

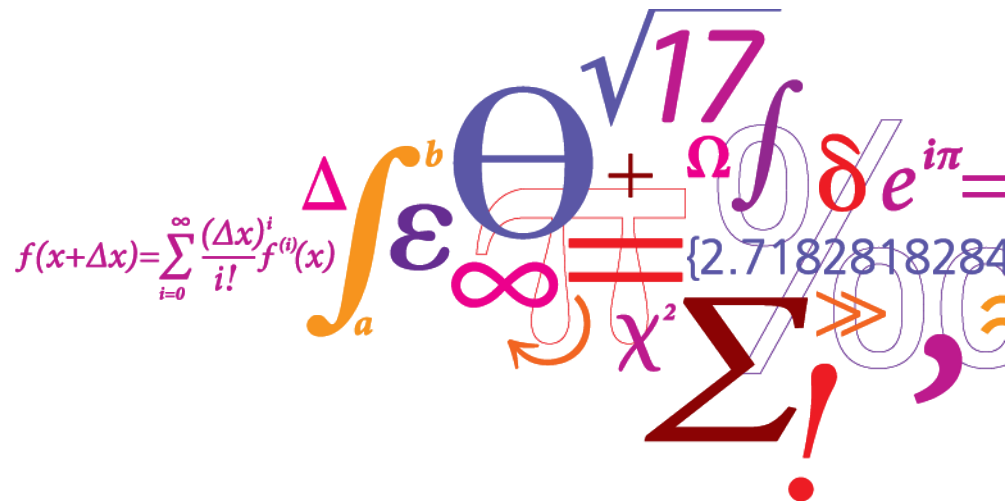
# Market Design for Integrated Energy Systems

## Part I: Preliminaries

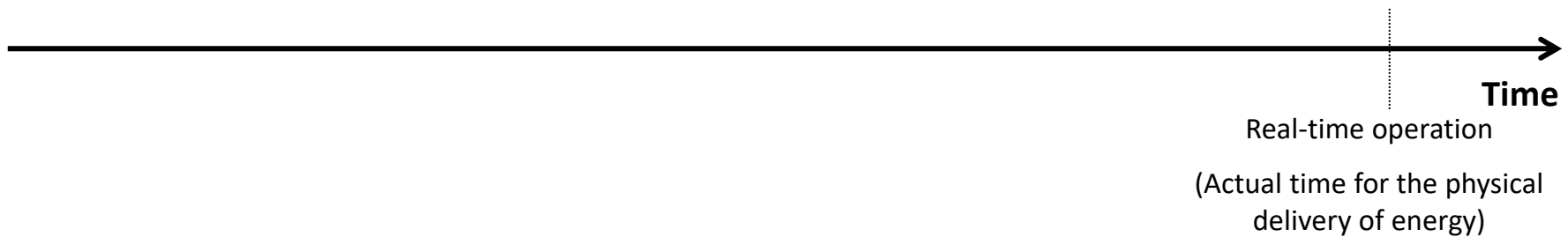
Jalal Kazempour

June 24, 2022

DTU Summer School 2022

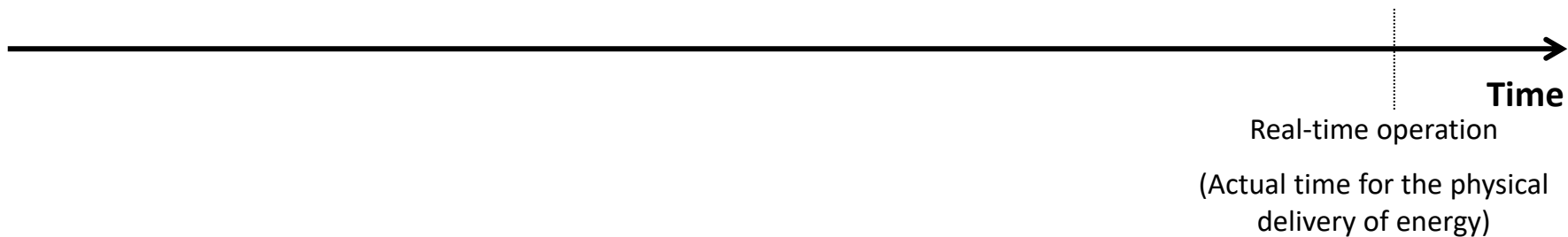
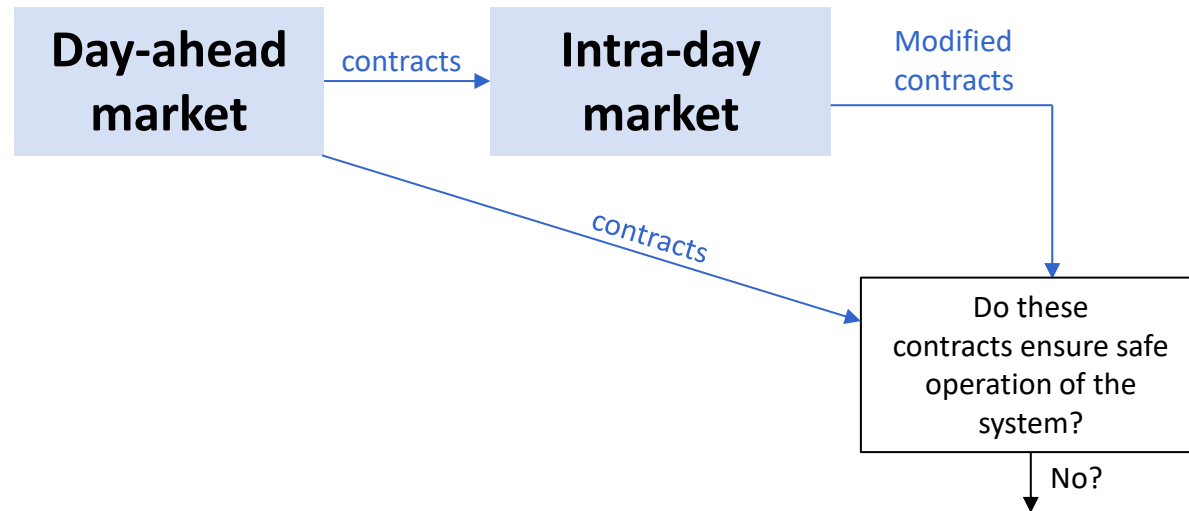


# From market to operation



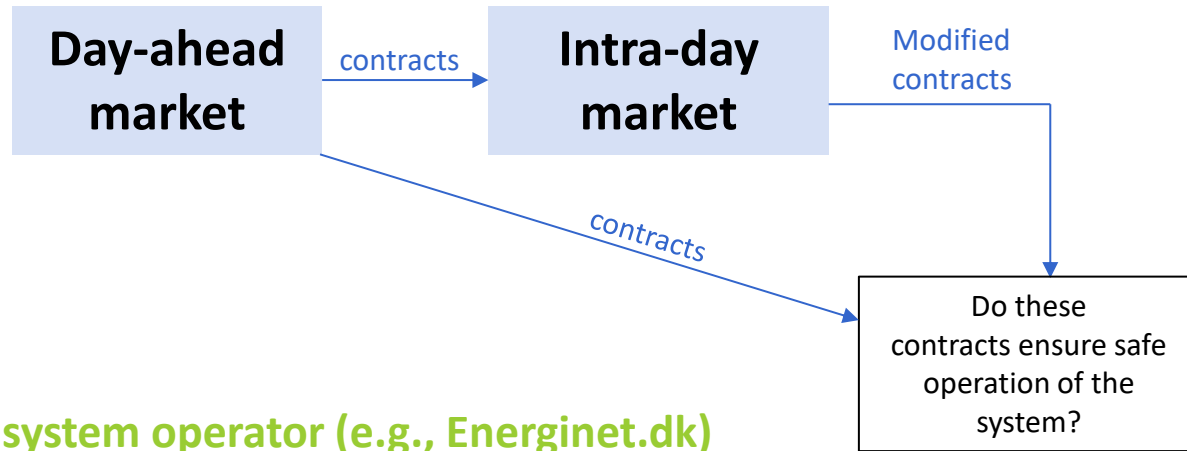
# From market to operation

By the market operator (e.g., Nord Pool)

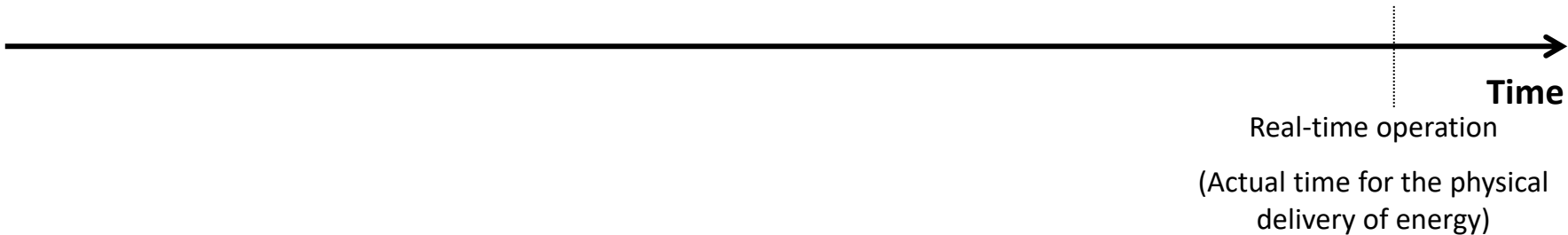


# From market to operation

By the market operator (e.g., Nord Pool)



By the transmission system operator (e.g., Energinet.dk)



# European vs U.S. electricity markets

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Common practice in Europe

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Transmission network is modeled in a **simplistic** way (zonal representation) within the day-ahead (and intra-day) market-clearing problem.



The **bidding zone** configuration in Europe in September 2020.

Source: <https://fsr.eui.eu/electricity-markets-in-the-eu/>

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Market actors, e.g., power producers, are **responsible** to ensure their offers/bids respect their technical constraints (e.g., ramp limits, minimum production limit and minimum up/down time limits of conventional generators).

- Market actors internalize their technical limits within their own offers/bids.
- They offer/bid for their whole portfolio (not per asset)
- **Complex orders** (bids and offers), while comparatively simple market-clearing problem.

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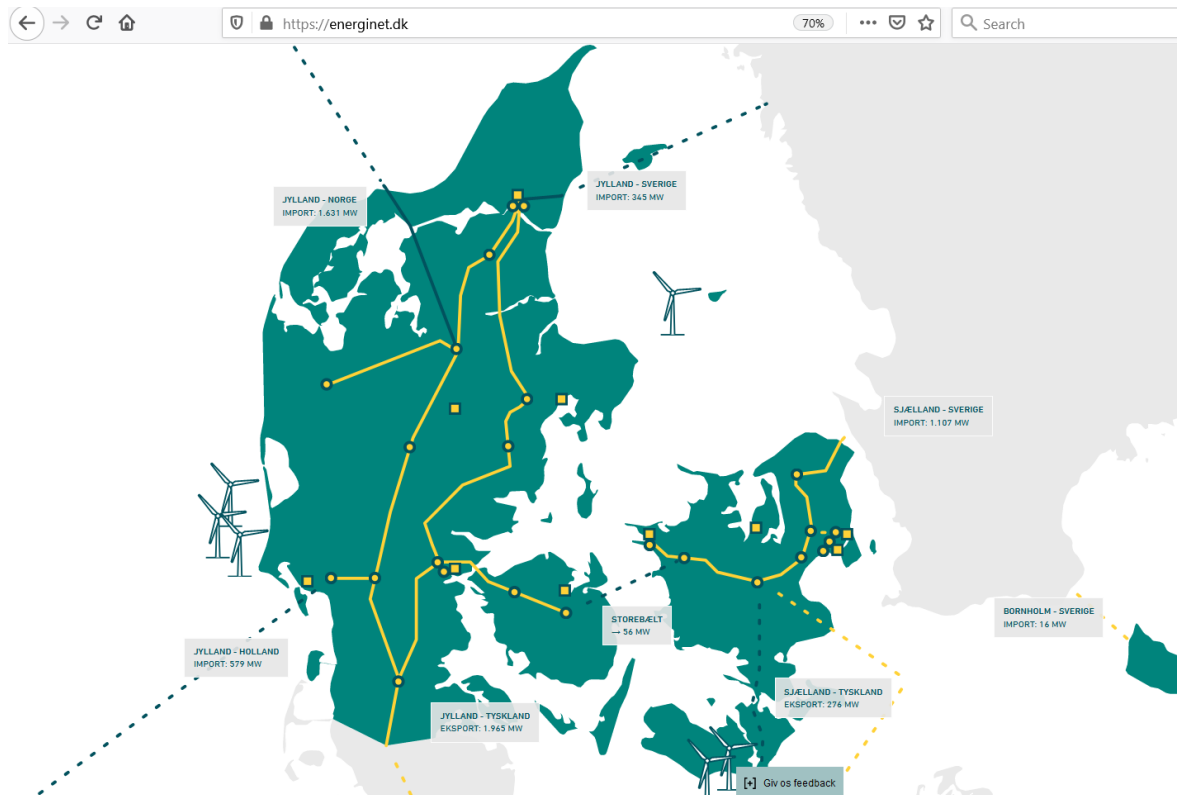
Market actors, e.g., power producers, **submit** to the market their all technical constraints (e.g., ramp limits, minimum production limit and minimum up/down time limits of conventional generators).

- Market-clearing problem becomes a unit commitment problem with on/off (0/1 binary) variables
- Pricing challenges due to binary variables (non-convexities); not to be discussed in this course
- **Complex market-clearing problem**, while comparatively simple bids/offers.

# Overview: Ancillary services

# Ancillary services

These services are necessary for the transmission system operator (TSO), e.g., Energinet in Denmark, to reliably operate the power system!



A snapshot of the Danish power system operation on the 28<sup>th</sup> of February 2021, 6:55pm ([www.energinet.dk](http://www.energinet.dk))

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- In the rest of this lecture, we will use “**ancillary services**” and “**flexibility services**”, interchangeably (though in general “ancillary services” is a boarder term including more products like voltage-supporting services)!

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## Flexibility (a.k.a. Operational Flexibility):

The capability of a power producer (consumer) to modify its production (consumption) level or state in response to an activation signal [1]

[1] Zhao J., Zheng T., and Litvinov E. A unified framework for defining and measuring flexibility in power system. *IEEE Transactions on Power Systems*, 2016;31(1):339–47.

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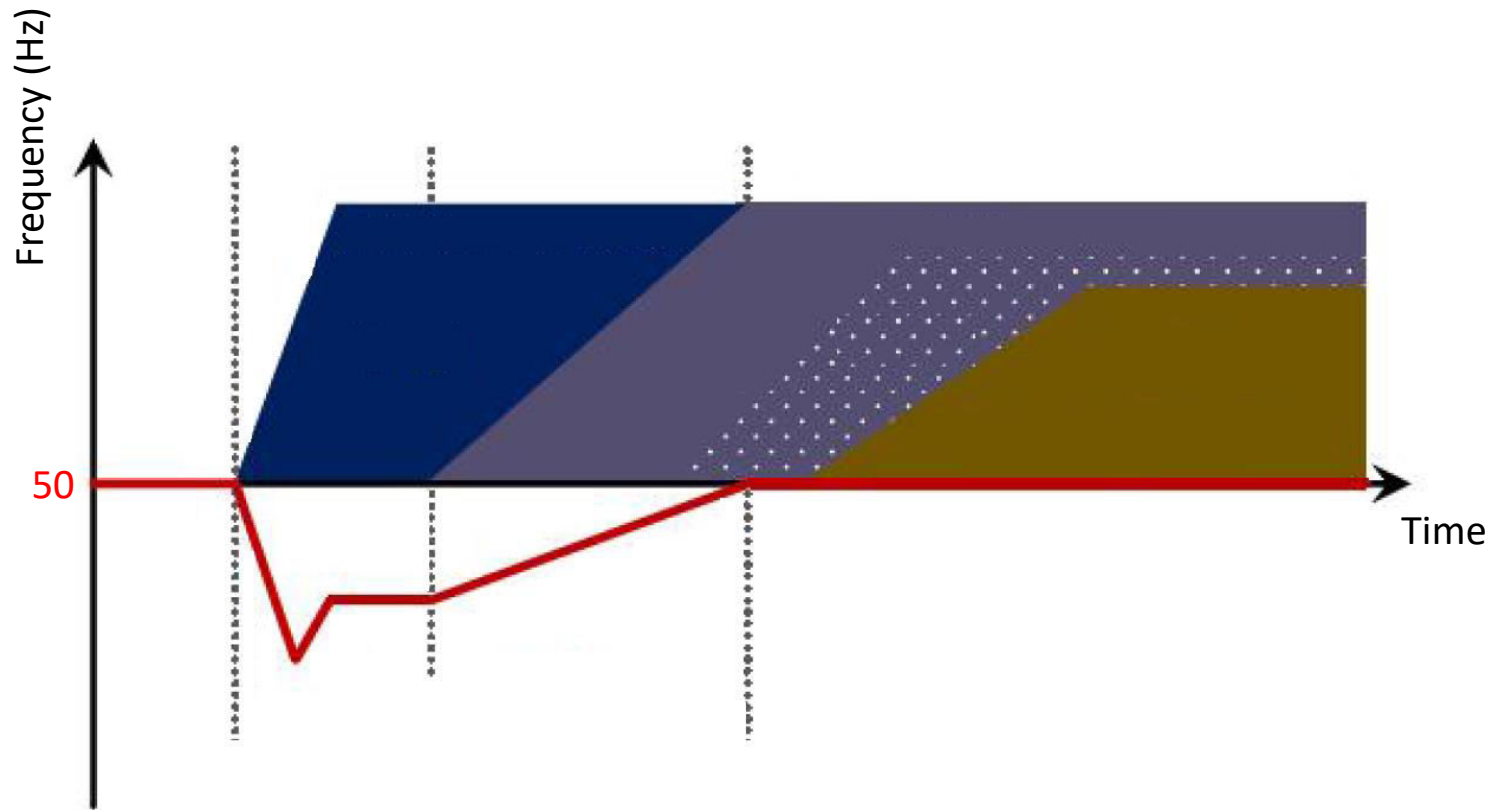
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## On the need for frequency-supporting services:

We can almost always expect a mismatch between “scheduled” power supply and demand due to the following disturbances:

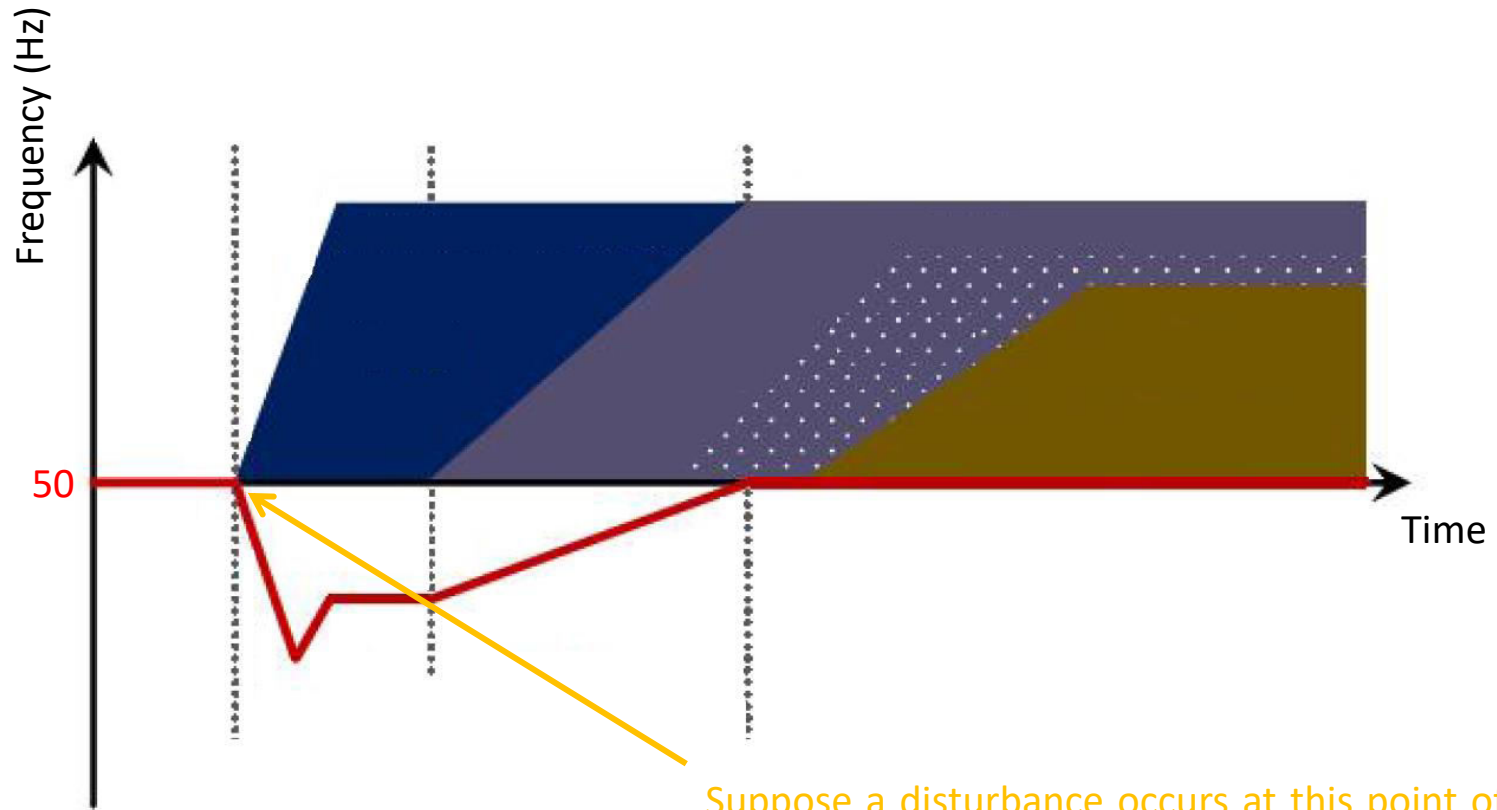
- Forecast errors in the prediction of renewable power supply and in the prediction of demand,
- Potential outages, i.e., failure of a generator, or a transmission line, or a transformer, or any other power system asset.

# Frequency-supporting flexibility services



Source of the picture (and relevant for further reading): Energinet report, “Ancillary services from new technologies,” provided by RAMBOLL, December 2019. Link: <https://energinet.dk/-/media/229625DCEA984813BF322090E7926844.pdf>

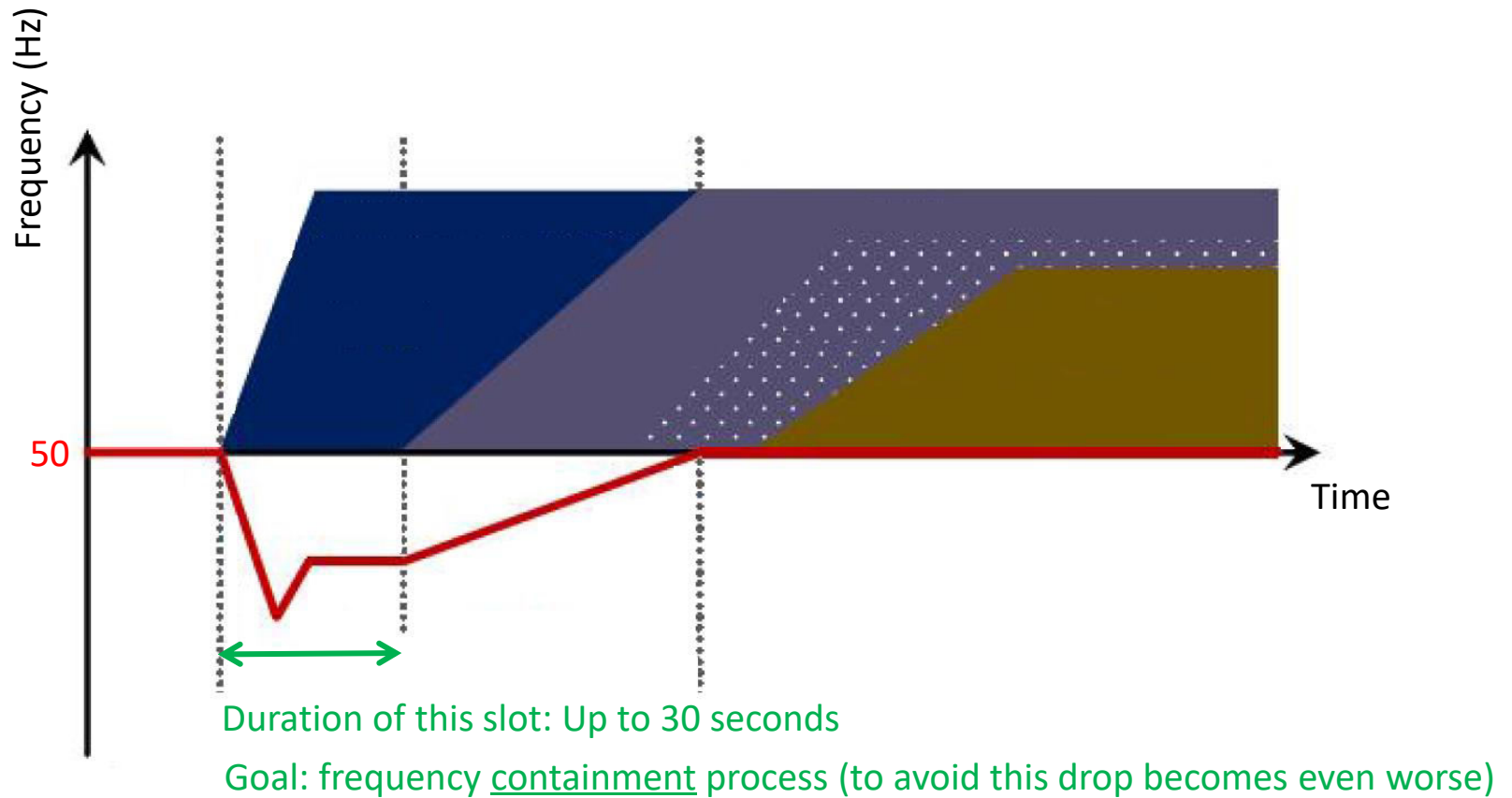
# Frequency-supporting flexibility services



Suppose a disturbance occurs at this point of time, leading to an imbalance (in this case, it is a power deficit, causing a frequency drop)

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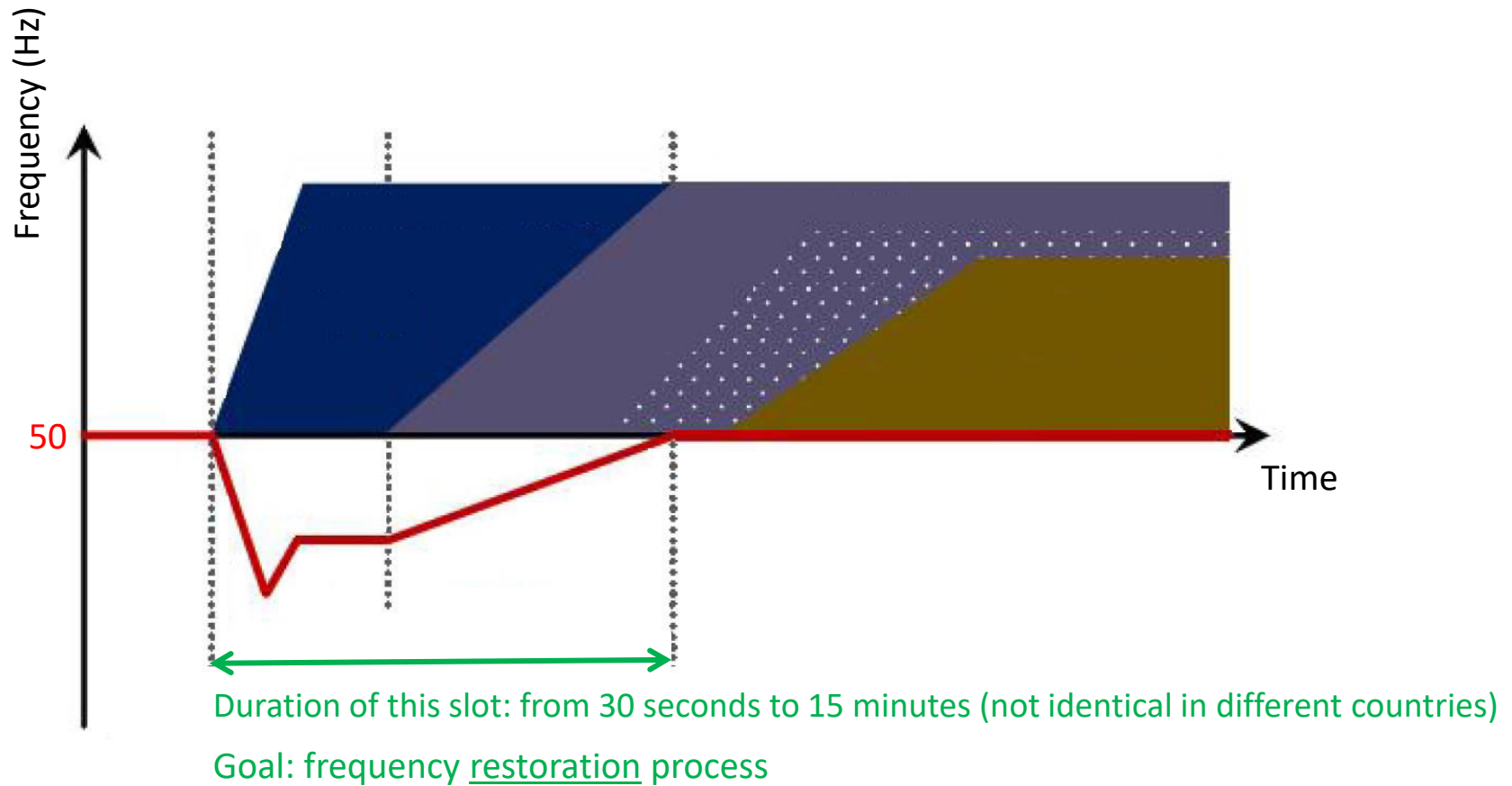
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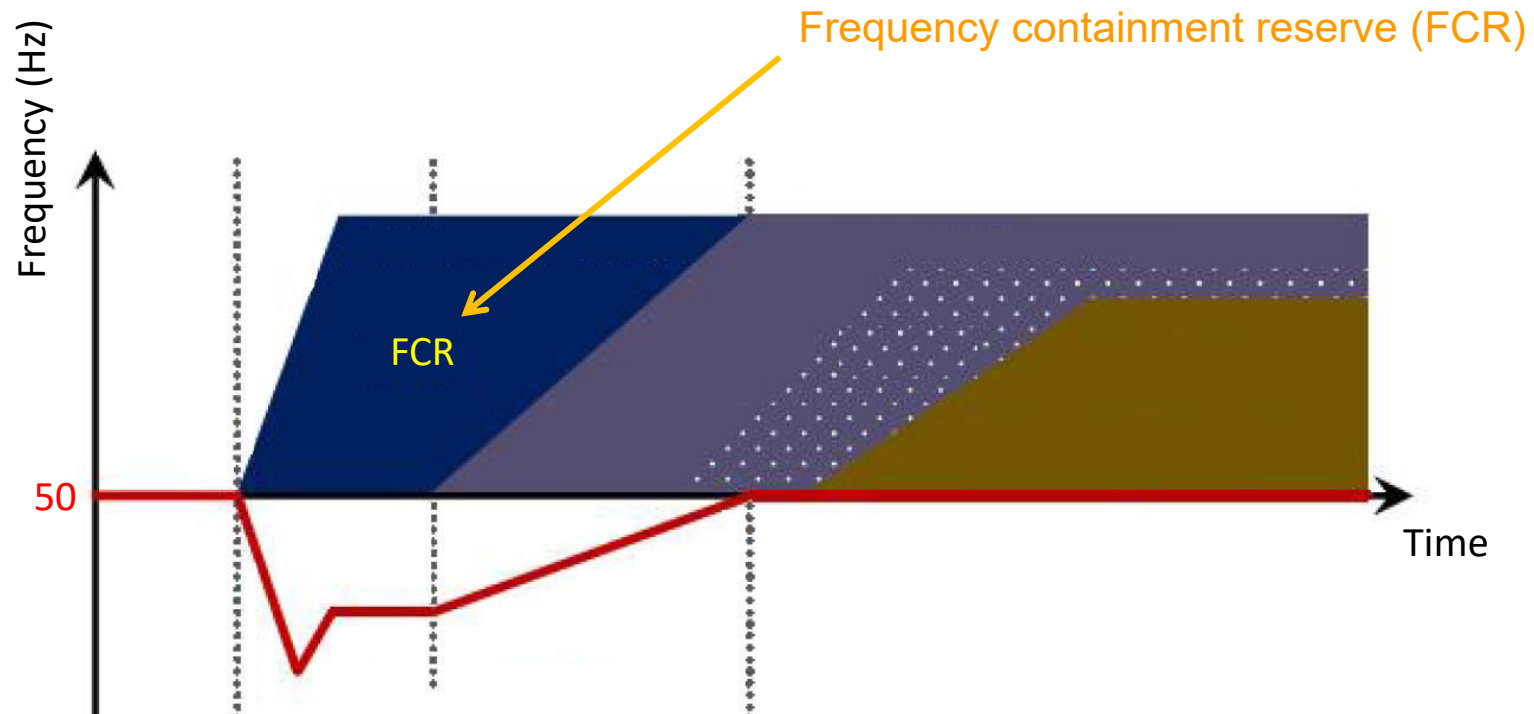


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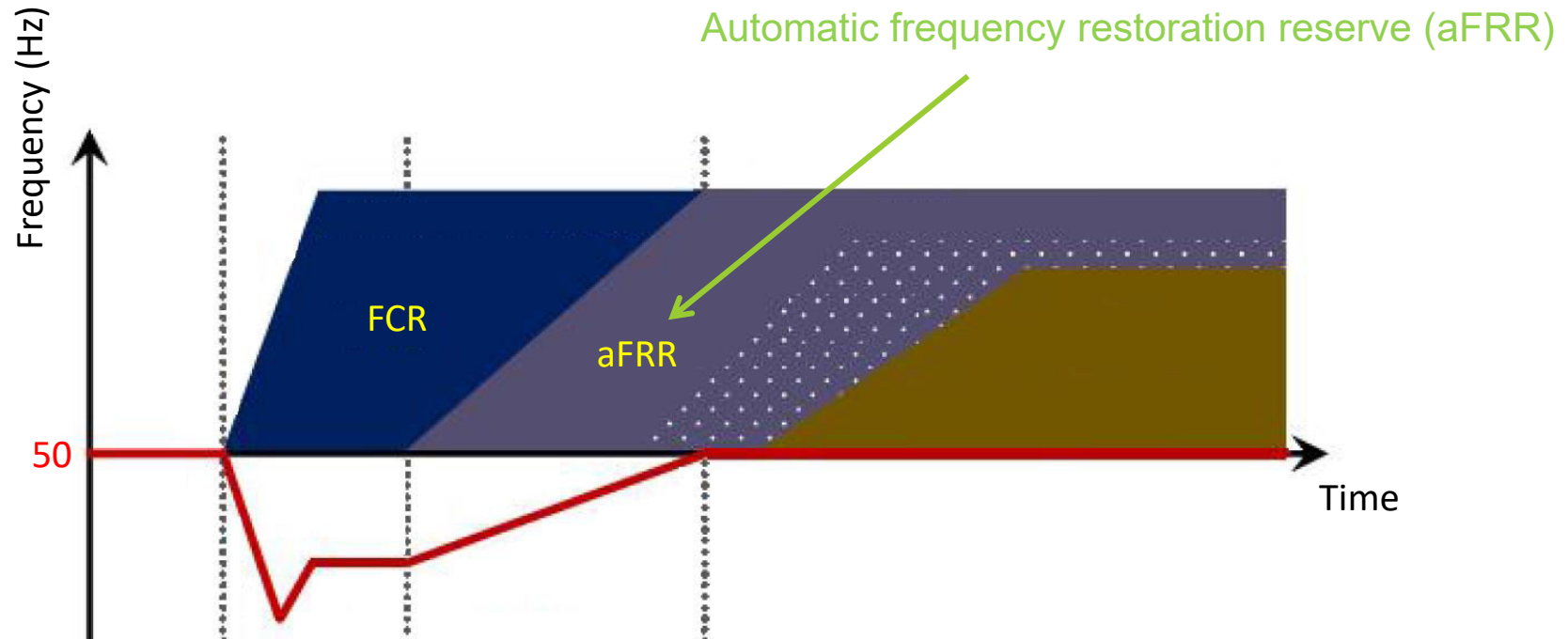
# Frequency-supporting flexibility services



- FCR is the fastest frequency-supporting flexibility service!
- Reaction and full response depend on the FCR provider, but it could be immediate or may take a few seconds.
- It is also known as “**primary reserve**” and “**regulating reserve**”.

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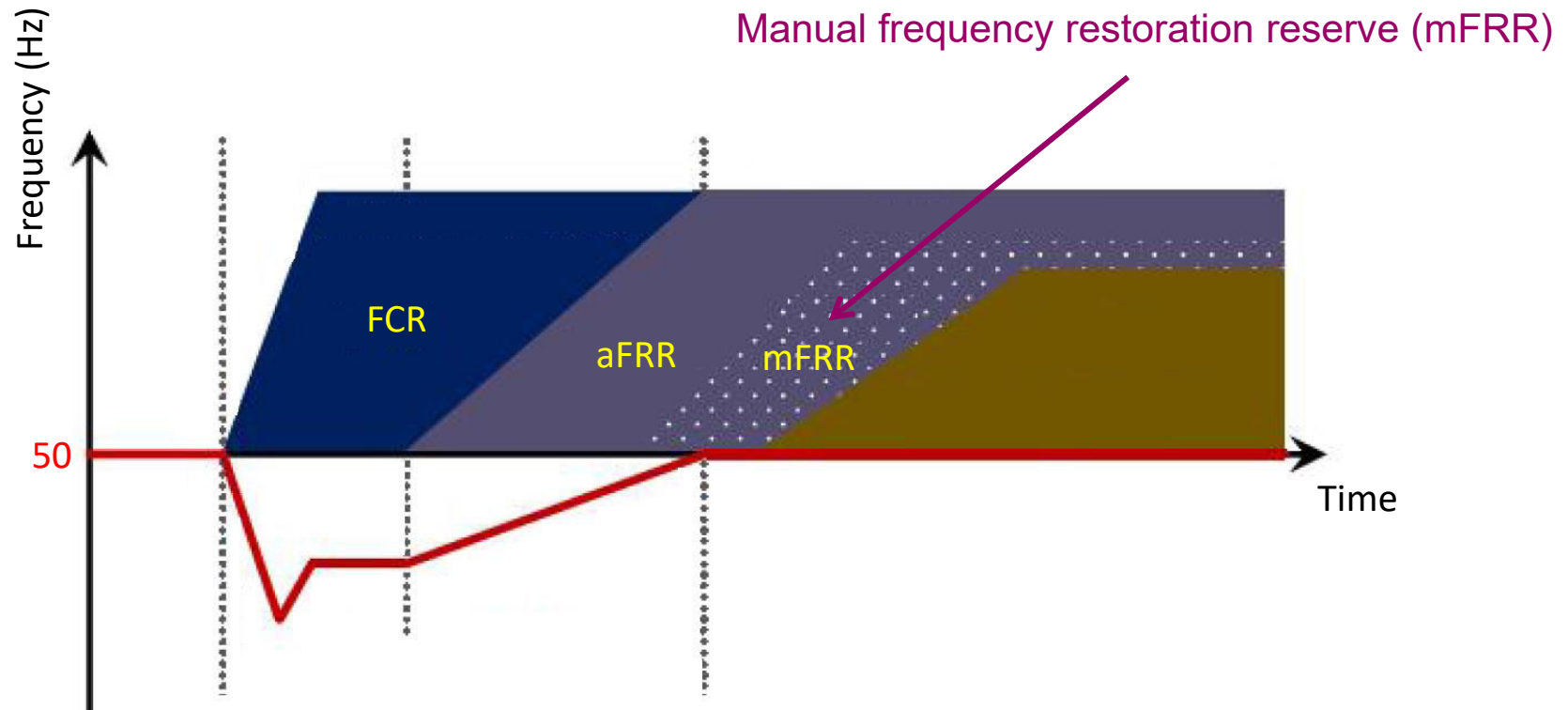
# Frequency-supporting flexibility services



- Reaction in a few seconds, but full response within 5-10 minutes
- Potential aFRR providers: spinning (on-line) generators, and non-spinning (off-line) generators if they are fast-start enough
- It is also known as “**secondary reserve**” and “**operating reserve**”.

Source of the picture (and relevant for further reading): Energinet report, “Ancillary services from new technologies,” provided by RAMBOLL, December 2019. Link: <https://energinet.dk/-/media/229625DCEA984813BF322090E7926844.pdf>

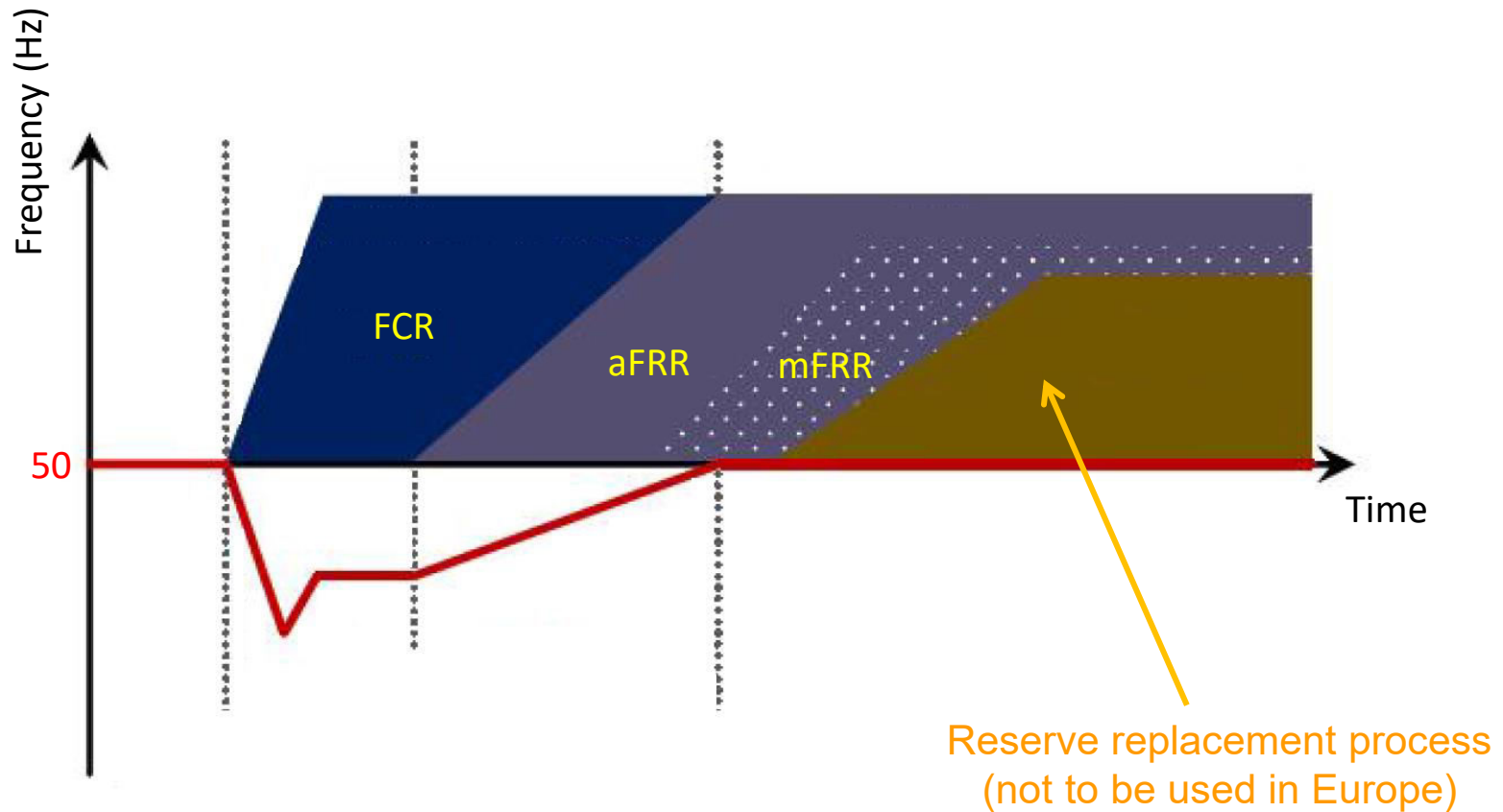
# Frequency-supporting flexibility services



- Full response within 30-60 minutes (this is a comparatively slow frequency-supporting flexibility service)
- It is also known as “**tertiary reserve**” and “**replacement reserve**”.

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# Frequency services in Denmark (DK1 & DK2)



# Upcoming pan-European balancing platforms

- **PICASSO**: An exchange platform for **aFRR** between European countries ([https://www.entsoe.eu/network\\_codes/eb/picasso/](https://www.entsoe.eu/network_codes/eb/picasso/))
- **MARI**: An exchange platform for **mFRR** between European countries ([https://www.entsoe.eu/network\\_codes/eb/mari/](https://www.entsoe.eu/network_codes/eb/mari/))

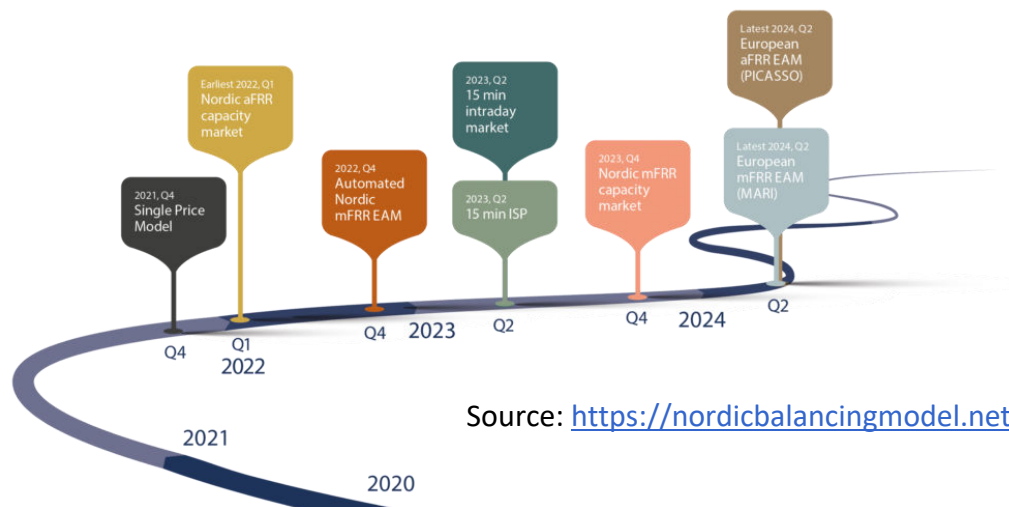
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Energinet has a close operation and market cooperation with the other Nordic TSO's and they have decided to implement a common project called *Nordic Balancing Model*, **NBM**, (<https://nordicbalancingmodel.net/>) to eventually join PICASSO and MARI.



Source: <https://nordicbalancingmodel.net/roadmap-and-projects/>



# From the TSO's perspective

There are two types of agents in the balancing market:

## 1) **Balancing service providers (BSPs):**

- Any generation- or demand-side market participant who is able to change her set-point in the real-time to help balance the system.
- Without having a proper reserve market in advance to book enough capacity, we may have balancing service scarcity in the real-time operation.

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## 2) Balancing responsible parties (BRPs):

- In European electricity markets, BRPs have agreement with TSOs and provide “financial” responsibilities. They could be even financial institutes and banks.
- Each producer or demand needs to assign a BRP who takes her financial responsibility for any mismatch that may happen between her “schedule” and her “true” production/consumption in the real-time.

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BSPs should be paid for flexibility service provision.

BRPs should be charged for imbalances caused by their clients.

# From Energinet.dk (Danish TSO)

## BALANCE RESPONSIBLE PLAYER

Balance responsible players buy and sell electricity at Nord Pool Spot on behalf of electricity suppliers and plant owners. On a daily basis, they submit plans to Energinet on the electricity expected to be generated and consumed in the next 24 hours by the producers and customers for whom they are balance responsible in the next 24 hours.

The balance responsible players are financially responsible to Energinet for imbalances between expected and actual generation and consumption in the day of operation.

Actually, it is not possible to predict a day's generation and consumption to perfection. The imbalance, which most frequently is between expected and actual generation and consumption during the day of operation, will be counterbalanced by Energinet. The cost of this will be invoiced to the balance responsible players who are responsible for the imbalances.

Link: <https://en.energinet.dk/Electricity/New-player/Roles-and-responsibilities>

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Discussion 1: Why energy communities (or local flexibility markets)?

Discussion 2: Why TSO-DSO coordination?





# Thank you!



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