Large-scale balancing and storage from hydropower - trends for the future

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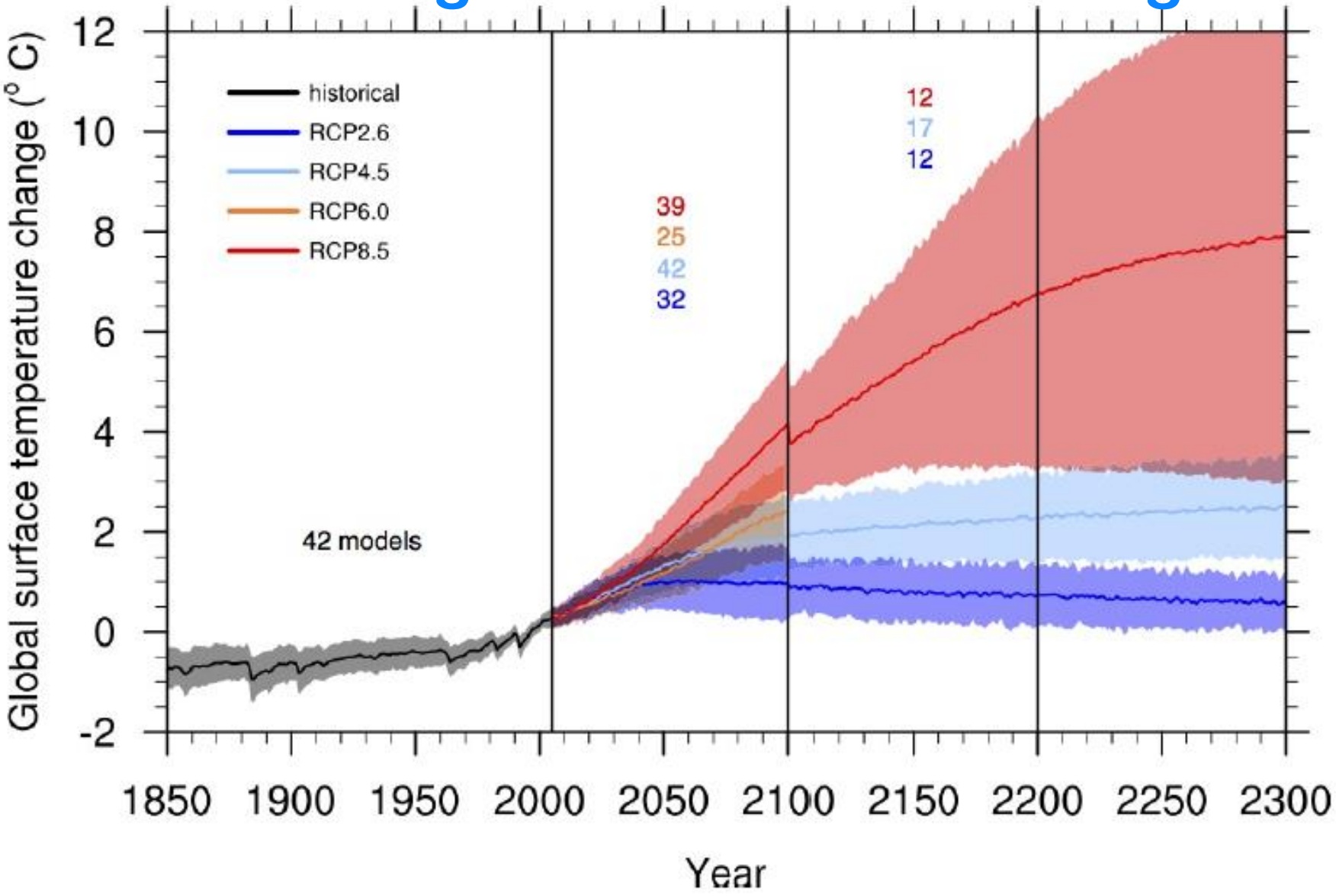
The Background – Climate Change



Some Main Challenges for the Future

- Stabilizing climate impact from fossil fuel use
- Meeting the energy demand of a growing global population
- Electricity to 1.6 Billion people without such access today
- Ensuring stable and secure energy access for all nations
- Transporting electricity long distances
  (from where it is generated to where it is used)

In Figures, the challenge for the year 2050 is :

1) Energy demand will increase by a factor of two globally
2) Simultaneously, CO_2 emissions must be reduced by a factor of two

(International Electrotechnical Commission, 2010)

WE NEED TO MOVE FROM FOSSIL TO RENEWABLE ENERGY

Renewable energy may be the future
But can RE really deliver?

- *The energy we need*
- *When we need it*
- *Where we need it*
- *With good enough quality??*

Climate-friendly 100% renewable electricity supply for Europe by 2050 (SRU, 2010)

SRU German Advisory Council on the Environment

Climate-friendly, reliable, affordable: 100% renewable electricity supply by 2050

Statement

May 2010 Nr. 15

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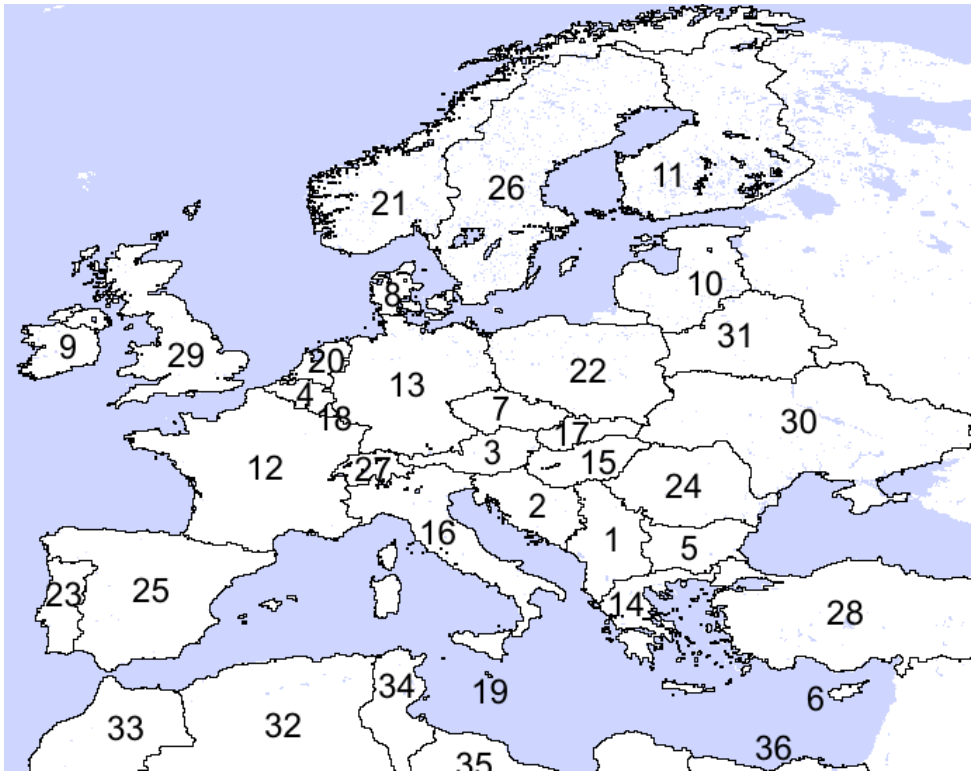
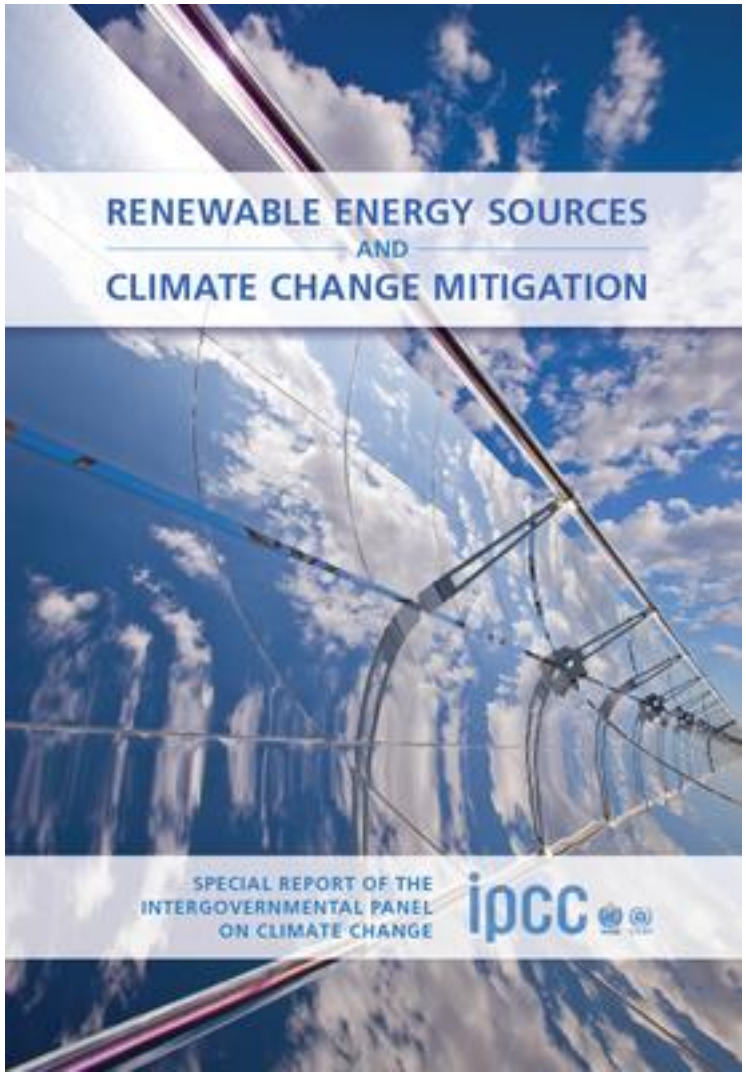


SRU German Advisory Council on the Environment

- **100% renewable electricity supply for Germany and Europe is possible by 2050 (2030 if needed)**
- **The system will mainly be based on wind and solar**
- **Storage and transmission will be crucial**
- **Pumped storage hydro will be in great demand**
- **Norway will become a unique swing provider for the European system due to its hydro resource**
- **We can start with bilateral cooperation**

IPPC Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN, 2011)



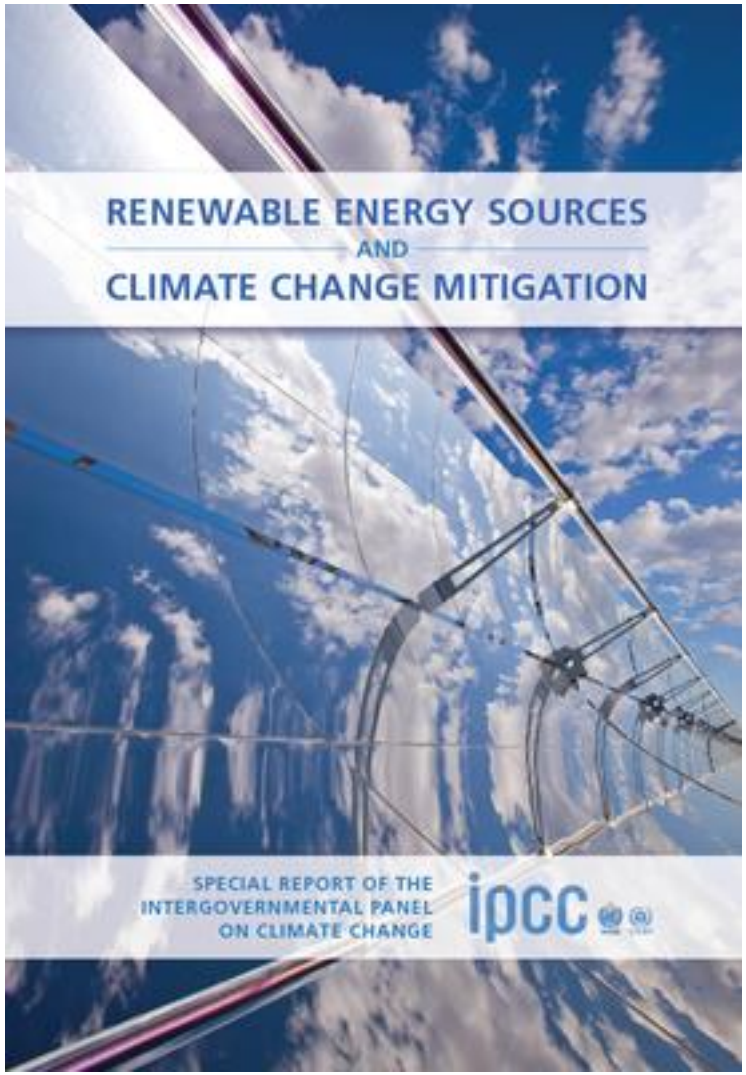
Up to 80% Renewable could be possible
If backed by the right enabling policies

The global technical potential of RE sources will not limit continued growth in the use of RE

A wide range of estimates are provided in the literature, but studies have consistently found that the total global technical potential for RE is substantially higher than global energy demand

The technical potential for solar energy is the highest among the RE sources, but substantial technical potential exists for all six RE sources

IPPC Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN, 2011)



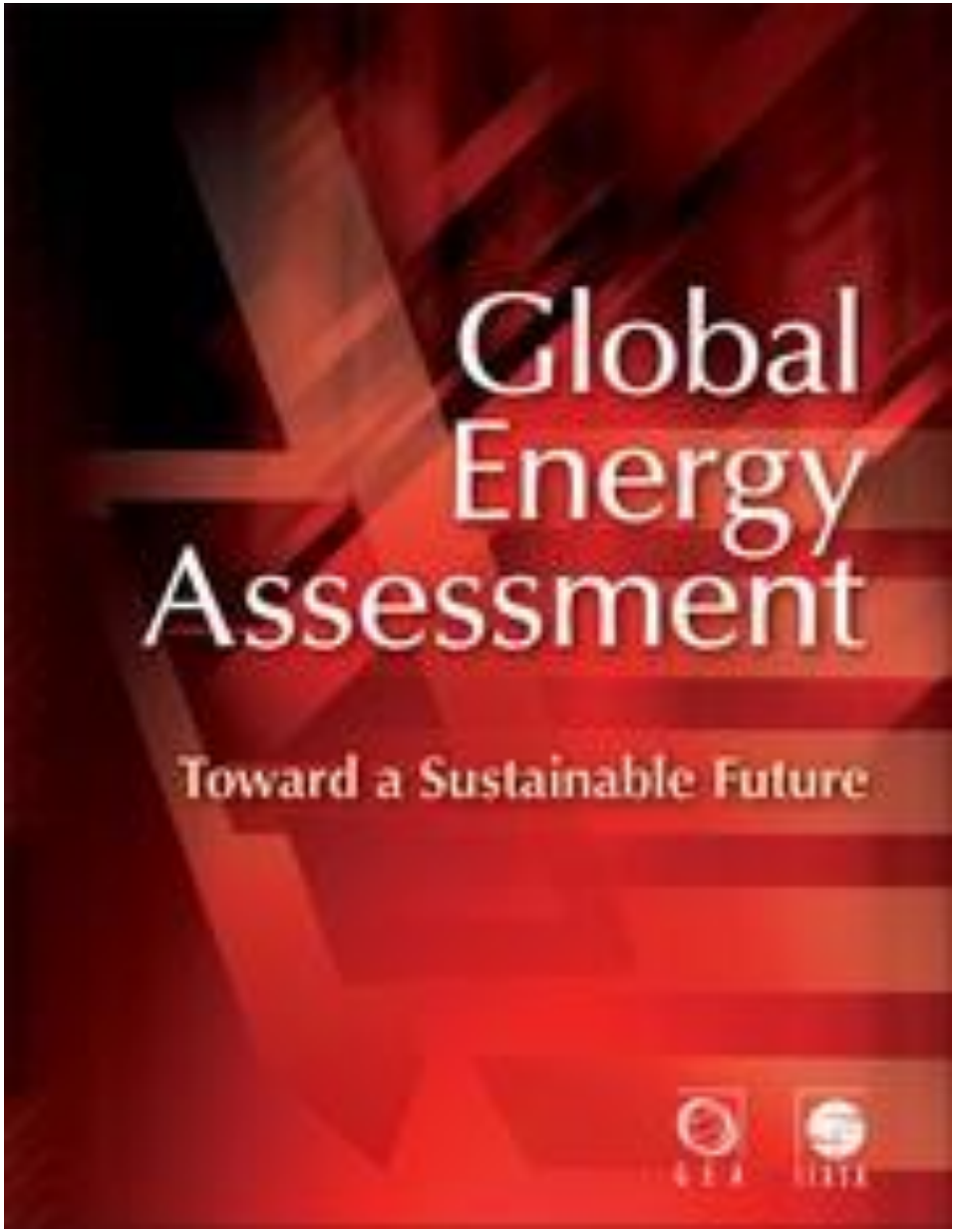
Some main challenges:

- Transmission and distribution infrastructure
- Energy storage technologies
- Demand side management
- Improved forecasting of resource availability

Renewable Electricity Futures Study (For US) (NREL , 2012)

Key Findings

"*Renewable electricity generation from technologies that are commercially available today, in combination with a more flexible electric system, is more than adequate to supply 80% of total U.S. electricity generation in 2050 while meeting electricity demand on an hourly basis in every region of the country*"



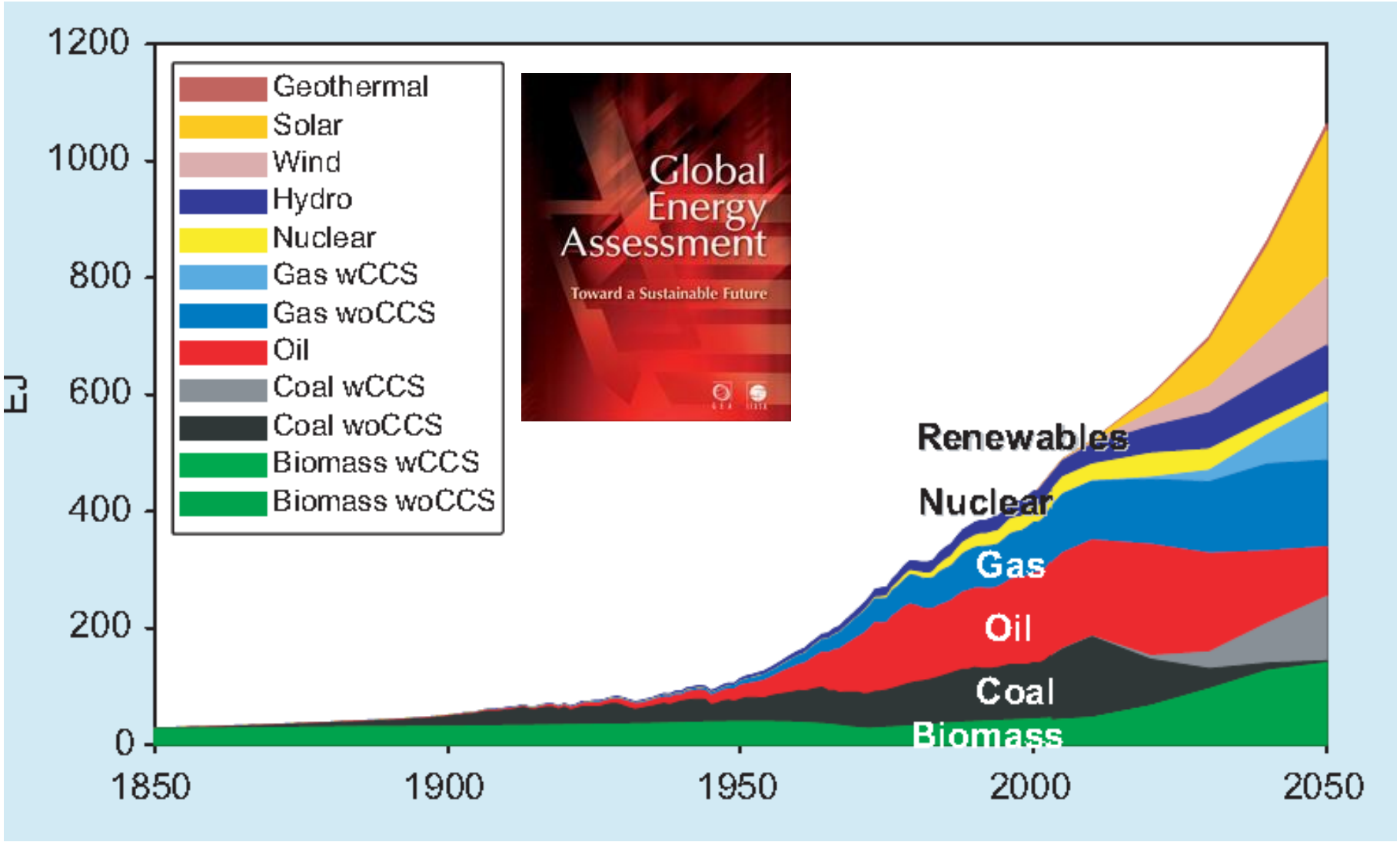
Transformation of energy system toward 2050 (to 60-80% Non-carbon):

- Energy efficiency
- Renewables
- Nuclear
- CCS
- Bio

- Integration of RE (wind & solar)
- Storage technologies
- Smart grids
- Demand side management

(GEA, IIASA, 2012)

GEA-Supply Pathway towards 2050
Alternative with Nuclear Phase-out by 2050



Conclusions in these and other studies are similar

Large scale RE development is possible with known technology

Three main sources will be dominating: Wind, Solar and Hydro

Few, if any, fundamental technical limits exist to the integration of a majority share of RE, but advancements in several areas are needed:

- **Transmission and distribution infrastructure**
- **Energy storage technologies**
- **Demand side management**
- **Improved forecasting of resource availability**

EU-Policy is very determined

"The energy challenge is one of the greatest tests faced by Europe today"

"Key decisions have to be taken to reduce drastically our emissions and fight climate change"

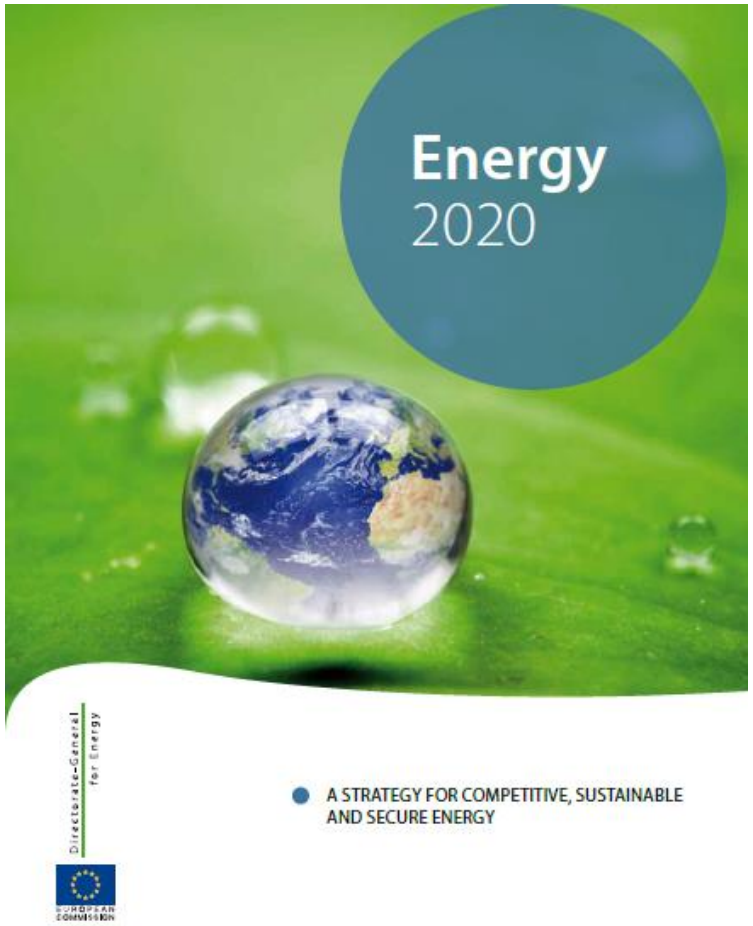
G. Oettinger (EU commisionar for energiy)
Energy 2020

The RES Directive (20/20/20 Goals)

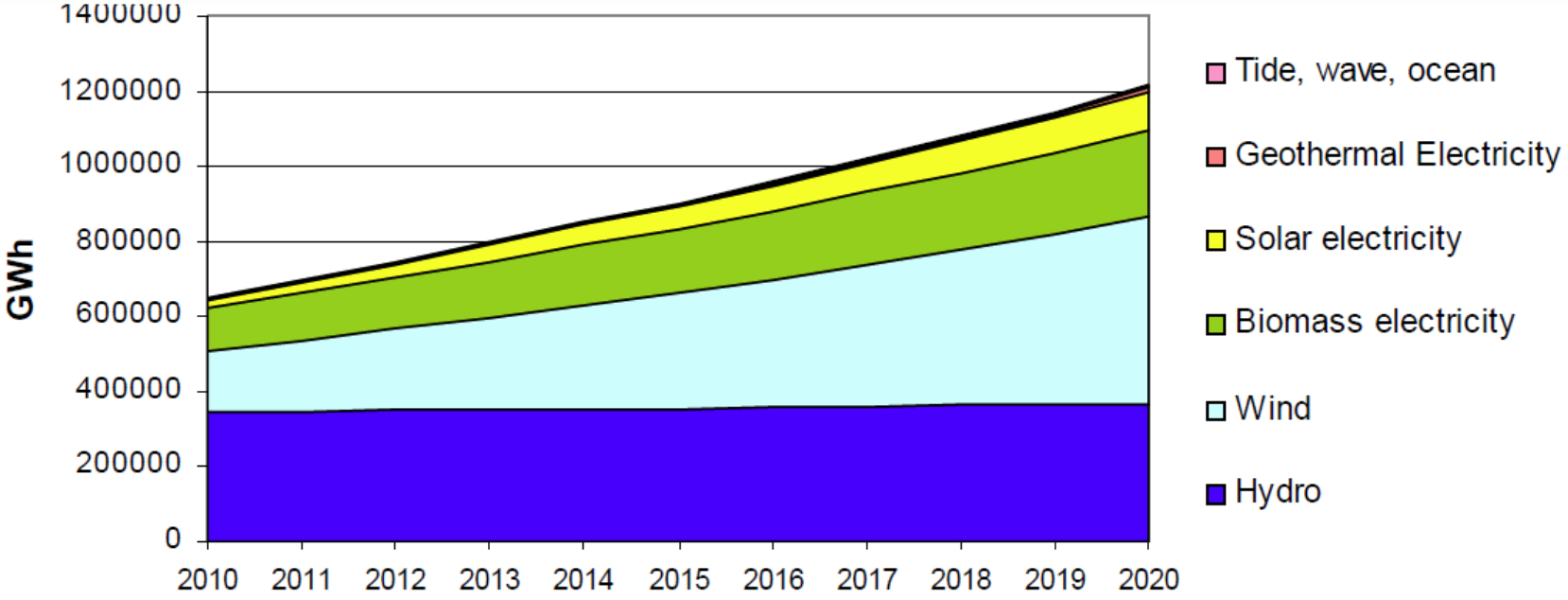
1. Main targets
- 20% reduction in GHG emissions
- 20% better energy efficiency
- 20% of energy from RES

For electricity 34% in 2020

Source: *Energy 2020 – A strategy for competetive, sustainable and secure energy*

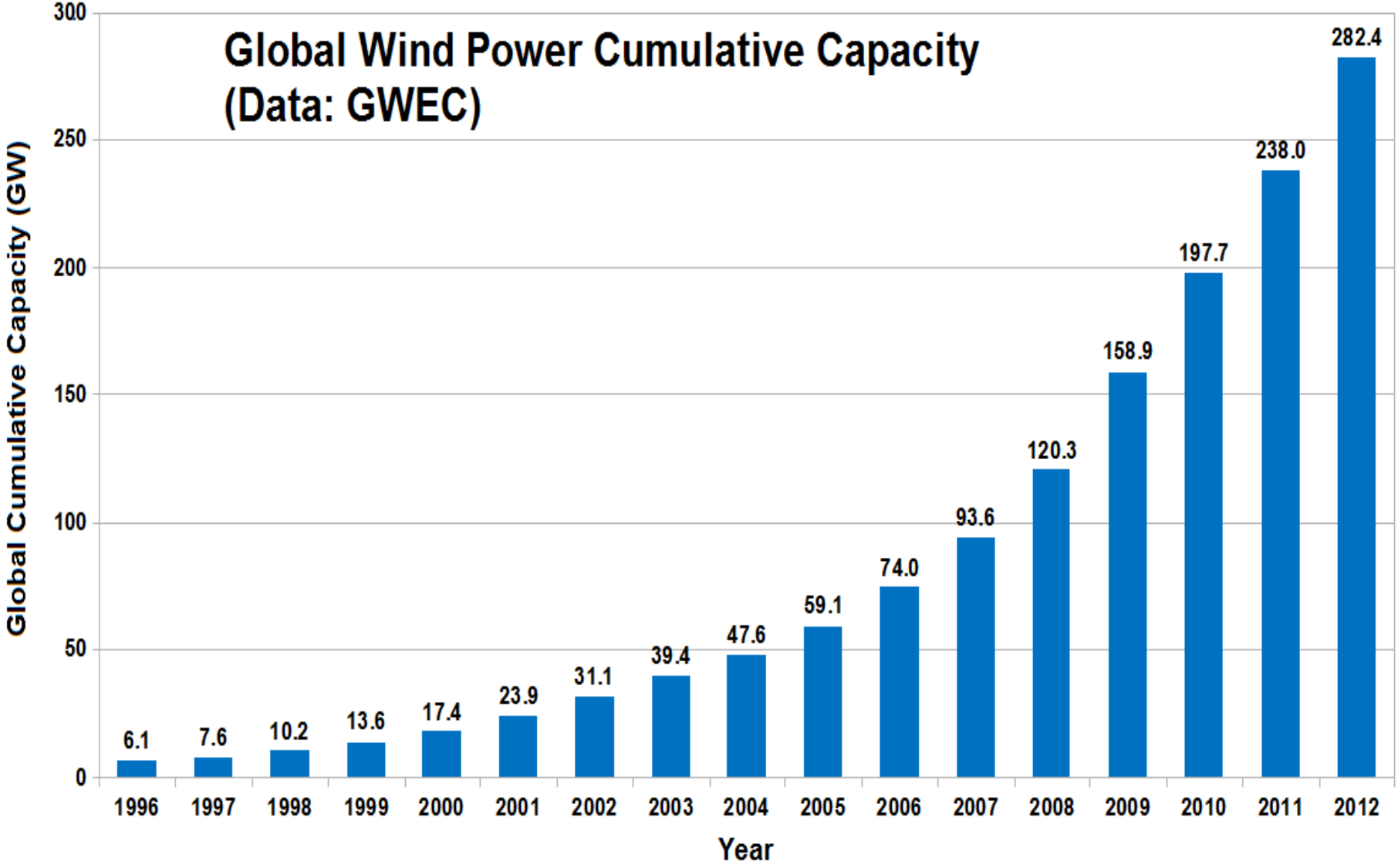


Towards 2020 – Implementation of the RES-directive



RES generation from **632** TWh in 2010 to **1152** TWh in 2020
Largest increase in Wind - ca 120 GW and 305 TWh
Also rapid increase in Solar PV - ca 65 GW og 100 TWh

➔ Increase of non-dispatchable power generation (wind, solar PV)


Global Wind Power Cumulative Capacity
(Data: GWEC)
Global Cumulative Capacity (GW)
300
250
200
150
100
50
0
6.1
7.6
10.2
13.6
17.4
23.9
31.1
39.4
47.6
59.1
74.0
93.6
120.3
158.9
197.7
238.0
282.4
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Year

EU - Energy Roadmap for 2050

- Decarbonization of Energy system by 2050
- Energy saving / Energy Efficiency
- Switching to Renewable Energy Sources
- More market integration / European approach
- Storage technologies remains critical
- Gas plays a key role in the transition
- Need for flexible resources
- Transition in close partnership with neighbours (Norway, …)
- Further interconnection with Norway and Switzerland … critical
- Engaging the public is crucial (Social dimension)

To achieve this new energy system ten conditions must be met:

(1) ... Implement fully the 2020 strategy …

(2) … more energy efficient …

(3) … more renewable energy …

(4) … more R&D …

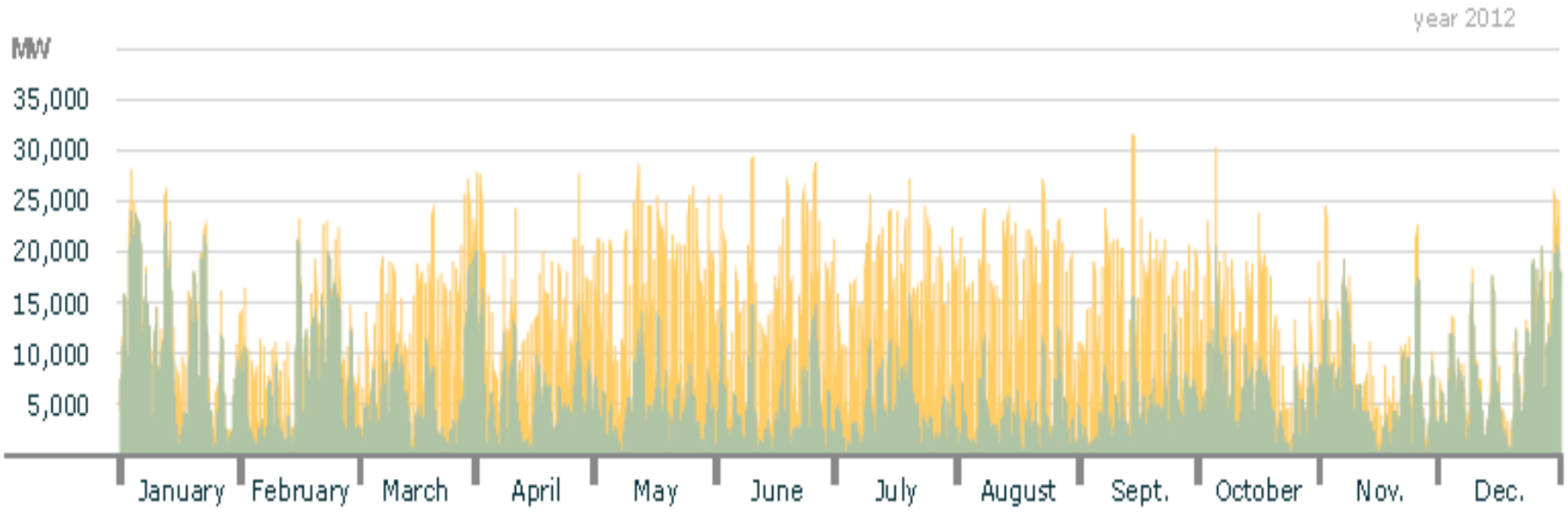
(7) A new sense of urgency and collective responsibility must be brought to bear on the development of **new energy infrastructure and storage capacities across Europe** and with neighbours.
…

(9) A broader and more coordinated EU approach to **international energy relations** must become the norm, including redoubling work to strengthen international climate action.

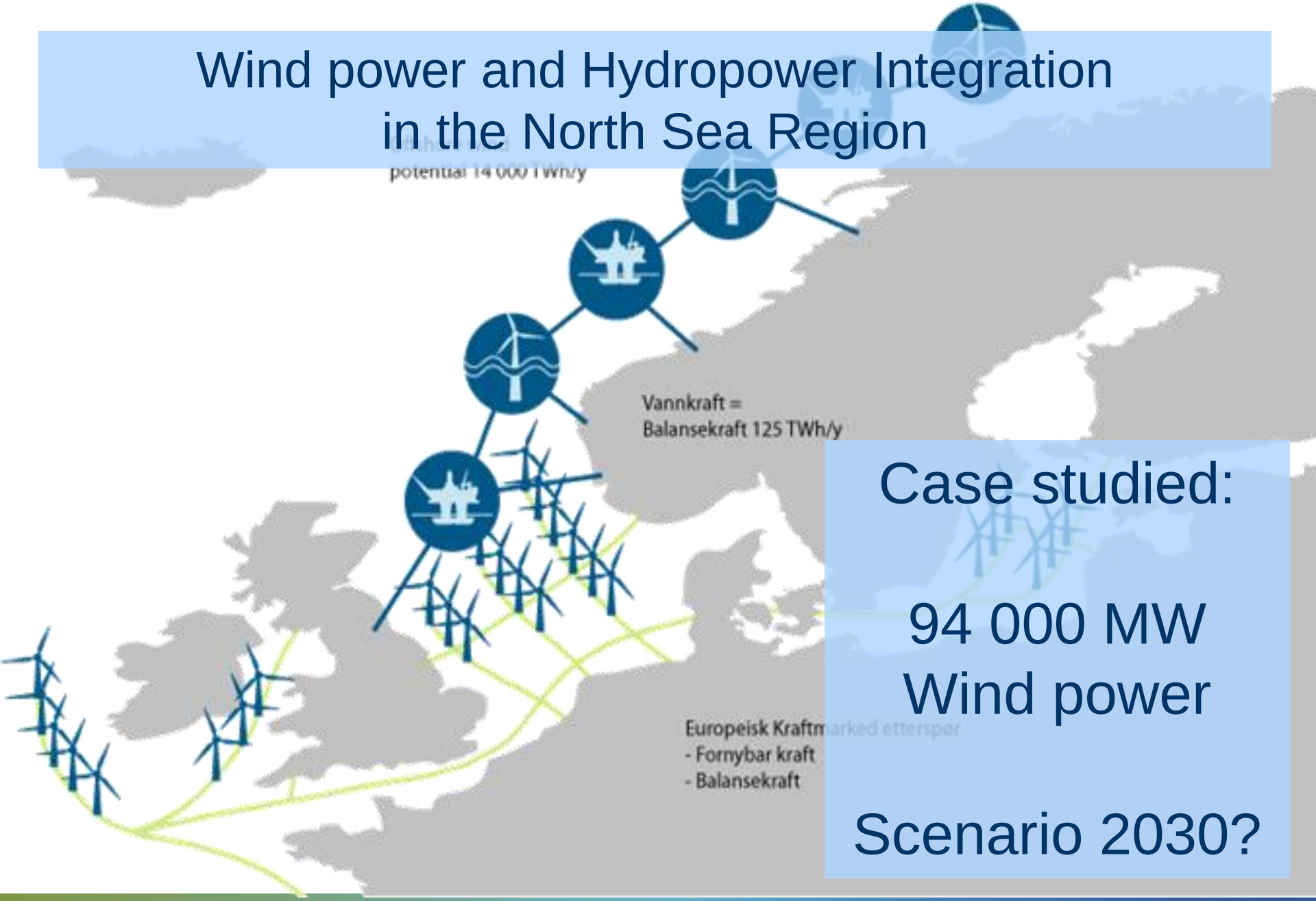
Main problem with
Wind and Solar Power:

- Intermittency
- Highly variable output
- Low predictability
- Non-Dispatchable

Actual production solar and wind (Germany 2012)



Wind power and Hydropower Integration in the North Sea Region



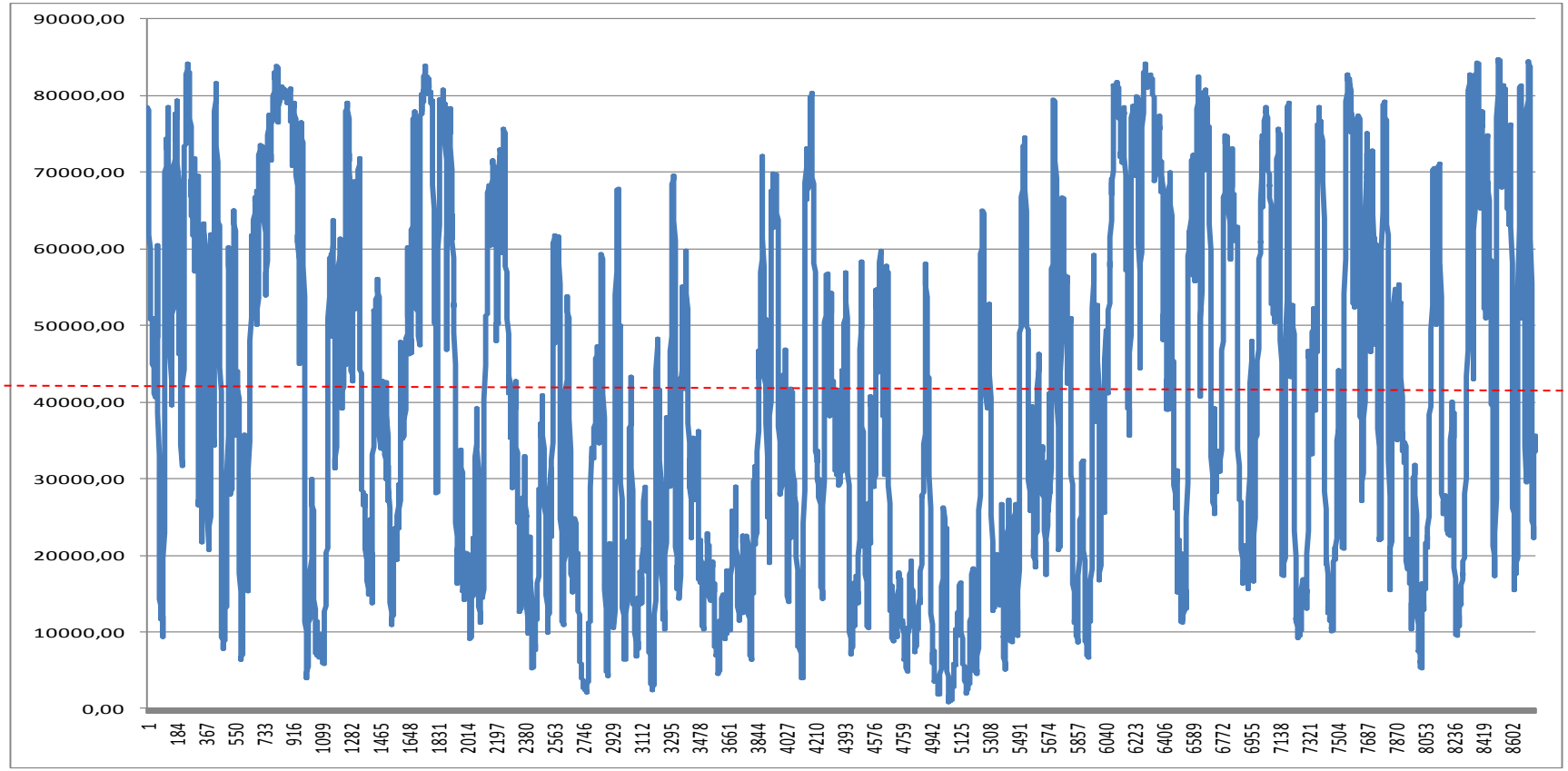
Case studied:

94 000 MW
Wind power

Scenario 2030?

However - Wind energy is highly variable

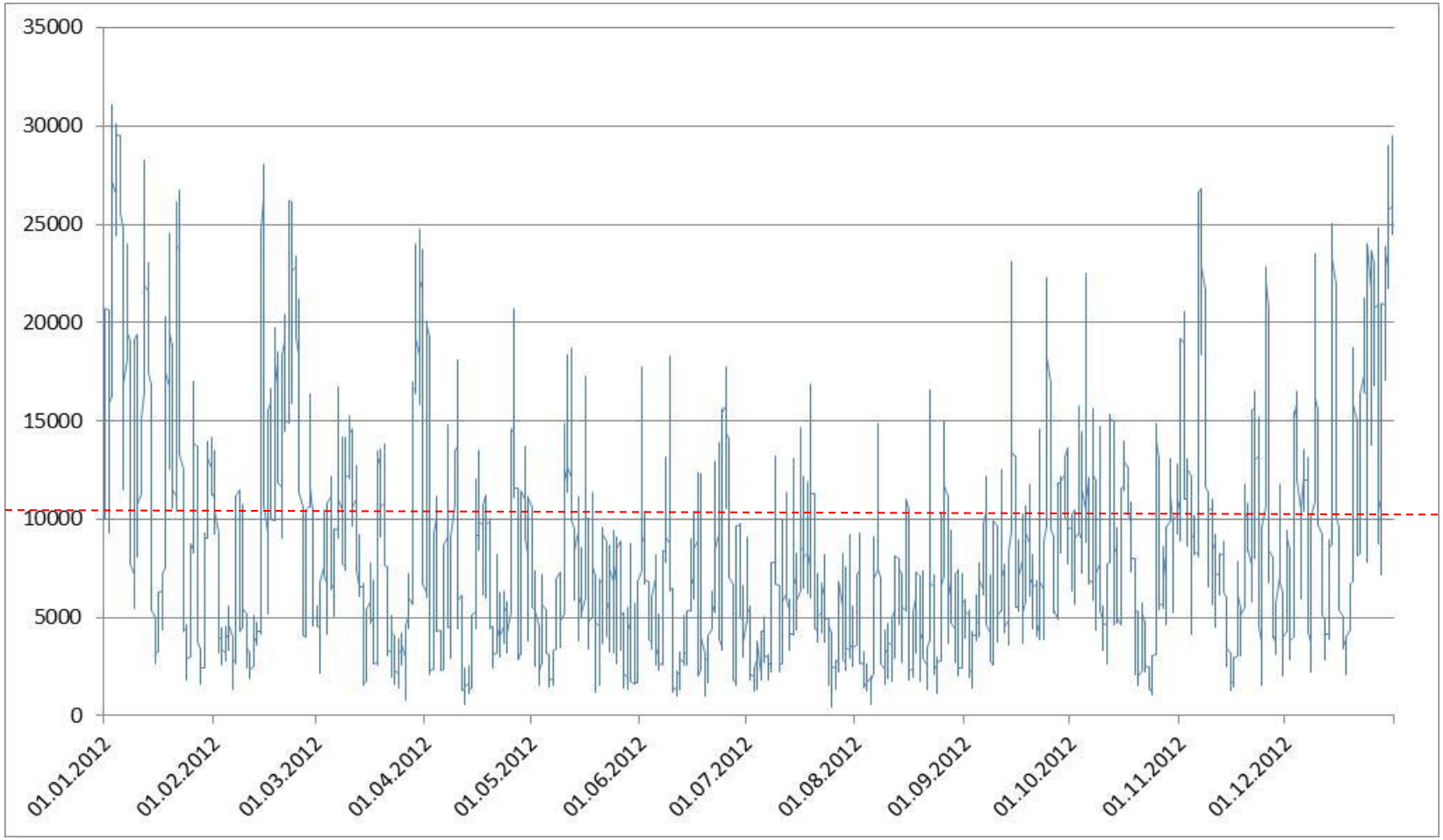
(Hourly simulated wind power for one year – data from TradeWind)



Simulated Wind energy production in a North-Sea system with 94000 MW installed capacity (Stadium 2030)

Maximum: 84 448 MW
Minimum: 2 774 MW
Typical: 40 000 MW

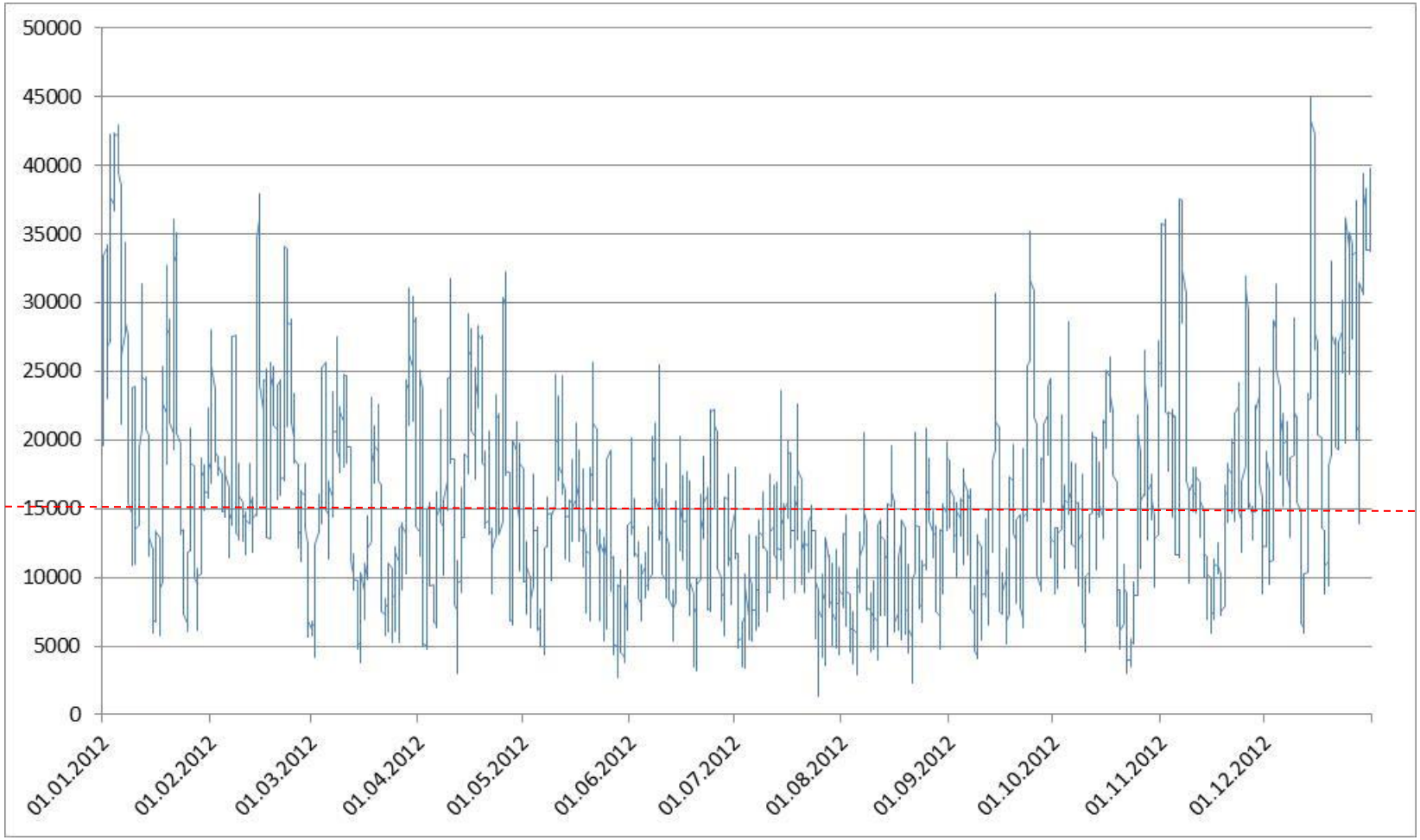
Wind Power in North-Sea Region (DE, DK, GB, IR) in 2012



Observed Wind energy production in a system with **45600 MW** installed capacity (Stadium 2012)

Maximum: 31062 MW
Minimum: 419 MW
Typical: 8300 MW
Capacity Factor: **0.18**

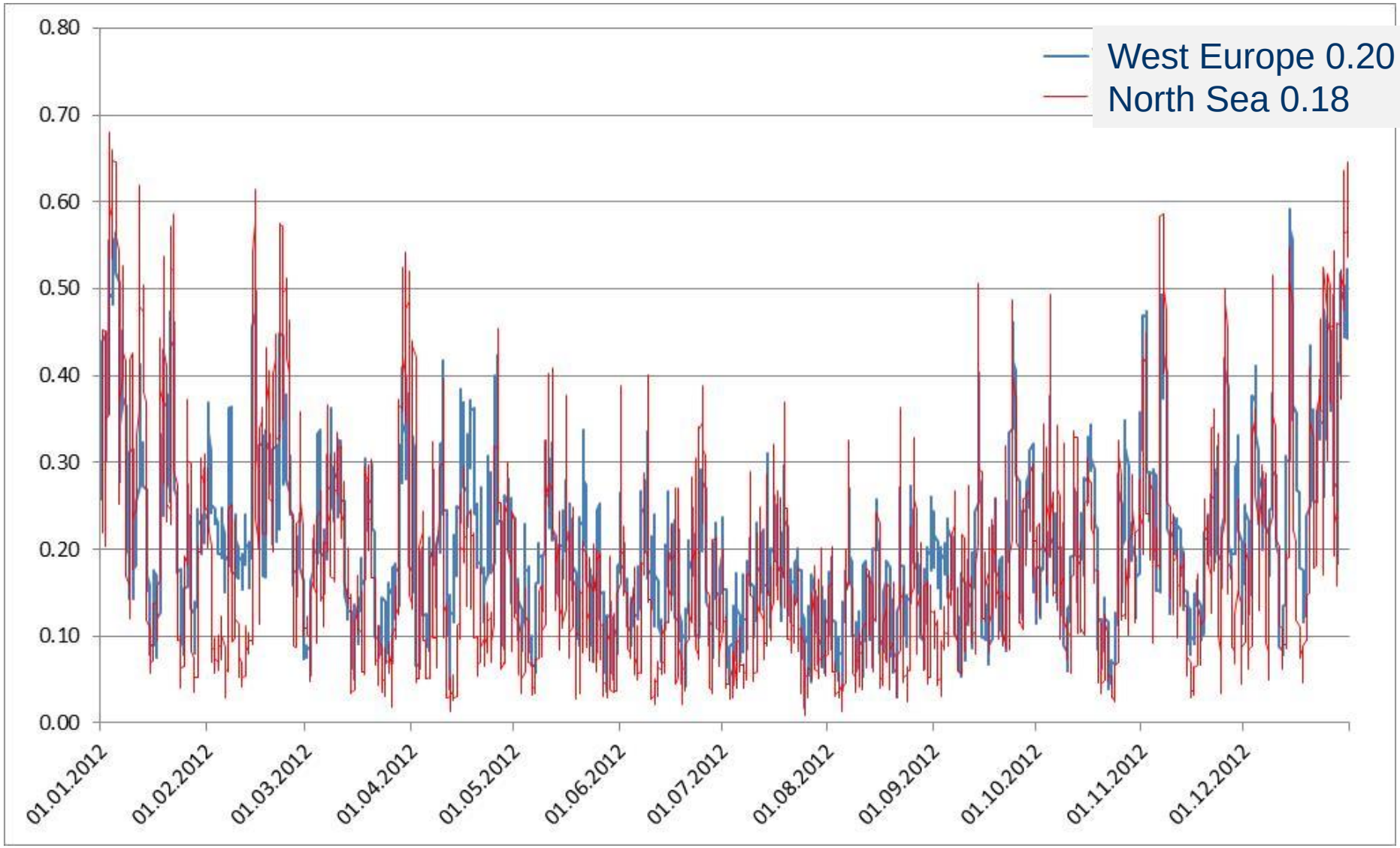
Wind Power in West Europe (ES, FR, DE, DK, GB, IR) 2012



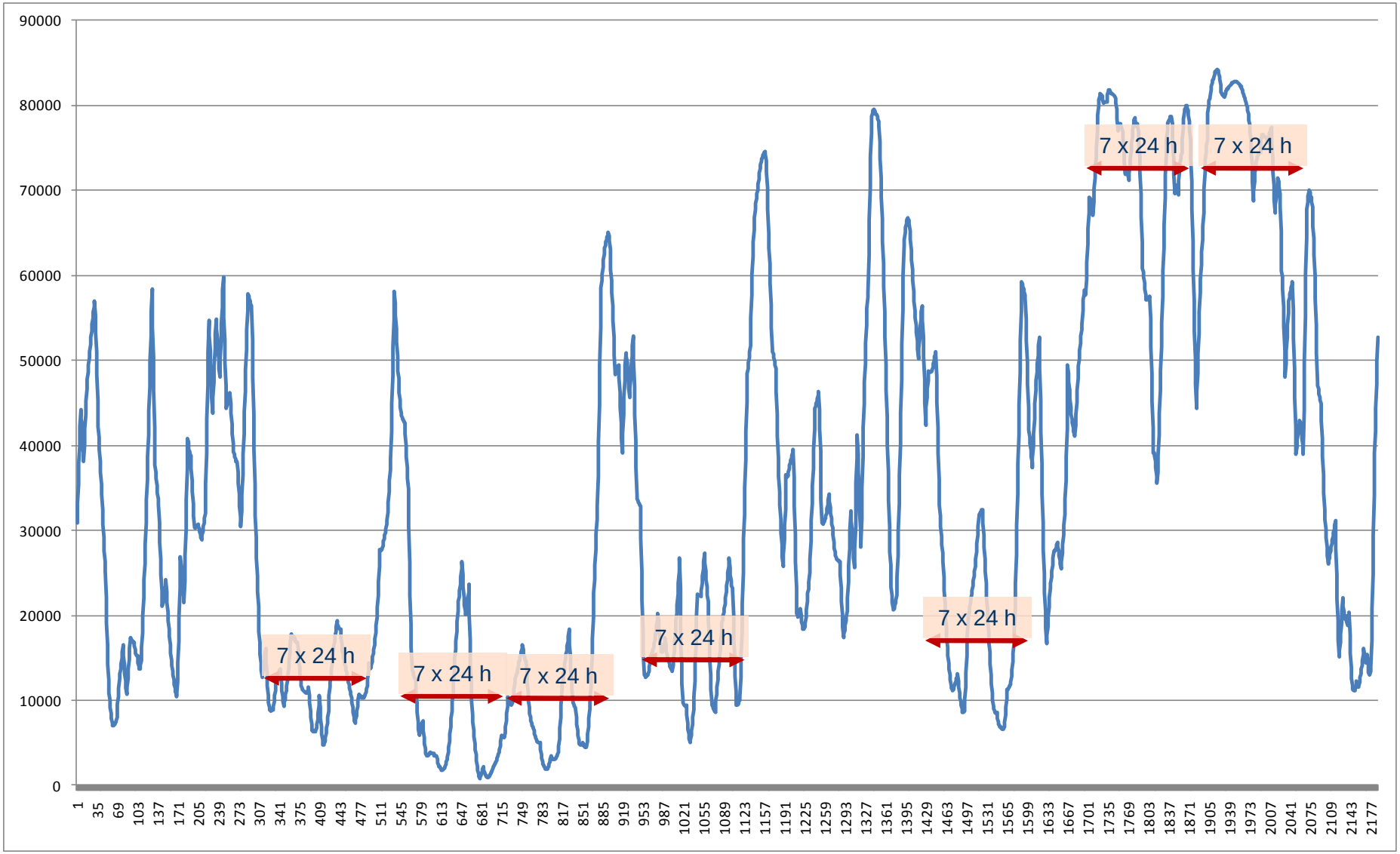
Observed Wind energy production
In a system with **76013** MW
installed capacity (Stadium 2012)

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

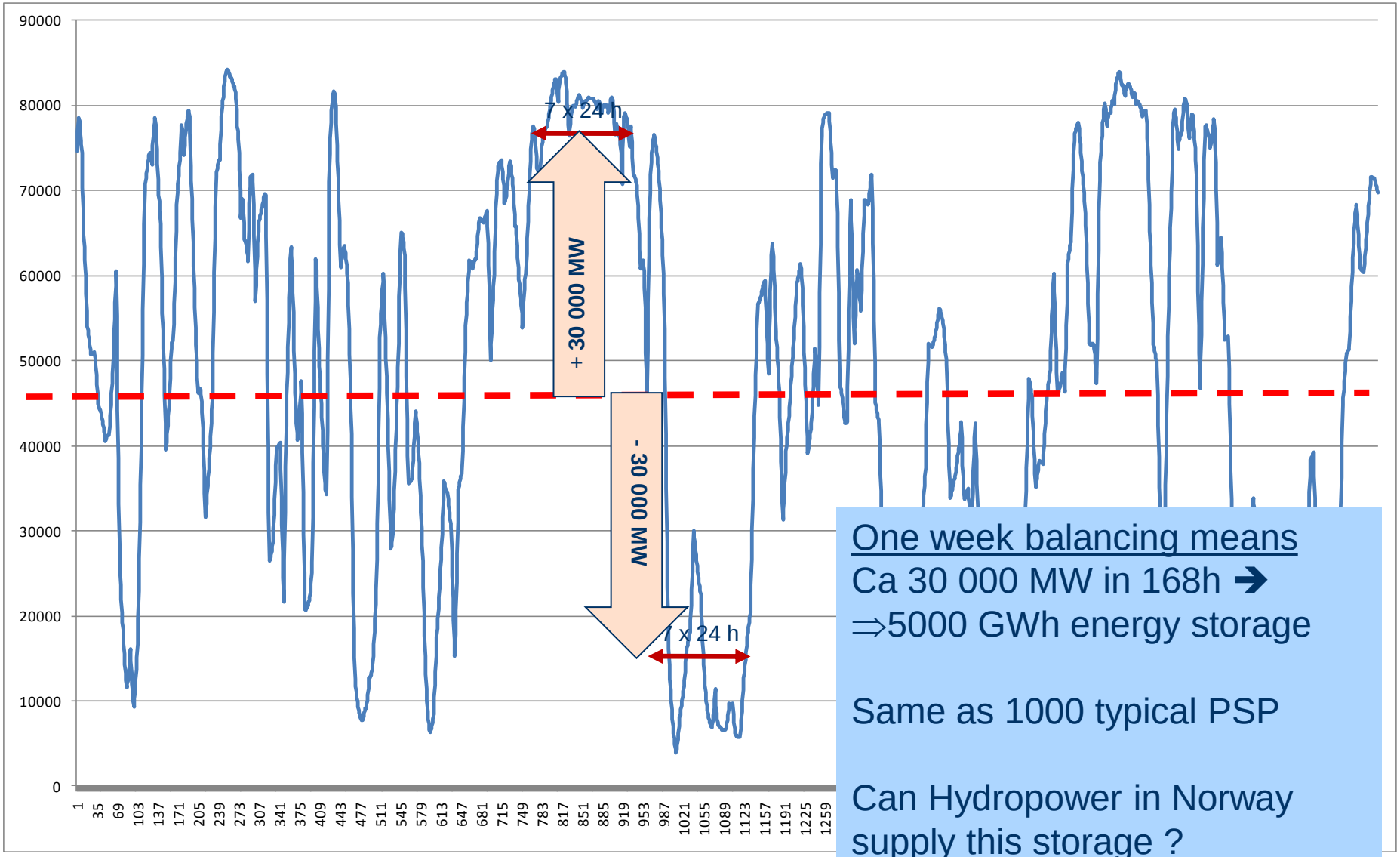
Wind Power Capacity Factor for the two regions in 2012



Sim. Wind Power North-Sea Region - July – Sep 2001



Simulated Wind Power North-Sea Region Jan–Mar 2001

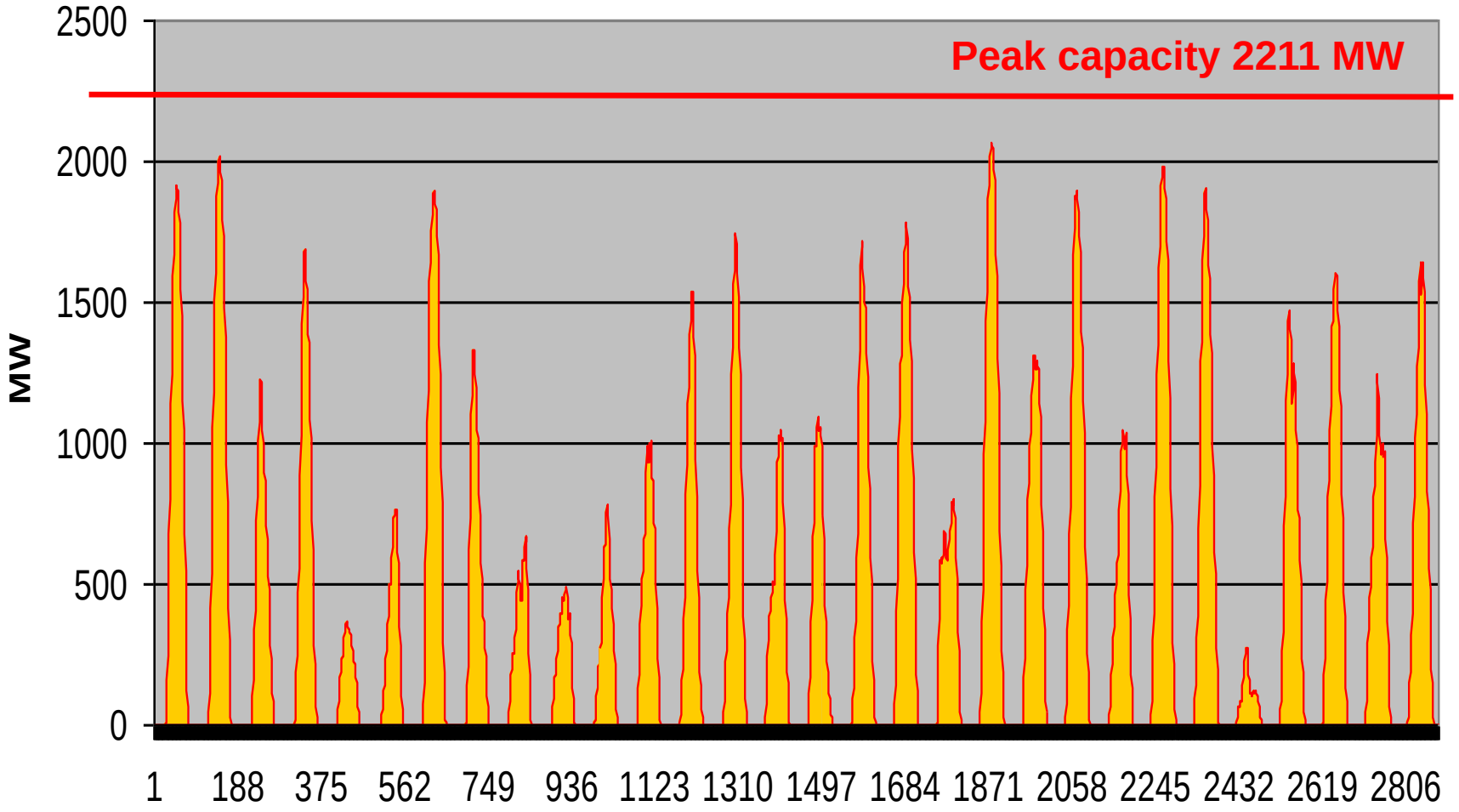


<u>One week balancing means</u>
Ca 30 000 MW in 168h ➔
⇒5000 GWh energy storage

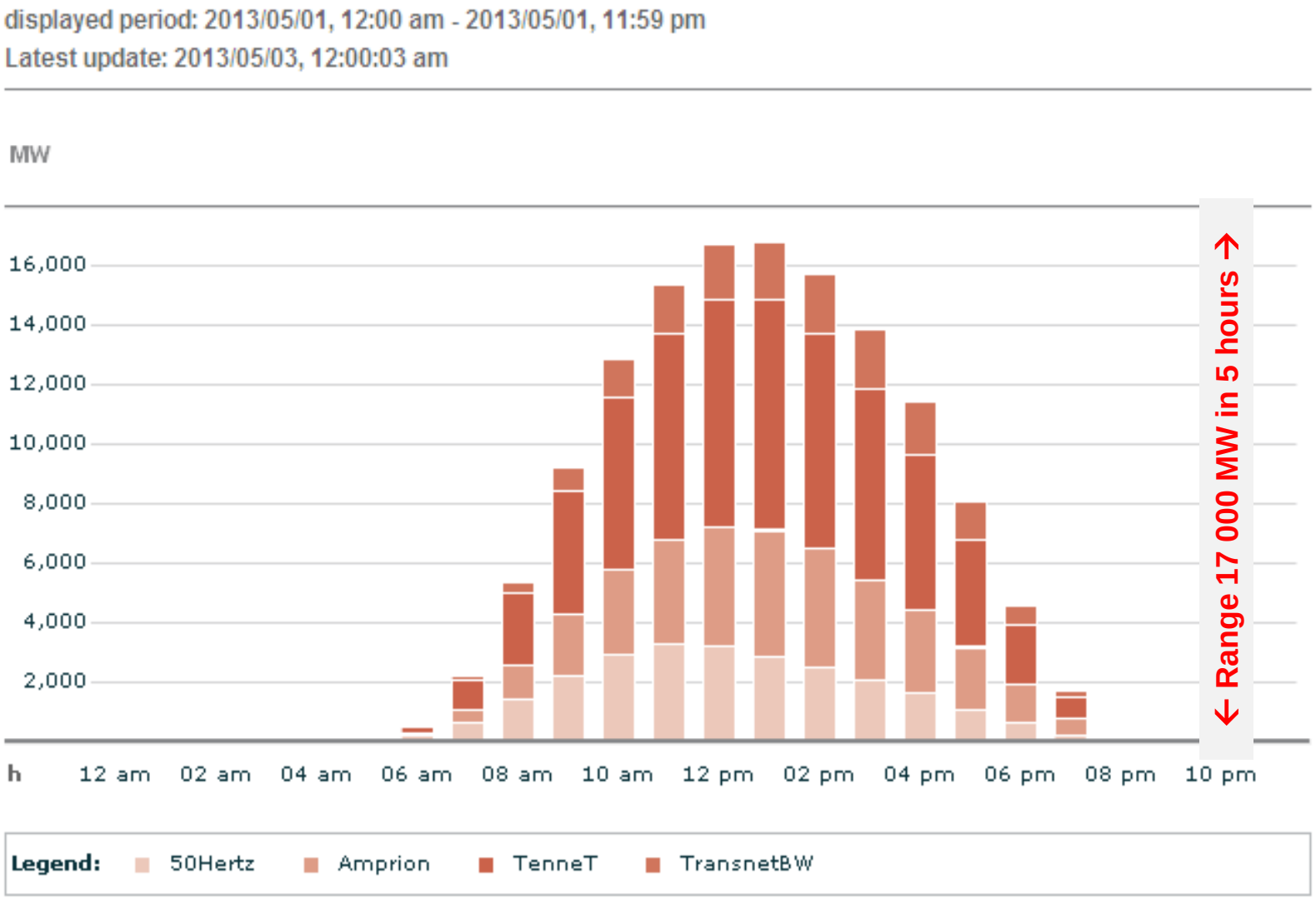
Same as 1000 typical PSP

Can Hydropower in Norway supply this storage ?

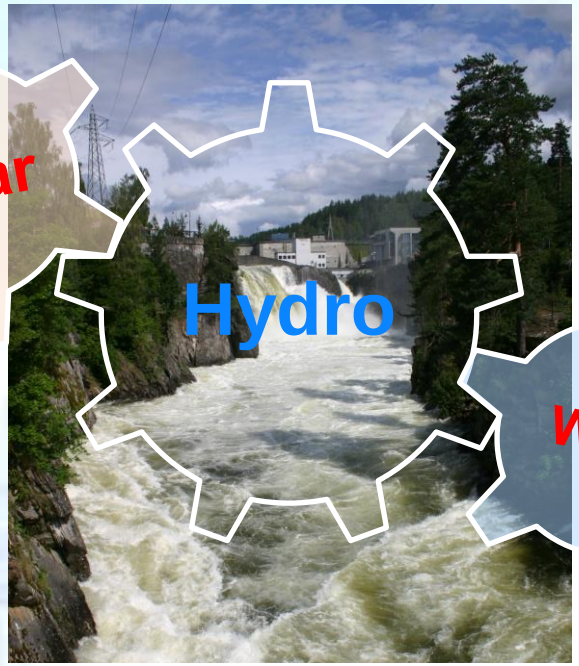
Solar (PV) Power generation in Belgium April 2013



Solar energy output (MW) in Germany May 5th 2013

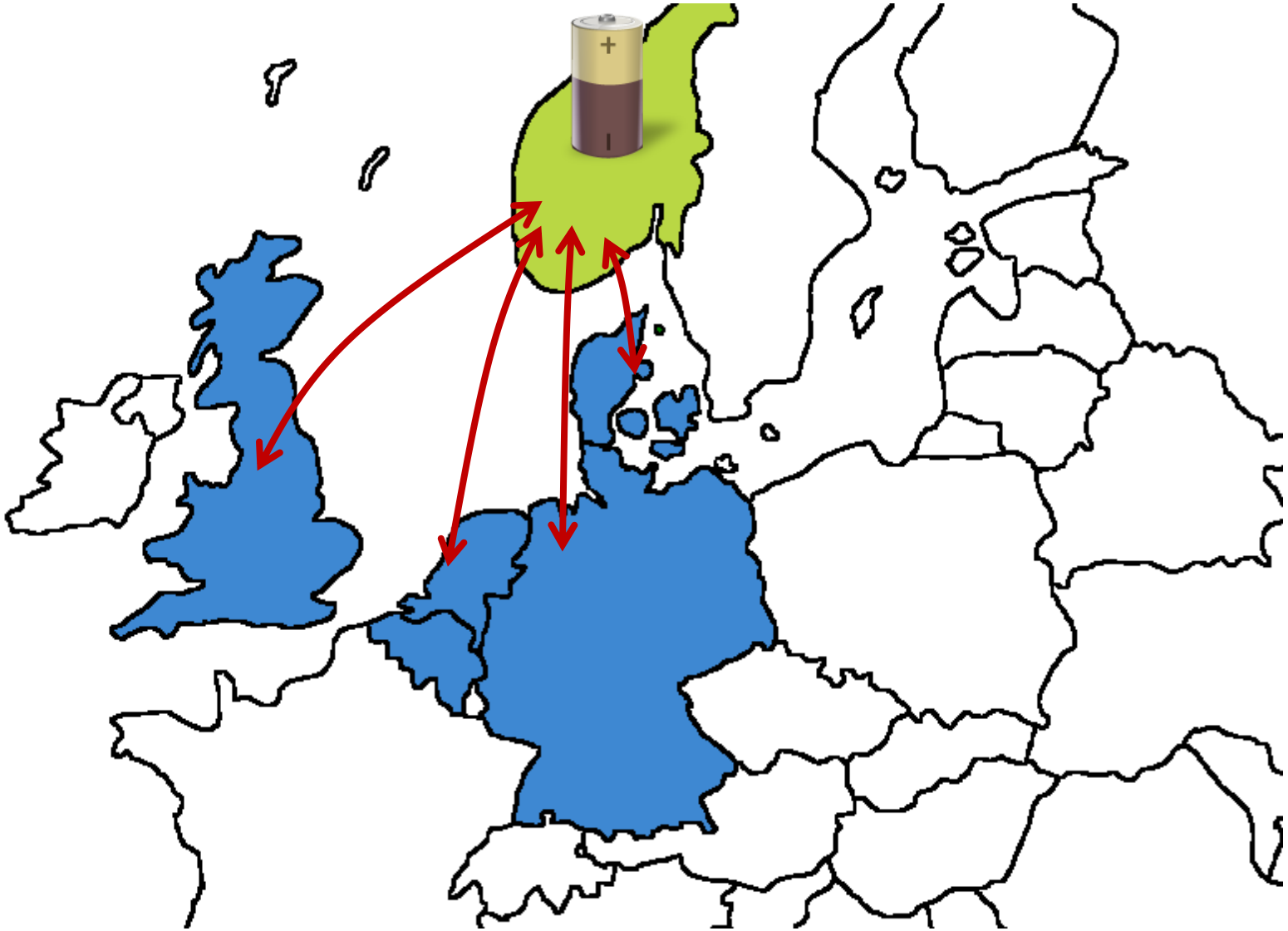


Hydropower – Supporting other Renewables



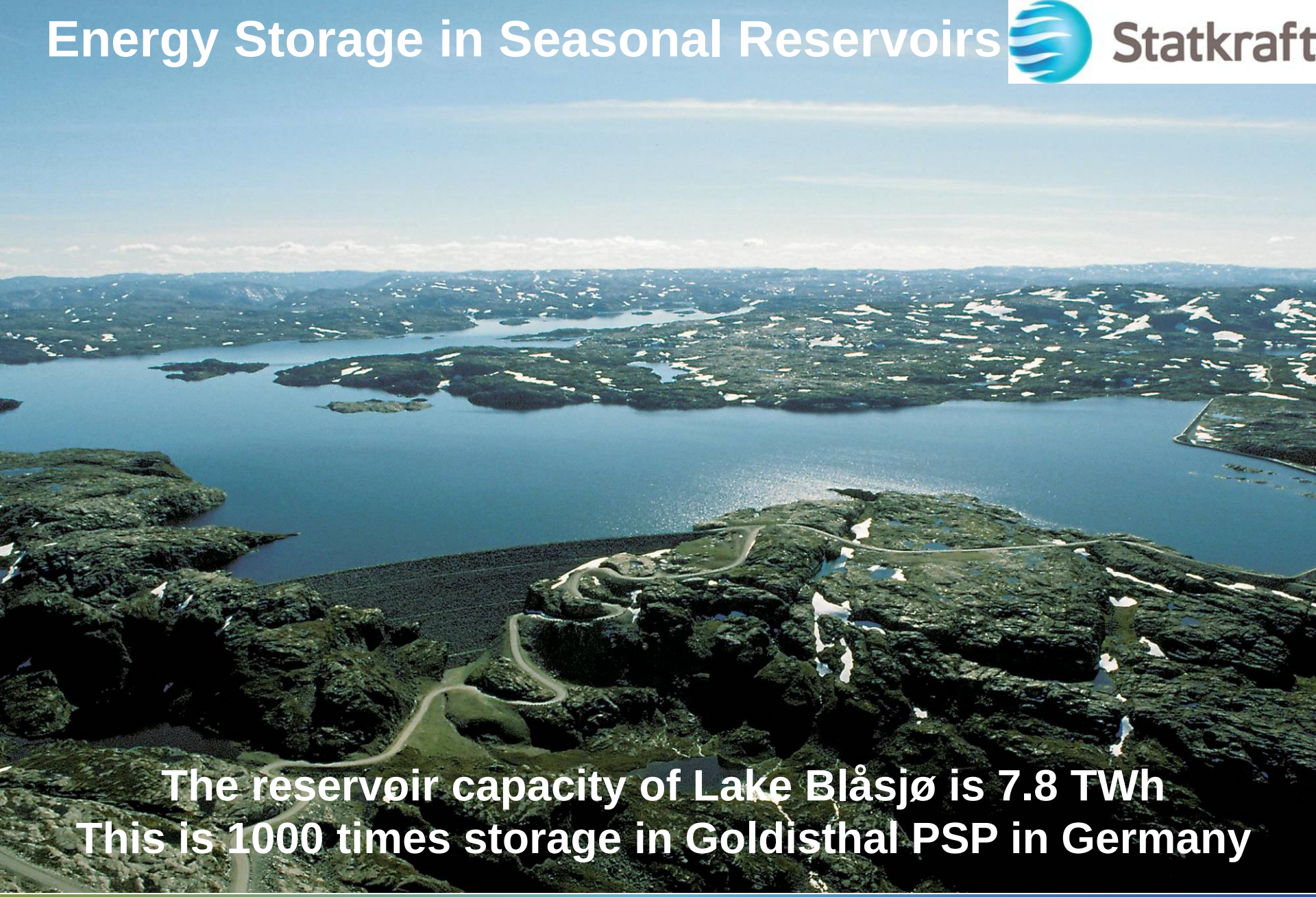
CEDREN studies in 2011 And 2012: How can Norway contribute?

Hydropower in Norway – The Green Battery of Europe



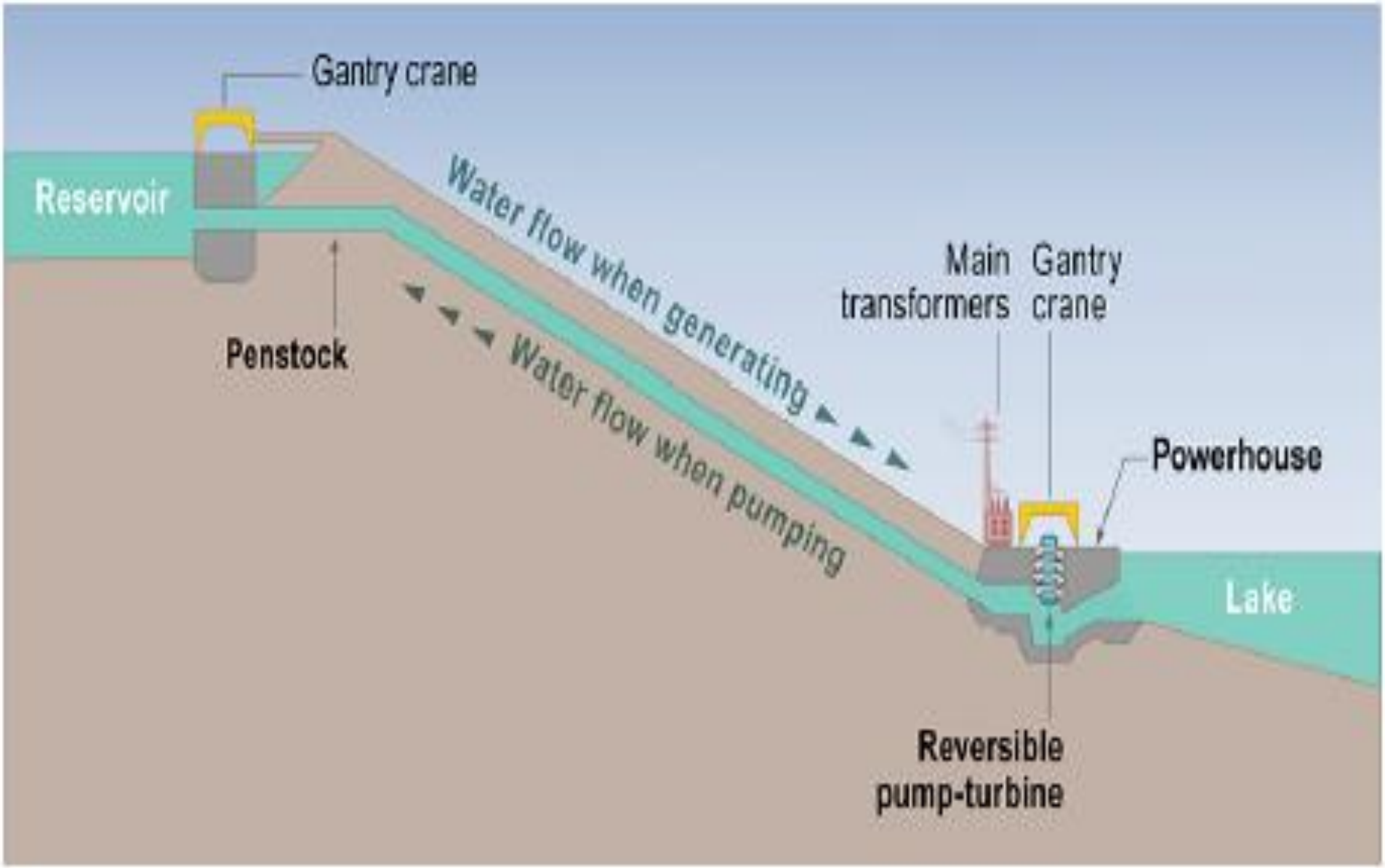
Energy Storage in Seasonal Reservoirs

Statkraft



The reservoir capacity of Lake Blåsjø is 7.8 TWh
This is 1000 times storage in Goldisthal PSP in Germany

Pumped Storage Hydropower (PSH)



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http://www.cedren.no/