ENERGINET

OUTLOOK FOR ANCILLARY SERVICES 2023-2040

CONTENT

INTRODUCTION

Globally, energy systems are transitioning towards 100 % renewable energy with unprecedented speed. The energy crisis and ambitious climate goals drive the change, which introduces new phenomena and characteristics on an almost daily basis. Some comfortably foreseen, others emerging from one day to the next, such as the lowest negative prices ever recorded followed by large imbalances during operation. These massive changes in and around the energy sector result in increasing demands for stability and balancing of the electricity system, or even new solutions. Concurrently, this development introduces increased risks for both operators, producers, and consumers, which conflicts with the much-needed pace of new solutions and investments.

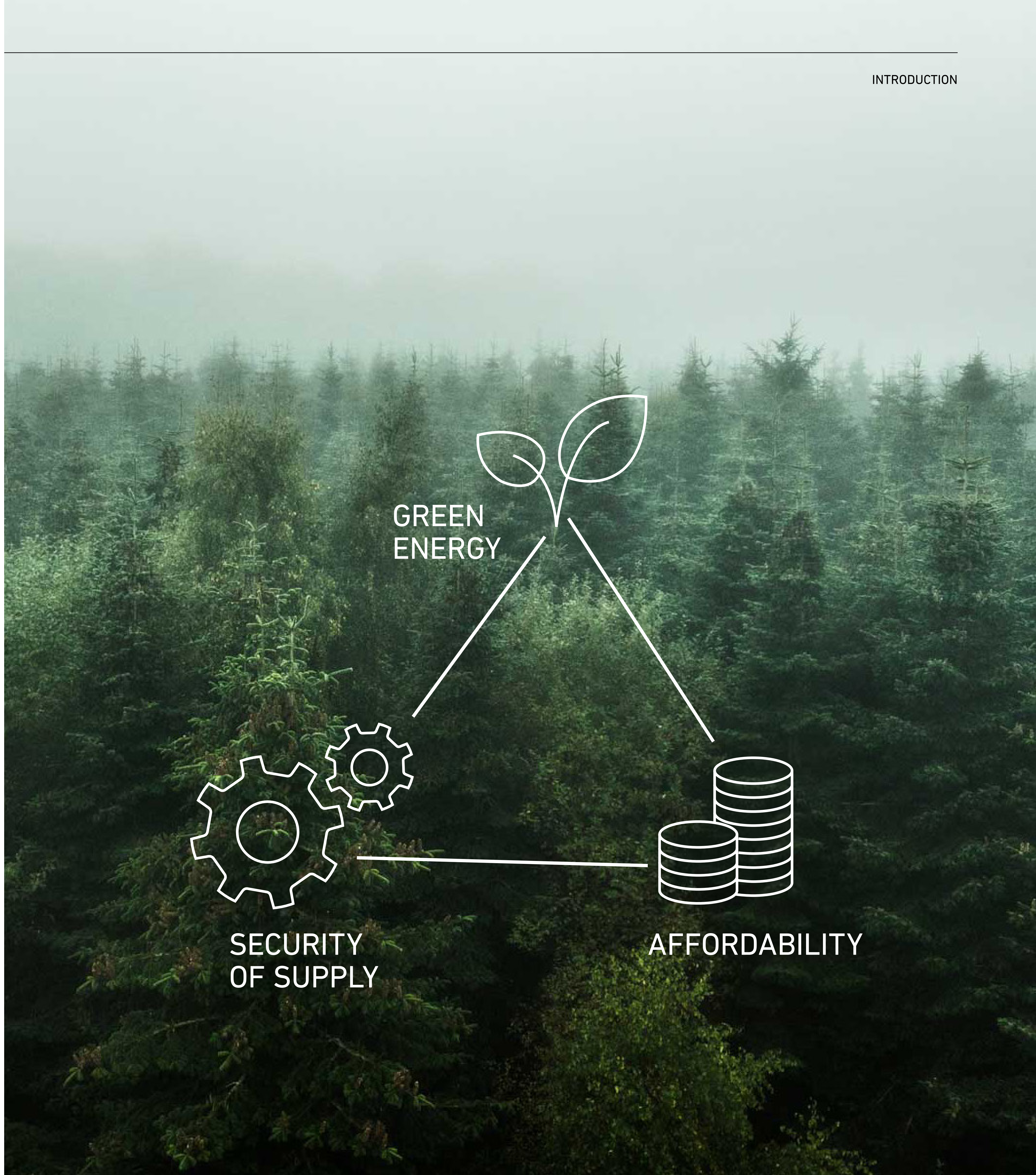
The purpose of this report is to give a thorough insight into the markets for ancillary services in Denmark and the expected developments for the next +10 years ahead - developments based on demands arising from the green transition and changes to the electricity system, but also changes introduced by Energinet to resolve challenges as best as possible, allowing us to safely operate the electricity system. Expectations are based on qualified estimations but should be used with caution.

It is not possible to eliminate risks and uncertainties related to the development of the energy system and ancillary service demand, products, and markets. Instead, transparency is key, and this report aims to share the perspectives of Energinet on future changes to stimulate dialogue with market parties and to share knowledge.

These great uncertainties should not block the progress towards a 100% renewable-based energy system and the goal of Energinet to efficiently balance the future system by purchasing ancillary services from market participants. This also highlights the importance of market participants taking part in the balancing markets with flexible production and consumption.

Hence, all parties must learn to navigate the unfamiliar territory together, based on trust and continued learning. Energinet strongly believes that market-based solutions will create the highest socio-economic value and best counter the energy trilemma depicted below.

The 'Outlook for Ancillary Services 2023-2040' is the second of its kind (and the first in English). Valuable feedback has led to changes compared to the first version from 2022, and feedback is still very welcome to continue to further improve future versions. The report is expected to be published annually in the late fall.



KEY EVENTS AND TAKEAWAYS FROM THE PAST YEAR

DEC-2022 ❯❯❯❯

aFRR CAPACITY MARKET, DK2

The Nordic TSOs successfully launched the Nordic aFRR capacity market (CM) on 7 December 2022.

The purpose of the common Nordic aFRR CM is to utilize capacity resources across the Nordic bidding-zones to allocate frequency restoration reserve capacity where needed across borders. The aim is to improve overall Nordic socio-economic welfare and security of supply by sharing capacity across borders.

The first evaluation of the market showed daily savings of approximately 100,000 EUR/day.

MAY-2023 ❯❯❯❯

NEW COUNTERTRADE MODEL

As planned, Energinet successfully went live with the procurement of countertrade energy in the cross-border intraday market on 2 May 2023, with the first deliveries made in the days right after. The new countertrade model was implemented to limit the amount of countertrade activated as special regulation in the Danish energy system to ensure operational security, but also to increase market competition, and to be compatible with the European balancing markets.

The procurement of countertrade energy in the intraday market was phased in gradually in steps of 200 MW, 500 MW, and 1,000 MW. Since 1 July 2023, the full need has been traded in the intraday market.

Liquidity in the intraday market has been sufficient to absorb capacities and has given the anticipated yield. Energy has been sold to DK1, Sweden, Norway, the Netherlands, and DK2.

JUN-2023 ❯❯❯❯

mFRR CAPACITY MARKET

The successful go-live of a Danish national mFRR capacity market was achieved on 20 June 2023.

As is the case with the Nordic aFRR capacity market, the common mFRR capacity market between DK1 and DK2 was implemented to utilize resources across the Danish bidding zones.

Denmark is the first Nordic country to implement a cross-zonal mFRR capacity market.

KEY TAKEAWAYS FROM PROJECTIONS

In general, Denmark is transitioning into a role as net producer rather than net consumer. This development affects the Danish need for ancillary services. Throughout this outlook, the trend is elevated Danish capacity needs - with aFRR and mFRR as the main sources of this increase.

The large increase in capacity need is a consequence of more fluctuating production from solar and wind resources, which results in a greater need for balancing resources.

Moreover, a highly diversified balancing portfolio is needed. During periods with high renewable production, there is a demand for balancing. During periods with low renewable production, demand is lower, but supply is also limited.

Energinet seeks to internationalize markets as much as possible to increase market volumes for Danish market participants, resulting in more robust price signals and maximizing total welfare.

+33%

estimated mFRR up-regulation need for DK2 in 2030.

2.000-3.000

estimated MW/h capacity required in total in 2030 for all services in DK2.

1.000-2.000

estimated MW/h capacity required in total in 2030 for all services in DK1.

+50%

estimated mFRR up-regulation need for DK1 in 2030.

PROJECTED DEVELOPMENT OF ANCILLARY SERVICES 2023 – 2040

HOW TO BALANCE THE POWER SYSTEM

Energinet procures different kinds of ancillary services – each product serves a specific purpose in maintaining or restoring balance between consumption and production, depending on the situation. In situations with electricity surplus, Energinet activates services, which lower production or increase consumption. In a reverse situation, Energinet activates services, which increase production or lower consumption.

"Energinet uses a proactive balancing philosophy. This means, that Energinet, using rolling forecasts of consumption, and wind and solar resources, combined with operational schedules submitted by market participants, continually predicts the imbalance in the electricity system and activates the necessary services accordingly."

Energinet's control centre monitors the power system continuously, focusing on two parameters especially: imbalances and frequency. There are always imbalances in the system caused by forecast deviations and outages. The control centre aims to minimize the size of imbalances. If imbalances become too large, this affects the frequency in the power system, which must be kept within certain thresholds. If there is too much electricity in the system, the frequency rises, and if there is too little, the frequency drops.

To minimize imbalances and keep a steady frequency, various ancillary services are utilized. These mainly vary on two parameters: Response time, i.e. how quickly a production or consumption unit must react when needed, and activation time, i.e. how long a production or consumption unit must stay active during an activation. The fastest ancillary services, called frequency containment reserves (FFR, FCR, FCR-D, FCR-N), which typically have the shortest activation time, ensure that the frequency does not deviate too much. The slower ancillary services, aFRR and mFRR, with significantly longer activation time are meant to replace frequency containment reserves when possible and ensure that system balance is re-established.

Energinet uses a proactive balancing philosophy. This means, that Energinet, using rolling forecasts of consumption, and wind and solar resources, combined with operational schedules submitted by market participants, continually predicts the imbalance in the electricity system and activates the necessary services accordingly. Therefore, Energinet is strongly dependent on market participants' operational schedules, which must match their actual production/consumption. When Energinet receives correct operational schedules, and thereby great forecasts, imbalances between consumption and production can be mitigated, thus decreasing imbalance costs and ensuring a stable electricity system and a high level of security of supply.

WHAT ARE ANCILLARY SERVICES?

Ancillary services cover a range of products, which Energinet procures to ensure equilibrium between electricity supply and electricity demand at all times of the day. Ancillary services are used to close gaps resulting from the difficulty of predicting and planning electricity production and consumption without minor deviations. If Energinet does not have access to ancillary services, the electricity system will be overloaded and, in a worst-case scenario, damaged.

HOW TO BALANCE THE POWER SYSTEM

Figure 1 shows how sudden imbalances or outages lead to frequency deviations, activating different ancillary services to restore the frequency to 50 Hz. The purpose of frequency containment reserves is to immediately add power to the system to restore the frequency, preventing that the frequency becomes either too low or too high. Heavy-duty products such as Automatic Frequency Restoration Reserve (aFRR) and Manual Frequency Restoration Reserve (mFRR) are meant to release frequency containment re-serves, making these services ready to handle new frequency deviations and thereby restoring balance in the power system.

Practically, proactive balancing means that the control centre activates mFRR before an expected large imbalance, allowing Energinet to be ahead of time and thereby reduce activation of the frequency containment reserves and aFRR, saving those for outages or other sudden imbalances.

> The purpose of this report is to give a thorough insight into the markets for ancillary services in Denmark and the expected developments for the next +10 years ahead.

FIGURE 1 ACTIVATION TIME OF ANCILLARY SERVICES

MARKET OVERVIEW

The tables below show how the different ancillary services are distributed on capacity and energy markets for DK1 (Western Denmark) and DK2 (Eastern Denmark).

DK1

PRODUCT	CAPACITY MARKET	ENERGY MARKET
FCR	Part of FCR Cooperation (European CM).	
aFRR	Part of common Nordic CM market (date unknown). Until then, local DK1 market.	Part of common European energy activation market PICASSO (by Q2 2024).
mFRR	Part of common Nordic mFRR CM (date unknown). Until then, a common DK1-DK2 market on the Nordic MMS.	Part of common Nordic mFRR EAM (by Q1 2025). Common European energy activation market MARI (by Q2 2026).

DK2

PRODUCT	CAPACITY MARKET	ENERGY MARKET
FFR	National FFR capacity market.	
FCR-D	Currently common market with Sweden.	
FCR-N	Currently common market with Sweden.	
aFRR	Common Nordic CM market (as of December 2022).	Part of common European energy activation market PICASSO (by Q2 2024).
mFRR	Part of common Nordic CM market (date unknown). Until then, a common DK1-DK2 market on the Nordic MMS.	Part of common Nordic mFRR EAM (by Q1 2025). Common European energy activation market MARI (by Q2 2026).

TIMELINE

This timeline indicates upcoming projects, which will lead to changes in the future ancillary service market. Dates listed are the officially announced times for when projects are expected to be implemented.

2023

Q4 2023
Viking Link go-live

2024

Q2 2024
New local aFRR capacity market in DK1

Q2 2024
Common European aFRR energy activation market for PICASSO

Q3 2024
Dynamic Dimensioning

2024/2025
Common Nordic mFRR capacity market

2025

Q1 2025
Automated Nordic mFRR energy action market

Q1 2025
15 min ISP/IDC

2026

2026
Common European mFRR energy activation market for MARI

2026
DK1 implemented in Nordic aFRR capacity market

2030

Q1 2030
Bornholm Energy Island go-live

2033

Q1 2033
North Sea Energy Island go-live (expected)

ASSUMPTIONS

This outlook is based on historical data and model-generated results from Energinet's advanced energy modelling tool (BID3). The underlying assumptions follow the National Trends (AF22) from the Danish Energy Agency as input for Denmark. Assumptions for other European countries are based on ERAA 2022 data and TYNDP22 data for 2025-2030 and 2040, respectively. This is in line with the base case scenarios used for the Security of Electricity Supply Report 2023 (RFE23).

The only correction made compared to RFE23 data is a correction of the capacity of North Sea Energy Island in 2033-2034 from 3 GW to 4 GW. Additionally, the capacity of the two interconnectors from North Sea Energy Island has been adjusted from two 700 MW cables to two 1 GW cables for the lifespan of North Sea Energy Island. This is based on the latest assumptions for the capacities of North Sea Energy Island, however still lacking a final decision on the realization of North Sea Energy Island. implementation.

The forecasted procurement values in this outlook are especially founded in expectations for the future, which adds some uncertainty to the values represented. The Outlook presents an estimated range for procurement values based on different climate years (historical years with measures insolation, wind, precipitation etc.). With the massive upward trend in renewables, climate years have a significant impact on the need for ancillary services – especially considering imbalances and system inertia. Further, the Danish sharing keys for FCR are calculated based on production and consumption, meaning that the more Denmark produces, the larger will our FCR sharing key and procurement responsibility be.

The model calculations behind this outlook have been done at a Pan-European level and thus includes development in other countries.

In summation, the values and ranges represented in this outlook are forecasted values and not procurement-binding values, but Energinet's best estimate of future needs – despite a world with great uncertainties.

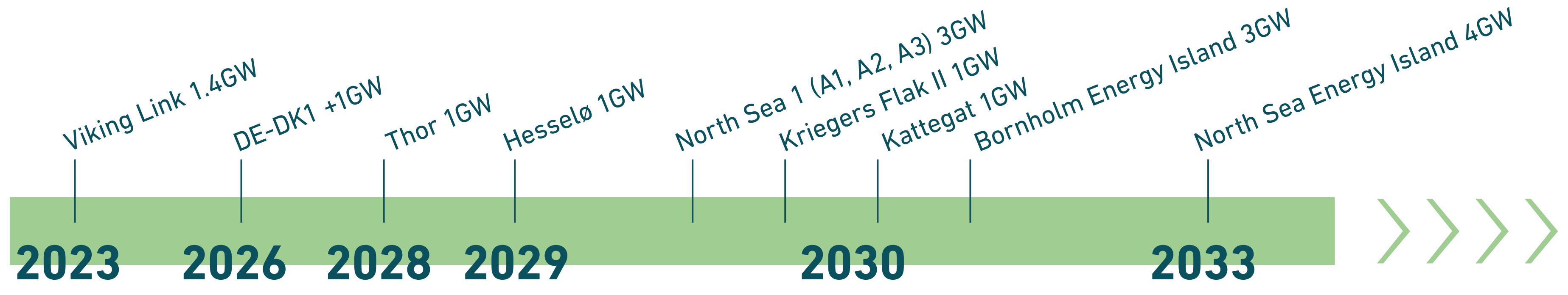


FIGURE 2 DANISH CAPACITY

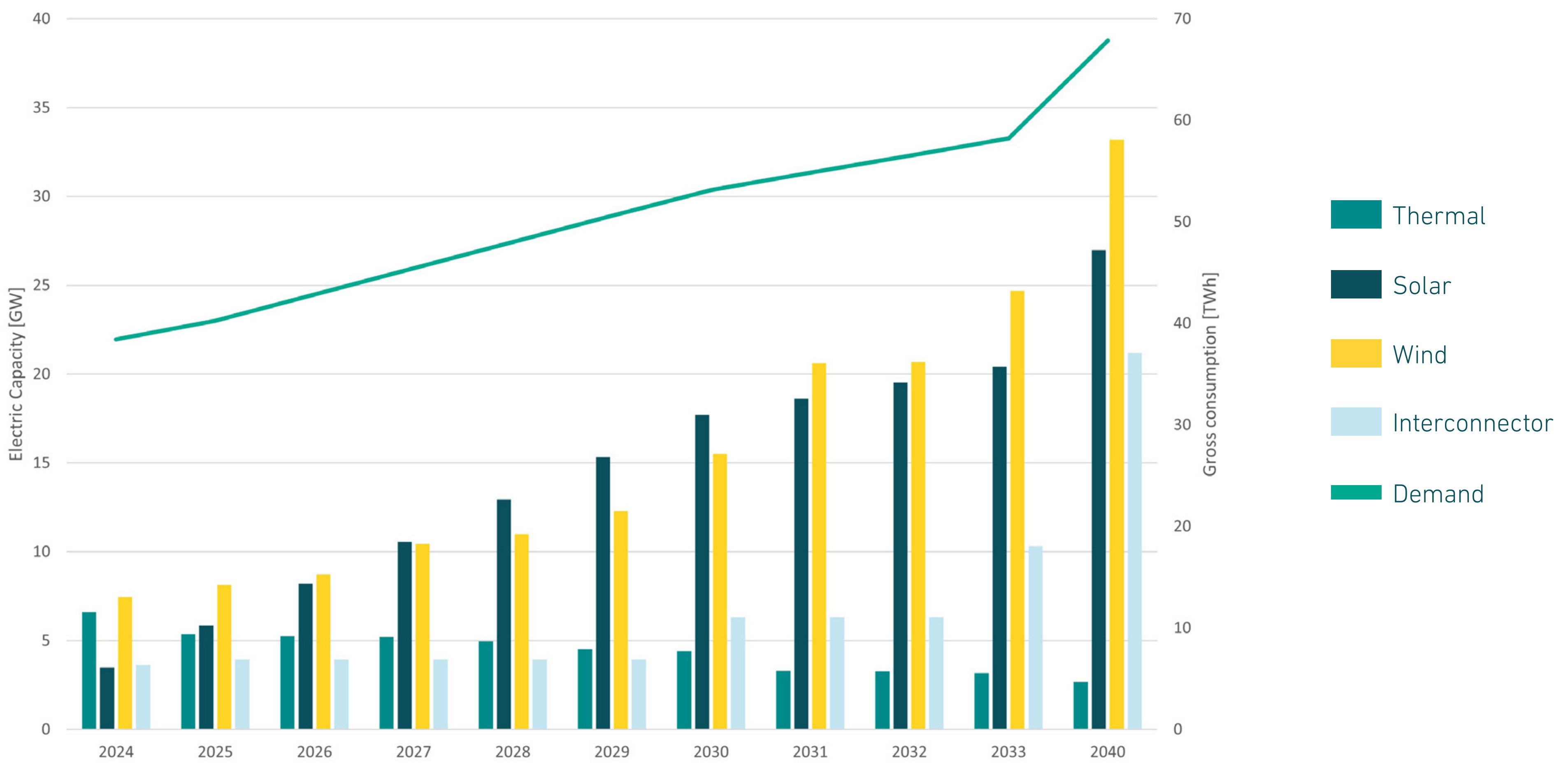
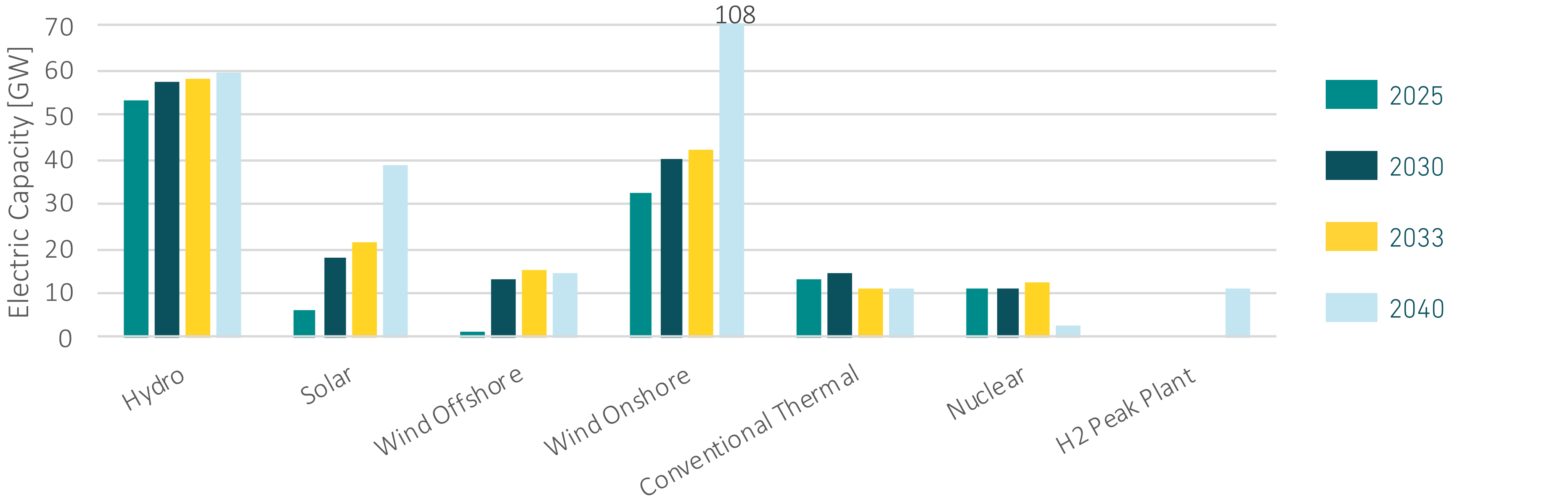


FIGURE 3 NORDIC CAPACITY



FREQUENCY CONTAINMENT RESERVES

STATUS: FFR DK2, FAST FREQUENCY RESERVE

INTRODUCTION

FFR, Fast Frequency Reserve, mitigates large frequency drops by rapidly providing up-regulation to the power system. This is typically done with load shedding or increased electricity production from fast-responding units.

The need for FFR typically arises during the summer months when consumption is low and few thermal plants are in operation, resulting in low system inertia. In October 2022, multiple, large, inertia-contributing nuclear plants were out for maintenance, resulting in increased procurement of FFR. Inertia refers to the rotational energy created by turbines in thermal plants, which is stored in the electricity system. Inertia makes the electricity system resilient to sudden frequency fluctuations. In periods with high shares of renewable energy and low inertia, the power system becomes more vulnerable to sudden changes, and the need for FFR arises.

Energinet has procured FFR since 2020. Originally, procurement was based on monthly contracts. From April 2021, it was changed to hourly procurement, and the need for FFR is continuously estimated by Energinet and the other Nordic TSOs.

By the end of 2022, the FFR market in DK2 was characterized by few bidders and an increased need for FRR during the winter. Consequently, Energinet reached out and encouraged market participants to report their available quantities so that the market could operate optimally. In 2023, more bidders have joined the market and are actively participating.

For 2023, approximately 10 MW of new capacity has been prequalified to provide FFR in DK2. The chart below shows the shares of prequalified capacity divided into different technology types. Four units were prequalified in this period, two of which are batteries. Before 2022, no batteries were prequalified for FFR.

FIGURE 4 MONTHLY PROCUREMENT OF PRIMARY RESERVE, FFR, IN DK2

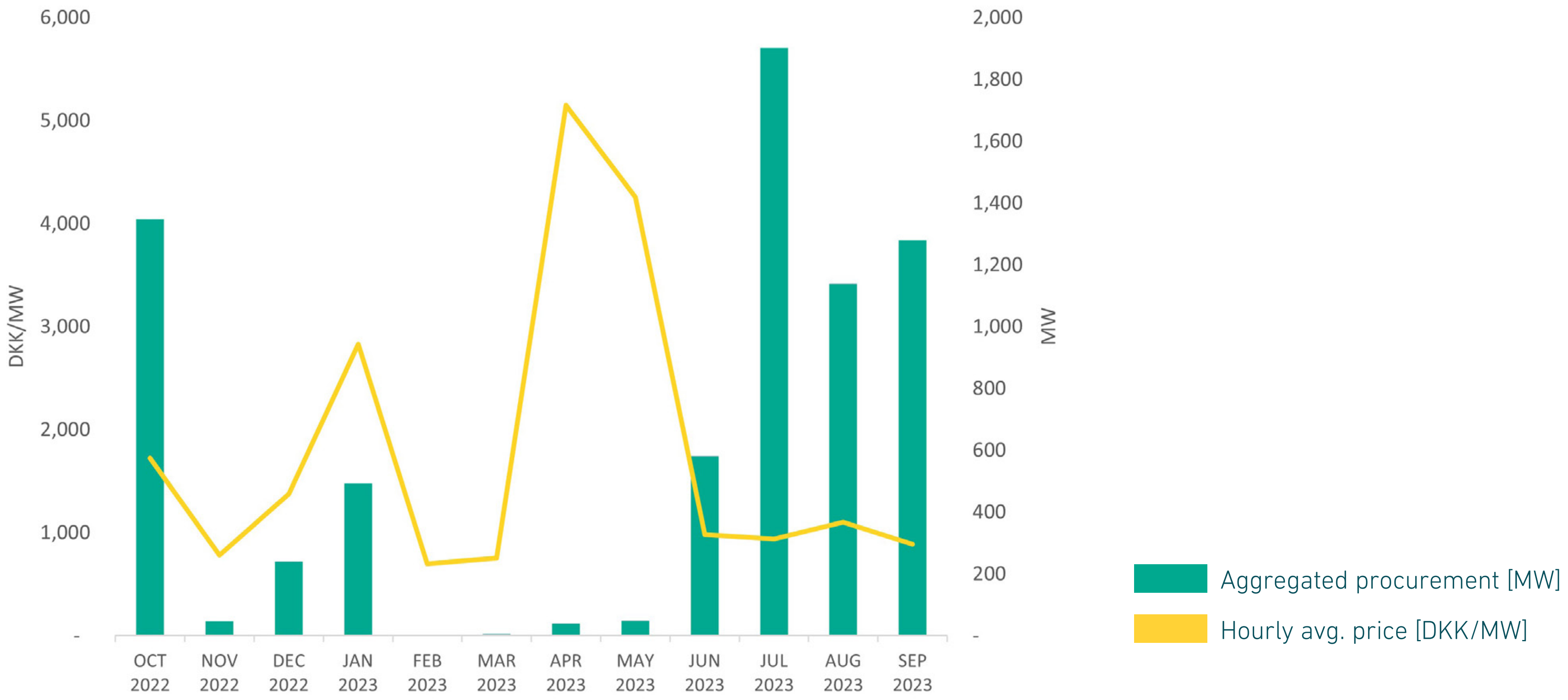
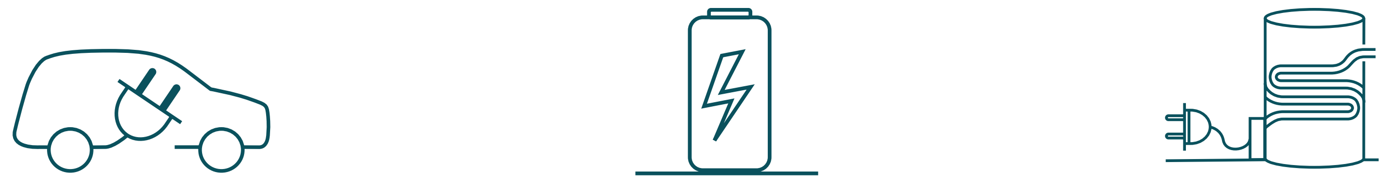


FIGURE 5 PREQUALIFIED FFR CAPACITY [MW] DISTRIBUTED ON TECHNOLOGY TYPE [2023]



0.5	1.1	8.5
Flexible consumption	Battery	Electric boiler

FORECAST: DEVELOPMENT IN FFR NEED DK2

The procurement of FFR (Fast Frequency Reserve) depends directly on the inertia in the Nordic electricity system, where nuclear power plants in particular contribute with inertia. Also, thermal power plants and hydroelectric power are large contributors.

Solar and wind power resources do not contribute with neither mechanical nor synthetic (yet) inertia, and by replacing nuclear and thermal power plants, the technology has a negative impact on the inertia level.

The expansion of renewable energy increases both the number of hours when FFR is required, and the necessary FFR volumes. Therefore, the FFR forecast is highly dependent on the assumptions about production from various technologies, which varies with the different climate years.

In general, the forecast shows a significant increase in FFR requirement towards 2040, largely due to the expansion of renewable energy and less operating hours for nuclear power plant in Sweden and Finland.

The lower end of the scenario corresponds to a climate year with low amounts of renewable energy in the system, and more operating hours for nuclear power plants. The upper end of the scenario represents a climate year with a high share of renewable energy and moderate water resources, combined with less operating hours for nuclear power plants.

Compared to last year's outlook, the need for FFR is estimated to be the same or a bit lower in hours with FFR requirements. However, it is estimated that there will be a need for FFR in more hours, giving an increased summarized procurement.

2025

The range of scenarios in 2025 shows hours with FFR requirements ranging from approximately 1,650-4,100 hours with an average volume of around 10-15 MW/h and a maximum of approximately 40-45 MW/h. The Danish share is expected to constitute about 6-7.5% of the overall Nordic FFR requirement.

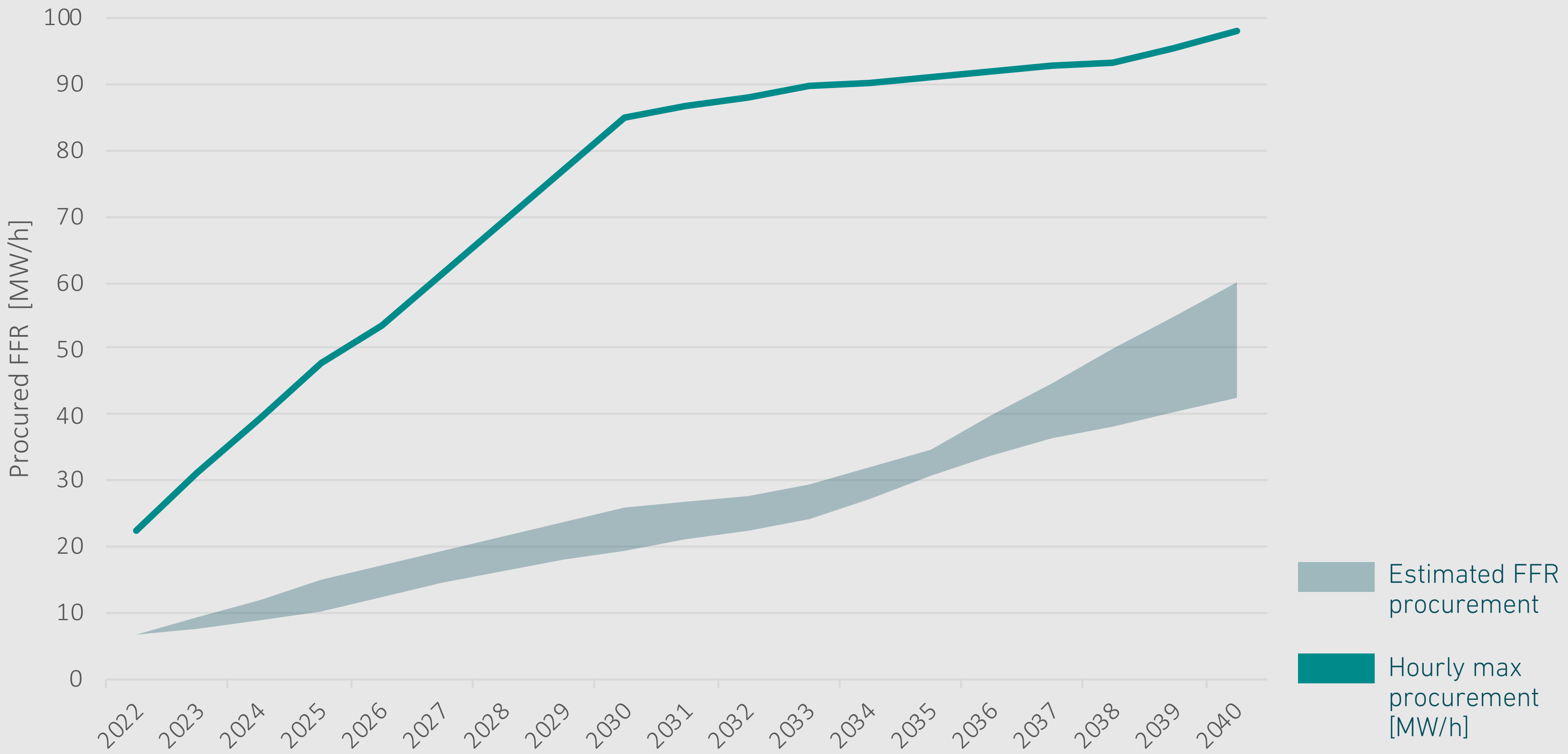
2030

The range of scenarios in 2030 shows hours with FFR requirements ranging from approximately 2,850-5,000 hours with an average volume of around 20-26 MW/h, and a maximum requirement of about 65-85 MW/h. The Danish share is expected to constitute about 10-12% of the overall Nordic FFR requirement.

2035

The range of scenarios in 2035 shows hours with FFR requirements ranging from approximately 3,750-5,550 hours with an average volume of around 30-35 MW/h, and a maximum requirement of about 75-90 MW/h. The Danish share is expected to constitute about 10.5-12% of the overall Nordic FFR requirement.

FIGURE 6 DEVELOPMENT IN FORECASTED NEED FOR FFR IN DK2



UNDERLYING METHODOLOGY

Model results on an hourly basis for 2025, 2030, 2033, and 2040 have been used to estimate electricity production in the Nordic synchronous area. This estimated electricity production is used to calculate system inertia, leading to a Nordic FFR requirement.

The Nordic FFR requirement is distributed among the bidding zones using sharing distribution keys, which are based on expected consumption and production. Therefore, the allocation key for DK2 is also projected along with the FFR requirement. Linear extrapolation has been used between the calculation years 2025, 2030, 2033, and 2040.

STATUS: FCR DK1, FREQUENCY CONTAINMENT RESERVE

INTRODUCTION

FCR, also known as Primary Reserve, automatically responds to frequency deviations in the power system, providing vital stability to the entire European synchronous area when there is a mismatch between consumption and production at the European level.

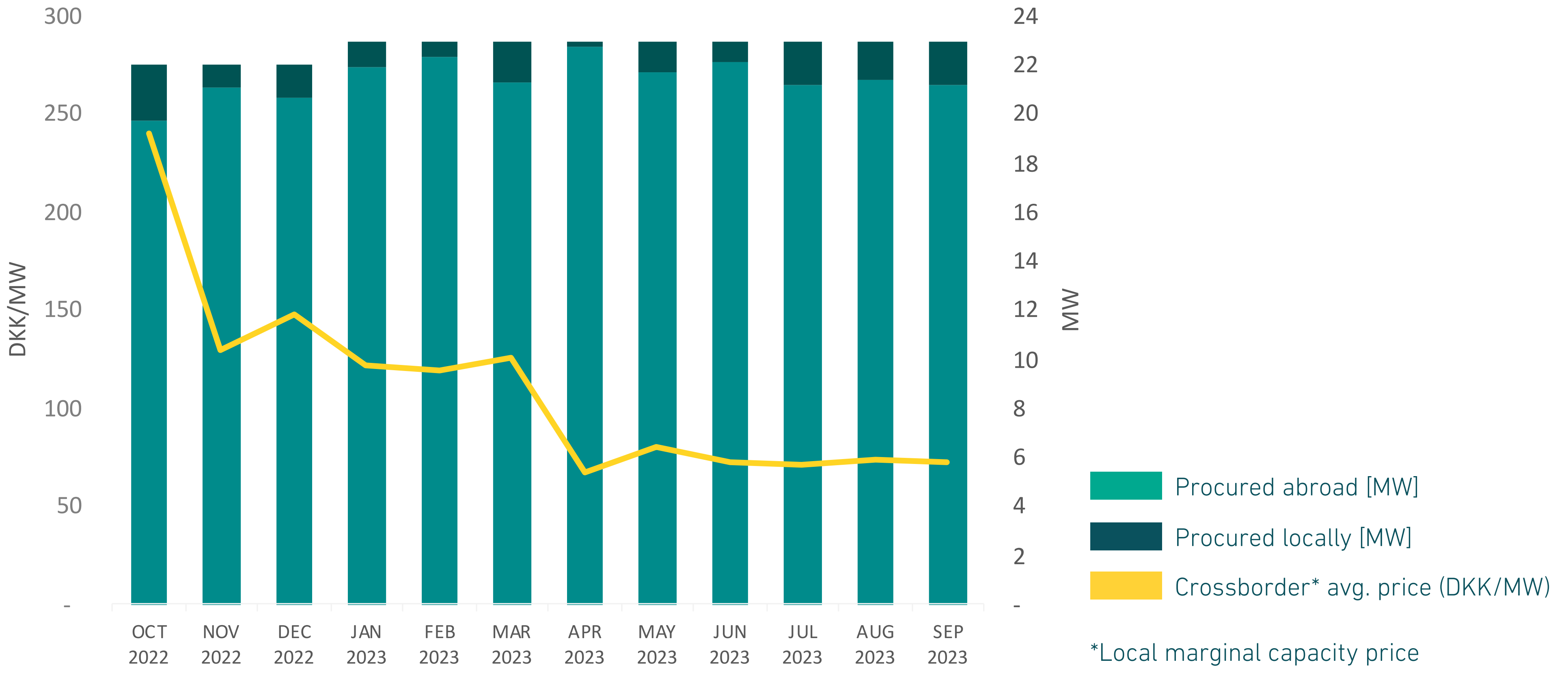
Each TSO is obligated to secure a share of the total FCR requirement for the Continental European synchronous area, amounting to +/- 3,000 MW.

FCR has an activation time of 30 seconds, and the delivery of FCR follows any frequency deviation proportionally.

In 2023, Energinet has procured approximately +/- 23 MW FCR per hour on an annual basis. Additionally, Danish market participants can export 100 MW FCR to Continental Europe. This means that Danish market participants have the potential to provide a total of 123 MW FCR.

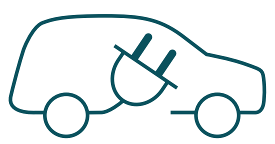
Moreover, approximately 65.5 MW new facilities have been prequalified to deliver symmetric FCR in 2023. Electric boilers represent the highest contribution to prequalified FCR capacity.

FIGURE 7 HOURLY PROCUREMENT OF PRIMARY RESERVE, FCR, IN DK1



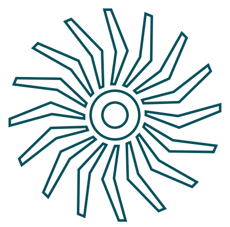
*Local marginal capacity price

FIGURE 8 PREQUALIFIED FCR CAPACITY [MW] DISTRIBUTED ON TECHNOLOGY TYPE [2023]



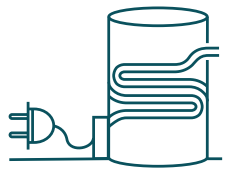
1.0

Flexible consumption



8.0

Power plant



56

Electric boiler

FORECAST: DEVELOPMENT IN FCR NEED DK1

The FCR (Frequency Containment Reserve) required for Continental Europe is stipulated in the System Operation Guideline (SO GL), Article 153. According to the SO GL, the requirement is set at 3,000 MW in both the upwards and downwards direction. Any changes to the overall requirement would require an in-depth European discussion with corresponding amendments to the SOGL.

Consequently, the overall 3,000 MW requirement will not be changed. Instead, focus is on Denmark's share of this requirement. The Danish share is determined based on the sum of consumption and production relative to the total production and consumption of the European synchronous area. Currently, the share of Western Denmark (DK1) is approximately 0.77%.

Western Denmark's share increases in proportion to the Danish level of electrification and increased Danish production capacity, resulting in an increase in the allocation key, thus amplifying Danish FCR requirements.

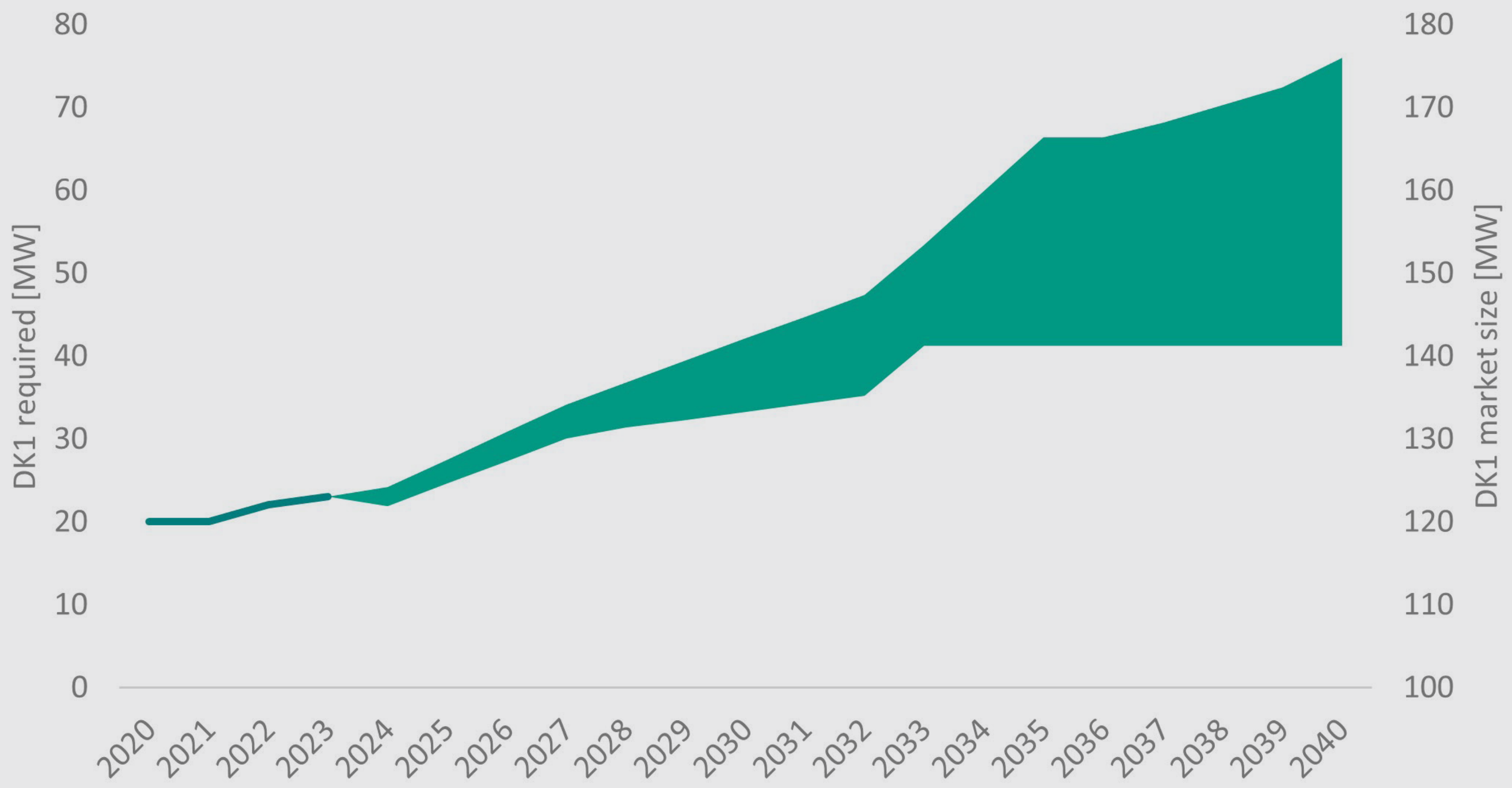
Energinet expects to procure 80-200% more FCR capacity by 2035 compared to the current level. The current prediction is a slightly increased share compared to last year's Outlook.

As stated in the section Assumptions, results are naturally influenced by changes to European plans.

In addition to the Danish share, there is a 100 MW possibility to export FCR to Continental Europe, which must be added to the Danish share. The FCR market in DK1 therefore ranges between 122-176 MW.

> Energinet expects to procure 80-200% more FCR capacity by 2035 compared to the current level. The current prediction is a slightly increased share compared to last year's Outlook.

FIGURE 9 DEVELOPMENT IN FORECASTED NEED FOR FCR IN DK1



UNDERLYING METHODOLOGY

Each year, the European TSOs must update their projections to assess Pan-European adequacy. This is used as model input for other countries in Energinet's energy models. Model results on an hourly basis for 2025, 2030, 2033, and 2040 have been used to estimate electricity production in the Continental Europe (CE) synchronous area and a scale for DK1 is then calculated based on this.

The Danish sharing key is multiplied by 3,000 MW, cf. SOGL, Article 153, with one year's delay, and the result is the FCR volume needed. Linear interpolation has been used between the calculation years.

STATUS: FCR-D DK2, FREQUENCY CONTAINMENT RESERVE FOR DISTURBANCE

INTRODUCTION

FCR-D, Frequency Containment Reserve - Disturbance, also known as Primary Reserve, is designed to stabilize the frequency in the power grid in DK2 and the rest of the Nordic synchronous area in the event of frequency drops or deviations. FCR-D is automatically activated based on measurements of the frequency in the power grid.

FCR-D is an asymmetric product, meaning that up-regulation and down-regulation are procured separately. FCR-D up-regulation is activated proportionally to the frequency deviation, starting from 0% delivery at a frequency below 49.9 Hz and gradually increasing to full delivery at 49.5 Hz. Similarly, for FCR-D down-regulation, this is activated at a frequency above 50.1 Hz and reaches full delivery at 50.5 Hz.

Energinet procures both FCR-D up-regulation and FCR-D down-regulation on a common Danish-Swedish market with the Swedish TSO, Svenska kraftnät. The market trades on an hourly basis and has a combined Danish-Swedish need of approximately 600 MW for FCR-D up-regulation, with a Danish share of 44 MW, and approximately 318 MW for FCR-D down-regulation, with a Danish share in 2022 of 42 MW. The maximum Danish coverage of the Swedish share is 1/3, meaning that the potential market is 244 MW and 150 MW, respectively, for FCR-D up-regulation and FCR-D down-regulation for a Danish BSP.

FCR-D is activated more frequently than FFR, and delivery is proportional to the frequency deviation. Since large frequency deviations are rare, full activation of FCR-D is only seen in extreme situations.

The FCR-D market runs efficiently, and Energinet finds it positive that increasing volumes are delivered by Danish market participants.

FIGURE 10 HOURLY PROCUREMENT OF PRIMARY RESERVE, FCR-D, IN DK2

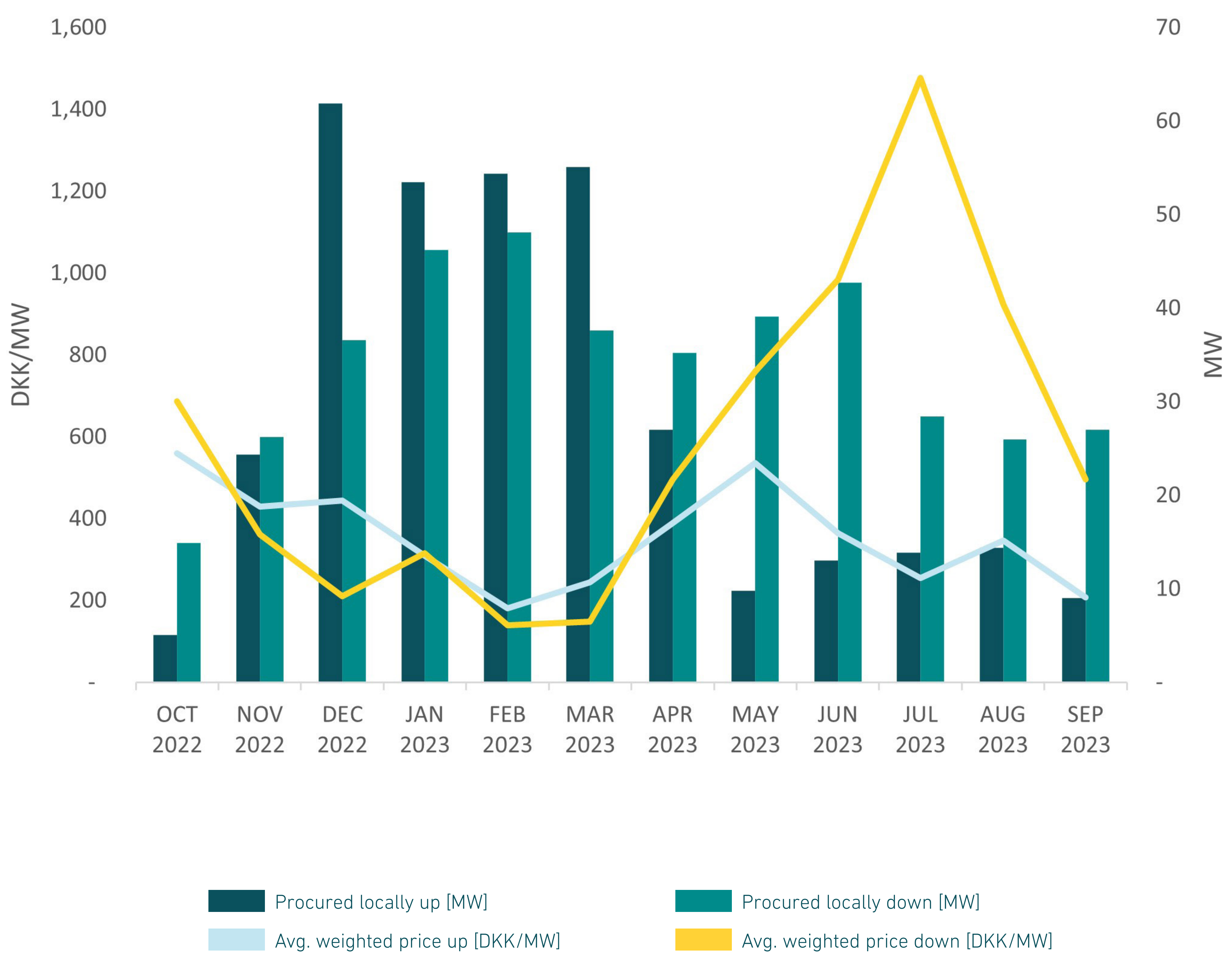


FIGURE 11 PREQUALIFIED FCR-D UP-REGULATION AND DOWN-REGULATION CAPACITY [MW] DISTRIBUTED ON TECHNOLOGY TYPE [2023]

FCR-D UP-REGULATION

Battery	Power plant	Electric boiler	Flexible consumption	Solar PV
5.0	104	3.6	0.5	0.5

FCR-D DOWN-REGULATION

Battery	Power plant	Electric boiler	Flexible consumption	Solar PV
2.1	48	2.0	1.7	15

"In 2023, new capacity of 115.2 MW FCR-D up-regulation and 68.85 MW FCR-D down-regulation have been prequalified, as shown in figure 12. During the summer of 2023, 5 MW and 15 MW of solar PV were prequalified for FCR-D up-regulation and down-regulation, respectively."

FORECAST: DEVELOPMENT IN FCR-D NEED DK2

The FCR-D (Frequency Containment Reserve - Disturbance) is dimensioned based on the largest incident (reference incident, RI) at the Nordic level for up-regulation and down-regulation, respectively. For up-regulation, the largest incident is Oskarshamn 3 with a maximum size of 1.45 GW, and for down-regulation, it is export via NordLink with a maximum size of 1.4 GW.

Dimensioning of the largest unit is continuously updated, resulting in variations in the requirement throughout the year. In the long term, with larger units and more fluctuating production, the FCR-D requirement will change even more often.

The projections of FCR-D down-regulation and FCR-D up-regulation do not involve changes to the largest incidents at Nordic level, but rather changes to the allocation key. Bornholm Energy Island at 3 GW could be closed during windy periods, but due to the plans for two HVDC connections to DK2 and DE, it will not affect Nordic dimensioning often.

The current allocation key for DK2 is approximately 3%, but this is expected to grow to 4-5% by 2035, leading to an increase in both FCR-D up-regulation and down-regulation. Based on AF22 assumptions, Danish FCR-D is projected to increase 30-70% by 2035.

The Swedish share is expected to decrease slightly due to the phasing out of nuclear power plants, but the extent depends heavily on the climate year.

When using the maximum 1/3 coverage of Swedish need, the total market size is between 200-245 MW for a Danish market participant in each direction (up-regulation and down-regulation).

UNDERLYING METHODOLOGY

Energy model results for 2025, 2030, 2033, and 2040 have been used to estimate electricity production and consumption in the Nordic synchronous area. This is converted into sharing keys assigned as a requirement to each country.

The sharing key calculations are naturally always one year behind, which is integrated as a one-year delay. The sharing key is multiplied by the Nordic reference incident. Linear extrapolation has been used between the calculation years.

FIGURE 12 DEVELOPMENT IN FORECASTED NEED FOR FCR-D UP-REGULATION, DK2-SE

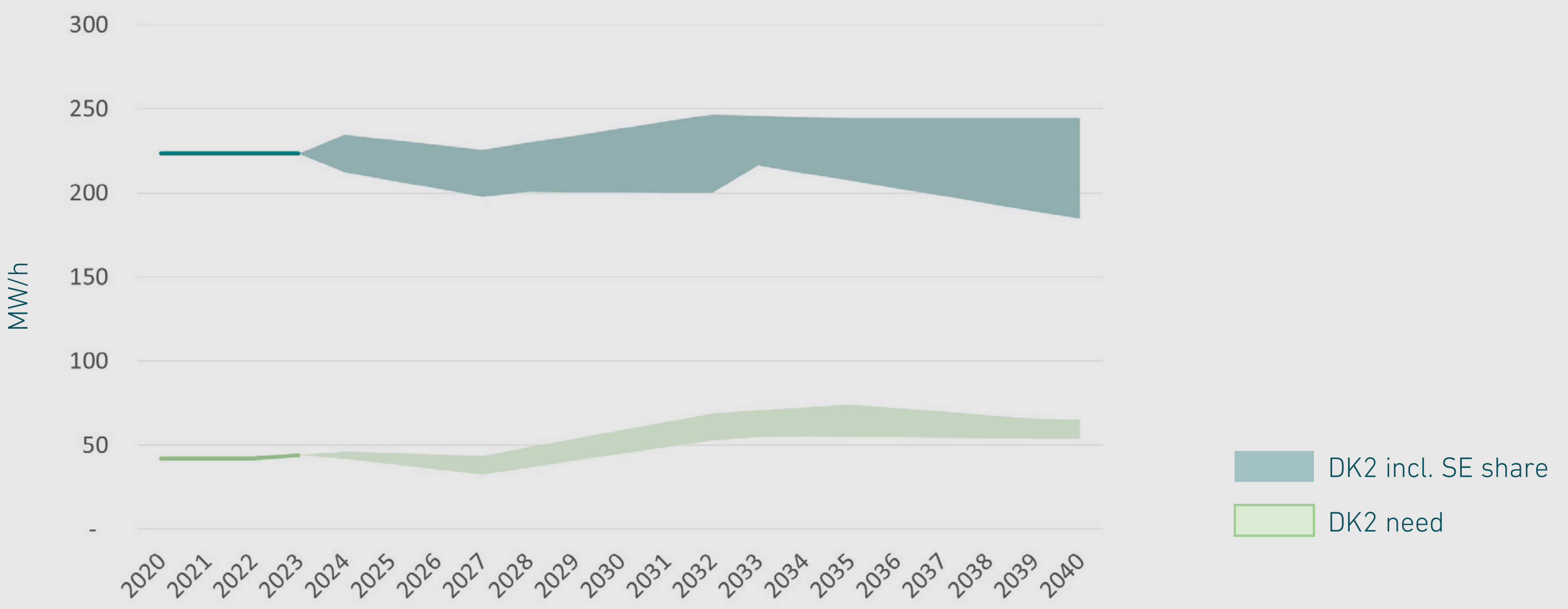
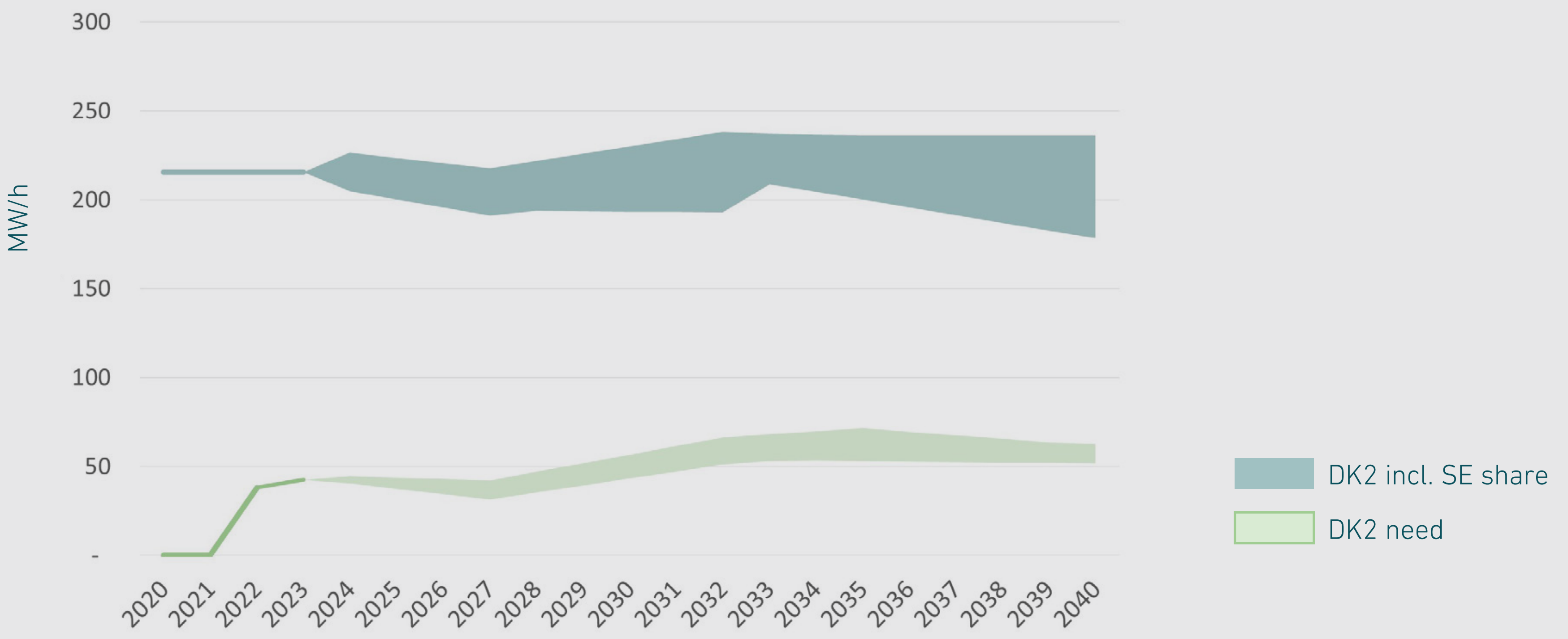


FIGURE 13 DEVELOPMENT IN FORECASTED NEED FOR FCR-D DOWN-REGULATION, DK2-SE



STATUS: FCR-N DK2, FREQUENCY CONTAINMENT RESERVE FOR NORMAL OPERATION

INTRODUCTION

FCR-N, Frequency Containment Reserve - Normal, also known as Primary Reserve, is designed to continuously stabilize the frequency in the power grid in DK2 and the rest of the Nordic synchronous area, and in the event of frequency drops or deviations. FCR-N is automatically activated based on measurements of the frequency in the power grid.

FCR-N is activated when the frequency deviates from 50 Hz and falls within the frequency band of 49.9-50.1 Hz. FCR-N is a symmetric product, meaning that both up-regulation and down-regulation must be provided. FCR-N follows the frequency proportionally, which means that it delivers 100% when the frequency is outside the band of 49.9-50.1 Hz.

Energinet procures FCR-N on a joint Danish-Swedish market with Svenska kraftnät. The market trades on an hourly basis and has a combined Danish-Swedish need of approximately 231 MW for FCR-N, with a Danish share of 18 MW in 2022. Like FCR-D, Danish BSPs can cover 1/3 of the Swedish need, making the maximum Danish procurement 104 MW.

FCR-N has a high activation rate since it is activated within the frequency range 49.9 Hz to 50.1 Hz. This means that FCR-N deliveries involve significant energy activation, resulting in energy payments based on the best of the regulating power price and spot price. As FCR-N is symmetric (both up-regulation and down-regulation), it typically reduces the overall energy from an FCR delivery since up-regulations and down-regulations tend to balance each other out over time.

In 2023, approximately 35 MW of new facilities have been prequalified to deliver FCR-N in DK2.

FIGURE 14 HOURLY PROCUREMENT OF PRIMARY RESERVE, FCR-N, IN DK2

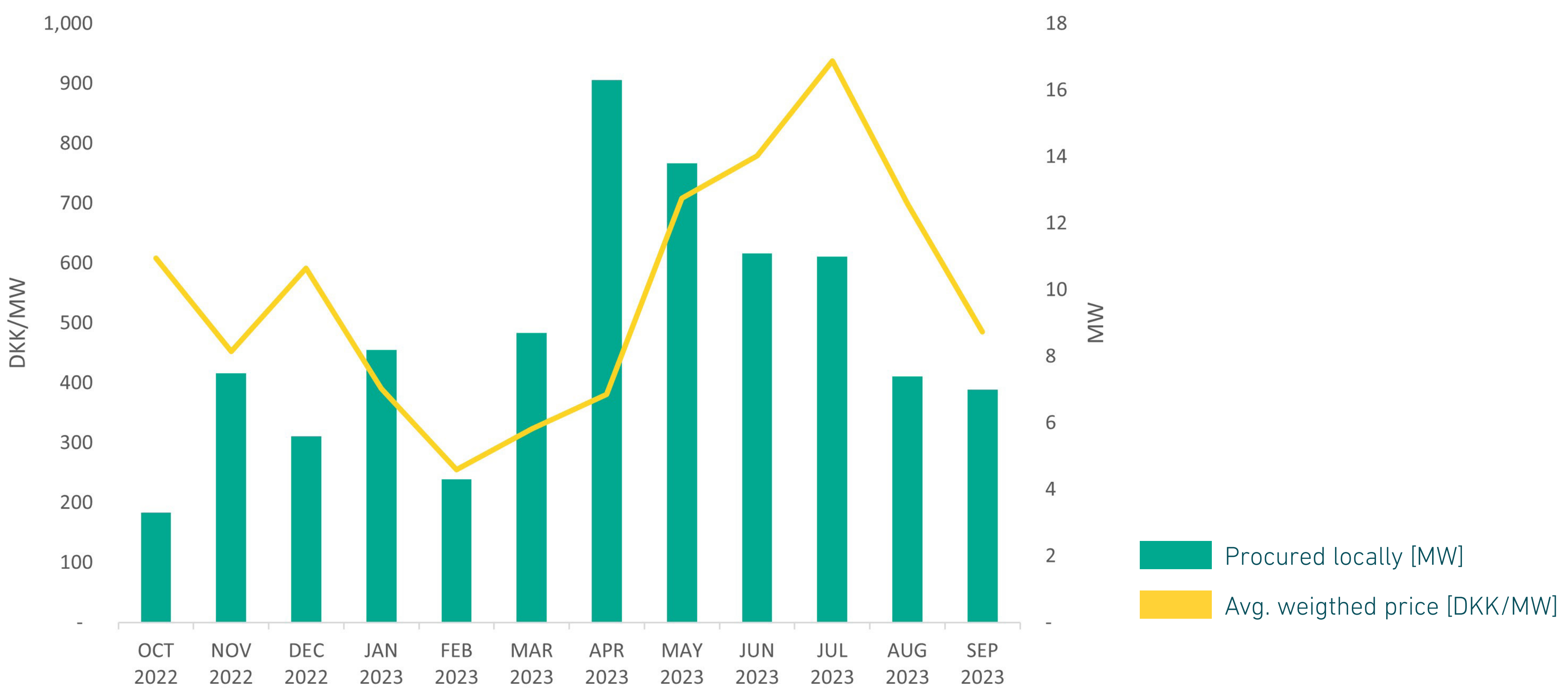
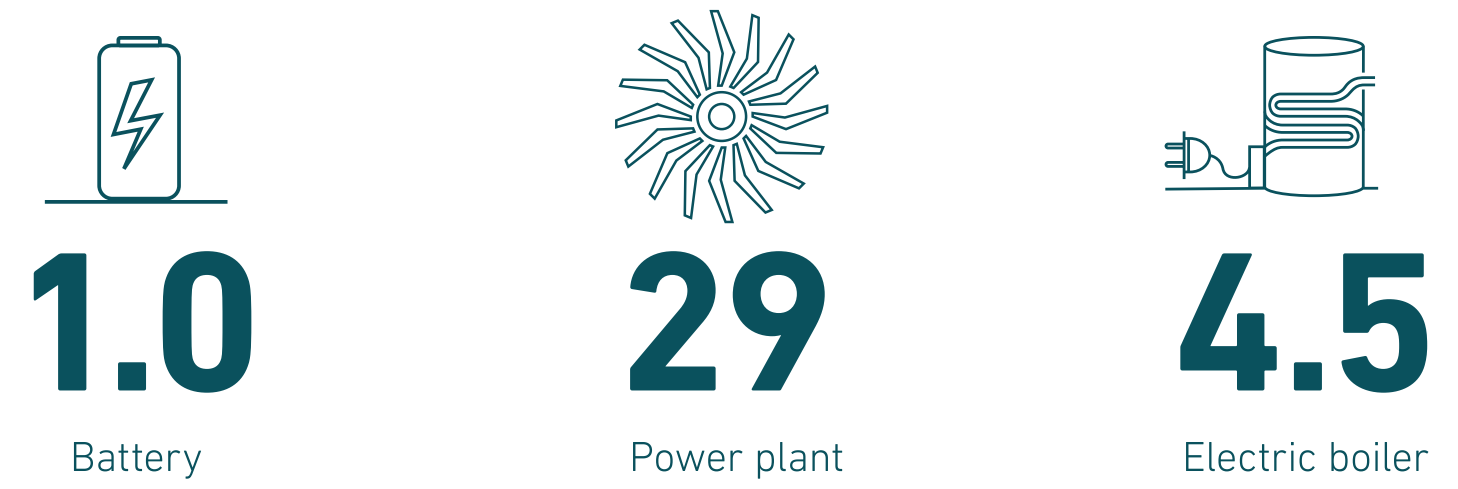


FIGURE 15 PREQUALIFIED FCR-N CAPACITY [MW] DISTRIBUTED ON TECHNOLOGY TYPE [2023]



FORECAST: DEVELOPMENT IN FCR-N NEED DK2

The FCR-N (Frequency Containment Reserve - Normal) is currently dimensioned based on a historical assumption that consumption can vary relatively quickly by approximately 1% of 60 GW, resulting in a minimum Nordic requirement of 600 MW. In the current projection, this assumption has not been changed, so only DK2's share has changed due to rising consumption and production, thereby increasing the Danish allocation key.

Currently, the Danish allocation key is 3%, but calculations show that it will increase to 4-5% by 2035. Based on AF22 assumptions, FCR-N is projected to increase 30-70% by 2035, similar to FCR-D.

There is an ongoing Nordic effort to re-evaluate FCR-N dimensioning, particularly in response to new activation rates for aFRR (automatic Frequency Restoration Reserve). However, it is too early to draw any inference about how this may affect the FCR-N requirement and volume.

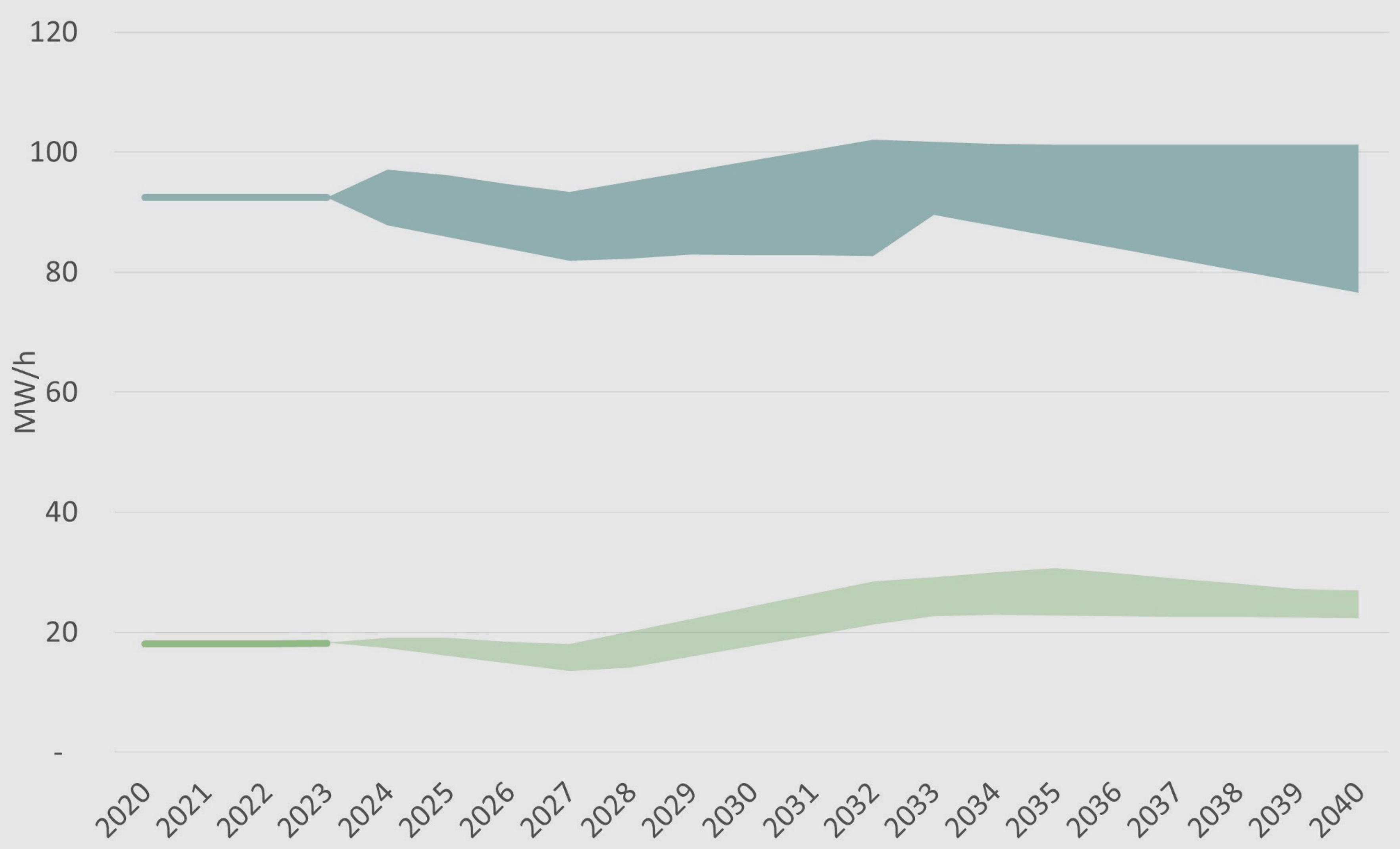
The Swedish share is expected to decrease slightly due to the phasing out of nuclear power plants, but the extent depends heavily on the climate year. Aggregating volumes for Eastern Denmark and Sweden, an increase is expected towards 2030, followed by a stagnation or a slight decrease in the share towards 2040. When including the Swedish share and the maximum Danish coverage of 1/3, the total market size for a Danish market participant is roughly 80-100 MW FCR-N.

UNDERLYING METHODOLOGY

Energy model results for 2025, 2030, 2033, and 2040 have been used to estimate electricity production and consumption in the Nordic synchronous area. This is converted into sharing keys assigned as a requirement to each country.

The sharing key calculations are naturally always one year behind, which is integrated as a one-year delay. The sharing key is then multiplied by 600 MW. Linear extrapolation has been used between the calculation years.

FIGURE 16 DEVELOPMENT IN FORECASTED NEED FOR FCR-N, DK2-SE



FREQUENCY RESTORATION RESERVES

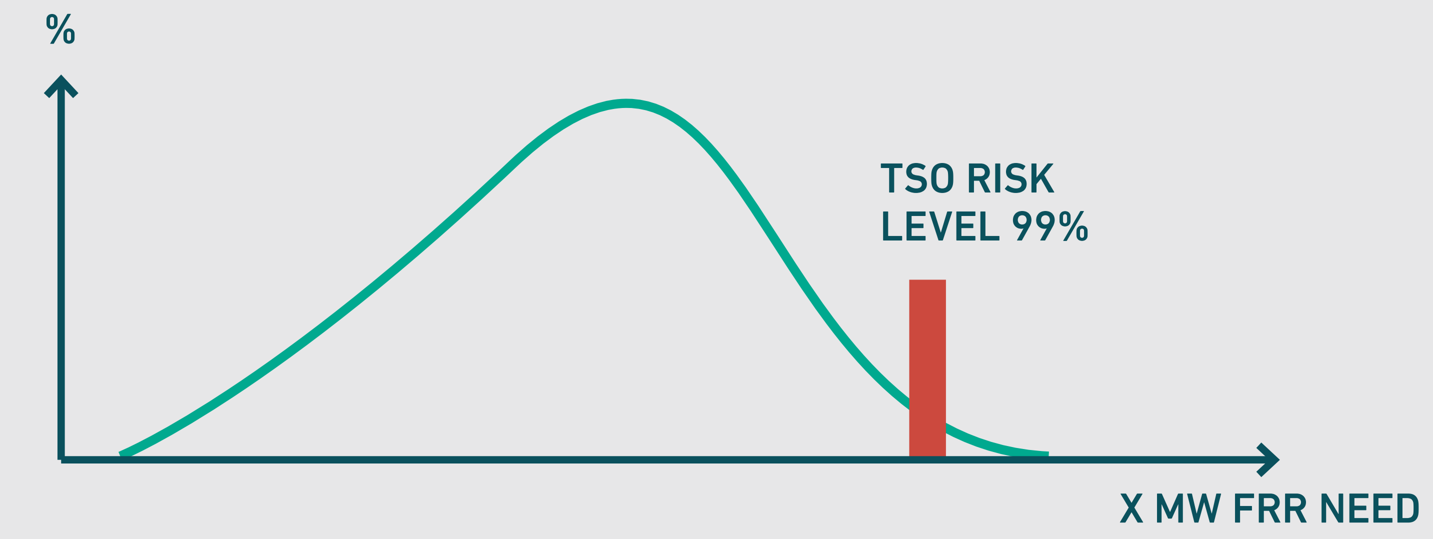
FORECAST: DEVELOPMENT IN FRR NEEDS DK1 AND DK2

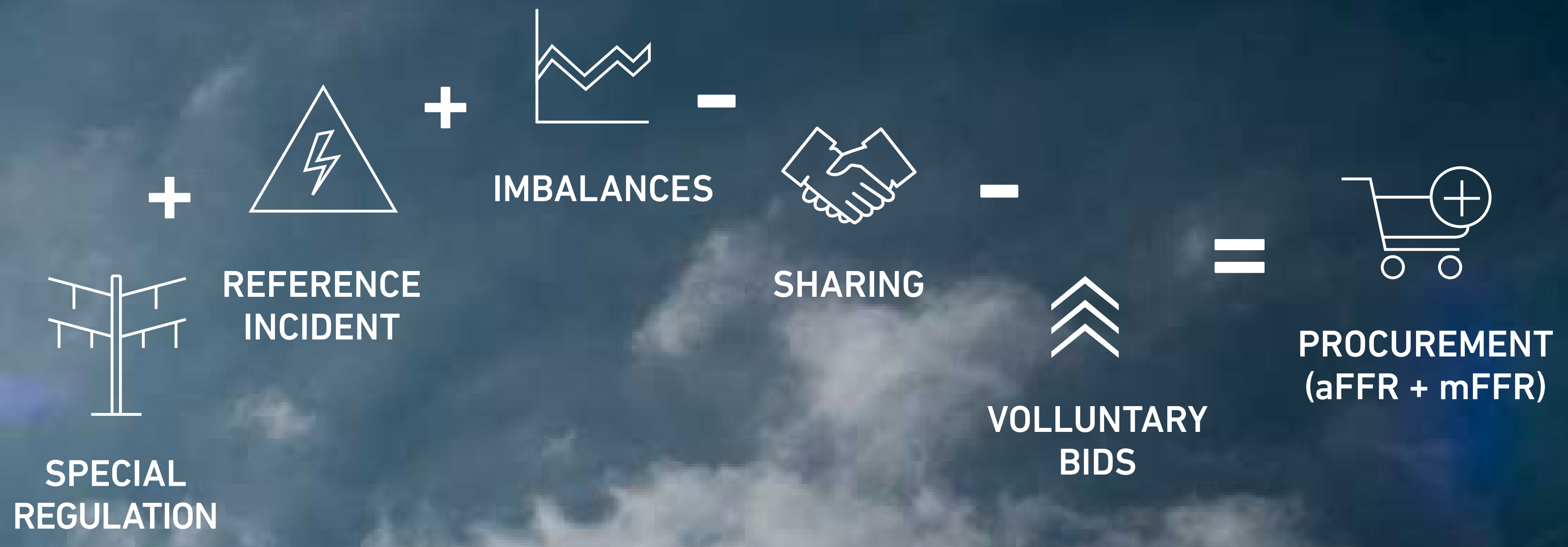
Frequency Restoration Reserve (FRR) consists of the manual Frequency Restoration Reserve (mFRR) and the automatic Frequency Restoration Reserve (aFRR). The sum of FRR resources must cover three most critical aspects: Special regulation (local needs), reference incident (N-1), and imbalances.

The sharing of reserves with other areas and voluntary bids must be subtracted from the total need, resulting in total FRR procurement needs for each area. The split between mFRR and aFRR is still under assessment; however, as a minimum, aFRR is meant to handle remaining needs after mFRR activation – to a certain extent.

Currently, dimensioning is solely based on the reference incident. The Nordic Dimensioning methodology will take effect by Q2/Q3 2024 for DK2 and by 2025 for DK1. Needs will then increase to mitigate the largest incidents simultaneously with imbalances within a given percentile. The TSOs' draft proposal suggests using a percentile in the range of P95 to P99.

This will be applied with an hourly resolution, with a TSO forecast ensuring resources to cover the agreed percentile.





Special regulation is added to FRR needs to be able to resolve local congestion within a bidding zone.

Reference incident (RI), also known as N-1, are the reserves required to cover the largest trip of a technical unit that an area can experience.

Imbalances are the actual mismatches between consumption and production, typically resulting from forecast errors in relation to consumption and variable renewables, etc.

NORDIC SHARING AGREEMENTS

Sharing agreements are traditionally made for highly dominant flow directions, where a fixed and constant amount is agreed. With the Nordic Dimensioning methodology, sharing will be assessed hourly and with sharing restrictions. These are the current principles discussed for sharing:

Imbalance principle: Each area must be able to cover its own imbalances.

Voluntary bid restrictions: An excess of voluntary bids cannot be utilized as sharing resources. HVDC restrictions: Sharing via HVDC is restricted to 600 MW, aggregated per interconnector.

Reference incident restrictions: Maximum sharing allowed between two areas is 50 % of the lowest RI of the two areas.

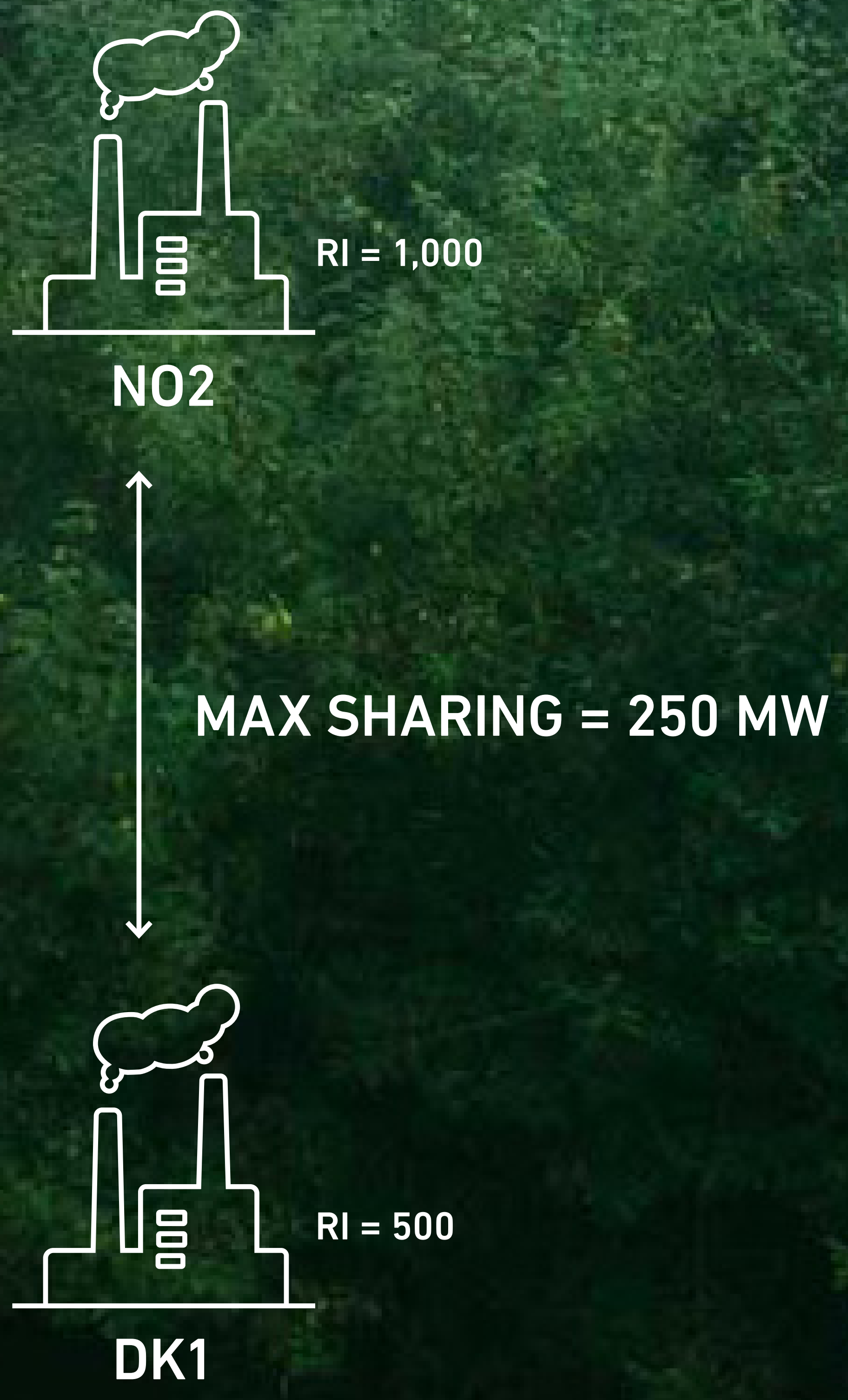
Nordic needs: There will be a minimum procurement level for each area in the Nordics to ensure a minimum of resources in every operational hour across the Nordics.

UNDERLYING METHODOLOGY

Imbalances and voluntary bids: Dimensioning is based on historical imbalances and voluntary bids on an hourly basis for 2022. Estimated imbalances from future renewable energy installations are added as the AF22 expansion progresses. The result is a development in imbalances based on which a 99/95 percentile is used for dimensioning.

N-1: Model results on an hourly basis for 2025, 2030, 2033, and 2040 have been used to estimate electricity production in Denmark. In the scenarios, the RI (single contingency) is also assessed on an hourly basis.

Sharing agreements: Energinet collaborates with the other Nordic TSOs on dynamic dimensioning, thus creating the dimensioning principles that will take effect.



FORECAST: METHODOLOGY FOR PREDICTED IMBALANCES

As mentioned, the Nordic Dimensioning methodology depends on the imbalances. Therefore, this outlook presents a prediction of future imbalances and procurement needs for aFRR and mFRR.

Method: Renewable energy units and other fluctuating production or consumption participate in the energy market based on forecasts. However, in real time, the forecasted and the actual values will differ, thus creating an imbalance.From a TSO perspective, these forecast errors, especially from wind and solar resources, are already evident at a system level. With increased capacity, these errors are thought to affect the imbalances of the system even more. The methodology for generating future imbalances is based on anticipated forecast errors with forecasts running one hour in advance. Hence, this includes errors, which hardly can be handled via the Intraday market. Hourly solar and wind production values for each simulation year and climate year are generated by BID and used for a stochastic process.

All solar and wind parks are used in a Monte Carlo simulation, yielding errors at plant level relative to the production level. Errors are summed for all plants, resulting in total system imbalances for each hour. The Monte Carlo methodology provides simultaneity in errors, meaning that errors can balance each other out, offering a more realistic output. Results also exclude any error bias, giving equal spread in both the upwards and downwards directions.

The simulated imbalances for 2025, 2030, 2033, and 2040 are shown in figures 17 and 18 for DK1 and DK2, respectively, (positive values are down-regulation and negative are up-regulation).

Compared to actual imbalance values from 2022, the simulated 2025 results for both DK1 and DK2 show a lower spread, which seems reasonable as the methodology only evaluates solar and wind errors and not imbalances from consumption, trading, and outages. The 2030, 2033, and 2040 results get increasingly more extreme, with 2040 as the year most prone to produce the largest imbalances for DK1. Even though the method does not evaluate all imbalances, the 2040 results are roughly 2-3 times the actual 2022 values and emphasise the need for balancing resources.

The large changes in imbalances from 2025 to 2030 for DK2 are the consequences of Bornholm Energy Island. With low geographical spread and large capacity, errors here will impact the system greatly. Likewise, for DK1 from 2030 to 2033, when North Sea Energy island is established.

Both aFRR and mFRR are to some extent designed to handle these imbalances. The split between aFRR and mFRR relies on the nature of the imbalances. Long-lasting imbalances will be countered by mFRR, while aFRR will address the remaining and more fluctuating imbalances. The upcoming pages will go through the results for aFRR and mFRR, respectively.

FIGURE 17 SOLAR AND WIND IMBALANCES IN DIFFERENT SIMULATION AND CLIMATE YEARS FOR DK1

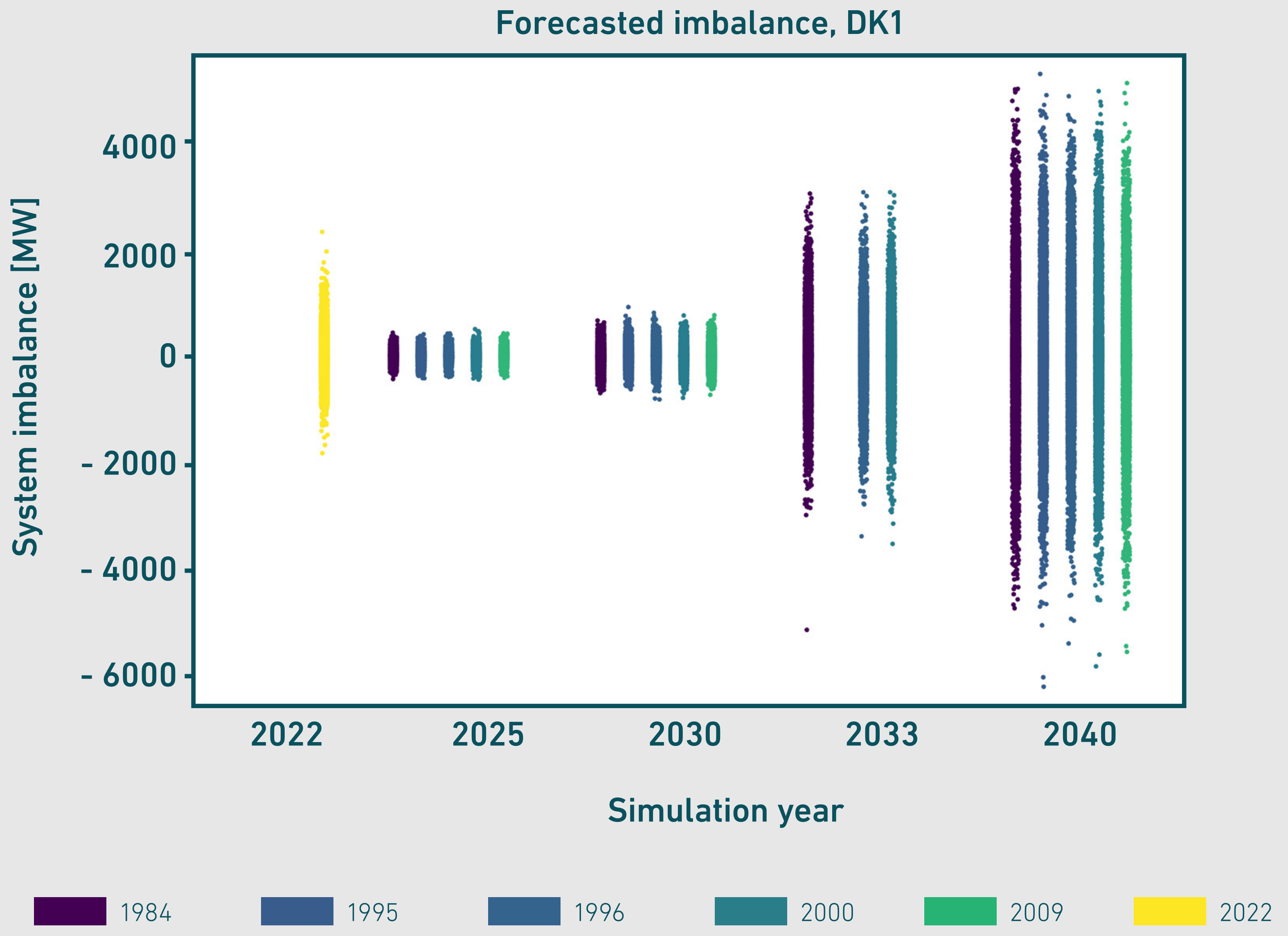
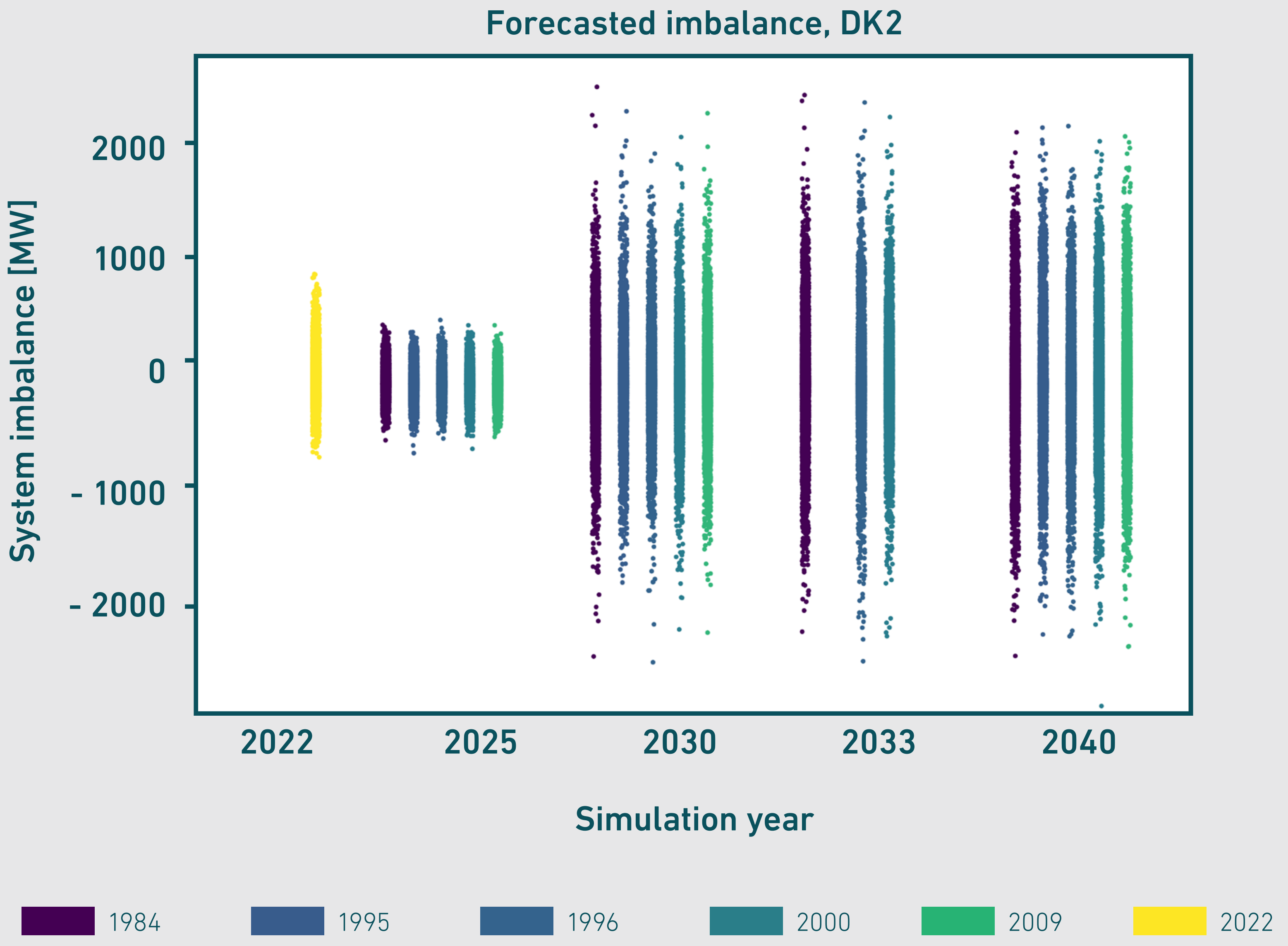


FIGURE 18 SOLAR AND WIND IMBALANCE IN DIFFERENT SIMULATION AND CLIMATE YEARS FOR DK2



The two graphs show the simulated hourly imbalances on the y-axis with the respective years on the x-axis, differentiated by various climate years represented by different colours. These simulations incorporate forecast errors derived from a Monte Carlo simulation.

STATUS: aFRR DK1, AUTOMATIC FREQUENCY RESTORATION RESERVE

INTRODUCTION

aFRR, Automatic Frequency Restoration Reserve, also known as the secondary reserve, helps to address large imbalances and regulates the frequency back to 50 Hz after the primary reserve, FCR, has stabilized the frequency. Overall, aFRR serves two purposes:

1. Frees up the primary reserve, FCR, by restoring the frequency to 50 Hz.
2. Restores imbalances on interconnections to the agreed plan.

aFRR is currently a symmetric product, which means that it involves both up-regulation and down-regulation of consumption and/or production or a portfolio of units that can provide regulation in each direction. The need for aFRR in DK1 is initially determined based on the recommendations of ENTSO-E RG CE and currently amounts to 100 MW in DK1.

Energinet procures aFRR capacity with energy commitment in weekly auctions exclusively for providers in DK1. The aFRR need in DK1 has been stable at 100 MW for many years. Previously, Energinet procured aFRR capacity with energy commitment in monthly auctions. However, from December 2021, Energinet has seen a lack of competition in the aFRR market in DK1. As a result, Energinet has changed the market design to encourage more bidders to participate.

During this period, Energinet had to force delivery in a few cases where no one was willing to deliver. In the case of a single bidder, settlement is made at the regulated price, and bidders have the right to ask for settlement with Cost Plus.

Efforts are being made to integrate DK1 in the Nordic aFRR capacity market in the long term. Until this is possible, changes will be made in the DK1 capacity market to improve the quality of the aFRR product and align the capacity market with the upcoming European aFRR energy market (PICASSO), thus targeting separate capacity and energy activation markets, as for mFRR.

In 2023, approximately 138 MW new facilities have been prequalified to deliver symmetrical aFRR in DK1.

FIGURE 19 HOURLY PRICES OF SECONDARY RESERVE, aFRR, IN DK1

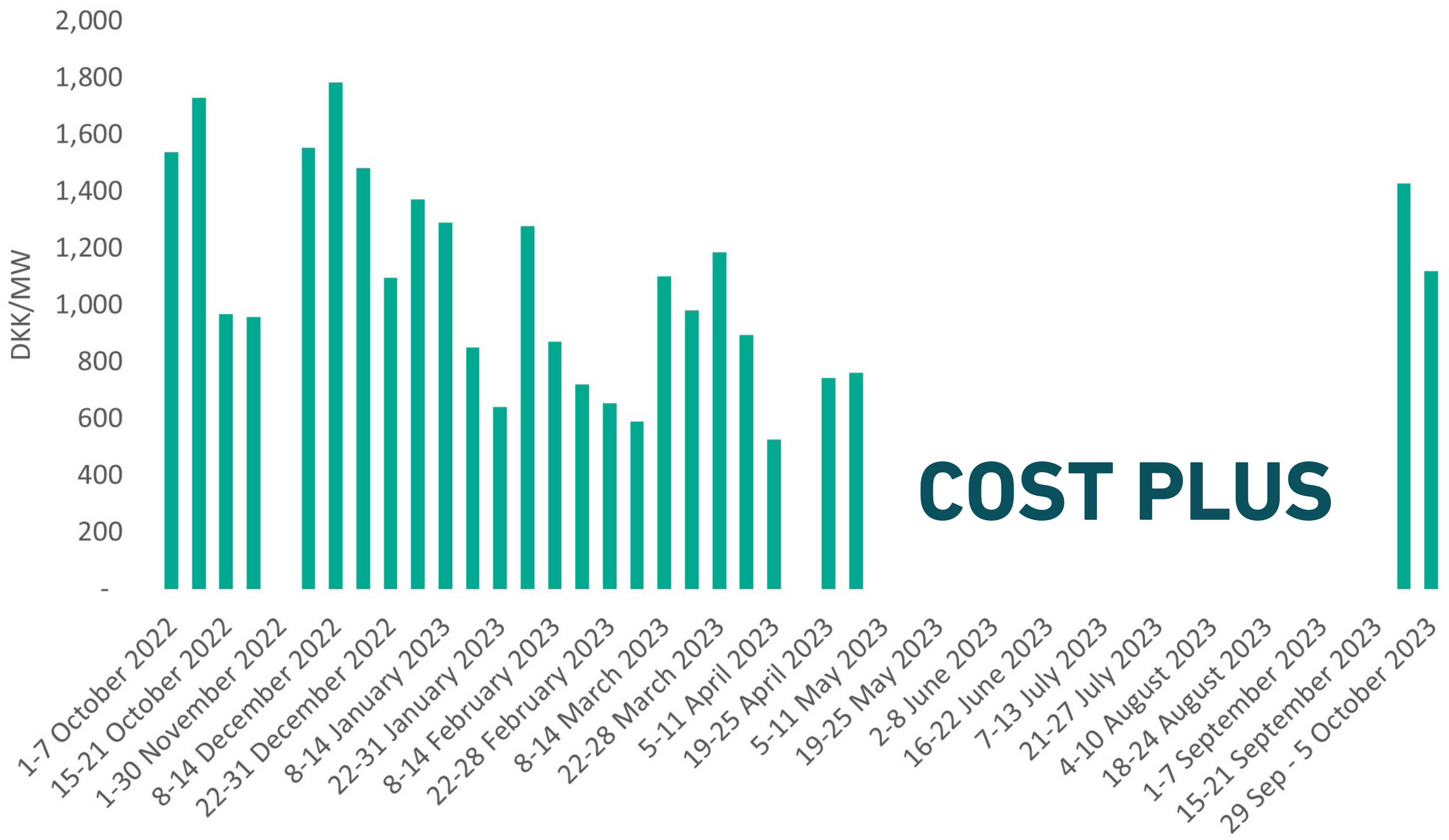
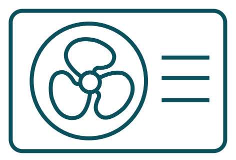
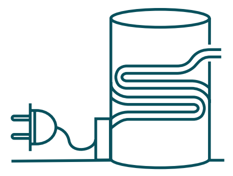


FIGURE 20 PREQUALIFIED aFRR CAPACITY [MW] IN DK1 DISTRIBUTED ON TECHNOLOGY TYPE [2023]



0.7

Heat pump



138

Electric boiler

FORECAST: DEVELOPMENT IN aFRR NEED DK1

The aFRR (automatic Frequency Restoration Reserve) requirement is based on the size of non-regulated imbalances (imbalances that are not countered by mFRR) and their duration, also known as Frequency Restoration Control Error (FRCE).

All TSOs are obligated to maintain FRCE values within certain limits stated in European regulation. DK1 is currently experiencing issues with the FRCE values and mitigating measures will soon become necessary. In the coming years, aFRR capacity and aFRR energy will be procured separately. In the beginning, capacity will be acquired in a local DK1 market, with the possibility of a Nordic capacity market in the future. aFRR energy will be procured in the European aFRR energy market, PICASSO, also with separate up-regulation and down-regulation.

Historically, the procurement need in DK1 has been 100 MW. This is not expected to change until the technical requirements for aFRR in DK1 are changed to a full activation time of 5 minutes rather than 15 minutes. Energinet's analyses indicate that increased aFRR capacity with 15-minute full activation time (FAT) does not improve FRCE values significantly. Therefore, an increased aFRR requirement is not expected until aFRR transitions to markets with 5-minute FATs (Nordic aFRR CM and PICASSO). Thus, the lower limit of forecasted values remains 100 MW until the FAT changes. The results for up-regulation and down-regulation line up until 2027. The need slowly increases towards 2030, and in 2033 it increases significantly. The main reason is the large increase in capacity from solar and wind parks. The resulting 2030 needs are slightly reduced compared to assumptions from last year (20 MW).

This is only the DK1 need. However, in the coming years, DK1 market participants will also be able to make bids in international aFRR capacity markets, either Nordic or Pan-European. Looking only at the Nordic capacity market, DK1 can export roughly 300 MW.

UNDERLYING METHODOLOGY

The dimensioning of aFRR is calculated by assessing imbalances at minute level, where aFRR is determined as the difference between the running 5-minute and 15-minute average imbalances. The resulting aFRR requirement is determined based on the 2.5th percentile for both directions. The aFRR need is projected by following an assumed development in the properties of imbalances. Imbalances are generated stochastically and with a strong correlation to production from renewables. The remaining need to cover imbalances is handled with mFRR.

FIGURE 21 DEVELOPMENT IN FORECASTED NEED FOR aFRR UP-REGULATION FOR DK1

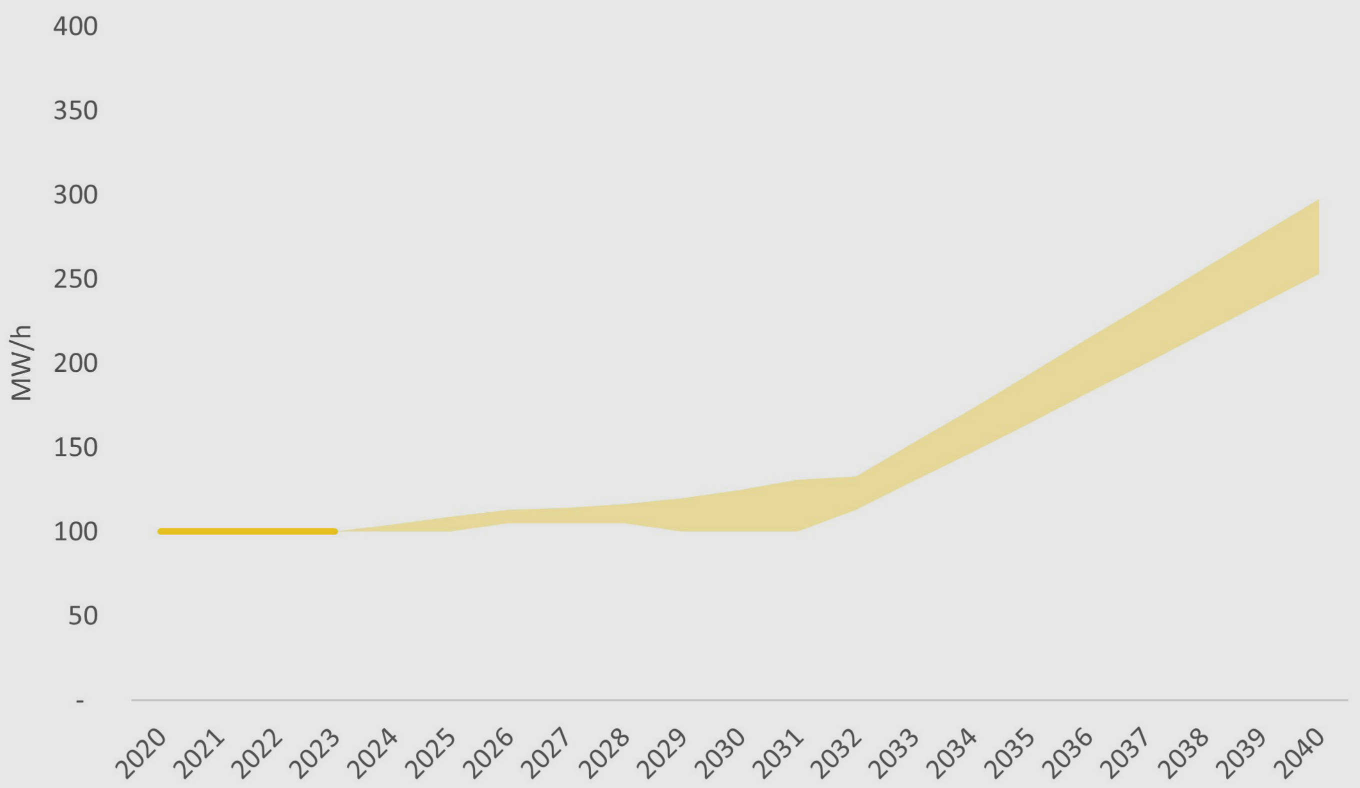
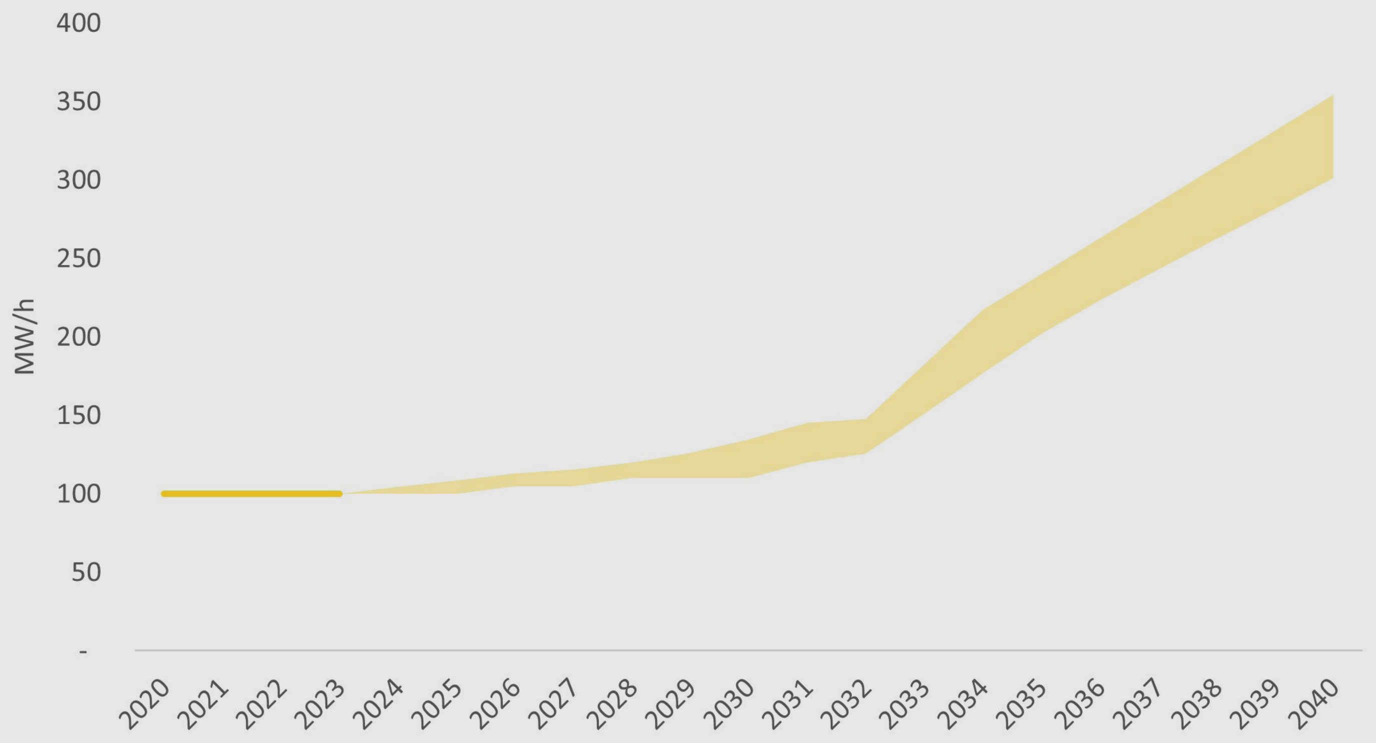


FIGURE 22 DEVELOPMENT IN FORECASTED NEED FOR aFRR DOWN-REGULATION FOR DK1



STATUS: aFRR DK2, AUTOMATIC FREQUENCY RESTORATION RESERVE

INTRODUCTION

aFRR, Automatic Frequency Restoration Reserve, also known as the secondary reserve, helps to address large imbalances and regulates the frequency back to 50 Hz after the primary reserves, FCR-D and FCR-N, have stabilized the frequency. In general, aFRR serves two purposes:

1. Frees up the primary reserve, FCR, by restoring the frequency to 50 Hz.
2. Restores imbalances on interconnections to the agreed plan.

aFRR is procured as an asymmetric product, which means separate procurement of up-regulation and down-regulation. The need for aFRR in DK2 is initially determined based on the recommendations of all Nordic TSOs and currently amounts to +/- 0/38/52 MW in DK2.

Energinet procures aFRR capacity in DK2 based on current need, primarily assessed continuously by all Nordic TSOs. aFRR is procured for hour 1 and hours 6-24 every day, with a volume of 300 MW in most hours and 400 MW in the morning hours on weekdays. In the late evening hours, 400 MW of down-regulation is also procured.

The current Danish need is: +/- 0/38/52 MW. aFRR is procured hourly in a common Nordic market, with separate auctions for up-regulation and down-regulation.

aFRR energy deliveries are settled as follows: Up-regulation is settled either at the maximum of the spot price in DK2, or the regulation price in DK2 for up-regulation. Down-regulation is settled either at the minimum of the spot price in DK2, or the regulation price in DK2 for down-regulation.

Figure 23 shows procured capacity per hour and the average hourly price per MW. The figure indicates, that Danish market participants have supplied a relatively small share of the Nordic demand, which is surprisingly little compared to Energinet's expectations. At the same time, it is evident that the price has remained relatively stable over the period.

FIGURE 23 HOURLY PROCUREMENT OF SECONDARY RESERVES, aFRR, IN DK2

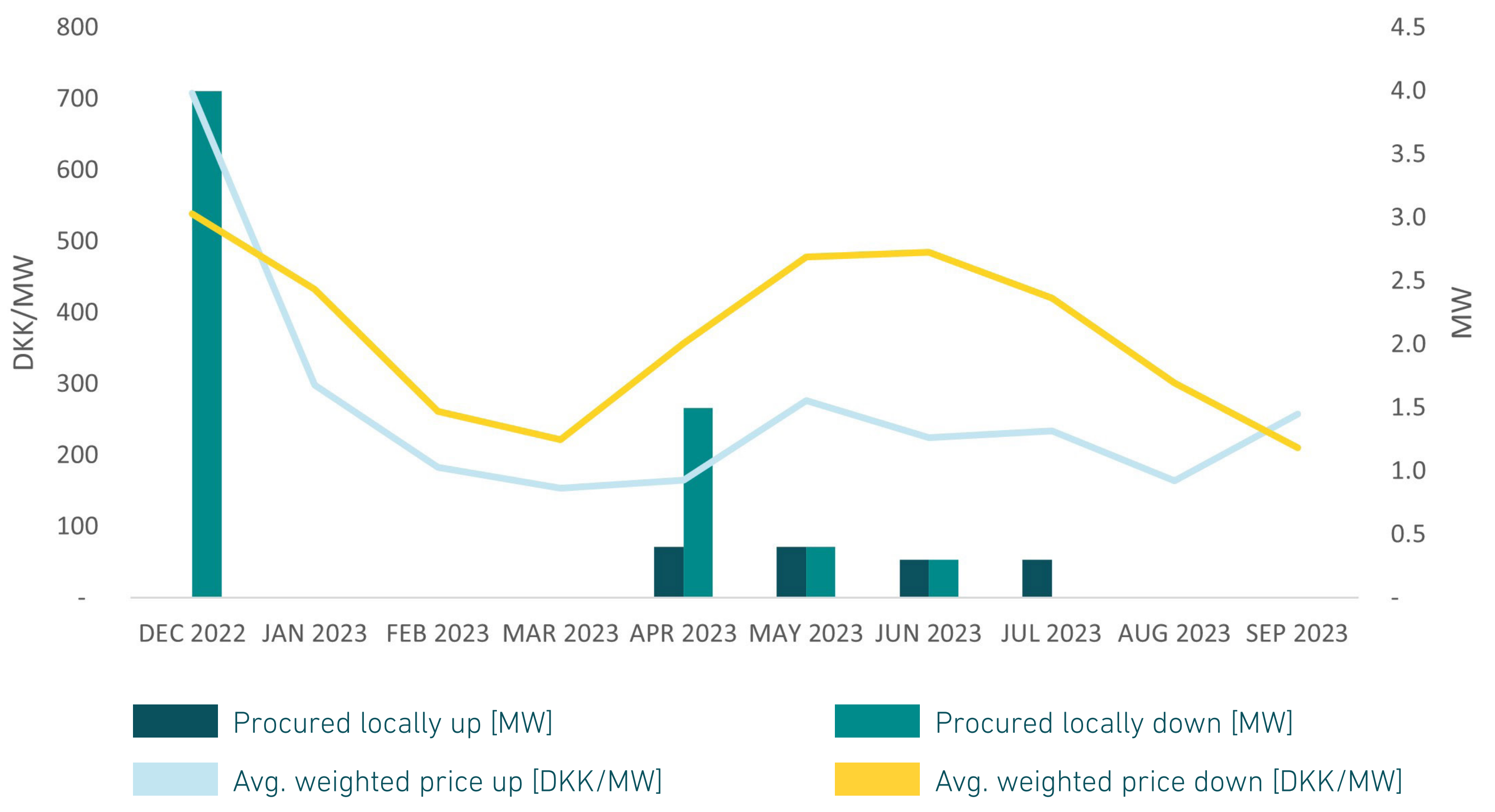
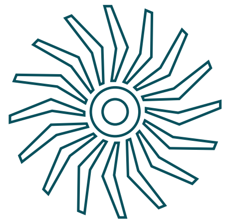
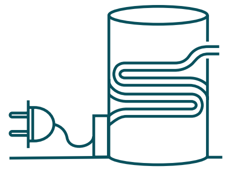


FIGURE 24 PREQUALIFIED aFRR CAPACITY [MW] IN DK2 DISTRIBUTED ON TECHNOLOGY TYPE [2023]



86

Power plant



20

Electric boiler

FORECAST: DEVELOPMENT IN aFRR NEED DK2

The aFRR (automatic Frequency Restoration Reserve) requirement is based on the size of non-regulated imbalances (imbalances that are not countered by mFRR) and their duration, also known as Frequency Restoration Control Error (FRCE).

All TSOs are obligated to ensure FRCE values in an area that does not exceed certain limits stated in European regulation. Currently for DK2, this is handled at a Nordic block level, meaning that a centralized regulation signal is sent to each of the Nordic areas with pro rata activation. In the coming years, FRCE responsibility will be transferred to each bidding zone, meaning that DK2 must dimension and activate based on local DK2 imbalances.

In DK2, aFRR capacity is procured in a Nordic aFRR capacity market. With this market, 10% of cross-zonal capacity can be reserved for exchange of aFRR across bidding zones, which increases the possibilities of exporting aFRR beyond the projected need. Export options include 170 MW to SE4 and an additional 60 MW to DK1, meaning that an additional 230 MW can be added to the DK2 need shown in the figure to the right.

In the coming years, aFRR capacity and energy will be separated. aFRR energy will be procured in the European aFRR energy market, known as PICASSO, providing Danish market participants the opportunity to deliver to a large aFRR energy market where countries like Germany have needs in the GW scale. The aFRR requirement in DK2 for 2023 is approximately 40 MW for both up-regulation and down-regulation. However, when moving to DK2 imbalances, the current need will be around 50 MW.

In DK2, the aFRR need escalates quicker due to the upcoming Hesselø and Bornholm Energy Island projects. As a result, the need in 2035 is roughly 2-3 times the current estimated need. From 2035 to 2040, the prediction seems to only increase slightly.

UNDERLYING METHODOLOGY

The dimensioning of aFRR is calculated by assessing imbalances at a minute level, where aFRR is determined as the difference between the running 5-minute and 15-minute average imbalances. The resulting aFRR requirement is determined based on the 2.5th percentile for both directions. The aFRR need is projected by following an assumed development in the properties of imbalances. The imbalances are generated stochastically and with a strong correlation to the production from renewables. The remaining need to cover imbalances is handled with mFRR.

FIGURE 25 DEVELOPMENT IN FORECASTED NEED FOR aFRR UP-REGULATION IN DK2

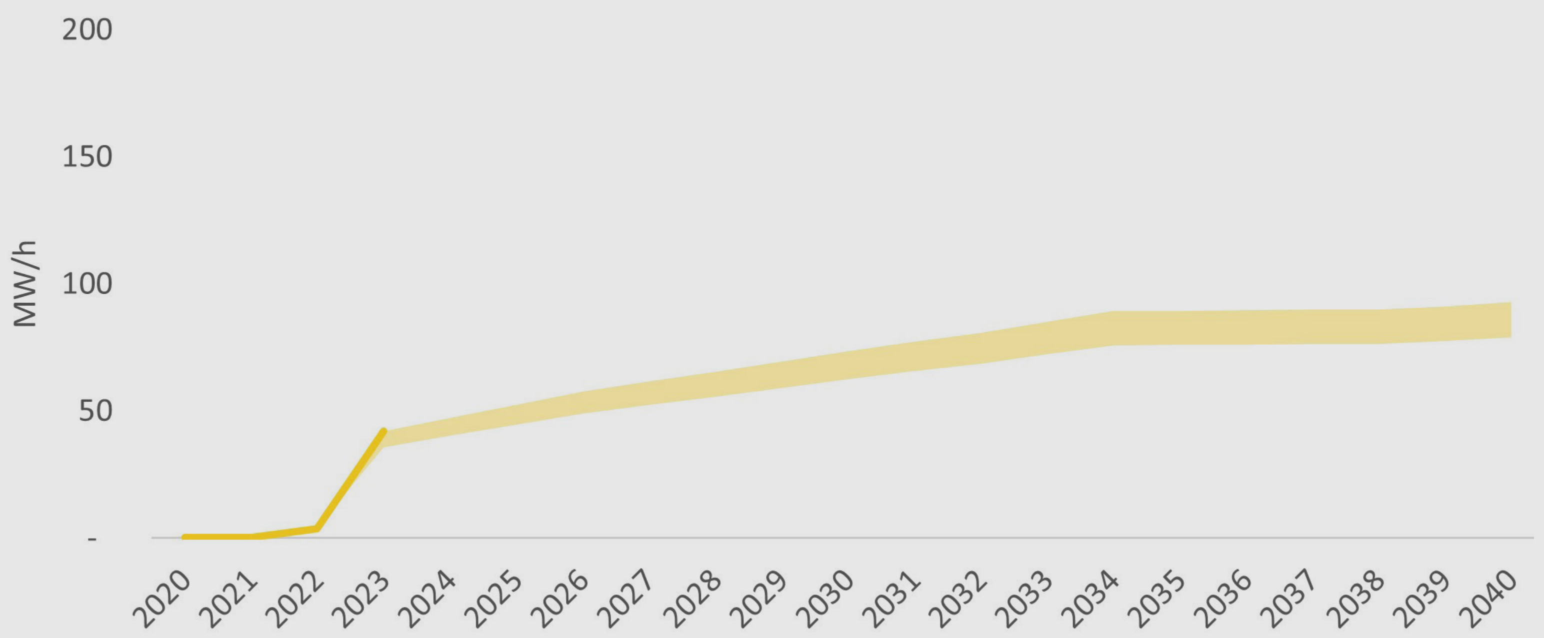
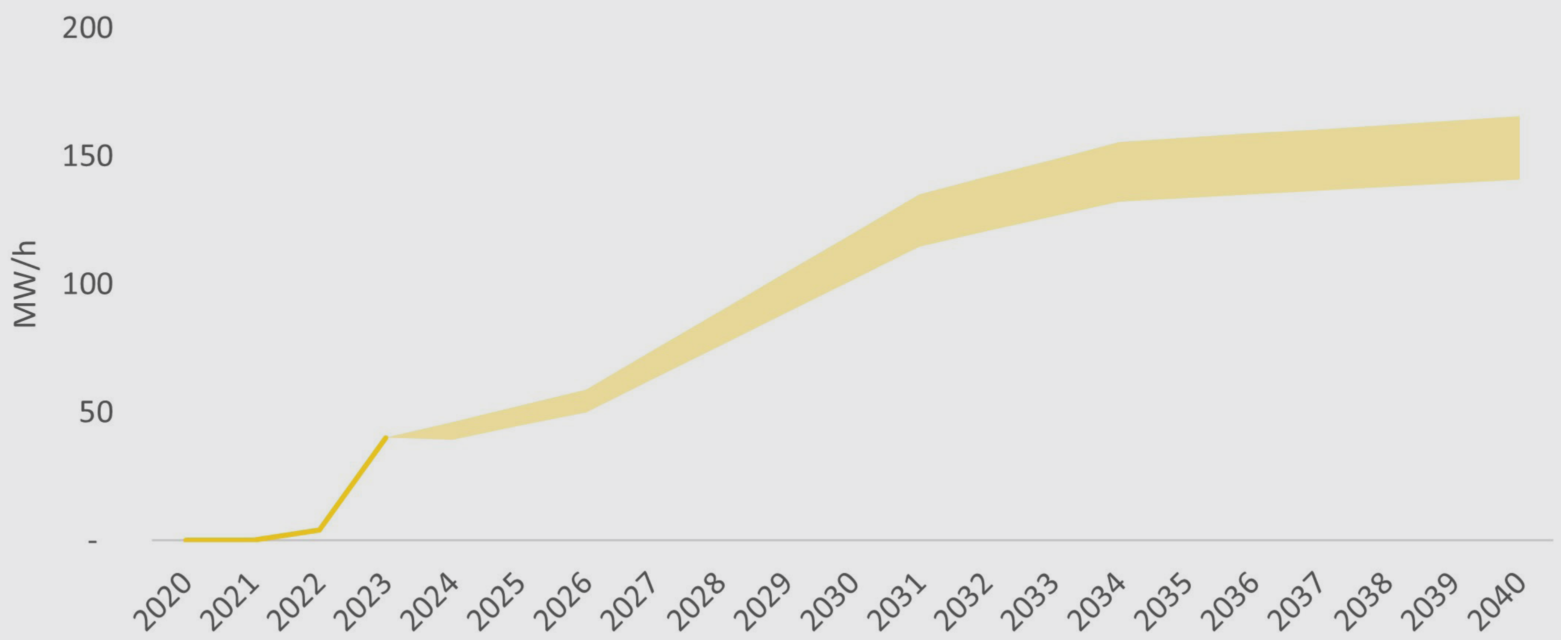


FIGURE 26 DEVELOPMENT IN FORECASTED NEED FOR aFRR DOWN-REGULATION IN DK2



STATUS: mFRR DAILY AUCTION DK1 AND DK2, MANUAL FREQUENCY RESTORATION RESERVE

INTRODUCTION

mFRR, Manual Frequency Restoration Reserve, helps to alleviate major imbalances and ensures that manual reserves maintain balance in the power system during extended periods of unplanned fluctuations in production or consumption. Energinet utilizes proactive activation, which means that imbalances are forecasted, and efforts are made to mitigate their magnitude through mFRR activation.

mFRR is an asymmetric product, where up-regulation and down-regulation are procured separately. Energinet only procures up-regulation capacity for availability. Energinet can activate energy in both the up-regulation and down-regulation directions by purchasing up-regulation or down-regulation bids from the common Nordic balancing market.

Energinet procures mFRR, Manual Frequency Restoration Reserve, to secure the necessary capacity in the energy activation market. This means that when offering mFRR capacity to Energinet, market participants commit themselves to ensuring that capacity is available as energy bids in the mFRR energy market. Capacity prices for mFRR and energy prices for mFRR are set independently, and market participants are remunerated separately for capacity and energy.

mFRR capacity is procured on an hourly basis at daily auctions in a common market between DK1 and DK2. The common market between DK1 and DK2 has been live since June 2023. With the common market, it is possible to exchange capacity between DK1 and DK2 via the Great Belt Connection. This means that demand in one area can be covered by supply in another area. Reservations of transmission capacity ensure that energy can be transferred at any point in time.

The need for mFRR is based on the loss of the largest local unit (reference incident). The resulting mFRR demand in DK1 is 284 MW, because a sharing agreement between DK1 and DK2 reduces demand in DK1 by 300 MW. aFRR procurement of 100 MW in DK1 reduces the need for mFRR as well. The demand in DK2 is 600 MW.

FIGURE 27 HOURLY PROCUREMENT OF MANUAL RESERVE, mFRR

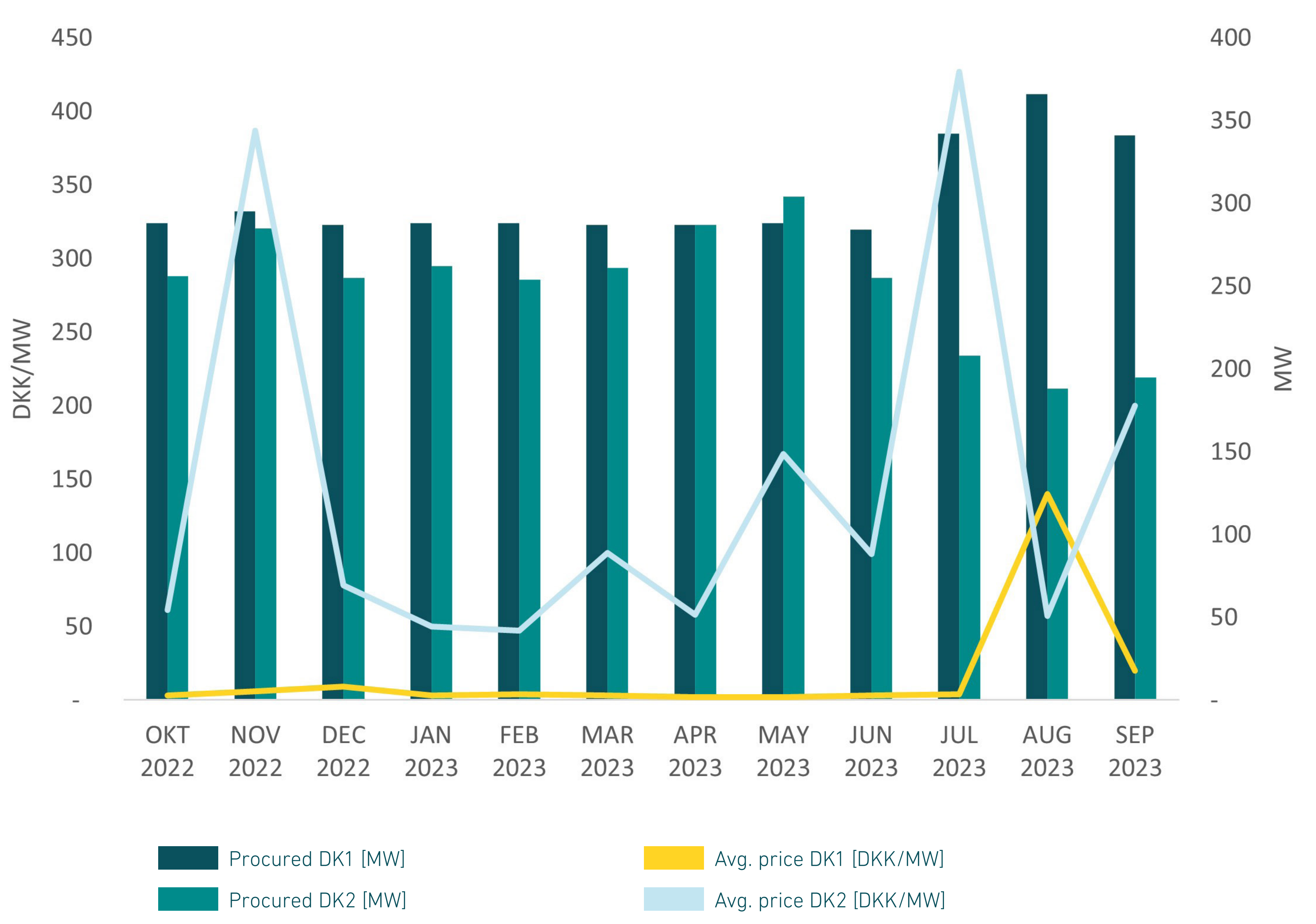


FIGURE 28 PREQUALIFIED mFRR CAPACITY [MW] DISTRIBUTED ON TECHNOLOGY TYPE [2023]

	Power plant	Electric boiler	Heat pump	Diesel engine	Battery
DK1	20	301	1.3	0.0	0.0
DK2	0.0	10	0.0	3.8	0.4

"In 2023, 322.3 MW new facilities have been prequalified to deliver mFRR in DK1, and 14.2 MW have been prequalified to deliver mFRR in DK2. Figure 28 shows the share of different technologies. In both DK1 and DK2, electric boilers have contributed the largest share of mFRR prequalified units."

FORECAST: DEVELOPMENT IN mFRR NEEDS DK1

Energinet currently procures 284 MW mFRR. COBRAcable is the reference incident at 684 MW. DK1 has a 300 MW sharing agreement with DK2 and aFRR procurement of 100 MW, bringing the remaining requirement to 284 MW mFRR.

In coming years, DK1 is expected to join the Nordic Dimensioning methodology and, consequently, procure mFRR for imbalances and down-regulation. Currently, this has been deemed unnecessary due to many voluntary bids. However, with the lack of bids for special regulation, the number of voluntary bids is expected to decline and may eventually lead to a procurement need.

The Outlook does not include a prediction of voluntary bids, mainly because of the many related uncertainties and the fact that the number might be insignificant. If voluntary bids were to be included, this could decrease the procurement need.

The spread in mFRR procurement is caused by interconnector flows and imbalances from wind and solar resources in the different climate years.
The reference incident towards 2030 will typically be the highest values of COBRAcable and Viking Link, but both with a single point of failure of 700 MW (Viking Link has a 700 MW contingency plan that involves Germany).

When North Sea Energy Island is commissioned in 2033, the largest incident will, in windy periods with full import, be 1 GW, equal to one of the HVDC interconnectors. This means that it is expected that the reference incident at this time will increase to 1000 MW in DK1, but no final decision has been made yet.

In addition, the 4 GW wind capacity, which is installed within a limited geographical space, is more prone to forecast errors. Even minor forecast errors in percentages has a high impact when scaled to 4 GW. Compared to the 2022 level, the increase in mFRR procurement in 2030 and 2035 is 2-3 and 5-8 times the 2022 level, respectively. Note that these numbers are based on future forecast errors involving high uncertainty.

With dynamic dimensioning, capacity procurement will be assessed for each hour, meaning that only windy periods will yield imbalance needs of this size. Compared to last year's predictions for 2030, the spread has been reduced significantly. The lower limit has changed from 230 MW to 570 MW and the upper limit from 900 MW to 800 MW. This is a small down-scaling in 2030, but a significant increase towards 2033 compared to last year's predictions.

Concerning North Sea Energy Island, there are still two uncertainties. One is whether Energinet will be allowed to require mandatory down-regulation bids. The other is whether the imbalances are to be transferred to DK2. Both will result in a decrease in procurement levels.

FIGURE 29 DEVELOPMENT IN FORECASTED NEED FOR mFRR UP-REGULATION IN DK1

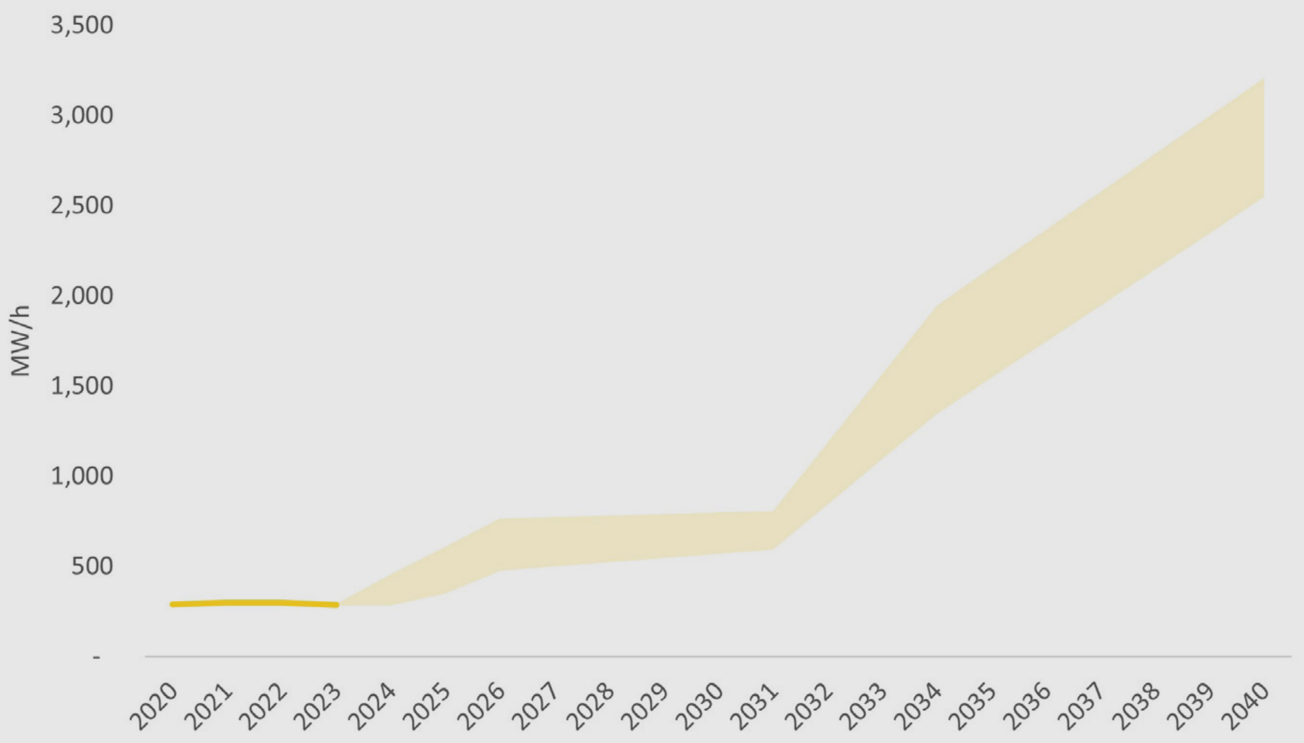
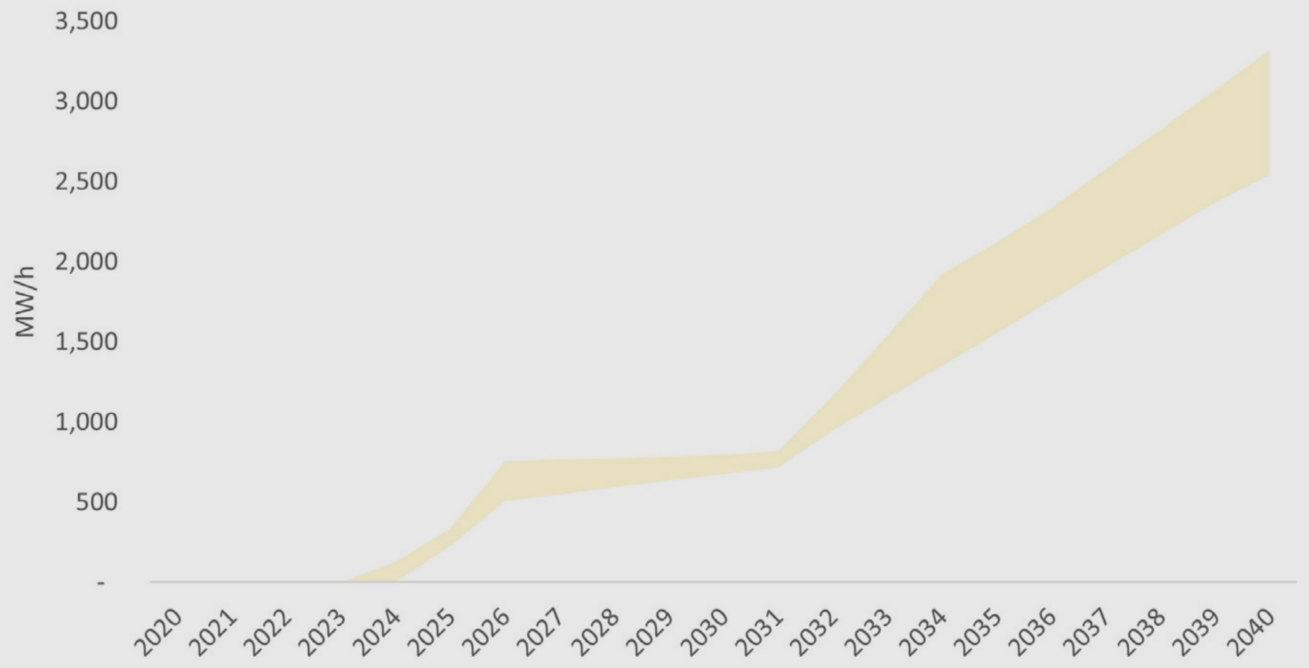


FIGURE 30 DEVELOPMENT IN FORECASTED NEED FOR mFRR DOWN-REGULATION IN DK1



STATUS: mFRR MONTHLY AUCTION DK2

INTRODUCTION

mFRR, Manual Frequency Restoration Reserve, helps to alleviate major imbalances and ensures that manual reserves maintain balance in the power system during extended periods of unplanned fluctuations in production or consumption. Energinet utilizes proactive activation, which means that imbalances are forecasted, and efforts are made to mitigate their magnitude through mFRR activation.

mFRR is an asymmetric product, where up-regulation and down-regulation are procured separately. Energinet only procures up-regulation capacity for availability. Energinet can activate energy in both the up-regulation and down-regulation directions by purchasing up-regulation or down-regulation bids from the common Nordic balancing market.

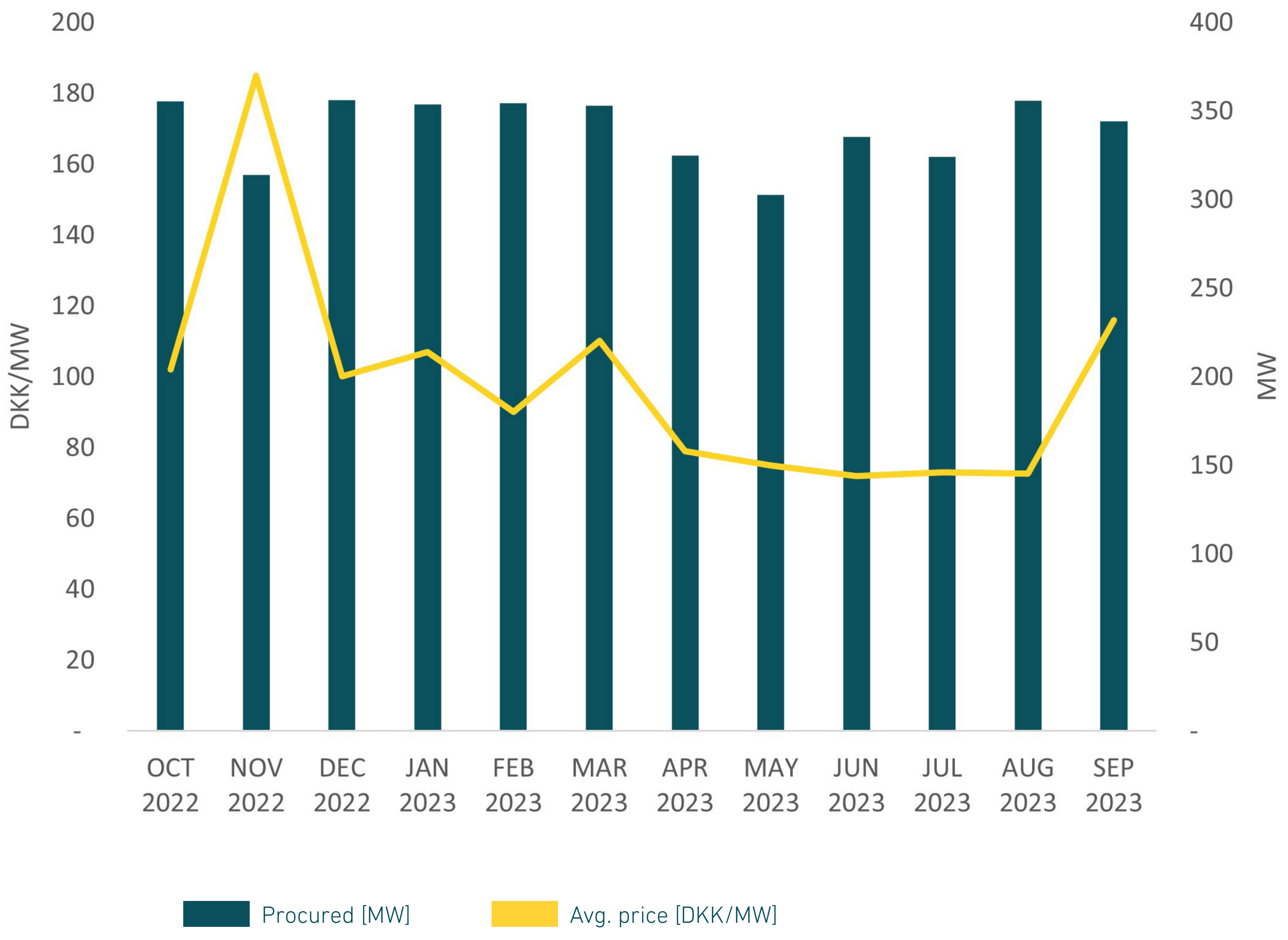
The monthly mFRR up-regulation auction is only applicable in DK2. The monthly market is only meant to cover a maximum of 60% of the mFRR need. The total need in DK2 is 600 MW, making the maximum procurement through monthly auctions 360 MW.
In the monthly mFRR auction, part of the assets can have a response time of up to 90 minutes, compared to the standard product with a response time of 15 minutes.

Energinet has the option to procure up to 300 MW slower reserves due to a sharing agreement with Svenska kraftnät. Slower reserves compete in the market equal to standard products up to the limit of 300 MW; hence, if standard product reserves are cheaper than slower reserves, standard products are activated.

Slower reserves are part of the market to increase competition and thus economic efficiency. Energinet does not plan to remove neither the monthly auction nor the possibility to use slower reserves.

As is the case with standard mFRR reserves, slower mFRR reserves must also place energy bids in all contracted hours.

FIGURE 31 HOURLY PROCUREMENT OF MANUAL RESERVE FOR mFRR IN DK2



FORECAST: DEVELOPMENT IN mFRR NEED DK2

Currently, the need for mFRR in DK2 is 600 MW which represents a trip of the Øresund connection to Sweden (DK2-SE4), the Great Belt link (DK2-DK1), or Kontek (DK2-DE). Procurement is slightly higher due to full bid acceptance.

Today, no mFRR down-regulation is procured in DK2 due to the transit flow pattern, with electricity flowing through DK2 mostly either from DK1 or SE4. With the implementation of the Nordic Dimensioning methodology, down-regulation capacity will be required.

Please note that this outlook does not include a prediction of voluntary bids, mainly because of the many related uncertainties and the fact that the number might be insignificant. If voluntary bids were to be included, this could decrease the procurement need.

In DK2, the reference incident is nearly always close to 600 MW, due to either the Øresund, Great Belt, or Kontek connections operating at full flow. This applies to both up-regulation and down-regulation.

Bornholm Energy Island will not change this outcome as the HVDC connections are split into 600 MW sizes. Neither does it seem likely that the Hesselø project will affect this in any way.

As a result, the main increase in the mFRR capacity need in DK2 is founded in imbalances. However, imbalances alone have a significant impact on procurement levels. Compared to 2022, the mFRR need in 2030 is expected to increase by 33-200%. Note that these numbers are based on future forecast errors involving high uncertainty.

After 2030, the increase will wear off and the lower limit only increases slightly towards 2040.

Compared to last year's predictions, the 2030 results are nearly 300 MW higher, which is primarily a result of the upscaling of Bornholm Energy Island from 2 GW to 3 GW and the accelerated time plan for full operation.

As to Bornholm Energy Island, two possibilities are expected to lead to a decrease in the level of mFRR procurement. The first is implementation of mandatory down-regulation bids from the windfarms. The second opportunity is the fact that imbalances are either sent to DK2 or Germany. If imbalances are sent (partly) to Germany, this will lead to a lower mFRR need than forecasted.

FIGURE 32 DEVELOPMENT IN FORECASTED NEED FOR mFRR UP-REGULATION IN DK2

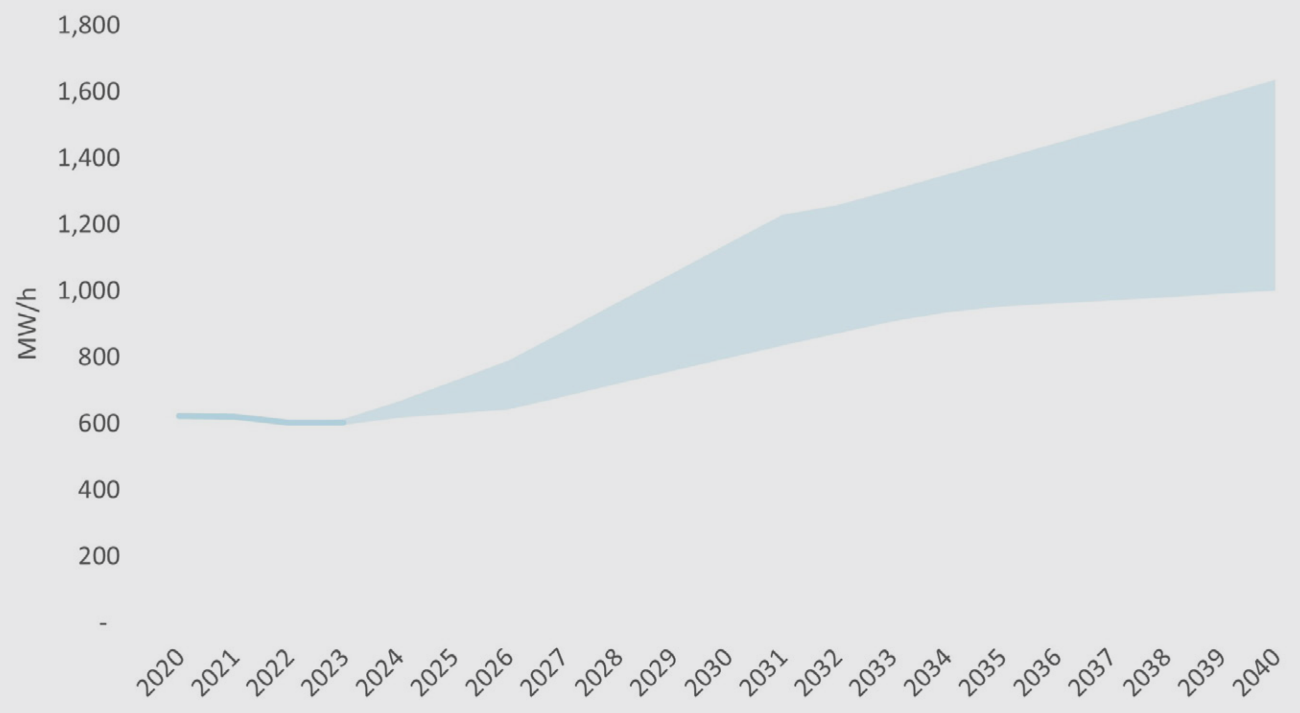
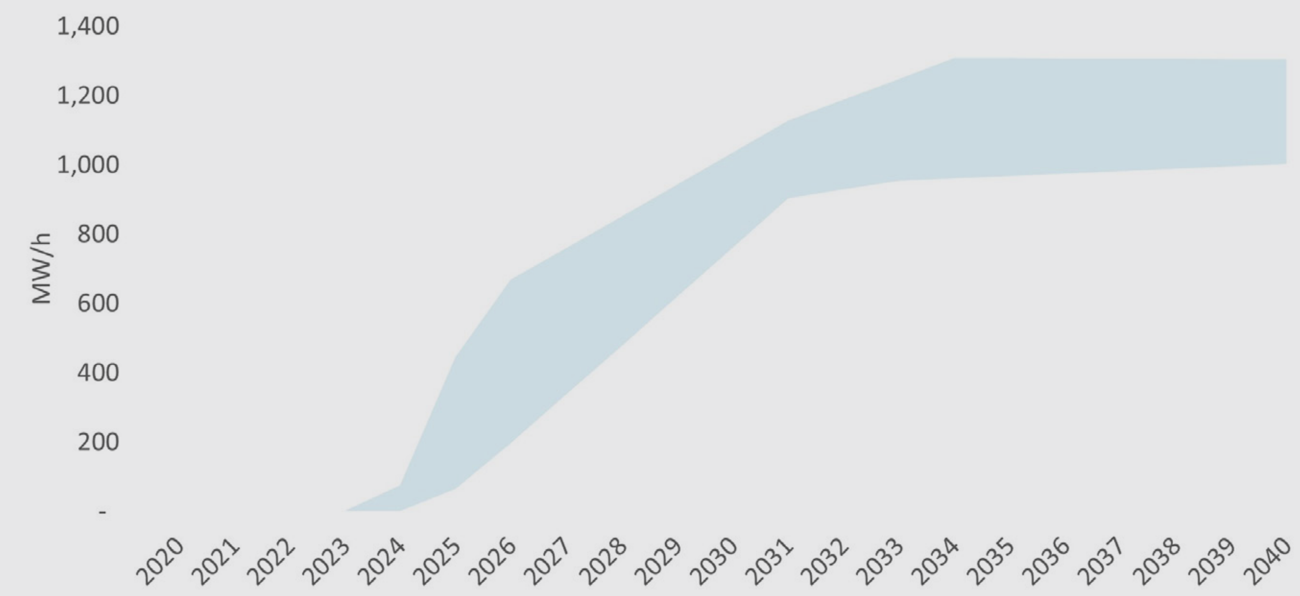


FIGURE 33 DEVELOPMENT IN FORECASTED NEED FOR mFRR DOWN-REGULATION IN DK2



EUROPEAN AND NORDIC PERSPECTIVE

EUROPEAN DEVELOPMENT

The green transition creates a more complex energy market where more fluctuating energy sources, such as wind and solar, are joining in. Renewable energy is putting the balancing market under pressure and the need for flexibility becomes an even more important topic, not only in Denmark, but throughout Europe.

With the Electricity Balancing Guideline (EBGL) of 2017, it was determined that common European energy markets should be developed for aFRR (PICASSO) and mFRR (MARI). Energinet participates in the development of these two platforms for balancing energy. Parallel to European development, Energinet also takes part in development of the Nordic Balancing Model (NBM).

The NBM program was established by the four Nordic TSOs to ensure mutual coordination and implementation of all the changes to the balancing markets in Europe and in the Nordics. NBM was launched in 2018, and includes several market, IT, and operational development projects. These include 15-minute imbalance settlement (ISP15) and 15-minute market time unit (MTU), new Nordic capacity markets for aFRR and mFRR, and an automated Nordic energy activation market for mFRR, namely mFRR EAM. mFRR EAM will act as a steppingstone for the Nordics towards joining MARI and is a necessity due to the complexity of internationalizing and automating mFRR activations.

MARI

MARI has operated with the first connected TSOs since October 2022

According to EBGL, the legal deadline for go-live of MARI was 24 July 2022. However, the platform's operational processes were not ready until 15 September 2022, with the four German TSOs and the Czech Republic going live in October. The war in Ukraine was an indirect cause of the delay of the go-live since it meant that TSOs had to reprioritize their efforts. Furthermore, the war also caused challenges for the MARI IT provider, Unicorn, since they are partly located in Kyiv, Ukraine. All National Regulatory Authorities (NRAs) were informed about the delay.

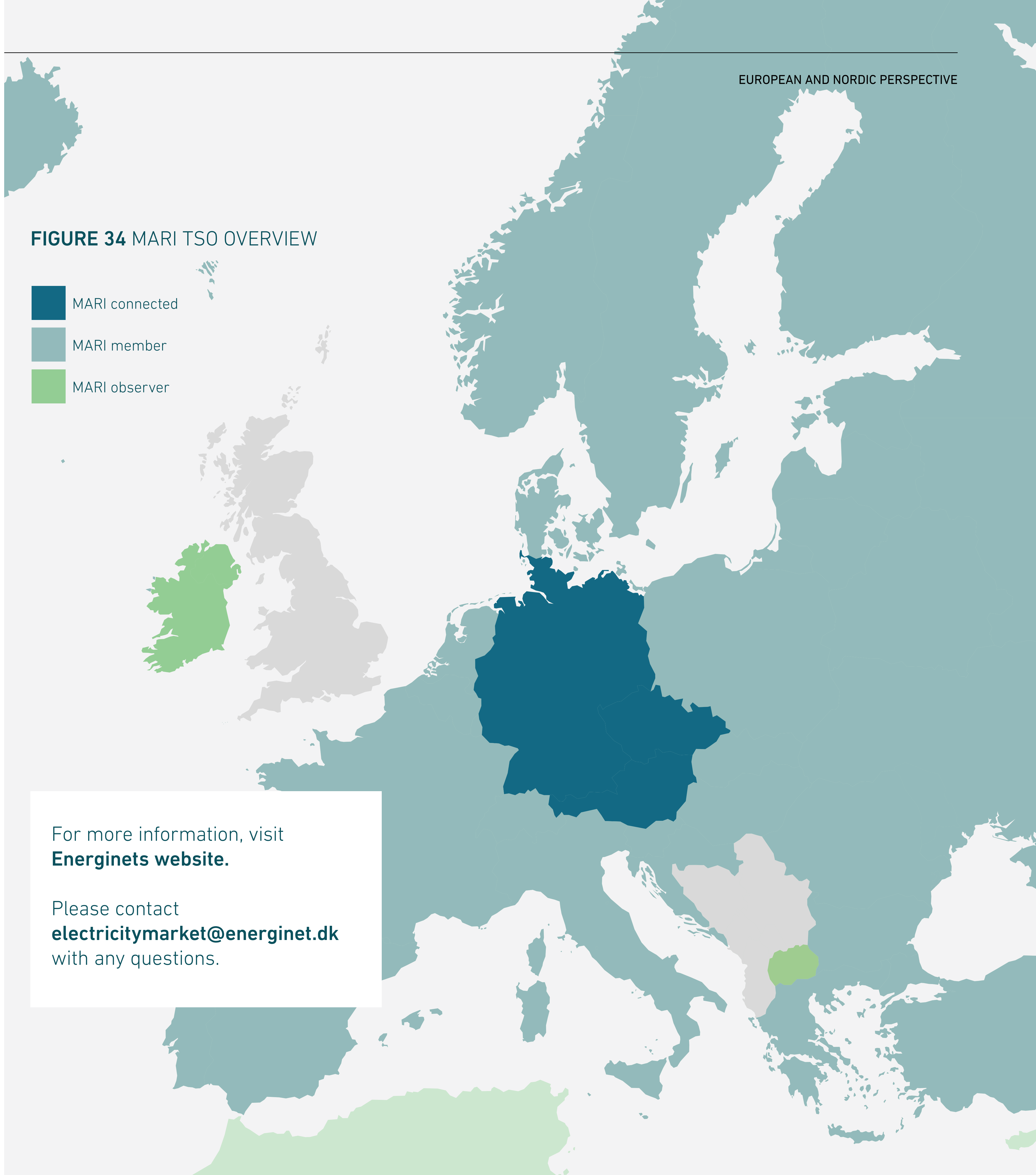
Austria went live on MARI in June 2023. The rest of the TSOs are expected to connect to MARI from 2024 onwards. Energinet will connect to MARI concurrently with the other Nordic countries. Due to delays in the NBM program, the Nordics will not connect to MARI before the legal deadline.

Currently, the total bid volume in MARI is relatively low. However, the bid volume is expected to increase considerably once the Nordics and other mFRR-intensive TSOs connect to the platform. This is also one of the reasons why a common Nordic accession to MARI is prioritized.

SOME HIGHLIGHTS FROM 2022 TO MAY 2023 ARE:

- Technical go-live of the platform on 15 September 2022.
- Market go-live for the four German TSOs and the Czech Republic on 5 October 2022.
- Creation of the operational set-up and the organization.
- Launch of version 5 and 6 of the platform with newly added functionalities.
- Development of the concept for transparency and reporting for all external stakeholders to use.

FIGURE 34 MARI TSO OVERVIEW



For more information, visit **Energinets website.**

Please contact **electricitymarket@energinet.dk** with any questions.

PICASSO

PICASSO has operated with the first connected TSOs since June 2022

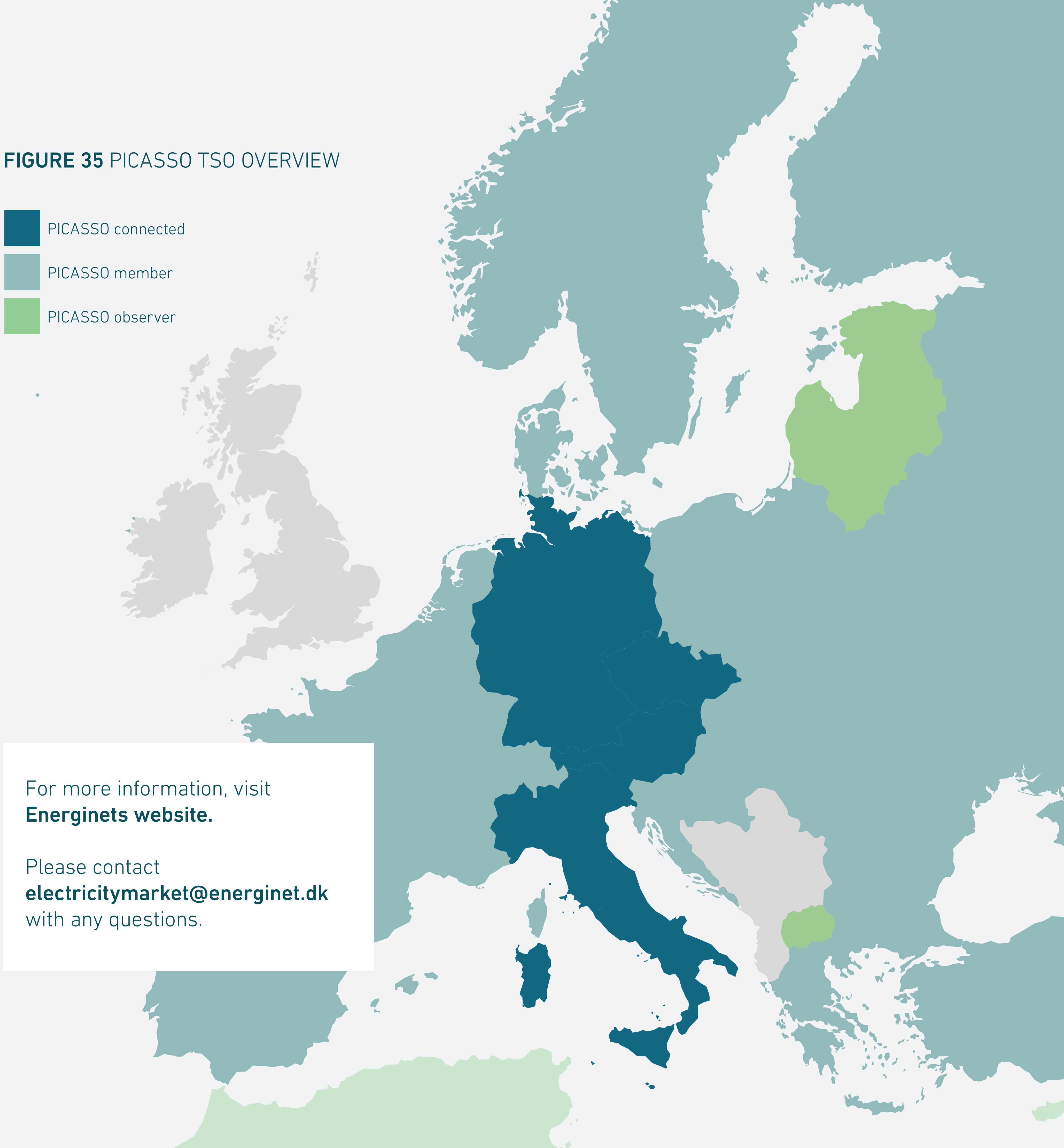
From June 2022 onwards, focus has been on go-live and go-live preparations. Currently, the four German TSOs, the Czech Republic, Austria, and Italy have gone live. The remaining countries are expected to connect to the platform from 2024 onwards. Energinet plans to be among the countries that connect to PICASSO in 2024.

Energinet invites all interested parties to join the information meetings on the PICASSO connection and on how to participate in the new aFRR energy activation market.

SOME HIGHLIGHTS FROM 2022 TO MAY 2023 ARE:

- Completion of important documents (i.e., the Implementation Guide).
- Completion of the final Activation Optimization Function (AOF) design before go-live.
- Design, implementation, and testing of the communication interface for the platforms (TSO communication).
- Development of the concept for transparency and reporting for all external stakeholders to use.

FIGURE 35 PICASSO TSO OVERVIEW



For more information, visit **Energinets website.**

Please contact **electricitymarket@energinet.dk** with any questions.

PICASSO: HIGH PRICES ON EUROPEAN BALANCING PLATFORMS

Since the first cross-border activation of aFRR energy (PICASSO) between Austria, the Czech Republic, and Germany on 22 June 2022, a relatively large amount of very high clearing prices has been observed. Thus, much time has been spent analysing this in project groups. In total, 235 price incidents were observed on PICASSO in 2022, equivalent to 1.27% of all operational hours. For MARI, only two such incidents were observed. With that, the issue is limited to the PICASSO platform (aFRR).

The reason for the high clearing prices is found both on the demand and the supply sides, as well as in the way the cross-border marginal price (CBMP) is determined. High TSO demand combined with low-liquidity and high prices at the end of the bid curve automatically causes activation of expensive bids. Moreover, available capacity on cables (ATC) has a great impact on the CBMP.

In most instances, price incidents have lasted only for a short period of time which means that these have not had a direct impact on imbalance settlement, since this is calculated as a volume-weighted average price. This is also the case in the opposite scenario with short time periods of low clearing prices. Even though the high prices did not directly impact imbalance settlement, the TSOs have found it necessary to initiate a discussion with ACER and the local NRAs about possible solutions.

One of the main reasons for the TSOs wanting this discussion is that not everyone finds the prices to be an expression of the true value of the energy delivered. Especially the bids at the end of the merit order can be excessively expensive and have a great impact on the total cost. Furthermore, price levels are considered an expression of the fact that the new market design does not adequately incentivize new market participants to join the market.The TSOs continue to support the European model with integrated balancing markets across borders and see great advantages to this approach. To improve the market further, the discussion about high prices has been initiated with ACER and local NRAs alongside market participant to find feasible solutions. Both short-term and long-term improvement solutions are being developed.

The TSOs see two main reasons for the need to discuss this topic. The first is the fear of national concerns about high prices and, consequently, concerns about the accession to the platforms of the TSOs that are not yet live. The other is that the TSOs want to discuss how to define price incidents. Reporting on price incidents that have no impact on the imbalance settlement takes up a lot of time and resources in the PICASSO project groups, and the value of this work is questioned when price incidents last only a short amount of time and do not have any direct consequences for the imbalance settlement.

NORDIC BALANCING MODEL (NBM)

In December 2022, it was announced that the Nordic TSOs found it impossible to meet the deadlines of the previous NBM roadmap, because more time was needed for local IT system development.

The first half of 2023, all four TSOs reassessed NBM and the program roadmap. After a thorough investigation, the continuous value of the NBM program was confirmed and measures to increase speed and reduce the scope of the program without losing value was introduced.

After the summer of 2023, NBM was ready to present a new roadmap. The roadmap has been developed in consideration of the dependencies between projects and the fixed European deadlines that cannot be postponed. This consideration resulted in the commitment to implement automated mFRR EAM prior to the European transition to a 15-minute market time unit (MTU) in Q1 2025. MARI will follow afterwards, alongside Swedish and Norwegian accession to PICASSO in 2026. Denmark and Finland aim to join PICASSO by the legal deadline in Q2 2024.

The timing of the Nordic mFRR capacity market is still being assessed but will not be realised before 2024. Furthermore, DK1's involvement in the Nordic aFRR capacity market has been paused for now, but the topic will be reopened at some point.

UPDATES TO THE NORDIC BALANCING MODEL ROADMAP

COMPLETED

2021, Q4
Single Price

2022, Q4
Nordic aFRR capacity market

2023, Q2
15 min ISP/60 min

2023, Q2
National mFRR capacity market Denmark

2023

2023, OCTOBER
National mFRR capacity market Sweden

2023, DECEMBER
National mFRR capacity market Norway

2024

2024, Q2**
European aFRR EAM (PICASSO) Finland and Denmark

2024/25*
Nordic mFRR capacity market

2025

2025, Q1
15 min ISP,15 min IDC

2025, Q1
Automated Nordic mFRR EAM

2026

2026***
European aFRR EAM (PICASSO)

2026
European mFRR EAM (MARI)

*The go-live of the Nordic mFRR capacity market is expected to be clarified during the autumn.
**National onboarding for Denmark and Finland is expected to take place 2024, Q2.
***Joint Nordic PICASSO-accession.

NORDIC CAPACITY MARKET: FCR-N, FCR-D, AND FFR

The four Nordic TSOs are working to develop common capacity markets for FCR-N and FCR-D and, at a later point in time, for FFR. For this to be implemented, harmonization on all levels is needed, which creates a potential long development phase (+5 years).

One step in the right direction is the harmonization of technical requirements for FCR-N and FCR-D. The requirements enter into force on 1 September 2023 in Denmark, Sweden, and Finland, with Norway to follow on 1 January 2024. The new requirements introduce a stability requirement and an updated performance requirement.

Harmonization is not the only reason for developing new requirements. The previous requirements were not found sufficient to secure a stable future system. Providers will have a 5-year transition phase to move to the new requirements, which means that we will not see the full effect of the requirements before 2028.

FCR-D is divided into two products: dynamic and static. Both products have the same activation scheme, but the dynamic product follows the frequency during deactivation, while the static product can have a slow deactivation. In a future system with low inertia levels, the static product can cause harm to the system and introduce a risk of oscillations. This is the reasoning behind developing a static FCR-D quota to limit static resources in the capacity market. The static FCR-D quota is currently not implemented.

The Nordic TSOs are currently investigating the possibilities of designing a dynamic FFR product, which will have a deactivation profile that matches its activation counterpart. This product is expected to secure system stability at very low inertia levels, which is deemed necessary in a 100% green system.

Another step in the direction of Nordic harmonization is the upcoming changes to the Danish/Swedish FCR-D and FCR-N markets. Implementation of marginal pricing is planned for Q1 2024. An asymmetric FCR-N product is also a point of discussion, but a timeline for implementation is not in place yet.

The plan is for all Nordic frequency-based products (FCR-N, FCR-D and FFR) to move to the Nordic MMS platform, which is currently used for bidding in the aFRR and mFRR markets. This means that the Nordics will have one single bidding platform for all ancillary services in the future.

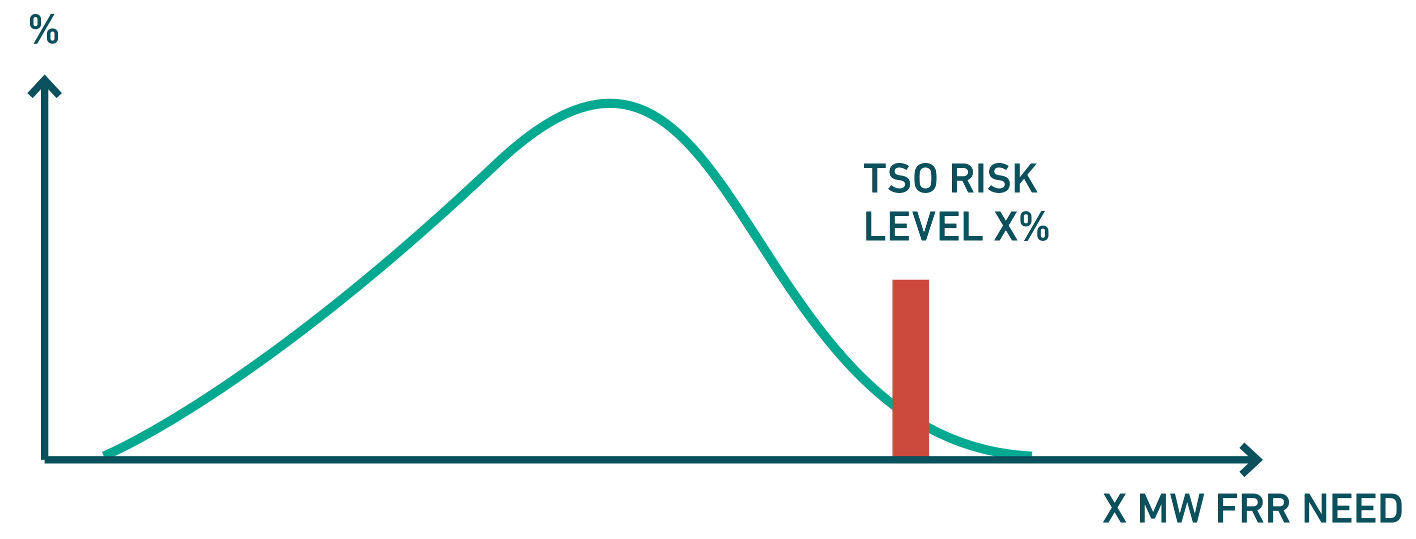
FIGURE 37 Nordic Synchronous Area

DYNAMIC DIMENSIONING

The need for reserves is growing due to still larger and more frequent imbalances. To accommodate this change, the Nordic TSOs have developed an updated methodology for dimensioning of FRR (balancing reserves) – Nordic Dynamic Dimensioning Methodology.

The updated dimensioning methodology, which was approved by the Nordic regulators in May 2023, allows for a dynamic implementation, meaning that the Nordic TSOs will assess the need for FRR for each direction for the next day of operation. This gives the TSOs the possibility to procure more intelligently based on anticipated needs. As a result of this approach, the TSOs can now procure more resources during windy periods when imbalances are more likely to arise and vice versa during periods with low production from renewables.

The entire dynamic methodology entails dimensioning based on forecast of imbalances, reference incidents (RI), local needs, voluntary bids, and scheduled flow on interconnections in the Nordic area. The overall assessment of the desired risk level determines the amount of FRR resources that should be covered.



DYNAMIC DIMENSIONING METHODOLOGY AND PLAN

TODAY:

Dimensioning is solely based on the reference incident (RI) in each area, as imbalances have been less significant historically.

As this outlook has shown earlier, imbalances will become increasingly significant.

NORDIC DEVELOPMENT:

Now, there is an ongoing Nordic development of a dimensioning methodology and an agreement on sharing concepts. This is the initial draft of the concept that awaits approval:

Imbalance principle: Each area must be able to cover its own imbalances.

Voluntary bids: Historic, available voluntary bids form the basis of the expected volumes for the coming day, which reduces the volume of reserves procurement.

HVDC restrictions: Sharing via HVDCs is restricted to 600 MW per HVDC interconnector due to ramping limits. Only cross-zonal capacity unused by the energy markets is available for sharing.

RI restriction: Maximum sharing allowed between two areas equals the lowest RI between the two areas. Sharing through multiple areas is not allowed (transit sharing).

Nordic needs: There will be a minimum procurement level for each area in the Nordics to ensure a lower limit of resources in the operational hour

THE METHODOLOGY RELIES ON DEVELOPING:

- The necessary data streams as input for training of a statistical model and for making a continuous forecast.
- A forecasting model that meets our precision and robustness acceptance criteria.
- An optimized approach to Nordic dimensioning in a holistic perspective.
- A secondary, corrective auction, if forecast errors are deemed too great.

GO-LIVE OF THE METHODOLOGY:

After go-live of the methodology, Energinet will continuously do checking and issue fixing to improve model performance.

LONG-TERM MARKET DEVELOPMENT

ENERGY ISLANDS

The Danish government has requested that Energinet construct two energy islands. One is to be located in the Baltic Sea by Bornholm and is planned to go into operation in 2030 with 3 GW offshore wind and interconnectors to DK2 (1 GW) and Germany (2 GW). The other is planned in the North Sea, and the intention is to connect 4 GW offshore wind.

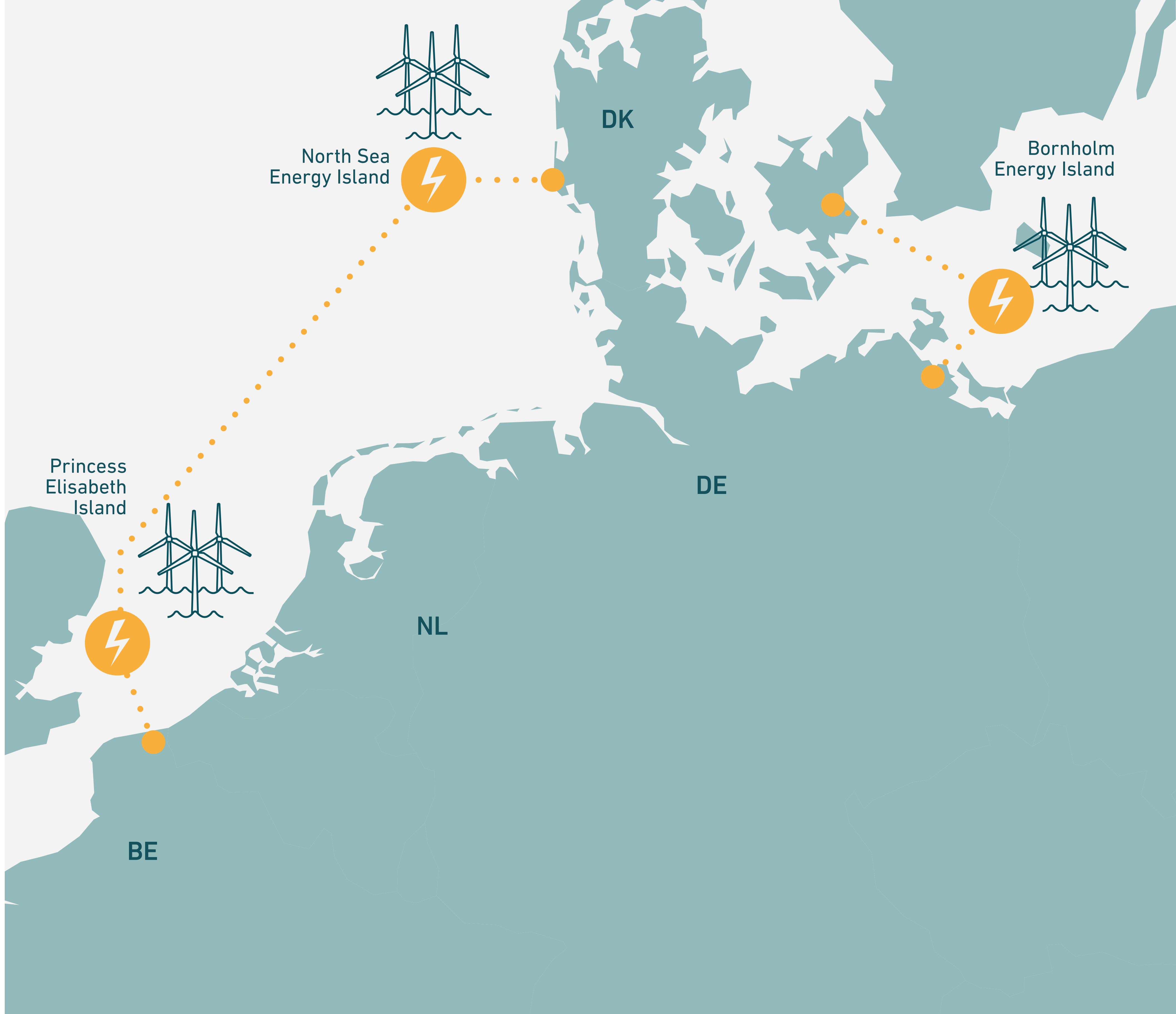
The energy islands are expected to become individual bidding zones and separate balancing areas, meaning that they will also be balanced individually using the European balancing platforms (PICASSO and MARI).

It can be assumed that no reserves will be procured for the energy islands. However, BSPs on the energy island will be able to provide balancing reserves or balancing energy to Energinet. Energinet intend to dimension reserves jointly for DK2 and Bornholm Energy Island (DK3), and jointly for DK1 and North Sea Energy Island (OBZ).

The wind farms are expected to be required to provide down-regulation energy bids for mFRR and aFRR without capacity payment.

North Sea Energy Island is expected to increase the DK1 FRR reference incident to 1 GW. No changes are expected for Bornholm Energy Island and DK2.

FIGURE 38 OVERVIEW OF ENERGY ISLANDS AND POSSIBLE INTERCONNECTORS



GEOGRAPICHAL NEEDS

Changes in electricity consumption and production owing to the green transition result in an increased energy volume that the electricity grid must handle. Decentralization away from the high-voltage grid, coupled with increased peak loads due to simultaneous consumption, wind power and solar power generation, puts additional pressure on the system.

These derived effects and the resulting added strain creates a need for either network expansion or management of flows and potential overload. Therefore, the green transition necessitates network expansion and the development of market solutions to address overload effectively. Local overload is handled within the balancing time frame, specifically in relation to the mFRR EAM (energy activation market).

As the mFRR EAM is intended for balancing purposes only (to avoid impacting the imbalance price, for example, due to internal bottlenecks), local bottlenecks are addressed with a national supplement to the mFRR EAM. Starting from 1 December 2023, Energinet will require geographical tags (geo-tags) on all mFRR energy bids.

Local bottlenecks will be alleviated by:

1. Activating the cheapest local energy bids.
2. Withholding local energy bids that worsen the situation (the bids cannot be used for balancing). Portfolio bids will not be activated if just one of the geo-tags of the bids will worsen the situation.

Local activations are settled using the pay-as-bid principle.

Energinet has also announced a method change that introduces a requirement for geo-tags in the aFRR market when Energinet connects to PICASSO. This is meant to ensure that aFRR activation does not worsen any potential bottlenecks either.

Energinet continuously assesses whether there may be a need for additional measures to ensure that it has the necessary reserves to balance the electricity grid. Therefore, Energinet expects that it may be necessary to introduce geo-tags on the capacity markets for both mFRR and aFRR in the coming years.

The reason is that Energinet anticipates an increase in bottlenecks in the grid, which means that more facilities will be unavailable to provide balancing services. As a result, Energinet must ensure that available assets are utilized efficiently through the implementation of geo-tags on the capacity markets for mFRR and aFRR.

Energinet continuously assesses whether there may be a need for further measures to address issues related to local bottlenecks, including their interaction with already planned solutions such as temporary limited grid access, direct lines, or geographical tariffs. The aim is to find effective solutions that optimize grid capacity and ensure efficient and reliable electricity transmission.

FIGURE 39 ILLUSTRATIVE LOCAL FLEX MAP

NEW WAYS OF BALANCING THE FUTURE ELECTRICITY GRID

Energinet's innovation initiative "*New ways of balancing the electricity grid of the future*" addresses the wicked problem of the green energy transition: How to balance an electricity grid based on 100% renewable energy resources in the future, when we expect to see larger imbalances, a lack of adjustable capacity, and markets with occasionally scarce liquidity.

The question as well as the answers are complex and must be investigated from a variety of different perspectives to get a comprehensive understanding of what is necessary for Energinet to be able to handle the balancing task responsibly in the future. The reference case of the initiative is a future, where the ongoing developments in ancillary services are implemented and in operation. Hence, the focus has been to identify additional needs and solutions for the long term, depicted in the figure below.

External parties, both within and outside the energy sector, have greatly contributed with knowledge and perspectives, allowing the initiative to thoroughly examine and understand the challenges related to balancing in the future. The goal has been to gain sufficient knowledge to specify and isolate challenges, identify relevant themes, and then describe opportunity spaces that will act as a framework for the ongoing work to address the challenges related to balancing the electricity grid in the future.

FIGURE 40 AMBITIONS FOR BALANCING OF THE FUTURE ELECTRICITY GRID

LONG TERM

BALANCING THE ELECTRICITY GRID OF THE FUTURE
Exploring possible solutions for balancing the electricity grid of the 100% renewable energy-based electricity system.

MEDIUM TERM

SUFFICIENT BALANCING RESSOURCES AND LIQUIDITY IN MARKETS
Attractive incentive structure that supports developments and predominantly active participation in electricity markets.

DYNAMIC AND RISK-BASED APPROACH
Development, implementation, and distribution of more dynamic and risk-based approaches.

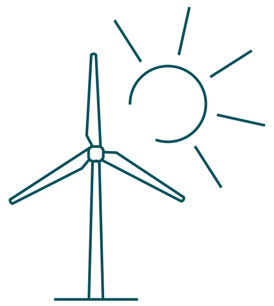
SHORT TERM

IMPLEMENTATION OF NORDIC AND EUROPEAN MARKETS
Implementing Nordic as well as European balancing platforms.

STRONG MARKET PARTICIPANT PERSPECTIVE
Focus on the support of market participants, business understanding and communication.

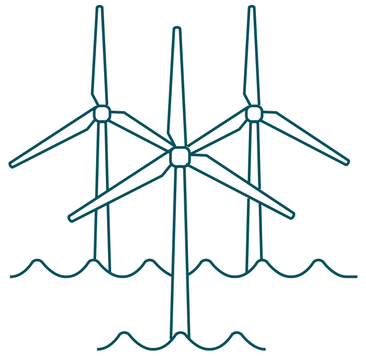
Three main challenges were identified, and five different opportunity spaces that Energinet will explore further in search of specific solutions and options to resolve the identified problems:

FIGURE 41 CHALLENGES



SCARCITY SITUATIONS
Lack of adjustable capacity in periods with low production from RE (very expensive).

LACK OF PARTICIPATION
Lacking adjustable capacity and liquidity in normal periods.



OUTAGES OF LARGE PLANTS
Production "cuts out" because of extreme weather.

OPPORTUNITIES IDENTIFIED

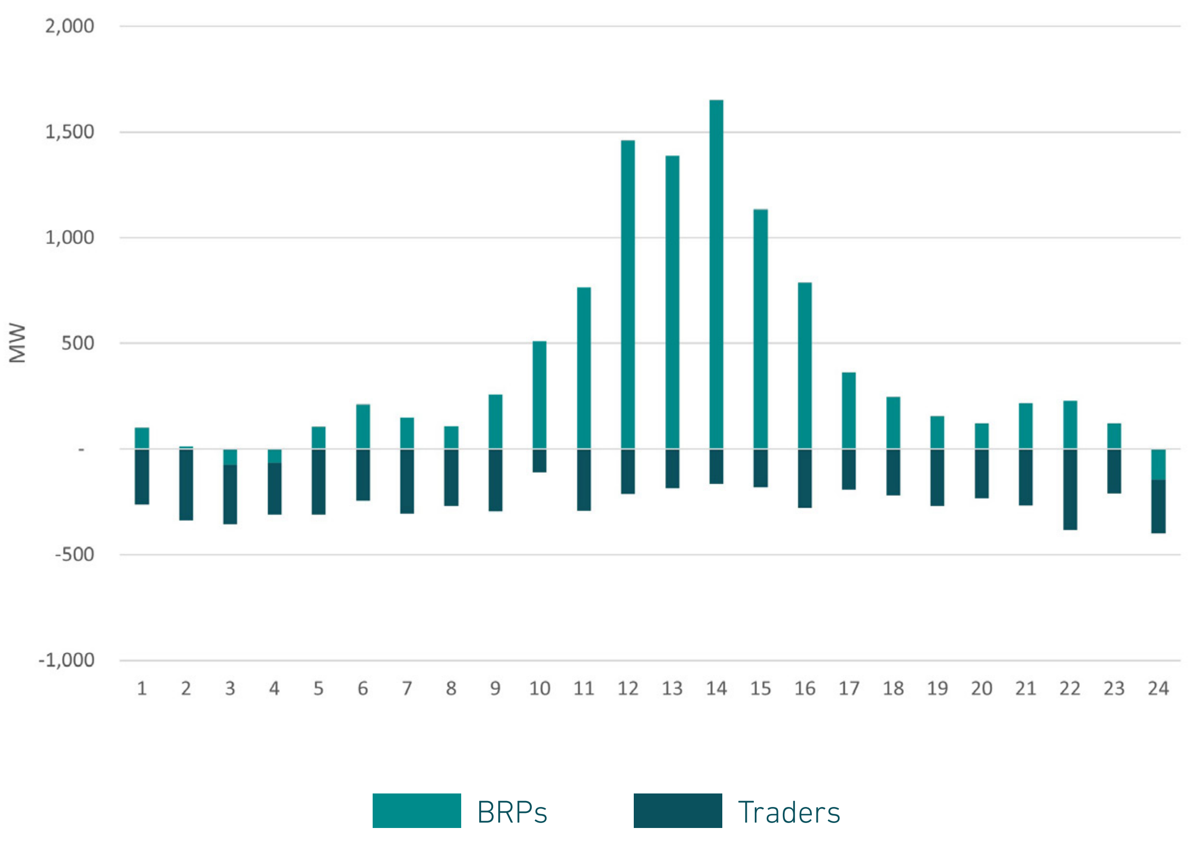
1. DIFFERENTIATED SECURITY OF SUPPLY: How can various market-based approaches support balancing in the future?
2. DISPATCH X: How can new approaches contribute to reduced complexity on the market side and leave this complexity to the TSO?
3. REGULATORY FRAMEWORKS AND DE-RISKING: How can storage technologies support balancing to a greater extent? How can market participant risks be minimized in terms of flexibility investments?
4. RETHINKING ROLES: How can we rethink the roles of the electricity market to provide stronger incentives to balance the electricity system as efficiently as possible?
5. RADICAL REQUIREMENTS FOR TECHNOLOGIES: How can we rethink requirements for new plants, aggregators, and balance-responsible parties to increase focus on ancillary services?

THE BSP'S ROLE IN THE FUTURE BALANCING MARKET

MISSED OPPORTUNITIES

In the last year, the energy system has experienced new challenging scenarios due to extreme weather situations and the introduction of a higher share of wind and solar energy. This has resulted in periods with both very high and negative electricity prices. These scenarios are difficult to foresee, and it can be relatively expensive to cause imbalances in these periods. Examples below show two situations from the previous year: One characterized by a massive down-regulation need and another with a massive up-regulation need.

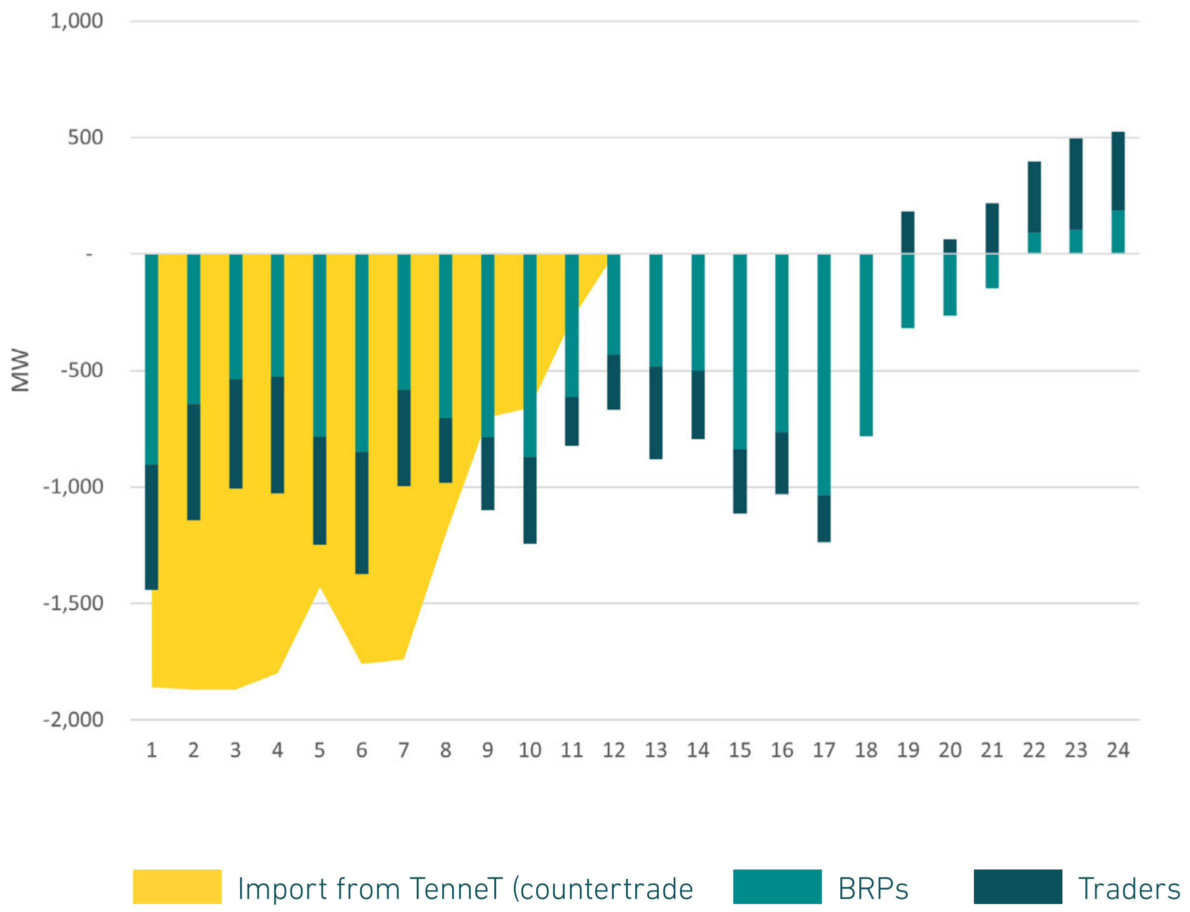
FIGURE 42 IMBALANCES FROM MARKET PARTICIPANTS IN DK1 ON 10 APRIL 2023*



Example 1:
Down-regulation need for balancing was at a record-high at 1,500 MW in DK1 with all-time lowest down-regulation price at –16,391 DKK/MWh. At the time, adjacent bidding zones had similar issues.

Reasons for down-regulation need:
- ½ was caused by more wind production than anticipated.
- ¼ was caused by more solar production than anticipated.
- ¼ was caused by procurement in the intraday market without knowledge of the situation in DK1.

FIGURE 43 I MBALANCES FROM MARKET PARTIFICPANTS IN DK1 ON 10 MAY 2023*



Example 2:
High up-regulation (moderate) need of 650 MW in the late afternoon. The most noticeable point was the record-high up-regulation price of 35,000 DKK/MWh.

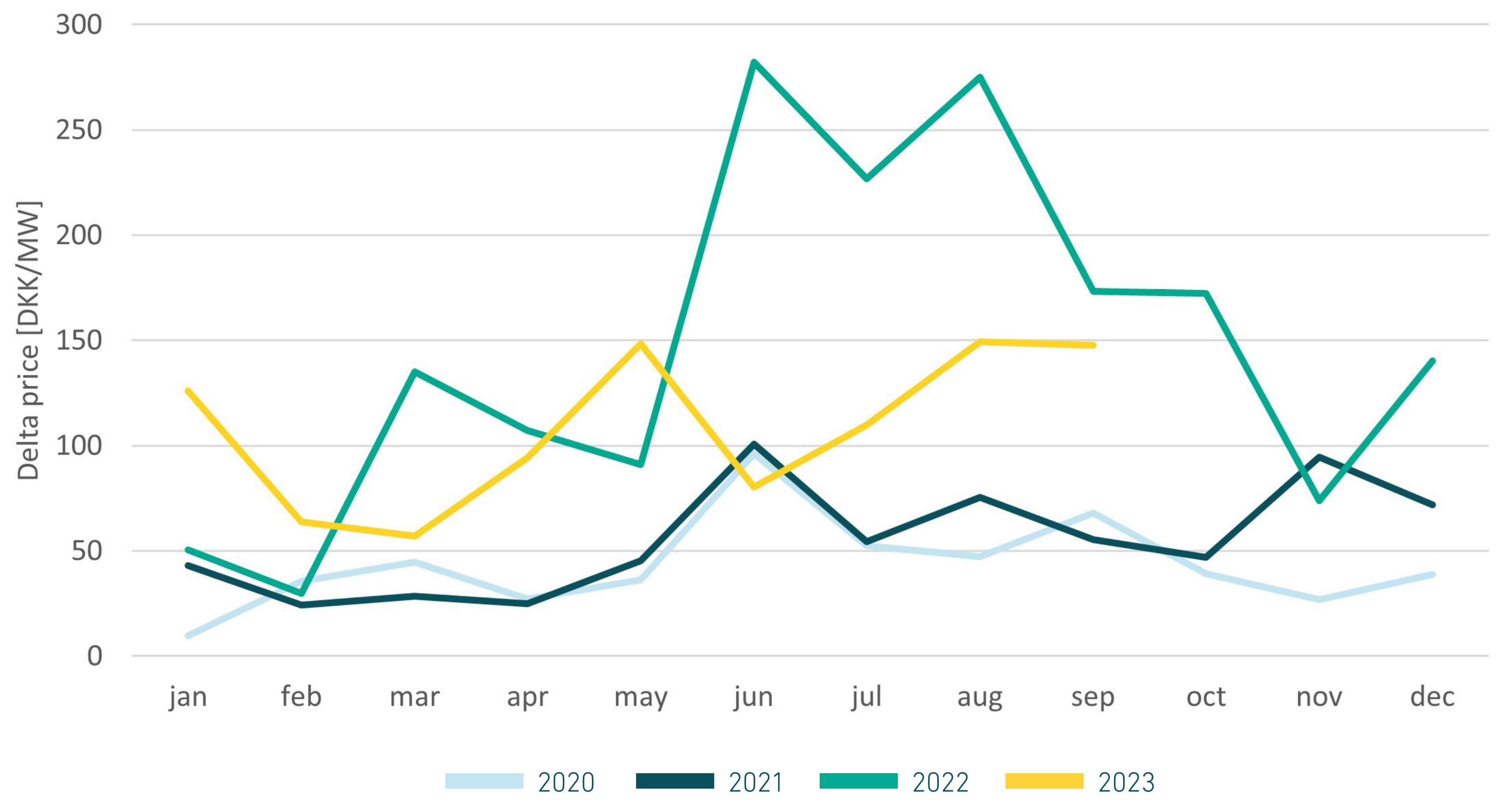
Reason for the high price:
- DK1 had very little remaining import capacity on Skagerrak and Kontiskan, which was partly used for the imbalances. Great Belt was in full import.

*Negative: Up-regulation need, Positive: Down-regulation need."

MISSED OPPORTUNITIES

These examples highlight the risks of introducing imbalances to the system and, at the same time, the opportunities related to providing balancing energy, which also aids the system. Figure 44 shows development of DK1 delta prices, i.e. the difference between average up-regulation and spot prices, which is a general increase. Additionally, the average imbalance prices also increased due to a close correlation to the spot prices, which has increased significantly in recent years.

FIGURE 44 DEVELOPMENT OF DK1 DELTA PRICES*



*Differences between average up-regulation price and spot price.

APPENDIX

APPENDIX 1

TABLE 1 HIGH AND LOW SCENARIOS FOR EACH ANCILLARY SERVICE

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
DK1																				
FCR-high	20	22	23	24	27	31	34	37	39	42	45	47	53	60	66	66	68	70	72	76
FCR-low	20	22	23	22	25	27	30	31	32	33	34	35	41	41	41	41	41	41	41	41
aFRR up-high	100	100	100	104	109	113	114	116	120	125	131	133	153	173	194	214	235	256	277	298
aFRR up-low	100	100	100	100	100	105	105	110	110	110	120	125	145	161	182	204	225	246	265	284
aFRR dow-high	100	100	100	100	100	105	105	110	110	110	120	125	161	186	210	234	258	283	307	331
aFRR down-low	100	100	100	100	100	105	105	110	110	110	120	125	161	186	210	234	258	283	307	331
mFRR up-high	299	297	291	453	608	764	772	781	789	798	806	1,185	1,564	1,943	2,153	2,364	2,574	2,785	2,995	3,206
mFRR up-low	299	297	279	279	347	474	498	521	544	567	590	841	1,093	1,344	1,544	1,745	1,945	2,146	2,346	2,547
mFRR down-high	-	-	-	-	126	335	753	763	773	783	793	817	1,157	1,538	1,920	2,121	2,330	2,577	2,823	3,069
mFRR down-low	-	-	-	-	-	225	506	549	591	634	676	717	944	1,148	1,351	1,554	1,757	1,960	2,164	2,366
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
DK2																				
FFR-high	7	6	9	12	15	17	19	22	24	26	27	28	29	32	35	40	45	50	55	60
FFR-low	-	-	2	3	5	5	5	5	6	7	6	5	5	5	4	6	9	12	15	18
FCR-D-high	223	223	223	234	232	229	226	230	234	238	242	247	246	245	245	245	245	245	245	245
FCR-D-low	223	223	223	212	207	203	198	201	200	200	200	200	216	212	207	203	198	194	189	185
FCR-D-high	216	216	216	226	224	221	218	222	226	230	234	238	237	237	236	236	236	236	236	236
FCR-D-low	216	216	216	205	200	196	191	194	194	193	193	193	209	204	200	196	191	187	183	178
FCR-N-high	92	92	92	97	96	95	93	95	97	99	100	102	102	101	101	101	101	101	101	101
FCR-N-low	92	92	92	88	86	84	82	82	83	83	83	83	90	88	86	84	82	80	78	77
aFRR up-high	-	4	42	47	52	58	62	65	69	73	77	81	85	89	89	90	90	90	91	93
aFRR up-low	-	4	36	40	45	49	52	56	59	62	66	68	72	76	76	76	76	76	77	79
aFRR down-high	-	4	40	46	53	59	74	89	105	120	135	142	149	155	157	159	160	162	164	165
aFRR down-low	-	4	40	39	45	50	63	76	89	102	115	121	126	132	134	135	136	138	139	141
mFRR up-high	620	603	614	665	727	789	877	965	1,053	1,141	1,229	1,257	1,302	1,350	1,397	1,445	1,492	1,540	1,587	1,635
mFRR up-low	620	603	596	616	629	642	681	719	758	797	835	871	906	934	952	961	971	981	990	1,000
mFRR down-high	-	-	-	74	445	668	760	852	944	1,035	1,127	1,187	1,248	1,308	1,307	1,307	1,306	1,305	1,305	1,304
mFRR down-low	-	-	-	-	65	196	337	479	620	762	903	929	954	961	968	975	982	989	996	1,003

QUANTILES FOR PREDICTED IMBALANCES

	2025	2030	2033	2040
DK1				
P (10) up	-84	-294	-344	-372
P (90) down	100	110	145	284
	2025	2030	2033	2040
DK2				
P (10) up	-78	-153	-621	-1,175
P (90) down	79	153	619	1,199

APPENDIX 2

During all hours of the year, Energinet procures capacity reserves of each ancillary service, which can be activated in case of system imbalances and/or frequency deviations. Energinet procures ancillary services to the extent necessary to ensure that significant frequency deviations and/or faults can be handled. Therefore, it is extremely rare that all capacity procured is fully activated.

Table 3 shows required activation in percentages for 2021 and 2022. Note that this is not the actual response from providers, which tends to be slower than the target values. The hours represented on the x-axis are the number of hours with the related activation – and not the length of activation. The figure shows aggregated results for up-regulation and down-regulation.

Using mFRR in DK1 as an example, around 6,200 hours in 2021 had a 0-10% activation need, 700 hours required 10-20% activation and so forth.

It is evident that FCR-N, aFRR, and mFRR have more activation hours than FCR, FCR-D, and FFR. FFR, for instance, is rarely needed, but a small fraction shows +60% activation, which owes to FFR being a step response.

TABLE 2 FREQUENCY DISTURBANCE COUNT

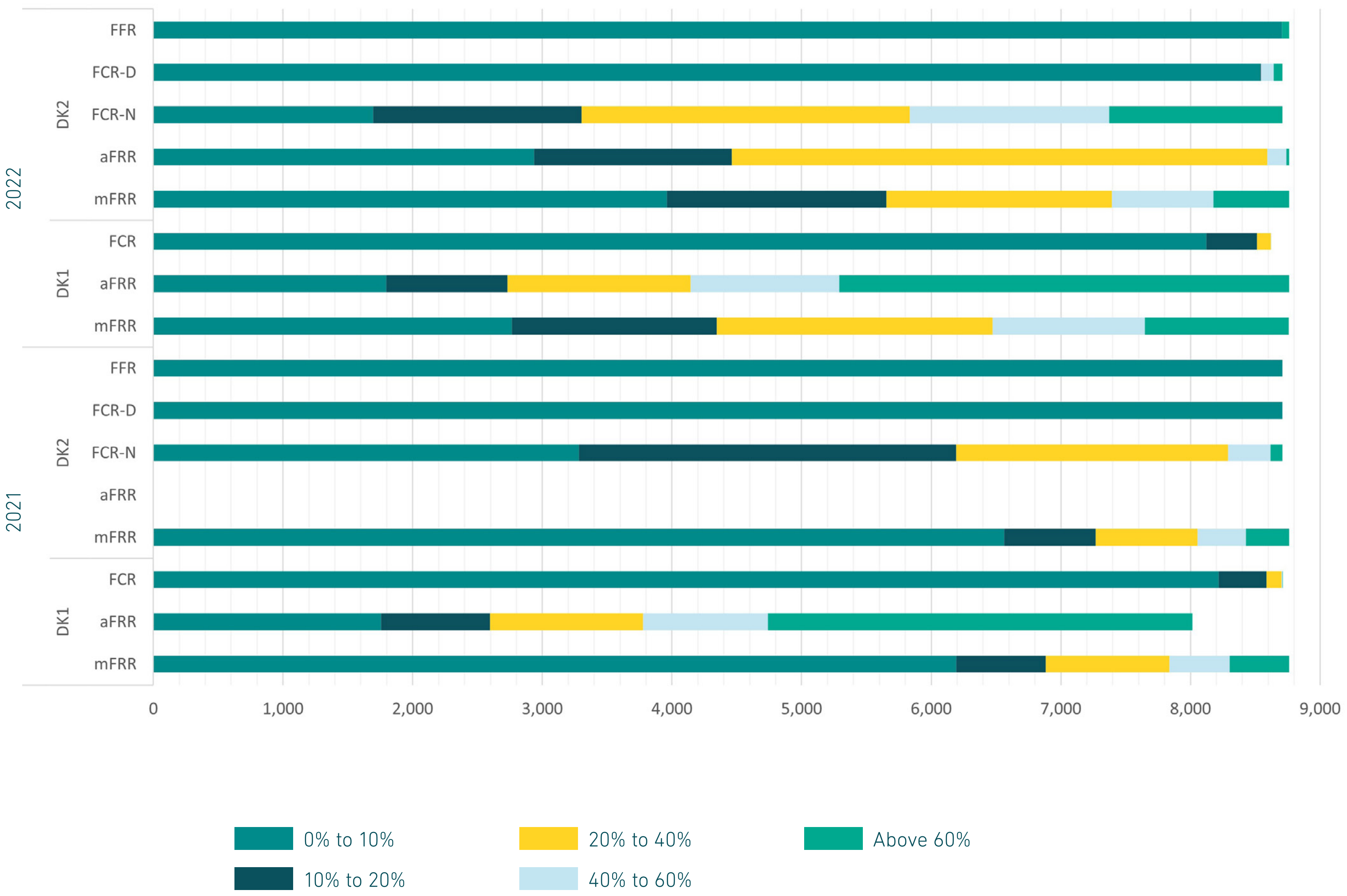
DK1

Year	2022		2021	
Frequency deviation [mHz]	> 200	< -200	> 200	< -200
Instances	0	2	0	2
Max duration [s]	0	20	0	19

DK2

Year	2022		2021	
Frequency deviation [mHz]	> 200	< -200	> 200	< -200
Instances	99	47	0	2
Max duration [s]	139	83	0	19

TABLE 3 HISTORICAL DEGREE OF ACTIVATION FOR EACH ANCILLARY SERVICE



Note: Due to a lack of data for some periods of the year, not all the plots include a whole year (8,760 hours).