Flow-Based Market Coupling – key topics for the Nordic & European markets

Matin Bagherpour, Senior algorithm design expert, Nord Pool

EURONEXT

From Complexity to Simplicity

The physical world

Complexity → Simplicity

Detailed grid model → FB → CNTC

Capacity calculation is the process of translating the complex physical grid into a simplified form that can be understood and applied by the power exchange

The commercial world

https://www.statnett.no/globalassets/for-aktorer-i-kraftsystemet/utvikling-av-kraftsystemet/flow_based_capacity_calculation_methodology.pdf

Change in flow after flow-based

Flow-based allows for more day-ahead flow through the Nordic system during the period we have looked at

North cut:
Average flow increases by 32%
Maximum flow is reduced by 6% 4320 → 4074 MWh

Central cut:
Average flow increases 31%
Maximum flow increases by 9% 8023 → 8711 MWh

Southern cut:
Average flow increases by 0.2%
Maximum flow increases by 9% 5336 → 5790 MWh

Southern Norway:
Average flow increases by 243%
Maximum flow increases by 23% 2564 → 3156 MWh

HVDC Cables
Average flow increases by 6%

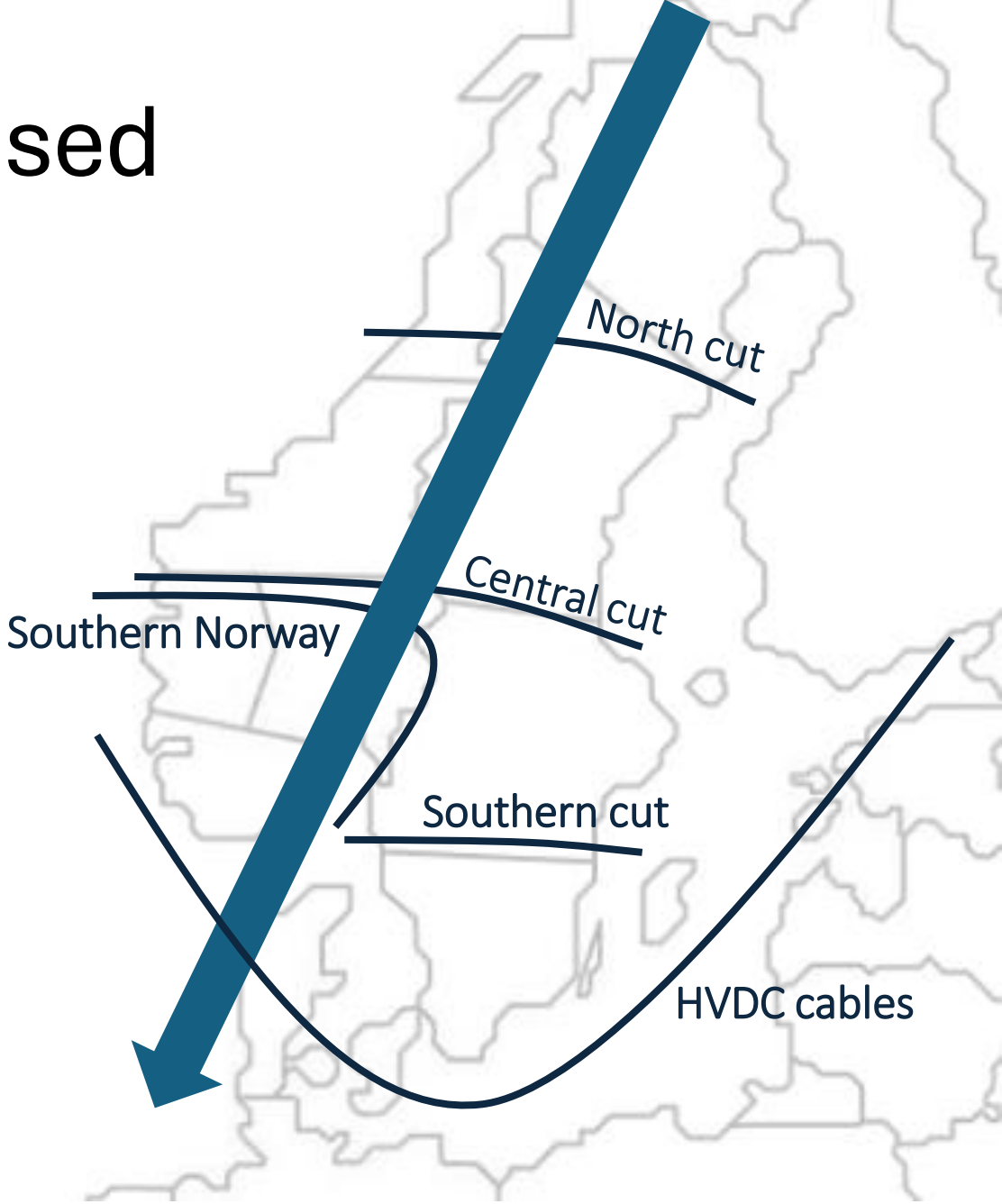


Figure: Nordic flow first year after go-live compared with flow from the two years before.

Low price in NO4 and high price in NO3

MORE WIND

↓

MORE FLOW

↓

MORE CONGESTION

↓

CONSTRAINT BINDS

↓

SHIFT TO EXPENSIVE GEN

↓

HIGHER PRICE

Background

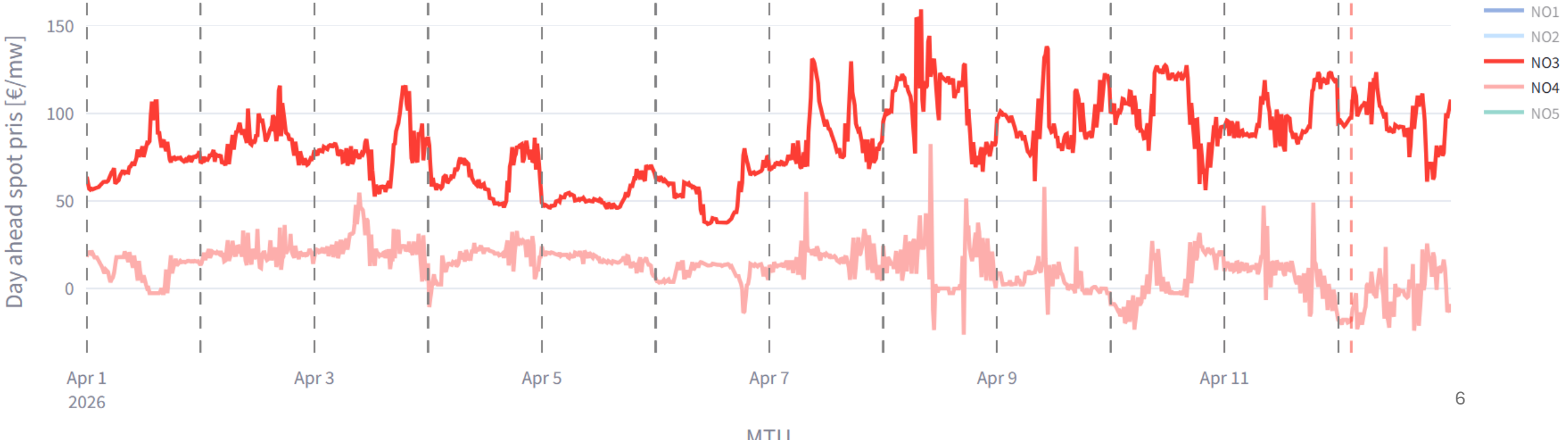
Last autumn, the line **Sogndal-Aurland** in NO5 was upgraded to 420kV. It previously limited the capacity **NO3→NO5 and NO3→NO1**. After the upgrade, **Klæbu-Orkdal** in NO3 has often been limiting to the market

A **maintenance** on Ørskog-Sykkylven in NO3, **low hydrological balance** (high water values) and periods of **high wind** has caused high prices in NO3

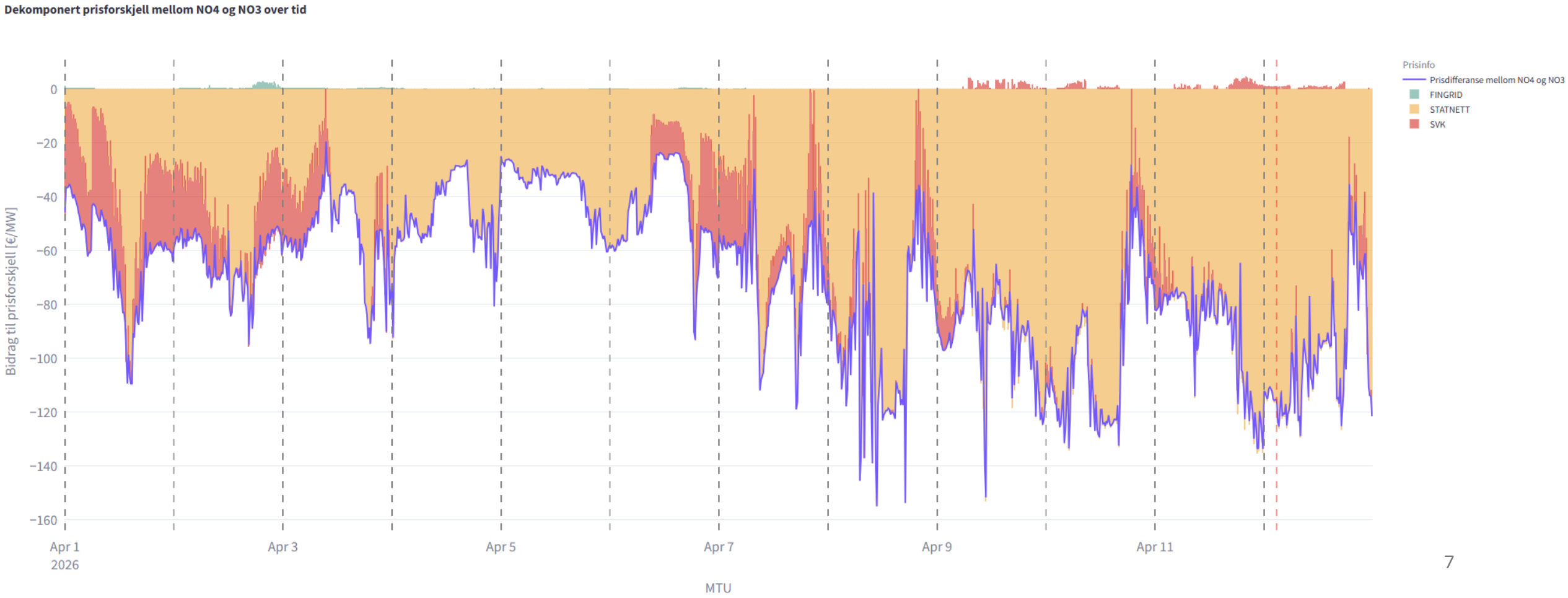
The price is a consequence of how the market reacts on the Klæbu-Orkdal CNEC

In the last few weeks, prices in NO3 have been higher than usual and very low in NO4

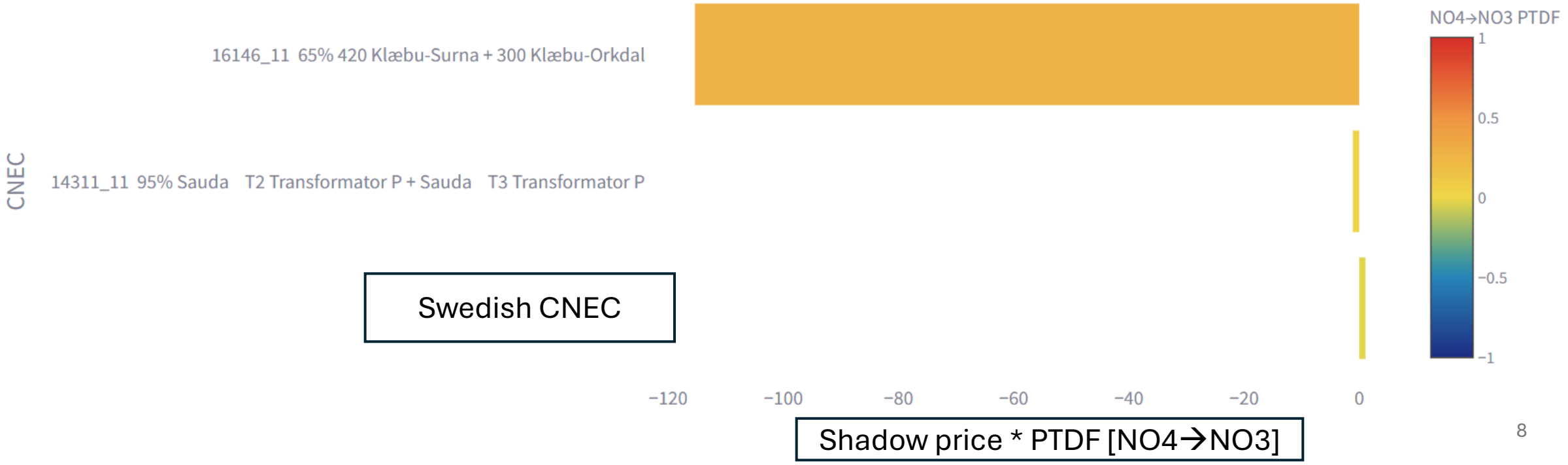
- NO4 has a very high reservoir filling, and there is still a lot of import into NO4 or low export
- NO3 on the other hand has very low hydrological balance as producing more, although still a lot of import



It is primarily Norwegian CNEC(s) that cause this price difference

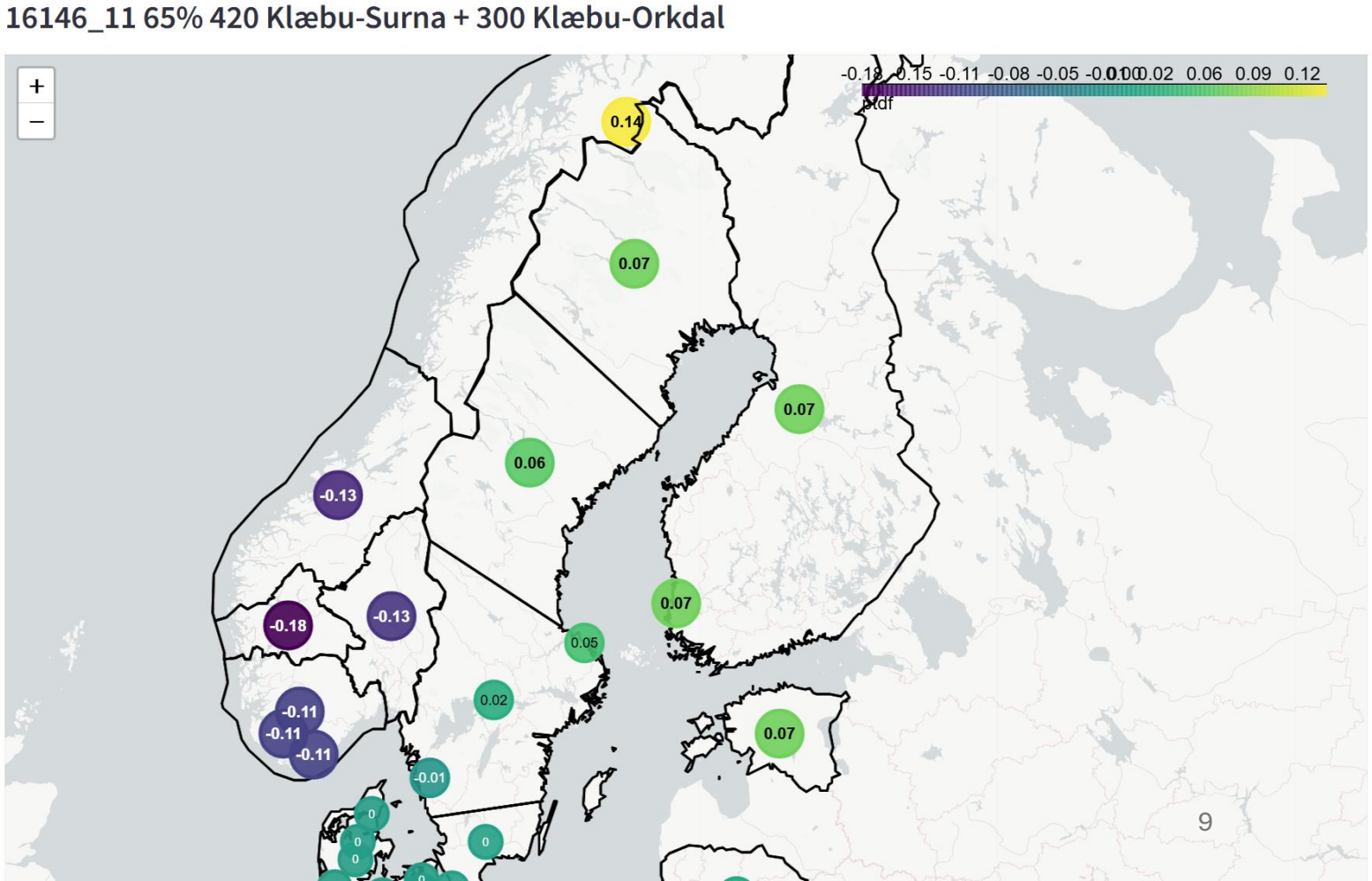


The CNE Klæbu-Orkdal is responsible for the large price difference



The PTDFs can explain the price formations and flows

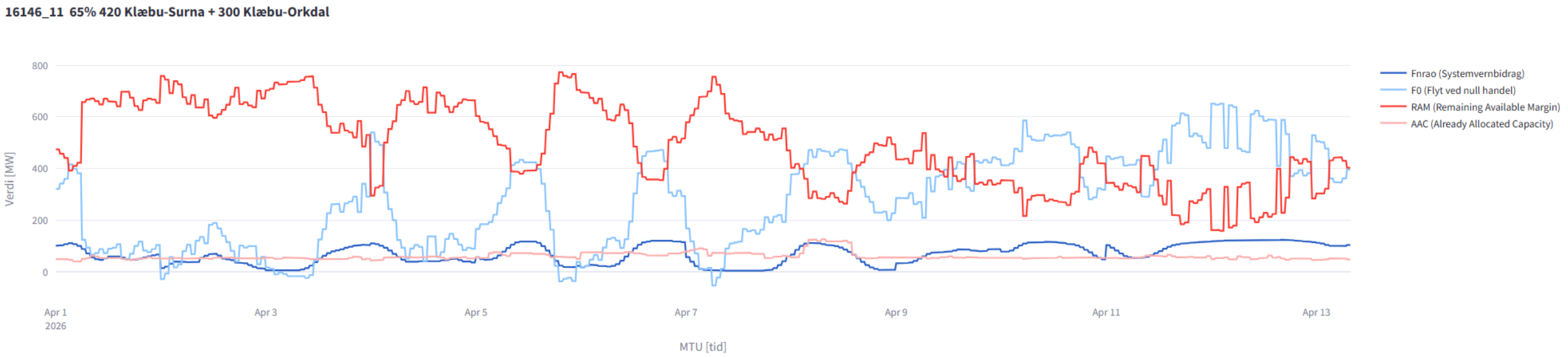
- The PTDF is double in NO4 compared to SE1 and SE2, so producing in NO4 loads the limiting CNEC much more
- Producing in NO3 (and NO5) and limiting production in NO4 minimizes the shadow price and maximizes socio-economic welfare
- The system "ignores" the high reservoir filling in NO4 to improve the overall system



Higher wind production can actually lead to higher prices

- In the north of NO3, there is a radial of wind production (Fosen)
- When there is high wind production in Fosen (or high production north of the CNEC), f0 (flow with zero net position) gets very high, limiting the remaining capacity on Klæbu-Orkdal
- Even with remedial action active, f0 still limits the CNEC more than the RA increases the RAM
- The rest of the production is in the south of NO3, and producing there relieves the CNEC
- The reservoir filling in NO3 is very low, so the water value there is high
- Thus, more production north of the CNEC (like Fosen) leads to even more expensive hydro power being activated, leading to higher prices

Remedial actions help increase the capacity on the CNEC somewhat, but not as much as f0 reduces it



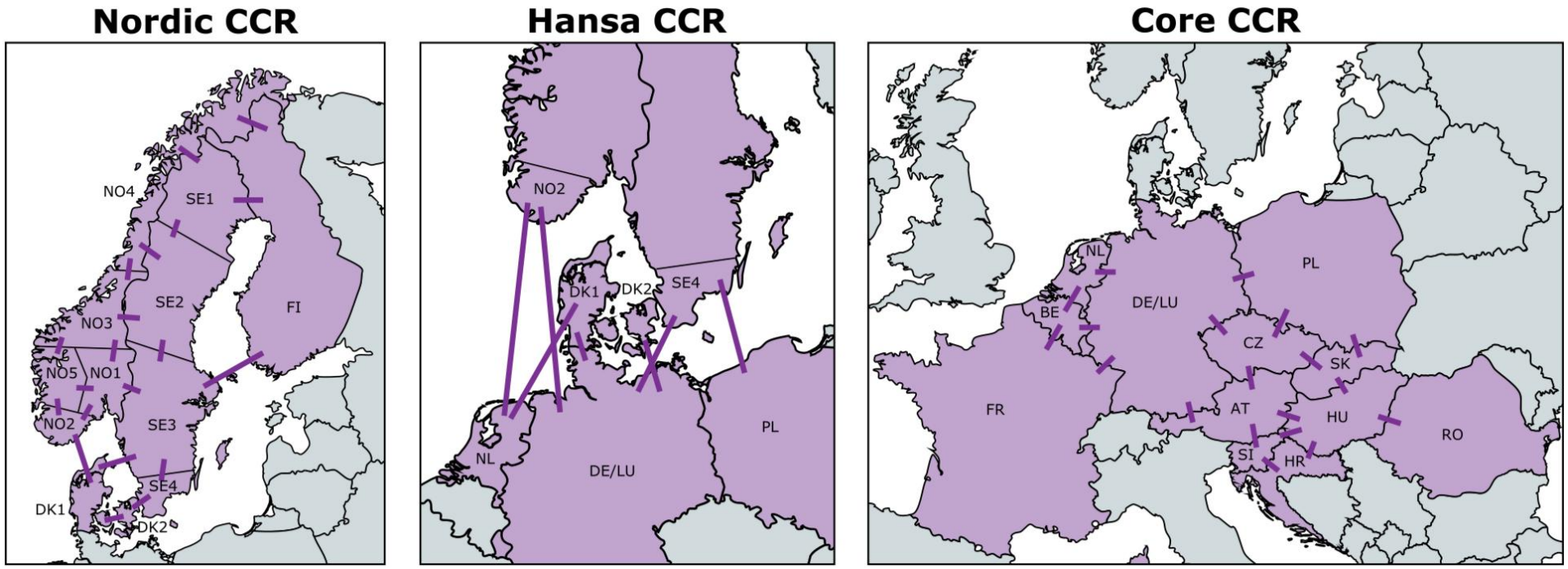
Statnett changes flow-based strategy for NO3-NO4

- The system operator has announced that the so-called GSK strategy will be changed for Central Norway (NO3) and Northern Norway (NO4) from GSK 6 to GSK 3 as of June 1.
- The GSK strategy can briefly be described as the method Statnett and other system operators use to aggregate constraints in the transmission grid from busbar level at power plants and substations up to the bidding-zone level.
- GSK (Generation Shift Keys) describes how a change in net position—total production and consumption—in a bidding zone is distributed across the underlying busbars.
- The new strategy, GSK 3, uses installed generation capacity as the aggregation variable. According to Statnett, this change will therefore result in more predictable capacity calculations compared with the GSK 6 strategy, which is based on forecast values and can thus lead to greater variability.

Impact of future changes on short-term markets

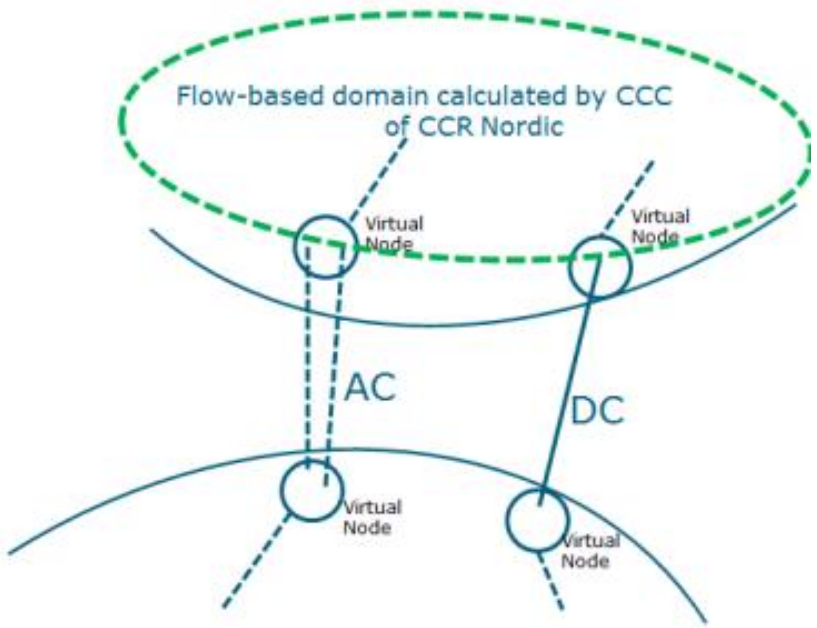
- **Core Advanced Hybrid Coupling (AHC)**
- Long-Term Flow-Based

Core Advanced Hybrid Coupling



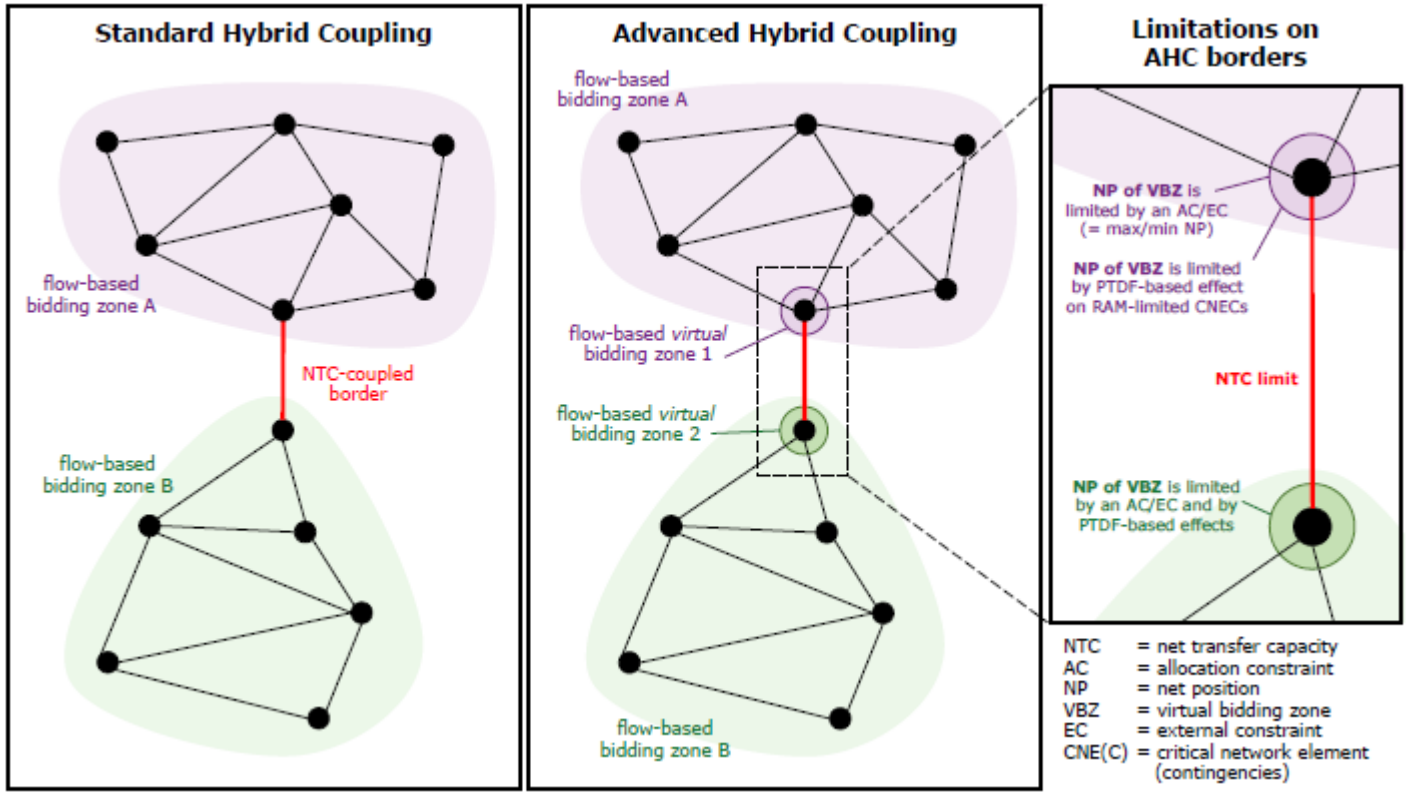
Core AHC – What Changes for Traders

- Go-live: June 10, 2026
- Core AHC removes forecast-based capacity reservation
- Lets all trades compete directly for scarce Core grid capacity
- Increasing efficiency but making price formation more model-dependent.



From SHC to AHC

- SHC: Non-Core flows pre-reserved on Core CNECs
- AHC: No priority for non-Core flows
- All trades compete in a non-discriminatory way



Who Is Most Affected – Renewables

AHC **favours zones with high renewable** variability, because it removes an inefficiency that penalises them under SHC.

Why this matters for renewables:

SHC reserves capacity ex-ante for forecasted flows

Forecast errors are larger when vRES output is high

AHC reallocates capacity dynamically during high RES feed-in

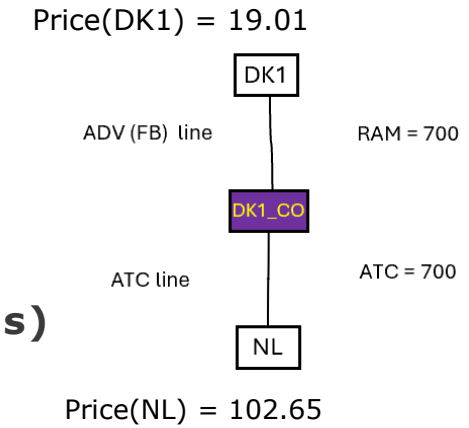
Price Difference Between CCRs

Main message: visibility of VBZs makes it easier to understand price differences

Date: 2024.11.16, Period = 1 (00-01)

Flow(DK1->NL) = 652.9 < ATC(DK1->NL) = 700,

no binding ramping limit, no loss



Why do DK1 and NL have so different prices? (83.68 Euros)

The virtual BZs are used to model HVDC lines in Advanced Hybrid Coupling, so from market clearing algorithm's (Euphemia) point of view DK1 is connected to the virtual BZ DK1_CO via a flow-based line, and then the ATC line is between DK1_CO and NL.

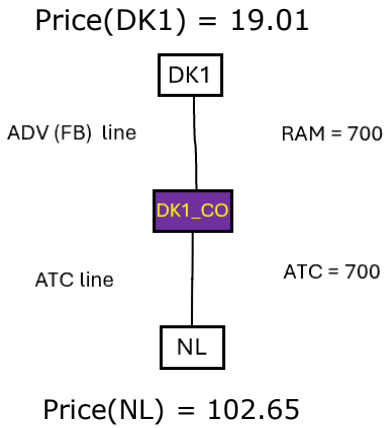
Price Difference Explanation

Date: 2024.11.16, Period = 1 (00-01)

Why do DK1 and NL have so different prices?

Capacity:

- Same value (700 MW) is given for both sides (ATC of the DK1_CO-NL line and RAM of the corresponding border CNEC connecting DK1_CO to DK1).
- So, the price difference cannot be caused by the different limit used in PTDF constraint.



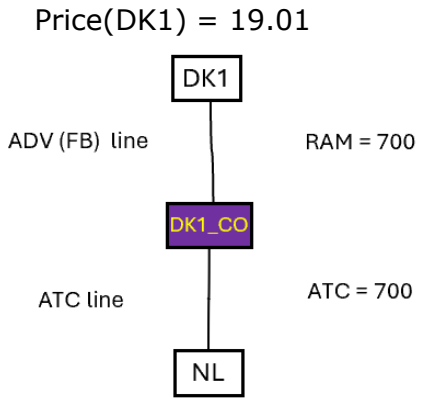
Price difference between CCRs

•Why DK1 and NL have so different prices?

Date: 2024.11.16, Period = 1 (00-01)

- For DK1 and DK1_CO to have same prices, their corresponding PTDF factors must be identical for all binding CNECs (CNE with positive shadow price).
- A quick check reveals that this is not the case. There is only one binding CNEC (shadow price > 0) in Jutland in this period, for which the PTDFs looks like this:

Bidding zone	factor
DK1	0.14778
DK1_SK	-0.11083
DK1_KS	0.20893
DK1_SB	0.06263
DK1_DE	0
DK1_CO	-0.01952



DK1 and DK1_CO can have different PTDF values because they impact the grid in two different ways.

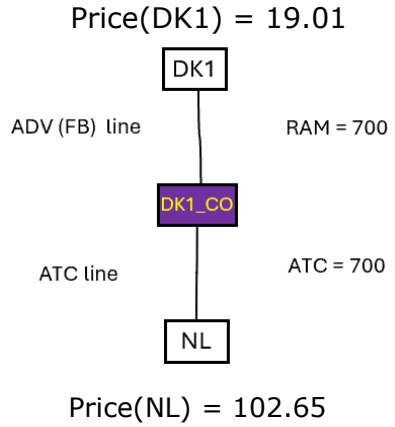
The impact on a specific CNEC differs depending on whether it originates from an import via the HVDC line or from an increase in sold production (increased NP) in DK1.

Price Difference via PTDFs

Date: 2024.11.16, Period = 1 (00-01)

- The difference in clearing price can be explained by the difference in flow factors weighed by the PTDF shadow price.

Bidding zone	factor
DK1	0.14778
DK1_SK	-0.11083
DK1_KS	0.20893
DK1_SB	0.06263
DK1_DE	0
DK1_CO	-0.01952



- Shadow Price= 499.95611869318816
- Price Difference = Shadow Price * (PTDF(DK1) – PTDF(DK1_CO)) = 83.68

Impact of future changes on short-term markets

- Core Advanced Hybrid Coupling (AHC)
- **Long-Term Flow-Based**

Long-Term Flow-based

Long-term (year-ahead) transmission rights auction
NTC vs LT-FB allocation

Setup

- One limiting CNEC: **1 000 MW RAM**
- Two borders competing indirectly
  - Border A (high spread): expected DA spread = **€25/MWh**
  - Border B (lower spread): expected DA spread = **€10/MWh**
- PTDFs on the same CNEC:
  - Border A: **0.5**
  - Border B: **0.4**

Case A: NTC-based long-term auction

Each border has its own NTC:

- NTC(A) = 1 000 MW
- NTC(B) = 1 000 MW

✅ **Auction result**

- Border A: 1 000 MW allocated
- Border B: 1 000 MW allocated

✅ **Trader payoff expectation**

- A: 25 000 €/h
- B: 10 000 €/h

Total implied hedging capacity = 2 000 MW

Case B: Long-term flow-based auction

System constraint:

$$0.5 \cdot Q_A + 0.4 \cdot Q_B \leq 1\,000$$

Welfare per MW of CNEC:

- Border A: 25 / 0.5 = **50 €/MW-CNE**
- Border B: 10 / 0.4 = **25 €/MW-CNE**

The optimisation prioritises **border A**.

✅ **Auction result**

- Border A: 1 000 MW ⟹ uses 500 MW CNEC
- Remaining CNEC: 500 MW
- Border B: 500 / 0.4 = **1 250 MW**, but capped by bids → assume **600 MW**

Border	Allocated LTTR
A	1 000 MW
B	600 MW

Border B bids only ~600 MW because bidding more is economically irrational once the bidder expects a low allocation probability and high exposure risk under flow-based competition.

✅ **Outcome**

🔻 Border B loses **40 % of hedging volume**

✅ **This exact concentration effect is observed in ACER's Core LT-FB experimentation**, where capacity systematically moves toward higher-spread borders in yearly auctions.

Impact on forward price risk & bidding behaviour

Same setup, now with trader risk

Under LT-FB, allocation is uncertain until *system-wide* clearing.

Assume trader on Border B:

- Needs **800 MW** for hedge
- Allocation probability under FB ≈ 0.75
- Expected shortfall = 200 MW
- Expected DA volatility = 30 €/MWh

📉 **Expected risk cost**

- $200 \times 30 = €6\,000/h$

✅ **Rational trader response**

- Bid for **600 MW instead of 800 MW**
- Or exit the border entirely

This behaviour — *volume shading due to FB uncertainty* — is documented by **Energy Traders Europe and Eurelectric** in LT-FB auction feedback.

Interaction between long-term FB and DA market

Setup (Core-like system)

- LT-FB allocates capacity mainly to **North–South corridor**
- East–West corridor receives less LT hedging

Under NTC

- Most traders hedged
- DA prices move moderately
  → Price spread ≈ **€15/MWh**

Under LT-FB

- Fewer traders hedged on secondary corridors
- Physical capacity exists but **is not financially hedged**
- Traders price in risk

Day-ahead consequence

In a stress hour:

- Demand shock in South
- Limited redispatch margin

✅ **Observed result**

- DA price spread widens to **€25/MWh**
- DA volumes become more volatile

Increased importance of price-spread forecasting

Under LT-FB allocation:

- Winning capacity depends not only on local spreads, but on how those spreads rank **relative to all other borders**.
- Forecast errors are penalised more severely because bids lose in a global optimisation rather than a bilateral auction.

Strategic response:

- More conservative bids on uncertain corridors.
- Concentration on borders with historically stable spreads (e.g. Nordics–Continental Europe, DE–FR).

Collateral constraints directly shape bidding strategies

Because LT-FB auctions aggregate exposure across many borders:

- **Collateral requirements are structurally higher** than under NTC-based auctions.
- Bids may be rejected purely due to credit limits, not economics.

Observed bidding effects:

- Fewer bids from smaller players.
- Strategic underbidding (volume reduction) to remain within collateral limits.
- Selective bidding on fewer borders with higher expected payoff.
- This effect is **unique to long-term markets**; it does not arise in day-ahead FB market coupling

Summary

Market	What changes numerically under LT-FB
Long-term auctions	Capacity concentrates on high €/MW-CNE borders
Hedging volumes	↓ on secondary borders (often 20–50%)
Bid strategies	Volume shading, selective border bidding
Day-ahead	Higher price sensitivity on less-hedged borders
Cross-border	External trades crowd out internal ones

New Publication of Non-anonymized Swedish CNECs

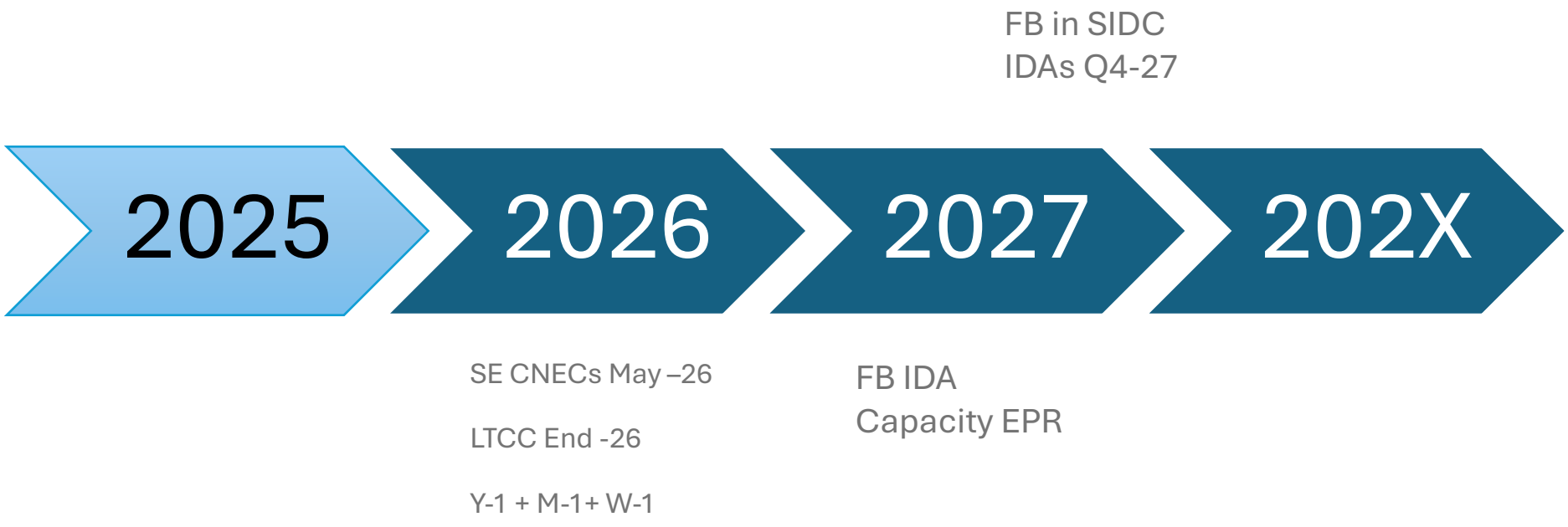
We have picked up following message from SvK (Swedish TSO).

Publication of Non-anonymized Swedish CNECs

Svenska kraftnät will disclose the names of network elements when publishing CNECs

- Simplify analysis for market participants and increases transparency
- Information will be made available on the publication tool provided by JAO and the data is then sent to ENTSO-E's transparency platform.
- Publication will take place as soon as the NRCC has implemented the necessary process changes (Anticipated in May)

Summary timeline (status as of May-26)



5.-LT-monthly-CC-go-live-and-NUCS.pdf