Experience from the Nordic Balancing Markets and Future Prospects for Auctions

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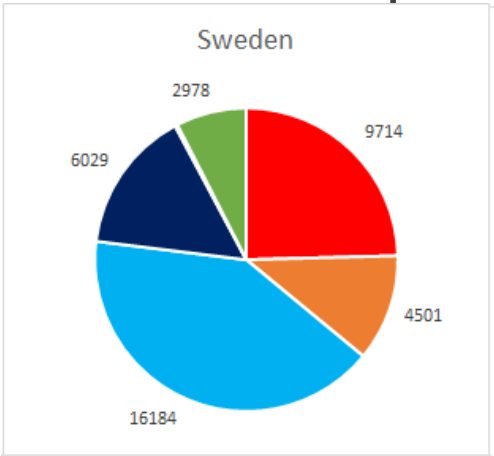
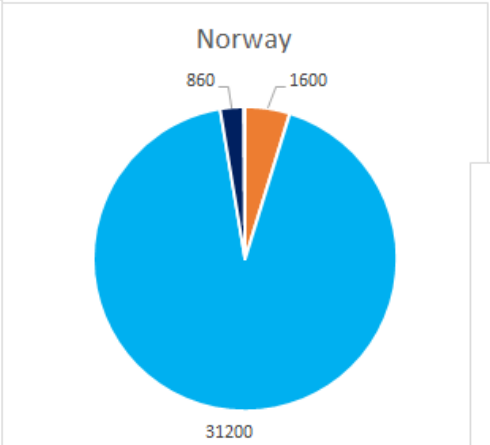
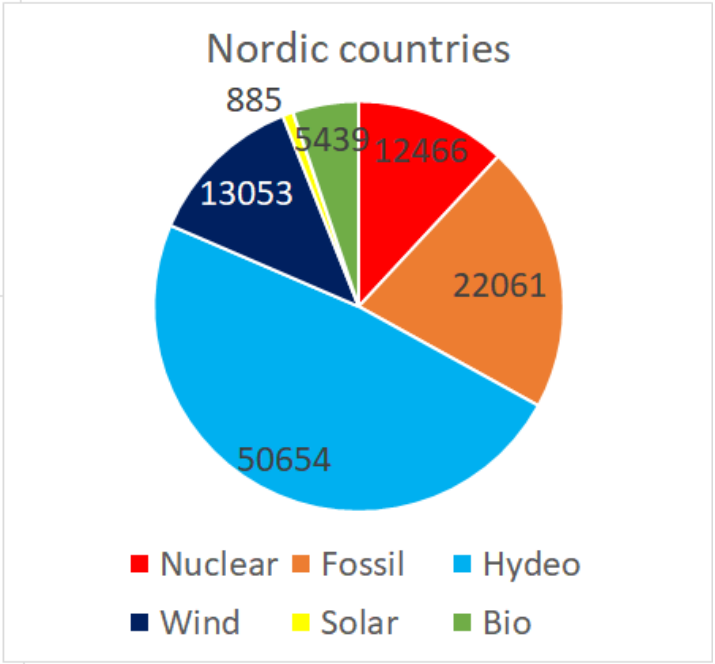
Overview

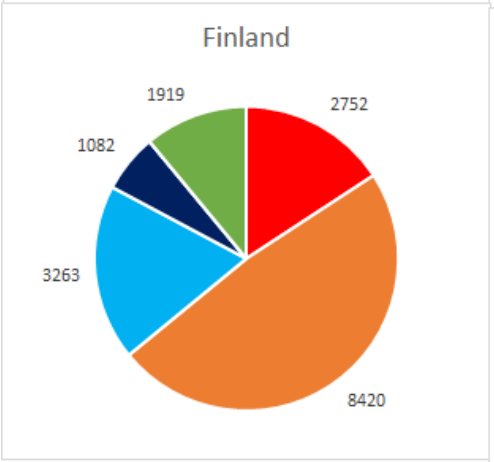
- Nordic power market
- Nordic reserve markets, overview
- Focus on auctions
  - Frequency Controlled Reserves
  - Frequency Restoration Reserves
- Exchange of aFRR reserve capacity Norway-Sweden
- Some auction design characteristics
- Summing up

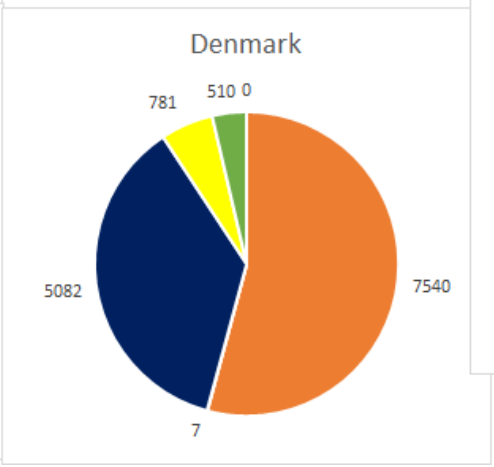
Nordic capacity 2015 (MW)



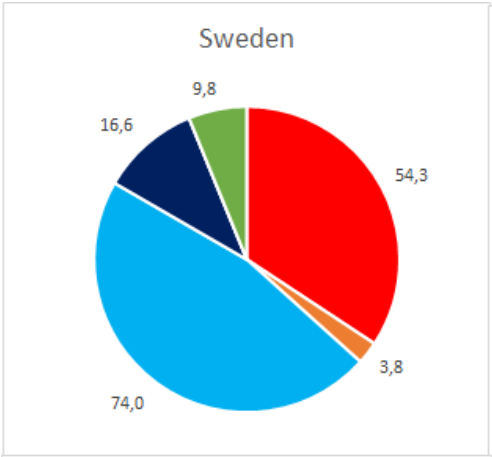


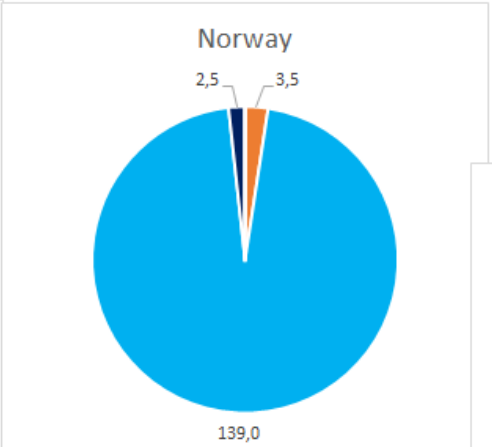


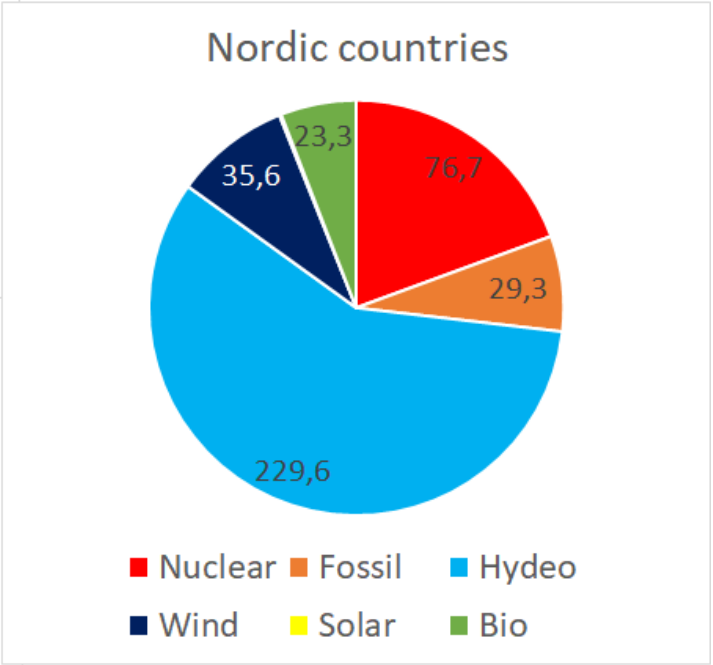


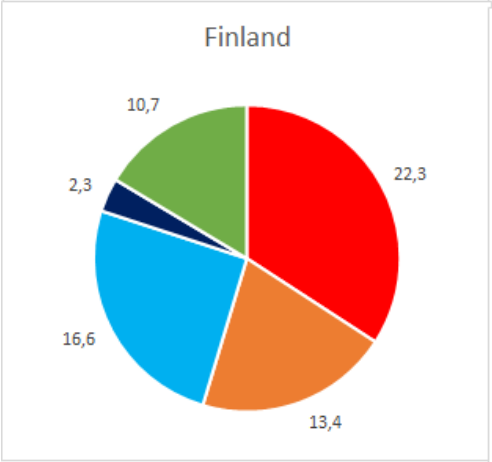


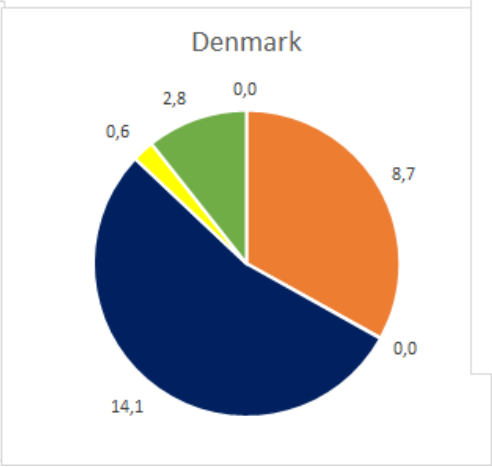
Nordic electricity generation 2015 (TWh)



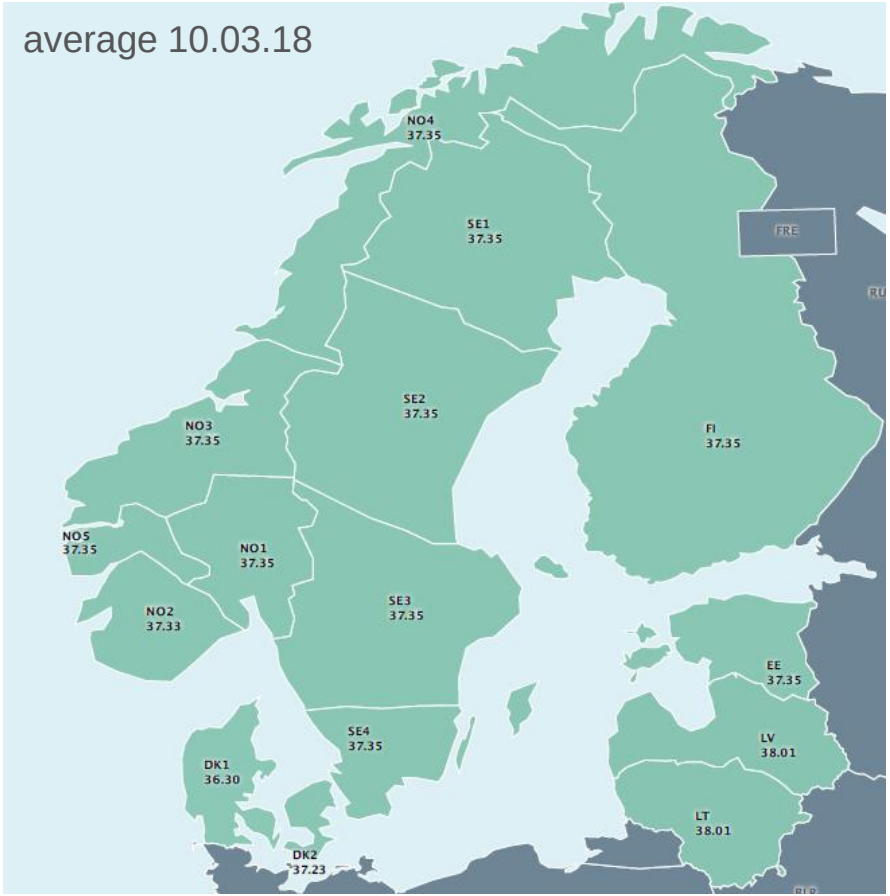


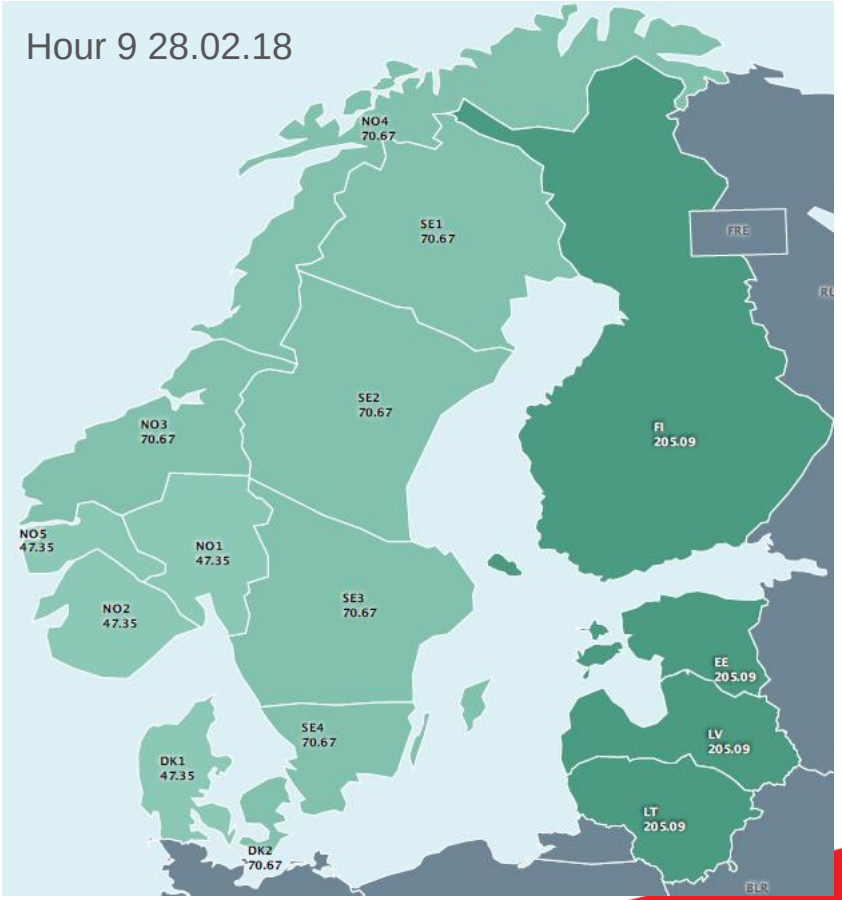






Bidding zones



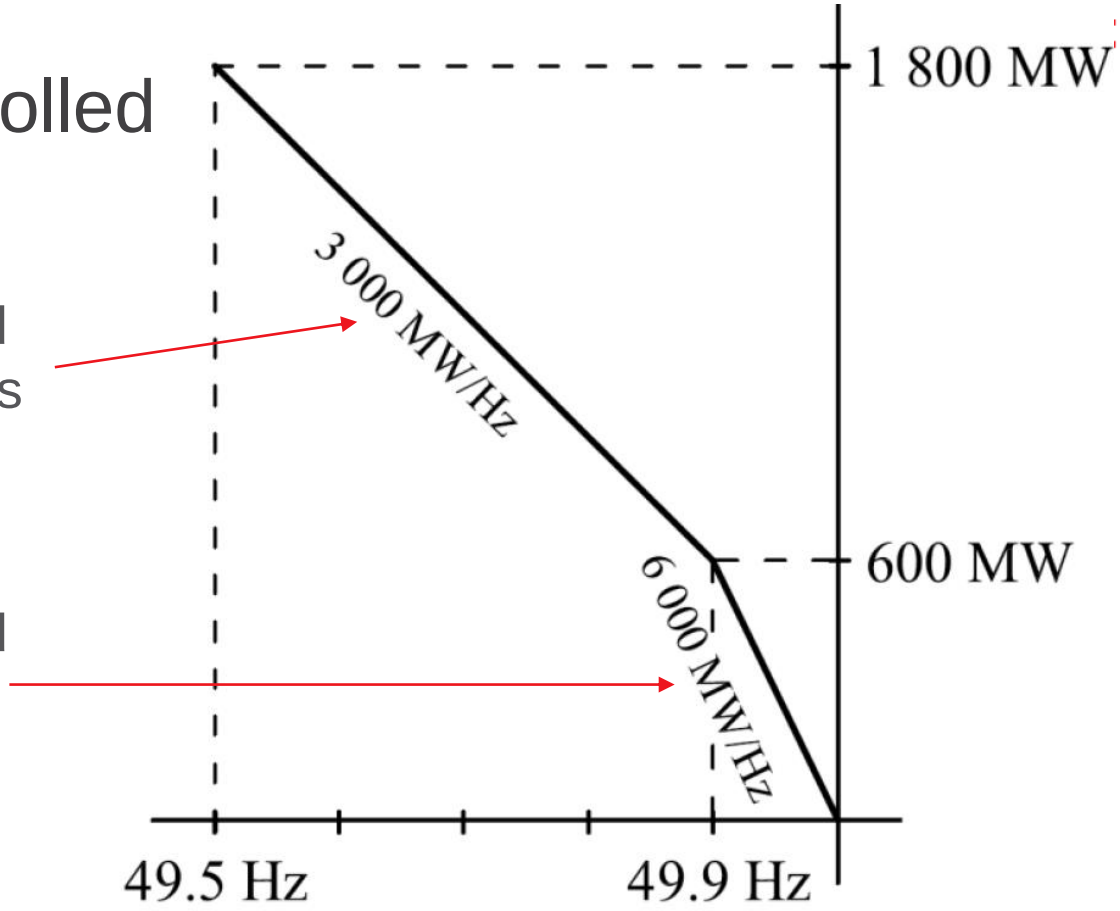


Nordic reserve markets

- Frequency Controlled Reserves (FCR) (Primärregelung)
  - Normal operation (FCR-N) 600 MW
  - Disturbance (FCR-D) 1200 MW
- Manual Frequency Restoration Reserves (mFRR) (Minutenreserve)
  - 4090 MW (Statnett +600 MW)
- Automatic Frequency Restoration Reserves (mFRR) (Sekundärregelung)
  - 300 MW, few hours per day
  - Increases planned

Frequency controlled reserves

- Frequency Controlled Disturbance Reserves (FCR-D)
  - Only upward
- Frequency Controlled Normal Operating Reserves (FCR-N)
  - Symmetric



Distribution of reserves

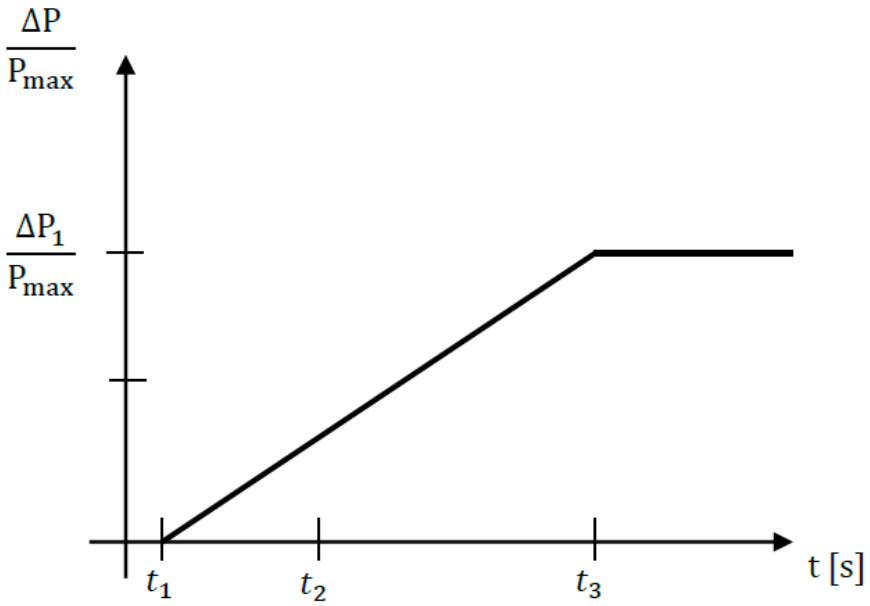
	Annual consumption 2013 (TWh)	Frequency controlled normal operation reserve (MW)
Eastern Denmark	13.7	22
Finland	85.2	138
Norway	130.0	210
Sweden	142.5	230
Synchronous system	371.4	600

	Dimensioning faults (MW)	Frequency controlled disturbance reserve (MW)
Denmark	600	176.5
Finland	880	258.8
Norway	1,200	352.9
Sweden	1,400	411.8
Total		**1,200**

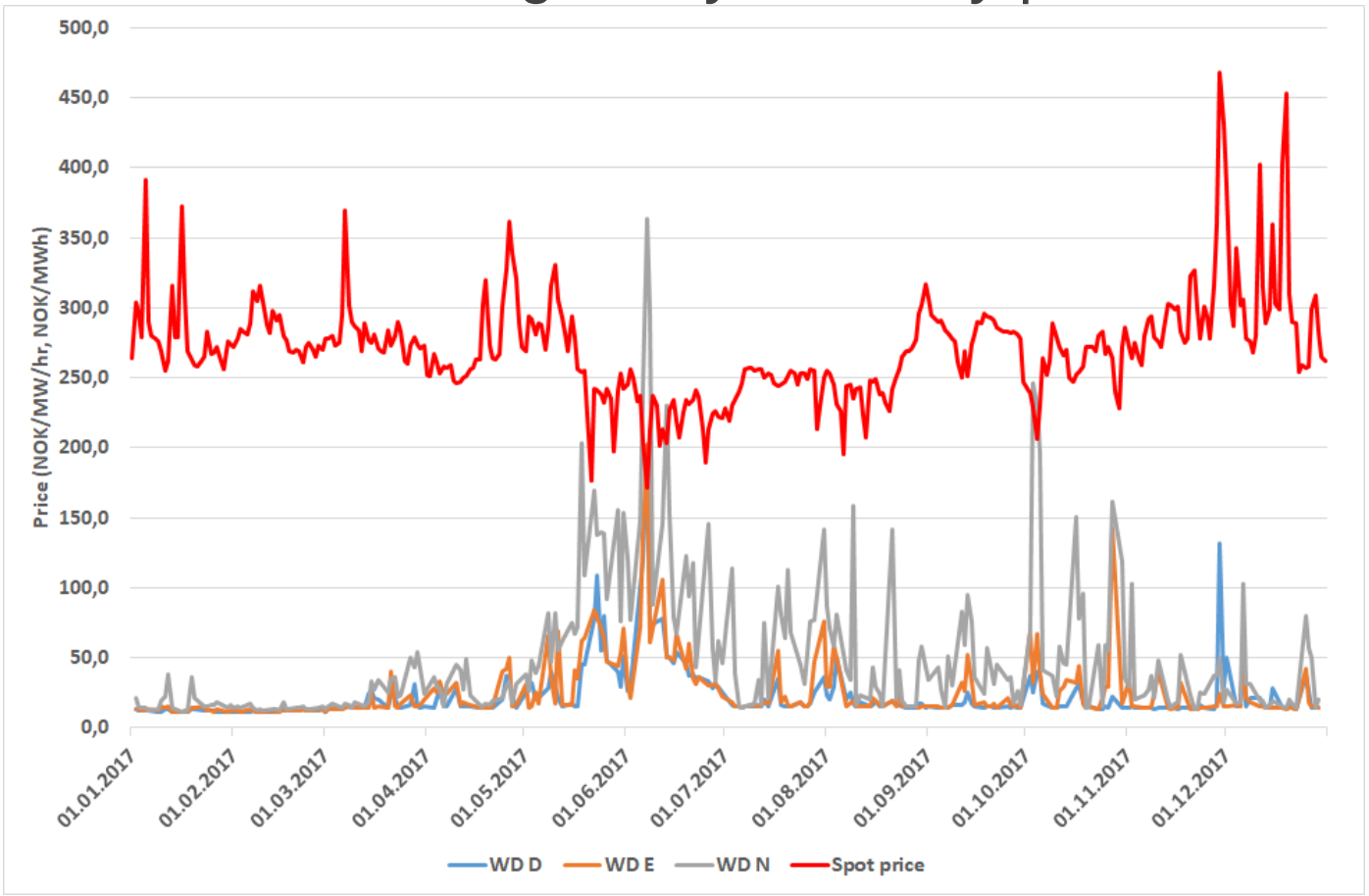
	Manual Frequncy Restoration Reserves (MW)
Denmark-East	600
Finland	1000
Norway	1200+600
Sweden	1290
Total	4090(+600)

Norway, reserve capacity - FCR

- Weekly auctions FCR-N
  - Six blocks
    - weekday/weekend and day/evening/night
- Daily auctions (after DA clearing), FCR-N and FCR-D
  - Hourly resolution
- All auctions paid-as-cleared (marginal price)
- Volumes per bidding zone
- Minimum bid size 1 MW
- Excess capacity may be sold to Sweden
- Voluntary participation
  - Units ≥ 10 MW that do not participate are obliged to provide
    - ≤ 12 % droop in winter
    - ≤ 6 % droop in summer
    - Administrative payment


ΔP / P_max
ΔP_1 / P_max
t_1
t_2
t_3
t [s]

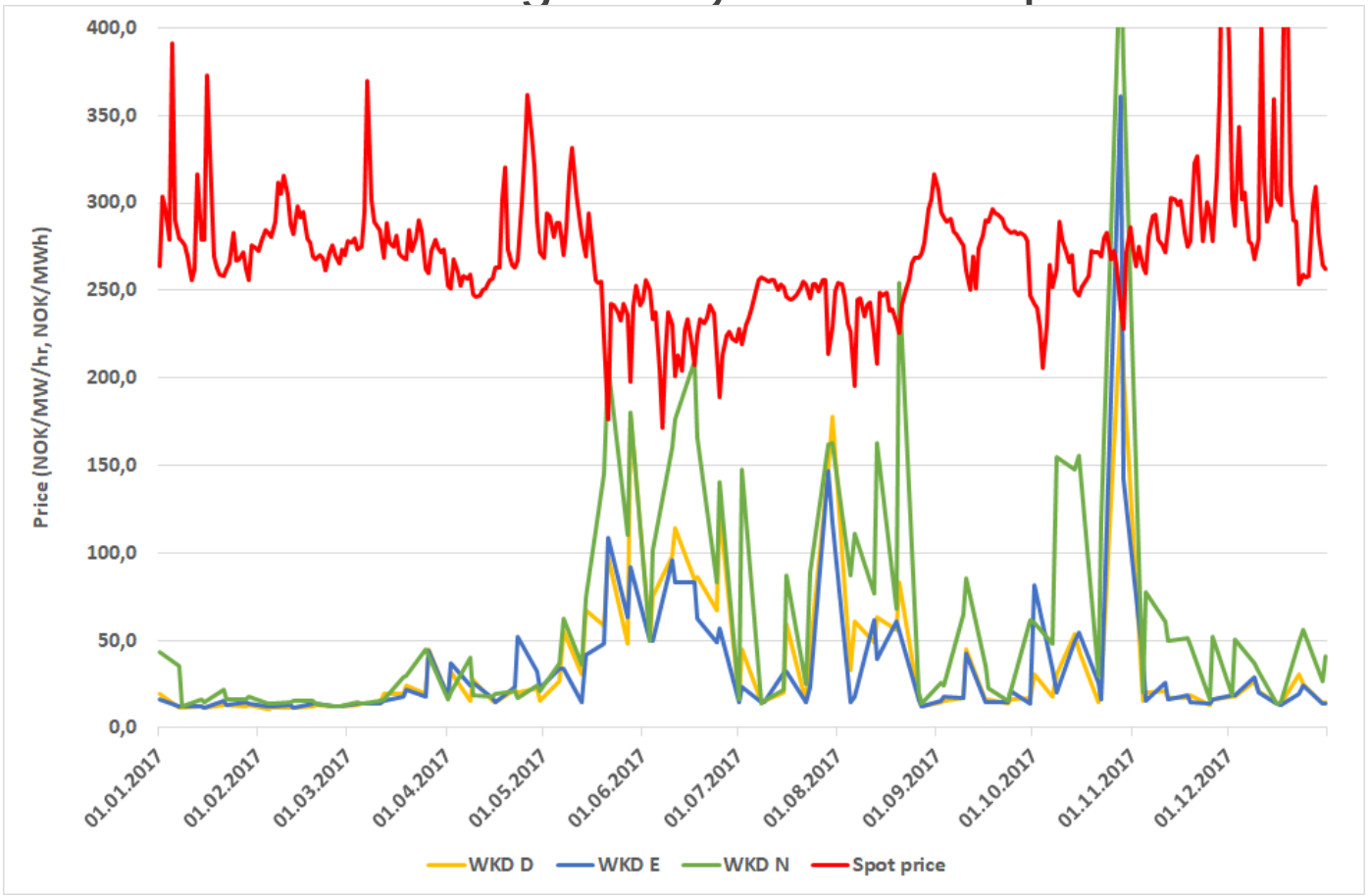
FCR-N NO1 average daily weekday prices 2017



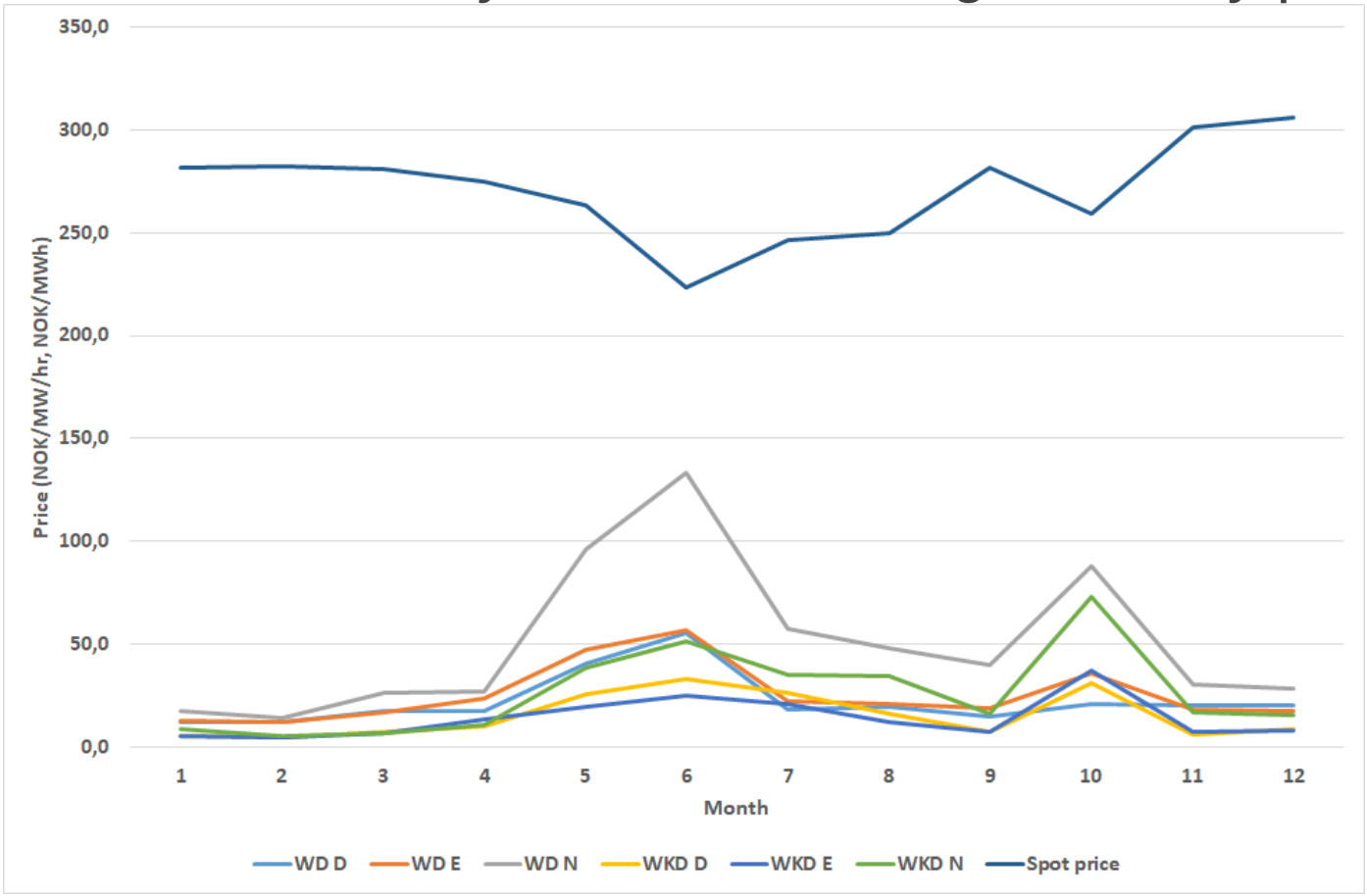
FCR prices normally equal for all bidding zones

1NOK ≈ 0,105 Euro

FCR-N NO1 average daily weekend prices 2017



FCR-N NO1, daily auctions, average monthly prices 2017



mFRR activation market (1)

- mFRR is the main balancing resource
  - Normally it is the only resource (besides FCR)
- Before 2000, it was only based on free bids
  - Large pool because of hydro turbine characteristics
    - Max efficiency at ~80 % of P_{max}, very short startup times
- Required response: full delivery within 15 minutes
  - In practice most Norwegian units much faster

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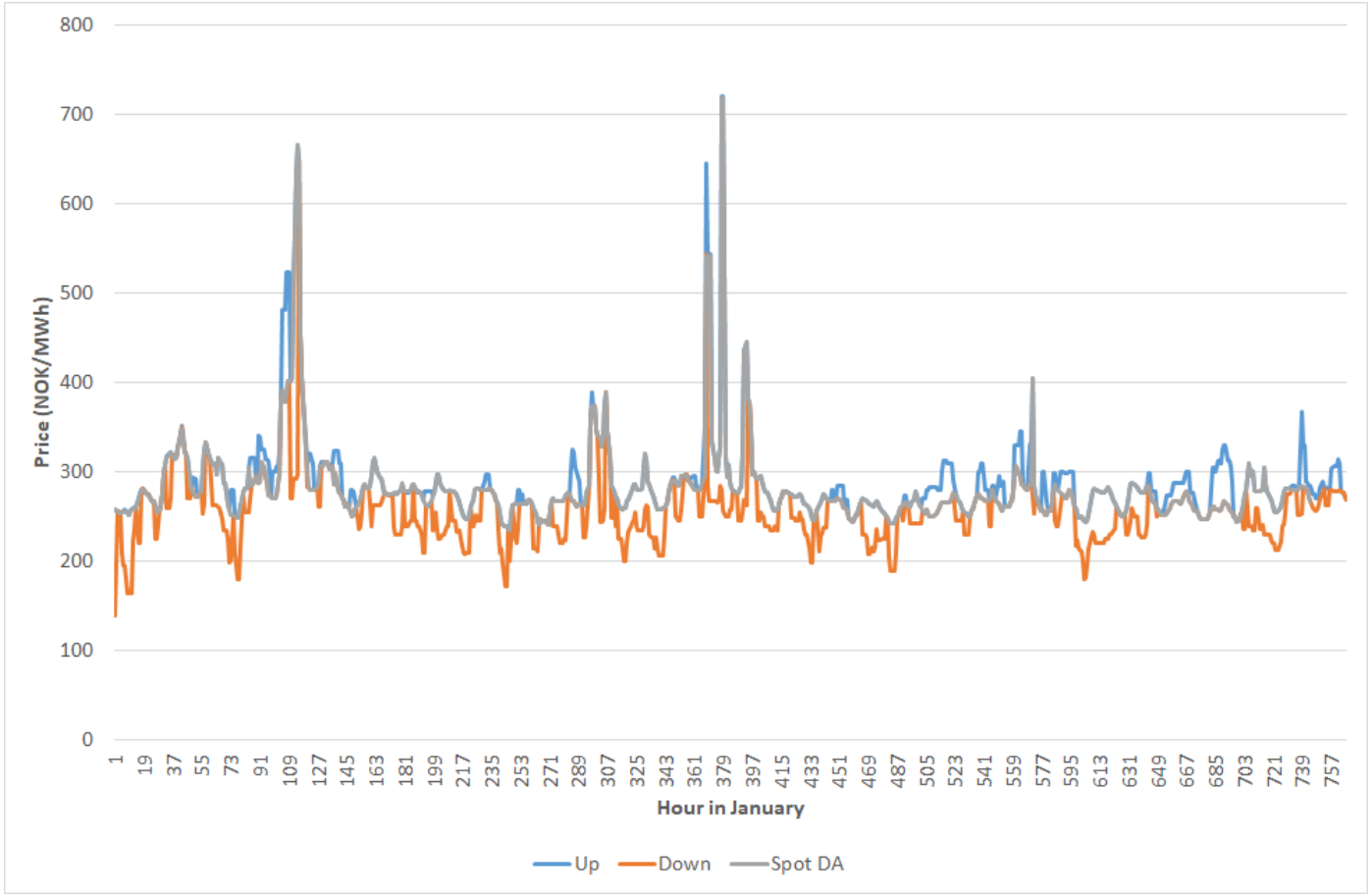
mFRR activation market (2)

- Activation market paid-as-cleared (marginal pricing)
- Prices may split across bidding zones
  - Price-split may be different from day-ahead market
- Price cap 5000 €/MWh
- Same bids used for intra-zonal congestion management
  - Do not (directly) impact balancing price
  - Paid-as-bid

Spot and mFRR prices NO1 January 2017



Norway, reserve capacity – mFRR (1)

- RCOM – Reserve Capacity Option Market
- Bids are given in each bidding zone
  - Grid location is also provided
- Two qualities
  - B – limited duration (≥1 hr), resting time (≤ 8 hrs)
  - H – high quality, no constraints
  - Minimum quantity H
- Distribution between bidding zones determined by TSO

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Price reductions for lower quality mFRR

- Price equal to: Dfact · Rfact · clearing price

Duration (hrs)	**≥ 4**	**4**	**3**	**2**	**1**
Dfact	1,00	0,98	0,95	0,90	0,80
Resting time (hrs)	none	≤ 2	≤ 4	≤ 6	≤ 8
Rfact	1,00	0,98	0,95	0,90	0,80

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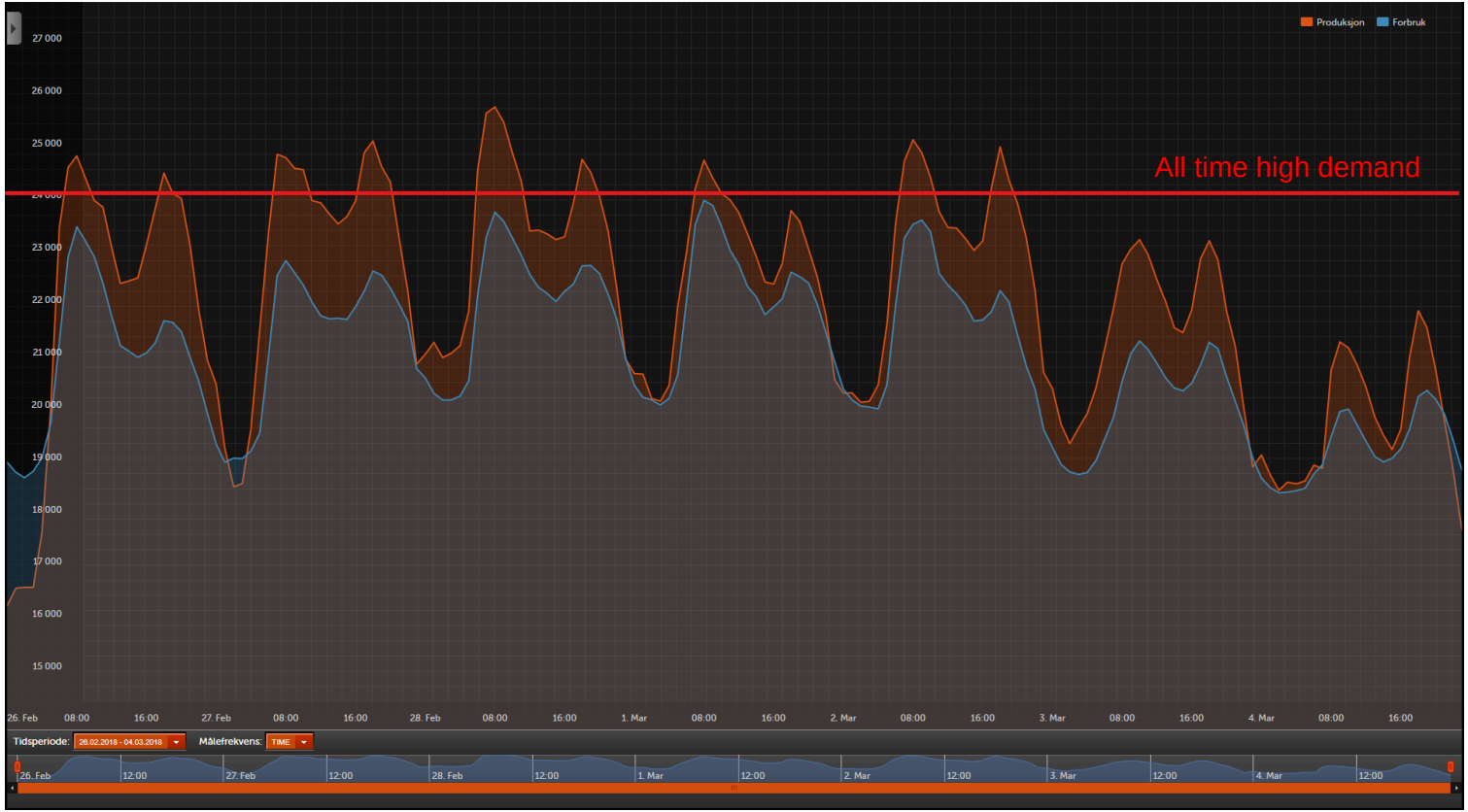
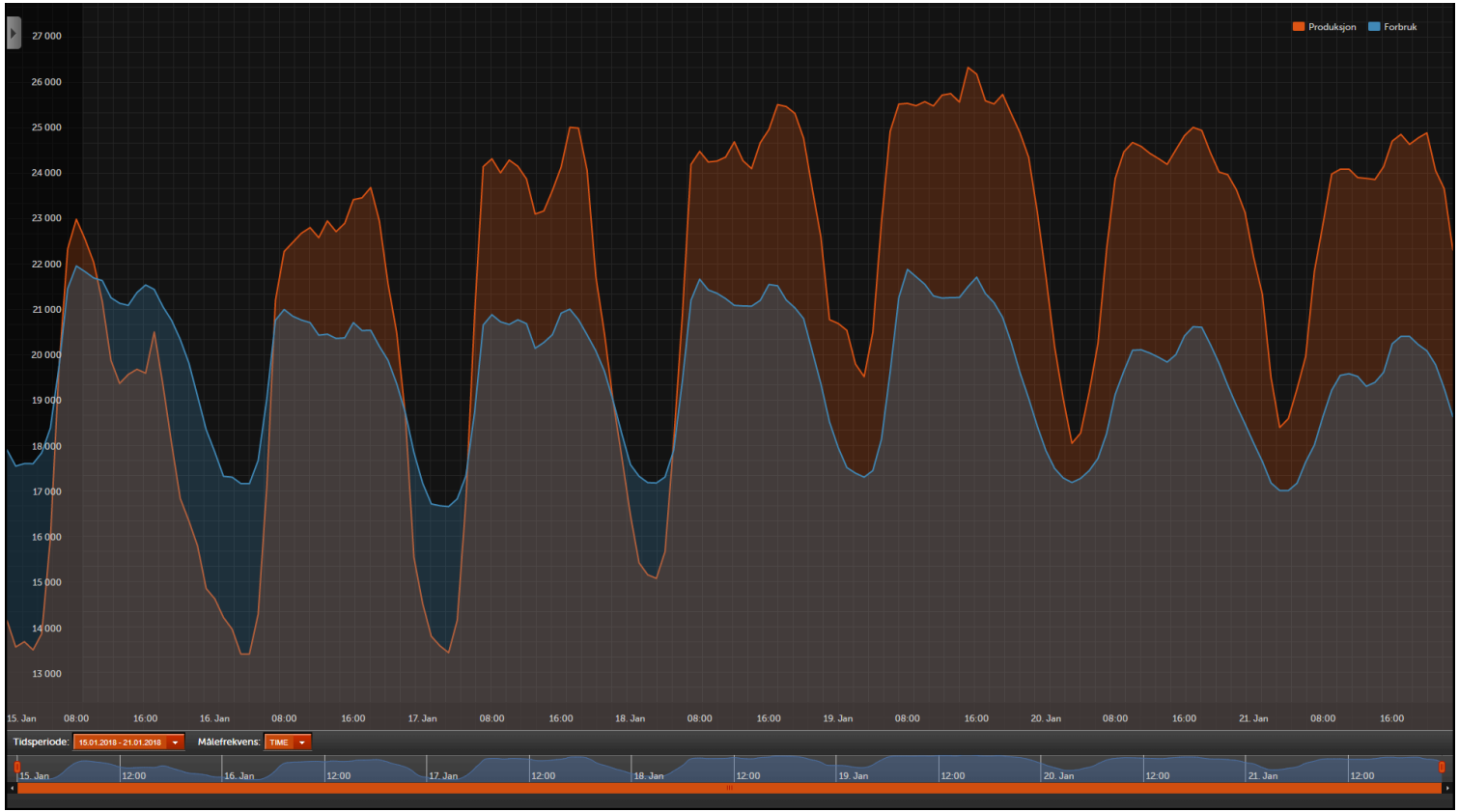
Norway, reserve capacity – mFRR (2)

- Total quantity depends on TSO's expectation of **free bids**
- ~November – April, 05:00-24:00, 7 days per week
  - Occasionally also during night if very high load (cold!)
  - In this period there may not be sufficient free bids
- One common auction, TSO decides minimum required volume of RCOM-H
  - Weekly, Friday afternoon
  - Required RCOM-H volume may lead to price split with RCOM-B
- Bids are for capacity only
  - Successful bidders are obliged to bid in the activation market
  - Price for energy bid up to their discretion

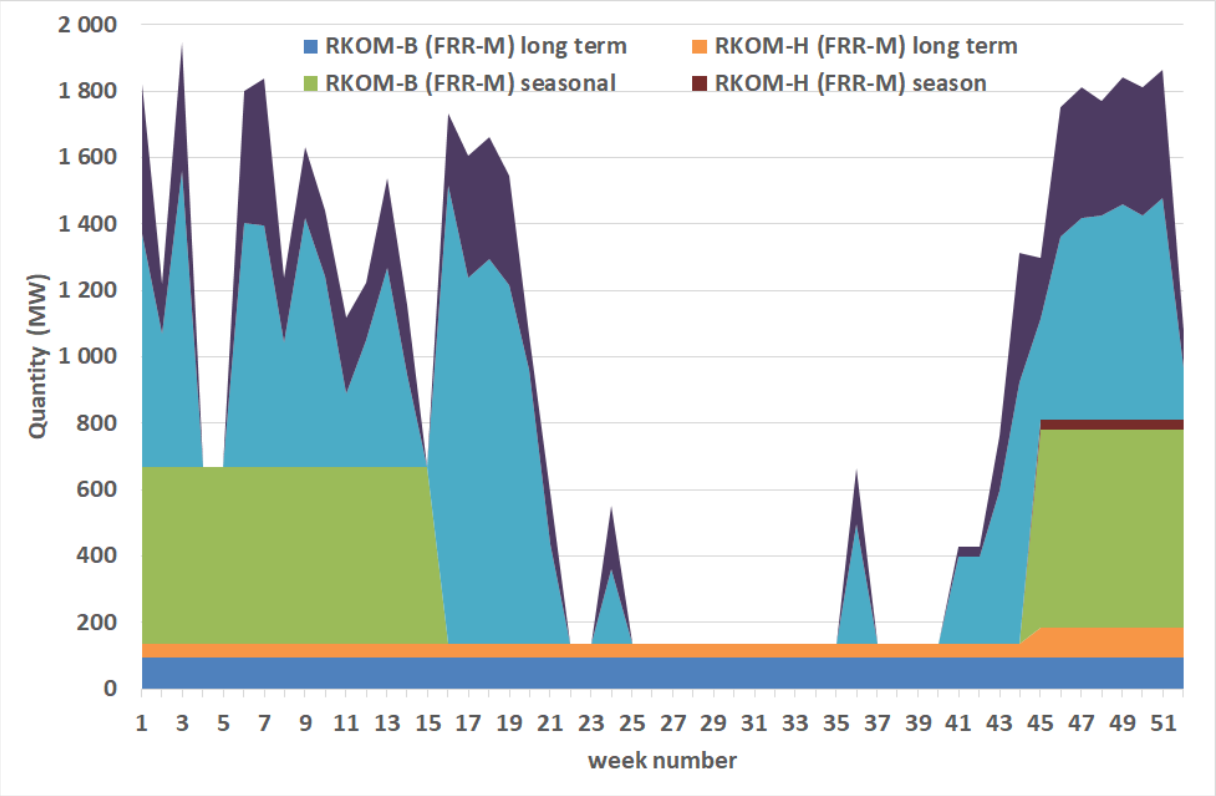
Generation and demand week 9 2018



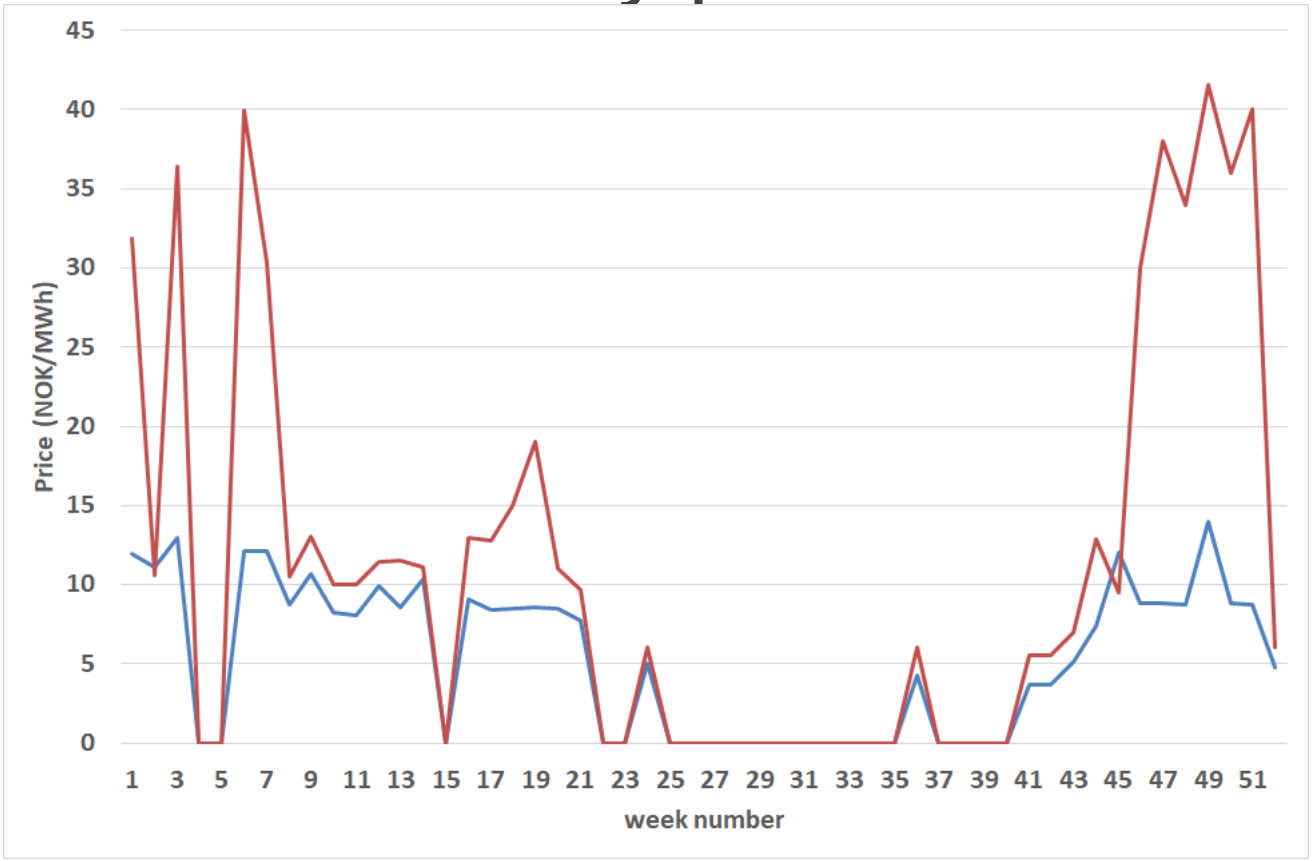
Generation and demand week 3 2018



Procured RCOM volumes 2017



RCOM weekly prices 2017

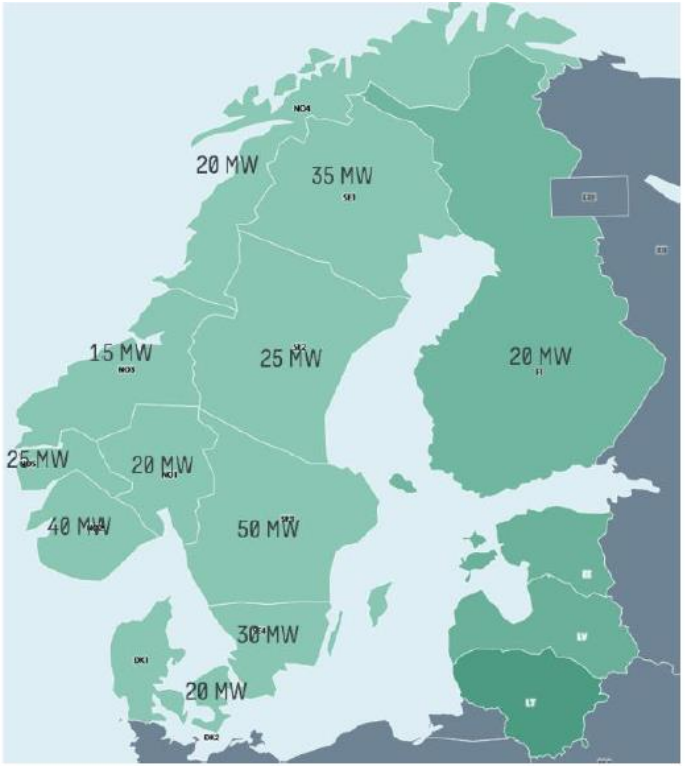


Nordic reserve capacity – aFRR (1)

- aFRR introduced in Nordic system in 2013
- Presently 300 MW
  - 04:00-08:00, working days
  - 3-4 evening hours, varying, season dependent
  - Increasing
- Procured per bidding zone

Example distribution aFRR

- Distribution based on bidding zones' historical short term imbalances
  - Varies over time



Source: Appendix 2 to Agreement on a Nordic Market for Frequency Restoration Reserves with automatic activation (aFRR)

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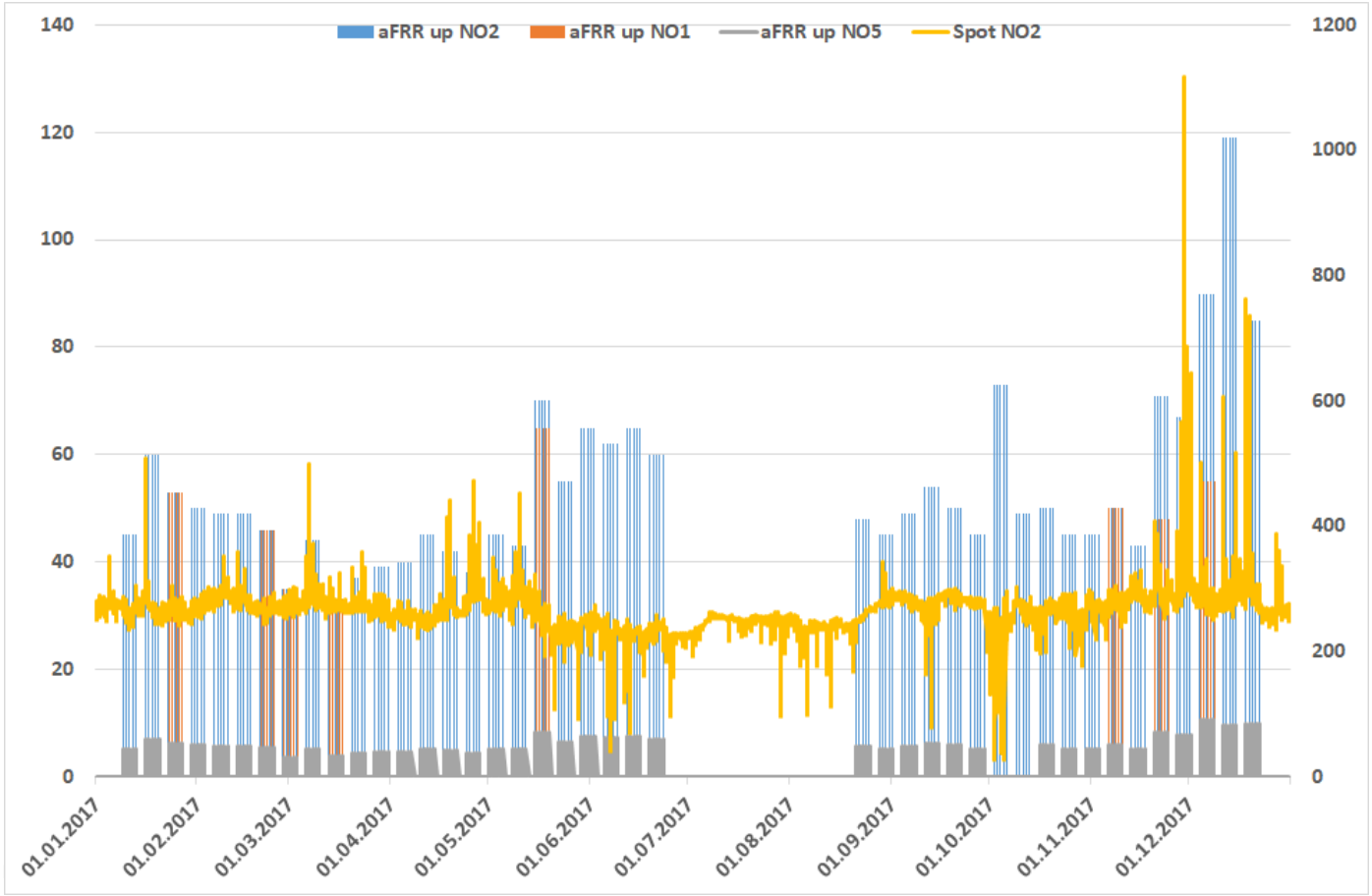
Nordic reserve capacity – aFRR (2)

- Weekly auctions, Thursday
- Bid per "Scheduling Resource" – group of plants
- Minimum bid 5 MW, maximum 35 MW
  - Divisible in 5 MW steps
- Paid-as-cleared per bidding zone
  - In special cases (grid), deviating bids paid-as-bid
- Proportional activation
- Payment according to mFRR activation clearing price

Spot and aFRR prices Norway 2017



Test: Hasle Pilot Norway-Sweden

8-weeks test of aFRR capacity exchange

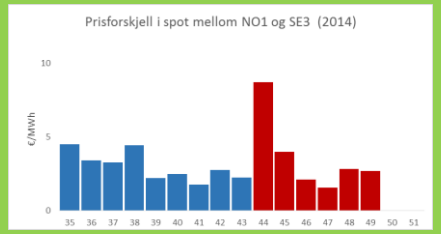
aFRR-bids for week *n* from Norwegian and Swedish service providers

Cross Zonal Capacity forecast for week *n*

Actual spotprices week *n*-1 (proxy for forecast week *n*)

OPTIMIZATION

Comparing marginal value of exchanging aFRR with forecasted marginal value of exchange in spot

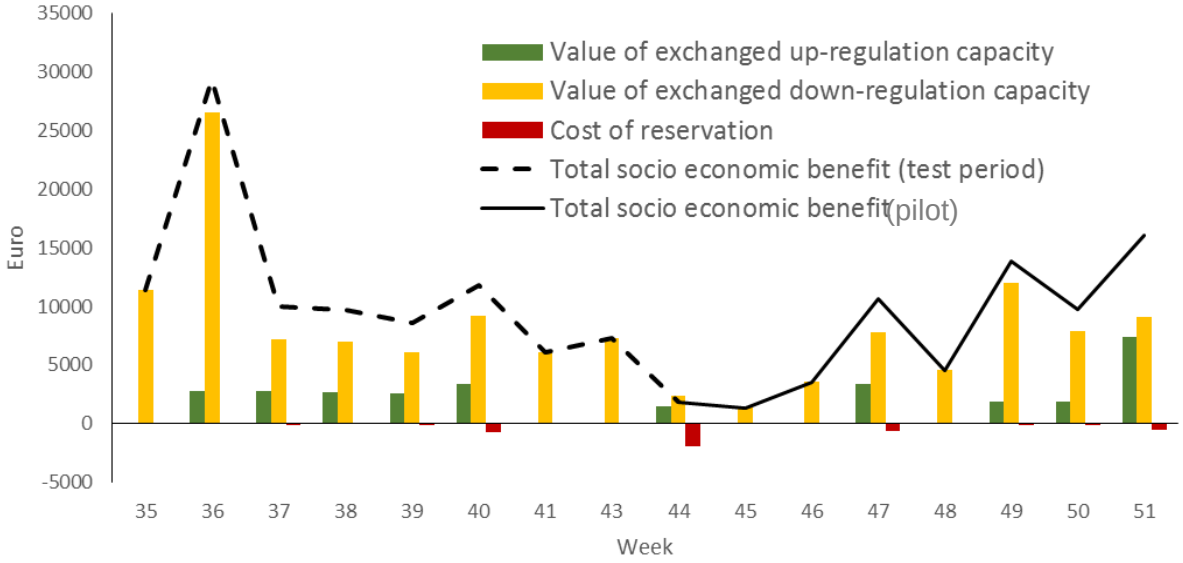


Check that pre-defined requirements are fulfilled

Procurement and exchange

Reservation

Increase of socio economic welfare*)



*) Socio economic costs are estimated as actual price difference x reserved transmission capacity. Subsequent analysis showed only minor price impacts in the market.

Reserve capacity auction design - timing and block length

- Major cost component: alternative cost
  - High spot price → lost revenues from spot
  - Low spot price → revenues do not cover operational cost
- When should auction be held?
- Block length: week – day – high/low – hour?

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Auction timing

- Before spot DA
  - BSPs must forecast spot price to prepare bids
  - Forecast errors result in non-optimal dispatch and cost increase
  - But TSO has certainty of reserve capacity availability
- After spot DA
  - Price and dispatch are known, BSP can prepare optimal bids
  - Optimal dispatch (but disregarding reserves in spot clearing)
  - But no certainty for reserve capacity availability
- Together with DA – co-optimization
  - BSPs do not know DA spot price when preparing
  - But that should not matter if alternative cost is dominating cost component

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Auction time block length

- Long blocks
  - BSPs need to reserve capacity for long period
  - May result in loss for some hours
  - Results in cost increase

- Shorter blocks → hour
  - Optimal adaptation between electricity production and reserve capacity
  - Perfect solution combined with co-optimization

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Summing up

- Nordic power systems dominated by production without CO2 emissions
- Bidding zones essential part of market design
- Norway: procurement of capacity for all reserves in auctions – seasonal, weekly, daily
- Auction timing and time block length important design variables