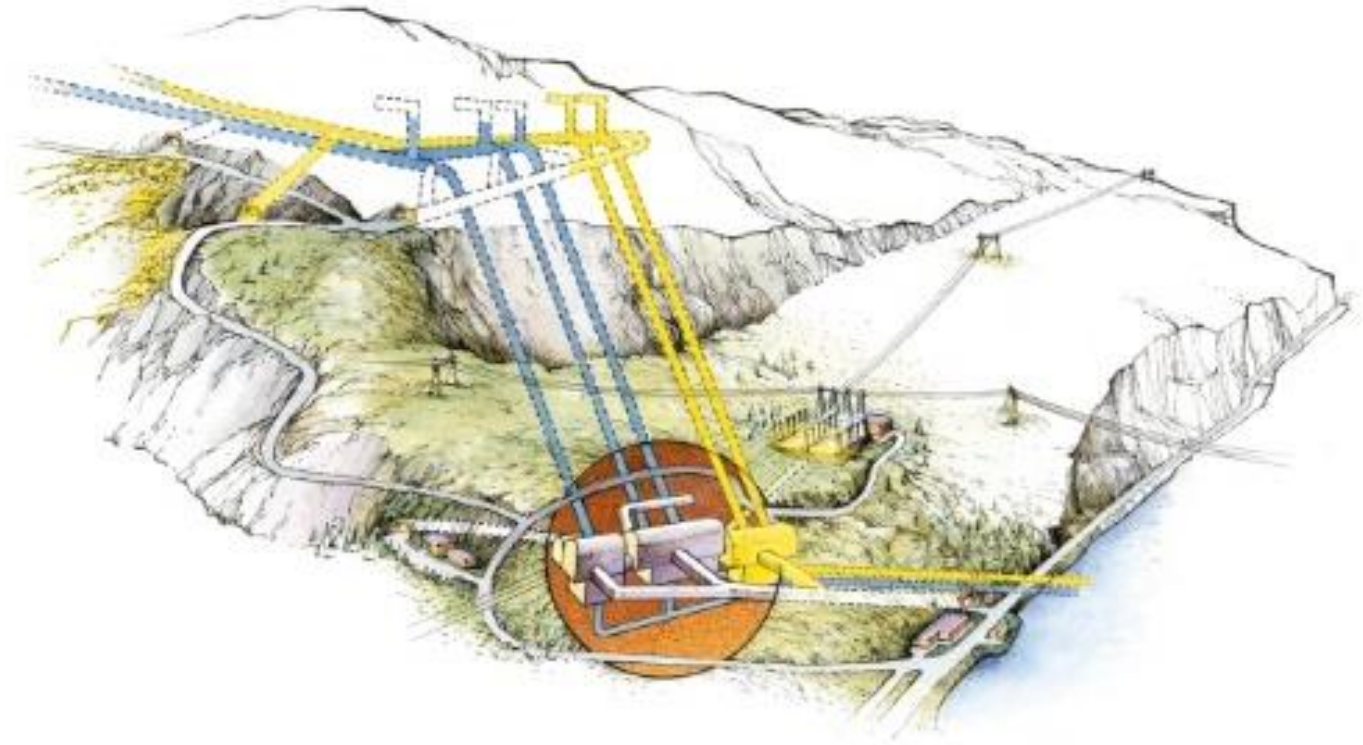
Current price variation

- European electricity prices affects the Nordic market

$$\Delta p_{min} = \frac{1}{\eta_p \cdot \eta_t} > 1.3 \text{ (> 30\% price diff.)}$$



Converting HPP to PSP



Bi-lateral power cables

- **Existing**
 - 800 MW to the Netherlands, *NOR-NED*
 - 1500 MW to Denmark, *Skagerak I – IV*
 - > 3000 MW capacity through Sweden
- **Under construction**
 - 1400 MW to UK
 - 1400 MW to Germany
- **Private investors are pushing the Government**
 - Political debate 'North Connect'



The future market situation

- More cables (> 9000 MW) to neighboring countries introduce
 - More international trading
 - Altering power prices
 - Less demand for seasonal storage
 - Availability of power in the dry period
- High impact on Norwegian PSP
- Norwegian HPPs are not designed for this
- *'Nobody knows'?*



The future market situation

- Higher value of flexible operation
- Possibilities to sell auxiliary services on the international market
 - Frequency [Hz]
 - Voltage [V]
 - Spinning reserves
- Reduced peak prices?
- Smart grids?



Conclusions

- **Most likely future situation**
 - **Upgrading of existing hydro with additional parallel reversible turbines**
 - **Profit from cables (....to UK...?)**
 - **System services**
- **Very high financial risk**
- **Political decisions about coal, no-carbon, nuclear, *general growth* in Europa etc. are the major triggers**

