CAPACITY RESERVES FROM RENEWABLES & BALANCING WITH HIGH SHARE OF VRE

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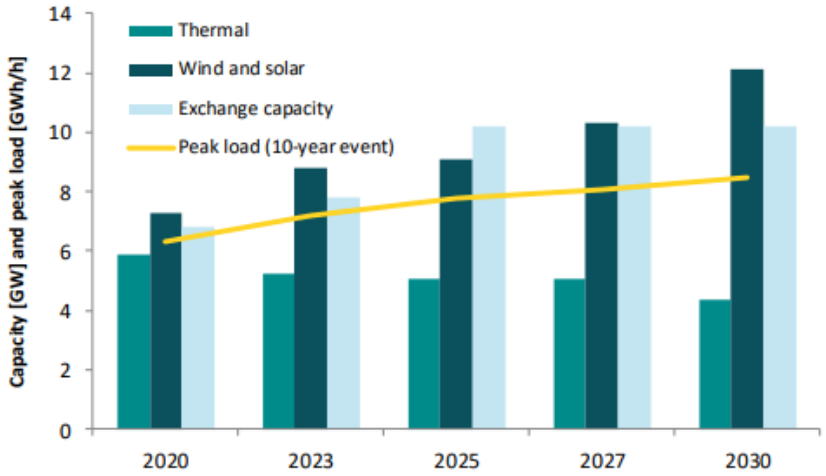
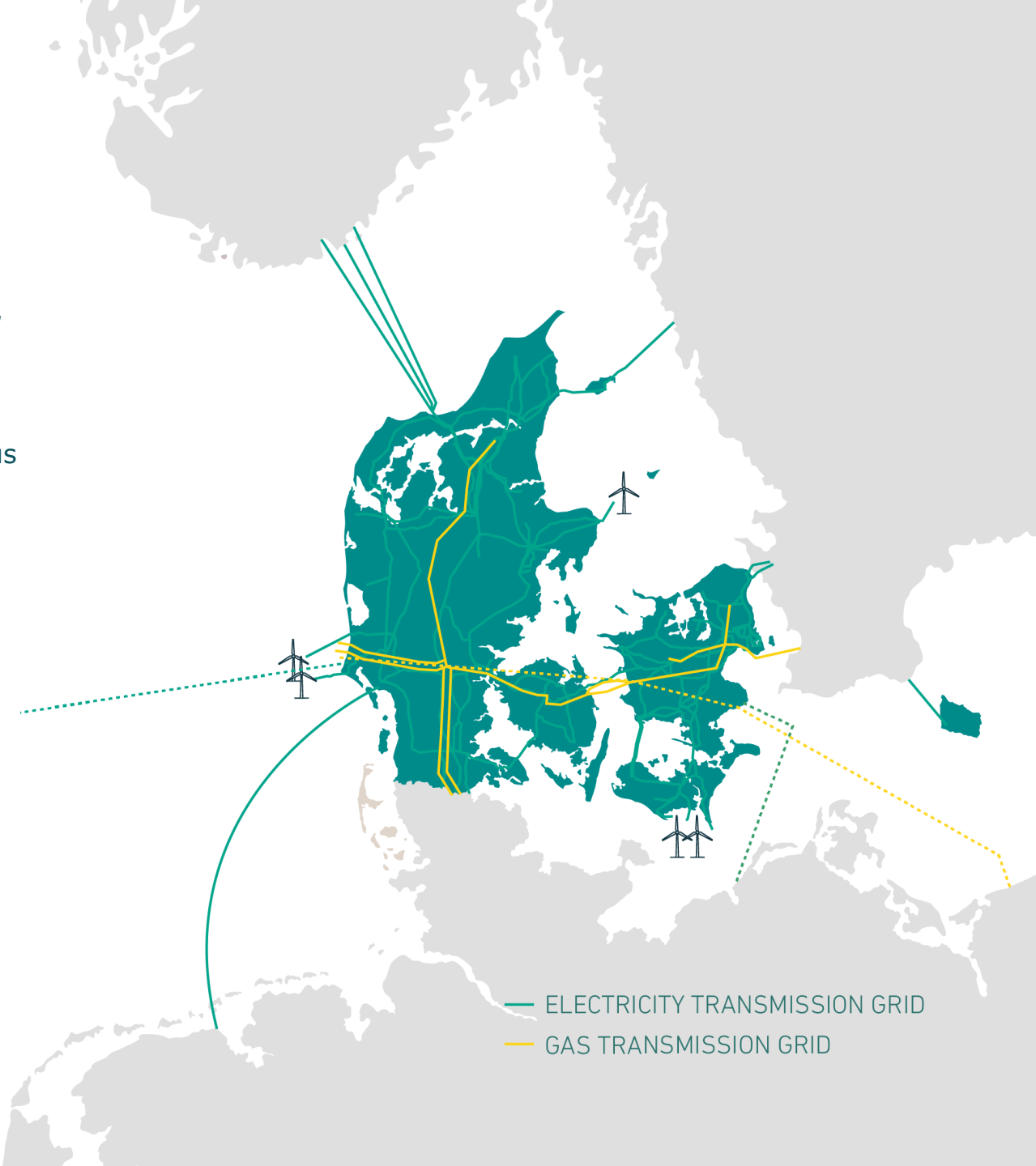
ENERGINET

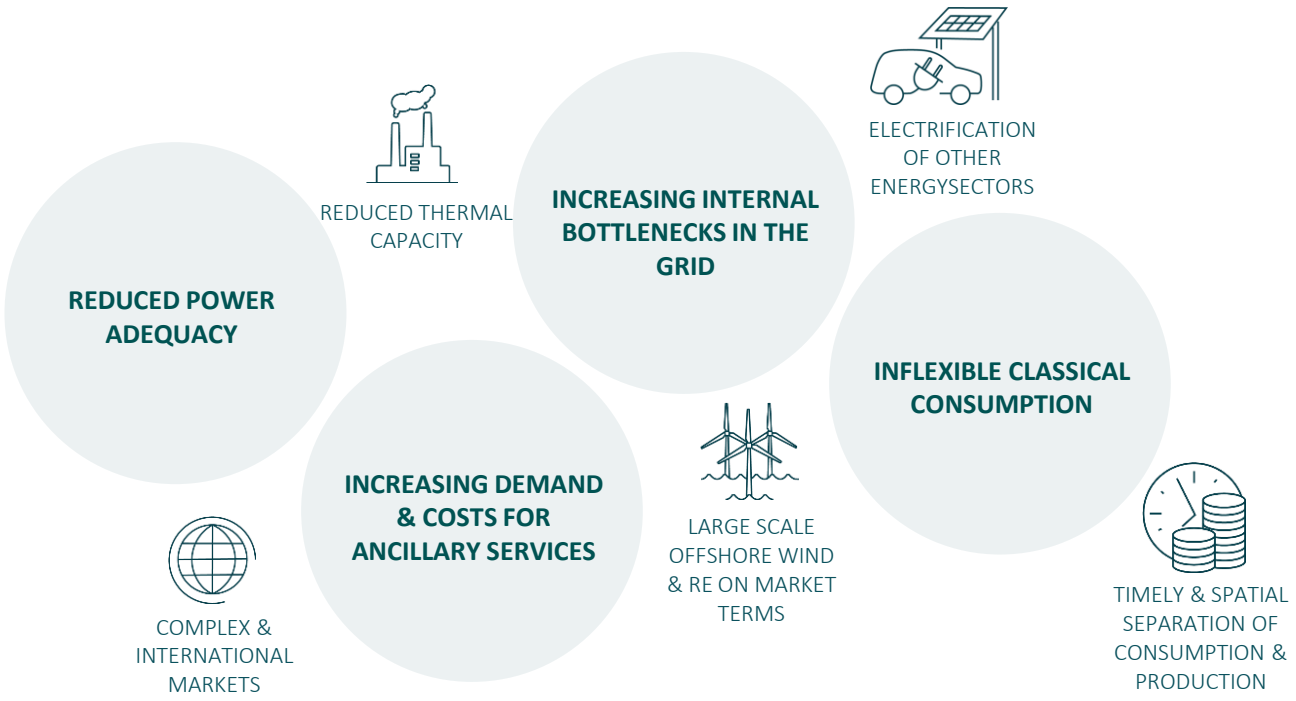
Social Mission: *A renewable energy system with a high level of security of supply and at an affordable price.*

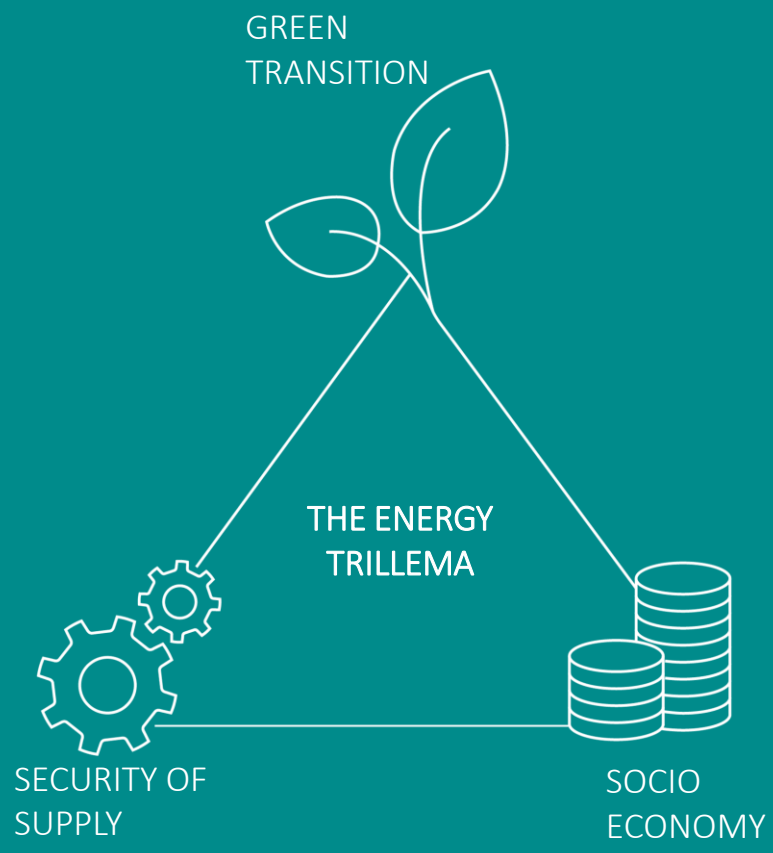
- Balances the Danish electricity system consisting of two synchronous areas (DK1 in Continental Europe and DK2 in the Nordic area) connected through HVDC (600 MW).
- Owns and operates ~7.000 km transmission lines in Denmark.
- Connected to Sweden, Norway, Germany, the Netherlands and soon UK.

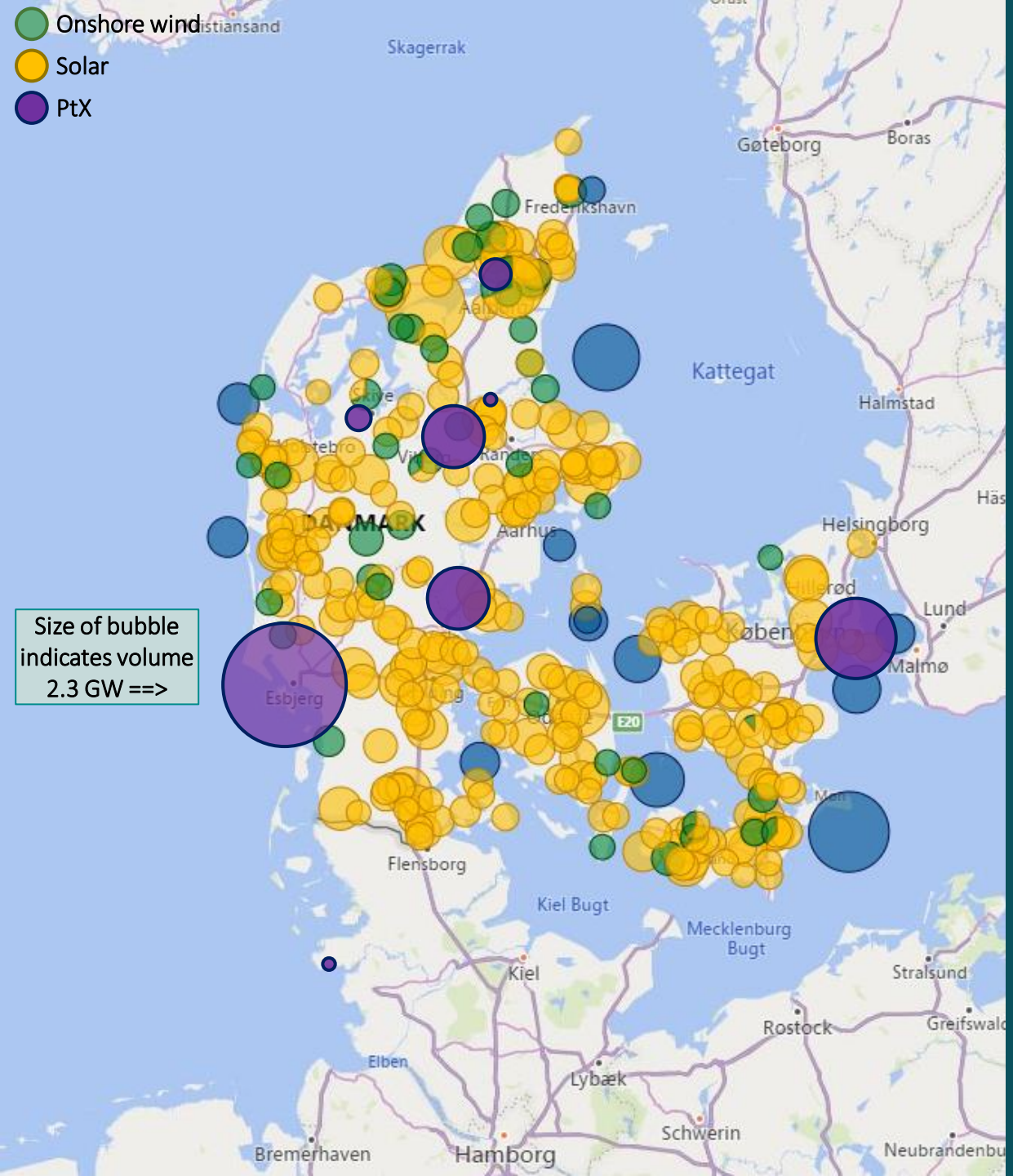




What is the challenge in a 100% RE based electricity system?







RENEWABLE ENERGY PROJECTS IN PIPELINE

Updated: 20-06-2022

The map shows the location of part of the potential onshore wind and solar projects in the RE-pipeline – and active PtX projects.

The map does not include planned and additional potential for offshore wind power and energy islands!

Planned offshore capacity in 2030 is between **5-10 GW**.

The map sums to **31 GW of RE energy**. The 2020 RE capacity was around 6-7 GW. As were peak consumption, interconnector capacity and thermal power capacity.

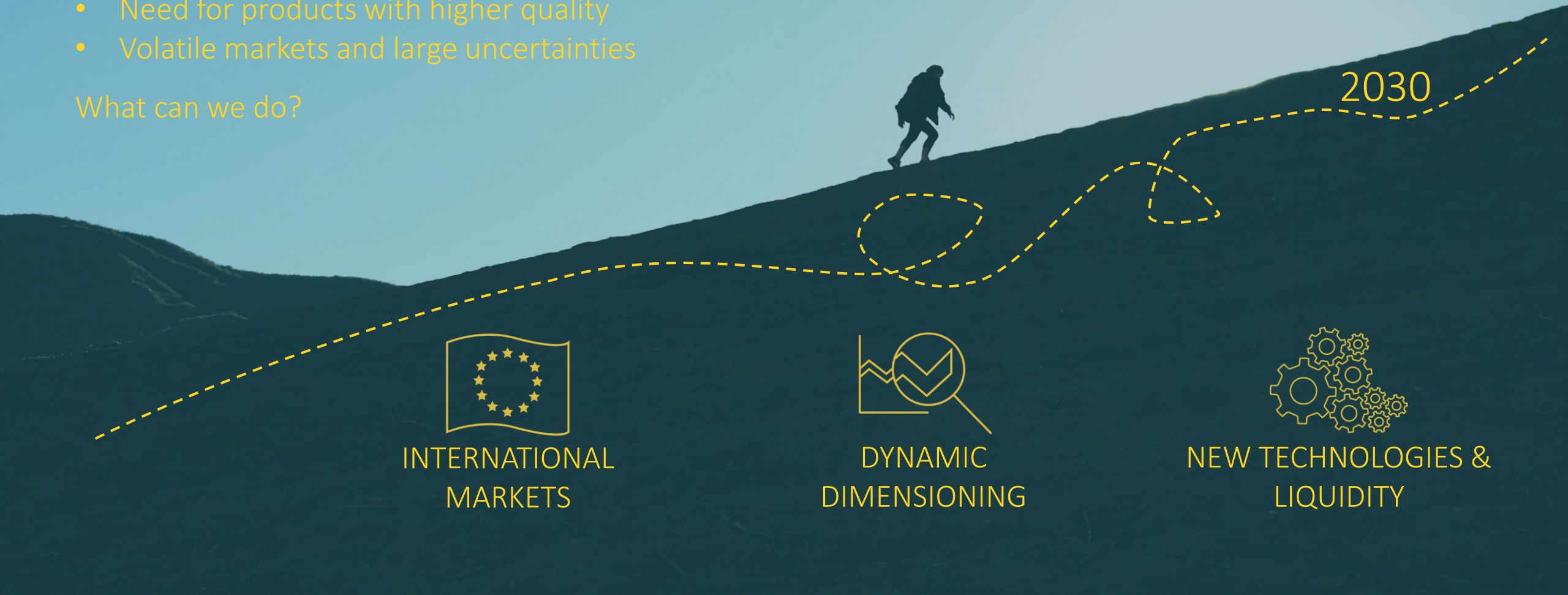
Consumption is expected to increase heavily – e.g., **+7 GW PtX plans**.

Interconnector capacity will also increase, but thermal power capacity is expected to **roughly half** towards 2030.

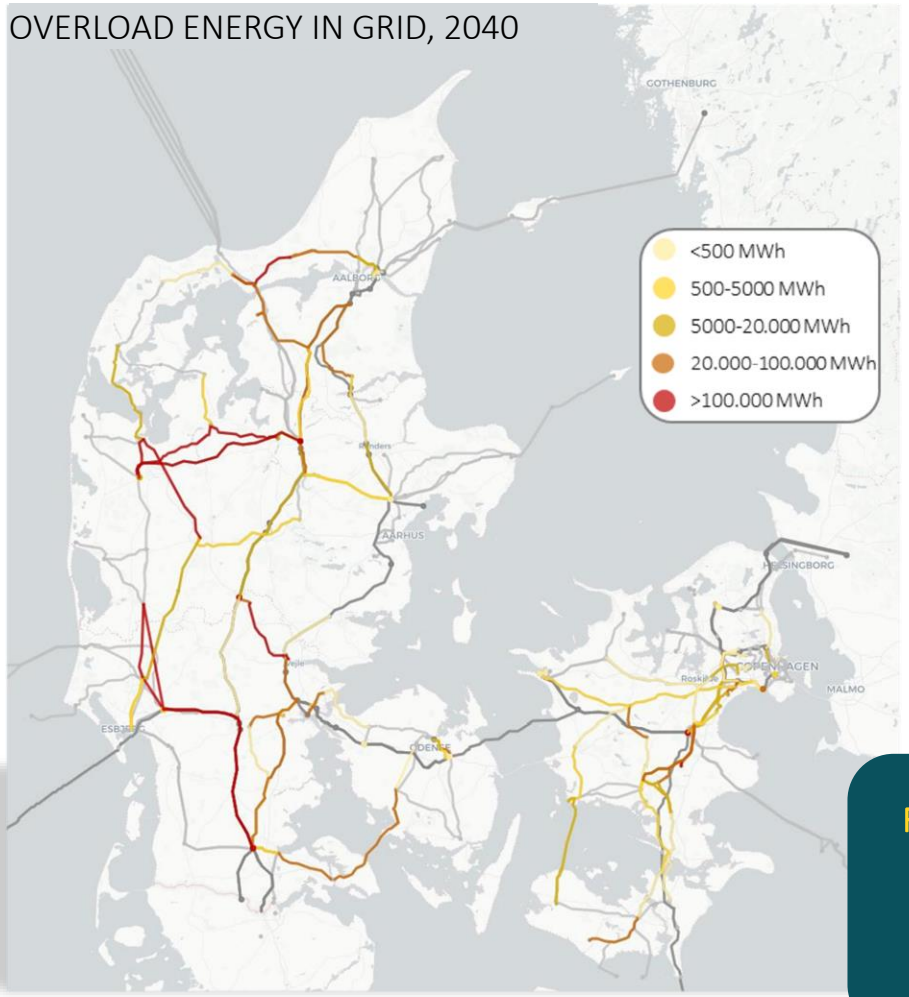
The main challenges when balancing the Danish high-VRE system

- Larger imbalances & bottlenecks
- Larger reference incidents
- Need for products with higher quality
- Volatile markets and large uncertainties

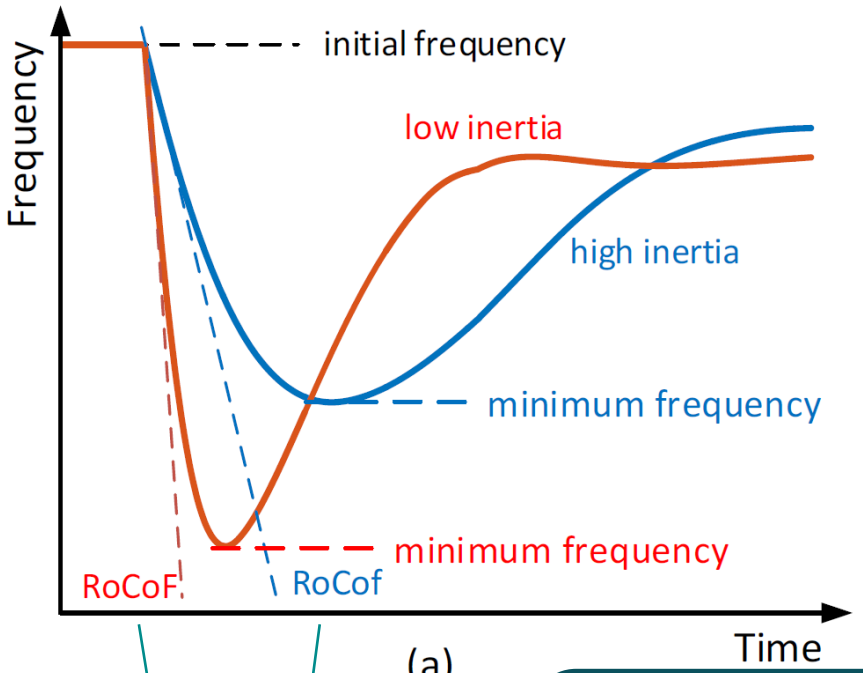
What can we do?



Grid challenges with renewable energy integration



Annual accumulated energy, that will lead to overloading of internal grid components



Rate of Change of Frequency (df/dt)

Renewable energy leads to bottlenecks

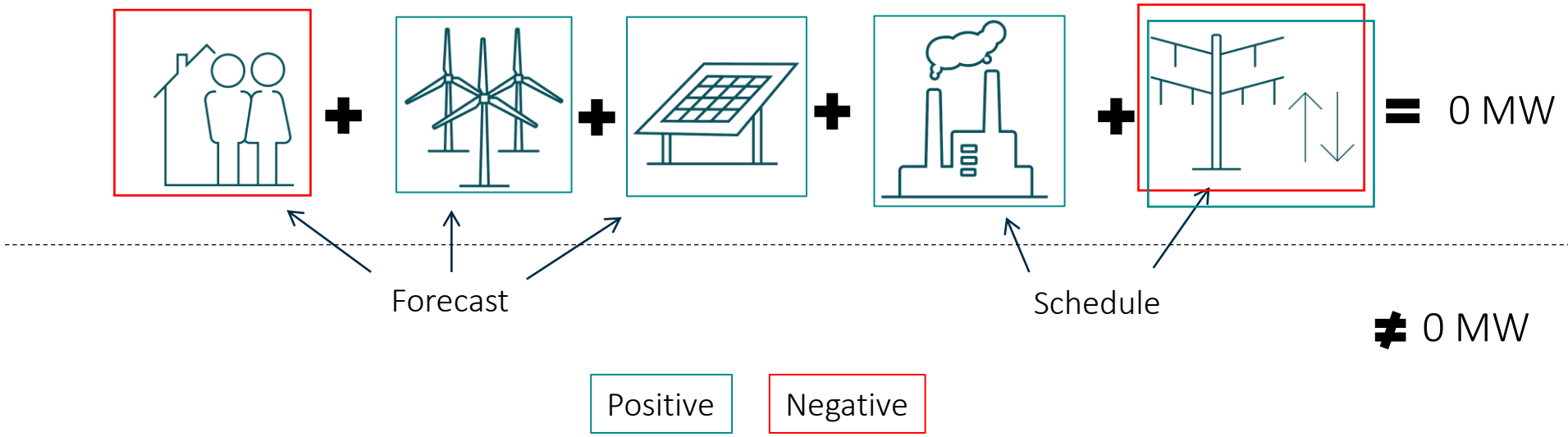
1) Local flexibility
2) Grid expansion

Power electronics leads to weaker grid

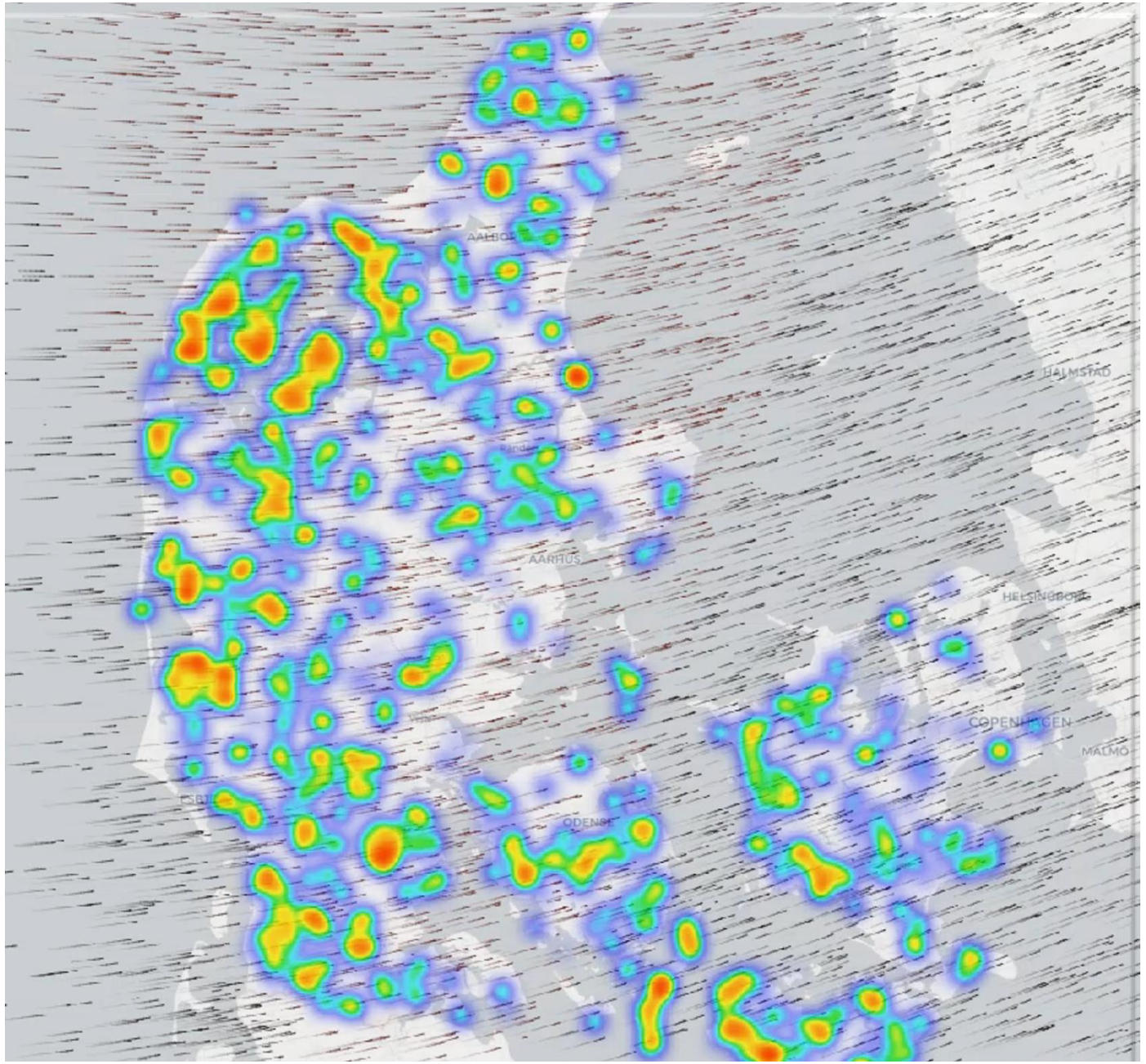
=> Nordic region has implemented Fast Frequency Reserve as synthetic inertia.

FORECAST AND SCHEDULES TO BALANCE THE ELECTRICITY SYSTEM

Forecasting of imbalances to proactively utilize mFRR to maintain balance
Unforeseen imbalances are handled by aFRR. aFRR is replaced by mFRR.



Visualization of the Energinet forecast for onshore wind



Energinet forecasts the total RE production, separated for PV, offshore & onshore wind.

BRPs do the same, but Energinet only requires production plans that indicates the amount of curtailed VRE.

Energinet has also developed micro-forecasts to monitor reserve provision from VRE

[MW]	For 5,3 GW wind (as in 2020)						Scaled to 10,9 GW wind					
	Day-ahead, 2020			Intra-day, 2020			Day-ahead, 2030			Intra-day, 2030		
Quantiles	Offshore	Onshore	Sum	Offshore	Onshore	Sum	Offshore	Onshore	Sum	Offshore	Onshore	Sum
99,5 %	*405*	*609*	*882*	*332*	*311*	*500*	*1636*	*832*	*2167*	*1340*	*425*	*1475*
0,5%	*-315*	*-536*	*-720*	*-219*	*-322*	*-399*	*-1273*	*-733*	*-1705*	*-885*	*-441*	*-1036*

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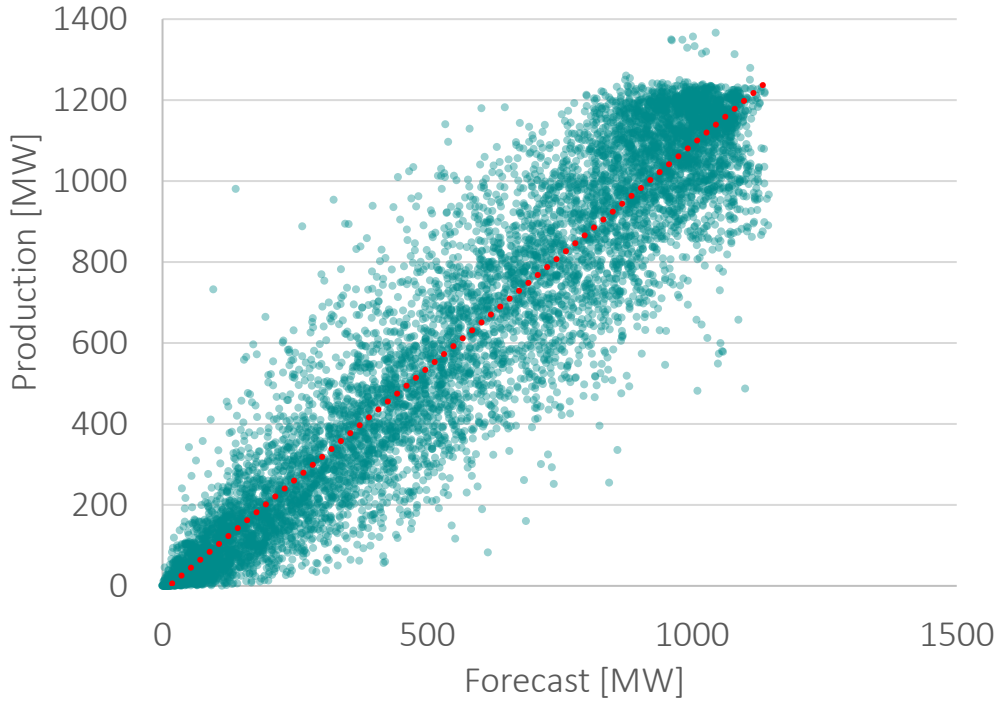
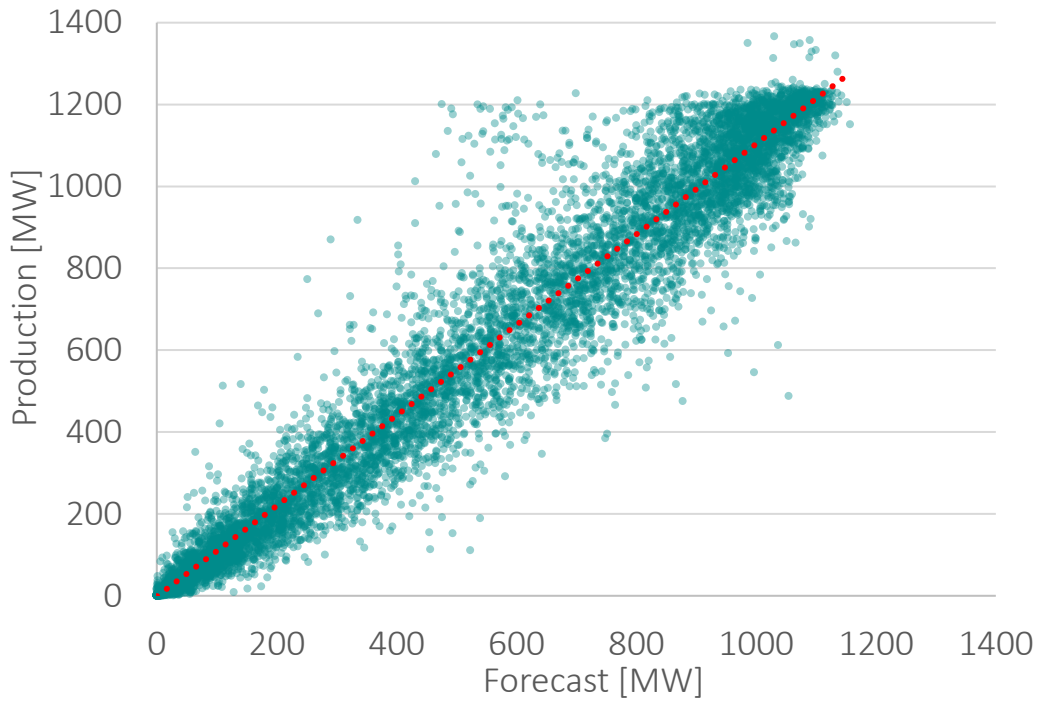
Offshore wind, day-ahead forecast compared to production, DK1



Offshore wind, intra-day forecast compared to production, DK1



Each dot in the graphs represent historical data, where forecasted production is compared to actual production

FORECASTING ERROR VS. ACE OL

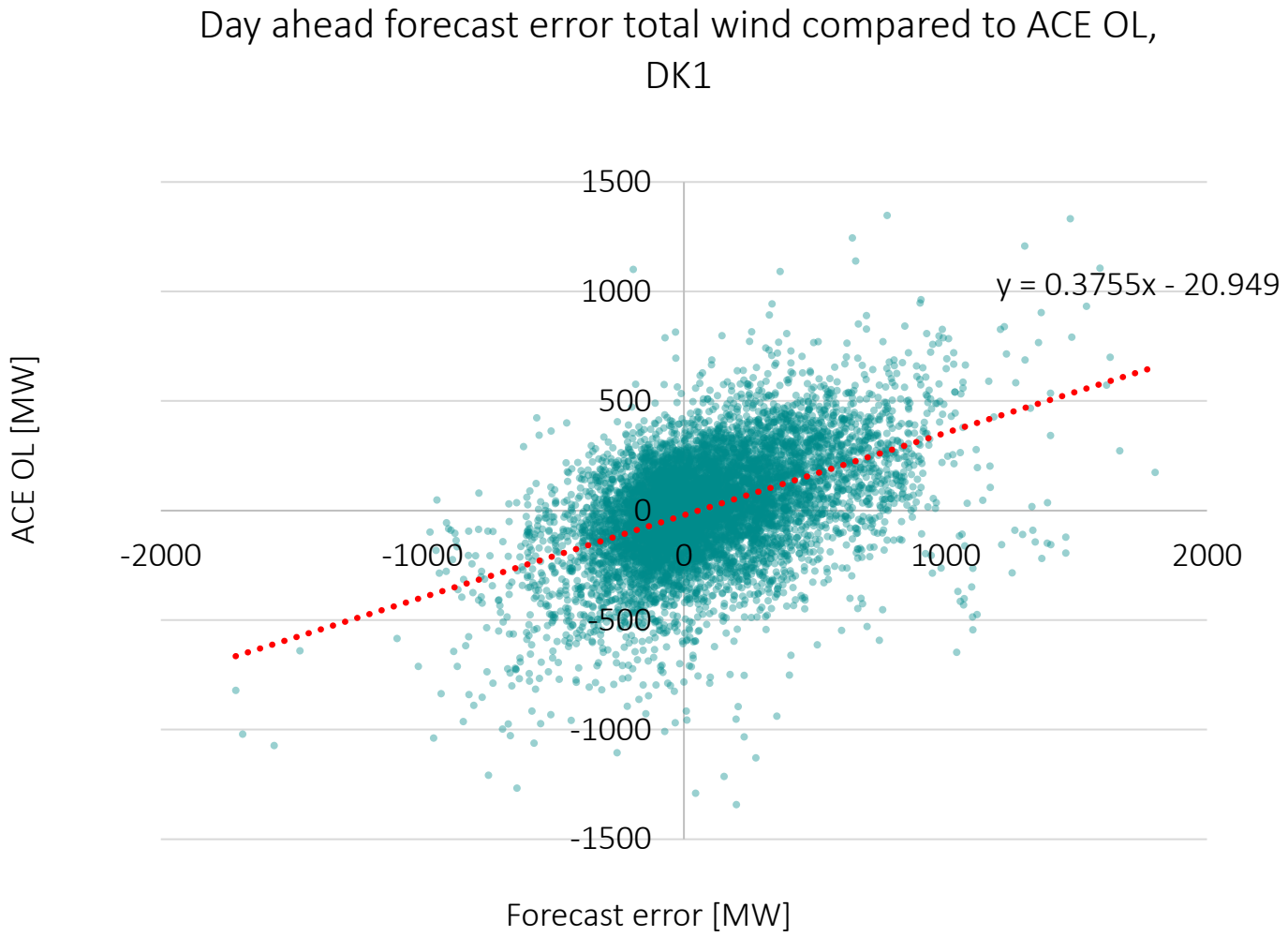
ACE OL = THE UNREGULATED IMBALANCE BEFORE BALANCING ACTIONS BY THE TSO

Correlation between the forecasting error of the total wind portfolio and the total unregulated imbalance in DK1 for 2020. From D-1 forecast.

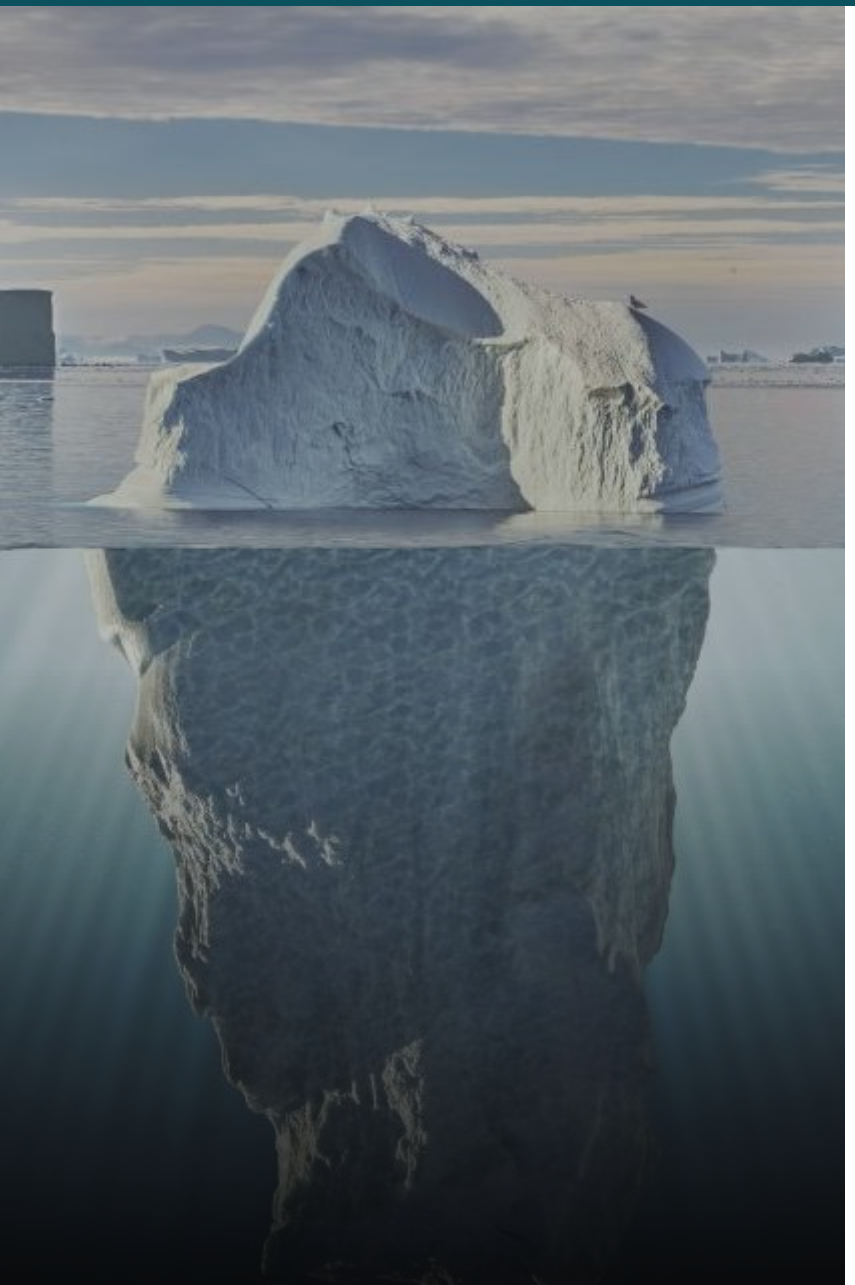
Visible trend. Forecasting errors leads to higher total imbalances.

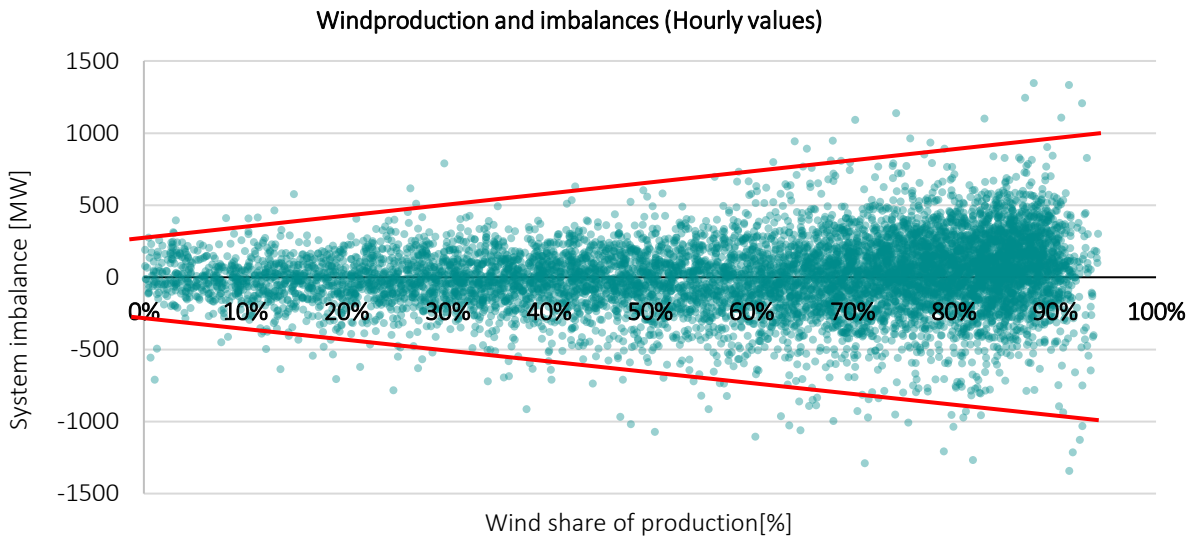
Size of forecasting errors increases with more RE.

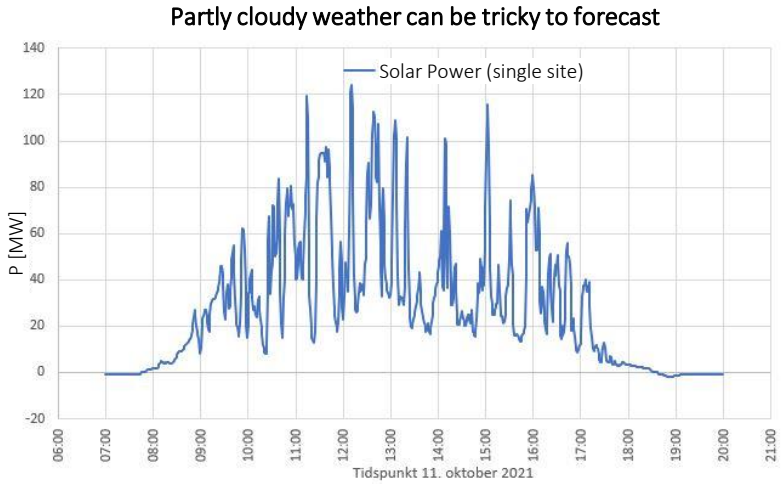
Hence → More RE = Larger imbalances, if nothing else changes.



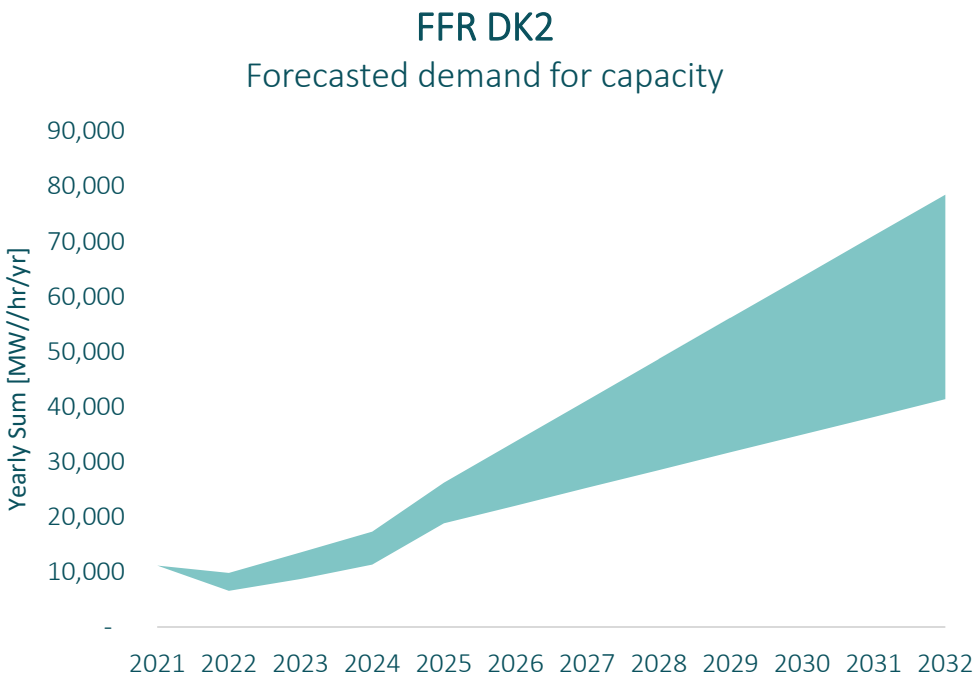
The need for balancing is rising with the share of renewable energy

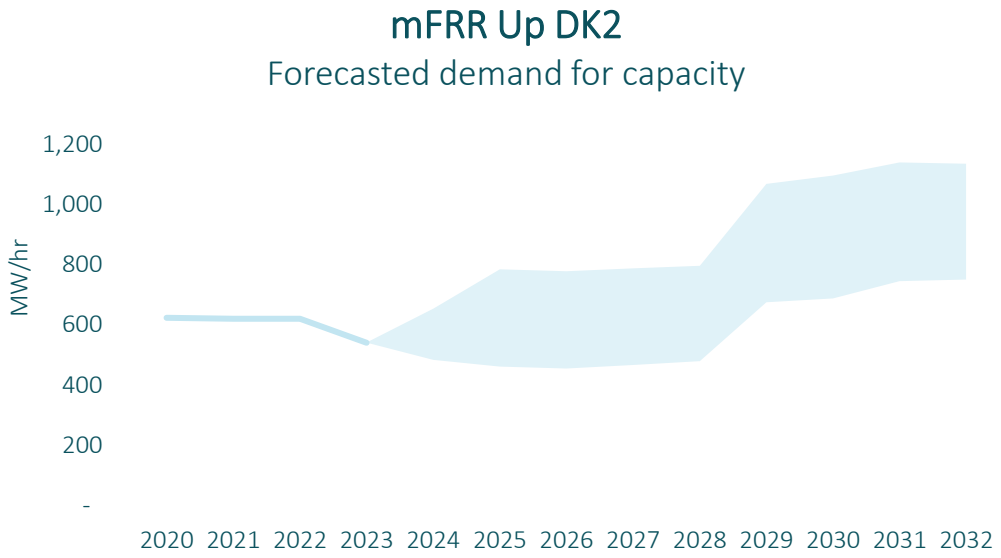






UNCERTAIN DEVELOPMENT FOR THE NEED OF ANCILLARY SERVICES





ANCILLARY SERVICES FROM RENEWABLES AND CONSUMPTION

Renewable energy is simultaneously the problem and the part of the solution

CHANGES IN THE PROVIDER PORTFOLIO

We are going to see two different market behaviors:

High RES => Short term marginal price
Low RES => Long term marginal price

HIGH RES

Renewables
Dominating direction : ↓↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine

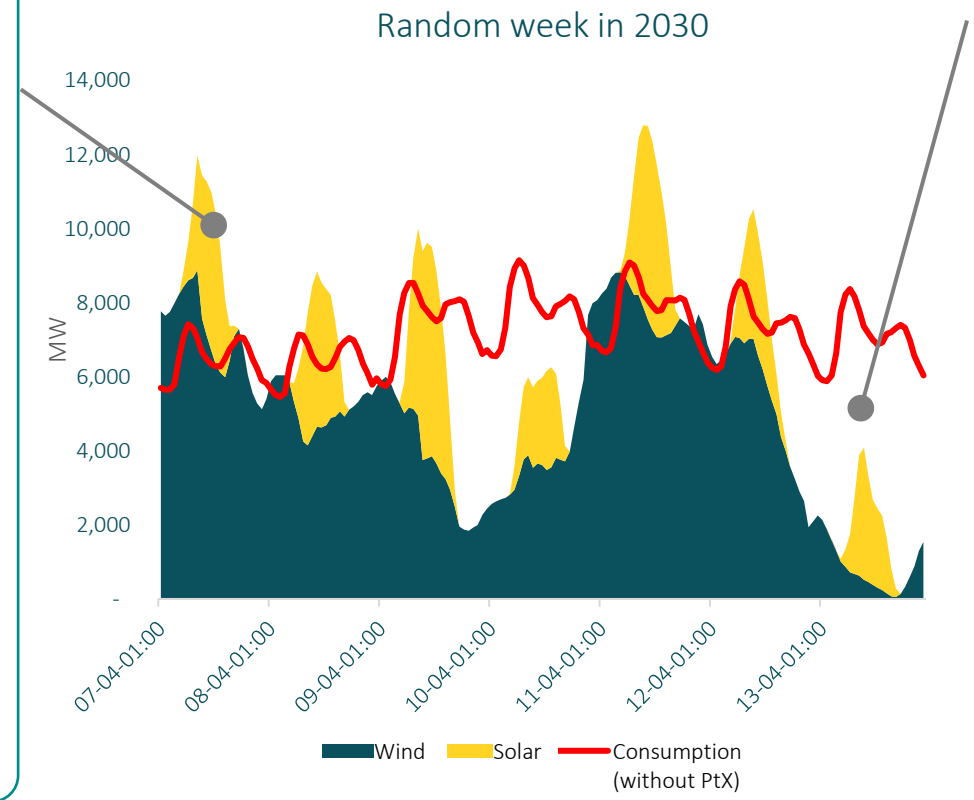
Ptx
Dominating direction: ↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine

Classic consumption (flexible)
Dominating direction: ↑
Frequency services: Fine
aFRR: Limited energy
mFRR: Limited energy

Batteries (discharge)
Dominating direction: ↓
Frequency services: Fine
aFRR: Limited energy
mFRR: Limited energy

Electric boiler
Dominating direction: ↓↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine

Heat pumps
Dominating direction: ↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine



LOW RES

CHP's
Dominating direction : ↓↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine

Heat pumps
Dominating direction : ↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine

Classic consumption (flexible)
Dominating direction : ↑
Frequency services: Fine
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Batteries (discharge)
Dominating direction : ↑
Frequency services: Fine
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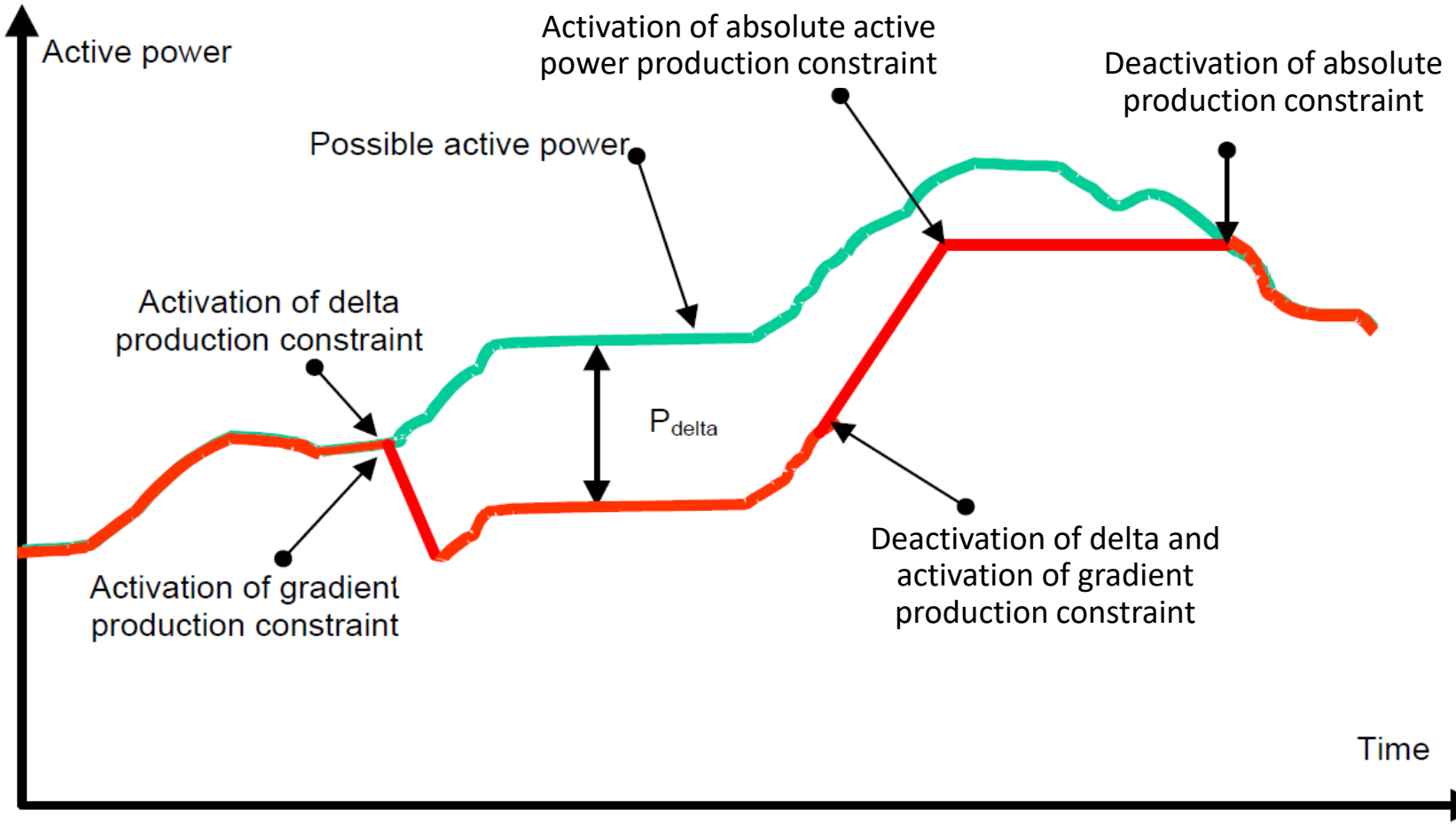
Electric boiler
Dominating direction: ↓
Frequency services: Fine
aFRR: Fine
mFRR: Fine

ACTIVE POWER CONTROL FROM RE

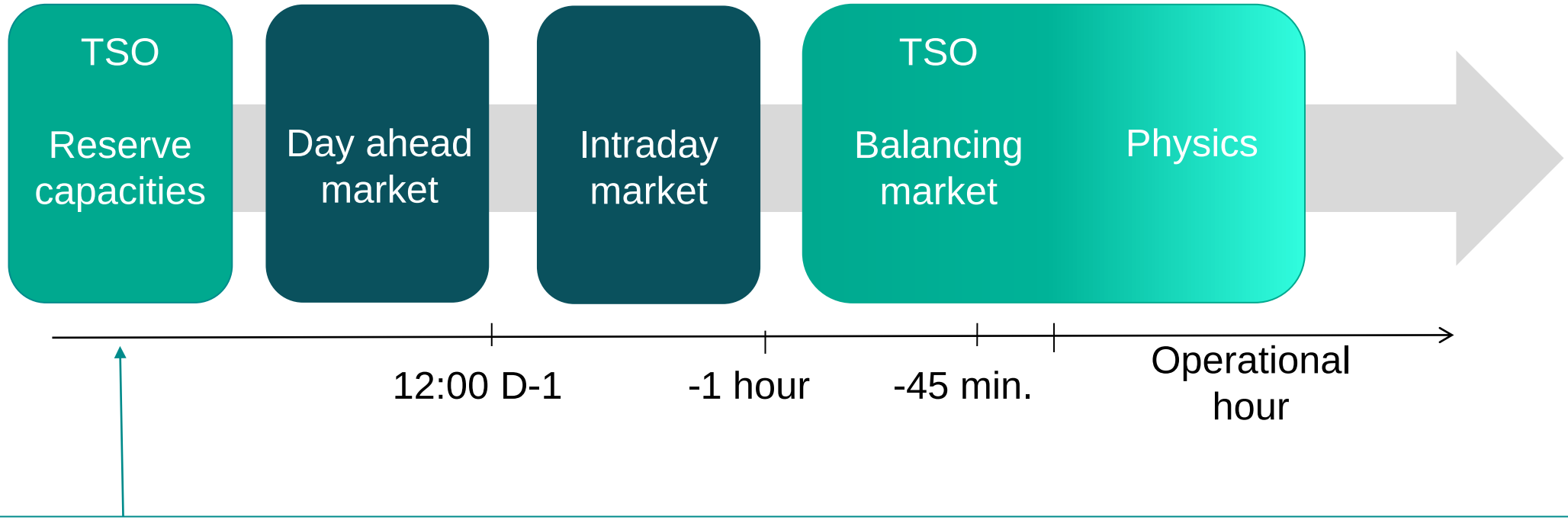


Renewables can provide:

- frequency control
- balancing energy
- synthetic inertia
- Other grid-forming properties

… So how to get them into play?

THE ENERGY AND RESERVE MARKETS



Forecast for day-ahead prices + margin, can be used to set the bidding price for upwards capacity for RE

CAPACITY RESERVES FROM RENEWABLES AND FLEXIBLE DEMAND

Assumptions: Forecasting precision and tools have high enough quality to meet firmness requirements.

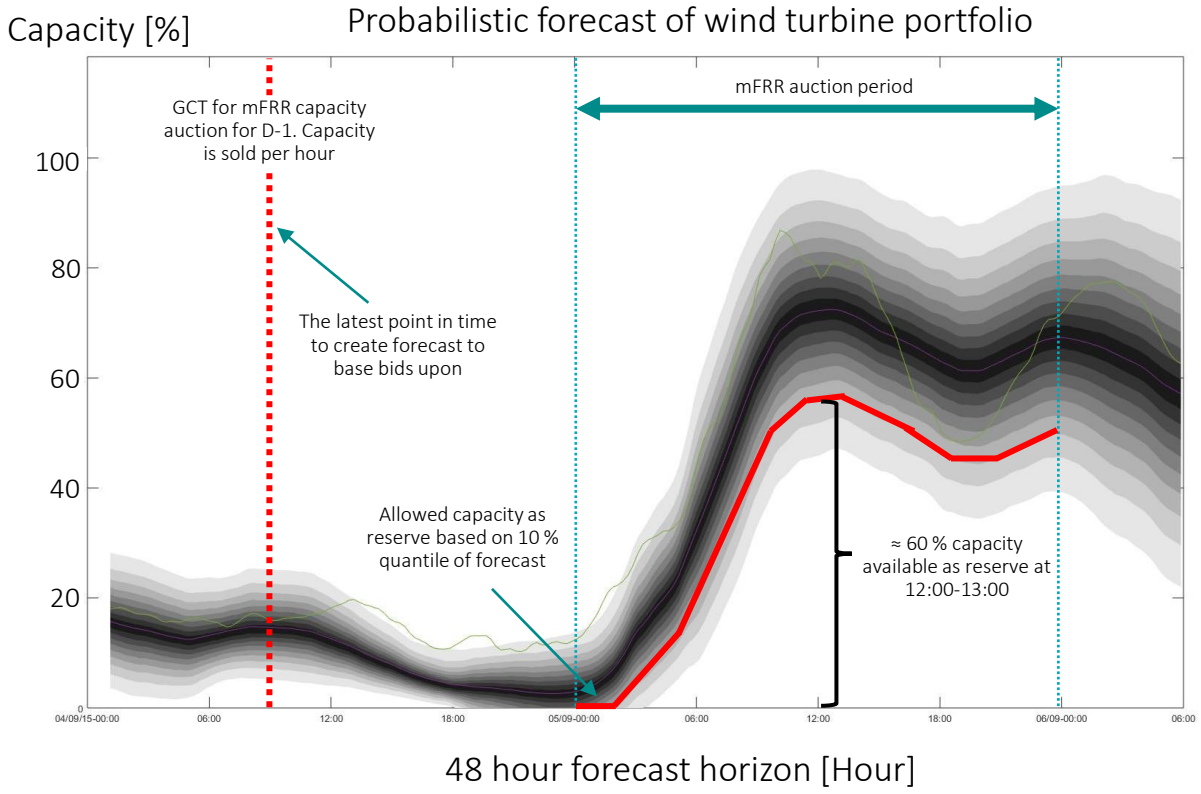
Result: Increased liquidity and better utilization of existing resources.

Method: Precision of forecasting must be proven based on at least 3 months of historical data.

Renewables & Flexible demand will be allowed to bid in capacity equal to the **10 % quantile of a probabilistic forecast**, to ensure that the capacity is available.

The rest can be bid into the energy markets, day-ahead and intra-day from the 10 % quantile and up.

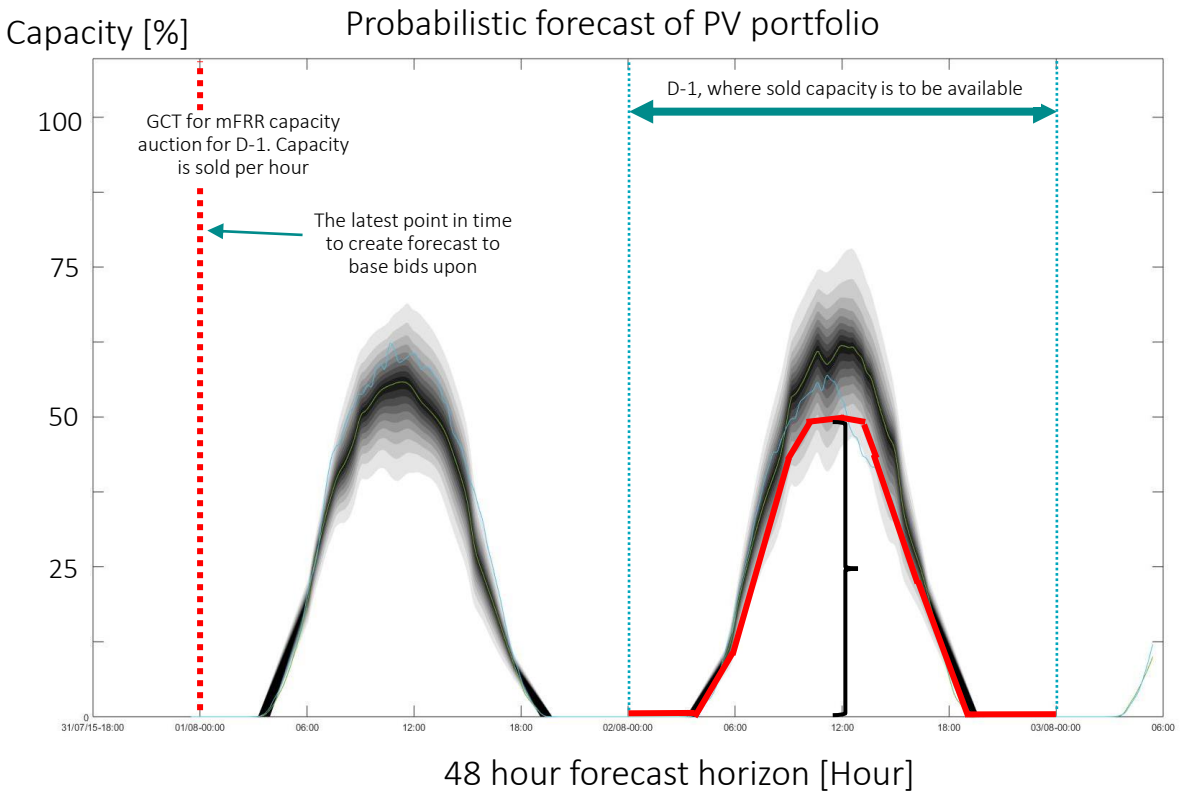
At times with the largest uncertainties the spread is larger, and hence the capacity that can be bid is reduced (to maintain firmness)



The Figure shows the spread of production from a wind turbine portfolio, where every shade represents 5 % quantile.

10 % QUANTILE CAN BE SOLD AS CAPACITY

10 % is chosen to ensure that the full capacity is available (90 % of the time if the forecast is accurate, and slightly less the remaining 10 % of the time).



Similar forecasting precision from a point-based forecast can also be used.

I.e. by implementing a margin ensuring that the sold capacity is available at least 90 % of the time.

MONITORING OF RESPONSE FROM RE

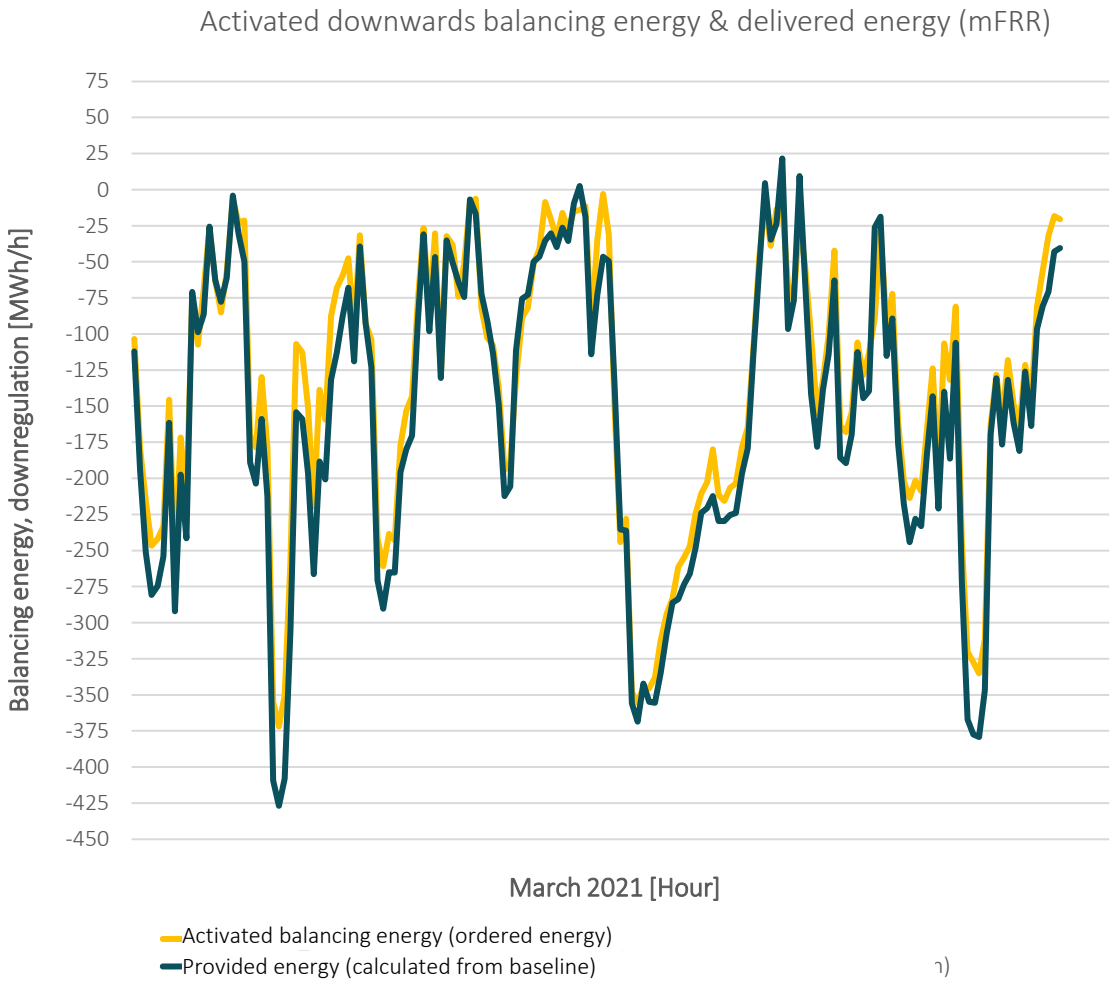
Both RE and non-RE is monitored, and sample testing is performed for periods of interest

The response based upon activations in the reserve or balancing markets are monitored.

For RE Energinet has developed a tool, to estimate provided/delivered energy as the difference between possible power production per turbine and actual production. This is compared to activated/ordered energy.

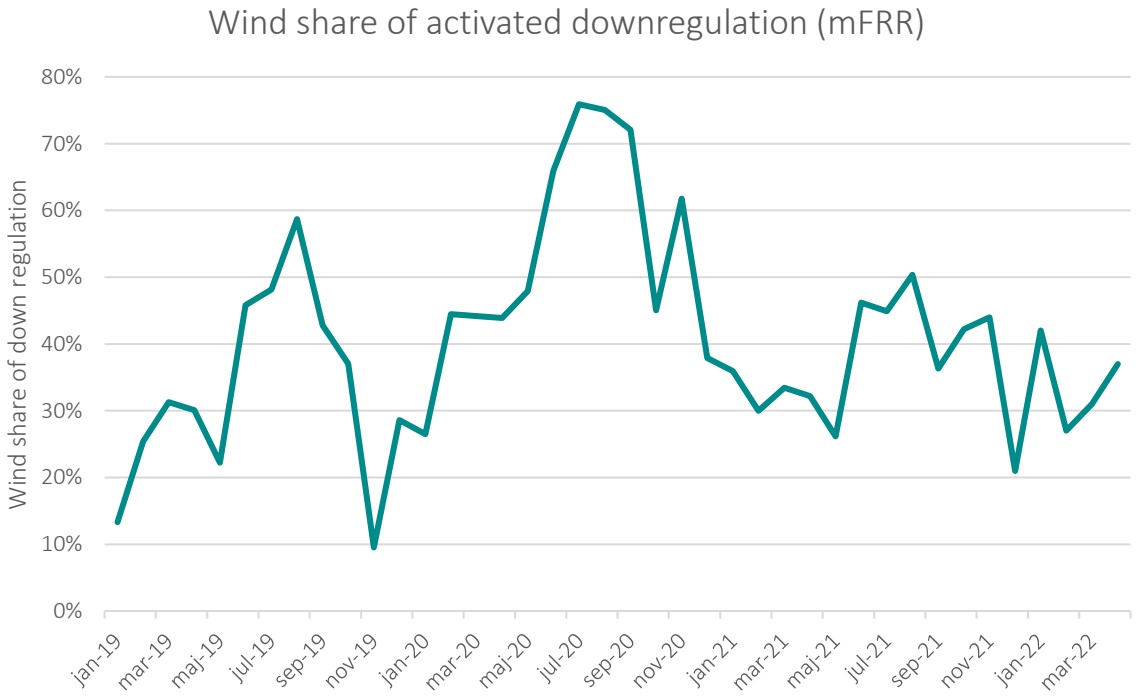
The general performance is very good as shown on the right (for mFRR energy activations).

Similar monitoring is performed for FFR, FCR and aFRR with the relevant resolution, i.e. 1 s for FCR.



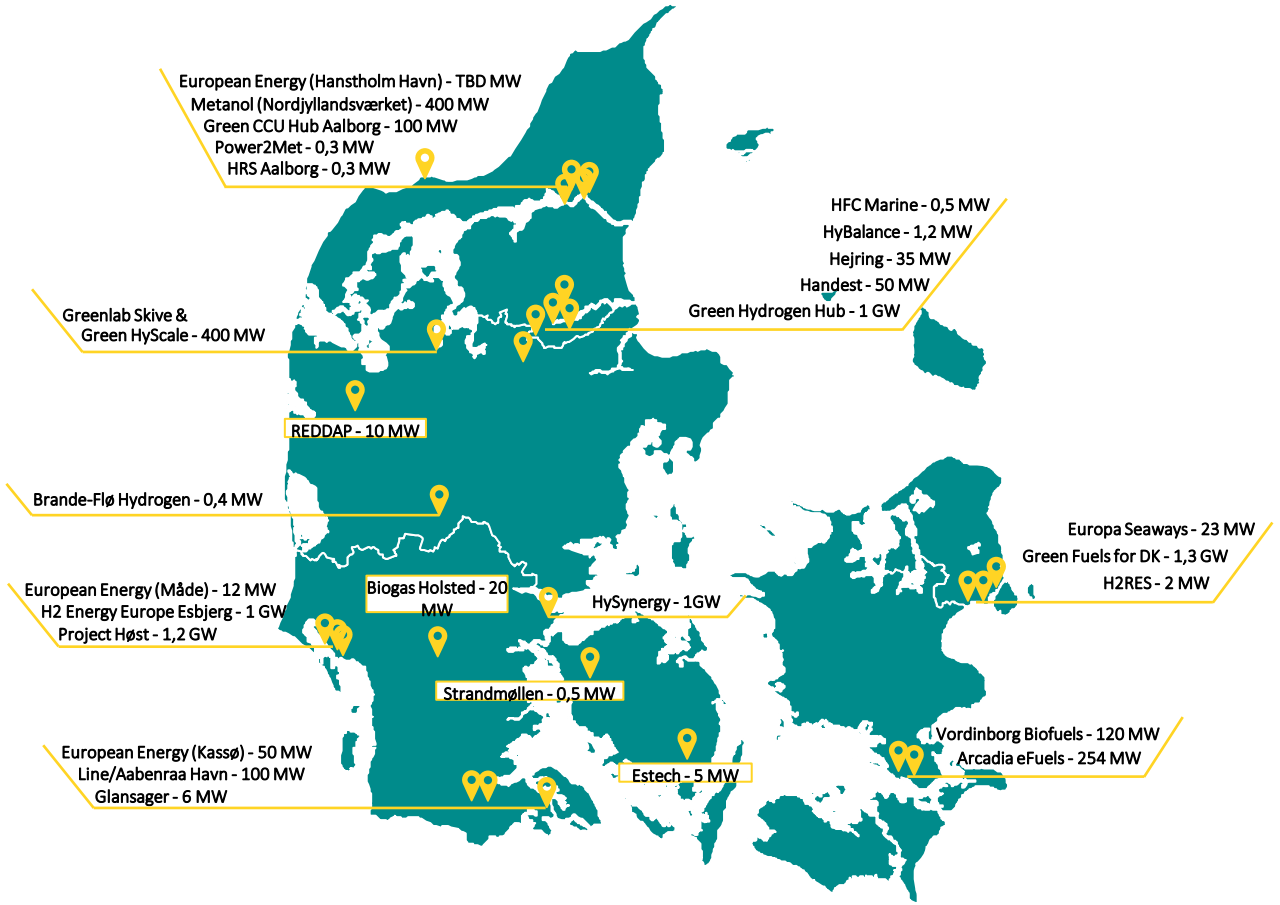
FLEXIBLE WIND - STATUS IN DENMARK

- In Denmark, wind has participated in the balancing market many years.
- Windfarms primarily deliver down regulation.
- We have approved two large offshore windfarms for capacity markets (both up and down) + smaller onshore parks.
- PVs are coming fast!



RAPID INCREASE IN PTX-PROJECTS

Publicly announced electrolysis capacity from PtX projects/visions for 2030 has increased since 2020 from 40 MW to more than ~10 GW!

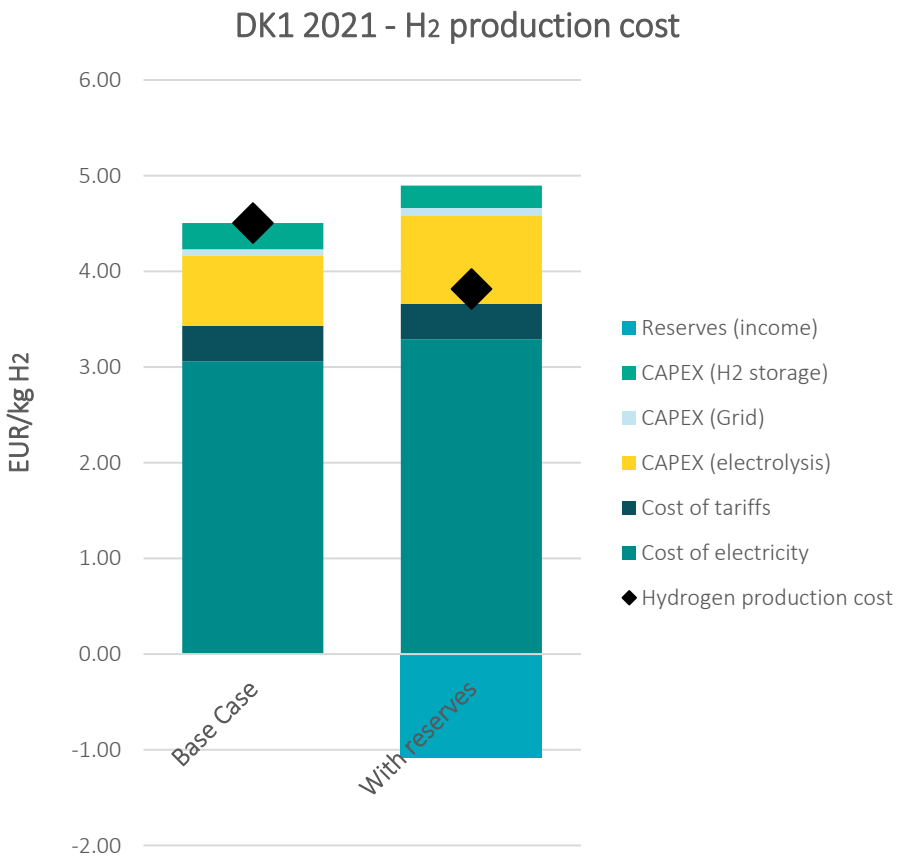


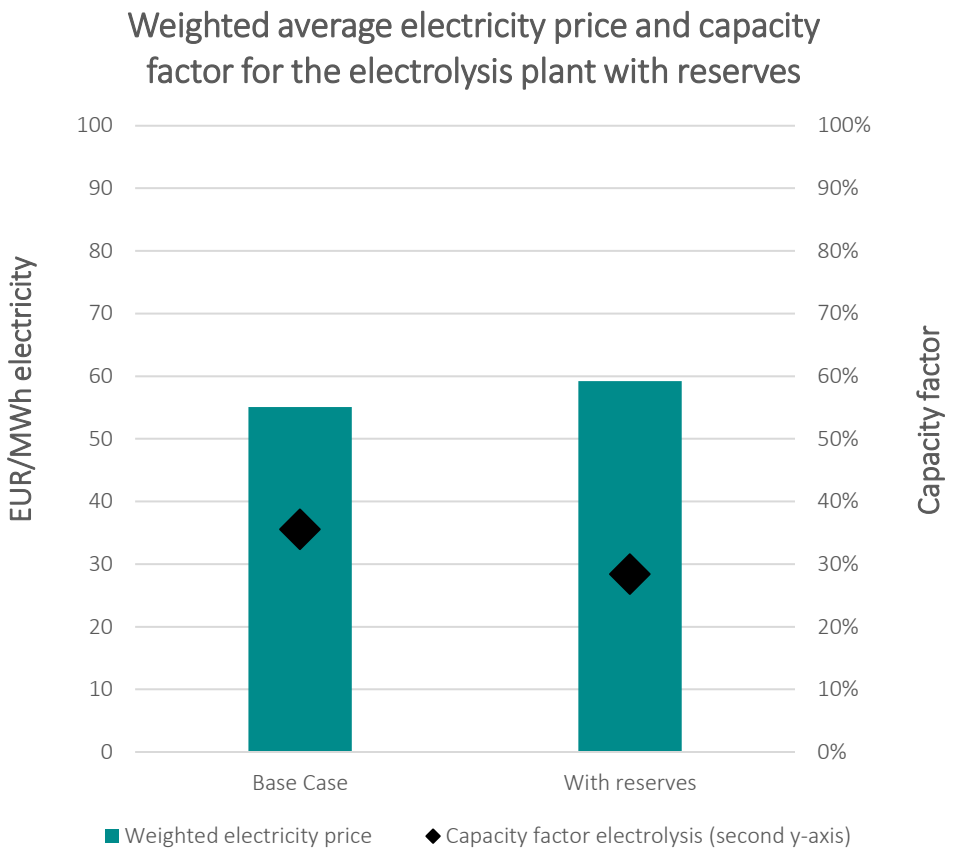
Kilde: https://brintbranchen.dk/danske-brintprojekter/ og offentliggjorte PtX-projekter i danske medier.

Increase in announced electrolysis capacity in 2025 og 2030 from PtX projects/visions

Announced capacity (MW)	In operation in 2025	In operation in 2030
Primo 2019	4	4
Primo 2020	40	40
Primo 2021	400	3.000
Primo 2022	2.500	6.900

The value of flexibility for electrolysis – An optimization based on 2021





Energinet has published a report where the calculations are described, and more examples are given:
https://energinet.dk/El/Systemydelser/Nyheder-om-systemydelser/20221018-Linear-Optimizer-PtX

THE ACTORS IN THE ELECTRICITY MARKET

Energinet actively seeks dialogue (continuously) with many actors in the electricity market, both bilateral & plenum meetings, innovation collaborations & pilots.

epexspot NORD POOL

NEMOs
(stock exchange)

Consumer

Citizen Energy
Communities

Balance responsible party (BRP) /
Balance Service Provider (BSP)

Electricity supplier

Distribution system operator (DSO)

VRE/PtX
developer,
Producer &
OEM

Energinet
Transmission System Operator (TSO)

Nasdaq

Financial exchange

Aggregator

ANCILLARY SERVICES THE TECHNOLOGIES WHO PROVIDE

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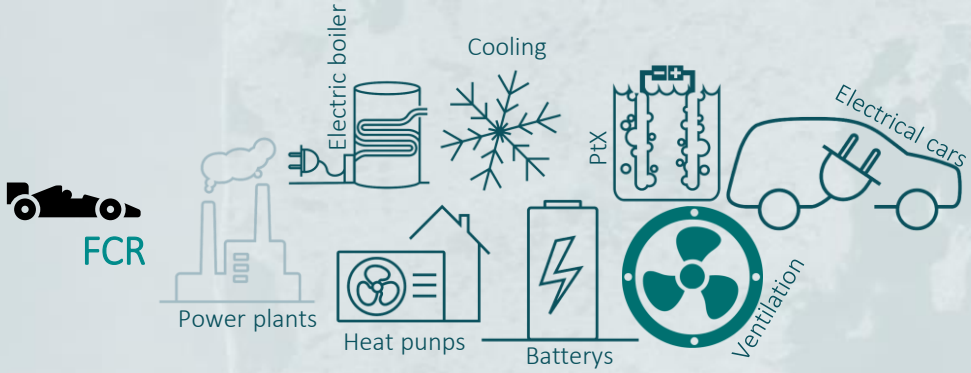
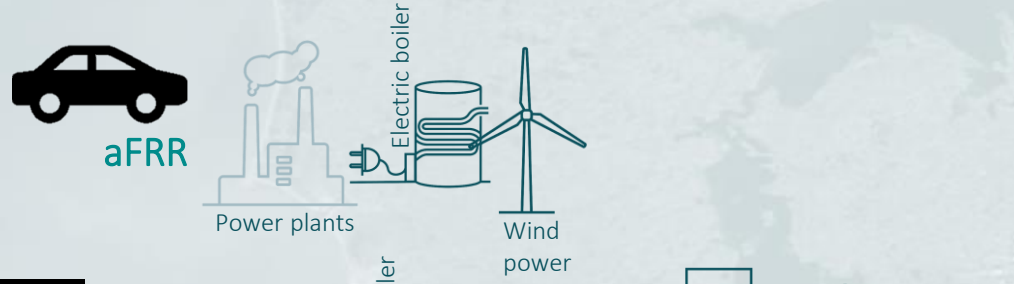
Energinet works to adapt requirements to allow new types of resources to participate in the markets

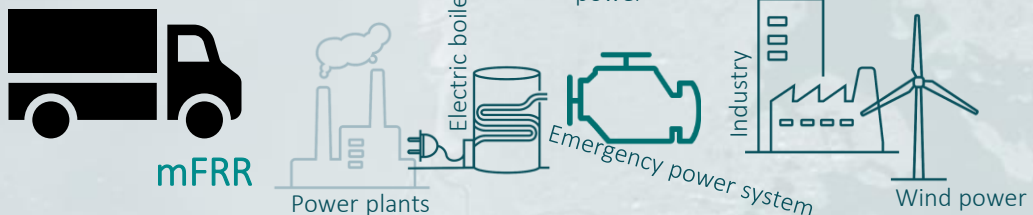
I.e. provision of frequency reserves without a BRP, baseline & forecast requirements

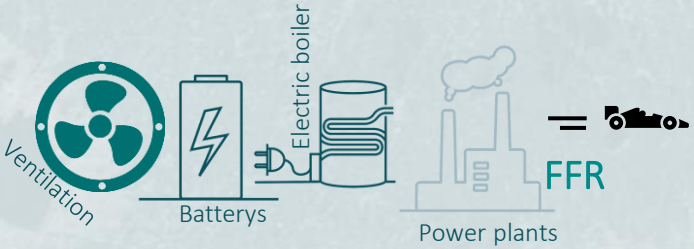
DK1

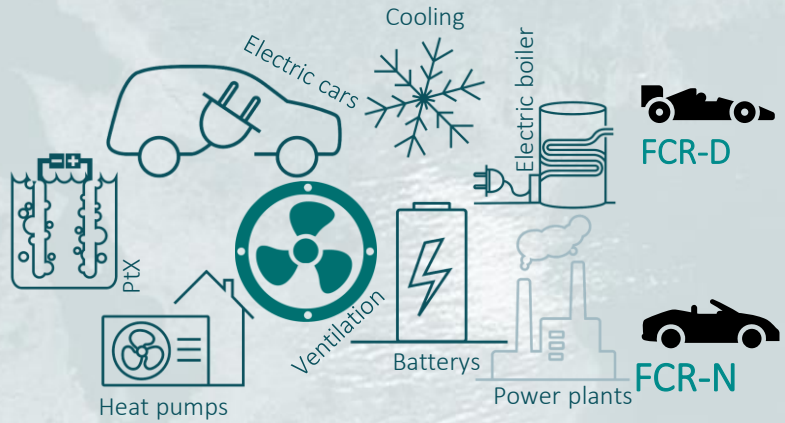
DK2

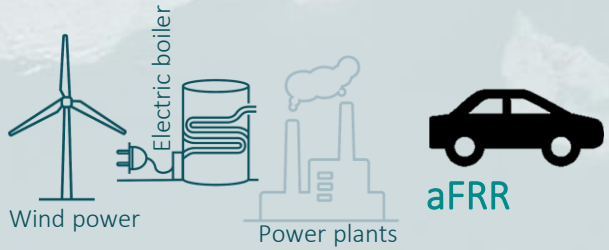










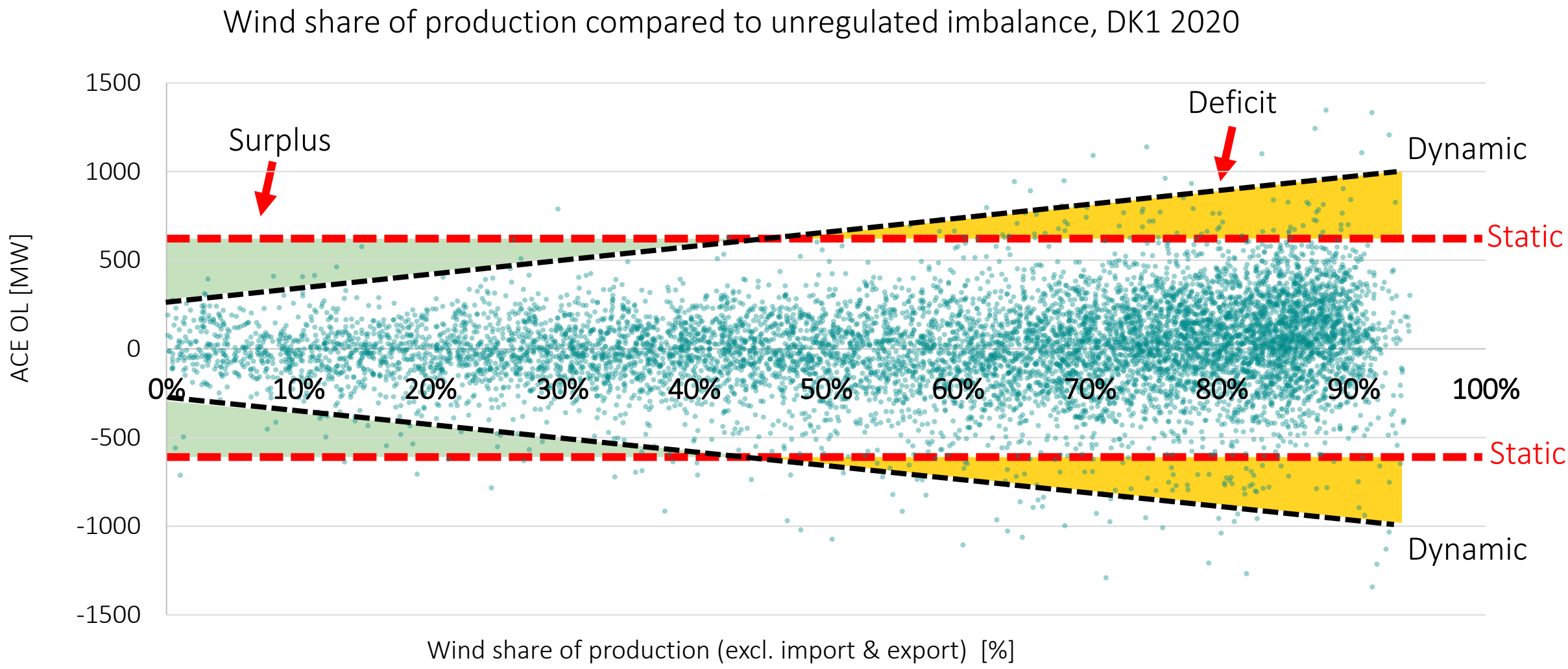


DYNAMIC DIMENSIONING OF BALANCING RESERVES

The operational scenarios will vary much more in the future. Hence, the reserve demand should reflect that

IMBALANCES COMPARED TO HISTORICAL RESERVES

A SIMPLISTIC COMPARISON



WHAT IS DYNAMIC DIMENSIONING?

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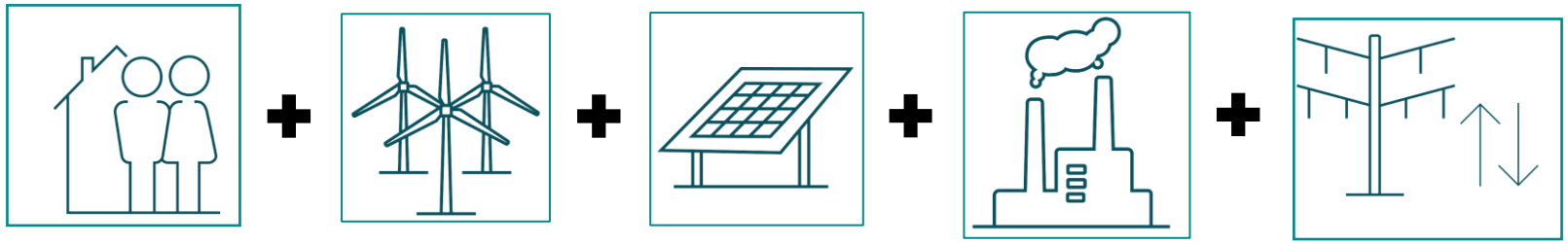
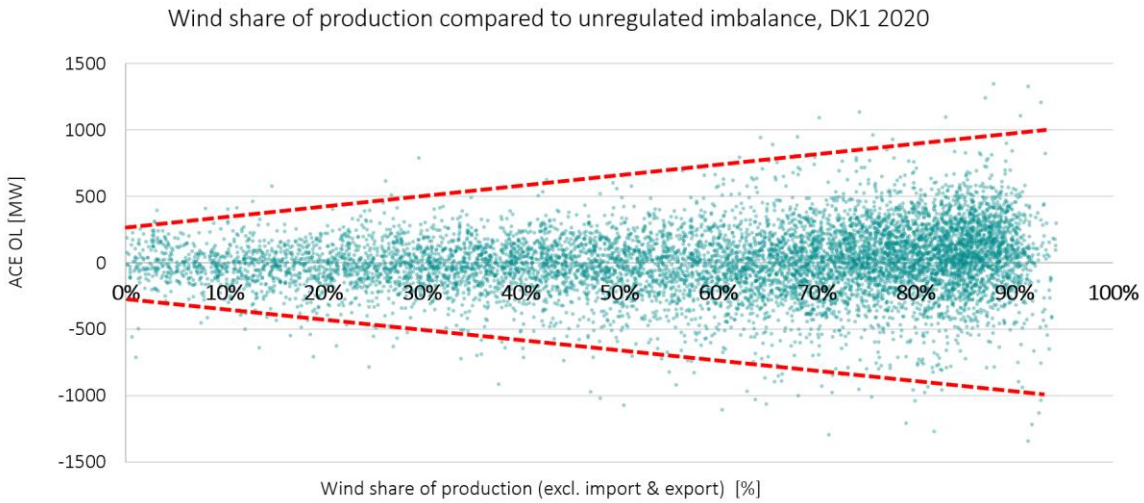


Consumption + Wind prod. + PV prod. + Thermal prod. + Nordic inertia + Tie-line flow

Forecasts of the above – to forecast the below!



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- Voluntary energy bids
- Flow on interconnectors (for sharing)

Instead of relying on distributions based on historical data for the last year

THE PRECISION OF FORECASTING IMBALANCES

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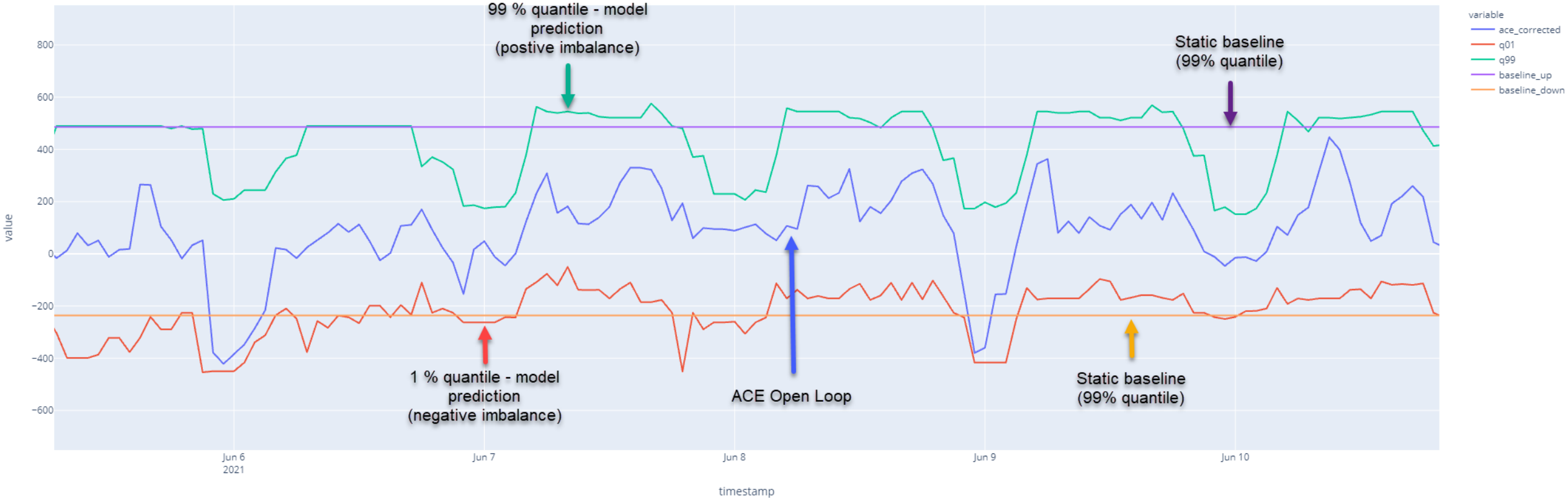
Preliminary results for DK2



Dynamic dimensioning of FRR is forecasting the expected range of imbalances for the coming day.

It is also forecasting of voluntary FRR energy bids and flow on interconnectors, which can reduce the need for buying reserves (we simply get the balancing energy from elsewhere)

RISKBASED PROCUREMENT OF RESERVES

A probabilistic approach