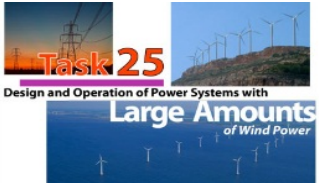
Summary of Wind and Solar Integration Study Results – IEA WIND Task 25 summary report briefing

H Holttinen (VTT)
Operating Agent, Task 25

IEA Wind Task 25 – What Does It Do?

- Started in 2006, now 17 countries + WindEurope participate to provide an international forum for exchange of knowledge
- State-of-the-art: review and analyze the results so far: latest report end 2018
- Formulate guidelines- Recommended Practices for Integration Studies: Update published in August
- Fact sheets and wind power production time series. Literature list.

- *https://community.ieawind.org/task25/*



Task 14 and Task 25 collaboration: Recommended Practices for wind and PV integration studies

https://community.ieawind.org/

Excellent benchmarking for all integration studies!

Based on upcoming report ‘Design and operation of power systems with high amounts of wind power. Final report of IEA WIND Task 25 phase 4 (2015-17)’

Authors: Hannele Holttinen, Juha Kiviluoma, Thomas Levy, Liu Jun, Peter Borre Eriksen, Antje Orths, Nicolaos Cutululis, Vera Silva, Emmanuel Neau, Jan Dobschinski, Serafin von Roon, Jody Dillon, Enrico Maria Carlini, Ryuya Tanabe, Yoh Yasuda, Miguel Ramirez, Jose Rueda Torres, Til Kristian Vrana, Magnus Korpås, Ana Estanqueiro, Antonio Couto, Emilio Gomez Lazaro, Lennart Söder, Danny Pudjianto, Goran Strbac, Bri-Mathias Hodge, J Charles Smith, Debbie Lew, Daniel Fraile

Contents

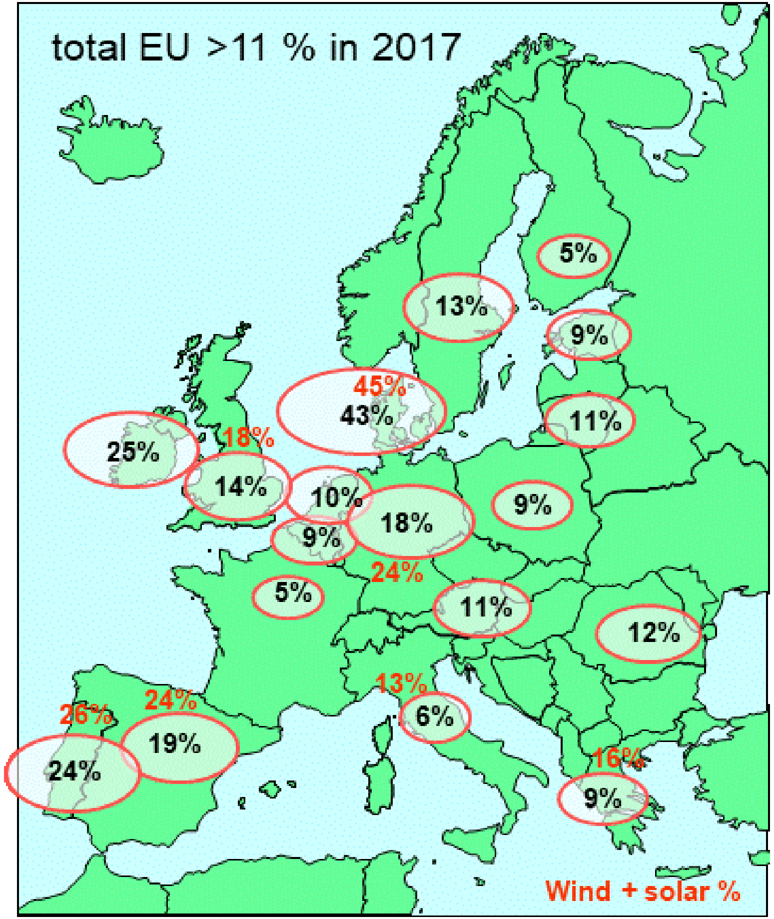
- Share of wind and solar increasing
- Experience reported in wind (and solar) integration
- Results on studies for wind (and solar) integration
  - Long term planning for capacity and grid
  - Short term operational impacts

DK Denmark
DE Germany
ES Spain
NO Norway
SE Sweden
FI Finland
IE Ireland
IT Italy
PT Portugal
MX Mexico
JP Japan
CAN Canada

Experience of wind integration is increasing

- Higher shares integrated in European countries, on average and as hourly maximum share:
  - Denmark and Portugal > 100%
  - Germany 80 %
  - Ireland > 60 % of demand

- Wind energy in Europe :
  - Ranges 5-52% of installed capacity,
  - max duration of low generation:
  38 hours < 10% of capacity

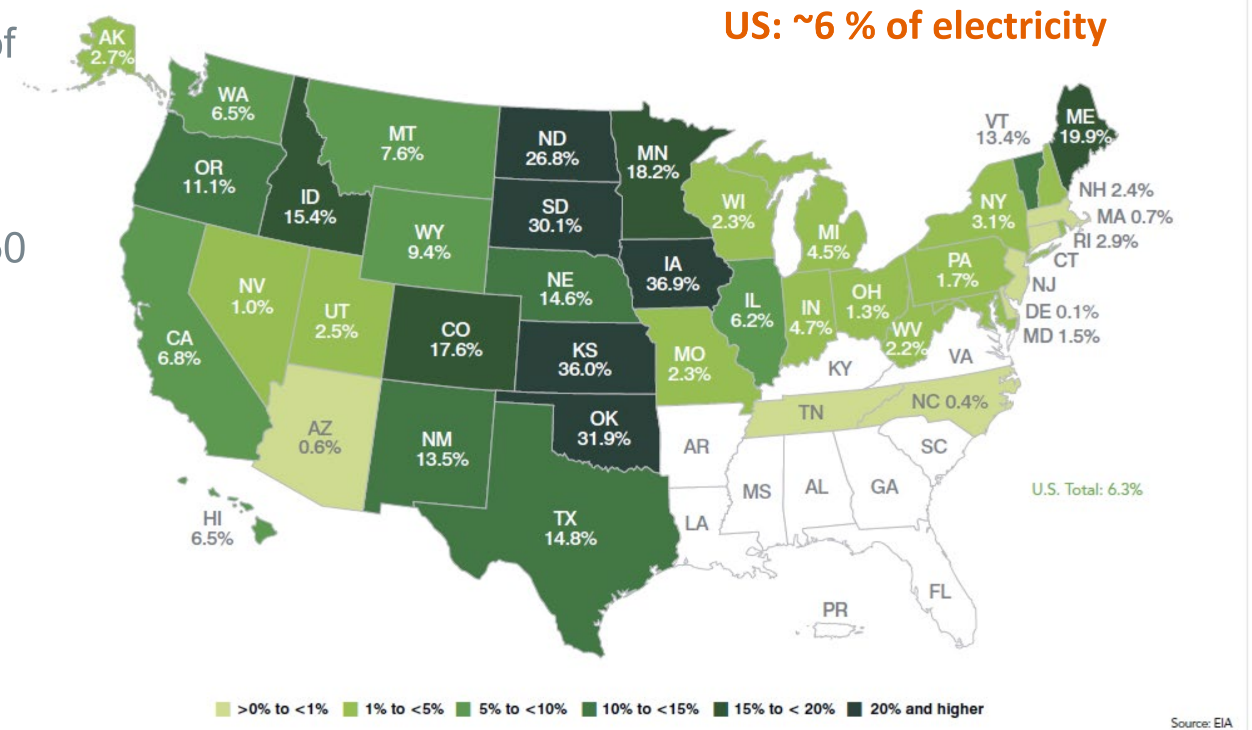


iea wind

High wind shares in US

- US states > 30 % share of wind: Iowa, Kansas, Oklahoma, South Dakota
- Highest hourly shares > 50 % in SPP (Southwest Power Pool) and Ercot (Texas)

Figure 24
U.S. Wind Energy Share of Electricity Generation, by State



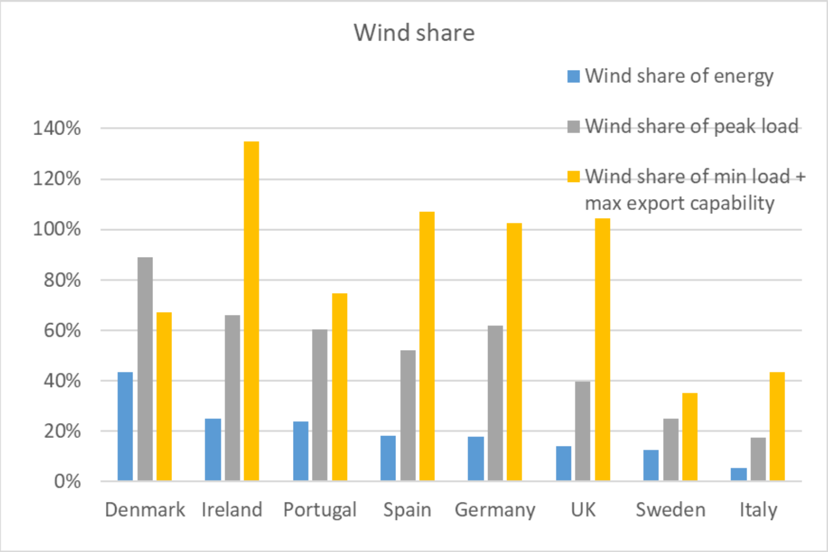
Source: EIA

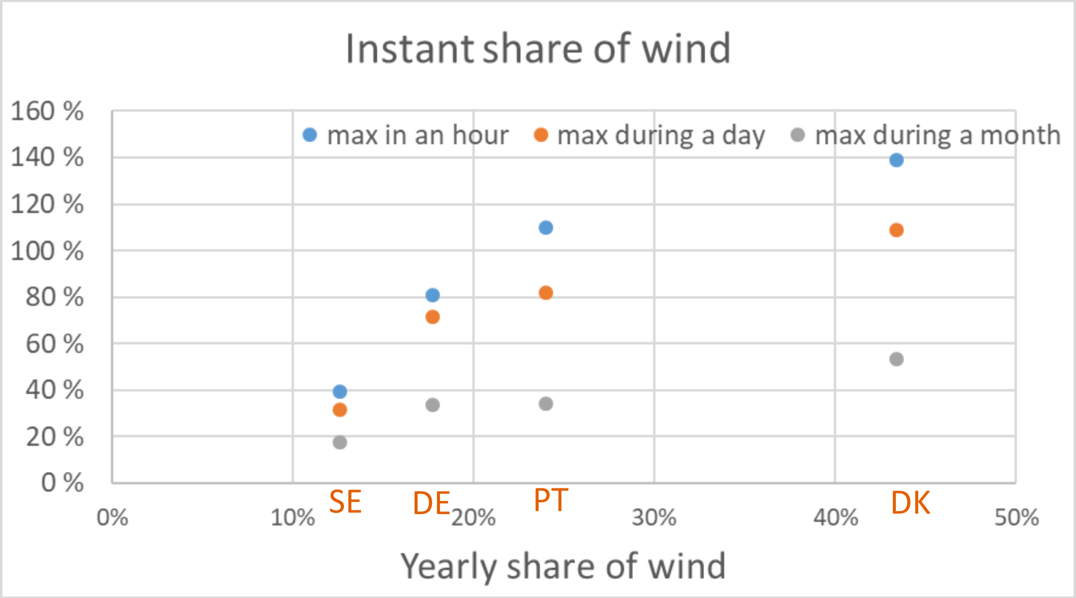
American Wind Energy Association | U.S. Wind Industry Annual Market Report Year Ending 2017 35

iea wind

Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power

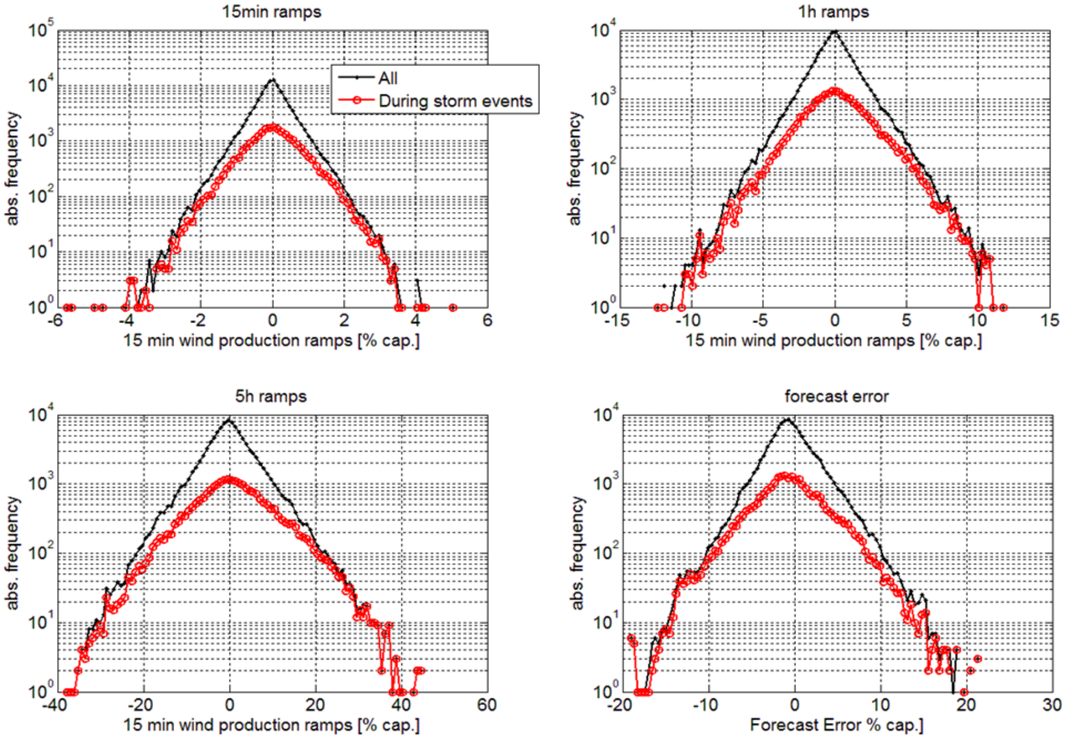
Wind share – of energy, power. Instant shares relative to average yearly share





Ramping – extremes in storms

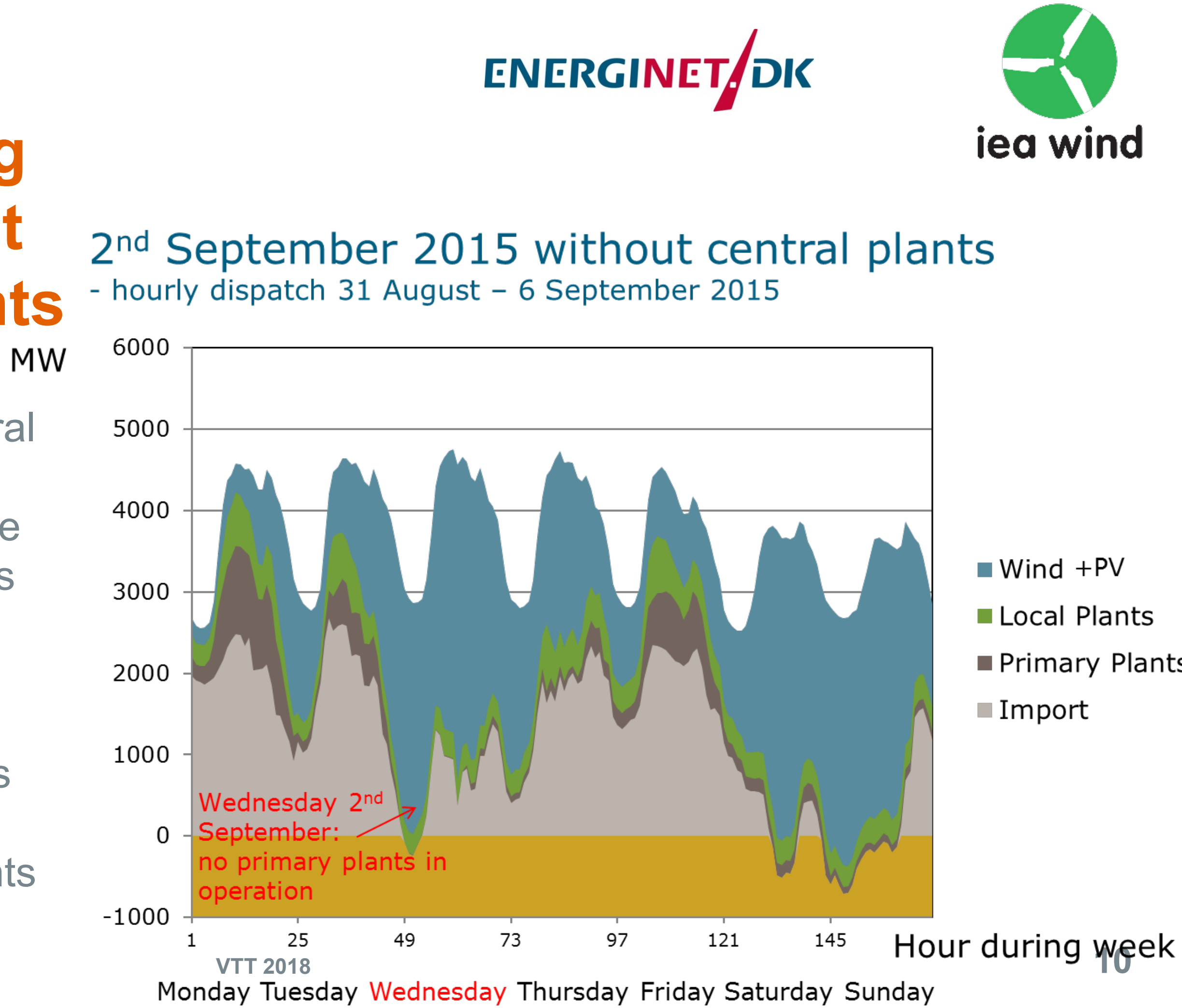
- Max 15 min ramps recorded
  - Germany ± 6 %
  - Denmark ± 6 %
  - Portugal -11… +7 % of capacity,



Germany: Freq distributions of 15min, 1h and 5h ramps and forecast errors (3.3 years).

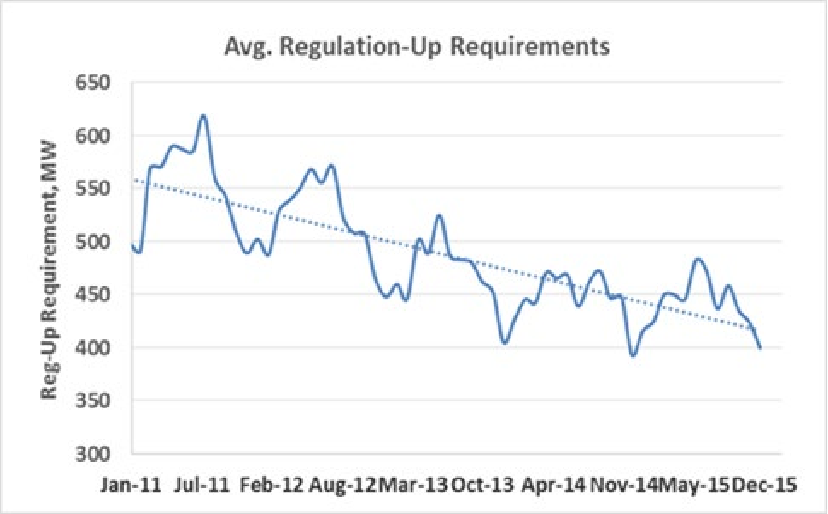
Experience: Denmark operating the system without central power plants

- First time in 2015 and several times since then, all central power plants shut down. The necessary system support is built into the grid:
- HVDC link: 700 MW Denmark-Norway
- synchronous compensators 4 in DK-W and 2 in DK-E
- and small scale power plants



Experience: Wind power giving frequency support

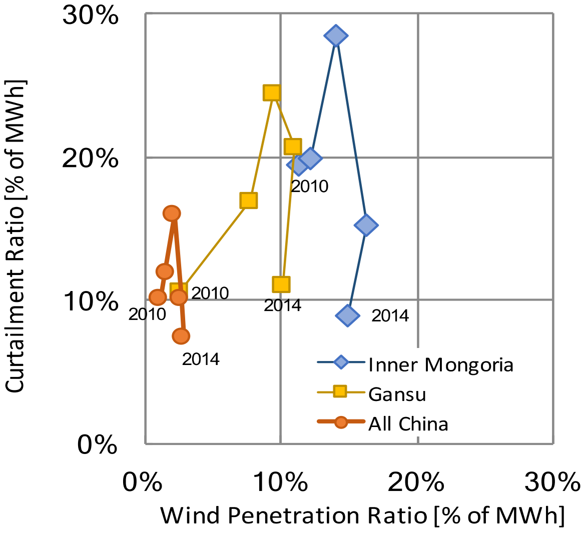
- Colorado: wind used as AGC (secondary control) when curtailed
- Texas: wind power plants actively used in frequency control: fast response actually contributes to reducing the overall need for frequency support services
- Quebec: wind providing fast reserves, also synthetic inertia
- Spain: more than 50 % of wind power plants provide frequency support
  - 6 % of tertiary reserves from wind power in 2017

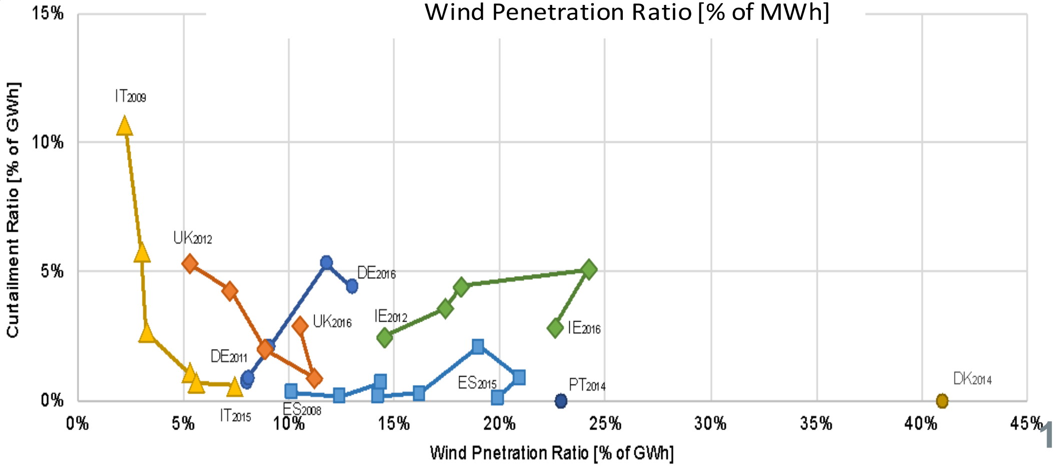


Source: Julia Matevosyan, ERCOT

Experience: curtailments

- Curtailing wind power generation is one signal of lack of flexibility in the power system
  - Due to delays of transmission: Italy and Texas – diminished after grid build out. Germany, still an issue
  - Due to inflexibilities of coal power plants and tariffs: China
  - Due to limits of non synchronous generation: Ireland (small system)



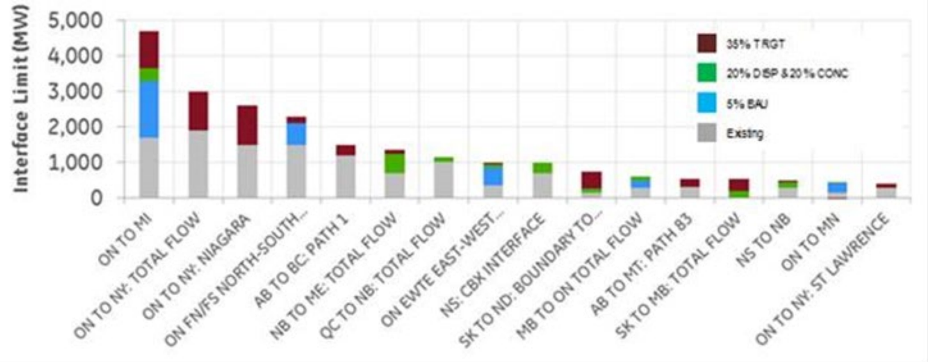


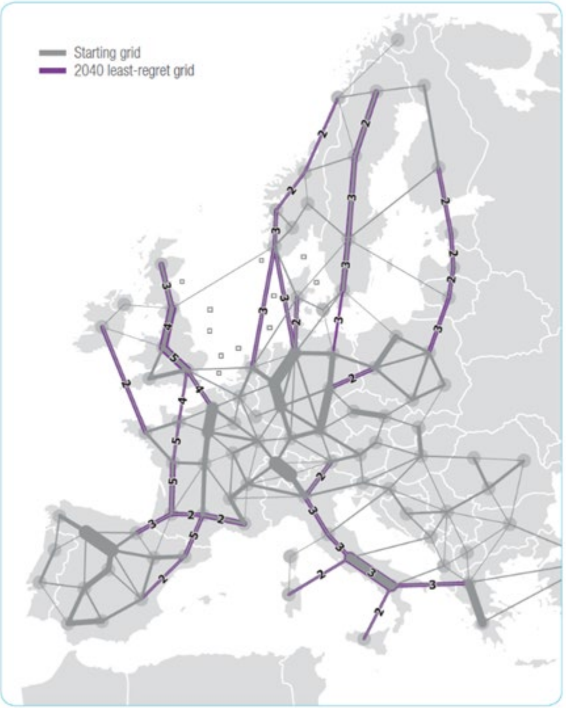
VTT

iea wind

Results for grid adequacy

- E-highways: UHV overlay grid not the most cost effective result –increasing North-South interconnectors for most of the scenarios
- Pan Canadian wind study: inter-area transmission reinforcements for 25-35% share of wind – with low pay-back times

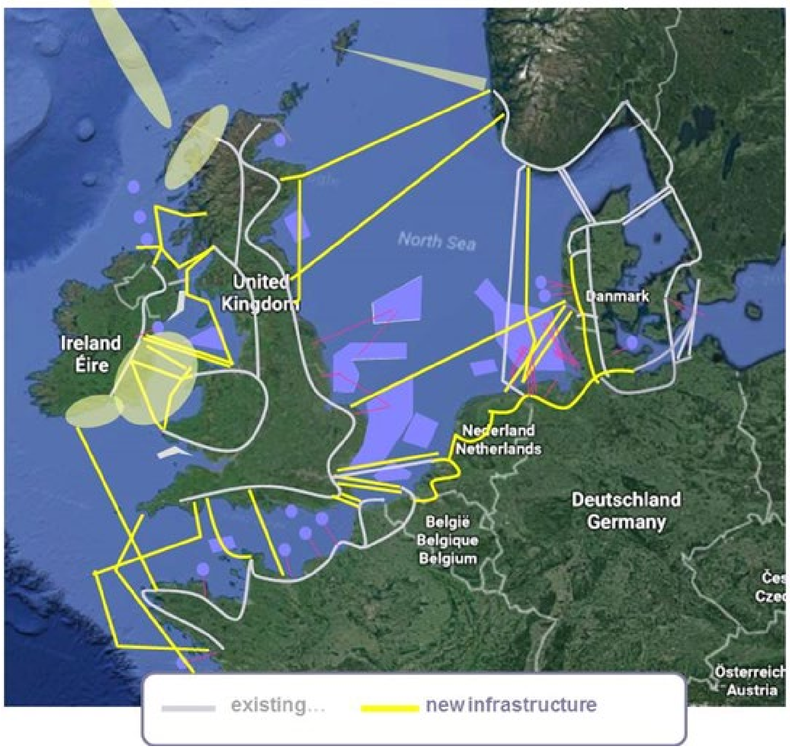




The most robust Europe wide grid architecture for a low carbon future 2040 from e-Highways

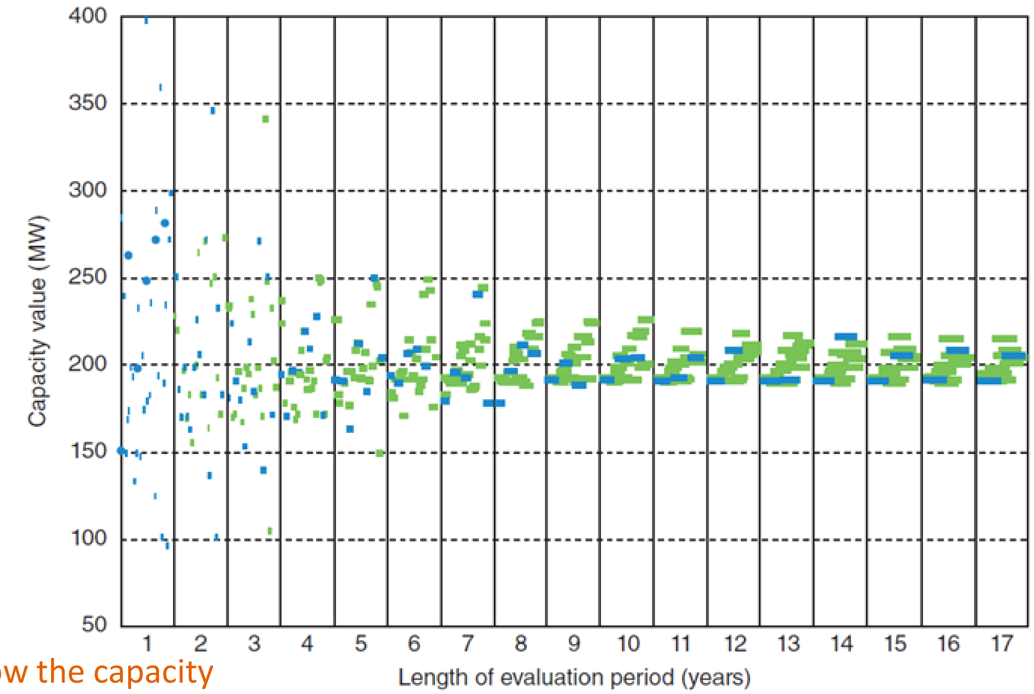
Results for offshore grids

- Offshore grids – previous studies taken for ENTSO-E TYNDP16, combined single offshore projects pay off when analysed as one
- Overplanting wind capacity to transmission capacity was cost efficient in some cases for offshore wind UK
- The North Sea Wind Power Hub (NSWPH) joint initiative by TenneT (NL, DE), Energinet (DK), cost saving potential related to offshore platforms



Results for capacity adequacy

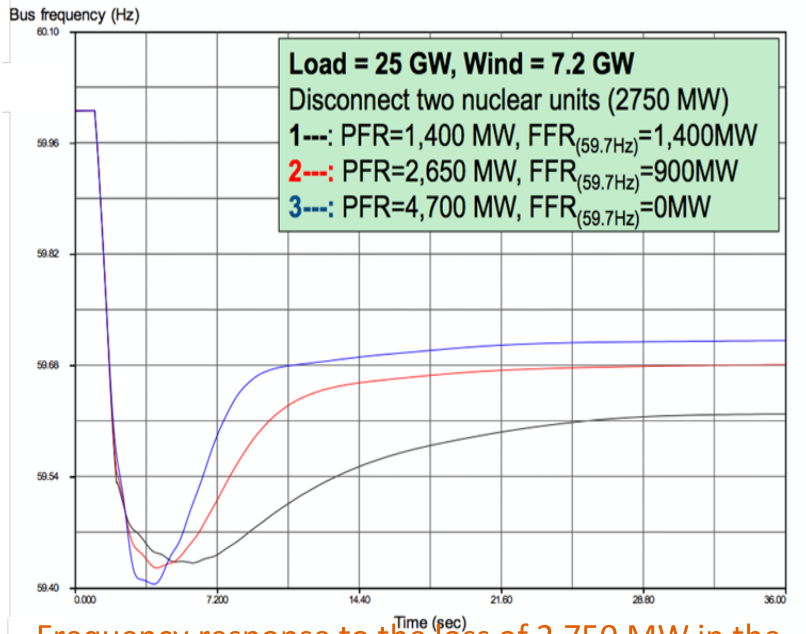
- FR, FI: Need 15…30 years of data for robust result on capacity value of wind
- Multi-area methods evolving (SE, ENTSO-E)
  - Important to assess the capacity adequacy for larger areas when interconnected



See also WIW- Söder et al 7B Friday morning on how the capacity calculations are made and wind taken into account

Results of stability studies

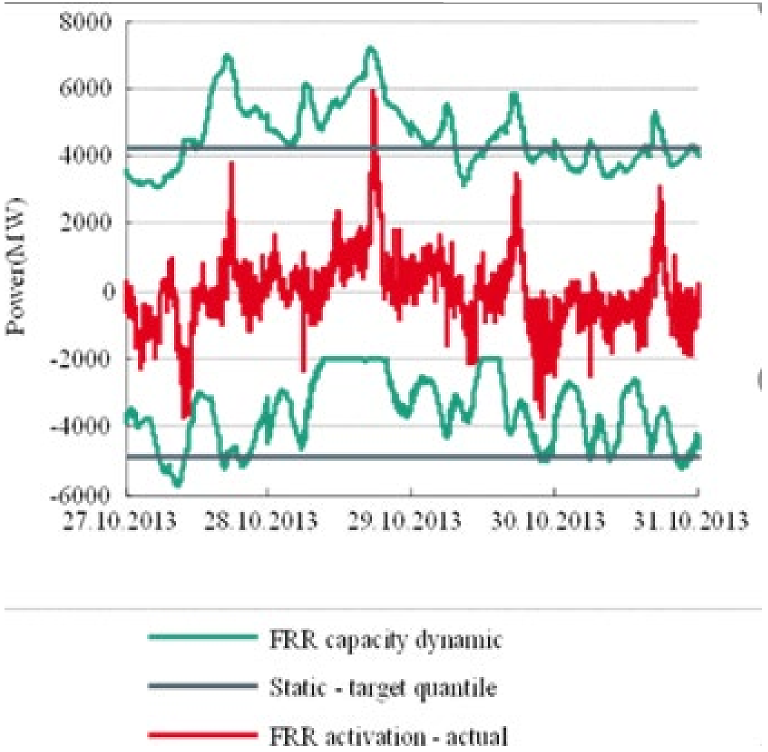
- Texas: 1 MW of fast response gives same reliability impact as 2.35 MW of primary freq response
- US WWSIS3 wind governor/inertial control supports system
  - Similar results in MX; offshore wind /HVDC links can also give support
  - Nordic system with more HVDC may result in more oscillations after disturbances if converter controllers are not tuned to damp these oscillations



Frequency response to the loss of 2,750 MW in the Western Interconnection with three combinations of frequency controls on wind power plants (Source: WWSIS3)

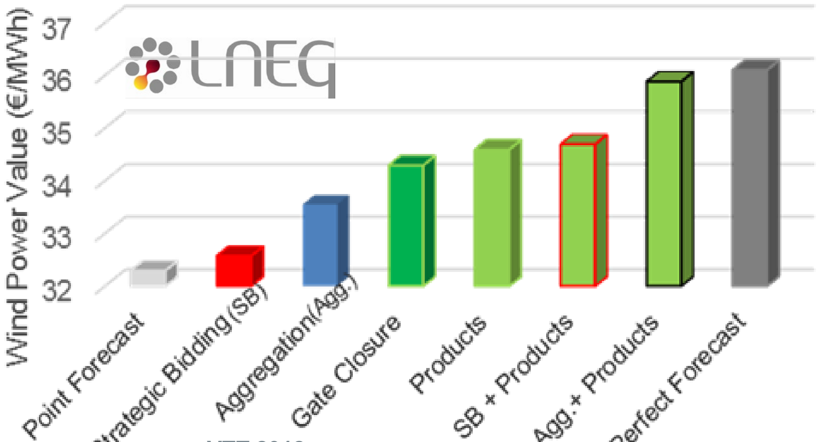
Results for operating reserve requirements

- DE: Dynamic day-ahead dimensioning of manually activated (FRR) reserve capacities in Germany. Allocating the reserves to automatic and manual can be improved.
- FI: reserve requirements due to forecast errors day-ahead are twice as much as for hour ahead uncertainty
- JP: LORP, Loss Of Reserve capacity Probability method: adequacy of reserve capacity for the duration curves on the magnitude and speed of net-load ramp



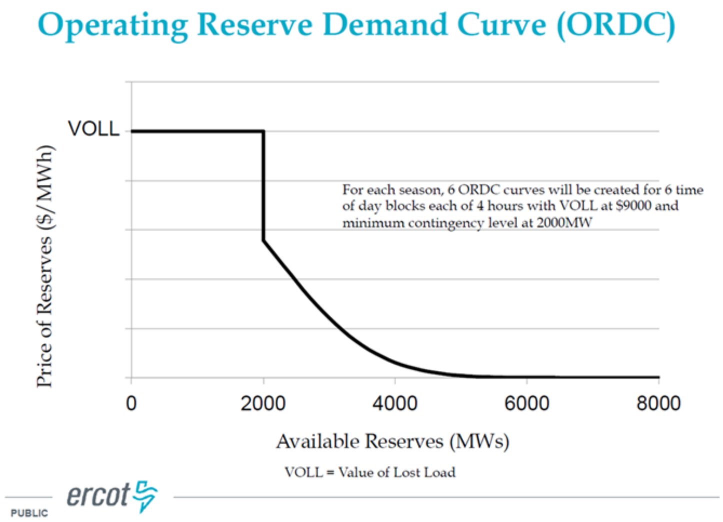
Operational practices: market design to enable wind integration

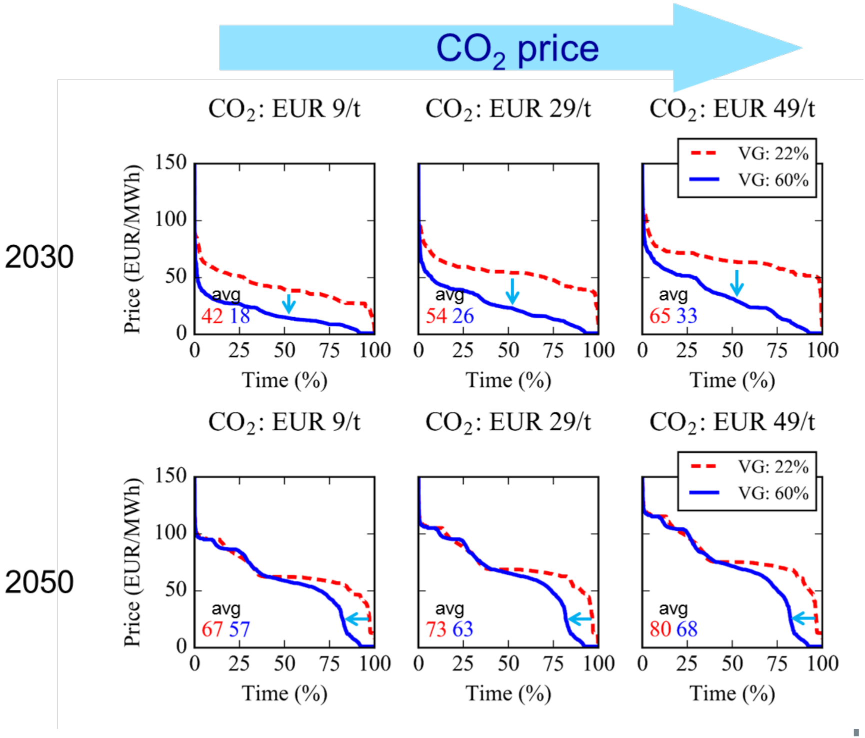
- Enabling wind power plants to bid their flexibility to the markets
- With extra gains from balancing products



Energy only markets – revenue sufficiency and scarcity pricing

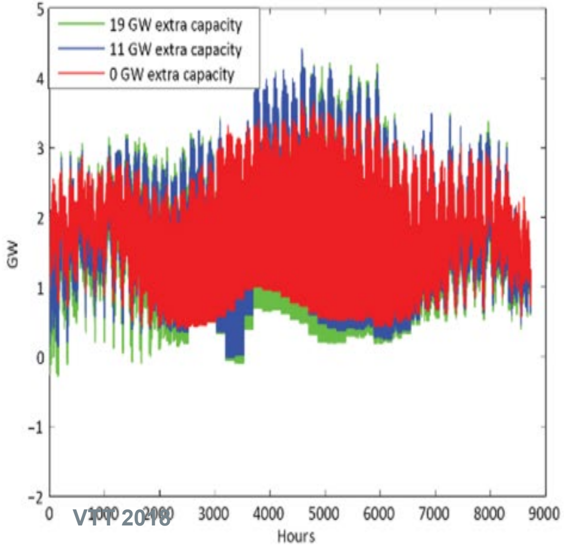
- FI, FR,Nordic TSOs: future energy only market prices
- US: scarcity pricing

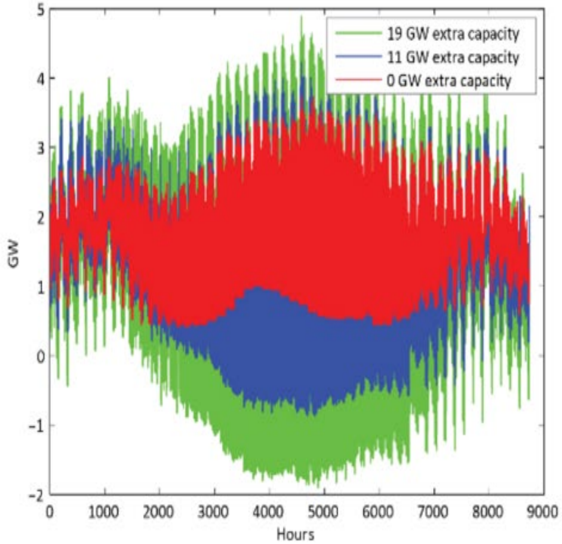




Benefits from hydro power flexibility

- CAN: hydro scheduling against real time net load saves operational costs at 20 % share of wind
- NO: high shares of wind and solar require more detailed scheduling models





VTT

iea wind

Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power

SINTEF

Other flexibility benefits

China: interconnector and demand side flexibilities reduce curtailments

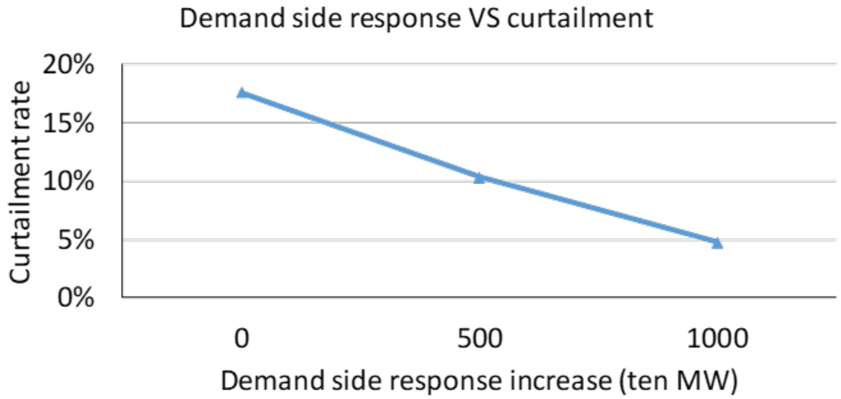
Combining power and heat:

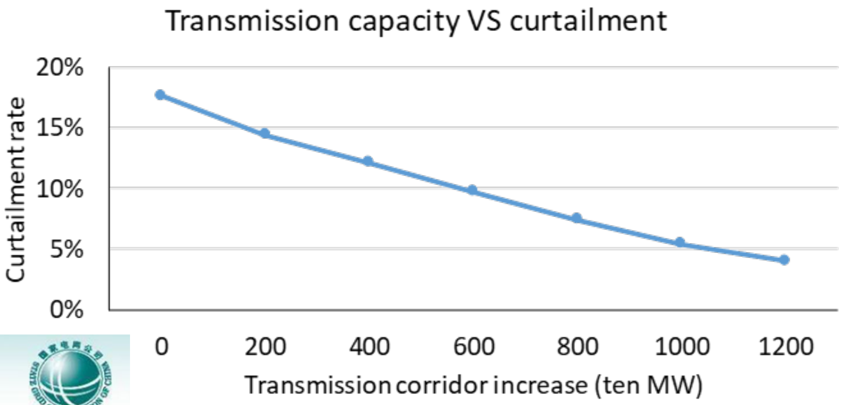
- China: decreases curtailments
- FI: District heating related flexibilities increased the share of wind power while
- electric vehicles increased the share of PV

Operational practices:

- PT, DE, IT: Dynamic line ratings in congestion management

See also grid/DLR WIW- Estanqueiro et al 4C Thursday

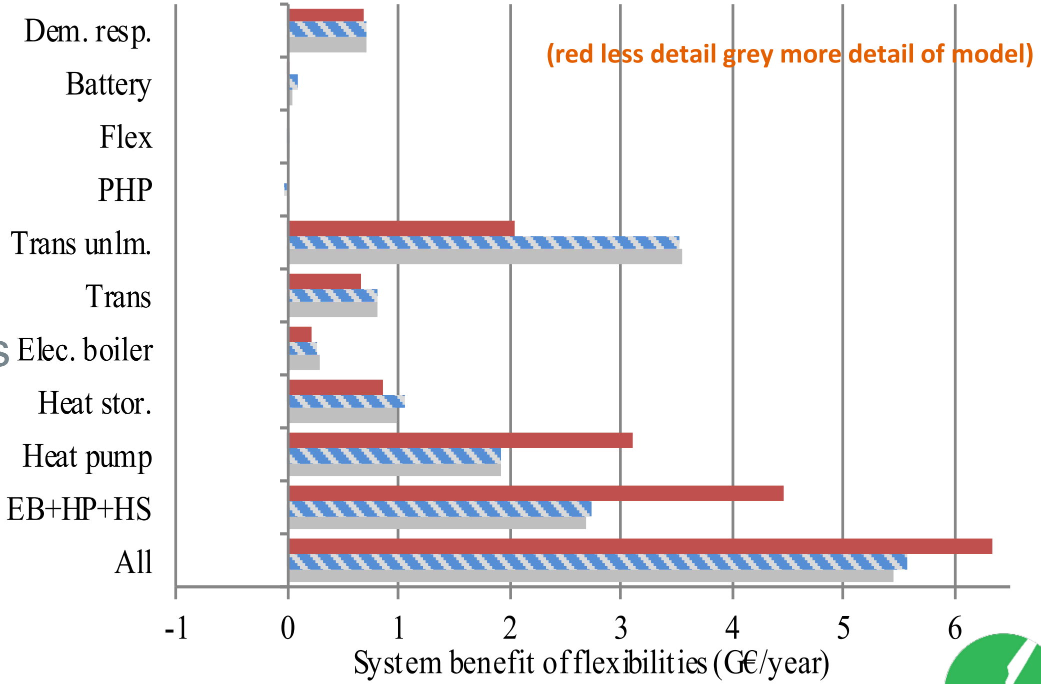




Value of flexibilities in North Europe for 40-50 % share of wind power

VTT

- FI: Transmission and trade with neighbouring areas and power to heat offers good cost benefit, Demand response is cost effective when low costs
  - All flexibilities together: less benefit than individual flexibilities separately
- NO: batteries reduce the need for OCGT, while pumped hydro reduces the need for CCGT
- For batteries to play an important role in balancing, costs must come down to 100 €/kWh



Case North Europe 40-50 % wind
Power system operational costs for one year, difference of with/without flexibility option

iea wind

Pushing the limits: towards higher shares of wind and solar energy

- Sweden ~100% renewables, replacing nuclear with wind/PV: ~5 GW additional of peak power, energy is ~ 1 % of total production and the cost <0.3 Eurocent/kWh
- FI: 100% renewable study (Global TIMES/Balmorel for Nordic countries): Even assuming low PV and P2G investement costs, synthetic gas will be more expensive than gas today
- FR: Europe 60 % study, inertia will be an issue.
- SE: Nordic system inertia issue: reducing generation from largest unit for coping with low inertia N-1 event in 2017
  - FI study indicates that assuming wind inertial/fast response could manage 100% renewables in the Nordic hydro dominated system

Conclusions

- More and more experience – and wind power plants proving to be excellent fast response source for grid support
- Flexibility for future systems: transmission, power to heat, demand side all reduce system costs, and integration costs: from integration costs to cost of inflexibility
- Towards 100% renewables the new challenge – methodologies evolving for future studies

See also WIW- Müller et al 7B Friday morning on integration costs