Grid integration of Variable Generation – best practices from international experience

Task 25: Design and Operation of Energy Systems with Large Amounts of Variable Generation

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SmartGrid, NewDelhi, Sep 4th, 2019

iea wind

Contents

- Lessons learned from challenges of wind and solar
  - Balancing: unlock flexibility through system operation practices
  - Grid infrastructure – connect and transport electricity
  - Using the grid support capabilities of wind and solar
- Long term: Changing the optimal generation mix

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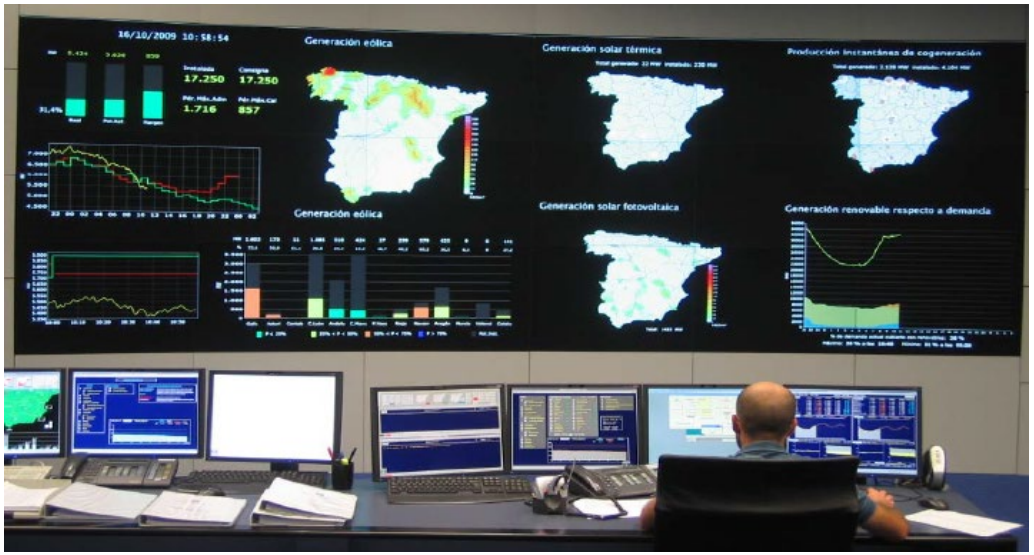
IEA Wind Task 25 – Best practice of VG integration

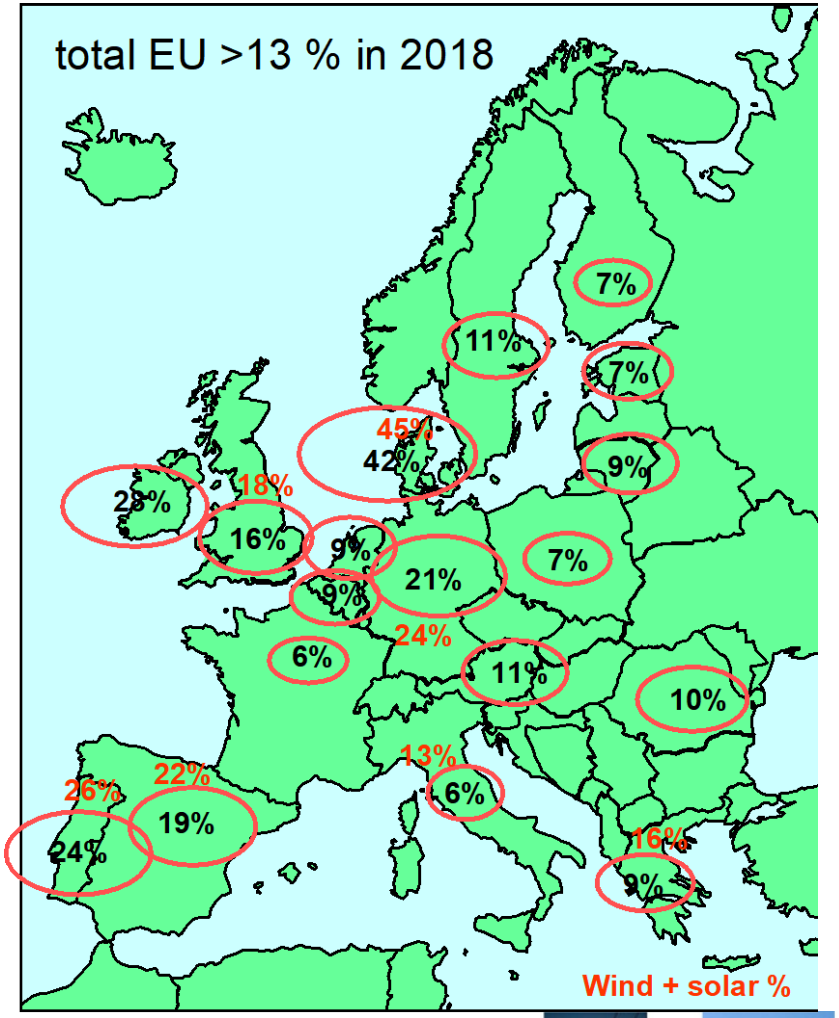
- Started in 2006, now 17 countries + WindEurope participate to provide an international forum for exchange of knowledge
- State-of-the-art: review and analyze the results so far (Jan 2019)
- Formulate guidelines- Recommended Practices for Wind/PV Integration Studies (RP Ed.2 July 2018)
- Fact sheets and integration study time series (wind, solar, load…)

https://community.ieawind.org/task25

Experience from Wind and Solar Integration is Growing

- First 10-20 % share of wind:
  - Updated information from on-line production and forecasts.
  - Possibility to curtail in critical situations.
  - Grid connection codes





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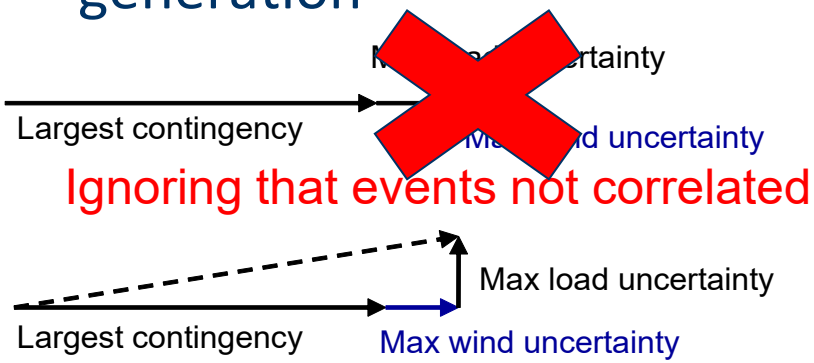
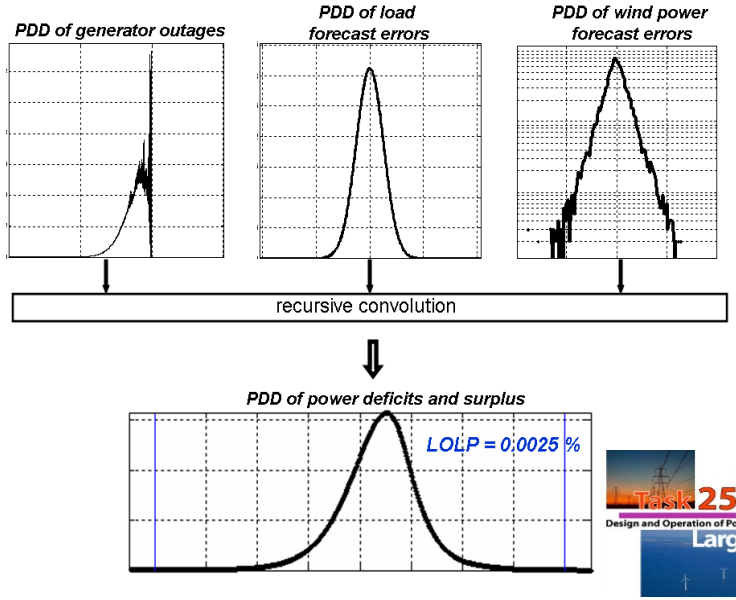
Using short term forecasting

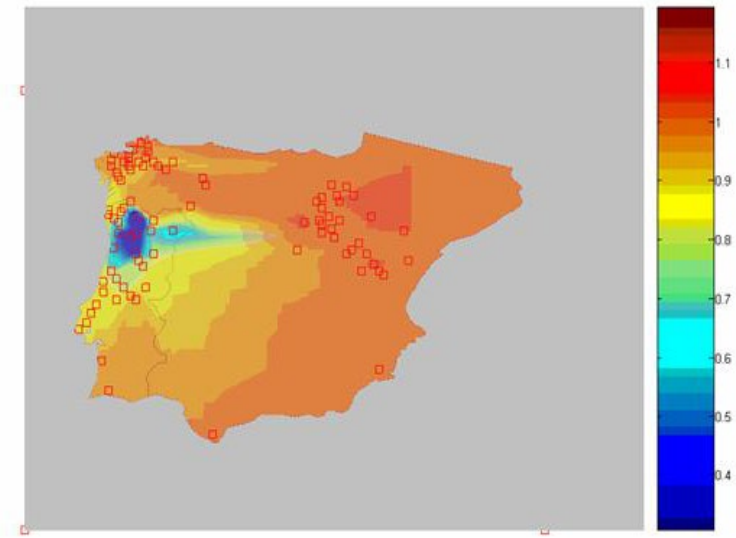
- Wind and solar taken in the day-ahead unit commitment and dispatch, with smoothing impact
  - Energy traded at markets with forecasting
- Flexibility during operating hour – allocating reserves
  - forecast errors determine the need for operating reserve – combining uncertainty from load, wind, solar and generation





Experience with grid codes:

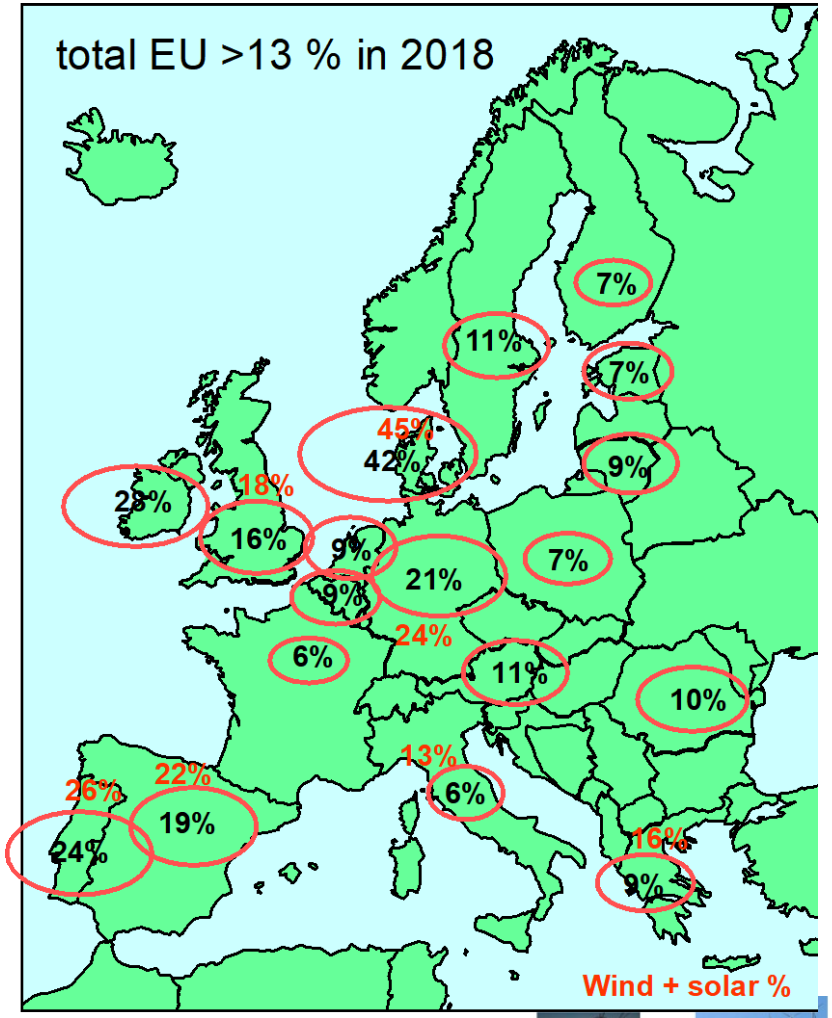
- Requiring fault-ride-through, and setting frequency/voltage limits when trip-off
  - Low voltages due to short-circuits may lead to the disconnection of large shares of generation -modern turbines comply with this
  - Australia case, for weak systems need to require many consecutive faults
  - Germany, California case solar: setting of inverters to trip off at high frequency may also create an issue of losing too much generation instantly



Ride through fault capabilities attenuate the problem.

Experience from Wind and Solar Integration for higher shares

- Sharing balancing
- Enabling also wind and solar in grid support
- Generation flexibility and adequacy
- Transmission a key enabler, with regional planning efforts
  - Local markets, PV and storages emerging as another solution



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Trade with neighbouring areas will help balancing more than wind adds

- Sharing balancing task with neighbouring system operators in Germany has resulted in reduction of use of frequency control, while wind and solar have increased
- Denmark integration of close to 50% wind share is based on using Nordic hydro power system flexibility

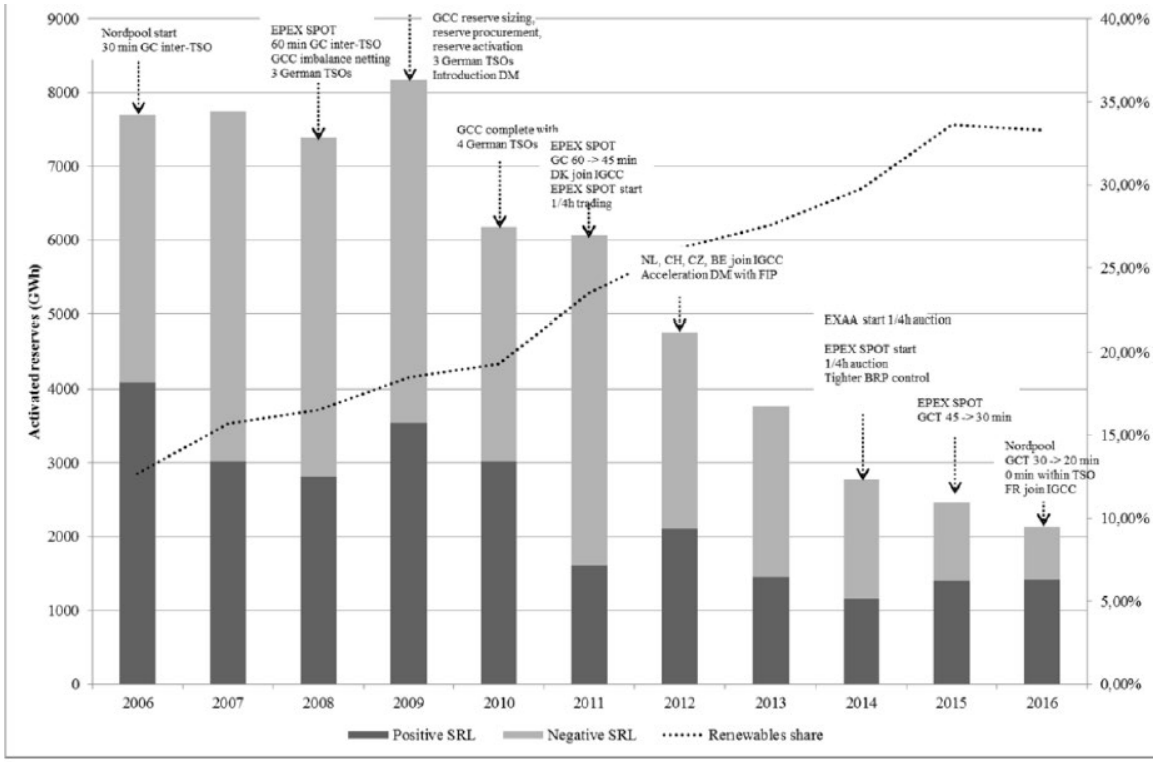

Figure 13: Total activated German Secondary Reserves (or aFRR) per year marked with events considered in this paper.

Rena Kuwahata, Peter Merk, WIW17

Using flexibility of thermal plants. Case Denmark.

- Changing the tariffs of smaller CHP plants to operate according to market prices
- Retrofitting the larger thermal plants

HIGH FLEXIBILITY OF POWER PLANTS

Operational range:
10–100%

Regulating rate:
3-4% per minute

Technical key data of Esbjergværket CHP Plant

Commissioned	1992
Max power production (net)	378 MW
Max district heat production	460 MJ/s
Coal consumption at full load	120 t/h
Oil consumption at full load	73 t/h
Steam pressure	251 bar
Steam temperature	560 °C

Source: Dong Energy

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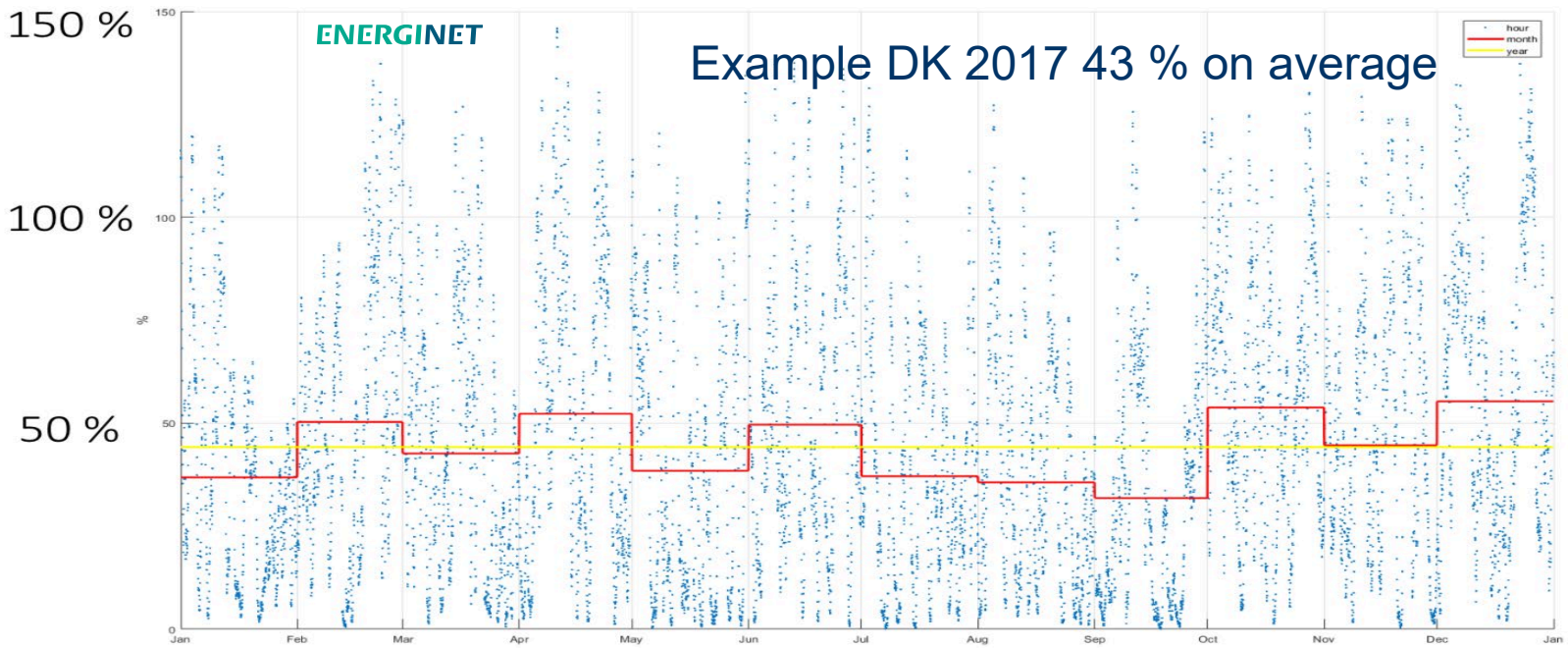
High share of VRE operation already well before 50 % yearly share

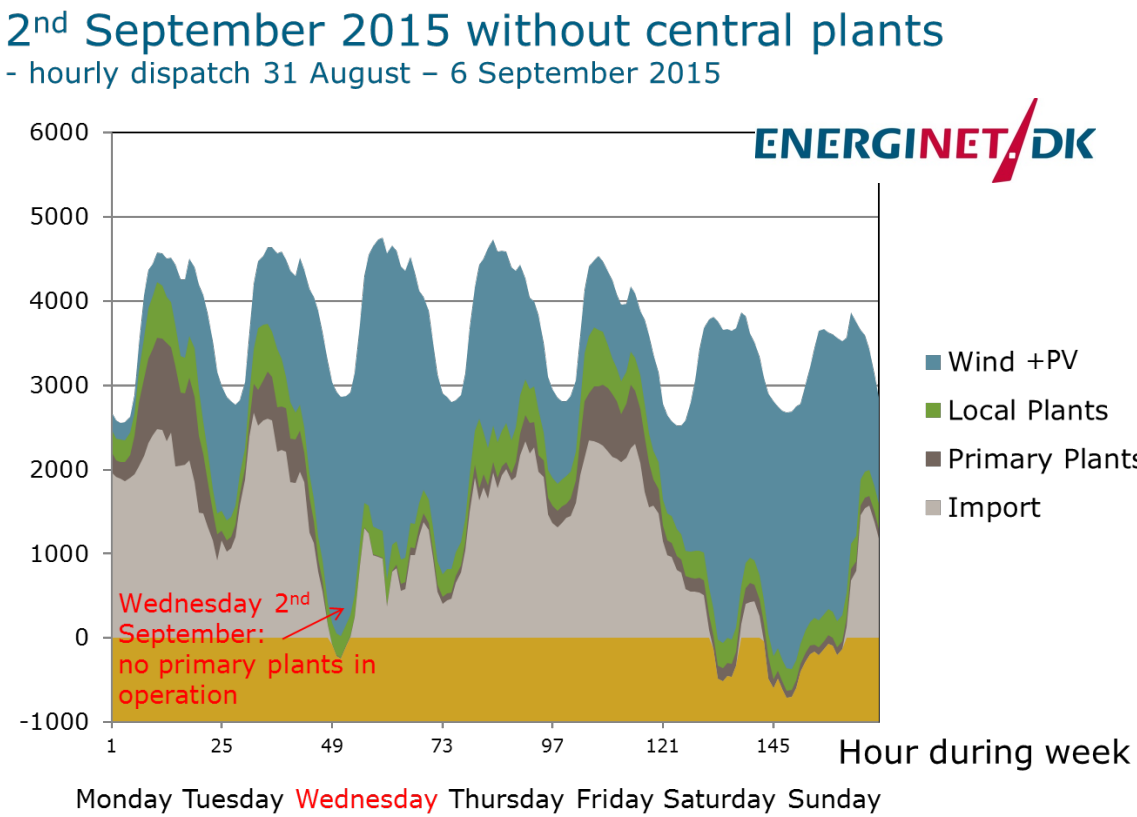
- Instant 100% will be faced already when less than 25 % on average



Pushing the limits: Denmark operating the system without central power plants

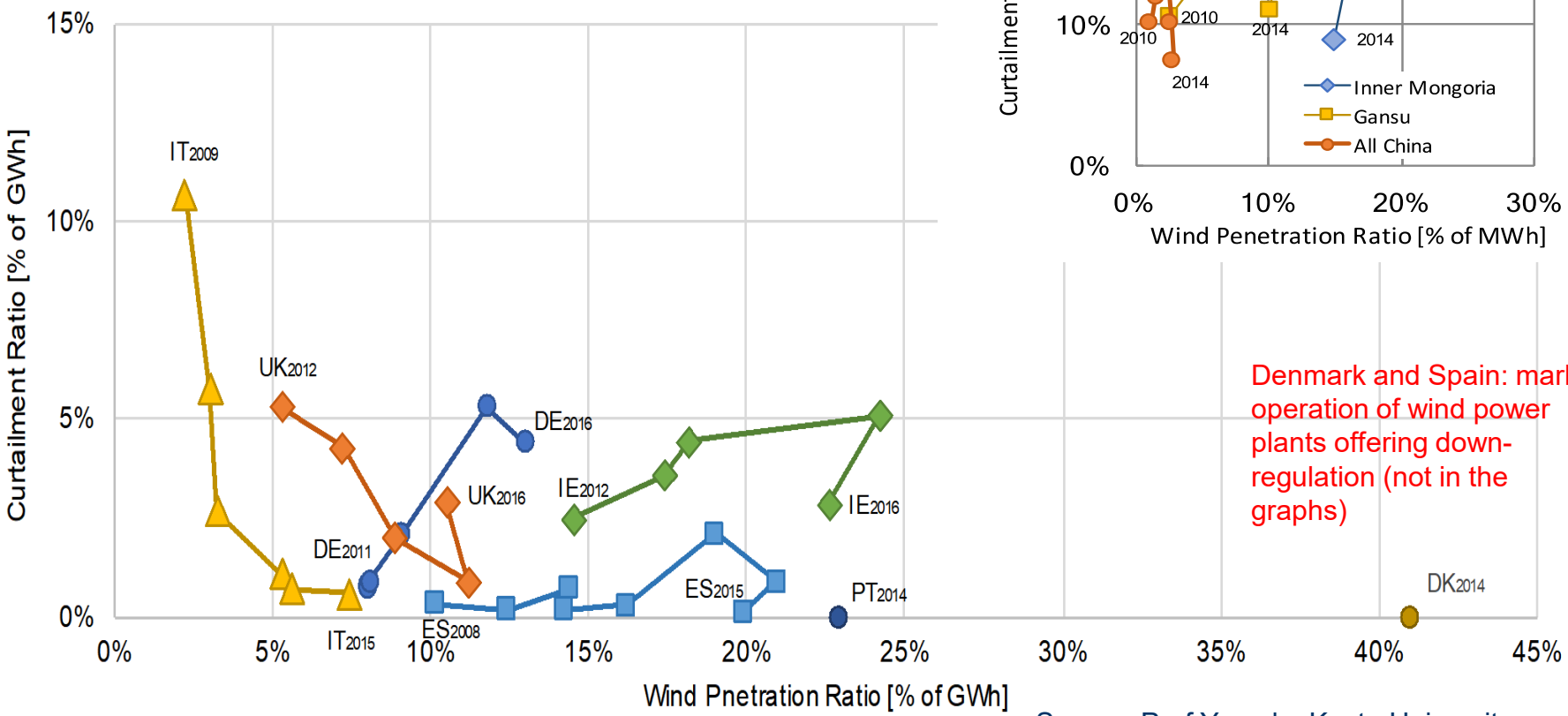
First time in 2015 and several times since then, all central power plants shut down. The necessary system support from:

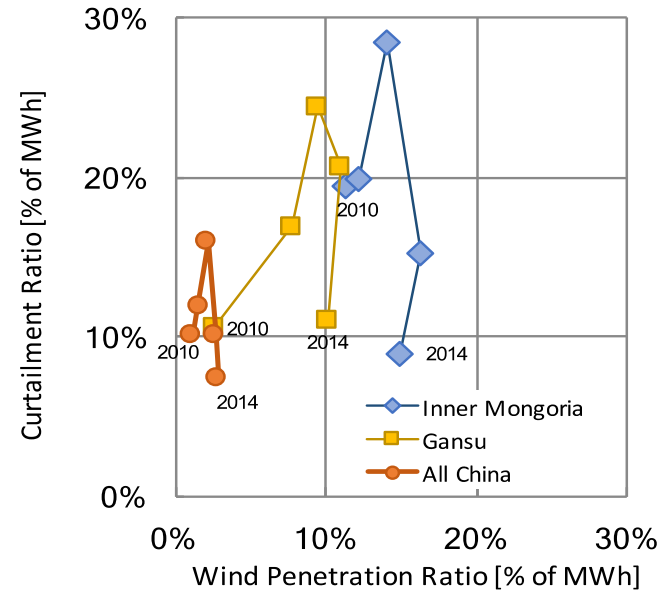
- HVDC link: 700 MW Denmark-Norway
- synchronous compensators 4 in DK-W and 2 in DK-E
- and small scale power plants



Curtailments are a signal of lack of flexibility

- Delays of transmission: Italy and Texas – diminished after grid build out. Germany, still an issue
- Inflexibilities of coal power plants and tariffs: China



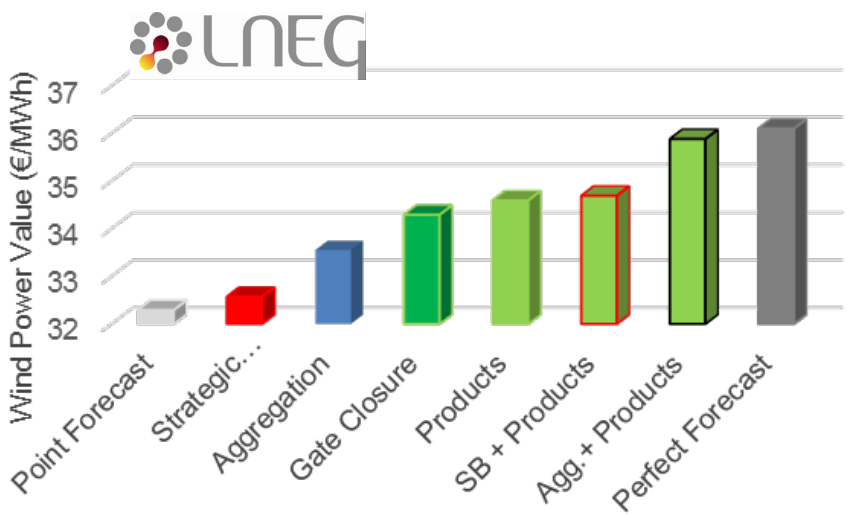


Denmark and Spain: market operation of wind power plants offering down-regulation (not in the graphs)

Source: Prof Yasuda, Kyoto University

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



Enabling system services from wind and solar

- Asking for capabilities in grid codes, and paying for services of system support if needed/used
- Experience of frequency response: Very fast (inertial) in Quebec, fast (primary) response in Texas, secondary in Colorado. Market compliance in Spain, Denmark.

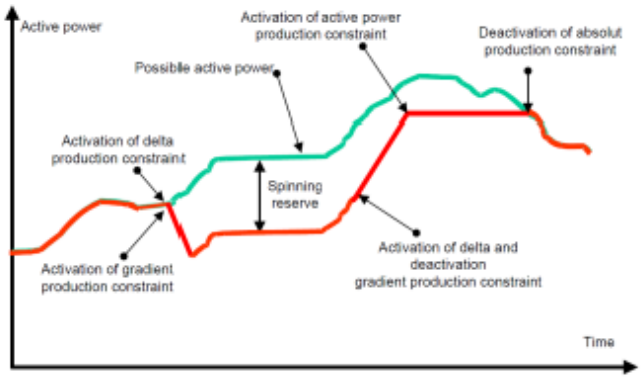


Figure 12: delta control mode – denoted with spinning reserve (Energinet.dk, 2010)

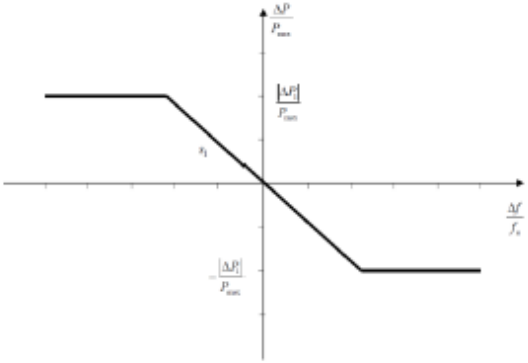
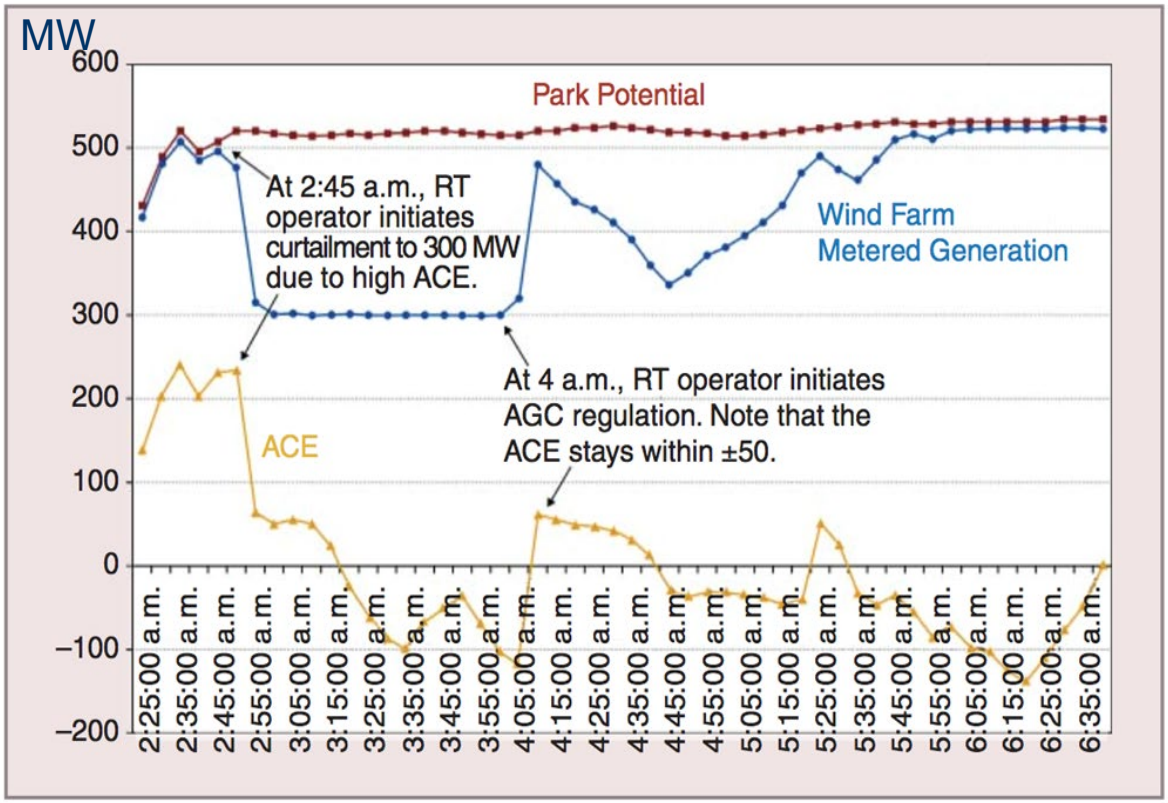


Figure 13: active power setpoint as a function of frequency deviation (ENTSO-E, 2012)

Use wind power plants at AGC when otherwise curtailed

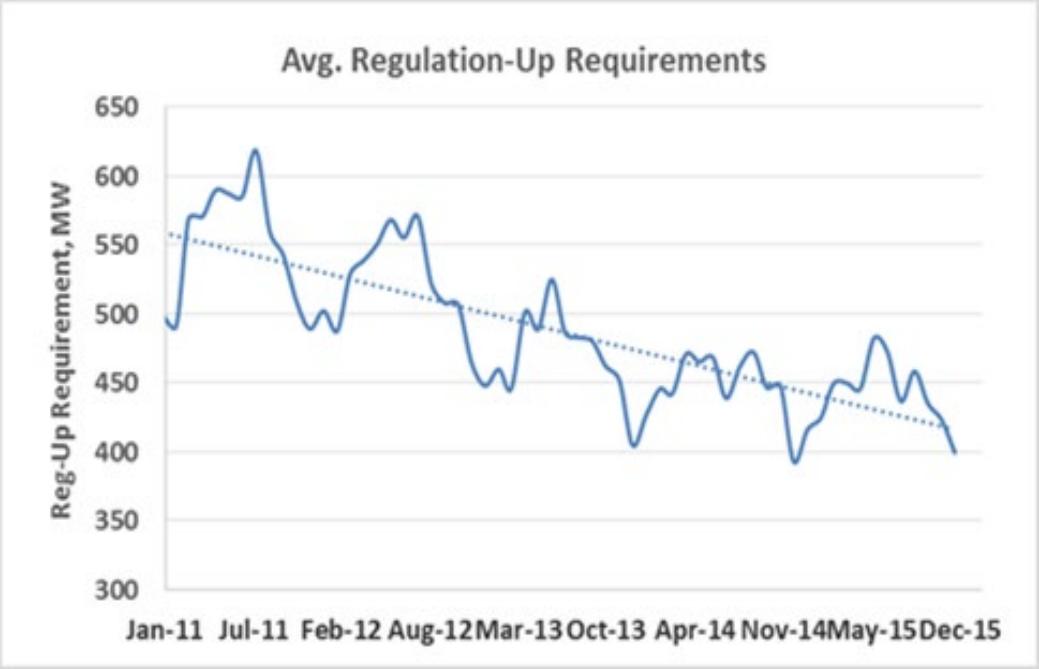
- Wind power plant in Xcel/PSCO is first manually block curtailed and then put on AGC regulation.

- Resulting area control error is shown in yellow.



Experience: Wind power frequency response is fast and high quality

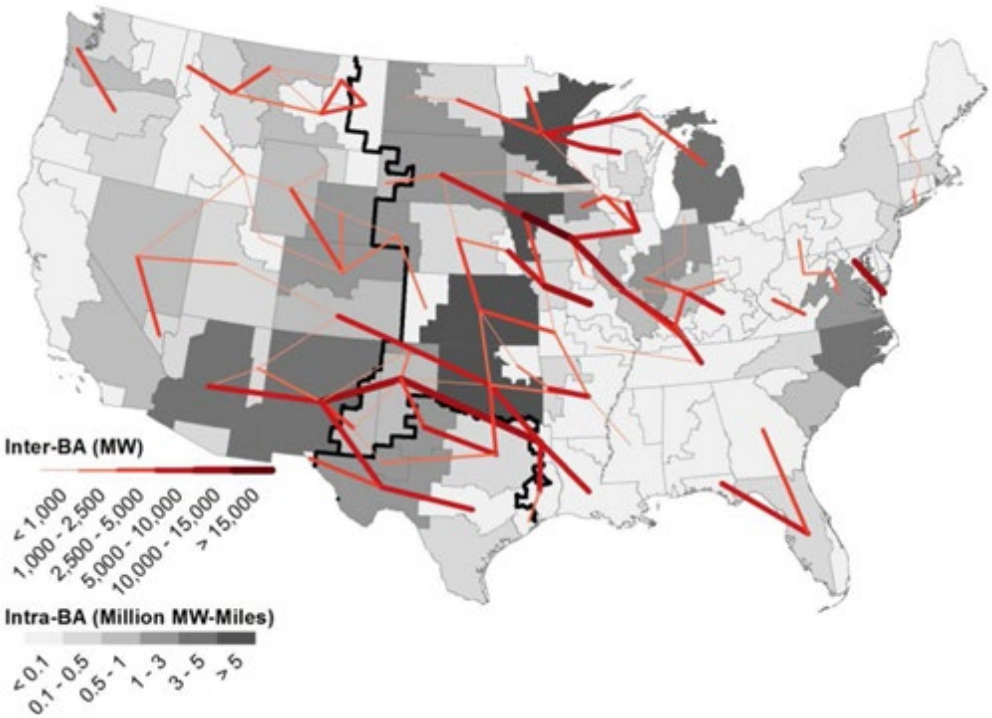
- ERCOT in Texas:
  - fast response of WPPs reduce the overall need for automatically activated frequency support services
- California report showing responses from PV better than conventional generators https://www.caiso.com/Documents/UsingRenewablesTo OperateLow-CarbonGrid.pdf



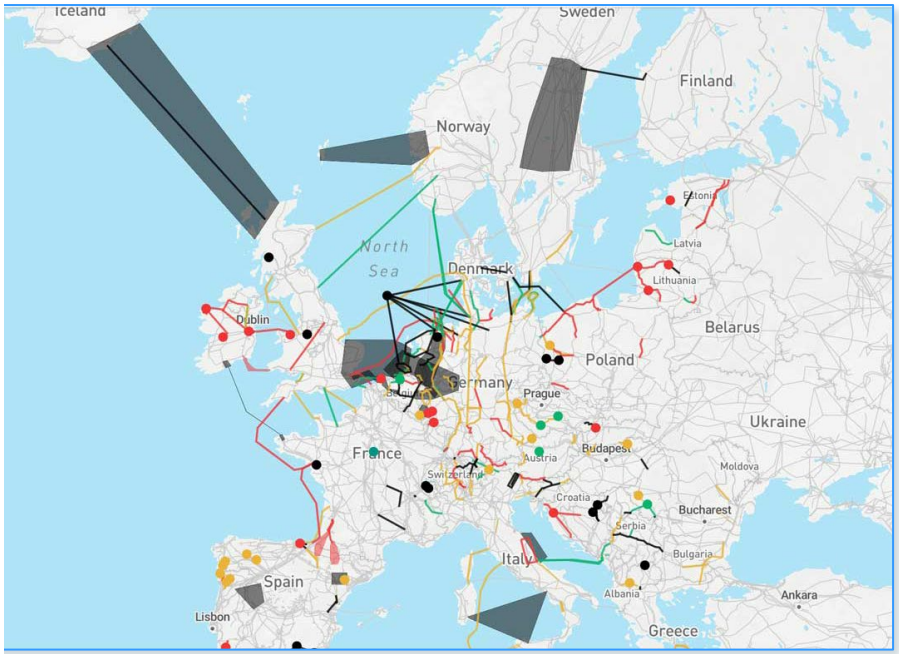
Source: Julia Matevosjana, ERCOT

Long term planning for grid adequacy

- Transmission planning – towards regional planning



Source NREL NATIONAL RENEWABLE ENERGY LABORATORY
http://www.nrel.gov/analysis/re_futures/



Source TYNDP (ENTSO-E, 2018)

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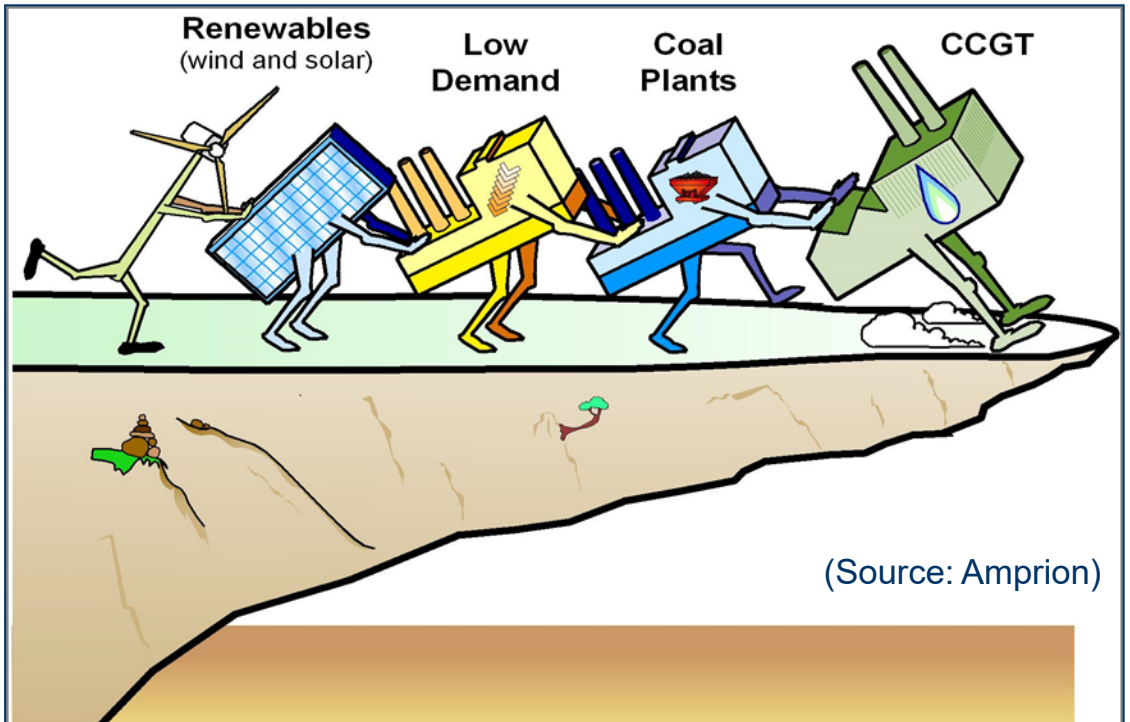
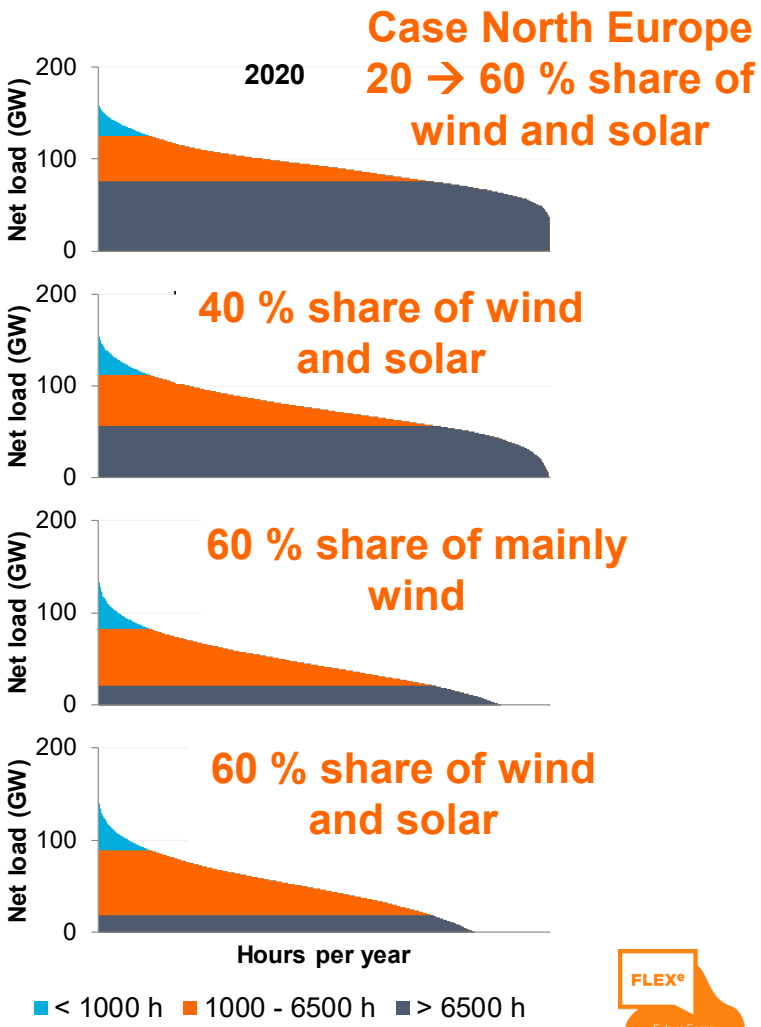
Challenge- conventional power plant retirement

- Total operating time reduces, but capacity still needed
  - Challenges differ for high-growth systems and where load growth no longer substantial



Towards higher shares of wind and solar energy

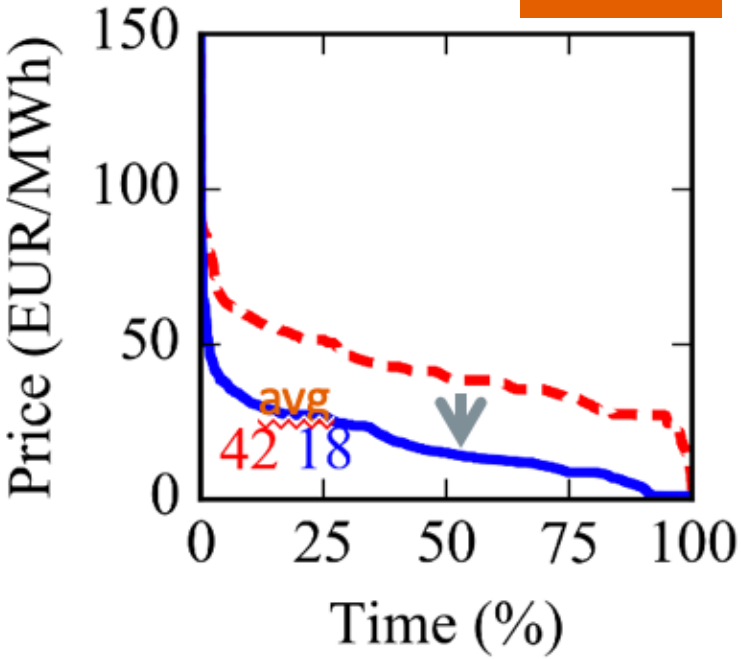
- The time of base load power plants is over
  - Less and less time operating (full load hours), resulting in costs/MWh getting high
- The time of flexible power plants is here
  - producing less than 5000 hours per year, much of that time at part load operation
- Beware of stranded costs when investing in conventional power plants



EL-TRAN
strategic RESEARCH
FLEXe Future Energy System

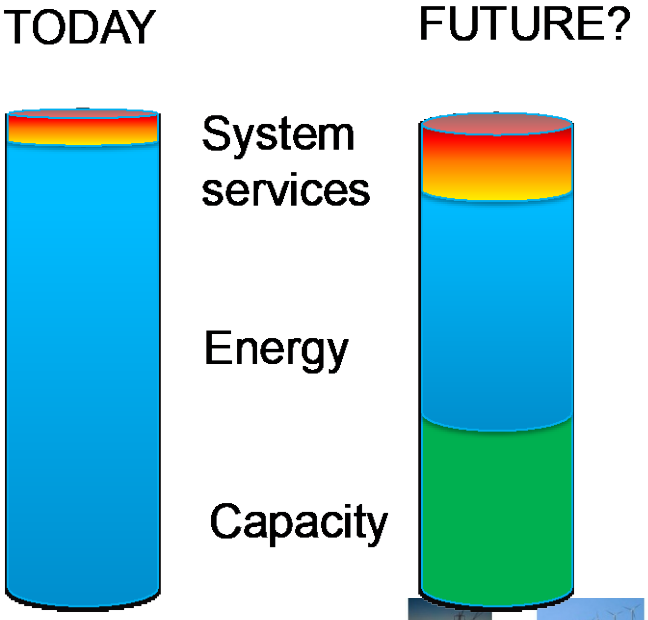
Market challenge: revenue sufficiency

- Due to 0 marginal cost renewables
- Due to flexible loads
- Stakeholder changes
- Can P2X loads change the picture?
  - If timing when wind/PV available
- Storage may be an option



Market income for revenue sufficiency

- Larger market area – keeping prices up
  - less correlated wind power production
- Faster markets – balancing costs down
  - Improved load/net load following dispatch
- Frequency control from wind and solar
  - where surplus energy /very low prices, wind/PV can operate part load and offer fast up- and down-regulation
  - Often this becomes cost effective at larger (>20%) shares of wind and solar



Transition towards renewable future means adaptation

Integration challenge is easier if

- variable generation is built dispersed to larger area and including wind and solar – smoothing
- **power system operation** enables aggregation benefits from larger area: strong transmission/distribution grid and sharing balancing
- there is **flexibility** in the generation fleet – and in demand

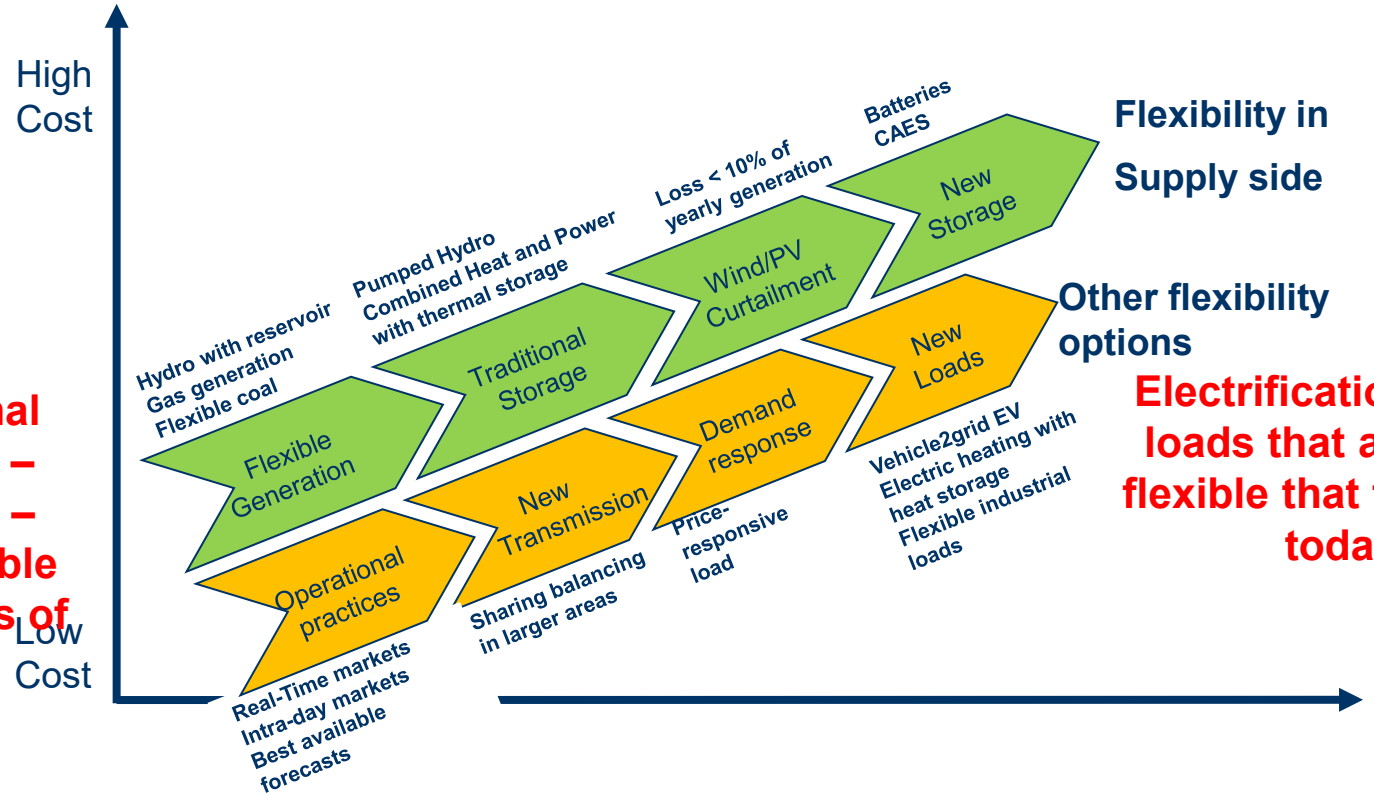
Adaptation will greatly reduce the costs

- **From cost of integration to cost of inflexibility**

Opportunities: development happening helping renewables

- Load transition: changing the fixed load paradigm
  - Digitalisation, home appliances, prosumers
  - Energy system coupling, decarbonisation, electrification bringing new type of demand
- Decentralisation and Smart grids: local markets, DSO role
- Inverter controls: rapid responses, synchronous machine characteristics – grid forming converters enabling wind and solar to be the backbone of future 100% renewable grids

Balancing and flexibility – using more of the solutions we know



Operational practices – and tools – key to enable high shares of VIBRES

Electrification – new loads that are more flexible that the loads today

Low share of wind/PV

High share of wind/PV

VIBREs – and loads and electrical storage can provide the system support services provided by generators today

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Thank You!!

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