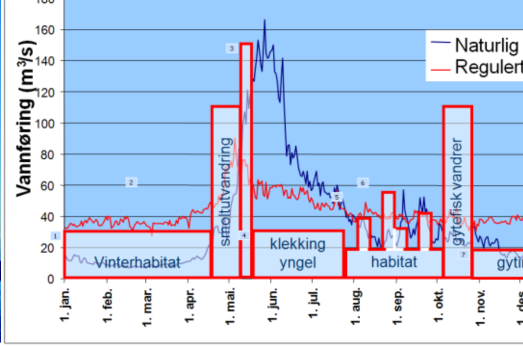




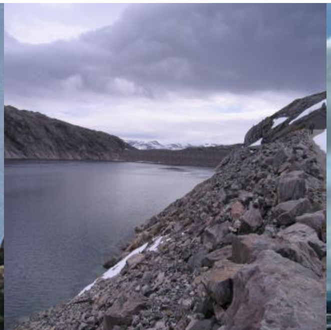


Centre for environmental design of renewable energy - CEDREN

SINTEF
NTNU 100 skapende år
NINA
NATURHISTORISK MUSEUM UNIVERSITETET I OSLO
NIVA
uni Research

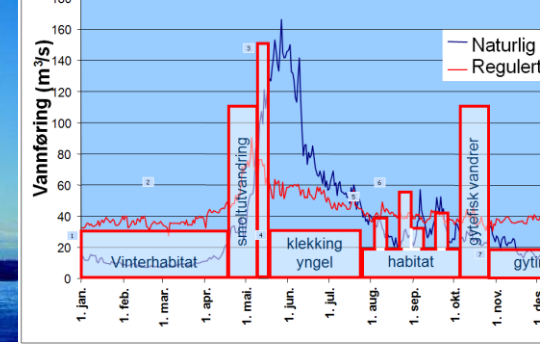
Atle Harby, Director











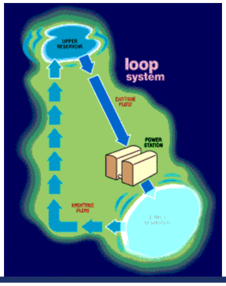
- 8 years (2009 – 2016)
- 10 large research projects – two more from 2015
- 7 Norwegian research partners
- 16 Industry partners and 2 management partners
- Budget: ~40 M Euro (5 M Euro in 2016)
- 21 PhD and 7 Post-doc positions
- International collaboration

Renewable energy respecting nature

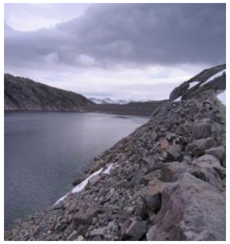
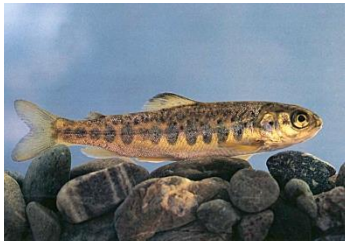




Hydropower technology

Environmental impacts of hydropower


Environmental impacts of wind power and power transmisson

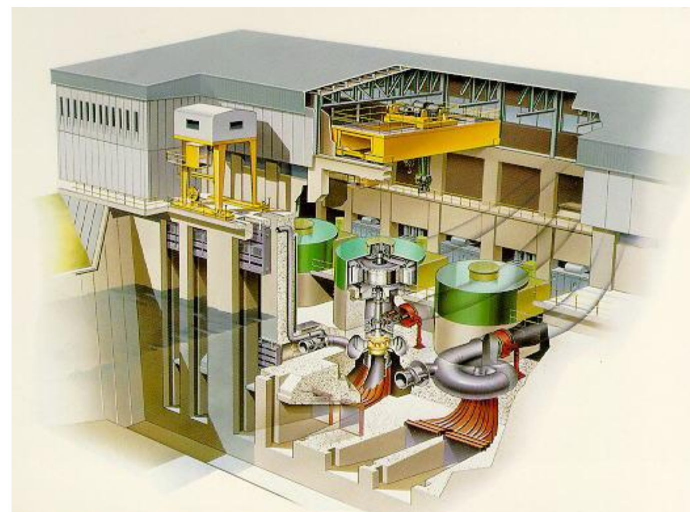


How to reconcile energy and environment policy?

Environmental design of regulated rivers

Adapting downstream flow

Constructing habitats



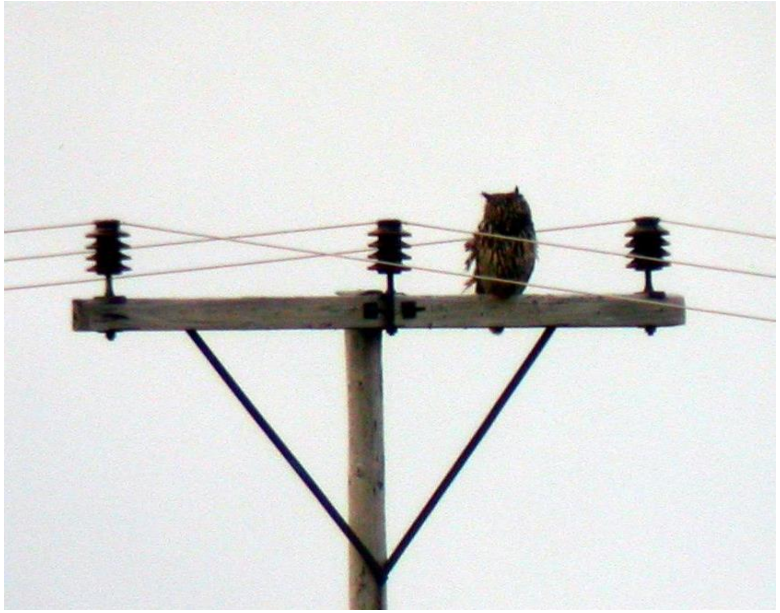
Increasing power production

Increasing both salmon and power production

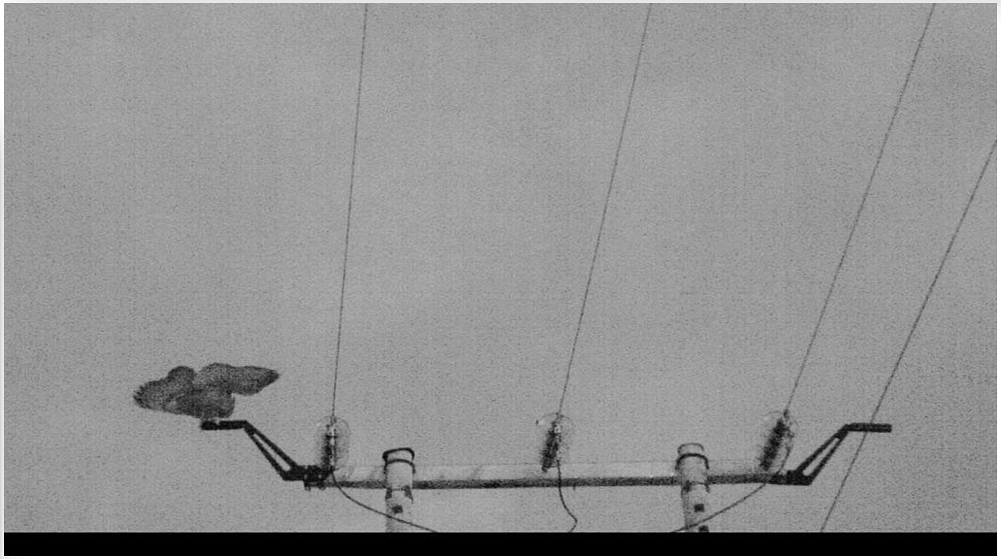
Renewable energy and birds

Electrocusion

Death of a white-tailed sea eagle in Norway



In danger!

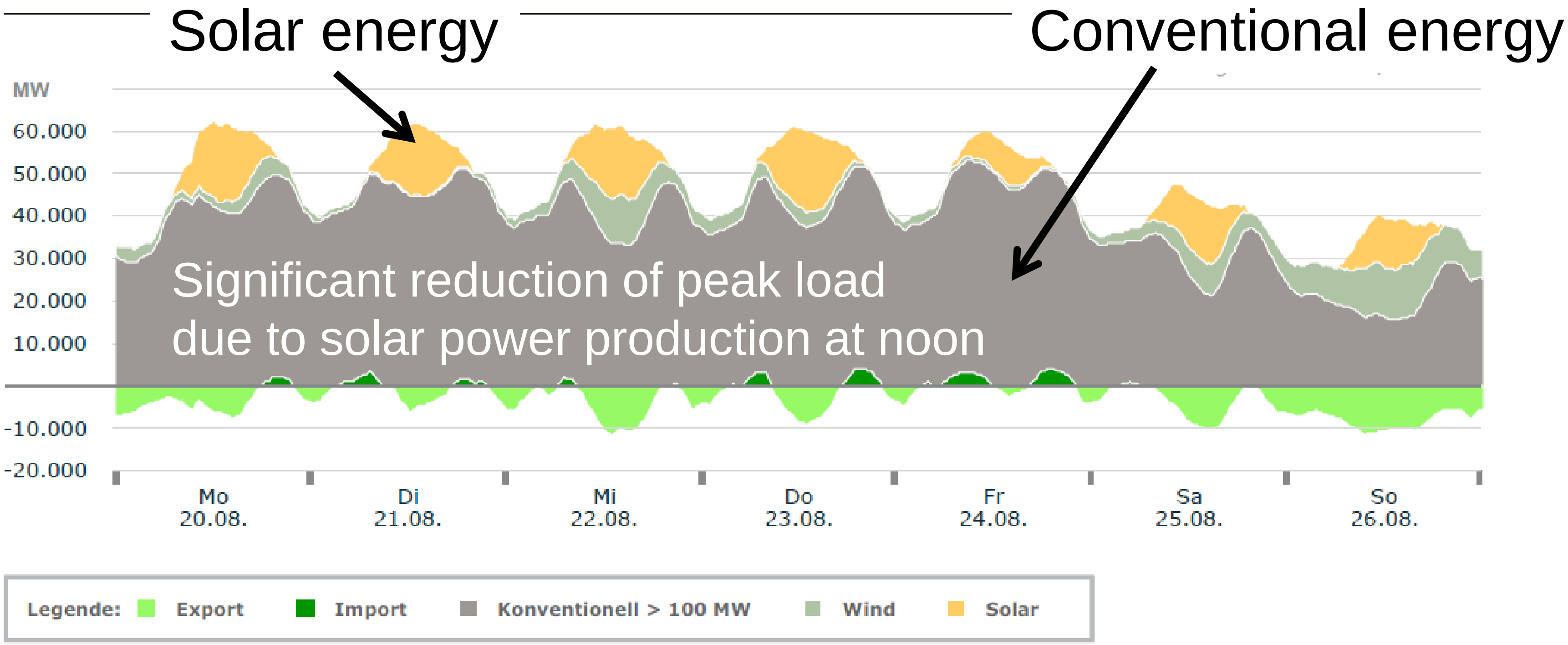


Energy scenarios

- ❑ Transmission and distribution <u>infrastructure</u>
- ❑ Energy <u>storage</u> technologies
- ❑ Demand side <u>management</u>
- ❑ Improved <u>forecasting</u> of resource availability

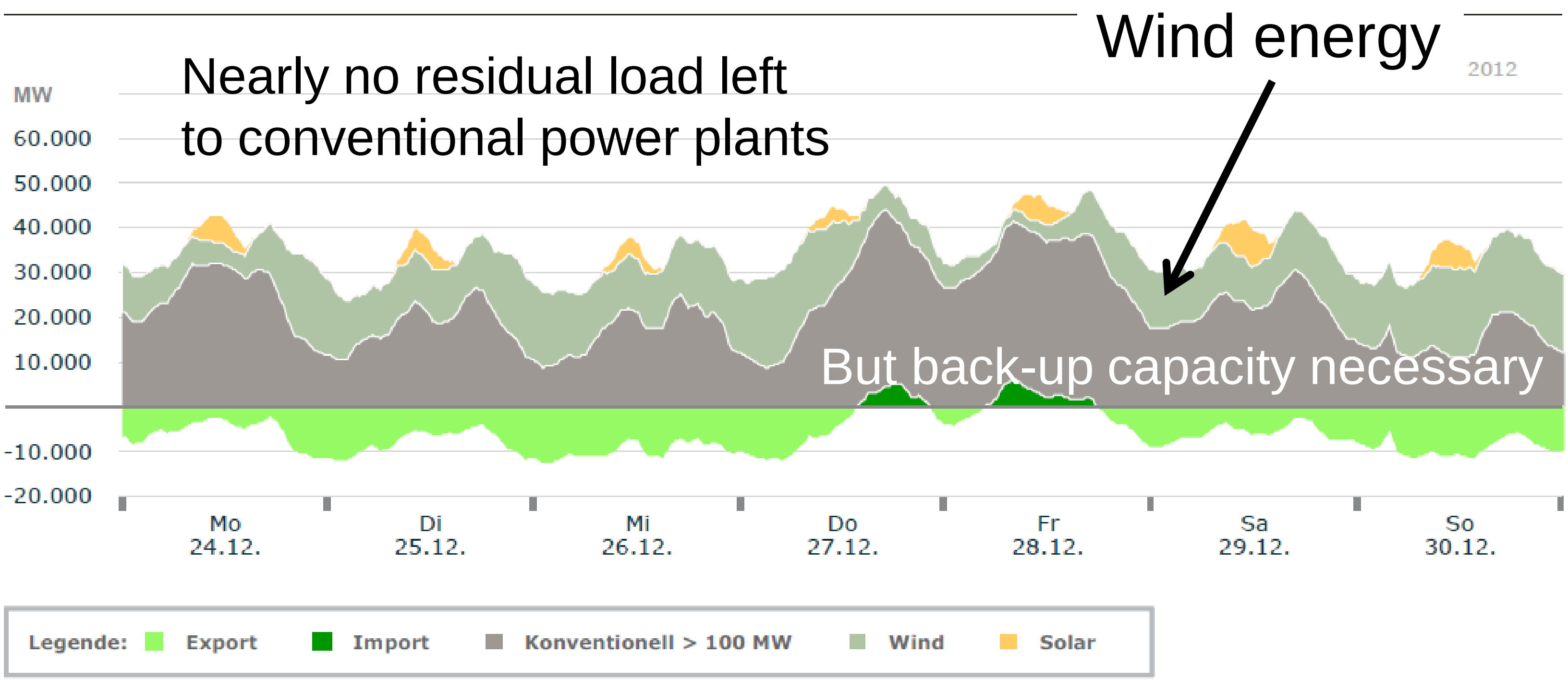
Maybe as much as 340 TWh of storage volume and 150 GW of balancing capacity needed in Europe by 2050

RES challenges - Germany
High Photovoltaic production
Summer



Source: Burger, B. "Electricity production from solar and wind energy in 2012", Fraunhofer ISE, presentation, February, 2013
URL: http://www.ise.fraunhofer.de/en/renewable-energy-data

RES challenges
High Wind power production
Winter



Source: Burger, B. "Electricity production from solar and wind energy in 2012", Fraunhofer ISE, presentation, February, 2013
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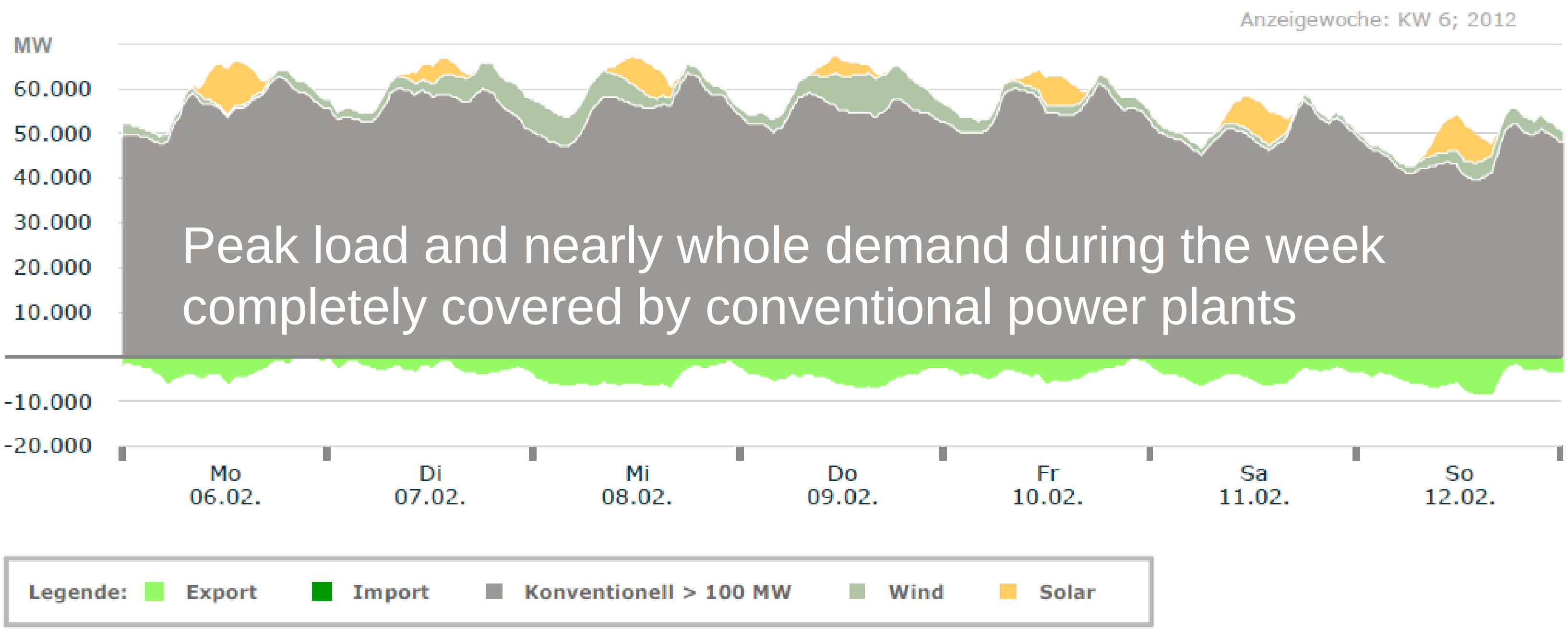
RES challenges
No production from RES
Winter



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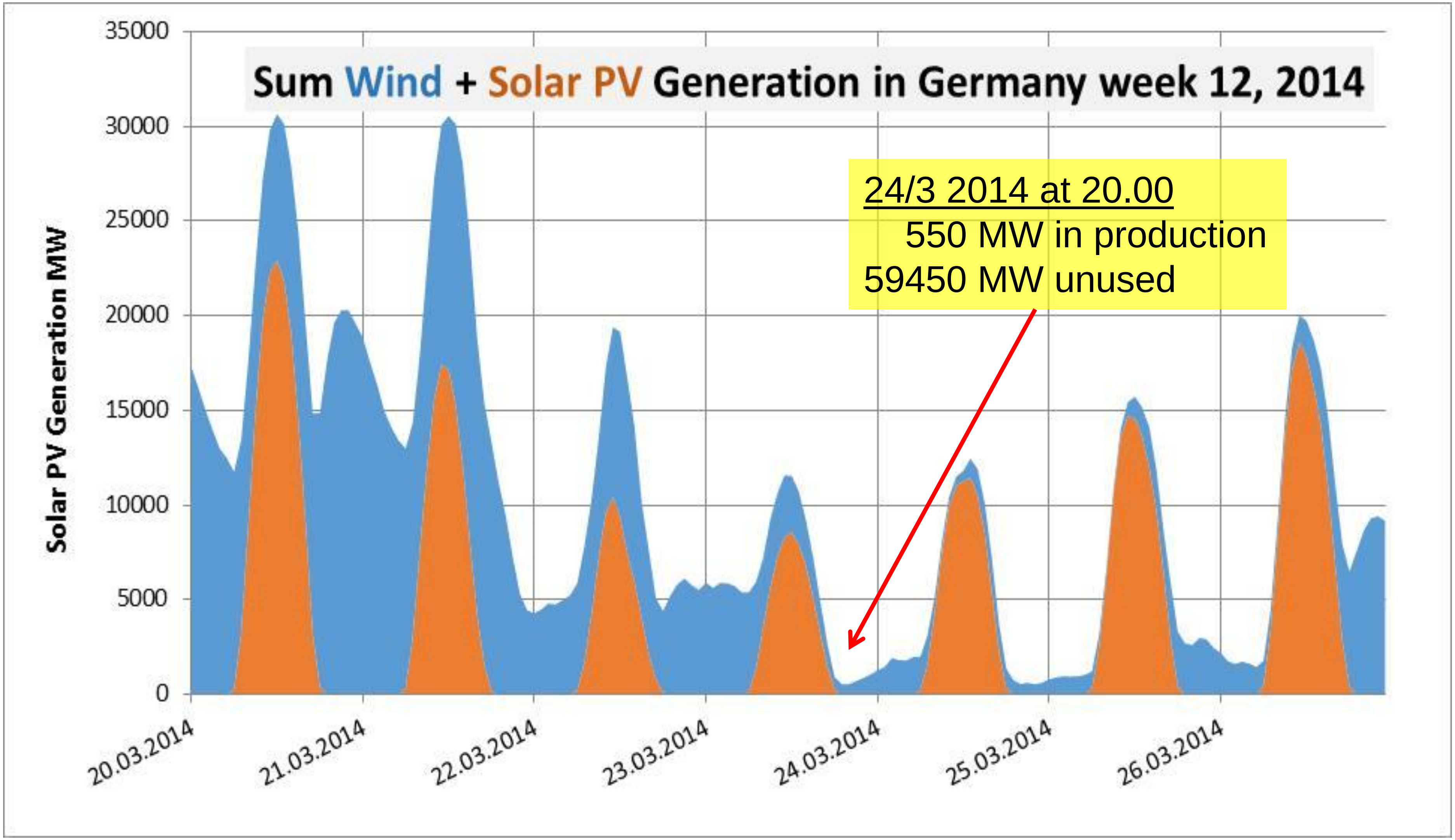
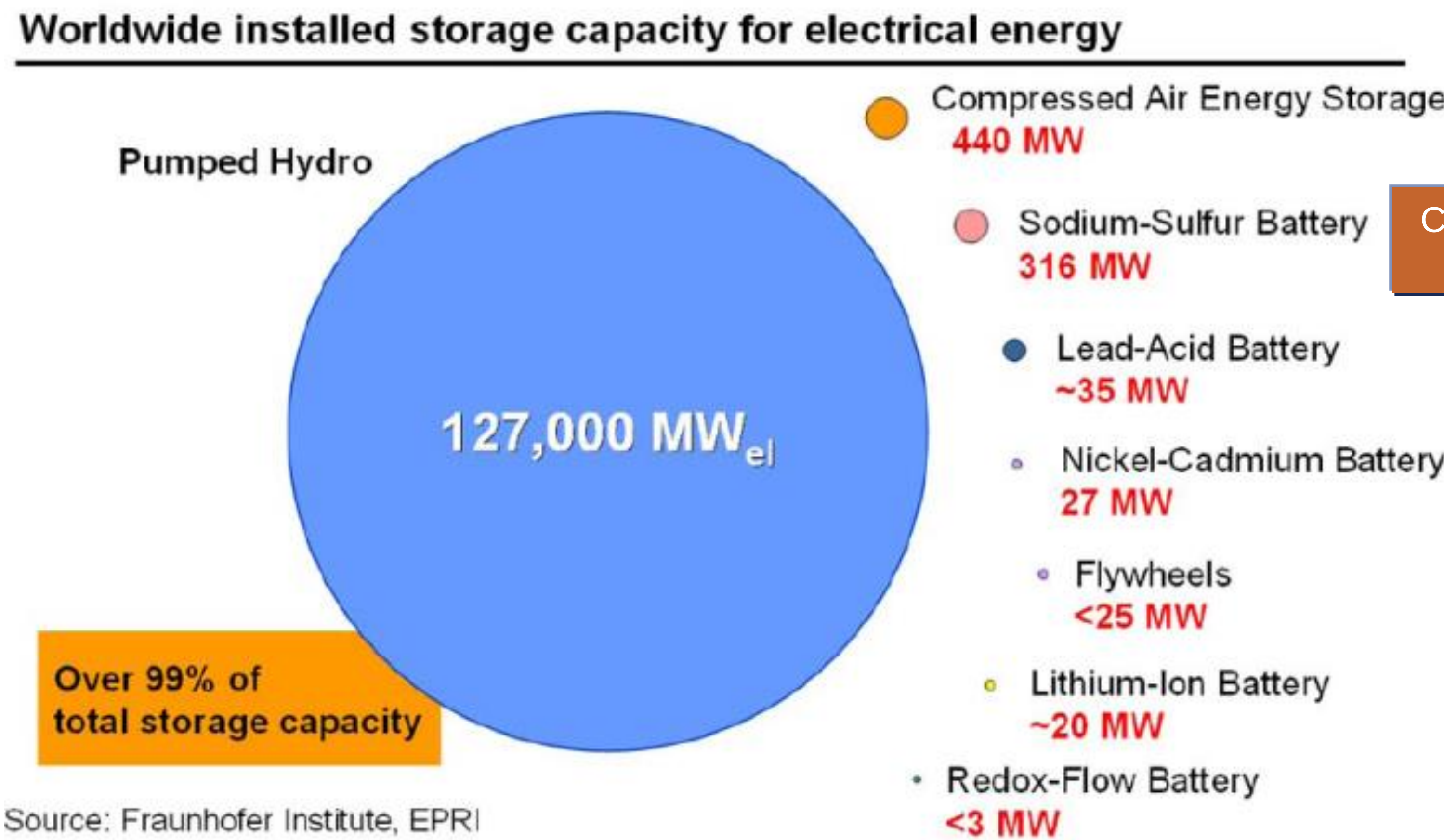
Wind + Solar energy in Germany week 12 2014
Capacity ~30 000 MW Wind + 30 000 MW PV




Hydro storage –
a renewable battery
+

German Minister of Economy, Philipp Roesler, visiting the Blue battery of Norway – guided by Regional Statkraft Director and CEDREN Chairman of the Board, Jan Alne.

Installed Energy Storage capacity



2 installations worldwide

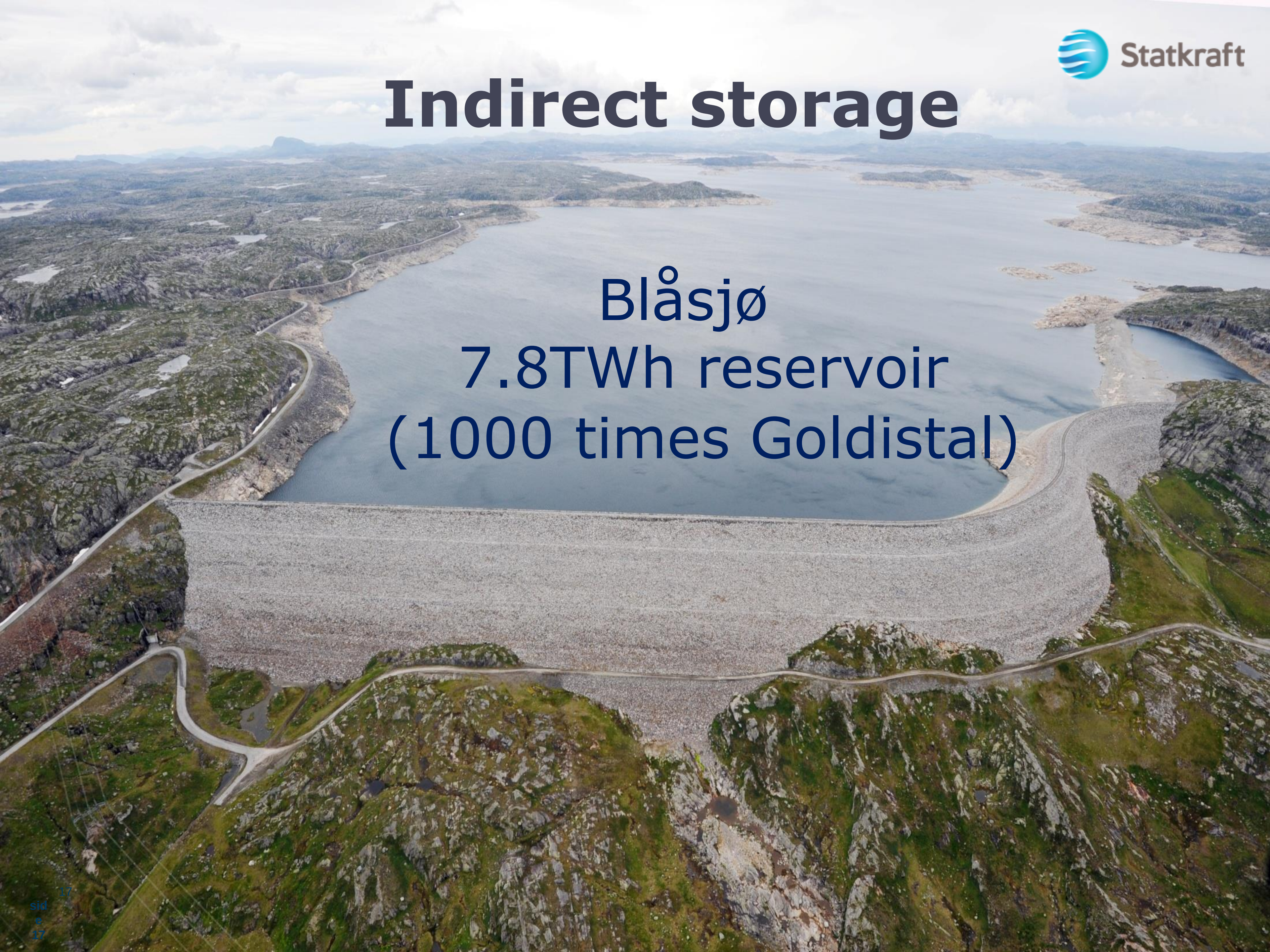
Ca 200 installations worldwide

*Worldwide installed rated power of storage facilities for **electrical energy**. Such power level can be sustained for up to several hours or shorter*

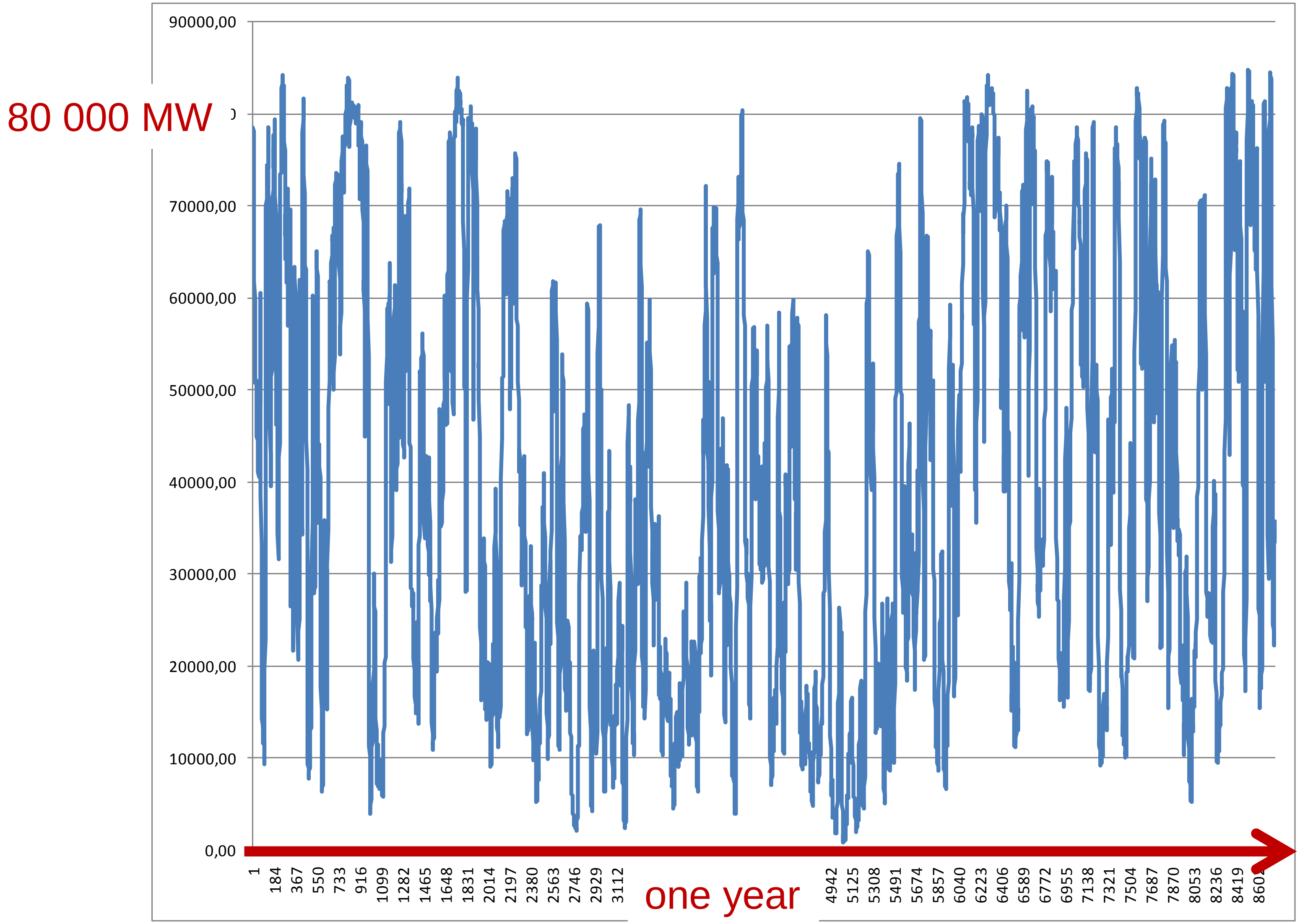
Goldistal, Germany

Indirect storage

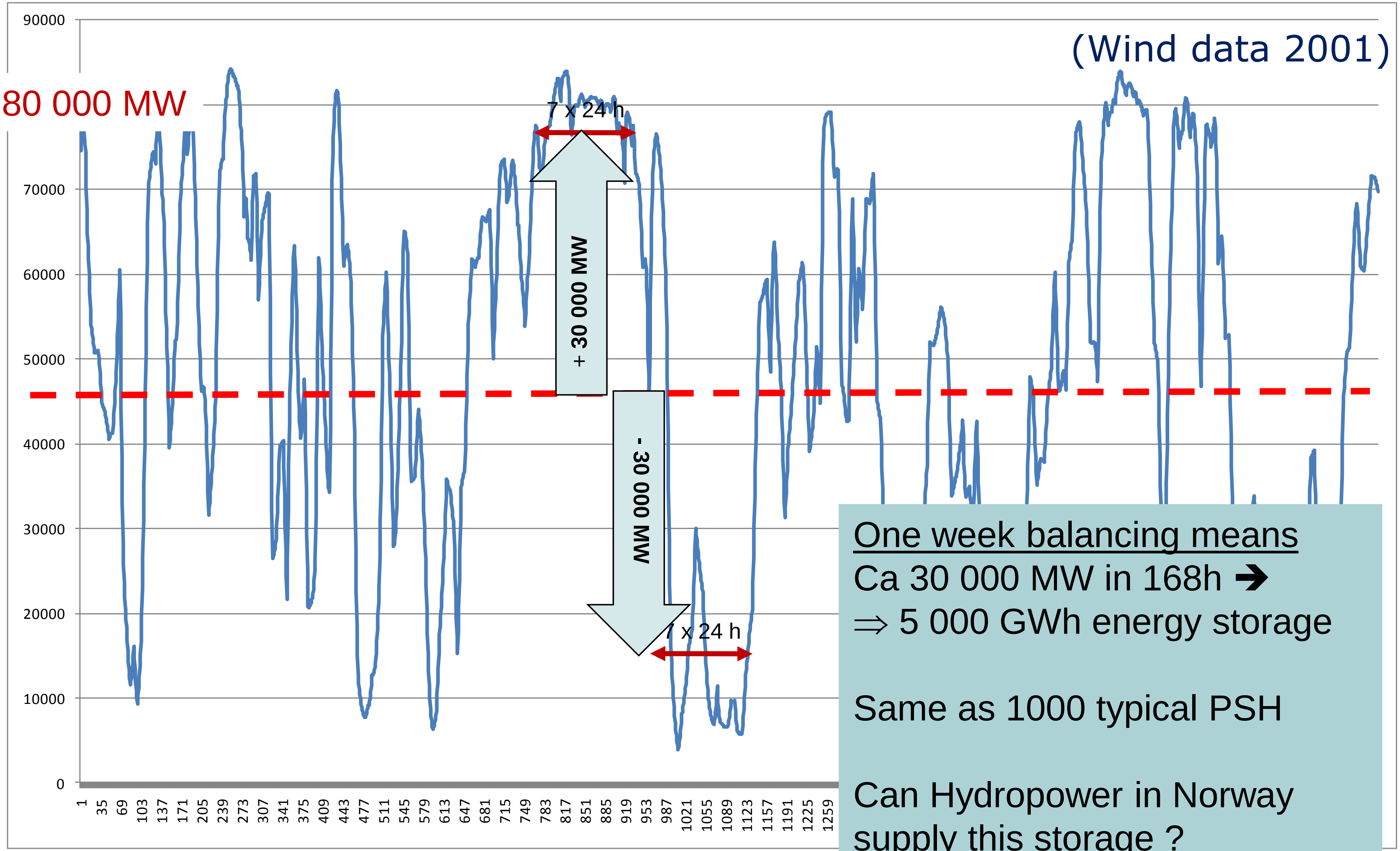
Blåsjø
7.8TWh reservoir
(1000 times Goldistal)



Simulated wind production in the North Sea area in 2030 – 95 000 MW installed capacity



Wind Power North-Sea Region - Jan – March

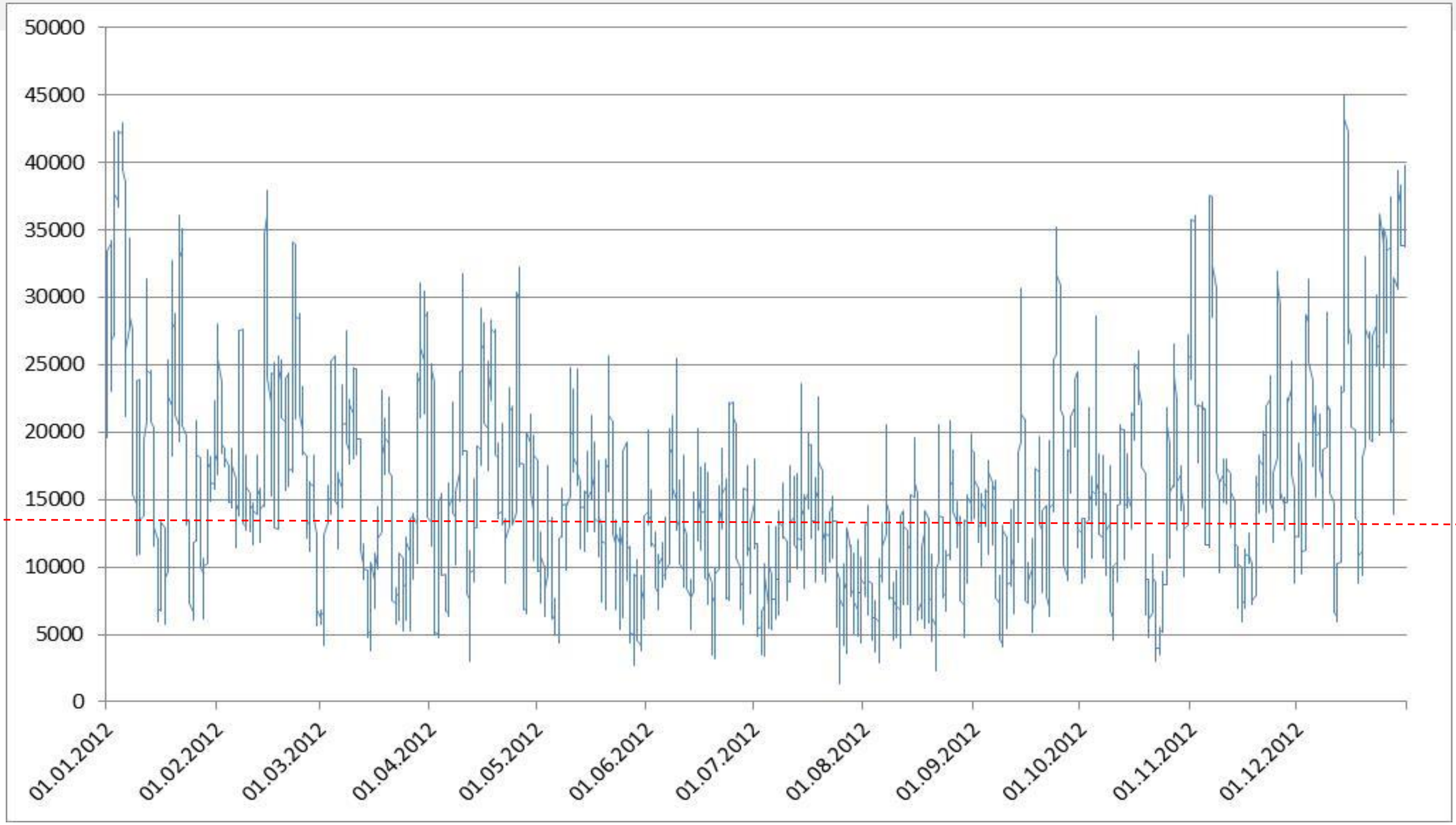


<u>One week balancing means</u>
Ca 30 000 MW in 168h ➔
⇒ 5 000 GWh energy storage

Same as 1000 typical PSH

Can Hydropower in Norway supply this storage ?

Faktisk produksjon i Vest-Europa (ES, FR, DE, DK, GB, IR) i 2012



Observed Wind energy production
In a system with **76013** MW
installed capacity (Stadium 2012)

Maximum: 44995 MW
Minimum: 1272 MW
Typical: 15400 MW
Capacity Factor: **0.20**

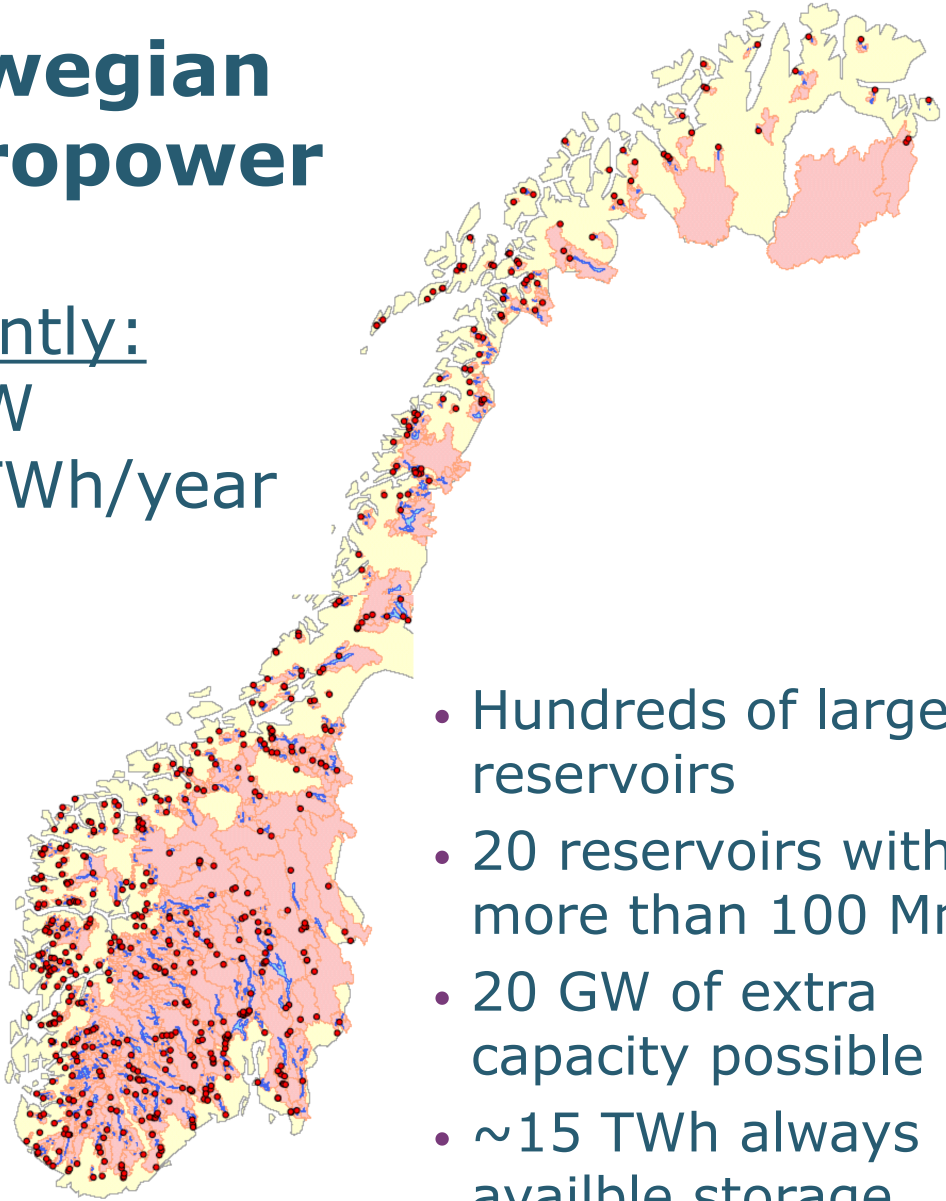
Hydropower in Norway – Resource base

Water, high head

Large natural reservoirs

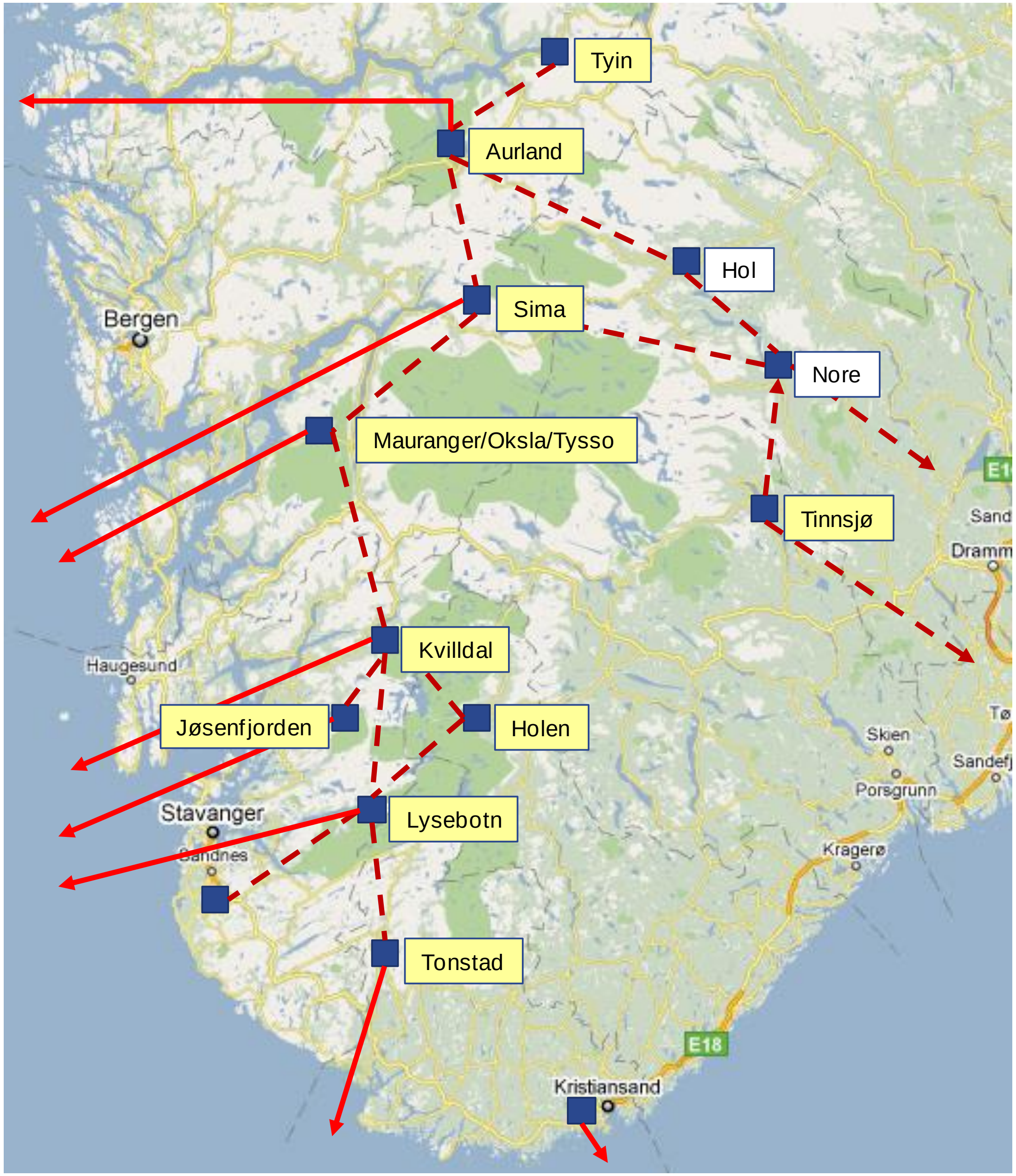
Norwegian hydropower

<u>Currently:</u>
32 GW
130 TWh/year

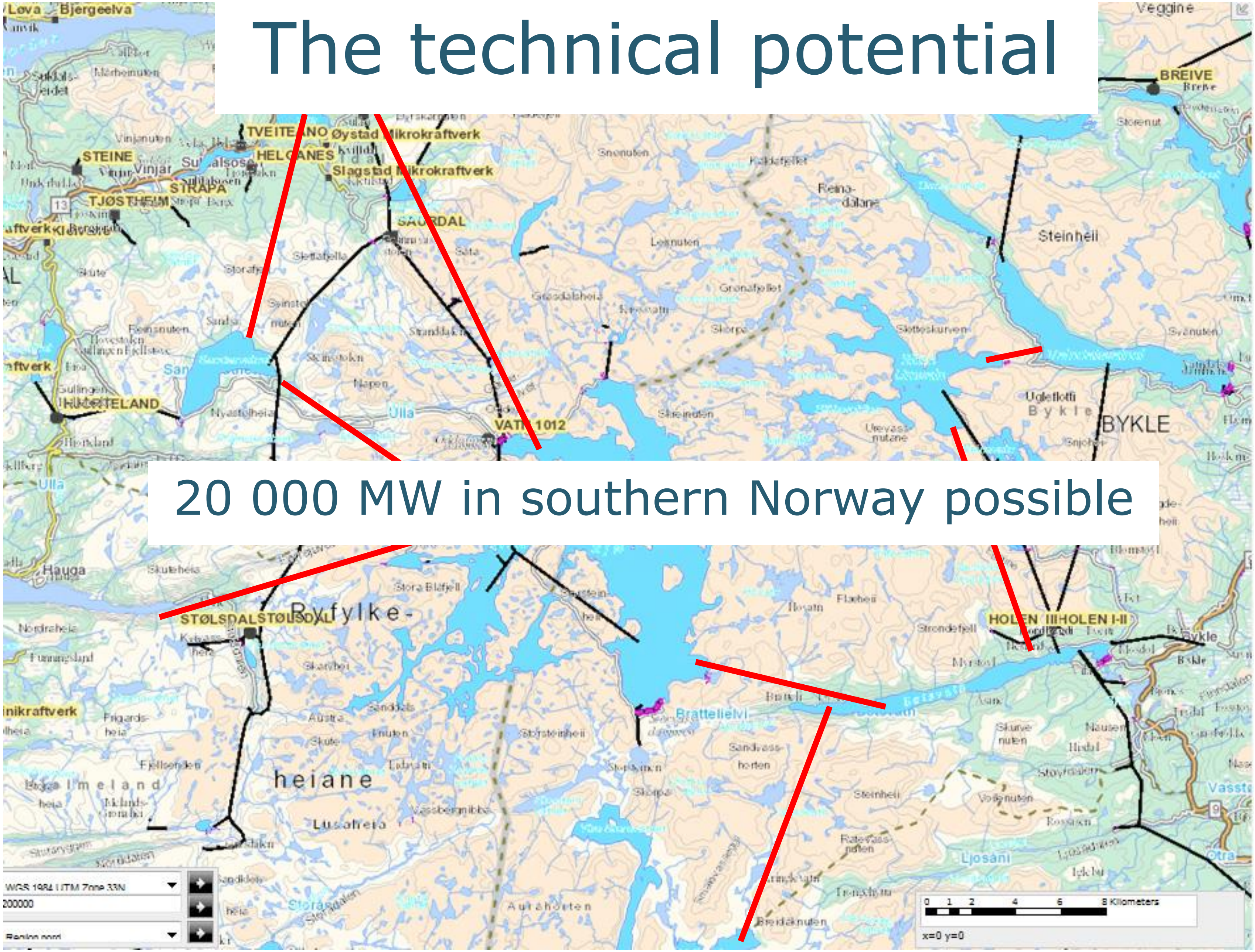


- Hundreds of large reservoirs
- 20 reservoirs with more than 100 Mm^3
- 20 GW of extra capacity possible
- ~15 TWh always availble storage

CEDREN Case study 2030



The technical potential



20 000 MW in southern Norway possible

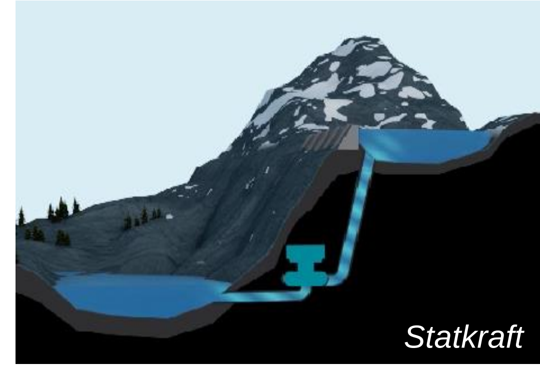
Transmission capacity

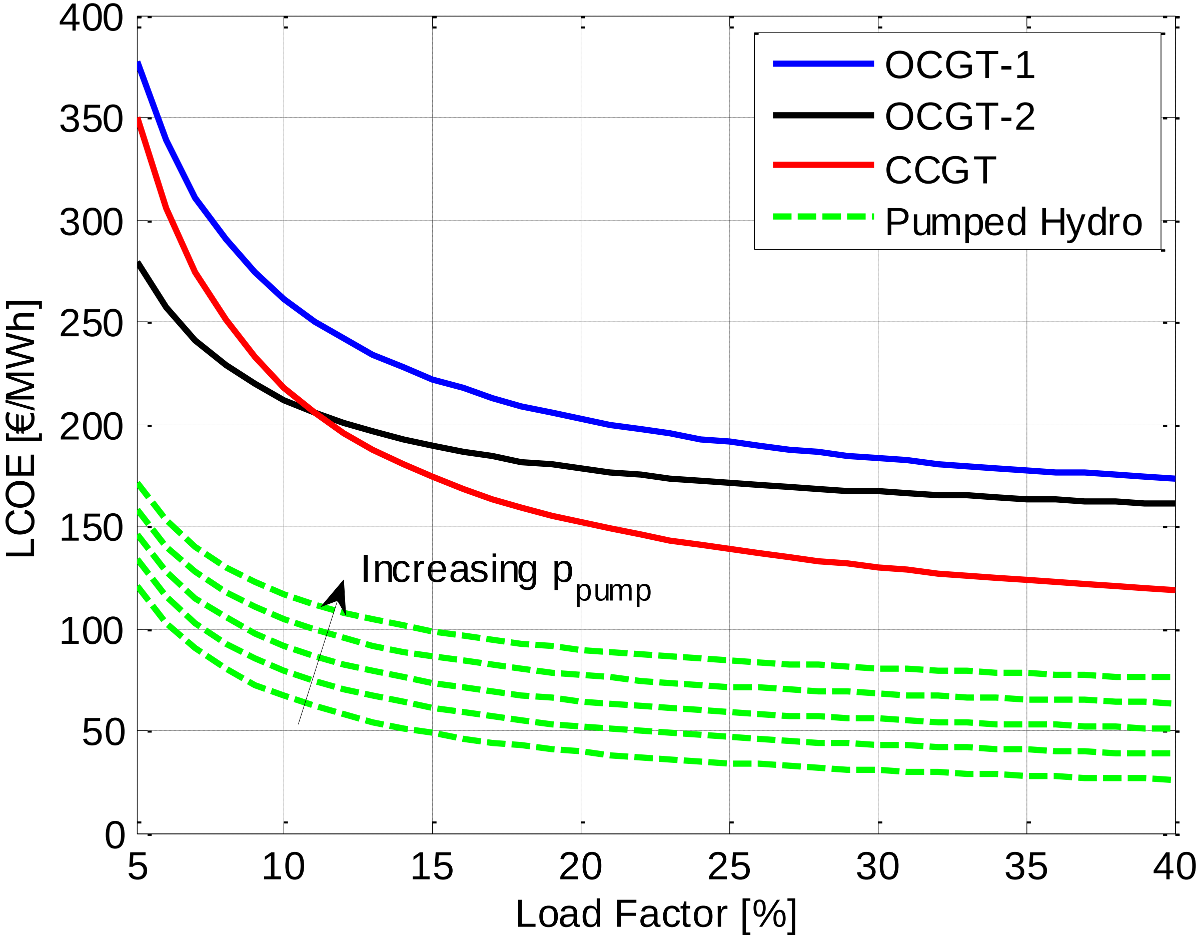
- **NO-Sweden**
  - North/Midle-Norway: 1 100 MW
  - South-Norway: 2 050 MW
  - SouthWest-link: 1 200 MW (2019)
- **NO-Denmark**
  - SK1-3: 950 MW
  - SK4: 600 MW (2014)
- **NO-Netherlands**
  - NorNed1 (NL): 700 MW
  - NorNed2 (NL): 700 MW (2016)
- **NO-Germany**
  - NorGer: 1 400 MW (2018)
  - NORD.LINK: 1 400 MW (2018)
- **NO-England**
  - 1 400 MW (2020)

Possible interconnection capacity in 2020:

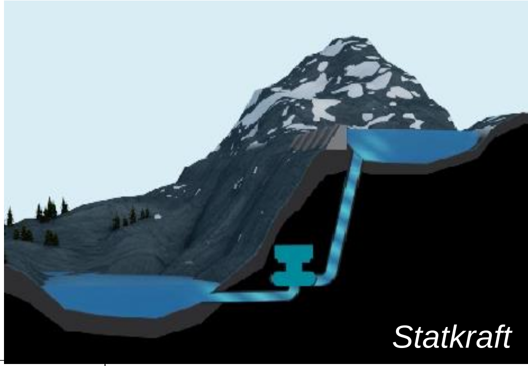
4 800 + 6 700 = 11 500 MW

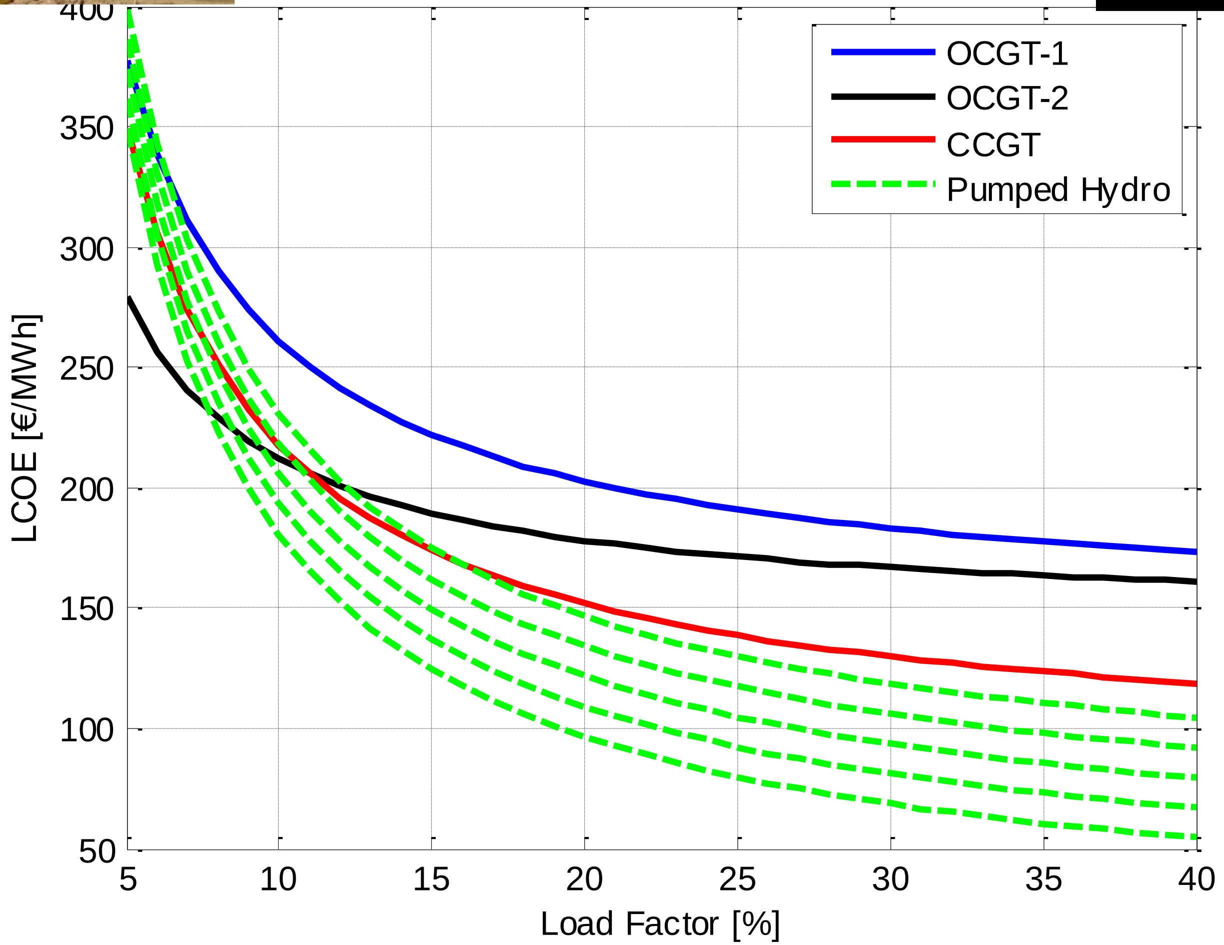
Comparing LCOE for Norwegian Pumped Hydro and Gas Power Plants



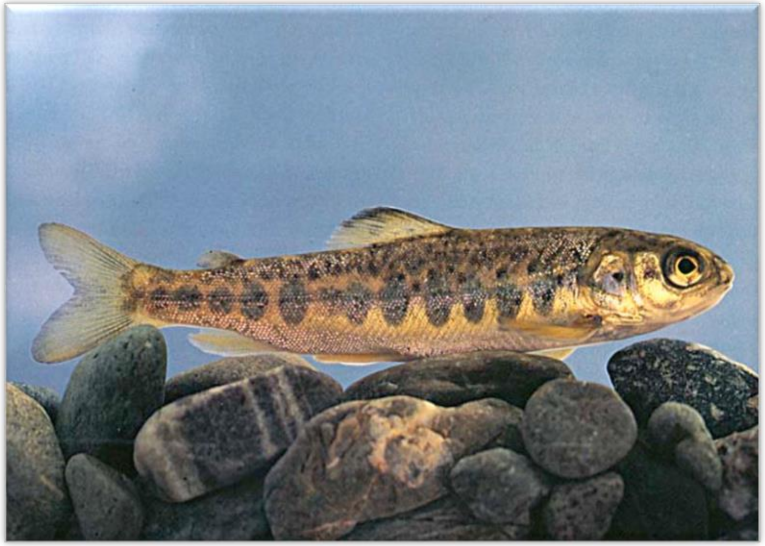


…even when grid and cable costs are included





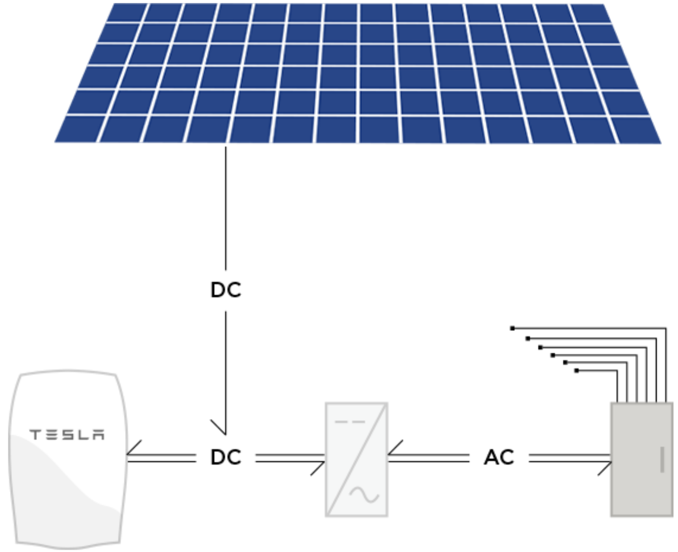
Environmental impacts



Social acceptance

Tesla PowerWall© - 10kWh units for homes

Roof-top solar panel or similar



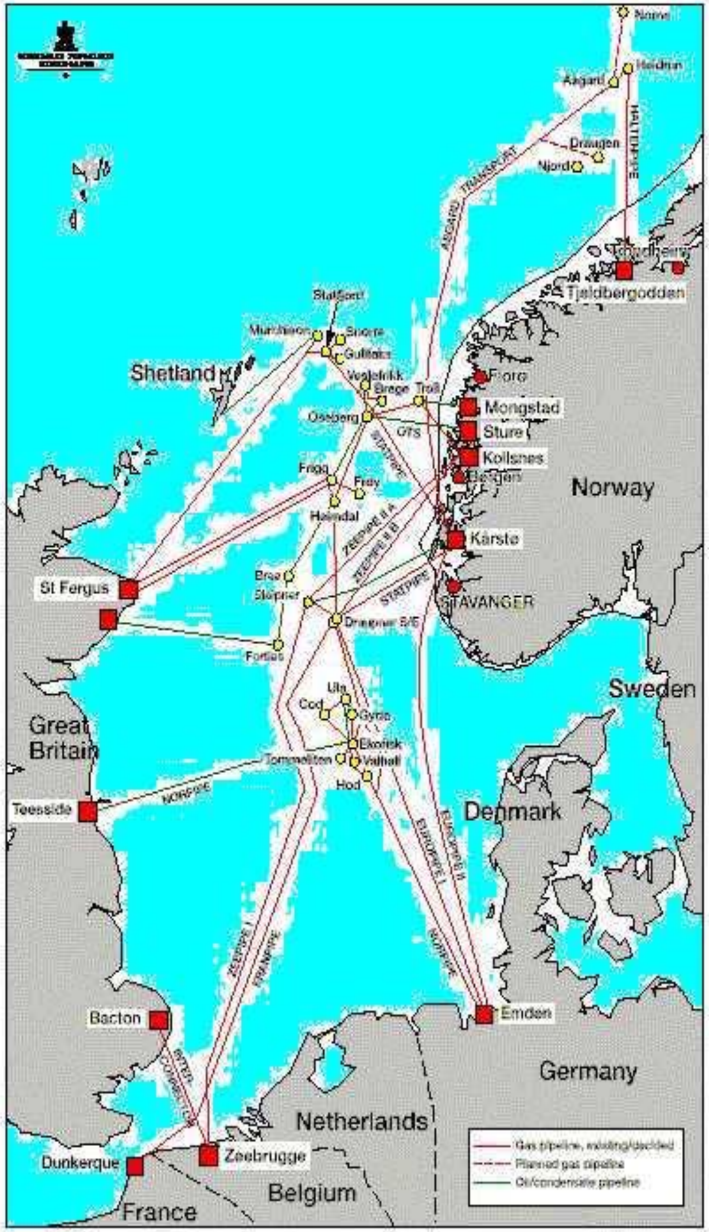
PowerWall©


- Balancing solar energy
- Energy security
- Off-grid solutions

The Great Wall

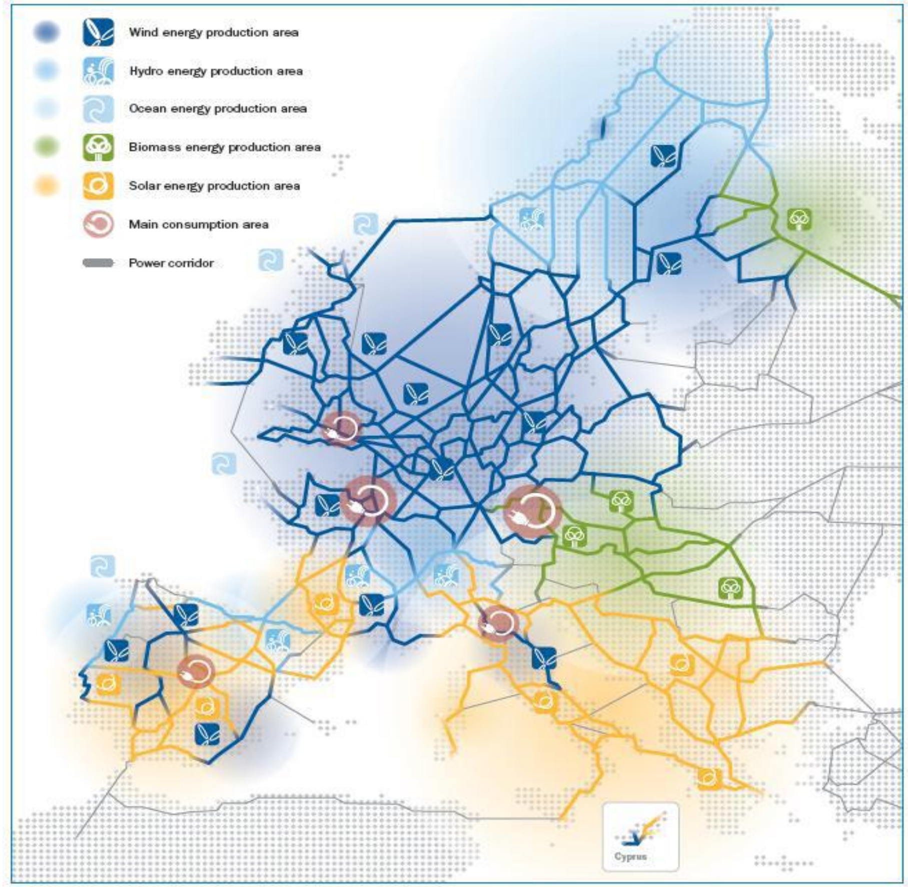
Cover with Tesla PowerWall©

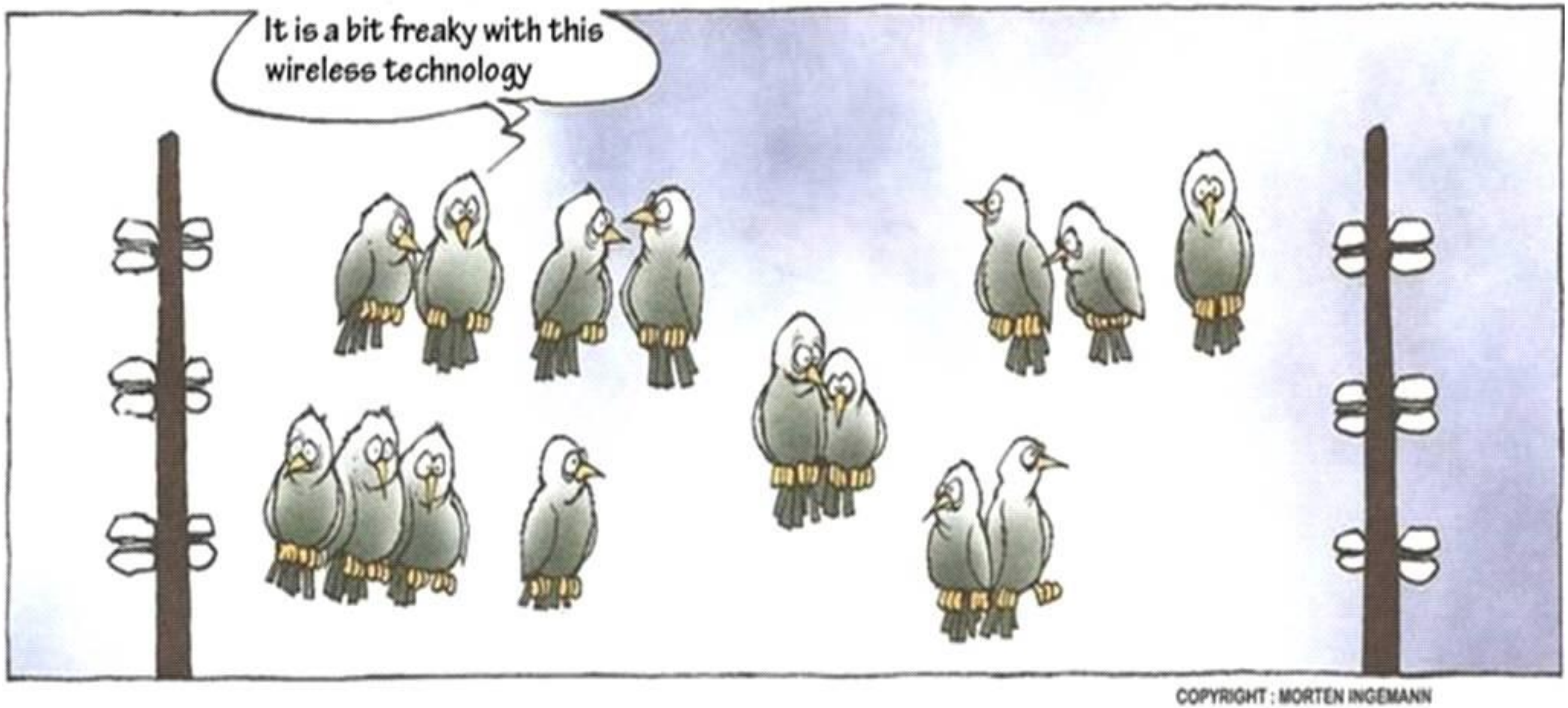
1,23 TWh = 15 % of Blåsjø



← Natural gas grid today

Can we establish a similar *electricity* grid for exchange?





- Uncertain future – many scenarios – new technologies (?)
- Increased need for energy and water storage
- Rapid changes may come (…Fukoshima)
- Hydro reservoirs = always an <u>excellent</u> energy storage
- We need to value all services from reservoirs properly

www.cedren.no

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