INTEGRATION OF RENEWABLES

System operation and grid codes- the case of Denmark

System Integration of Renewables
Japan, June 21 2018

Peter Børre Eriksen, Chief Engineer, Energinet

ENERGINET

THE DANISH TRANSMISSION SYSTEM OPERATOR

We own and operate the overall electricity and natural gas transmission system in Denmark.

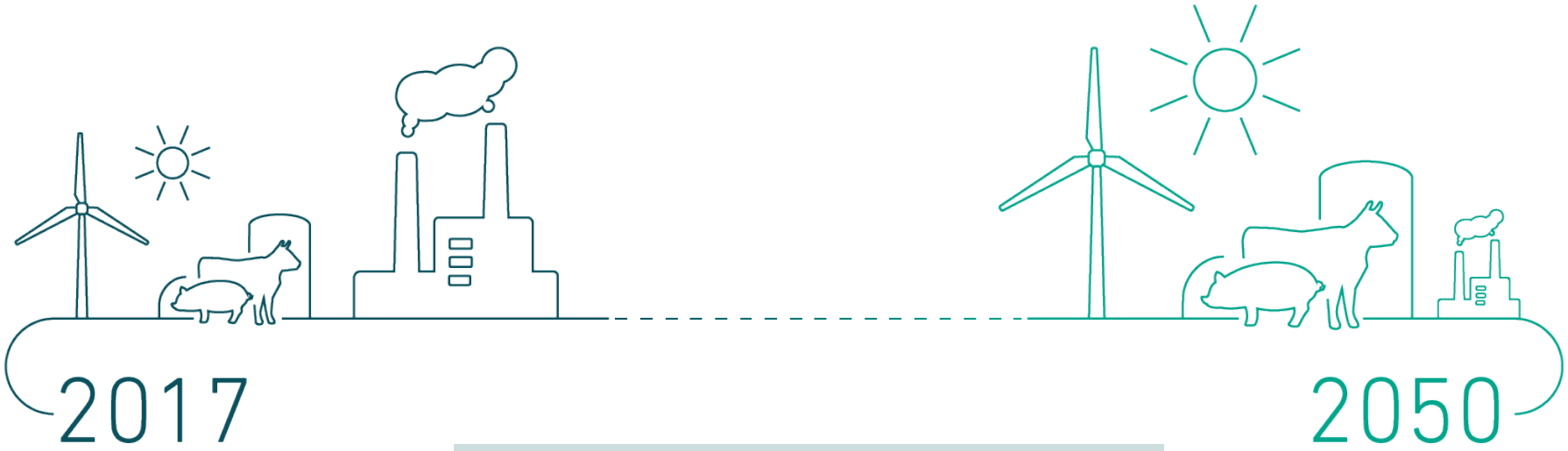
- Independent public enterprise owned by the Danish Ministry of Energy, Utilities and Climate
- The consumers contribute to our activities through tariffs
- Our finances are based on a break-even principle (regulation to be revised!)

Mission: Reliable energy for society

Vision: Balanced and sustainable energy supply

THE ENERGY SYSTEM IN DENMARK IS CHANGING

- By 2020, wind power will constitute 50% of the electricity consumption
- By 2030, renewable energy will constitute 50% of the energy consumption
- By 2050, Denmark will be independent of fossil fuels

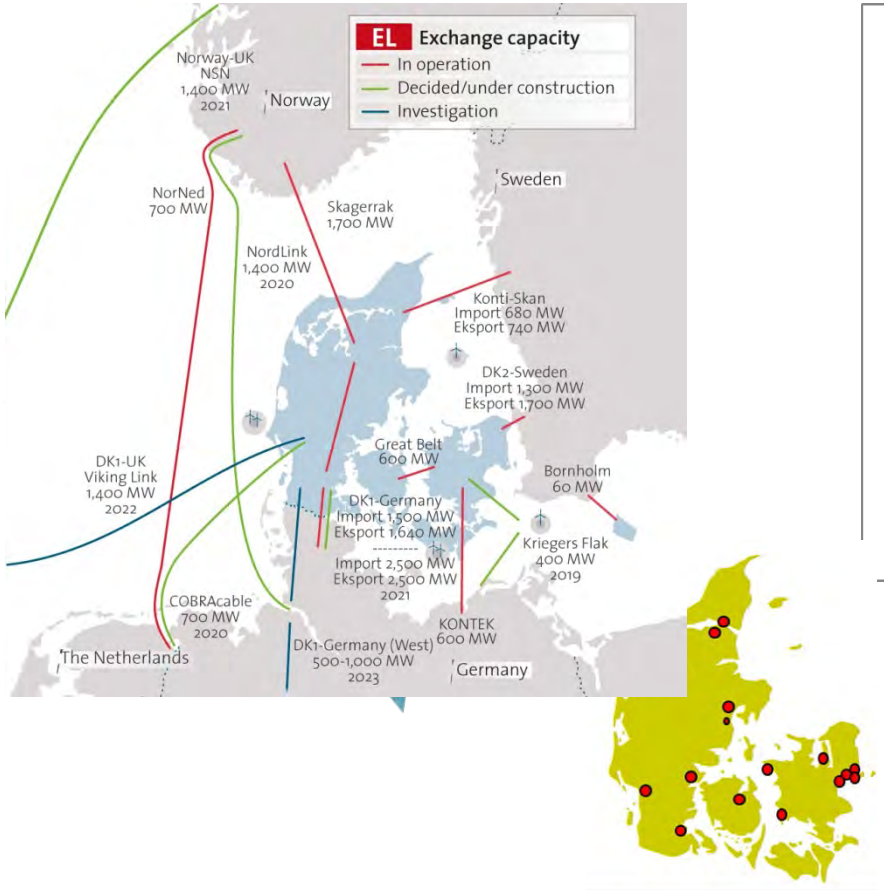


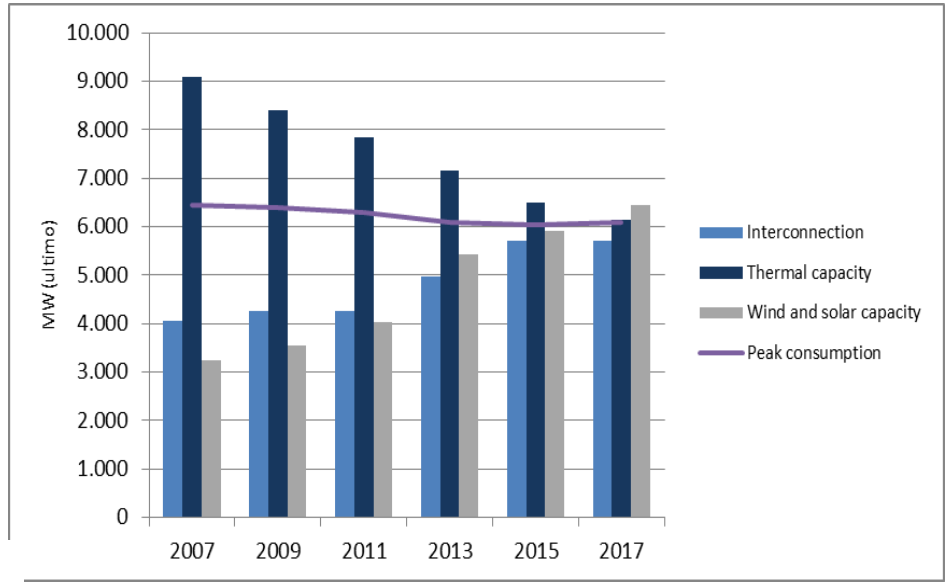
Strategic commitments of Energinet:

- Security of supply
- Efficient green transition
- Healthy investment climate

THE DANISH POWER SYSTEM – OVERVIEW

- Characteristics of the system



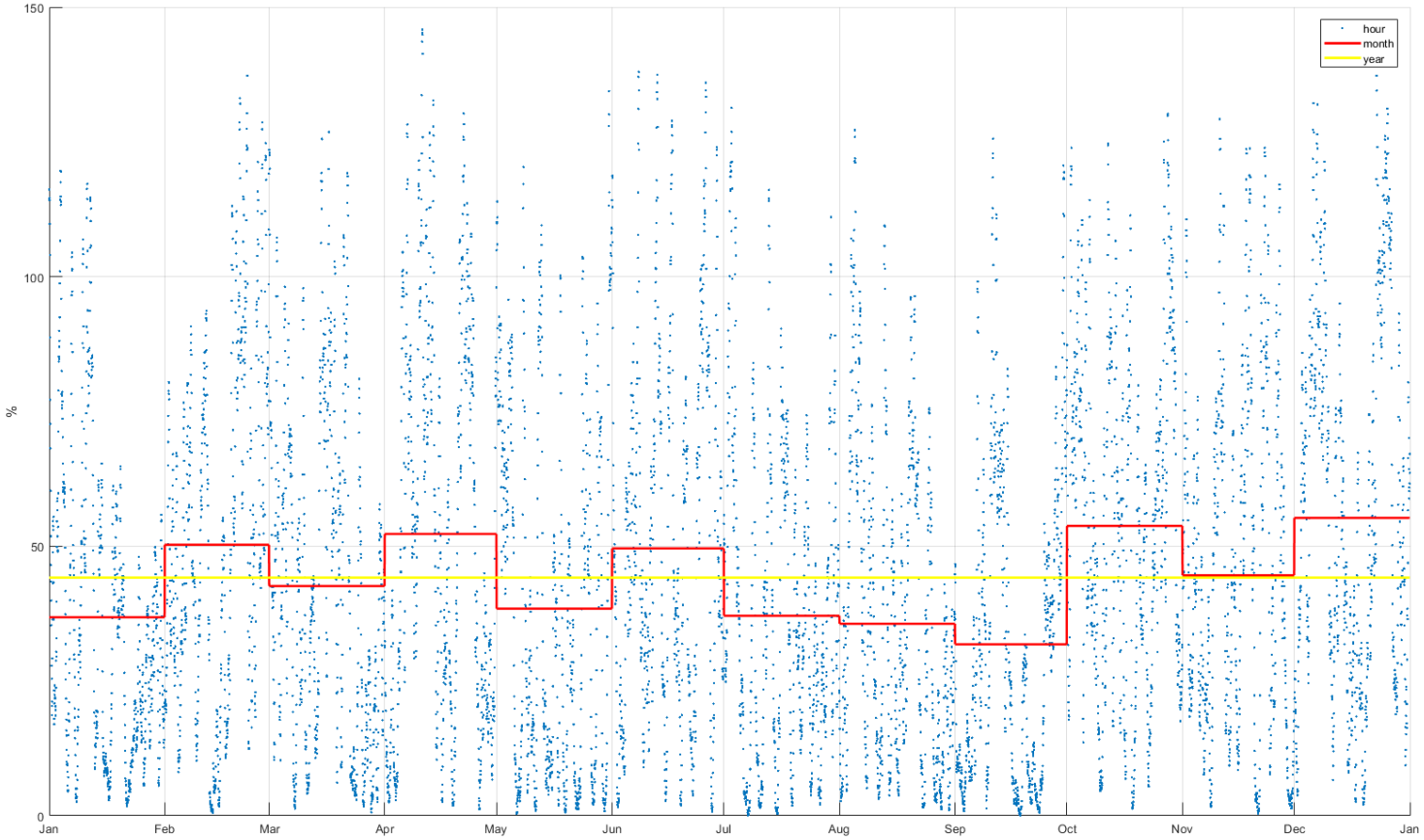


WIND POWER COVERAGE, 2017

150 %

100 %

50 %

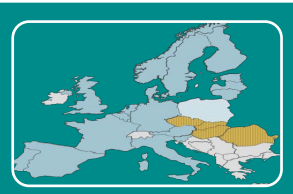


OUTAGE MINUTES (ELECTRICITY) IN EUROPE

- VERY HIGH SECURITY OF SUPPLY IN DENMARK IN PERIOD WITH INCREASING SHARE OF RENEWABLES

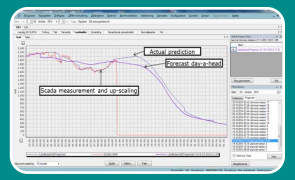
TOOLBOX FOR EFFICIENT LARGE SCALE RES INTEGRATION

Strong transmission grids and interconnectors



International electricity markets

Flexible generation system



Grid codes, high quality forecasts and market based operation

COMMON EUROPEAN GRID CODES being implemented– facilitate the Internal European Market on electricity

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Connection Codes

High Voltage Direct Current Connections

Requirement for Generators

Demand Connection Code

Required functionality and parameters =>
1) an efficient and harmonized system operation &
2)offers opportunities for creating market based services

Operation Codes

Emergency and Restoration

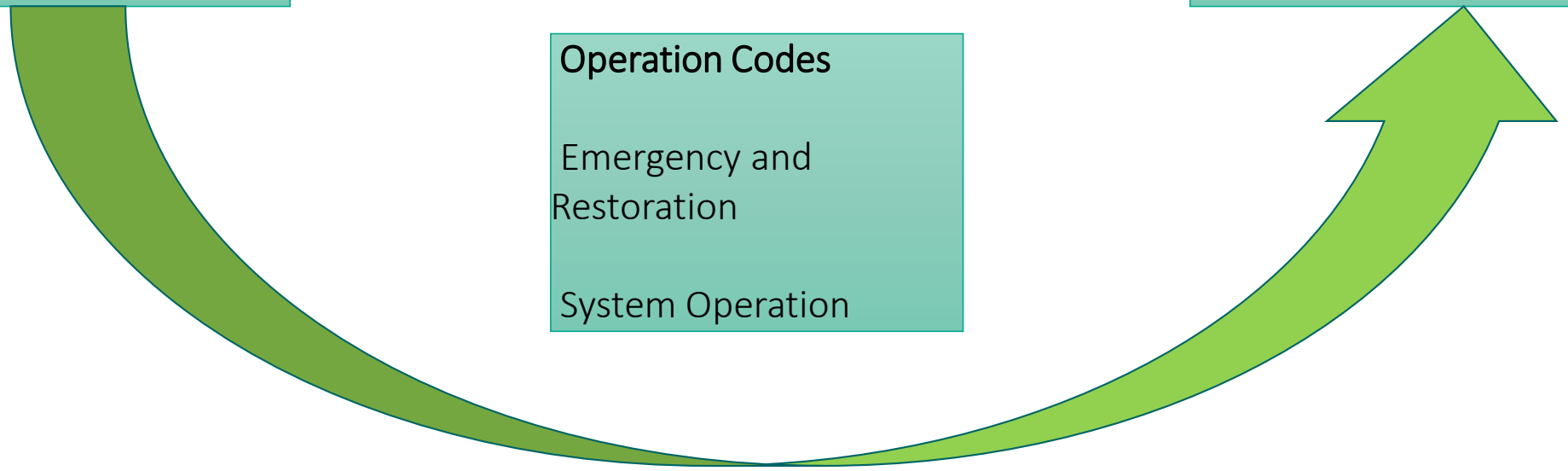
System Operation

Market Codes

Electricity Balancing

Capacity Allocation and Congestion Management

Forward Capacity Allocation



THE VALUE OF EUROPEAN GRID CODES /NETWORK CODES?

Value of having common European grid codes?

- **Facilitate** harmonisation, integration and efficiency of European electricity market (and rules for connections and power systems operation)
- Facilitate the drive towards the EU **climate goals**: 40 % CO2 reduction, 27 % renewables, 27% increase in energy efficiency by 2030
- **Non-discriminatory** , **transparent rules** for grid access (contrary to negotiated access)
- Harmonised grid codes facilitate **coordination** between grid planning, grid connection, grid operation for the transmission and distribution grid systems
- **Equal requirements** for all kinds of fuel (coal, biomass, hydro, wind, solar, …) facilitate a transparent competition between power generators
- …

SYSTEM OPERATION GUIDELINE

Examples of some important topics

Operational security

- System states
- Remedial actions
- Contingency
- Data exchange

Operational planning

- Common grid models
- Operational security analysis
- Regional security analysis
- Adequacy
- Ancillary services

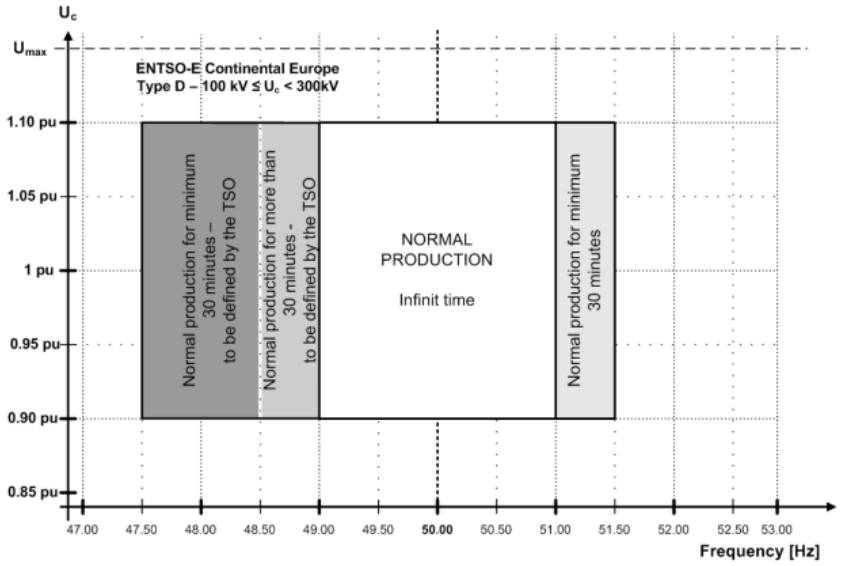
LFC and reserves

- LFC structure (blocks/areas)
- Frequency quality
- FCR
- FRR
- RR

Grid code requirements

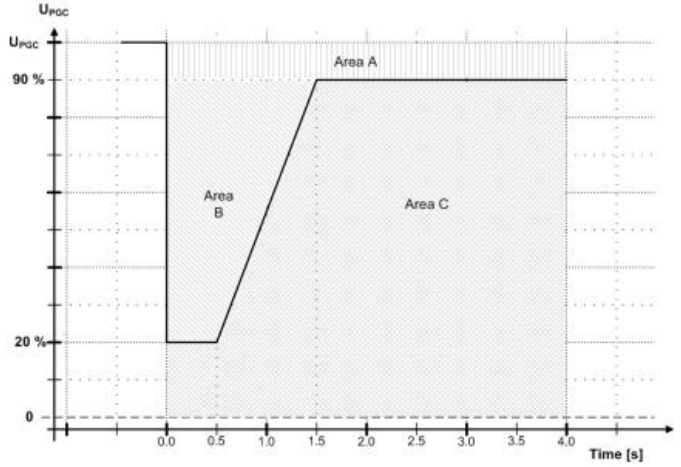
REQUIREMENTS ON FACILITY ROBUSTNESS

- Robustness against voltage variations
  - e.g. all facilities shall stay connected for supply voltage variations of up to ± 10%



- Robustness against frequency variations
  - e.g. all facilities shall stay connected for frequency variations of up to ± 6%

- Robustness against voltage dips and swells
  - e.g. all facilities shall stay connected during voltage **dips** down to 10% of the nominal supply voltage level for up to 250 msec
  - e.g. all facilities shall stay connected during voltage **swells** of up to 30% of the nominal supply voltage level for up to 250 msec



GRID CODES – REQUIREMENTS FOR GENERATORS (INCL. WIND)

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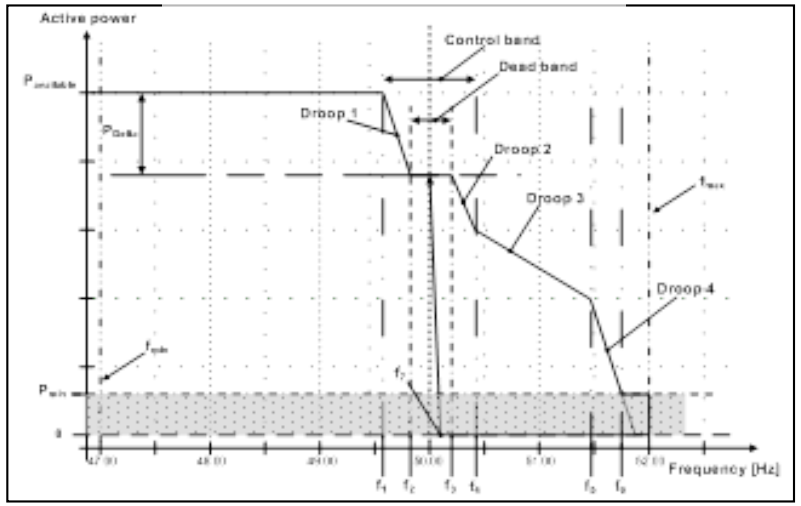
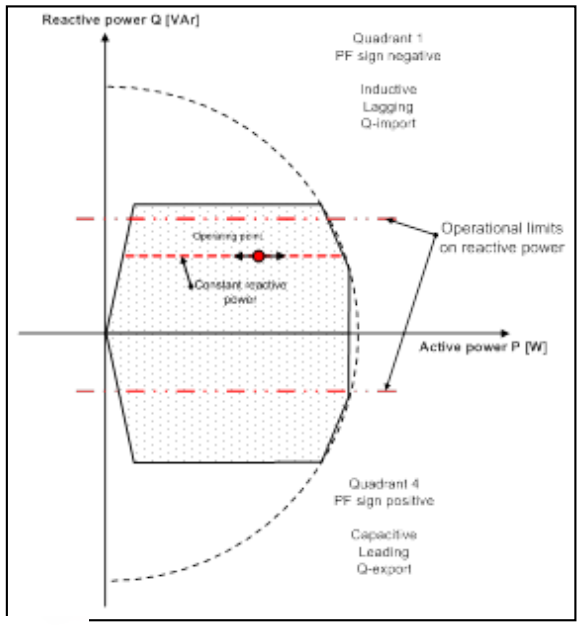
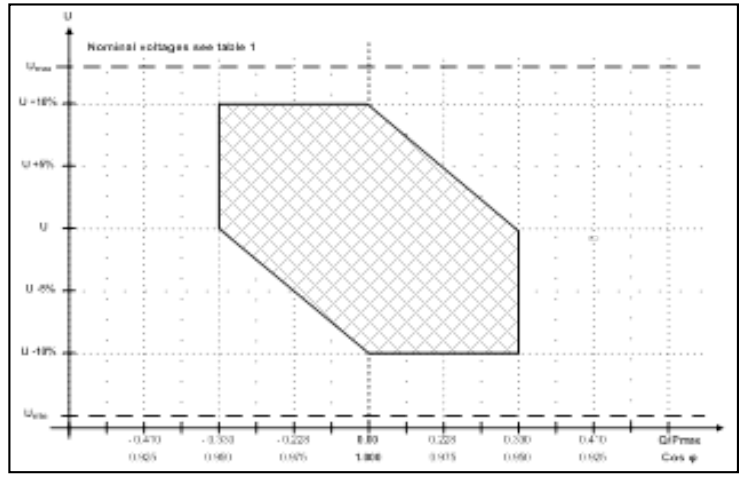
Active Power Requirements



Reactive Power Control



Reactive Power Requirements

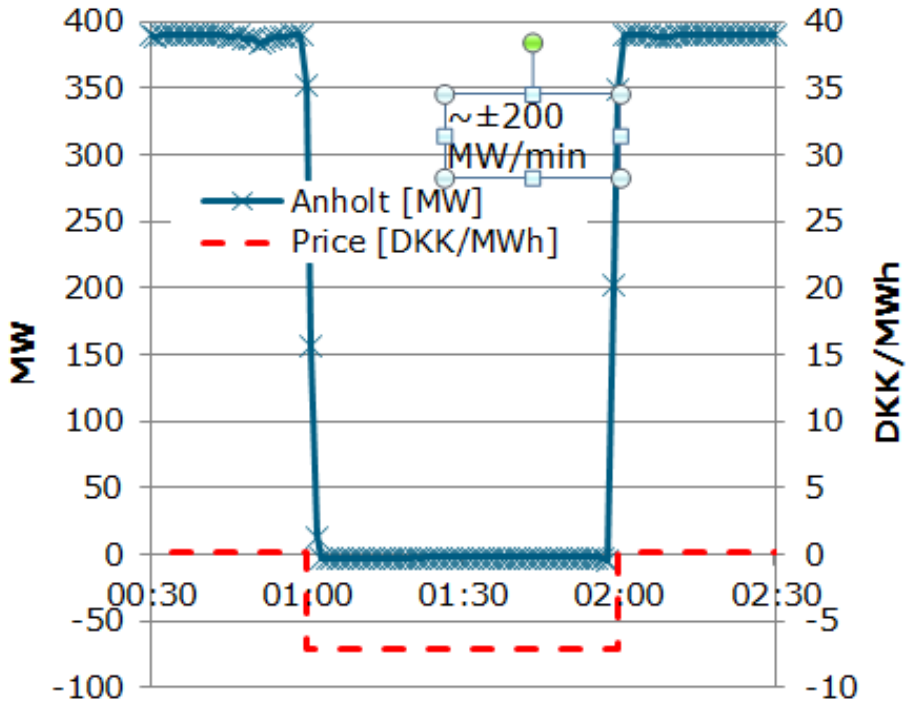


Protection Requirements

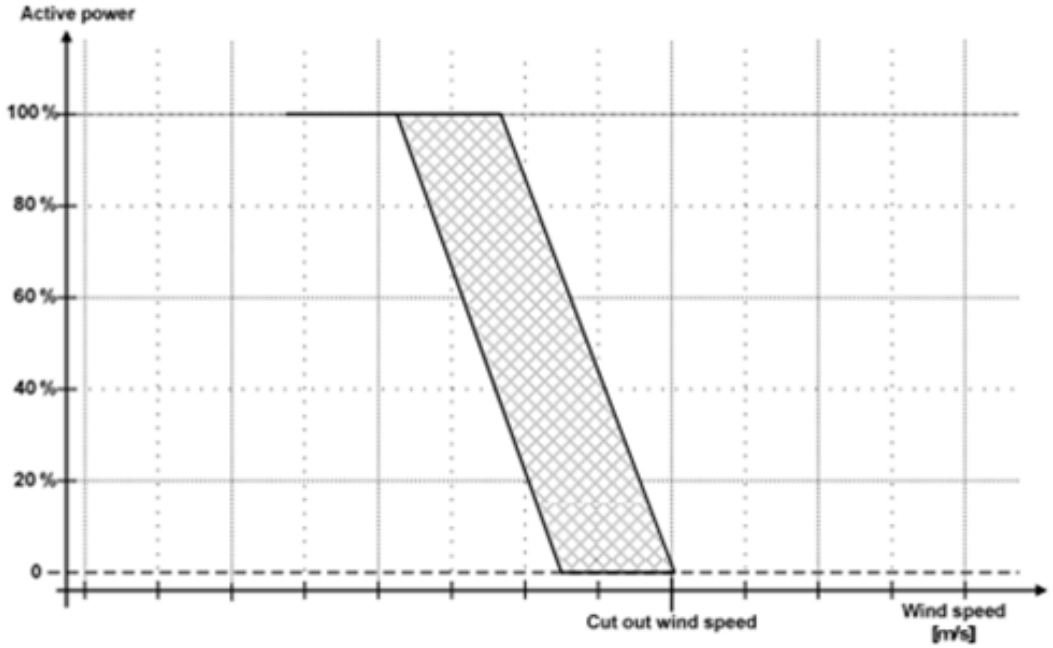
Grid Protection Requirements

GRID CODES: WIND POWER GRADIENTS

Market based down regulation



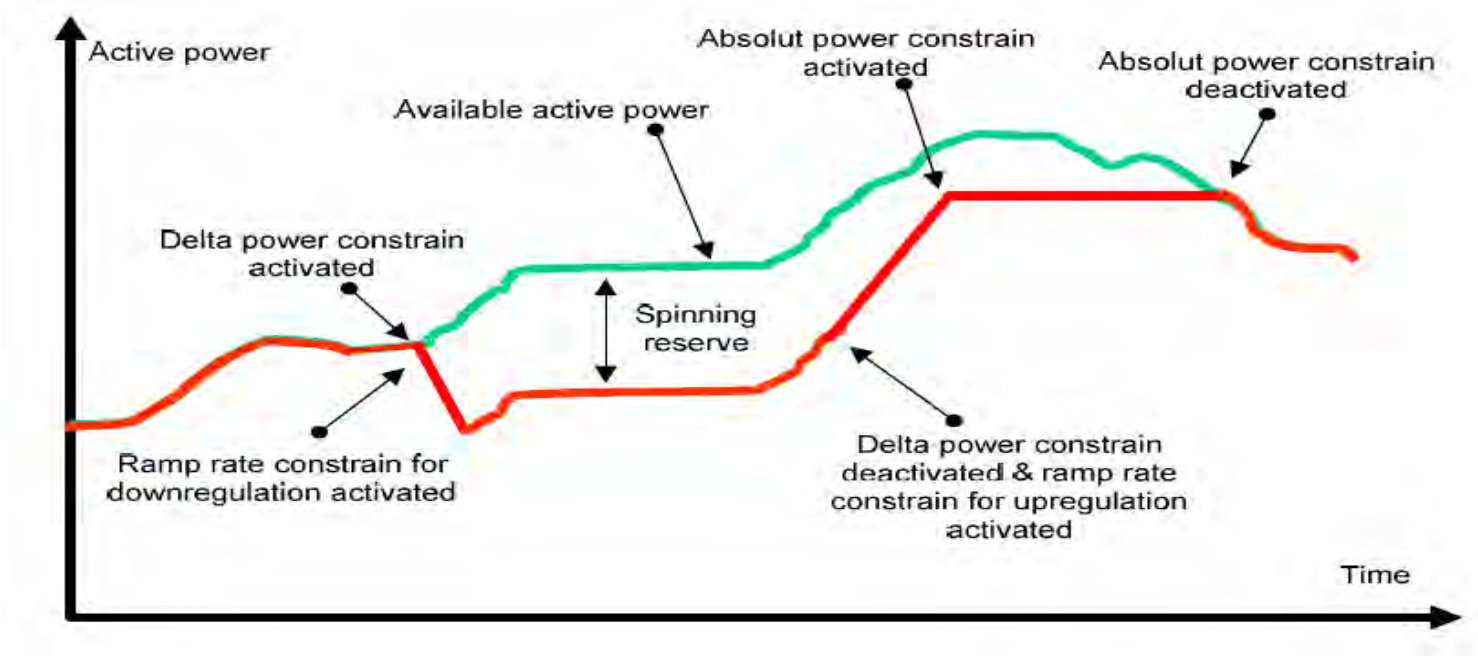
Technical cut-off wind speed



GRID CODES – REQUIREMENTS FOR PLANT CONTROL FUNCTIONALITY (E.G. WIND)

One or all of the following:

- Absolute power limiter
- Power ramp limiter
- Delta power limiter
- ..



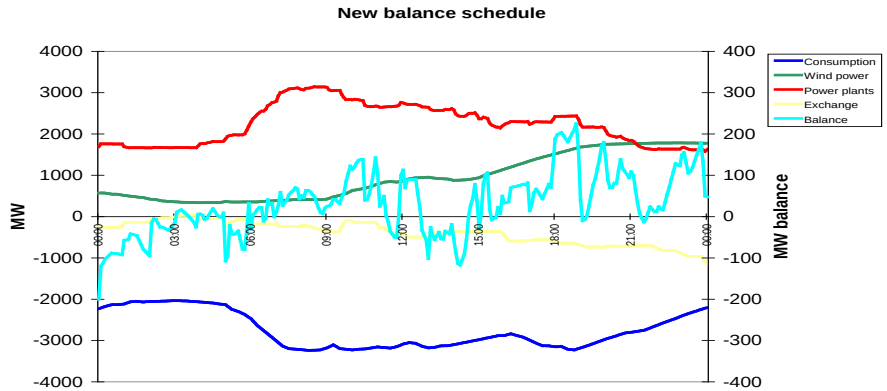
Market based operation & high quality forecasts (wind)

Energinet.dk forecasts
- Wind power
- Solar PV
- Load

BRP power schedules
- Planned production
- Technical min/max.

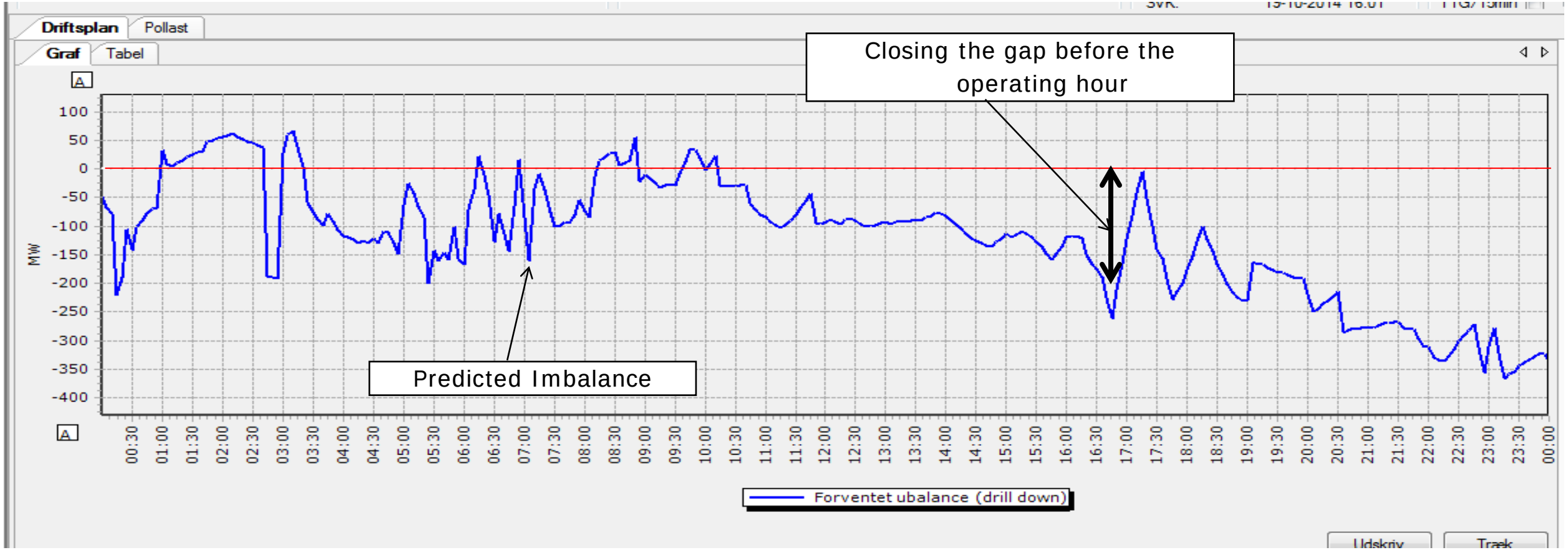
Energinet.dk online measurements
- Production
- Exchange
- Load

Interconnector schedules
- Germany
- Sweden
- Norway
- DK1-DK2

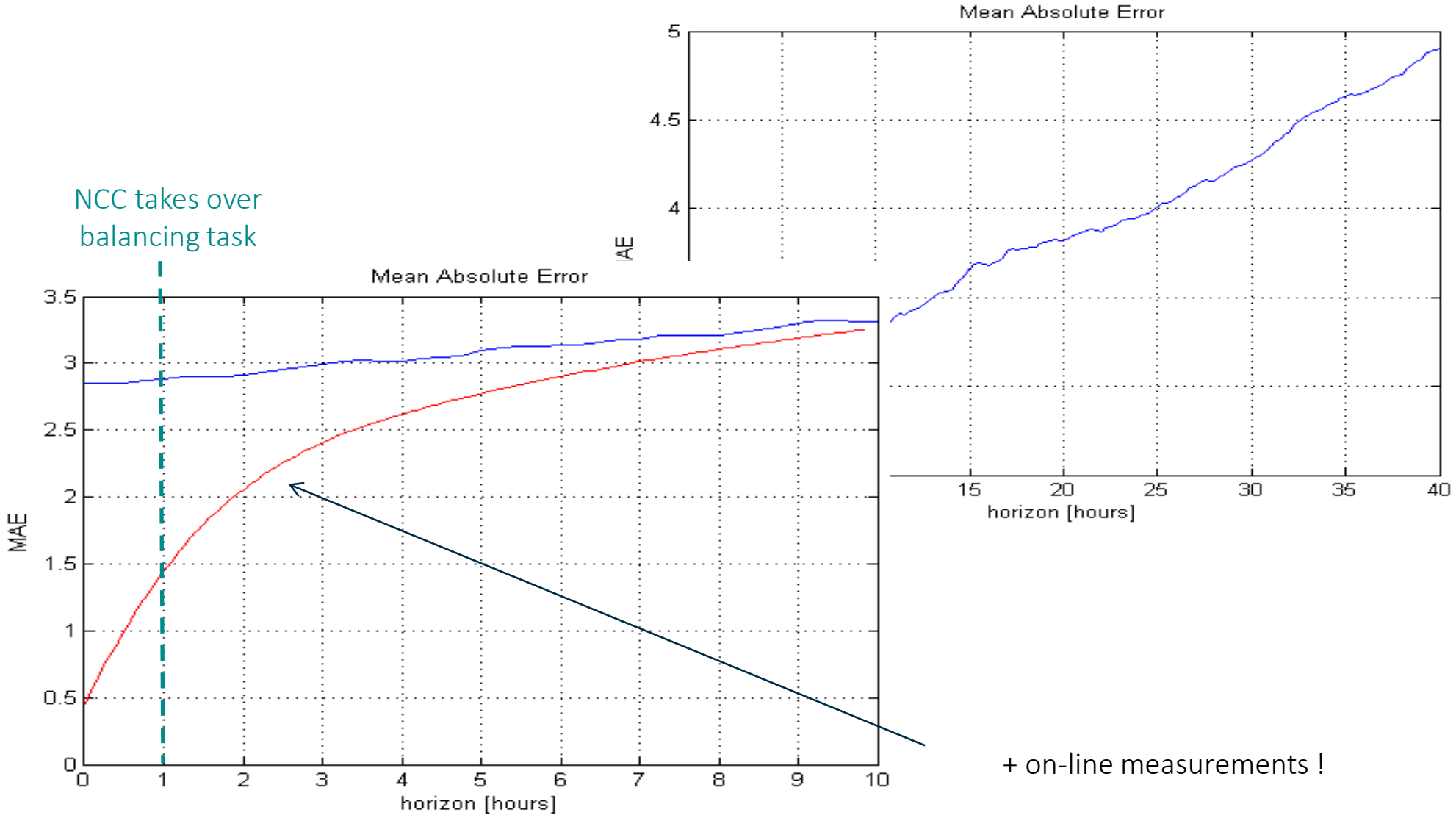


- All wind in DK has balance responsibility
- ~100 % wind traded on NordPool
- Economic support schemes for wind (e.g. market price plus 3-4 cent/kWh)
- Offshore parks: lowest price from tender

OPERATIONAL PLANNING SYSTEM
- PREDICTED IMBALANCE – ON-LINE UP-DATED



WIND POWER FORECASTING



+ on-line measurements !

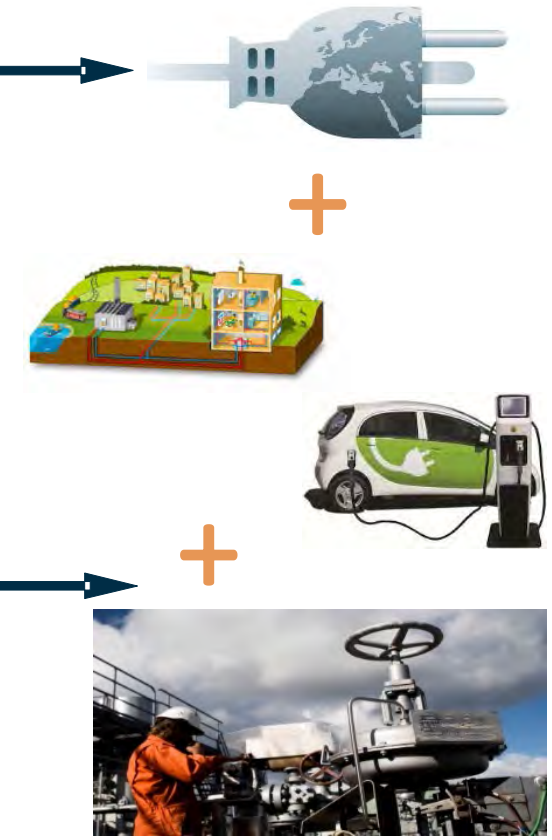
CONCLUSION

Measures of large scale renewables

Generation

50 % wind by 2020 =>
100 % fossil free by 2050

Measures and solutions



Strong transmission grids
International electricity markets
Flexible generation system
Harmonized Grid Codes
High quality forecasting
Market based operation

Integration of power system with the heat and transport sector

Long term:
integration with the gas sector (power to gas)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Thank You
for your attention
For more information visit www.energinet.dk

WHEN TO USE THE VARIOUS FUNCTIONS?

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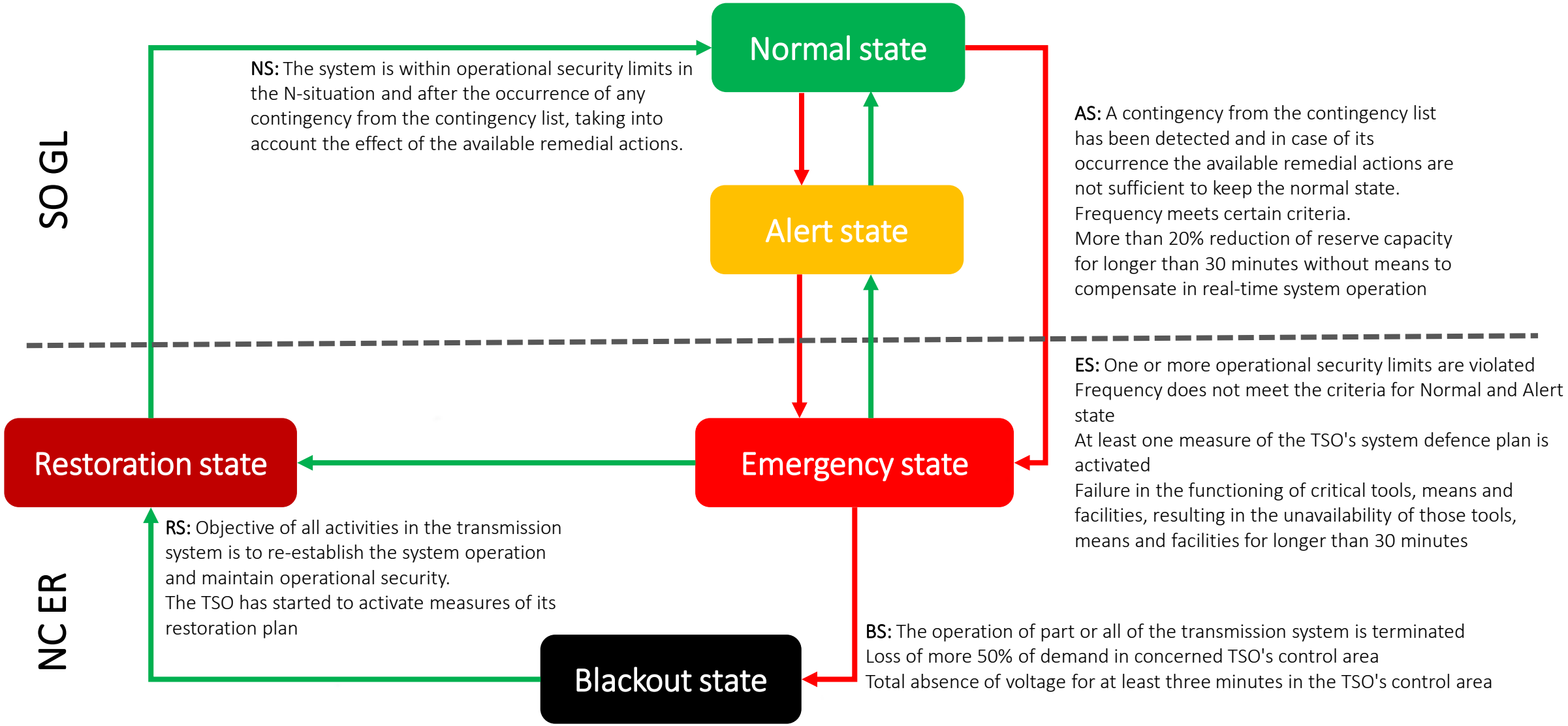
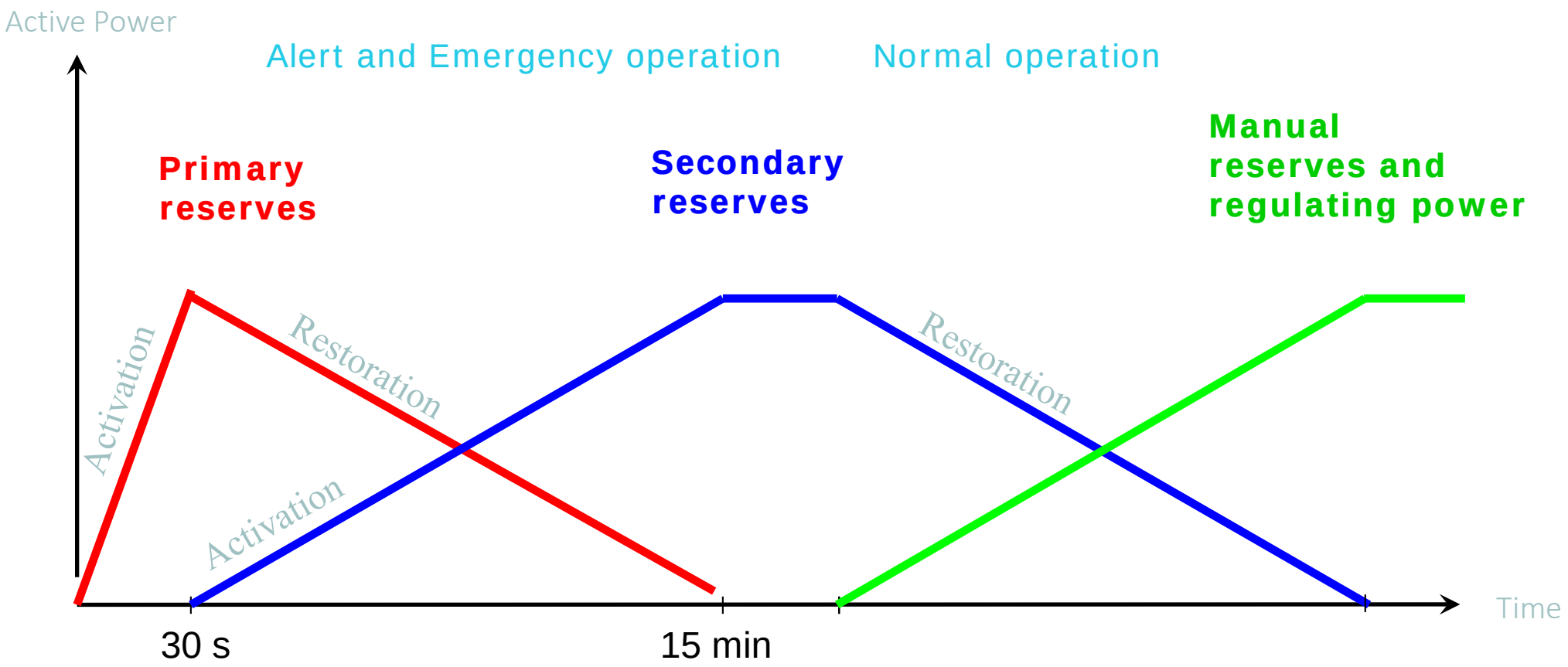


THE FUNCTION OF THE DIFFERENT RESERVES



TRANSMISSION – EUROPEAN COOPERATION

ENTSO-E Ten Year Network Development Plan (TYNDP 2016) for 2030:

- 40,000 km of new or refurbished grid
- 40 % reduction in congestion hours
- 45-60 % covering of demand with RES by 2030 (4 scenarios)
- 50-75 % reduction of CO2 (compared to 1990)

- 150 billions € of grid investments
  ~ 1-2 €/MWh on bills due to investments
  ~ but 1.5-5 €/MWh reduction in wholesale power prices

ENTSO-E: European Network of TSOs - Electricity

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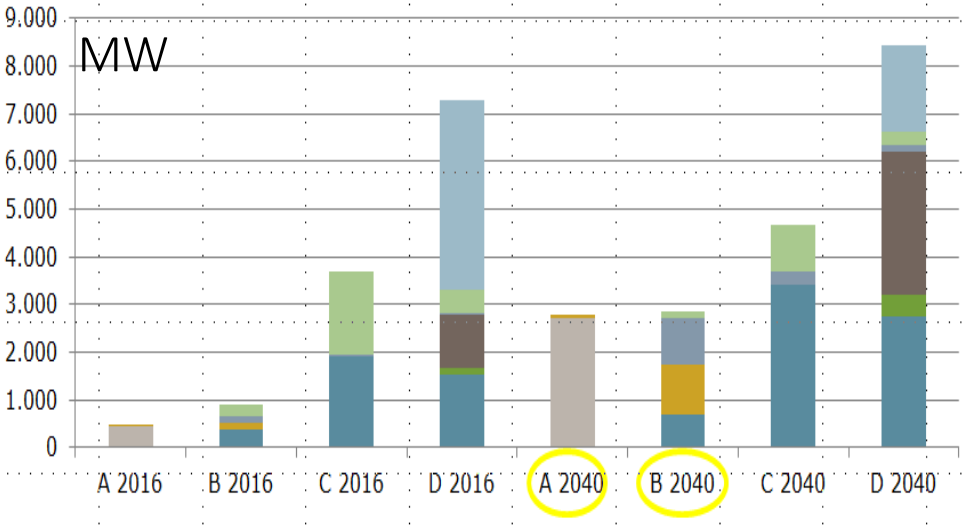
STABILITY IMPACT AND REQUIREMENTS

Categorization of generation/demand facilities can be applied to assign requirements

- **Size** matters!!! – also in electricity system stability

- Impact on grid stability is related to the aggregated **size** of the generation/demand facility, e.g. requirements for generation facilities in DK are sorted in following four categories:
  - A: generation/demand facilities from 0 kW to 0.125 MW
  - B: generation/demand facilities from 0.125 MW to 3 MW
  - C: generation/demand facilities from 3 MW to 25 MW
  - D: generation/demand facilities above 25 MW



- Requirements shall be specified as minimum requirements

WIND POWER FORECAST

We use two forecasting tools – one external and one internal:

External forecast

- Provider: Enfor A/S
- Online forecast (0-12 hours) every 5 minutes
- Day ahead forecast (0-48 hours) every hour

Internal forecast

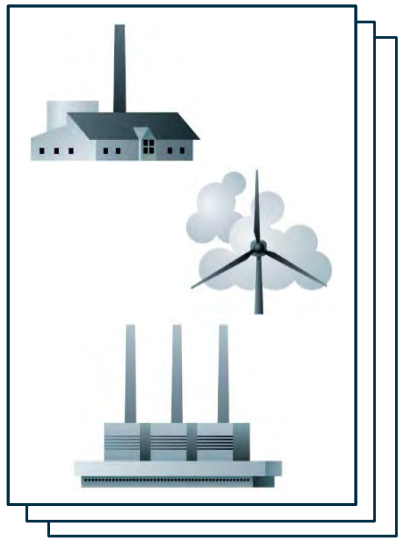
- Online forecast (0-10 hours) every 5 minutes
- Day ahead forecast (0-144 hours), triggered by new NWP

Each forecast is based on NWP's from three providers.

NWP: Numerical Weather Prediction

REGULATING POWER MARKET

PBR



Schedules

Regulation

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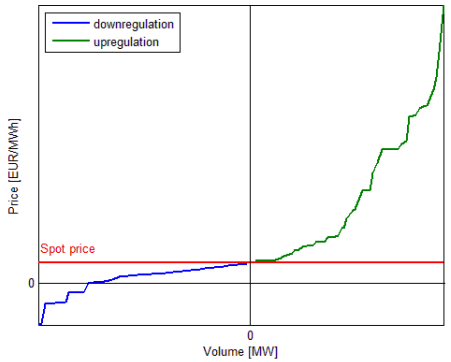
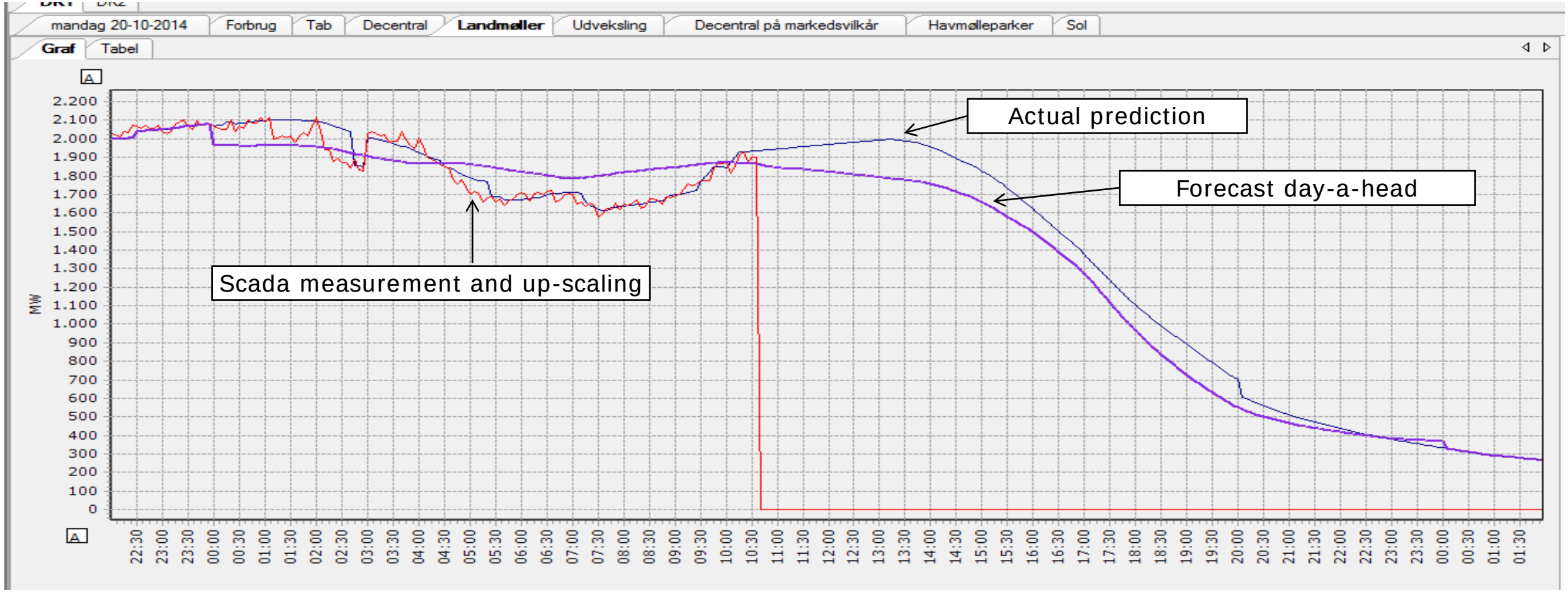


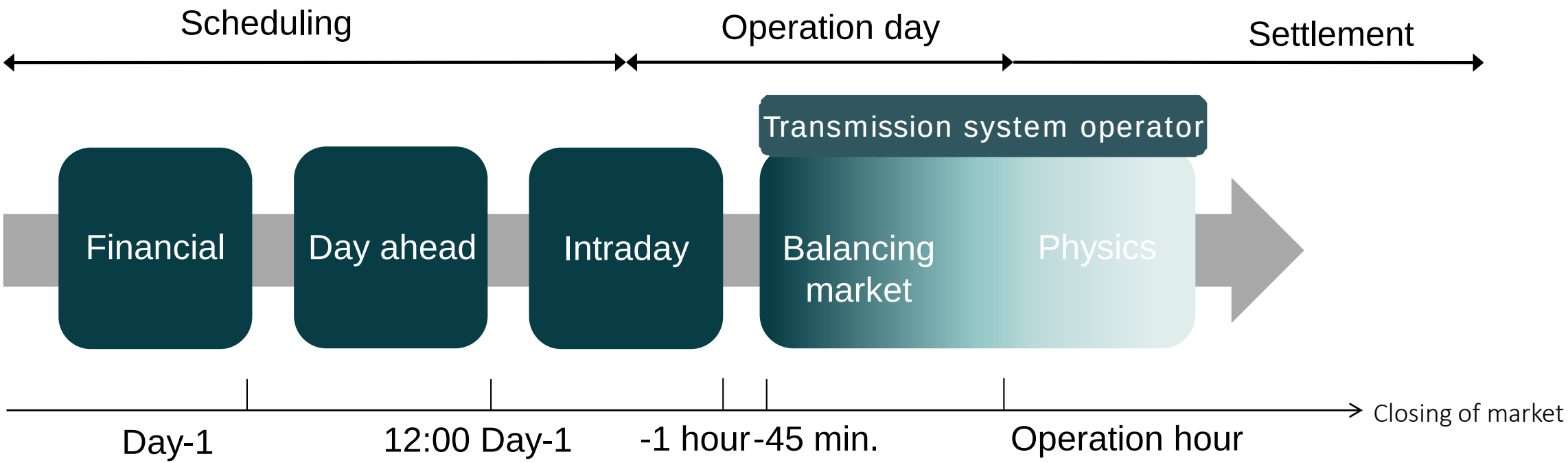
OPERATIONAL PLANNING SYSTEM

- CONTINUOUSLY UPDATED SCHEDULES AND FORECASTS



THE ELECTRICITY MARKETS

The Electricity market is not just one market, but a suite of markets



MARKET COUPLING IN EUROPE

Nordic Region	Price coupling since 1999 (Eastern Denmark 2000)
Belgium, France, Netherlands (TLC)	Price coupling since 2006
Nordic region-Germany (operated by EMCC)	Volume coupling since November 2009
Central West Europe (CWE)	Price coupling since November 2010
CWE-Nordic region (+ Estonia) Flow calculated by EMCC Prices calculated by PXs	**Interim solution NWE:** Interim Tight Volume Coupling (ITVC) since November 2010
Nordic region– Poland (SwePol)/ Nordic region-Lithuania/ Nordic region-Latvia/ Baltic region – Poland (LitPol)	Price coupling since Dec. 2010 / June 2012/ June 2013/December 2015
North West Europe (NWE) - One price calculation for entire area	Price coupling since February 2014 = target model
NWE+SWE = MRC (multi regional coupling) One price calculation	Price coupling since May 2014
MRC + Italian borders	Price coupling since February 2015
4MMC – not yet coupled to MRC, but using same algorithm	Price coupling since November 2014
Bulgaria/ Croatia (MRC members but no capacity implicitly allocated on any of the borders yet)	January 2016/ February 2016
Serbia	Independent operation of algorithm

EUROPEAN INTRADAY MARKETS – FACILITATES FLEXIBILITY

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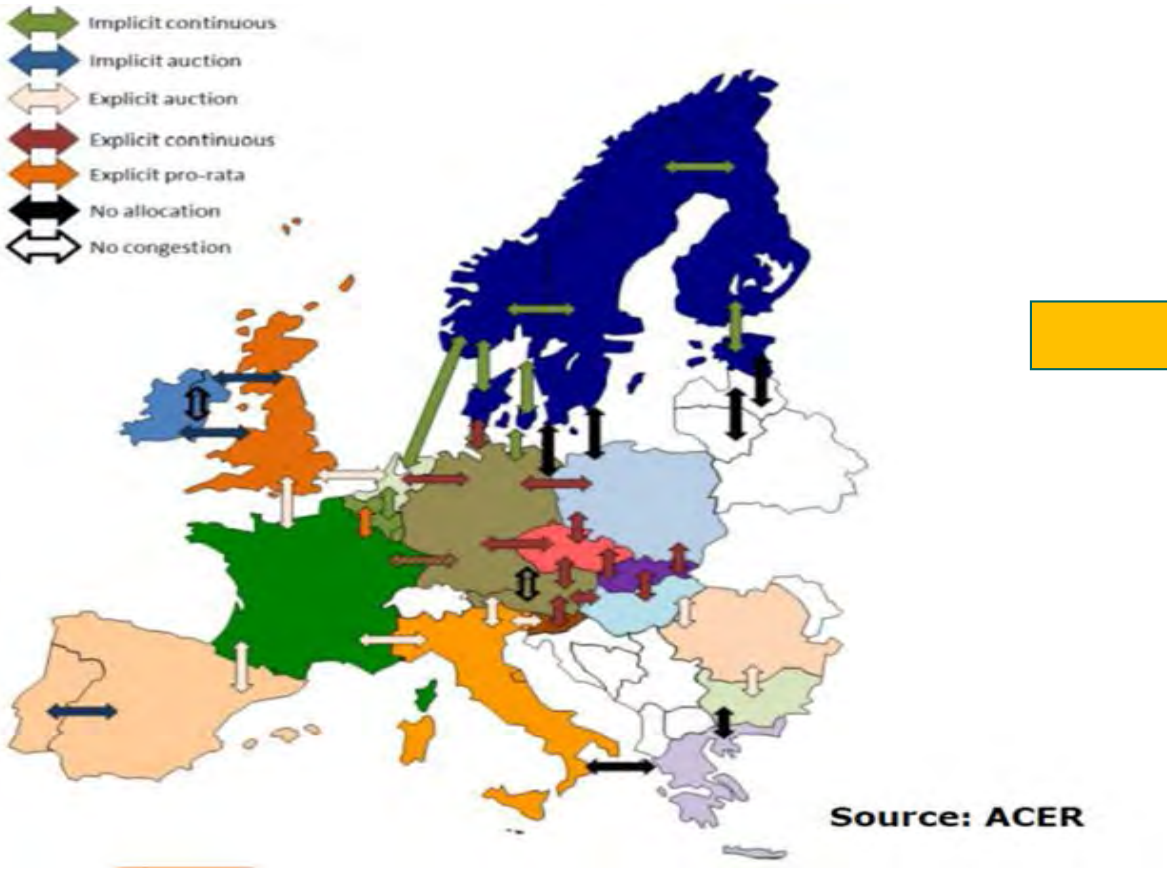
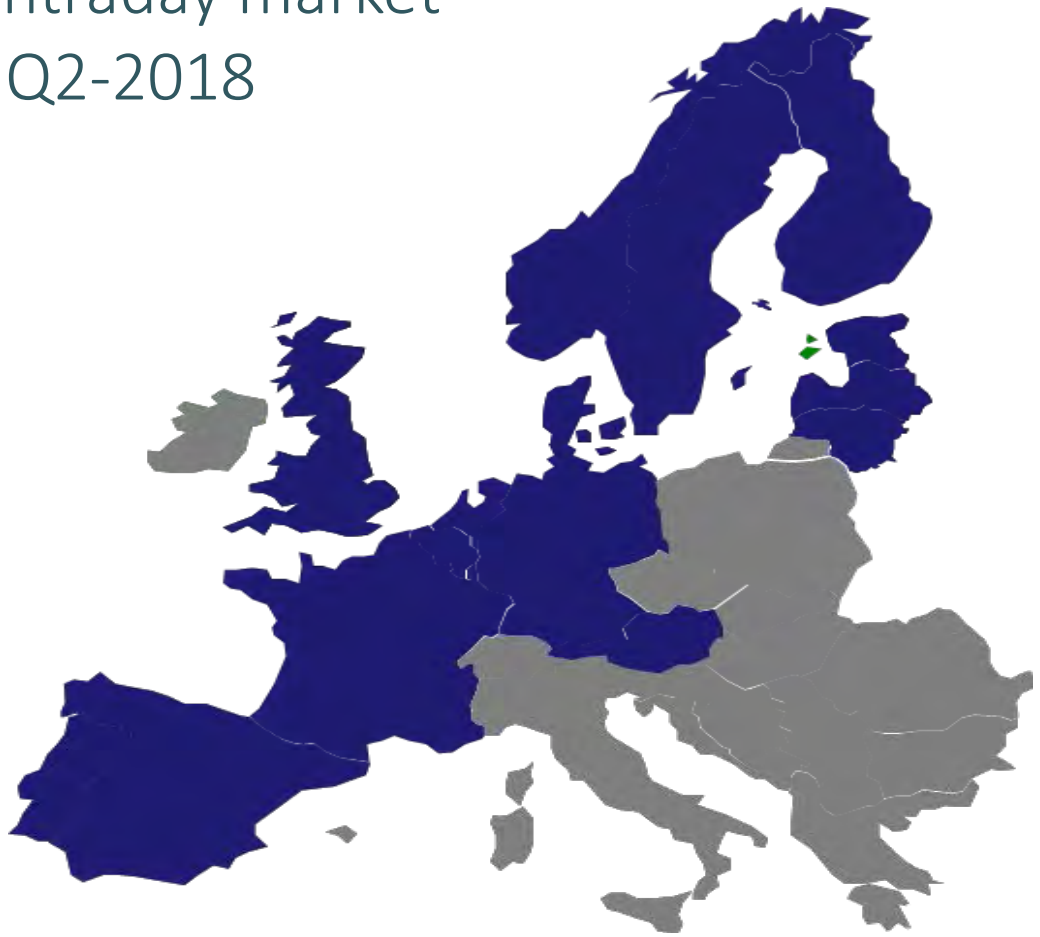
Today's
ID markets



One intraday market
from Q2-2018



HIGH FLEXIBILITY OF POWER PLANTS

Operational range:
10–100%

Regulating rate:
3-4% per minute

Heat accumulators and electric boilers

Source: Dong Energy