Evaluation Report

The Nordic aFRR capacity market

28 April 2023

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Executive Summary

The Nordic aFRR Capacity Market (aFRR CM) went live in the beginning of December 2022 after years of development and implementation. The intention with the common Nordic aFRR CM was to utilize capacity resources across the Nordic bidding-zones to improve both socio-economic welfare and security of supply.

This report provides an evaluation of the Nordic aFRR CM from go-live 8 December 2022 to March 24, 2023. The evaluation is broadly split in three. 1) the forecast methodology for cross-zonal capacity (CZC) values, 2) the 10% NTC limit for CZC and 3) the economic surplus from the exchange of balancing capacity in the aFRR CM.

The CZC values for exchange of balancing capacity used to clear the market consists of two parts - a forecasted day ahead market price spread and a dynamic markup. The forecasted price spread is done using a D-1 methodology. For the markup, the value used is based on historical forecast errors. This report compares the actual price spread observed in the DAM, with the D-1 price spread plus the markup to assess the accuracy of the methodologies (referred to as 'forecast error'). Results show that approximately 75% of the combined borders and hours have no errors. Overall, and over all border directions, about 9% of the hours have forecast errors below -5 EUR/MWh and about 12% of the hours have forecast errors higher than 5 EUR/MWh. We also see that, for most borders, the errors are most often in the 10-50 EUR/MW range (in absolute terms). Generally, we see that borders between countries have both higher number of error hours, higher absolute errors, and higher markups compared to borders connecting price areas within countries.

In terms of the 10% NTC limit for CZC, the report indicates that in most cases, the 10% NTC limit is sufficient for an efficient allocation of available CZC reserve across the Nordic countries. However, for a few of the borders, a higher capacity in some hours would allow for more efficient selection of cheaper bids in the Nordic market. The possibility of increasing the CZC limits until demand is satisfied or up to a maximum of 20% was only used by the TSO's for three hours during the entire evaluation period.

This report also analyses the impact of the exchange of balancing capacity in the aFRR CM on economic surplus in the SDAC and the aFRR CM. Due to the aFRR CM coupling, capacity available for the SDAC is either reduced or unaffected, which results in an economic surplus for this market that is always zero or negative. Results show that the negative effect on the SDAC is minor compared to the positive effect the exchange of balancing capacity has on the aFRR CM. Results also show that all days have a positive economic surplus. The methodology to calculate the surplus in the aFRR CM is to clear the market with no exchange between bidding zones and compare it with the actual market results. This methodology has its weaknesses because of the low bid volumes for certain bidding zones. An alternative approach is to clear the markets on a national basis (allowing for exchange within the countries) and compare these results with the actual market results. By doing this, the daily average economic surplus from the aFRR decreases a bit, but both methodologies, however, give a total positive economic surplus from the exchange of balancing capacity anyway.

Introduction

The Nordic aFRR Capacity Market (aFRR CM) went live in the beginning of December 2022 after years of development and implementation. The aim of the common Nordic aFRR CM was to utilize capacity resources across the Nordic bidding-zones to improve both socio-economic welfare and security of supply, by securing the availability of resources in all bidding zones at all points in time.

This report is a delivery to ACER Decision 22-2020 on Nordic CCR market-based allocation process methodology Annex I regarding “Methodology for the market-based allocation process of cross-zonal capacity for the exchange of balancing capacity for the Nordic CCR”, where it is requested in “Article 12 – Publication of information” that:

> 5. The TSOs shall monitor the efficiency of the forecasting methodology and shall, by three months after the go-live of the market-based allocation process and subsequently at least once a year, submit a report to the relevant regulatory authorities. This report shall include at least:
> a) a comparison of the forecasted and actual market values of cross-zonal capacity for the exchange of energy;
> b) assessment of occurred increases of the limits for the maximum volume of cross-zonal capacity allocated for the exchange of balancing capacity in accordance with Article 5(1)(b), including statistics on the amount of incidents, increased volumes and percentages, reasons for the incidents and an analysis of the economic surplus effects on the SDAC;
> c) assessment of impacts on the economic surplus of the SDAC and economic surplus from the exchange of balancing capacity from the application of the market-based allocation process and the specific impact following an increase of a default limit for the maximum volume of cross-zonal capacity allocated for the exchange of balancing capacity pursuant to the process described in Article 5(1)(c); and
> d) where necessary, proposals to improve the accuracy of the forecasted market values, including a different limit for the maximum volume of cross zonal capacity pursuant to Article 5(1) or different mark-up values per bidding zone border pursuant to Article 6(2).

The above points will be addressed one by one in this three month evaluation report, where point a) evaluates the performance of the forecast methodology, point b) evaluates the limit of 10% cross-zonal capacity for the use of exchange of reserves, and point c) calculates the economic effects of the common Nordic aFRR capacity market (aFRR CM). As for point c), it is necessary to mention that Simulation Facility has not been available, and therefore, other measures have been used to calculate the impact on the day-ahead market. In relation to point c), it is also worth mentioning, that the overall economic surplus is affected by the limitations implemented on the Swedish-Finnish border. This effect has thus not been quantified.

Point d) is only briefly touched upon since the amendment to the mark-up methodology is still in NRA process.

In addition to the above points, the Nordic TSOs have experienced a well-functioning market in general, where it has been possible to transfer capacity from high-liquidity areas to low-liquidity areas at all times. Other than that, we have seen that the increased competition across the Nordic area has impacted the volume of the bids submitted to the aFRR capacity markets. At the same time, the average price across all bidding zones has gone down and price volatility has decreased as indicated in Figure 1. Thus, in addition to the benefits presented in this report, the market integration itself has affected the competition and thereby reduced the price differences of the offered capacity between the bidding areas. This benefit will not be quantified further in this report.

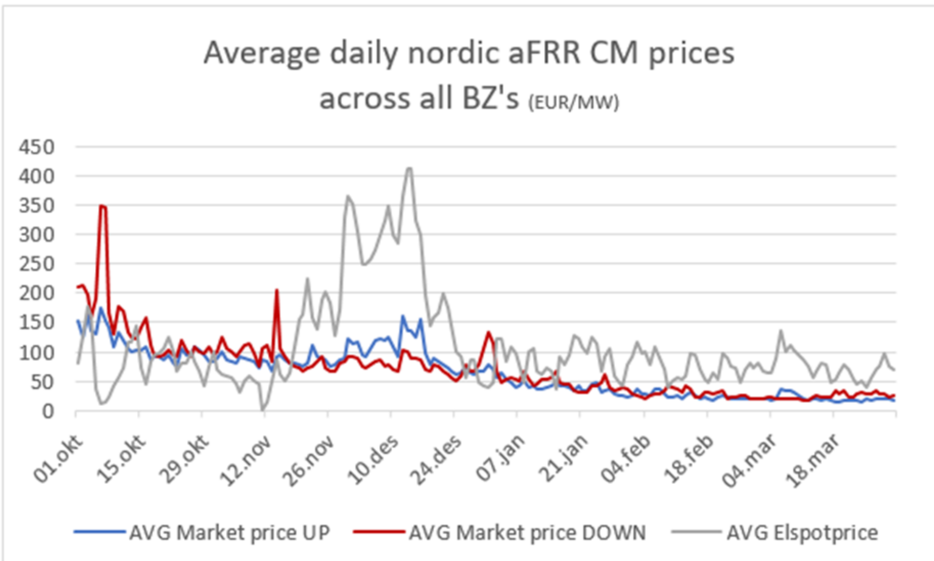


Figure 1 Average daily aFRR capacity prices across all bidding zones

5a Forecasted vs. actual market values of cross-zonal capacity

Cross-zonal capacity (CZC) on a line reserved for the aFRR CM is made unavailable for the day-ahead market (DAM[1]) auction, which is cleared later that day. Therefore, the value of this reserved capacity can be estimated as its alternative or opportunity value in the DAM. The (marginal) alternative value is then equal to the difference (spread) in DAM prices on each side of the border in question.

The cost of reserving CZC in the aFRR market clearing is calculated based on this alternative value. However, since the DAM is cleared after the aFRR CM, a forecast alternative value is used, based on the DAM prices from the previous day (24 hours prior). In addition, a dynamic markup is added to the forecasted value of CZC, which is a number between 1 and 5 EUR/MW, depending on the size of the forecast error for the previous (rolling) 30 days.

$$CZCcostForecast_{t,r,r'} = DAMspread_{t-24,r,r'} + markup_{t,r,r'}$$

Where t is the delivery hour, r is the export (“from”) price area and r' is the import (“to”) price area. This value is used as the cost of reserving CZC in the clearing algorithm.

To answer 5a) above, we will compare the forecasted CZC cost with the ex-post actual alternative cost of reserving CZC in the aFRR CM.

Forecasted	$\max(0, DAMprice_{t-24,r'} - DAMprice_{t-24,r}) + markup_{t,r,r'}$
- Actual	$\max(0, DAMprice_{t,r'} - DAMprice_{t,r})$
=Forecast Error	$forecasted - actual$

The analysis is structured by first analyzing the DAM spread, then the markup, and finally combining both to find the forecast errors.

DAM spread errors

To reiterate, the methodology to forecast the *DAM spread* uses DAM prices from the day before (D-1):

$$DAMspread_{t-24,r,r'} = \max(0, DAMprice_{t-24,r'} - DAMprice_{t-24,r})$$

The DAM spread is set equal to the price in the importing region (r’) minus the price in the exporting region (r). If the price in the exporting region (r) is greater than the price in the importing region (r’), i.e., the spread is negative, the forecasted value will be zero.

The DAM spread for hour *t-24* is used to set the CZC cost for hour *t*. For example, the DAM spread part of the CZC cost for the border from NO1 to SE3 in hour 6 on 8 December is the DAM price in hour 6 on 7 December for SE3 minus the DAM price in hour 6 on 7 December for NO1.

[1] In this report, we refer to the DAM (day-ahead market) and SDAC (single day-ahead coupling), depending on context. Both refer to the (same) coupled day-ahead market.

Below, we analyze the *DAM spread error* caused by using the DAM spread 24 hours before (that is, *t-24*) as a forecast for the DAM spread for hour *t*. The *DAM spread error* is calculated as the difference between the DAM spread for *t-24* and the DAM spread for hour *t* for each given border.

Note that in the exposition below, we refer to DAM spreads and DAM spread errors in €/MW rather than €/MWh. This is because the aFRR market is a capacity (MW) market, and the CZC costs are calculated in €/MW.

Frequency of non-zero DAM spread errors

The graph below shows DAM spread errors split into three groups – no difference, positive difference (forecast higher than actual), and negative difference (forecast lower than actual) for all borders and directions. In this report, a non-zero value is defined as a DAM spread error. We have included the SE1-FI border in this analysis, even though this border has not been 'active'[2] for all days of the period analyzed. The reason for the inclusion is that the border is expected to be included in the aFRR CM soon, and it is useful to show the performance of the D-1 methodology on this border as well.

When calculating the percentages, only hours when the market has reserve requirements have been included (i.e., all hours except hours 2, 3, 4 and 5).

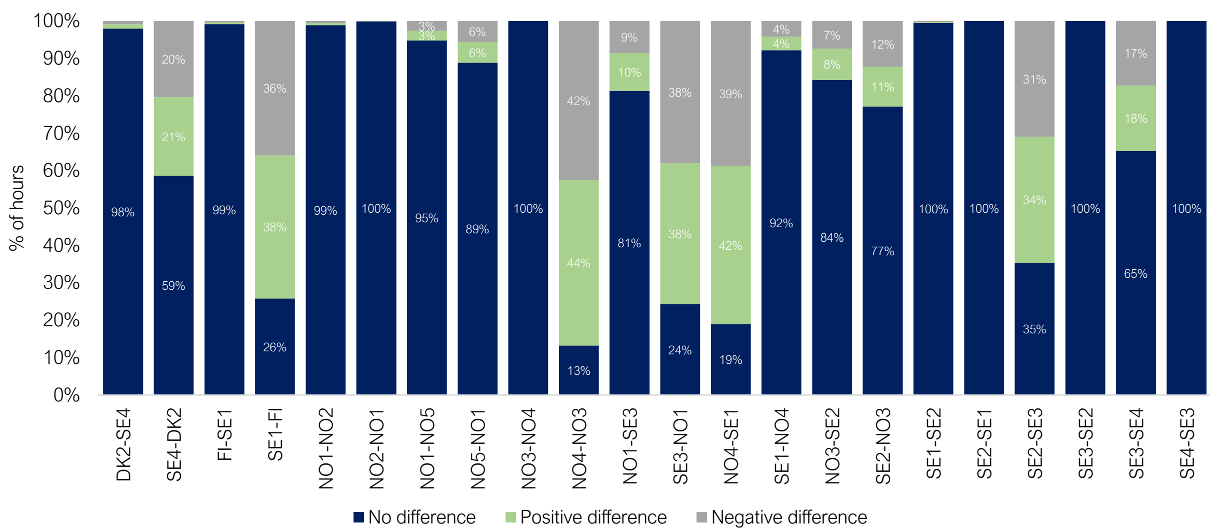


Figure 2 – DAM spread error in three categories [<0, 0, >0].

Fourteen of the borders have DAM spread errors in fewer than 20% of hours in the period analyzed. We can further split the borders into two groups. The first consists of borders with a low and similar number of hours with DAM spread errors in both directions, and the second consists of borders with few DAM spread errors in one direction, but substantially more hours with errors in the other direction. Based on data from 8 December 2022 to 24 March 2023, the first group consists of the borders (NO1, NO2), (NO1, NO5), (NO2, SE3), and (SE1, SE2). The second group consists of (DK2, SE4), (FI, SE1), (NO3, NO4), (NO1, SE3), (SE1, NO4), (SE2, SE3), and (SE3, SE4).

[2] Finland joined the market later on the 24 March 2022

Borders in the first group exhibit high correlations between the DAM prices in the two price areas on either side of the border. Even though the day-to-day price may differ substantially, the DAM spread error tends to be zero because the DAM spreads on these borders tend to be zero. Borders in the second group tend to have a dominant DAM flow direction where prices in the importing area tend to be higher than prices in the exporting area. Recall from the DAM spread formula that the DAM spread is set to 0 if the DAM price spread is negative. For borders in group 2, DAM spreads in most hours in one direction equal 0. The DAM spreads for a given hour on any two consecutive days are highly likely to both be 0, resulting in few DAM spread errors for that direction.

Not surprisingly, the cross-country borders have the highest number of hours with DAM spread errors. The three exceptions to this are (NO4, NO3), and (SE2, SE3) which also exhibit a higher number of hours with non-zero spread errors, and the (NO3, SE2) border which has relatively few hours with DAM spread errors in both directions.

Finally, the number of hours with positive and negative DAM spread errors tend to be similar on each border (albeit different from border to border).

Average DAM spread errors

Figure 3 shows the average DAM spread error for each border.

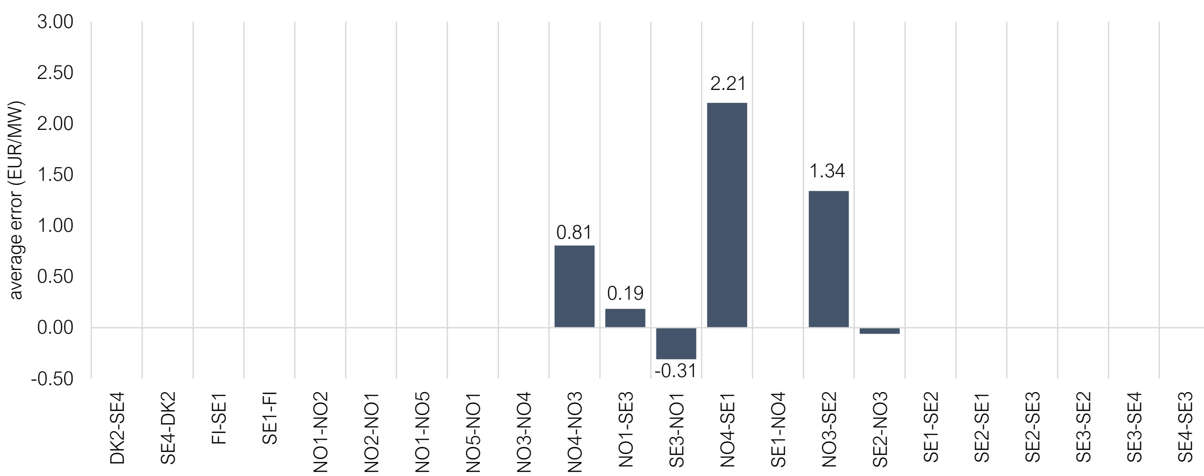


Figure 3 – Average DAM spread error (EUR/MW).

Overall, the average DAM spread errors are relatively low. Only two border directions have an average error > 1 EUR/MW: NO4->SE1 (2.21 €/MW) and NO3->SE2 (1.34 €/MW). A positive number means that the methodology of using the D-1 spread to forecast overestimates the actual spread. A negative number means that the forecasted spread (D-1) is underestimated compared to the actual spread. An average DAM spread error of zero essentially means that negative errors are balanced out by positive errors. With an extended analysis period, we would expect the DAM spread error to move towards zero for all borders.

Examining the absolute DAM spread errors[3] in Figure 4, we see a greater variation over borders and directions. On average over all border directions, the absolute error is 8 EUR/MW. However, these vary significantly from border to border, with 6 border directions having mean absolute DAM spread errors in excess of 10 €/MW (and a seventh with an error of 9.7 €/MW).

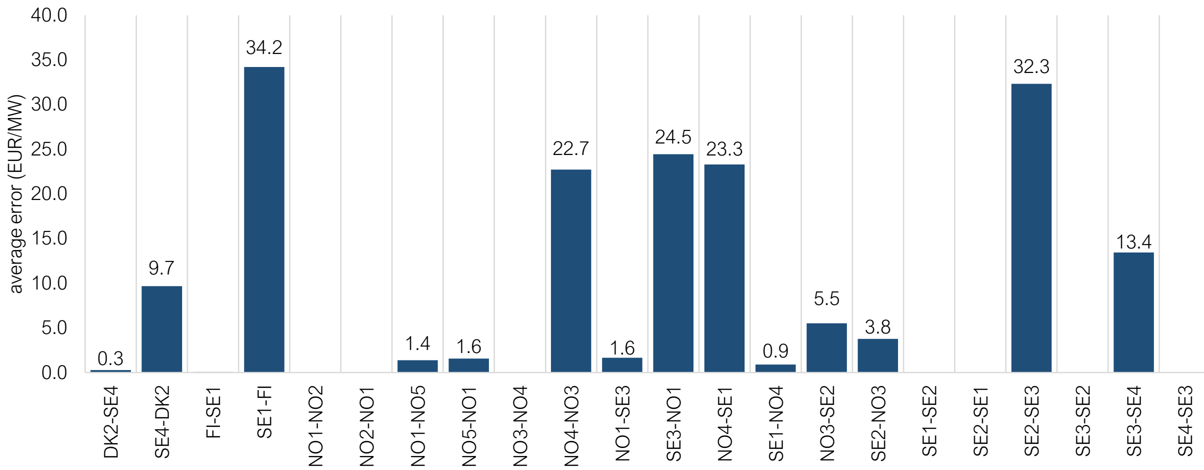


Figure 4 – Absolute average DAM spread error (EUR/MW).

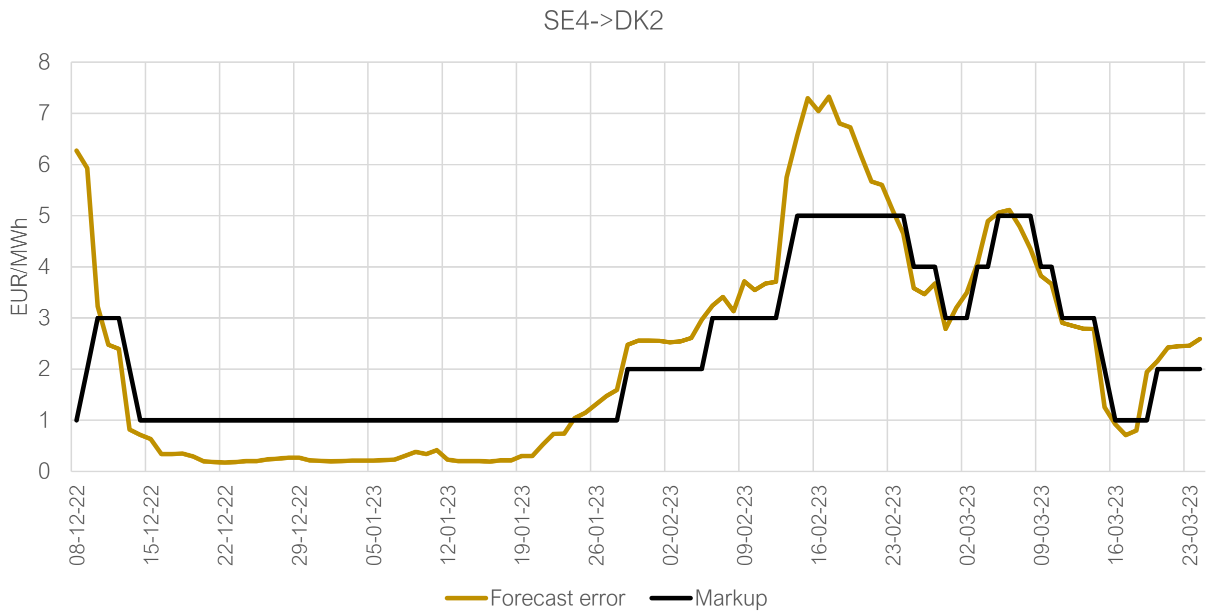
Markup

Recall that the cost of reserving CZC consists of two components, the *DAM spread* and a *dynamic markup*. The dynamic markup is calculated based on the average forecast error of the last 30 days and set to a value between 1 and 5 EUR/MW (in 1 EUR/MW steps), depending on the size of the average forecast error. The methodology only uses the positive errors and excludes the top 5% of error values.

The markup is a daily value for each border direction and is added to the hourly DAM spread for each hour. If the forecast DAM spread for an hour is zero, the markup is set to 0.1 for that hour. In general, and by design, markup is correlated with recently observed errors in the CZC cost forecast. This means, if the error in the CZC cost forecast on a border (based on DAM spread D-1) for the last 30 days is high, the markup is high, and if its low, the markup is low.

As an example, we can see how the markup changes with the 30-day historical forecast error for the SE4->DK2 border in the figure below. This markup value in the graph is the value used if the DAM spread is positive and non-zero. When the DAM spread is negative or zero, markup is automatically set to 0.1.

[3] The absolute value is $|x| = \begin{cases} x, if\ x \geq 0 \\ -x.if\ x \leq 0 \end{cases}$. So basically converting all the negative DAM spread errors to positive values.



We see how the markup follows the rolling horizon forecast error. When the difference between the forecast error and the markup for the previous day exceeds the markup value from the previous day, the markup value increases by one. The opposite effect will be seen when this difference drops below the markup.

The average markup over all hours (1680 hours from 8 December 2022 to 24 March 2023) is shown in Figure 5.

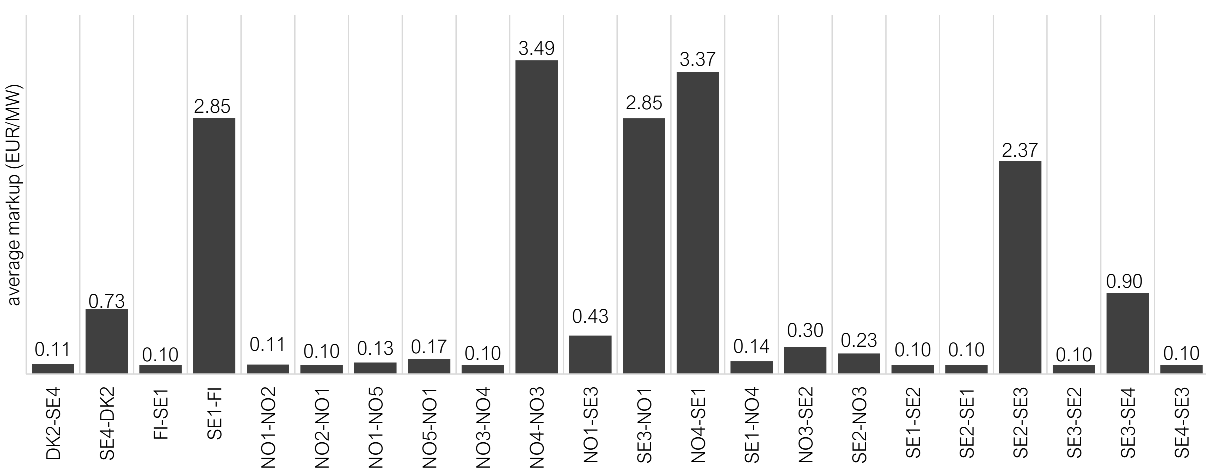


Figure 5 – Average markup (EUR/MW).

We see that borders with a high absolute DAM spread error also have a high average markup. This is to be expected since a high number of errors drives higher markups. Apart from five border directions, the average markup is low (<1€/MW). The five borders with markup exceeding one have an average markup of 2.99 EUR/MW. Graphs showing markup per day for these five borders are available in Appendix B.

In the graph below, we see how the six different markup possibilities are distributed across all hours for each border and direction.

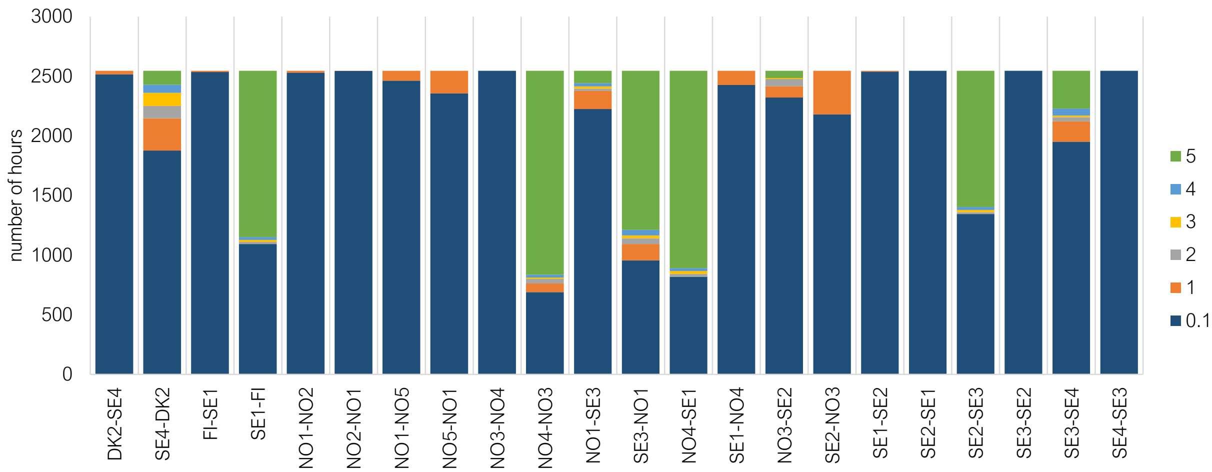


Figure 6 – Markup distribution (%).

Typically, markup values on a given border are either 0.1 or 1 €/MW, or 0.1 or 5 €/MW. Borders with high mean absolute DAM spread errors are in the latter group, with all other borders in the former.

CZC forecast error

Combining the forecast DAM spread and the markup for each border results in the forecast CZC cost used in the aFRR MC. Table 1 summarizes the DAM spread errors and average mark-up level, and the total CZC forecast error (both average error and average absolute error) for each border.

During the analysis period, the borders with the highest CZC forecast errors were cross-country borders, plus NO4->NO3, SE2->SE3 and SE3->SE4.

	DK2-SE4	SE4-DK2	FI-SE1	SE1-FI	NO1-NO2	NO2-NO1	NO1-NO5	NO5-NO1	NO3-NO4	NO4-NO3	NO1-SE3	SE3-NO1	NO4-SE1	SE1-NO4	NO3-SE2	SE2-NO3	SE1-SE2	SE2-SE1	SE2-SE3	SE3-SE2	SE3-SE4	SE4-SE3
Average spread error	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.2	-0.3	2.2	0.0	1.3	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Absolute spread error	0.3	9.7	0.1	34.2	0.0	0.0	1.4	1.6	0.0	22.7	1.6	24.5	23.3	0.9	5.5	3.8	0.0	0.0	32.3	0.0	13.4	0.0
Average markup	0.1	0.7	0.1	2.9	0.1	0.1	0.1	0.2	0.1	3.5	0.4	2.8	3.4	0.1	0.3	0.2	0.1	0.1	2.4	0.1	0.9	0.1
Average forecast error	**0.1**	**0.7**	**0.1**	**2.8**	**0.1**	**0.1**	**0.1**	**0.2**	**0.1**	**4.2**	**0.6**	**2.4**	**5.5**	**0.1**	**1.7**	**0.2**	**0.1**	**0.1**	**2.4**	**0.1**	**0.9**	**0.1**
Absolute forecast error	**0.4**	**10.2**	**0.2**	**35.6**	**0.1**	**0.1**	**1.5**	**1.7**	**0.1**	**23.9**	**2.0**	**25.4**	**24.5**	**1.0**	**5.8**	**3.9**	**0.1**	**0.1**	**33.7**	**0.1**	**14.0**	**0.1**

Table 1 – CZC forecast error summary.

Adding the markup to the DAM spread results in a higher absolute CZC forecast error than the DAM spread alone for all borders. Overall, there are 7 borders with absolute CZC forecast errors in excess of 10€/MW.

CZC forecast error distribution

The distribution duration curve for the CZC forecast errors for all hours and borders is shown in Figure 7. Similar graphs for each border are available in Appendix A.

Figure 7 – Forecast error duration curve (EUR/MW).

Approximately 75% of the combined borders and hours have no errors. 14% have a forecasted CZC cost greater than the actual value, and 11% are below the actual value. The main reason for this skewness is the markup (note that all markups >= 0.1), introducing a bias for positive CZC forecast errors.

Table 2 shows how errors for each border are distributed in predefined ranges.

	[-inf,-100>	[-100,-50>	[-50,-10>	[-10,-5>	[-5,-2>	[-2,-1>	[-1,0.1>	0.1	<0.1,1]	<1,2]	<2,5]	<5,10]	<10,50]	<50,100]	<100,inf]
AllBorders	0%	2%	5%	1%	1%	0%	1%	75%	0%	0%	1%	2%	7%	2%	1%
DK2-SE4	0%	0%	0%	0%	0%	0%	0%	98%	0%	0%	0%	0%	1%	0%	0%
SE4-DK2	0%	3%	5%	2%	6%	1%	1%	58%	0%	1%	3%	7%	7%	3%	1%
FI-SE1	0%	0%	0%	0%	0%	0%	0%	99%	0%	0%	0%	0%	0%	0%	0%
SE1-FI	3%	9%	17%	2%	2%	1%	1%	25%	0%	0%	1%	4%	20%	11%	4%
NO1-NO2	0%	0%	0%	0%	0%	0%	0%	99%	0%	0%	0%	0%	0%	0%	0%
NO2-NO1	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
NO1-NO5	0%	0%	2%	0%	0%	0%	0%	95%	0%	0%	0%	0%	1%	0%	0%
NO5-NO1	0%	0%	2%	2%	1%	0%	1%	89%	0%	1%	1%	1%	2%	0%	0%
NO3-NO4	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
NO4-NO3	1%	3%	17%	7%	5%	2%	2%	13%	1%	1%	4%	9%	29%	4%	2%
NO1-SE3	0%	0%	2%	2%	2%	1%	1%	81%	0%	2%	2%	4%	3%	0%	0%
SE3-NO1	0%	8%	18%	4%	2%	1%	1%	24%	1%	1%	2%	5%	21%	10%	1%
NO4-SE1	1%	4%	15%	6%	4%	2%	2%	19%	1%	1%	4%	9%	25%	5%	3%
SE1-NO4	0%	0%	2%	1%	1%	0%	0%	92%	0%	0%	0%	1%	2%	0%	0%
NO3-SE2	0%	1%	4%	1%	1%	0%	0%	84%	0%	0%	1%	1%	4%	1%	1%
SE2-NO3	0%	1%	5%	3%	2%	1%	0%	78%	0%	0%	2%	2%	5%	1%	0%
SE1-SE2	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
SE2-SE1	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
SE2-SE3	3%	9%	13%	2%	1%	1%	1%	35%	0%	0%	1%	3%	16%	12%	3%
SE3-SE2	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
SE3-SE4	1%	5%	6%	2%	2%	1%	1%	65%	0%	1%	1%	3%	7%	5%	1%
SE4-SE3	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%

Table 2 – Distribution of forecast errors (percent of hours in error ranges).

For most borders, the CZC forecast error distribution is multi-modal, with a peak negative error value, a peak positive error value, and a peak at an error of 0.1 €/MW. The most likely positive and negative errors are typically greater than 10€/MW for all borders. That is, for most borders and in most hours the error is either 0.1 or it is greater than 10€/MW.

Overall, and over all border directions, about 9% of the hours have forecast errors below -5 EUR/MWh and about 12% of the hours have forecast errors higher than 5 EUR/MWh. We also see that, for most borders, the errors are most often in the 10-50 EUR/MW range (in absolute terms).

Comments

The difference between forecasted and actual CZC value for the 22 border directions in the aFRR CM since 8 December 2022 varies significantly from border to border, both in error size and error frequency. The drivers behind large errors are:

- different DAM prices on both sides of the border
- changes in DAM prices from one day to the next.

The D-1 approach to forecast CZC values used in the aFRR CM can also be referred to as a naïve forecast (a technique in which the last period's actuals are used as this period's forecast). In well-functioning markets, the market price at any time represents the summation of all information available to the market. It can be thought of as an aggregate market "view" of what the price is, given such "underlying" information. For the next period, assuming relatively moderate changes in the underlying information, we may reasonably expect relatively moderate changes in market prices. In such a case, the naive forecast can be a fairly good short-term predictor. As we have seen, the naïve forecast gives 0 €/MW errors in 75% of the cases (hours + border directions) and in 21% of cases an (absolute) error greater than 5 €/MW. These larger errors are caused by changes in the spread from one day to the next. Drivers of such volatility can be hypothesized to include changes in weather conditions, change from business day to non-business day (and vice versa), and plant and grid unavailability.

It is difficult to quantify the economic effect of these errors, without having access to the full DAM and aFRR bids for each price area. In theory, a correct CZC cost will allow an optimal economic tradeoff between the aFRR and DAM markets. Deviating from this will result in one market "winning" and the other "losing"; however the relative sizes of the "win" and "loss" will depend on the bid curves (including the use of complex bids). However, since the DAM market is substantially larger in value than the aFRR market, it may be postulated that negative CZC errors (where the forecast CZC cost is less than the actual CZC cost and hence less capacity is made available to the DAM than is optimal) may result in greater net socio-economic loss than positive CZC errors.

It is also worth mentioning, that having forecast errors is not equal to reservations to the exchange of reserve capacity not being beneficial. If the value of reserving capacity for the exchange of reserve capacity is larger than the actual/realized value of cross-zonal capacity the reservation has still been socio-economically beneficial no matter the size of the forecast error.

5b Increase above the 10% NTC limits

According to the Nordic methodology, up to 10 % of the transmission capacity (NTC) on a border can be reserved for aFRR balancing capacity. In case of scarcity, reserved capacity can be increased until demand is satisfied. In such cases, the TSOs increase the CZC limits until demand is satisfied or up to the maximum of 20%.

The table below shows general statistics on CZC reservation in the period from 8 December 2022 to 24 March 2023. Only the hours with aFRR reserve requirements are included (i.e., hours 2-5 are excluded for all borders). Also, FI->SE1 results are calculated on auctions from the date that the border was opened for aFRR exchange (starting 25 December 2022).

	DK2-SE4	SE4-DK2	FI-SE1	SE1-FI	NO1-NO2	NO2-NO1	NO1-NO5	NO5-NO1	NO3-NO4	NO4-NO3	NO1-SE3	SE3-NO1	NO4-SE1	SE1-NO4	NO3-SE2	SE2-NO3	SE1-SE2	SE2-SE1	SE2-SE3	SE3-SE2	SE3-SE4	SE4-SE3
Max Res (MW)	50	52	66	0	190	200	60	123	24	24	205	204	44	47	48	47	99	109	121	130	68	84
Min Res (MW)	10	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	35
Average Res (MW)	40	41	13	0	49	85	27	37	7	4	93	43	13	14	15	18	12	20	7	61	53	67
Max Util (%)	29%	40%	60%	0%	100%	65%	100%	35%	120%	48%	100%	98%	88%	100%	80%	100%	30%	33%	17%	18%	17%	42%
Min Util (%)	6%	29%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	13%
Average Util (%)	24%	31%	10%	0%	26%	27%	58%	10%	36%	4%	48%	21%	23%	24%	25%	25%	4%	6%	1%	8%	12%	25%
Hours at 100% Util	0%	0%	0%	0%	0%	0%	26%	0%	11%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 3 – CZC reservation overview.

In the row with maximum utilization (i.e., the highest reserved/capacity[4] ratio), we see that six borders have one or more hours when the reserved capacity is equal to or greater than the available capacity at 10% NTC, but only one of these borders (NO3->NO4) utilizes the possibility of reserving more than 10% NTC. On 13 March 2023, NO3->NO4 had reservations of 24 MW in hours 7, 8 and 9 when the available capacity was 20 MW (i.e. a 12% NTC instead of 10%). This is 3 hours for one border, which is only 0.0067264% of all possible reservations in the aFRR CM in the period analyzed.

The effect on the aFRR CM is that we avoid a scarcity situation of 4 MW in the north of Norway. On the DAM, taking out 4 MW 'extra' did not have any effect on this day and for these hours since the results of the clearing later that day showed that the border had no flow and 176 MW of 'unused' capacity.

The results also show that for most of the borders, the 10% NTC limit is sufficient for an efficient allocation of aFRR across the Nordics. The NO1->NO5 border may be the only exception, where roughly every fourth hour had a CZC reservation equal to the capacity. A higher capacity on this line would most probably make it possible to select more and cheaper NO5 downward bids for the Nordic market.

[4] Capacity based on 10% NTC.

5c Impacts on economic surplus

The impact that exchange of balancing capacity in aFRR CM has on economic surplus can be split into two main parts: impact on the SDAC and impact on the aFRR CM.

SDAC

To calculate the change in economic surplus for the SDAC, we follow the methodology outlined below:

$$for\ each\ border\ (r, r')\ and\ hour\ t:$$

$$if\ flow_{t,(r,r')} = capacity_{t,(r,r')}:$$

$$surplus_{t,(r,r')} = CZCreservation_{t,(r,r')} \cdot (DAMprice_{t,r'} - DAMprice_{t,r})$$

$$else:$$

$$surplus_{t,(r,r')} = 0$$

In more detail this means that if a line in SDAC has a flow equal to the capacity, we multiply the CZC reservation from the aFRR with the spread in DAM prices for the border. A more sophisticated methodology would be to rerun the DAM clearing with higher capacities (original capacity + CZC reservation), but as mentioned in the introduction, Simulation Facility with actual bid curves is not available. since we remove capacity from the SDAC due to the aFRR CM coupling, the economic surplus for the SDAC will always be negative.

Following the methodology outlined above on data from 8 December 2022 to 24 March 2023, we get the results for each border stated in the table below.

Border	% hours congested	Surplus delta (EUR)
DK2-SE4	0.7%	-14'166
SE4-DK2	21.0%	-492'752
FI-SE1	0.1%	-34
SE1-FI	0.0%	0
NO1-NO2	0.0%	-91
NO2-NO1	0.0%	0
NO1-NO5	1.1%	-15'159
NO5-NO1	3.9%	-50'520
NO3-NO4	0.0%	0
NO4-NO3	15.6%	-298'179
NO1-SE3	11.8%	-237'038
SE3-NO1	0.0%	0

NO4-SE1	35.5%	-857'287
SE1-NO4	2.5%	-19'508
NO3-SE2	6.2%	-107'372
SE2-NO3	9.5%	-80'972
SE1-SE2	0.1%	-47
SE2-SE1	0.0%	0
SE2-SE3	7.2%	-650'348
SE3-SE2	0.0%	0
SE3-SE4	20.2%	-1'266'917
SE4-SE3	0.0%	0
Total	**6.2%**	**-4'090'390**

Table 4 – Economic impact on SDAC (EUR).

As shown, the change in total economic surplus for the SDAC is minus 4.09 mill. EUR over the 107 days from 8 December to 24 March 2023. This averages 38'228 EUR per day. We also see that five lines are 'congested' in more than 10% of the hours, and that NO4->SE1 is congested in 35% of all hours which results in a negative surplus of 857'287 EUR.

This methodology of estimating the economic surplus for the SDAC assumes that a congested line (flow=capacity) would use all the capacity reserved for the aFRR CM (flow = flow + CZCreservation) were it not for the aFRR CM. If we had access to the SDAC simulation facility, we would be able to get the actual flow, but that was not the case for this report. Consequently, the value calculated above might be a bit too extreme, which means that in reality, effects on SDAC might be lower.

aFRR CM

The methodology for estimating the economic surplus from the coupling of price areas in the aFRR CM follows the TSOs own benefit calculations, which are calculated as a comparison between how the market would be cleared without the possibility of exchange and the actual market results from 8 December 2022 to 24 March 2023. Therefore, the clearing and pricing algorithms used for the actual market results have also been used to clear the markets with no CZC between bidding zones.

When clearing the market without exchange possibility, only local bids are chosen. In bidding zones without sufficient bids, the unprocured demand is priced at the highest of the bidding zone's market prices in the two cases – with and without exchange. In the reference case without exchange, the highest price among local bids is taken as the market price. If there are no local bids, the local price of the market case (with exchange) is used also in the reference case.

As a consequence, in cases where there are some, but not enough, local bids, benefits can be high if the highest accepted bid price in the reference auction is high, but they can also be 0 if there are no local bids at all, since it is difficult and hence would be arbitrary to value the security of supply in the absence of local bid prices.

This is not optimal, and we could have used an arbitrary value for the prices of lacking reserves, based on e.g. historical prices, highest price in neighboring area, or otherwise, but this could result in very high benefits, which do not necessarily reflect reality. We have therefore decided on a conservative approach, where benefits are set to zero if the demand cannot be covered from local clearing and there are no local bids at all.

The overall results shown below are therefore also conservative, since the benefit of having access to reserves to cover demand at all points in time is not always priced and part of the analysis.

In the following analysis, we refer to the actual market results as 'market' and the results without exchange as 'reference.' Economic surplus in the aFRR CM consists of three main elements: producer surplus, consumer surplus, and congestion rents (when there is no change in the volumes produced and consumed, these three elements add up to the reduction of overall energy costs).

Case	Producer (BSP) surplus	Consumer surplus	Congestion rent
Market	The BSP Surplus in the market case is the difference between the clearing price in the market case and offered price times the accepted volume in the market case per bid.	TSO procurement cost for the market case (Procured capacity * market case clearing price).	For each price area, the sum of reserved czc*price spread over all lines out of the price area divided by two.
Reference	The BSP Surplus in the reference case is the difference between the clearing price and the offered price times the accepted volume in the reference case per bid.	TSO procurement cost for the reference case (Procured capacity * clearing price reference case).	0 for all price areas, since no exchange is allowed/possible.

Table 5- Producer surplus, consumer surplus and congestion rent definitions.

The economic surplus from the exchange of balancing capacity from the application of the market-based allocation process is the difference between these values between the market and the reference case:

$$\begin{aligned} economic\ surplus \\ &= \left(prodsurplus_{market} - prodsurplus_{ref}\right) \\ &+ \left(conssurplus_{market} - conssurplus_{ref}\right) + congestionrent \end{aligned}$$

Producer surplus results from 8 December 2022 to 24 March 2023 are shown in the graph below.

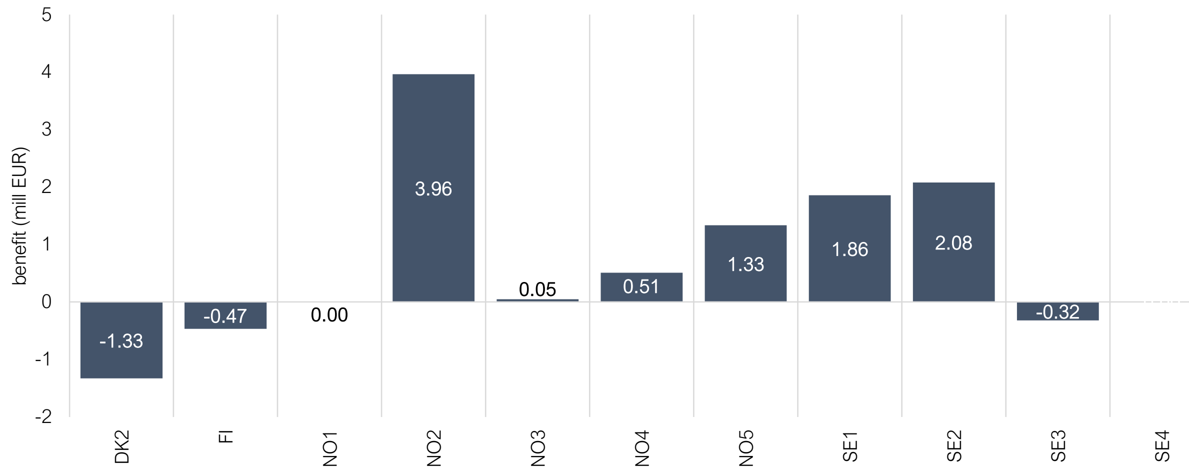


Figure 8 – BSP surplus benefit (mill. EUR).

We see that the producers that benefit the most from the exchange are those located in bidding zones NO2, NO4, NO5, SE1 and SE2. The benefit ranges from 0.51 to 3.96 mill. EUR. As a general rule, we can say that a bidding zone will have a positive producer surplus if the amount of accepted volumes in the bidding zone increases. An increase in accepted volumes typically means more expensive accepted bids which raise the (marginal) price, resulting in an increase in surplus for the producers in this price area. Most often, a negative producer surplus can be explained by a decrease in locally accepted bids and the import of cheaper bids lowering the price in the bidding area.

If we look at the consumer surplus in the graph below, the situation is different.

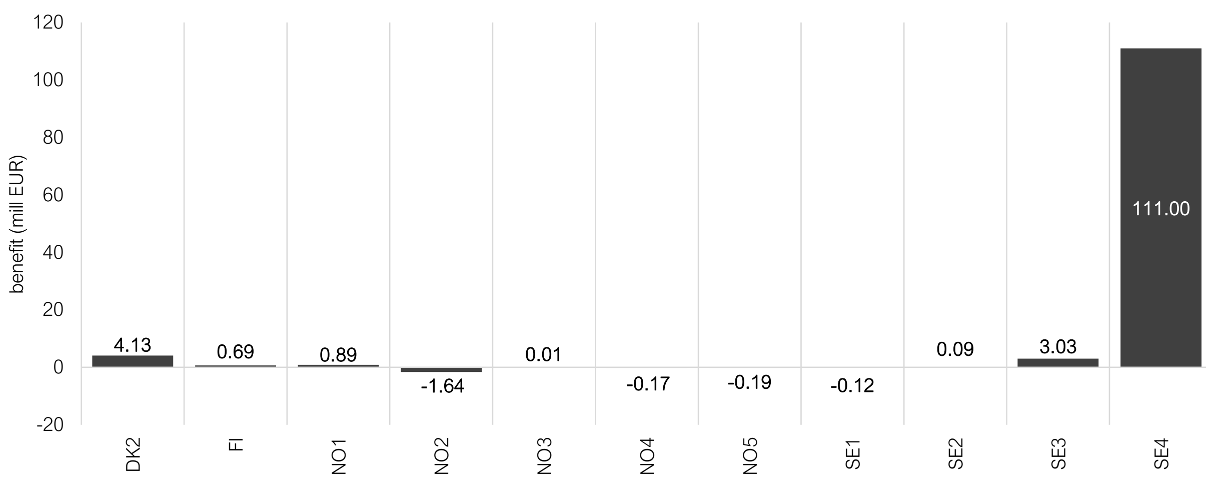


Figure 9 – Procurement benefit (mill. EUR).

A positive consumer surplus tells us that the cost of procuring aFRR has been reduced. Both the market and the reference case have the same demand, but different clearing prices. This tells us that (in general) a positive surplus comes from a decrease in clearing prices because of the exchange. On the other hand, a negative surplus could, in most cases, be explained by an increase in clearing prices for that area. Complex bid types and the fact that we may have unsatisfied demand (in the reference case in particular) complicates the analysis slightly. For SE4 for example, a large indivisible and expensive bid is used to satisfy demand in the reference case. This results in over-procurement and a remarkably high price in this price area. When exchange is allowed in the market case, this bid is not selected and the price is reduced dramatically, giving the large consumer surplus of 111 mill. EUR (approx. 1 mill. EUR per day). In reality, the SE4 reference case situation would make more BSPs put in bids and the large consumer surplus would go down relatively fast.

We can also see that almost all bidding zones with a positive producer surplus get a negative consumer surplus and vice versa. By excluding SE4 from the analysis, the total consumer surplus is 6.73 mill. EUR (average 62'282 EUR per day).

The third element of the economic surplus is the congestion income shown in the graph below.

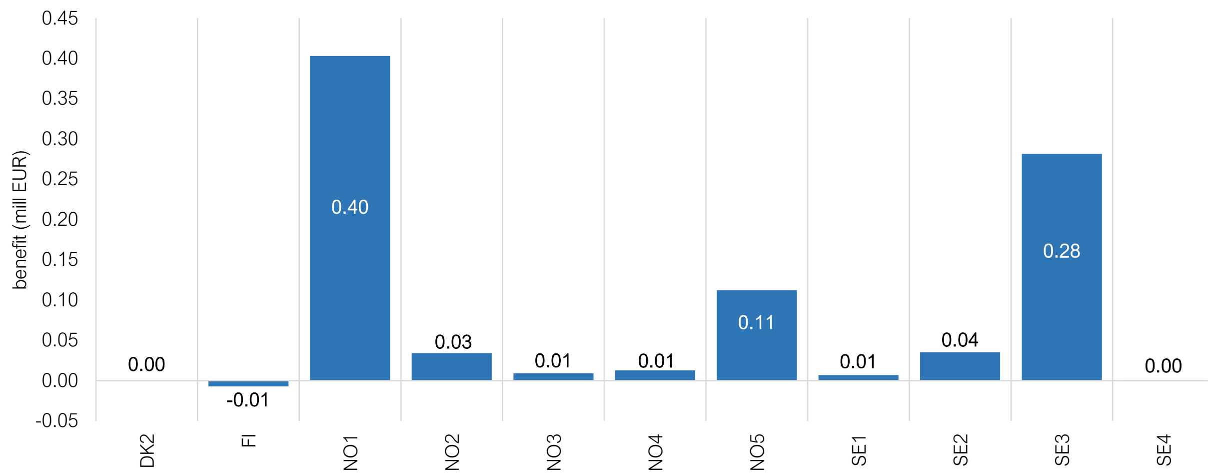


Figure 10 – Congestion income (mill. EUR).

The congestion income is the CZC reservation multiplied with the difference in clearing price on both sides of a border. To distribute the income from border to price area, the value is divided by two for the two price areas. A price area will therefore have congestion income if there is CZC reservation in and out of the area and a difference in clearing prices on both sides. The value gets higher if the CZC reservation and/or the clearing price difference is high. From the results we see that NO1 and SE3 have the highest congestion income. This is mostly driven by the border NO1-SE3, where CZC reservation is high and where there is a price difference for many of the hours.

If we add everything together, we get a total economic surplus of the exchange of balancing capacity.

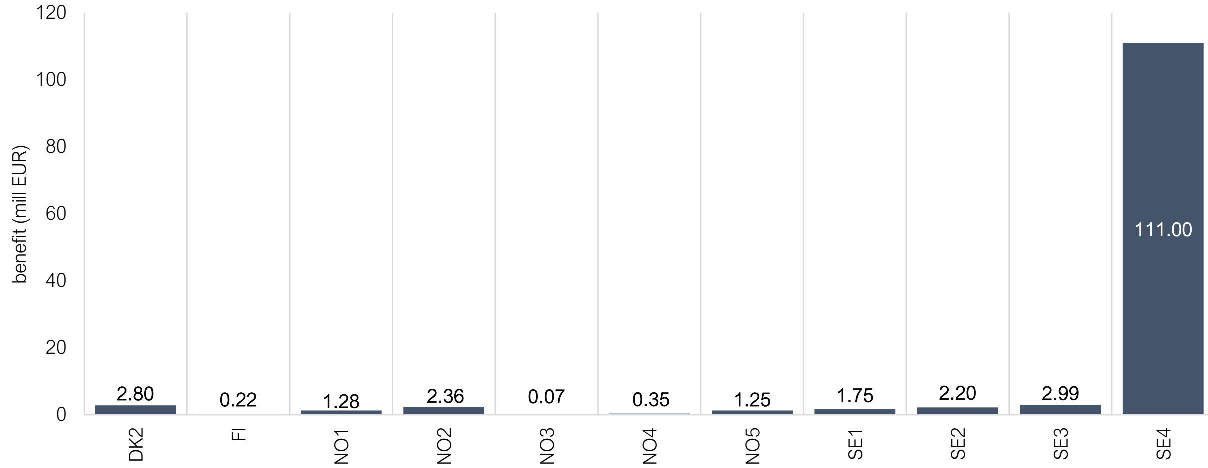


Figure 11 – Realized socio-economic benefit (mill. EUR).

The results are driven mainly by the congestion surplus in SE4 which is almost 88% of the total surplus of 126.27 mill. EUR. Average surplus each day is 1.18 mill. EUR for all bidding zones in total. We see from the graph that all bidding zones have a positive economic surplus. By excluding SE4 consumer surplus, we still end up with a positive economic surplus of 15.27 mill. EUR (average 142'697 EUR per day).

Total economic surplus SDAC + aFRR

The possibility of exchanging aFRR between price areas in the Nordics since 8 December 2022 has affected the SDAC by reducing the available transfer capacity and, consequently, a negative economic effect on the market. For the aFRR CM, it has effectively made cheaper resources available to the Nordics as a whole compared to before. This has had a positive economic impact on the market. The graph below shows daily surplus from both markets and a total (the sum of the two).

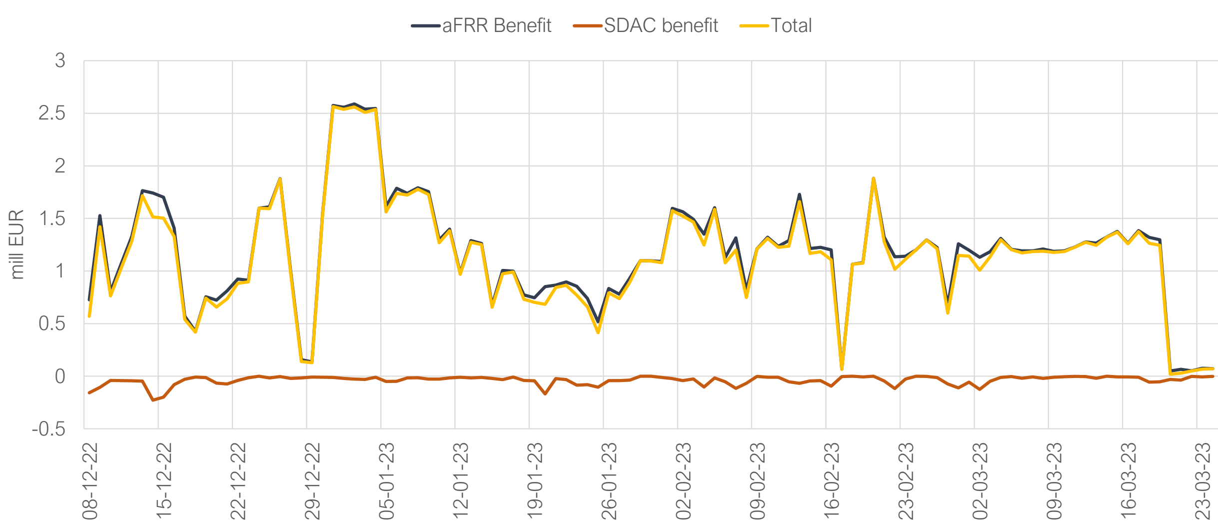


Figure 12 – Total economic surplus (mill. EUR).

We see that the negative effect on the SDAC is minor compared to the positive effect on the aFRR CM. The effect on the SDAC per day has been -38’228 EUR and the positive effect on the aFRR CM has been 1.18 mill. EUR. The graph also shows that all days have a positive economic surplus.

The table below summarizes the economic surplus results.

	SDAC surplus	aFRR surplus	Total surplus	Avg. daily surplus
All bidding zones	-4'090'390	126'269'066	122'178'676	1'141'857
Excl. SE4 cons.surplus	-4'090'390	15'268'590	11'178'200	104'469

Table 6 – Economic surplus summary (EUR)

In total from 8 December 2022 to 24 March 2023, the economic surplus from the exchange of balancing capacity was 122.178 mill. EUR (126.27 aFRR and -4.09 SDAC) with an average daily surplus of 1.14 mill. EUR. By excluding the SE4 consumer surplus, the total economic surplus is 11.178 mill. EUR with an average daily surplus of 104’469 EUR.

Alternative benefit calculation aFRR CM

The benefits from the aFRR CM presented above comes from the methodology of comparing the actual historic auction results with results based on auctions where each bidding zone (bz) is isolated from each other (i.e., no CZC between bidding zones). But if there was no Nordic market, the procurement in countries with more than one bidding zone would not correspond to this benefit. An alternative to this methodology is to compare the actual historic auction results with national markets, i.e. unlimited CZC between bidding zones within each country, which is closer to what the situation was before 8 December 2022. This methodology will give benefits that better reflect a ‘before/after’ Nordic market situation. The results from this methodology are presented below for the period 8 December 2022 to 23 March 2023 (i.e. 106 days). Hence the numbers in table 6 and table 8 differs, because there is one additional day in the calculations for table 6.

The table below shows the change in surplus from the original methodology (isolated bz’s) and the alternative methodology (national markets).

	Total surplus	Procurement benefit	BSP benefit
All bidding zones	-95%	-98%	-58%
Excl. SE4	-56%	-60%	-58%

Table 7 – Change in economic surplus isolated bz’s vs. national markets.

From the table we see that the economic surplus varies depending on the calculation methodology used, and that the national market methodology has a lower total surplus (change from original Nordic market auctions) than the isolated bidding zone methodology. If we exclude SE4 from the calculations, the methodology with isolated bidding zones has a total benefit that is more than two times higher than the total benefit from the national market methodology.

In the table below, we present the average daily total surplus over the 106 days by using the two benefit calculation methodologies (isolated bidding zones and national markets) and with and without SE4.

	Benefits calculated from Isolated BZ method	Benefits calculated from national markets method
All bidding zones	1'190'539	64'663
Excl. SE4	143'364	63'270

Table 8 – Average daily benefit (EUR) with the two different methods and with and without SE4.

By using the national market setup when estimating the total surplus from a Nordic CM, we see that the daily surplus (without SE4) goes from 143’364 EUR to 63’270 EUR.

Since most of the ‘cheaper’ bids are in only a few bidding zones, it comes as no surprise that allowing trade between bidding zones has positive economic benefits. This is why the total surplus is higher when comparing the Nordic market with a market where the bidding zones are isolated versus comparing it to national markets (internal trade in countries). A graph showing the total economic surplus for each bidding zone by using national markets as reference case is presented in Appendix C.

In summary it is challenging to calculate the economic surplus correctly. The surplus, that is calculated using isolated bidding zones in the reference case (as required in the Acer decisions), is very high due to the high bid prices in SE4 that drive reference case’s TSO procurement costs up.

Using national markets in the reference case resolves this issue, but both methods ignore the value of the security of supply in at least one bidding zone where there are no local bids (DK2/SE3). This is due to conservatively setting benefits to 0 for demand that can be satisfied in the Nordic auction but not in the reference case when there are no local bids at all.

The surplus is further reduced by the lack of trading possibilities in the direction SE1-->FI, and that market participants bid more competitively in the Nordic market, reducing the auction costs in the reference case.

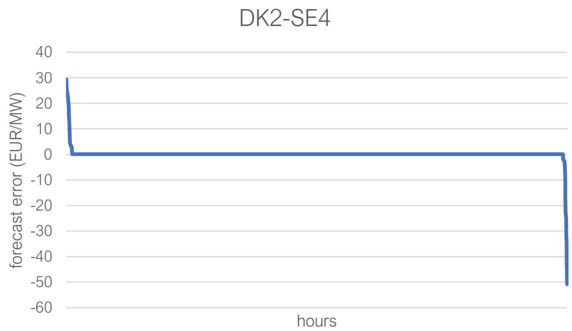
5d Proposals for improvement of forecast accuracy

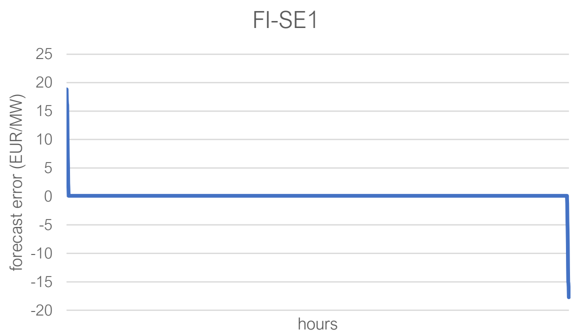
The TSOs have handed in an amendment to the markup methodology, which is still being processed by the NRAs. The TSOs have no further improvement proposals in regard to the markup methodology.

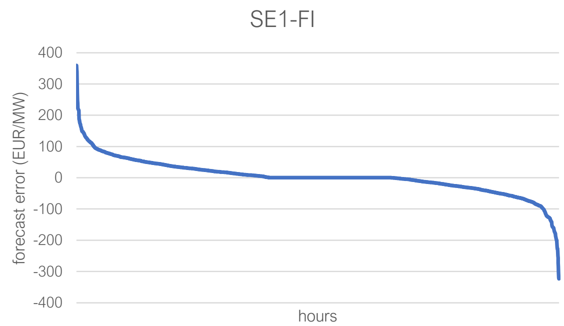
As concluded in section 5b, the limit on maximum volume for exchange of cross-zonal capacity is sufficient on most borders. Only few borders reach the limit often, but not in a way that has had consequences for the ability to cover TSO demand. However, if more capacity could be exchanged, cheaper resources, especially from NO5 would expectedly be able to cover a larger part of the Nordic demand and hence lower procurement prices across the Nordic region.

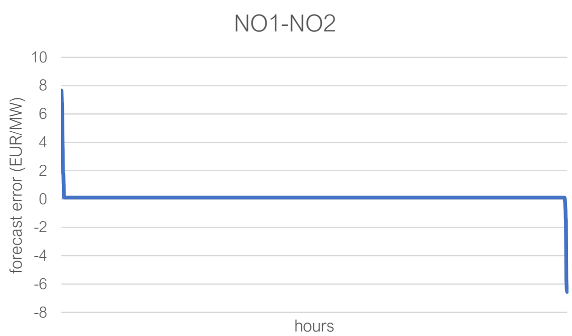
Appendix A

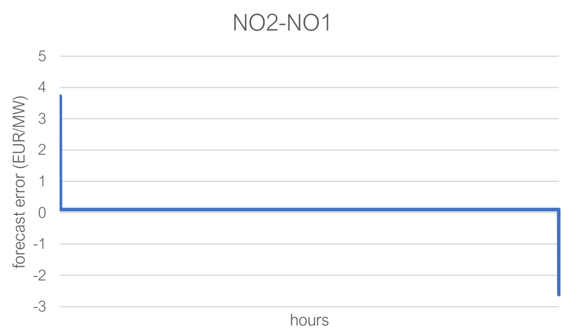
The following graphs are duration curves for the CZC forecast error for each border direction (from, to).

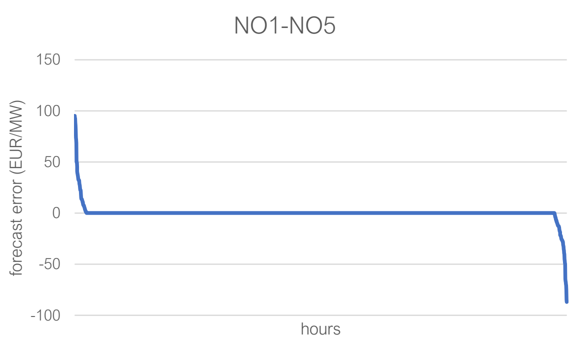


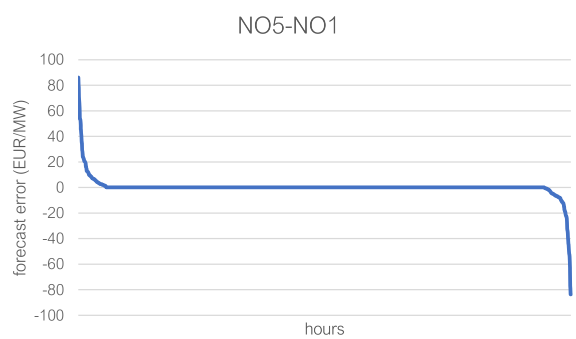


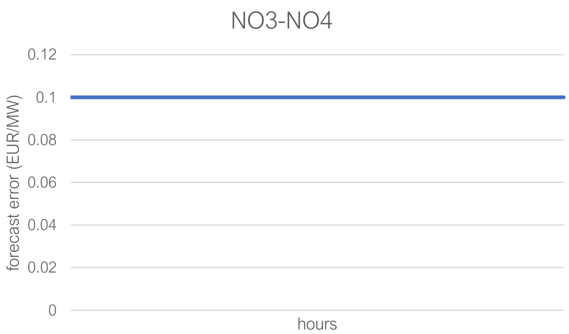


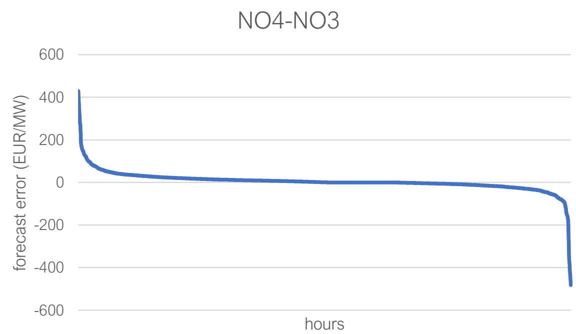


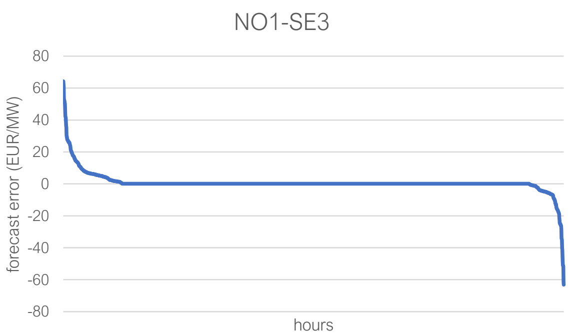


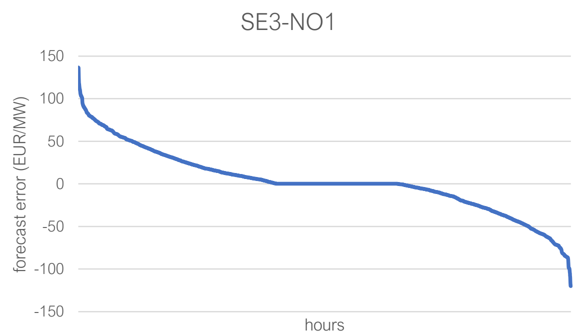


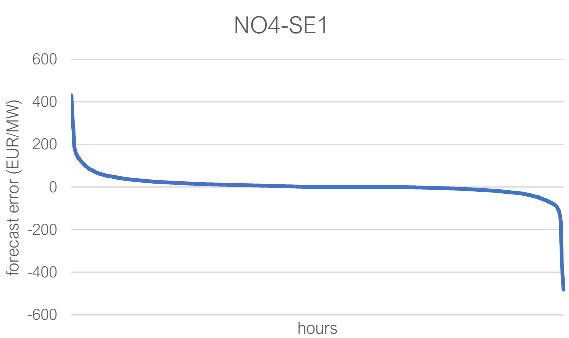


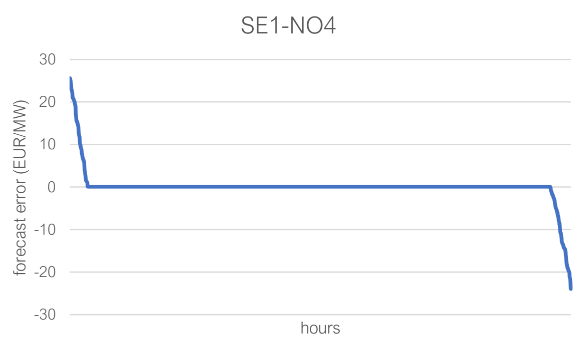

NO3-NO4
0.12
0.1
0.08
0.06
0.04
0.02
0
forecast error (EUR/MW)
hours

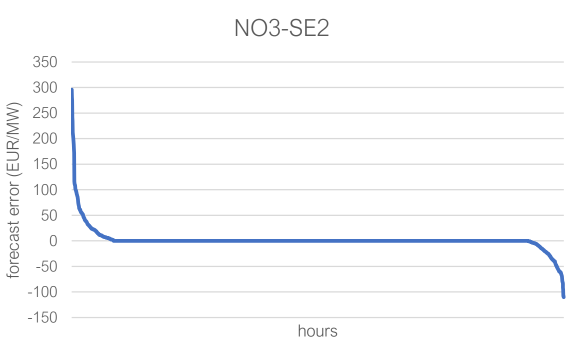

NO4-NO3
600
400
200
0
-200
-400
-600
forecast error (EUR/MW)
hours

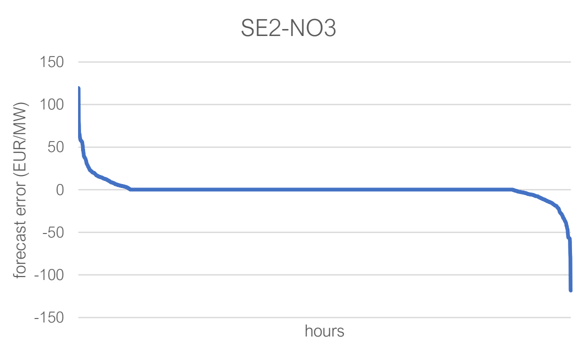

NO1-SE3
80
60
40
20
0
-20
-40
-60
-80
forecast error (EUR/MW)
hours


SE3-NO1
150
100
50
0
-50
-100
-150
forecast error (EUR/MW)
hours


NO4-SE1
600
400
200
0
-200
-400
-600
forecast error (EUR/MW)
hours


SE1-NO4
30
20
10
0
-10
-20
-30
forecast error (EUR/MW)
hours


NO3-SE2
350
300
250
200
150
100
50
0
-50
-100
-150
forecast error (EUR/MW)
hours


SE2-NO3
150
100
50
0
-50
-100
-150
forecast error (EUR/MW)
hours


SE1-SE2
15
10
5
0
-5
-10
-15
forecast error (EUR/MW)
hours


SE2-SE1
0.12
0.1
0.08
0.06
0.04
0.02
0
forecast error (EUR/MW)
hours


SE2-SE3
400
300
200
100
0
-100
-200
-300
-400
forecast error (EUR/MW)
hours

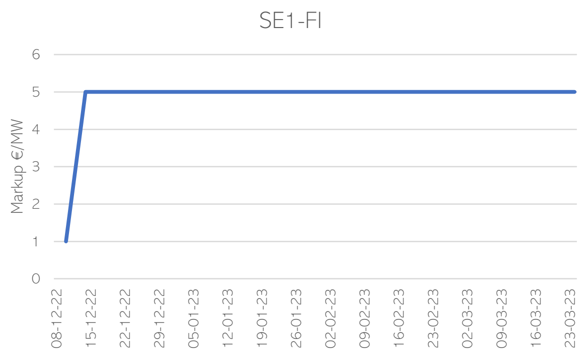

SE3-SE2
0.12
0.1
0.08
0.06
0.04
0.02
0
forecast error (EUR/MW)
hours

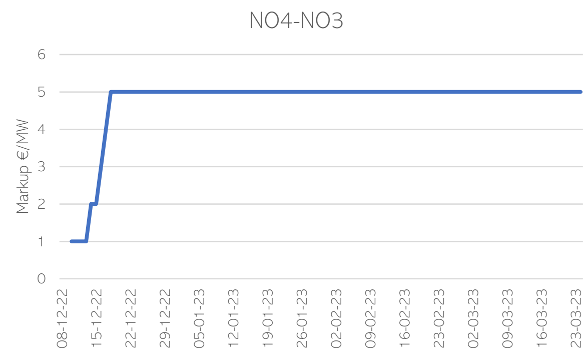

SE3-SE4
200
150
100
50
0
-50
-100
-150
-200
forecast error (EUR/MW)
hours

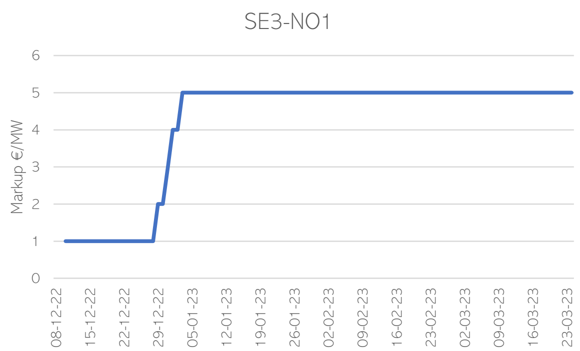

SE4-SE3
0.12
0.1
0.08
0.06
0.04
0.02
0
forecast error (EUR/MW)
hours

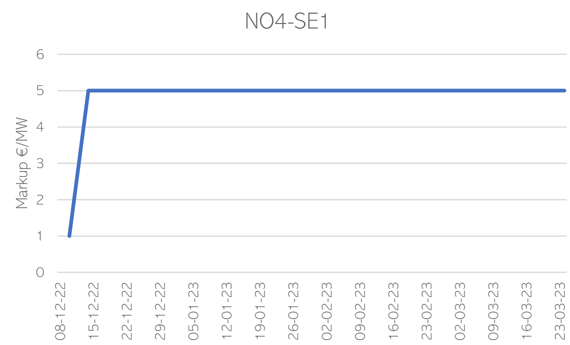
APPENDIX B

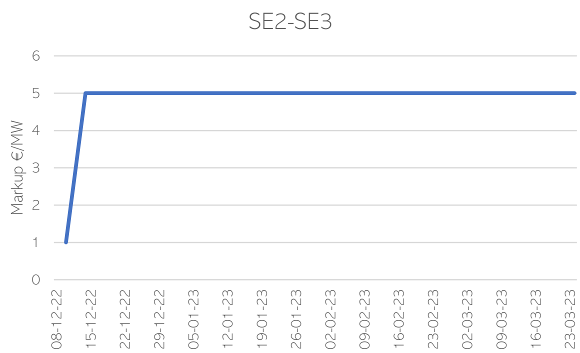
The graphs below show markups over time for the five borders with the highest average markups.











APPENDIX C

The graph below shows the aggregate impact on welfare compared to a reference cased based on national markets for each bidding zone for the period 8th December 2022 to 23rd March 2023.