SOME THOUGHTS ABOUT INTERCONNECTORS

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BERGEN ENERGY LAB 18 JAN 2022

NHH

ENE
Energy, Natural Resources and the Environment

NTRANS
Norwegian Centre for Energy Transition Strategies

European integration of electricity markets

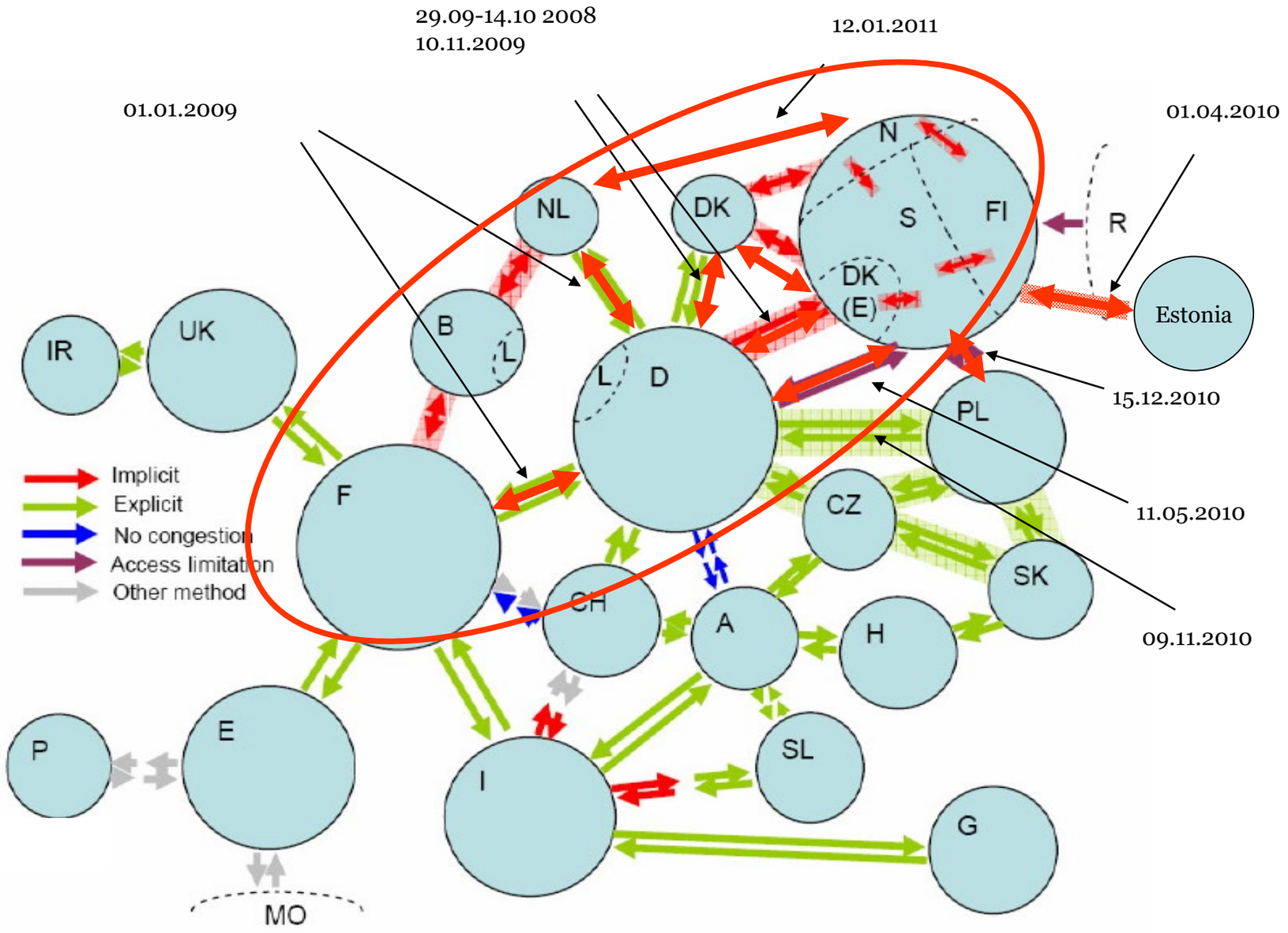
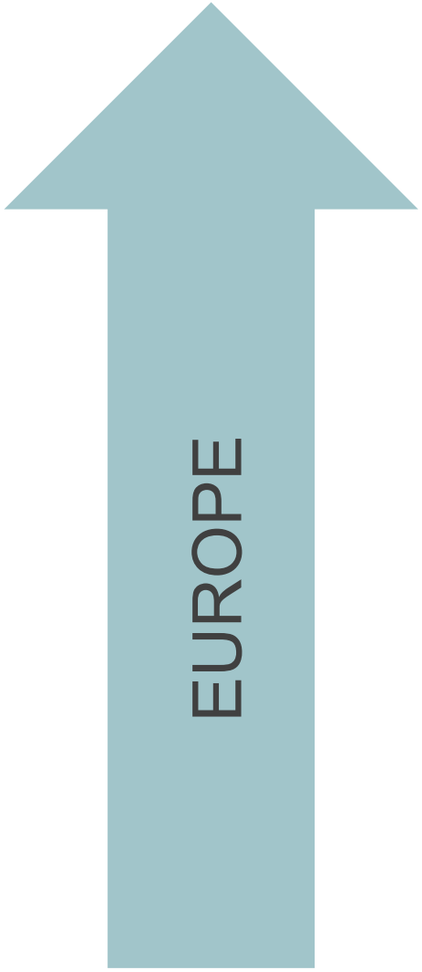


Figure 4.1 – Day-ahead transmission capacity allocations across Europe (updated June 2007)

Market coupling variants

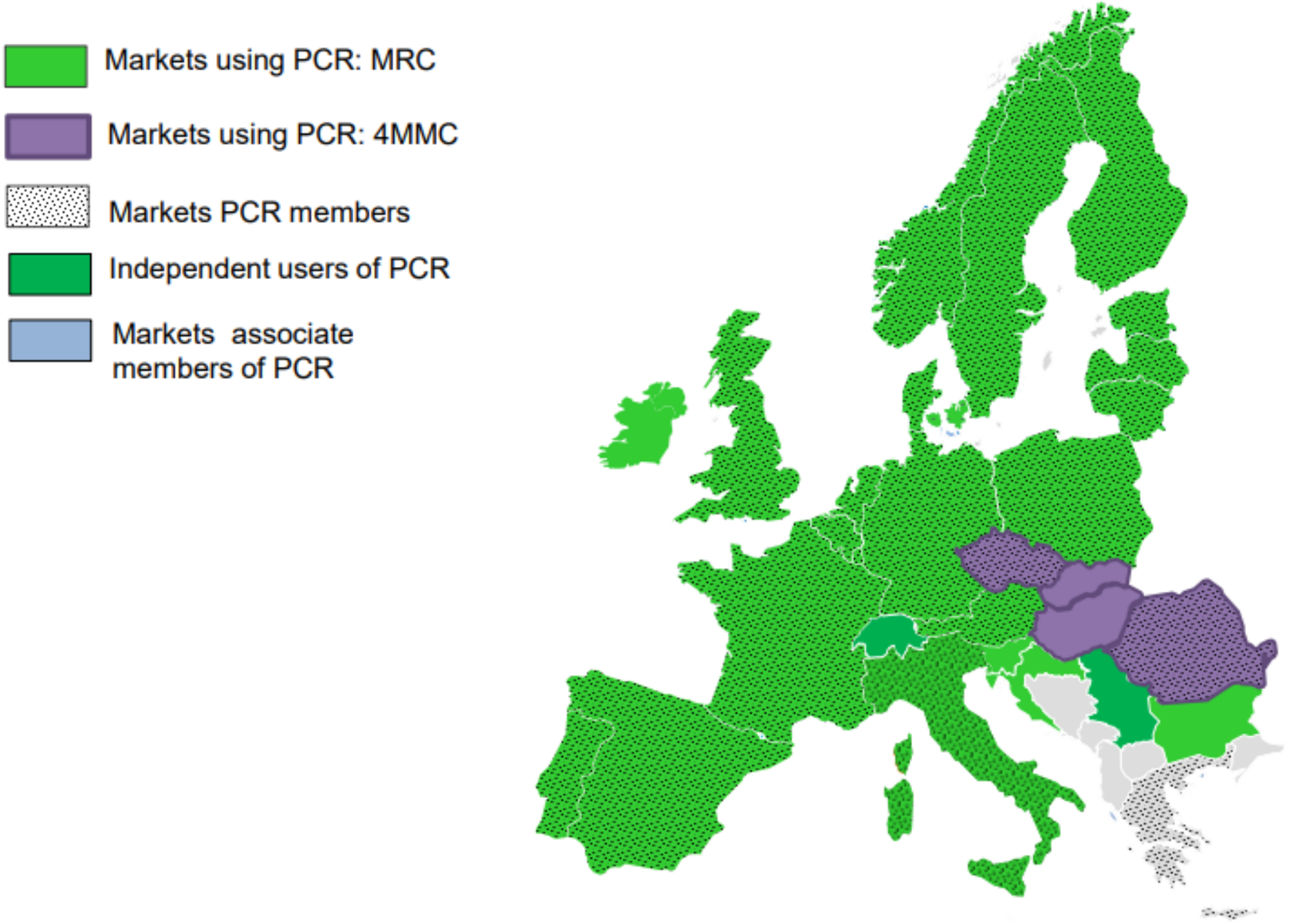
- Price coupling
  - Market prices and traded volumes are calculated by a single centralized system on the basis of all the relevant information (i.e. the amount of cross border capacity and the order books of all energy exchanges and TSOs in the coupled region)
  - The best quality of market coupling is achieved by means of a price coupling system
- Tight volume coupling
  - The volume traded between countries or regions is determined before the individual energy exchanges calculate their own prices
  - ‘Tight’ in this context means that the volume traded is calculated on the basis of all relevant information, as in the price coupling system
  - Offers almost the same quality level as price coupling, and is a very acceptable market coupling system
- Loose volume coupling
  - The volume traded between two countries or regions is calculated and then prices are calculated separately
  - The difference with tight volume coupling is that the calculation is performed using just some of the relevant information
  - Offers the lowest quality level



- **No. 18/2014 - Launch of full SWE coupling on 13 May 2014**
- *24-04-2014 12:00:00* The full coupling of the South-Western Europe (SWE) day-ahead market is scheduled to be launched on 13 May 2014. As a result, day-ahead markets of North-Western Europe (NWE) and SWE, projects stretching from Portugal to Finland, will be fully coupled. The achievement of the SWE full coupling is proof of the flexibility and reliability of the Price Coupling of Regions (PCR) solution.
- The NWE day-ahead price coupling was launched on 4 February. Simultaneously common synchronised operations of the NWE and the SWE day-ahead price coupling started. Since then, the day-ahead markets covered by these two projects have successfully been operated using the PCR model, developed by European Power Exchanges. Prices and transfers of energy are determined in a single calculation based on common order books and available cross-border capacities.
- Over this period, no capacity was offered to the price coupling at the French-Spanish border and the daily explicit auctions on this border were maintained. With the launch of SWE full price coupling on 13 May 2014, capacity for the French-Spanish border will be implicitly allocated through PCR in the day-ahead markets and the existing daily explicit auctions on this border will cease. The go-live is subject to the final approval by the involved regulatory authorities as well as the successful completion of the member tests.
- Full price coupling between the NWE and SWE projects based on the PCR solution, achieved with the collaboration of Transmission System Operators, is a significant step towards a fully harmonised European day-ahead electricity market. This allows cross-border infrastructures to be used more efficiently and to further increase market liquidity and social welfare.
- The combined day-ahead markets of the NWE and SWE projects cover 17 European countries *(see list below)*, accounting for about 2,400 TWh of yearly consumption. Since 4 February, the daily average cleared volume over these countries amounted to 3.2 TWh, with an average daily value of over €200m.
- *Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Great Britain, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland (via the SwePol Link), Portugal, Spain and Sweden.*

- **No. 21/2014 - South-Western and North-Western Europe day-ahead markets successfully coupled**
- *13-05-2014 14:00:00* In a landmark move towards an integrated European power market, the full coupling of the South-Western Europe (SWE) day-ahead markets was successfully launched today. As a result, the SWE and North-Western Europe (NWE) projects, stretching from Portugal to Finland, now operate under a common day-ahead power price calculation using the Price Coupling of Regions (PCR) solution.
- Today, for the first time, the day-ahead transmission capacity on the French-Spanish border has been implicitly allocated through the PCR solution, replacing the previous daily explicit allocation. Full price coupling between the NWE and SWE projects allows the simultaneous calculation of electricity prices and cross-border flows across the region. This will bring a benefit for end-consumers derived from a more efficient use of the power system and cross-border infrastructures as a consequence of a stronger coordination between energy markets.
- With the achievement of full coupling of SWE day-ahead markets, cross-border capacity of all interconnectors within and between the following NWE and SWE countries will now be optimally allocated in the day-ahead timeframe: Belgium, Denmark, Estonia, Finland, France, Germany/Austria, Great Britain, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland (via the SwePol Link), Portugal, Spain and Sweden.
- The combined day-ahead markets of the NWE and SWE projects account for about 2,400 TWh of yearly consumption. Since the launch of the PCR on 4 February, the daily average cleared volume over these markets amounted to 3.2 TWh, with an average daily value of over €200m.
- The SWE full market coupling represents a further step towards the implementation of the European target model for the Internal Electricity Market in Europe in the day-ahead timeframe. Following the NWE-SWE full coupling, further extensions of the market coupling with the PCR solution are envisaged.

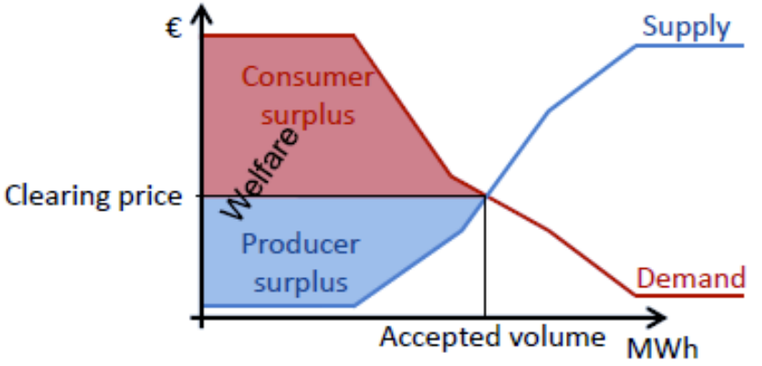
Price coupling of regions (PCR) from 2014



ALGORITHM EUPHEMIA

- EUPHEMIA is an algorithm that solves the market coupling problem on the PCR perimeter
  - EUPHEMIA stands for: EU + Pan-European Hybrid Electricity Market Integration Algorithm

- It maximises the welfare of the solution
  - Most competitive price will arise
  - Overall welfare increases
  - Efficient capacity allocation

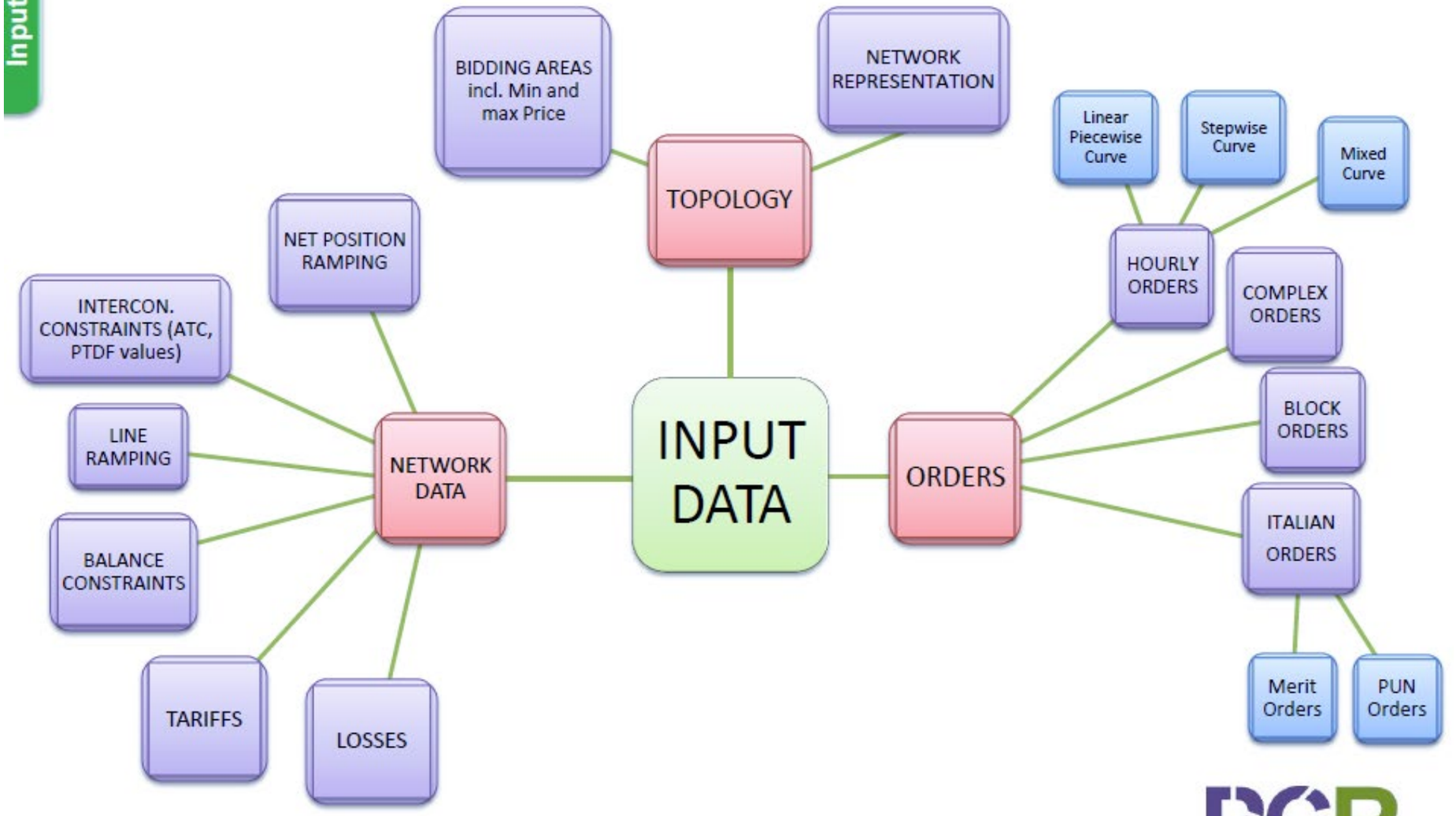


Algorithm has been tested using real 2011/2012/2013/2014 daily order books (around 50 bidding areas and 60 ATC lines)

PCR
PRICE COUPLING OF REGIONS

Input data

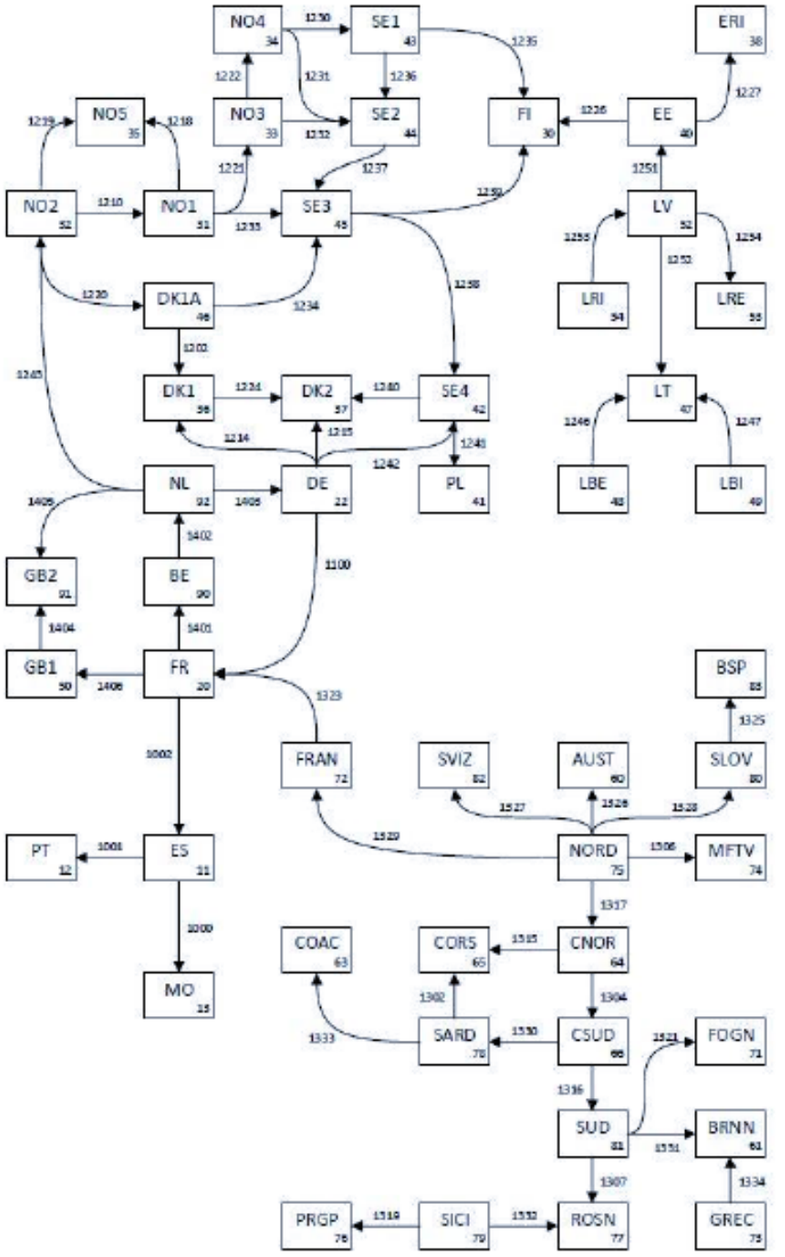
INPUT DATA



PCR
PRICE COUPLING OF REGIONS

MARKET DATA

- Each PX (Market) operates several bidding areas
- All bidding areas are matched at the same time
- A different price can be obtained for each bidding area
- The price for the bidding area must respect maximum and minimum price market boundaries



NETWORK DATA AND BALANCE CONSTRAINTS

The energy balance concept is defined as: The global supply minus the losses must be equal to the global demand of all markets involved. Depending on the manner the interconnections are modeled, there are the following:

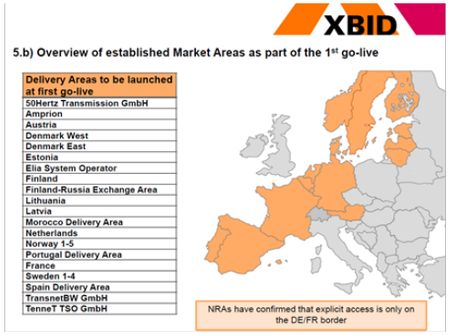
- ***ATC network model:*** The network is described as a set of lines interconnecting bidding areas. The nomination of the line can be made up to its Available Transfer Capacity (ATC)

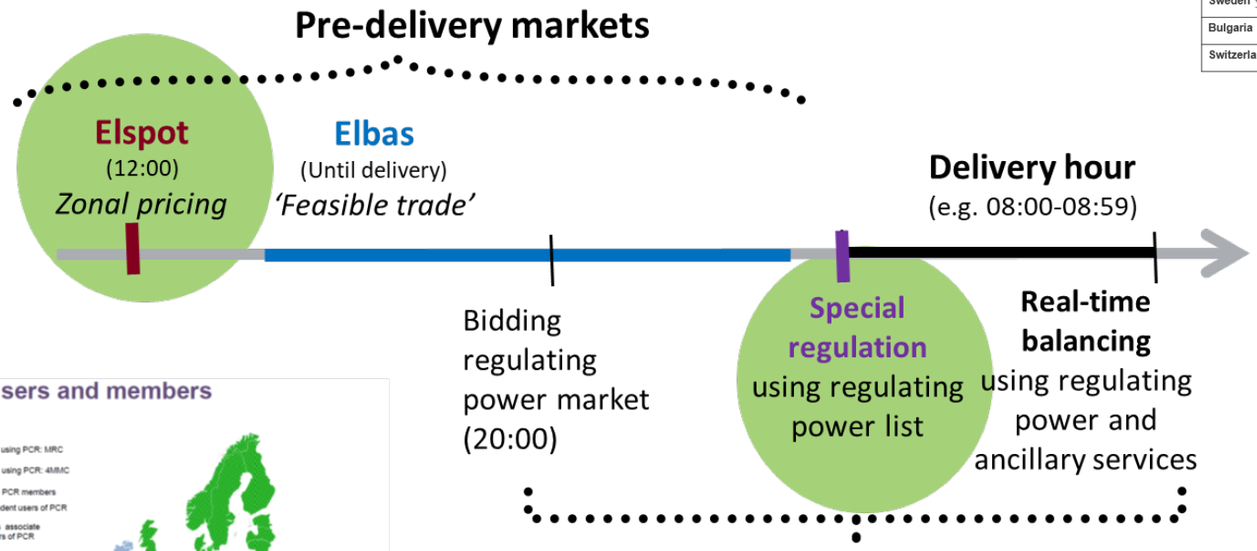
- ***Flow-based network model:*** Also known as PTDF model, with all bidding areas connected in a meshed network. It expresses the constraints arising from Kirchhoff's laws and physical elements of the network in the different contingency scenarios considered by the TSOs. It translates into linear constraints on the net positions of the different bidding areas

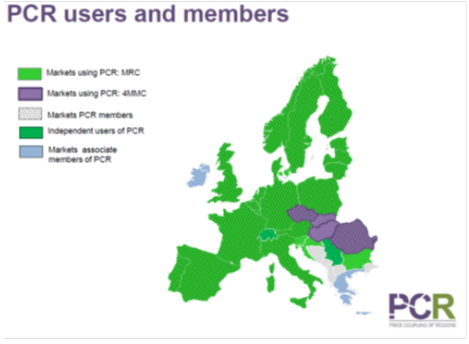
- ***Hybrid network model:*** Some bidding areas are connected using the Flow-based network model; the remaining using the ATC network model

PCR
PRICE COUPLING OF REGIONS

EUROPEAN MARKET INTEGRATION



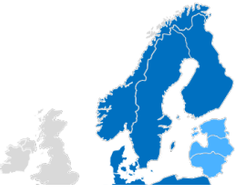




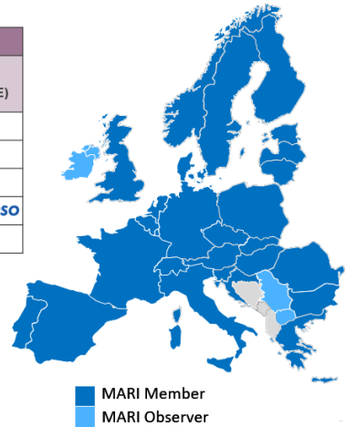
Markets and systems for:

- **Real-time balancing** (Regulating power market, and other ancillary services)
- **Congestion alleviation**

30 TSOs + ENTSO-E (Observer)		
PICASSO Members (26 TSOs)		PICASSO Observers (4 TSOs + ENTSO-E)
Austria APG	Hungary MAVIR	Latvia AST
Belgium elia	Italy Terna	Lithuania Litgrid
Croatia HOPS	The Netherlands TenneT	Estonia elering
Czech Republic CEPS	Nordic	
Denmark Energinet	Portugal	
Finland Fingrid	Poland	
France RTE	Romania	
Germany 50Hertz TransnetBW TenneT Amprion	Slovak Republic	
Sweden Svenska Kraftnät	Slovenia	
Bulgaria		
Switzerland swissgrid	Luxembourg	



34 TSOs + ENTSO-E (Observer)			
MARI Members (30 TSOs)			MARI Observers (4 TSOs + ENTSO-E)
Austria APG	Greece	Spain Red Eléctrica	Serbia EMC
Belgium elia	Italy Terna	Sweden Svenska Kraftnät	Ireland EirGrid
Croatia HOPS	Latvia AST	Switzerland swissgrid	Northern Ireland SONI
Czech Republic CEPS	Lithuania Litgrid	Great Britain nationalgridESO	North Macedonia MEPSO
Denmark Energinet	Norway Statnett		ENTSO-E entsoe
Estonia elering	Netherlands TenneT	Luxembourg Creos	
Finland Fingrid	Portugal REN	Bulgaria	
France RTE	Poland PSE		
Hungary MAVIR	Romania		
Germany 50Hertz Amprion TenneT TRANSNETBW	Slovak Republic		
	Slovenia ELES		



Measures of congestion cost

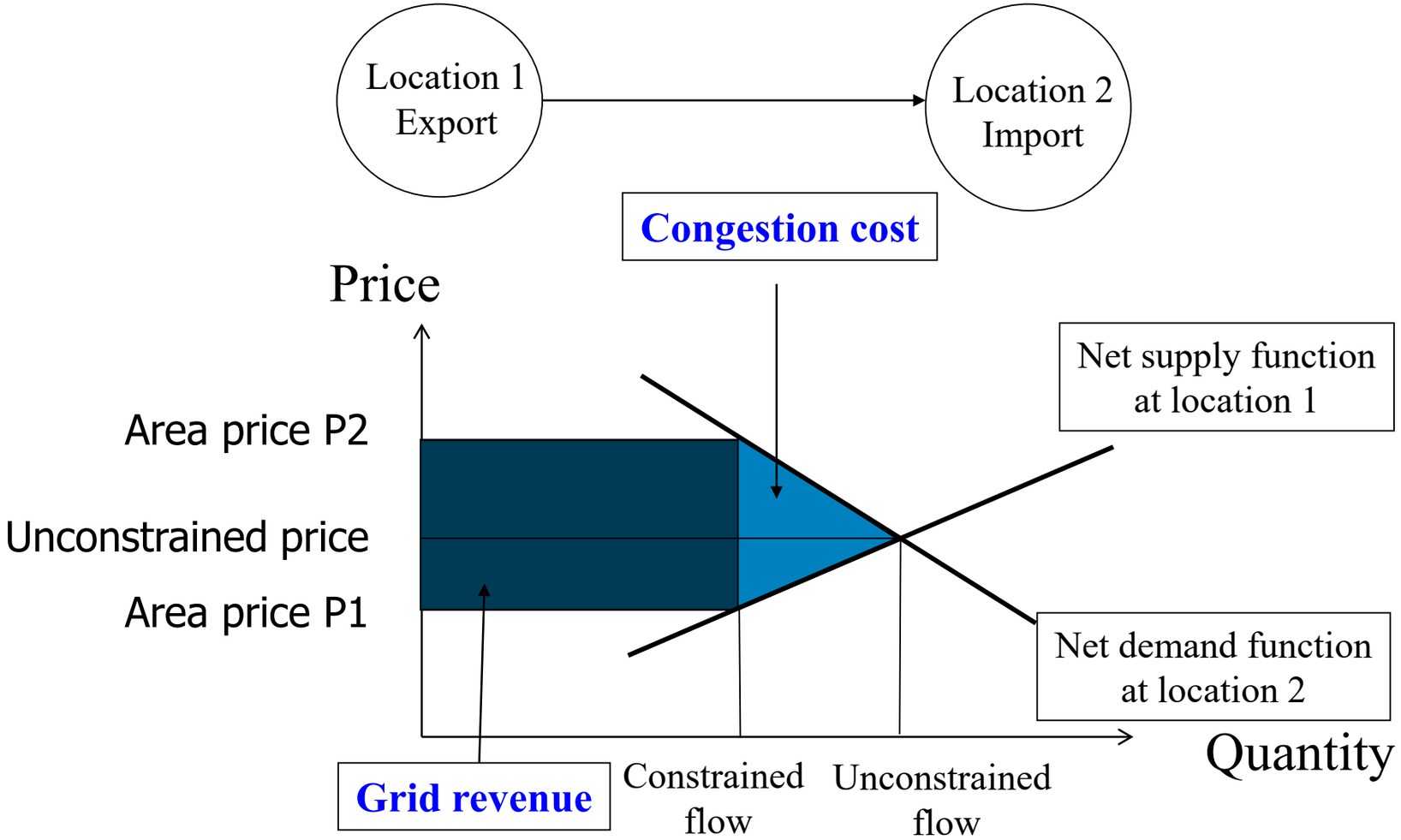
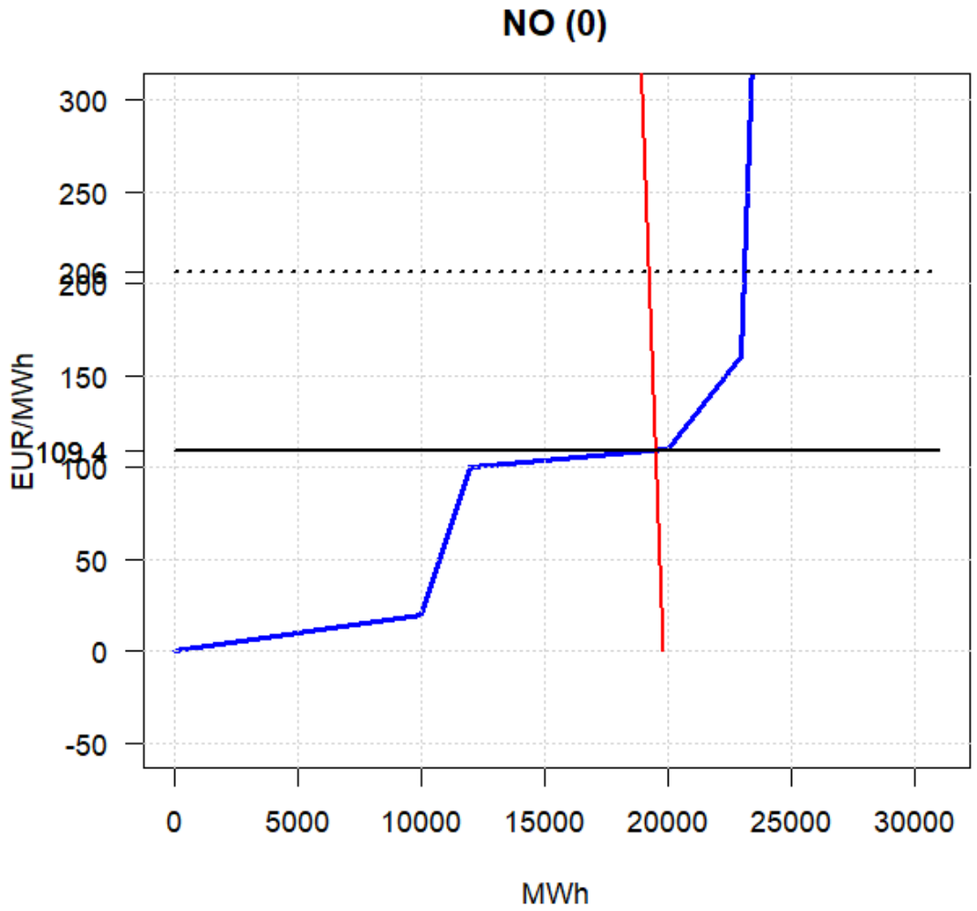
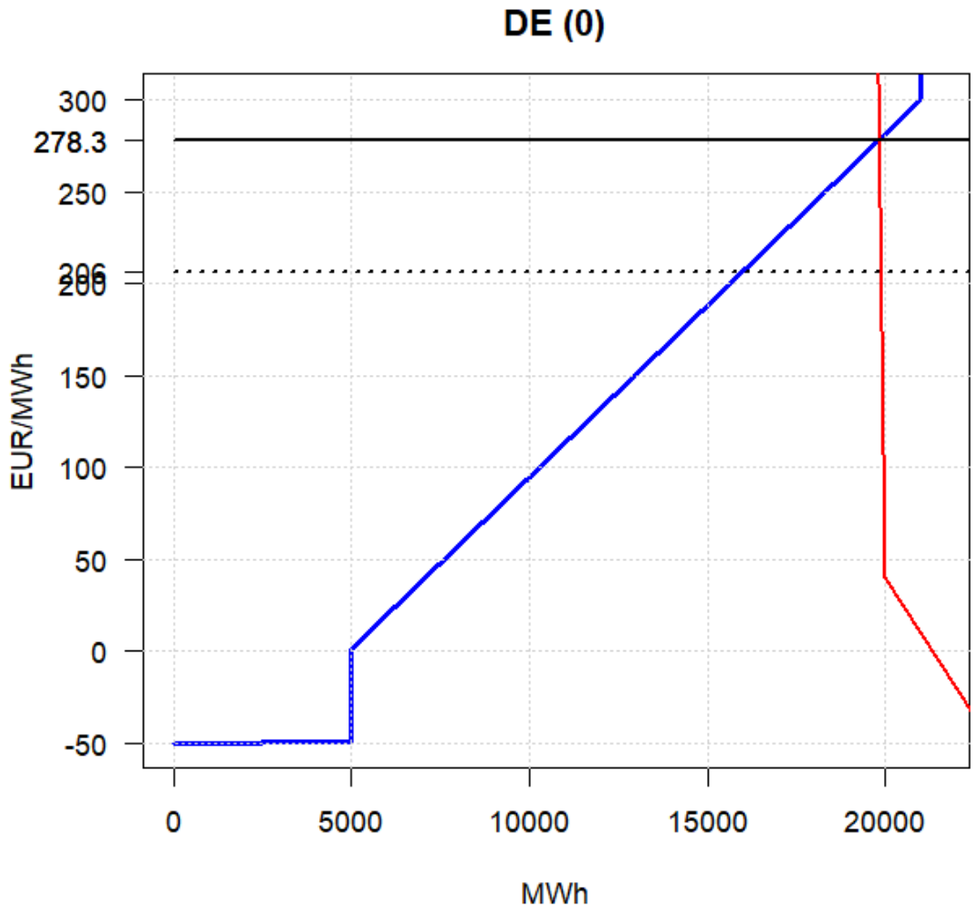
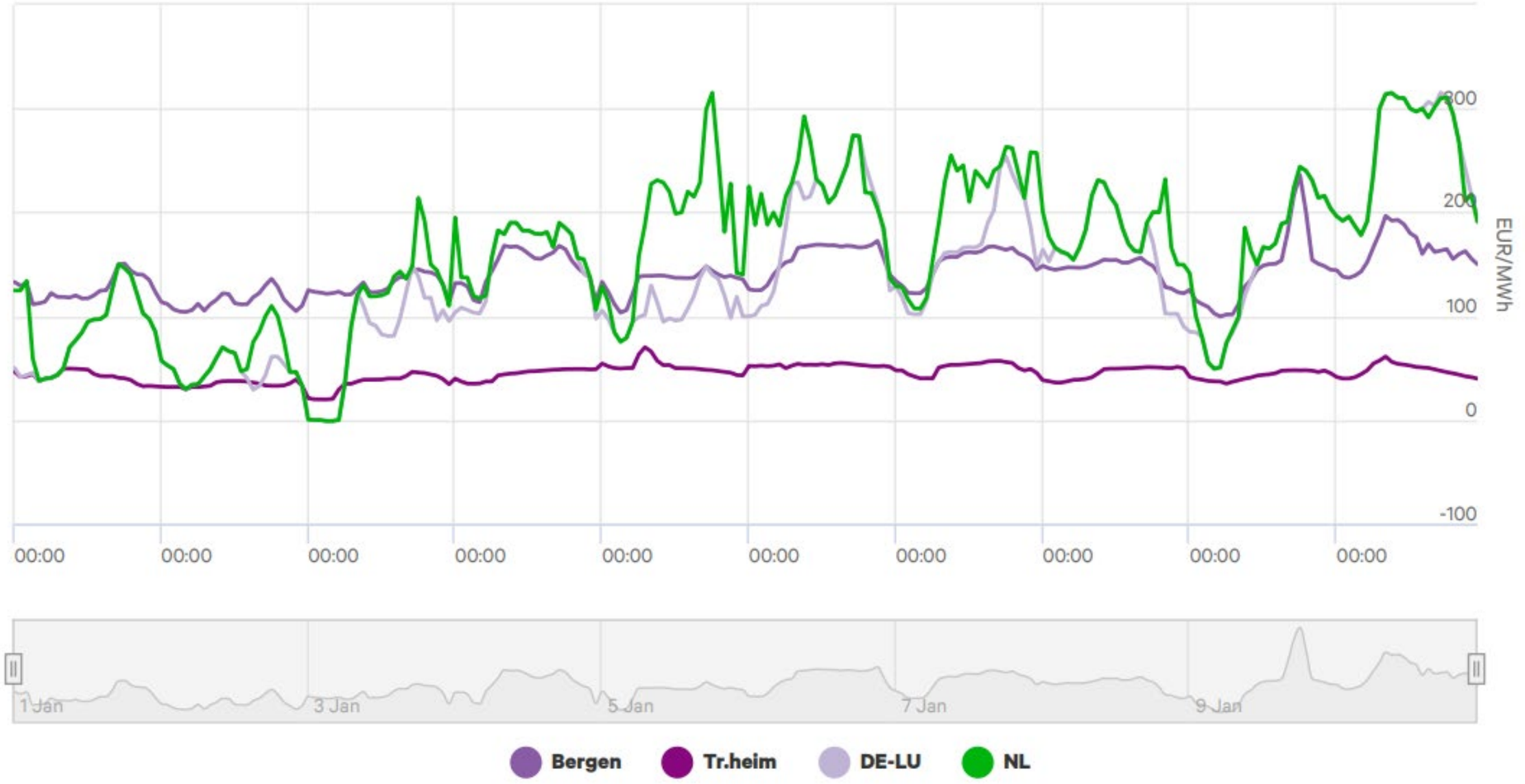


Illustration two interconnected markets






300
200
100
0
-100
EUR/MWh
00:00
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00:00
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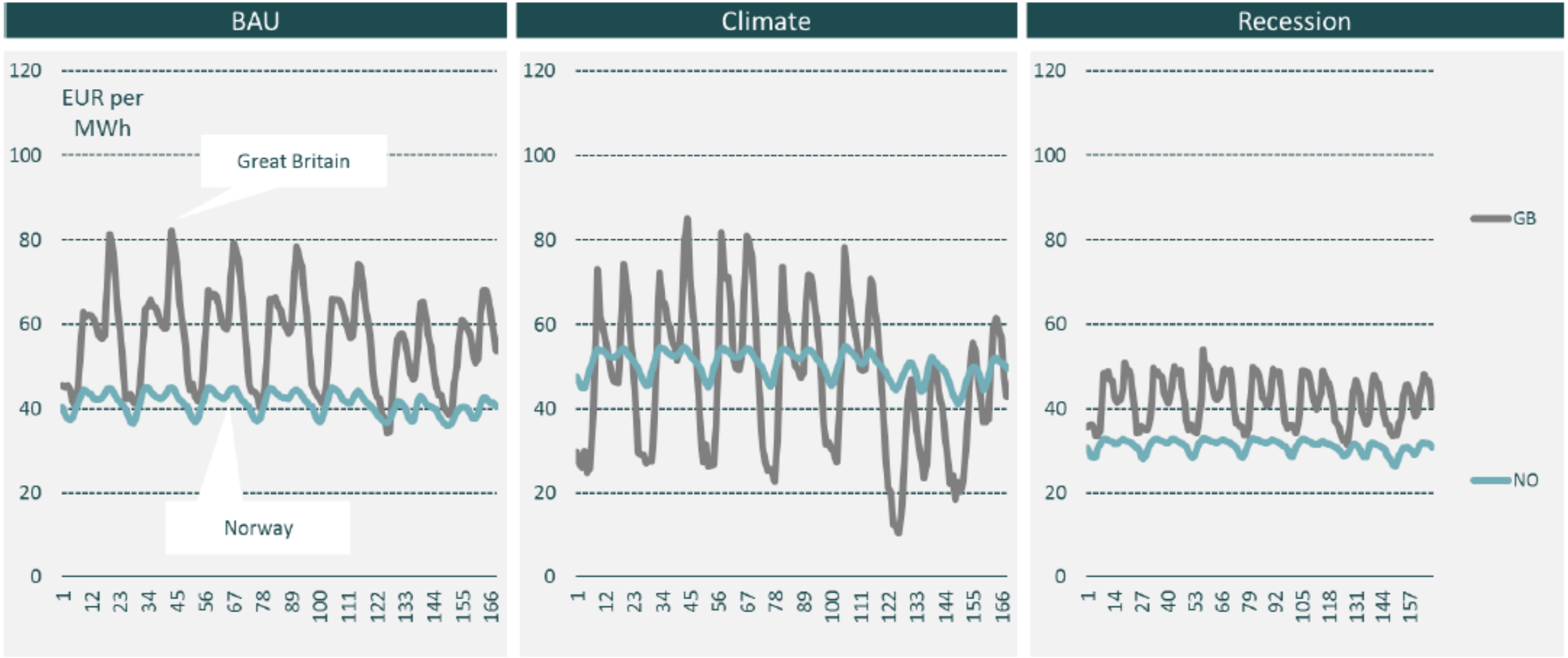
00:00
00:00
00:00
1 Jan
3 Jan
5 Jan
7 Jan
9 Jan
Bergen
Tr.heim
DE-LU
NL

Figure 12 Price structure in Norway and GB in 2030 all Scenarios



THEMA Report 2016-4

E24

Så mye tjener vi på kraftkablene

De siste fem årene har Statnett tjent 2,8 milliarder kroner på eksportkablene for strøm, og strømkundenes nettleie er redusert med 674 millioner, viser ferske tall.

TJENER PENGER: Statnett har tjent nesten 3 milliarder kroner på strømkablene til Danmark og Nederland de siste fem årene, og rundt 674 millioner kroner er brukt på å redusere strømkundenes nettleie, opplyser nettoperatøren. Dette er fra leggingen av Skagerak 4, den fjerde strømkabelen mellom Norge og Danmark, som ble satt i drift i 2014.
FOTO: STATNETT

Kjetil Malkenes Hovland

(E24) Publisert: 14:16 - 29.03.2017, Oppdatert: 14:17 - 29.03.2017

Denne uken var det gjennomslag i en 2 kilometer lang tunnel i Suldal.

Tunnelen er en liten del av verdens lengste strømkabel på 720 kilometer, som skal bygges mellom Norge og England.

Neste år begynner man å legge selve kabelen, som skal koste opptil to milliarder euro eller 18 milliarder kroner, fra Kvilldal og langs havbunnen over til Blyth ved Newcastle.

Nå legger Statnett frem ferske tall for hvor mye nettoperatøren og norske strømkunder har tjent på utenlandskablene de siste fem årene.

Statnetts inntekter fra kablene var på rundt 3 milliarder kroner de siste fem årene, eller 2,8 milliarder kroner hvis man trekker fra strømtapet.

Trekker man fra også investeringskostnader og utgifter til drift og vedlikehold, så bidro kablene med 674 millioner kroner som går til å redusere nettleien for strømkunder i Norge, ifølge Statnett.

– Disse kablene har gitt gode inntekter til Statnett, og dette gjør at vi kan betale ned på investeringene som er gjort i kablene og i tillegg finansiere forsterkninger i sentralnettet og redusere nettleien for norske forbrukere, sier konsernsjef Auke Lont i Statnett.

– Samtidig jobber vi for drifts- og markedsløsninger for mellomlandsforbindelsene som skal gi enda bedre inntjening for Norge, sier han.

Bygger flere kabler

Norge har i dag fire eksportkabler for strøm til Danmark, Skagerak 1-4, og en eksportkabel til Nederland, NorNed.

I tillegg bygges det nå to nye eksportkabler, en til Storbritannia og en til Tyskland.

For 2016 alene bokførte Statnett handelsinntekter for de seks eksisterende eksportkablene på 395 millioner kroner. Når kostnadene for strømtapet på kablene trekkes fra var inntekten på 348 millioner kroner, ifølge selskapet.

Taper 4 prosent

På vei til utlandet går rundt 4 prosent av strømmen tapt, noe som gjør at tapet noen ganger er høyere enn inntektene.

Statnett har siden 2015 en ordning som gjør at Norge bare eksporterer kraft gjennom kabelen til Nederland når det er lønnsomt, altså når prisforskjellen mellom Norge og Nederland gjør at Statnetts inntekter er høyere enn tapet.

Nettoperatøren opplyser at den også ønsker å få i stand en tilsvarende avtale på de fire danske kablene.

Den første kabelen til Danmark ble satt i drift i 1976, og den fjerde i 2014. NorNed ble satt i drift i 2008.

Skeptiske til nye kabler

Den siste tiden har industri Energi kommet med kraftig kritikk mot byggingen av eksportkabelen til Storbritannia, som fagforeningen frykter vil bidra til høyere strømpriser og industridød, med fare for 12.000 arbeidsplasser i kraftkrevende industri.

Industri Energi har derfor bedt Riksrevisjonen om å vurdere om kabelen er lovlig, og håper at byggingen kan stanses.

Fagforeningen har blant annet spådd strømsjokk med strømpriser som kan dobles til rundt 50 øre per kilowattime på sikt, fra 31,6 øre per kilowattime i fjor.

Les mer: Industri Energi advarer mot strømprissjokk

Omstridt kostnad

Norske myndigheter har imidlertid anslått effekten av kablene til å være mye mindre.

– I følge NVEs kraftmarkedsanalyse mot 2030 vil de to nye kablene isolert sett gi en svak økning i kraftprisene, skrev olje- og energiminister Terje Søviknes i et skriftlig svar til en partikollega i Stortinget nylig.

NVE-rapporten han viser til anslår at kablene fra Norge til Tyskland og Storbritannia i snitt vil øke kraftprisen i Norge med rundt 2 øre per kilowattime i 2030.

Les mer: Søviknes avviser dyr kabelstrøm

Selve strømmen er for øvrig ikke det eneste kundene betaler via strømregningen. I tillegg kommer nettleien og statlige avgifter. I fjor utgjorde selve strømmen bare drøyt en tredjedel av regningen.

Les mer: Så mye betalte du for strømmen i fjor

line	rent_export	rent_import	rent_total	rent_NO
NO1 - SE3	284,770,431	81,579,282	366,349,713	183,174,856.5
NO3 - SE2	27,004,618	16,970,059	43,974,677	21,987,338.5
NO4 - SE1	74,447,873	6,387,033	80,834,906	40,417,453.0
NO4 - SE2	14,021,425	-759,182	13,262,243	6,631,121.5
NO2 - DE	121,462,779	15,690,762	137,153,541	68,576,770.5
NO2 - UK	116,010,113	193,612	116,203,725	58,101,862.5
NO2 - DK1	545,222,666	136,619,737	681,842,403	340,921,201.5
NO2 - NL	255,840,760	8,093,643	263,934,403	131,967,201.5

NHH

Figure 30 - Progress made in the efficient use of electricity interconnectors in the DA market timeframe over the last 8 years – percentage of available capacity (NTC) used in the 'right direction' in the presence of a significant price differential (>1 euro/MWh)

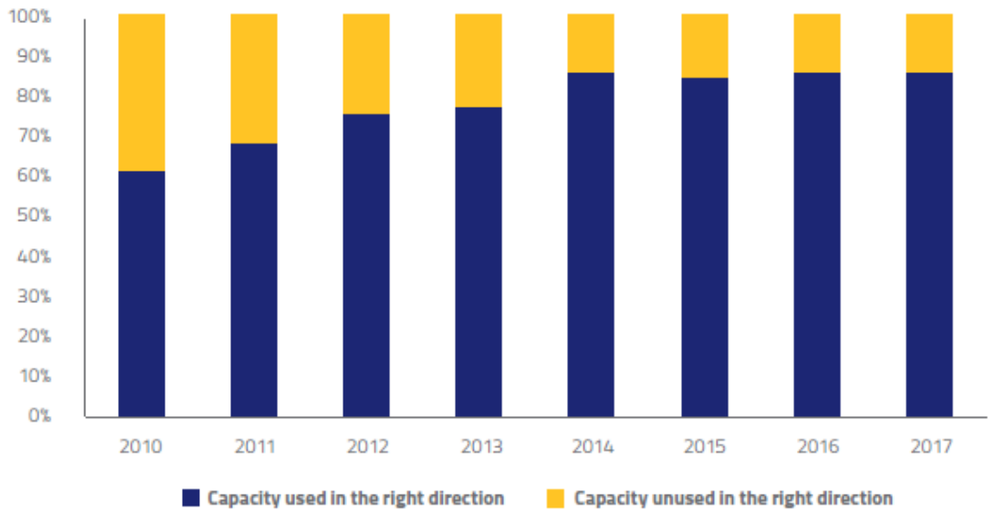
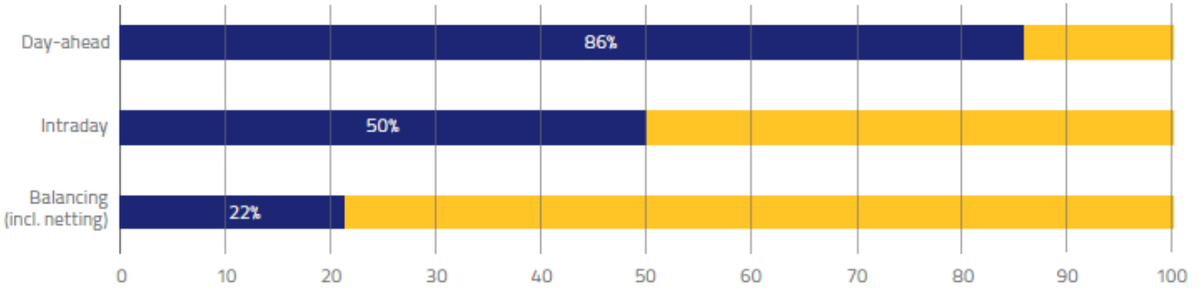
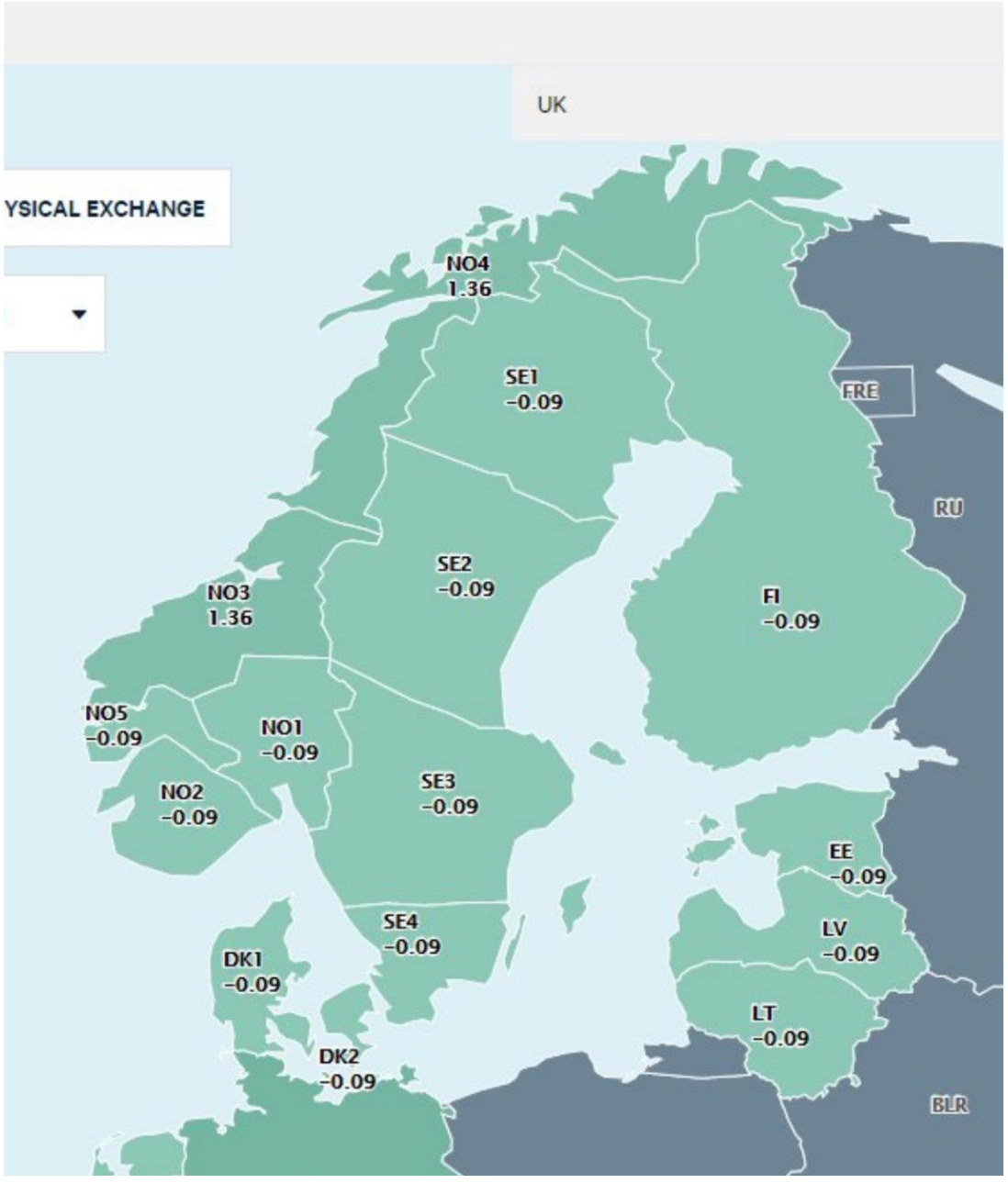


Figure 27 - Europe's interconnector efficiency for day-ahead, intraday and balancing trades (source: ACER)





E24+ TIPS OSS

STRØMPRISENE

Historisk lav strømpris: I natt fikk nordmenn betalt for strøm

I Norge har vi aldri før sett en negativ strømpris, men det fikk vi tidlig mandag morgen. Snø i fjellet, begrenset eksport og sommerferie er noen av grunnene.

Hos Nordmenn har det vært lavt forbruk som fører til vannkraft s… vis mer

Lise Åserud / NTB scanpix

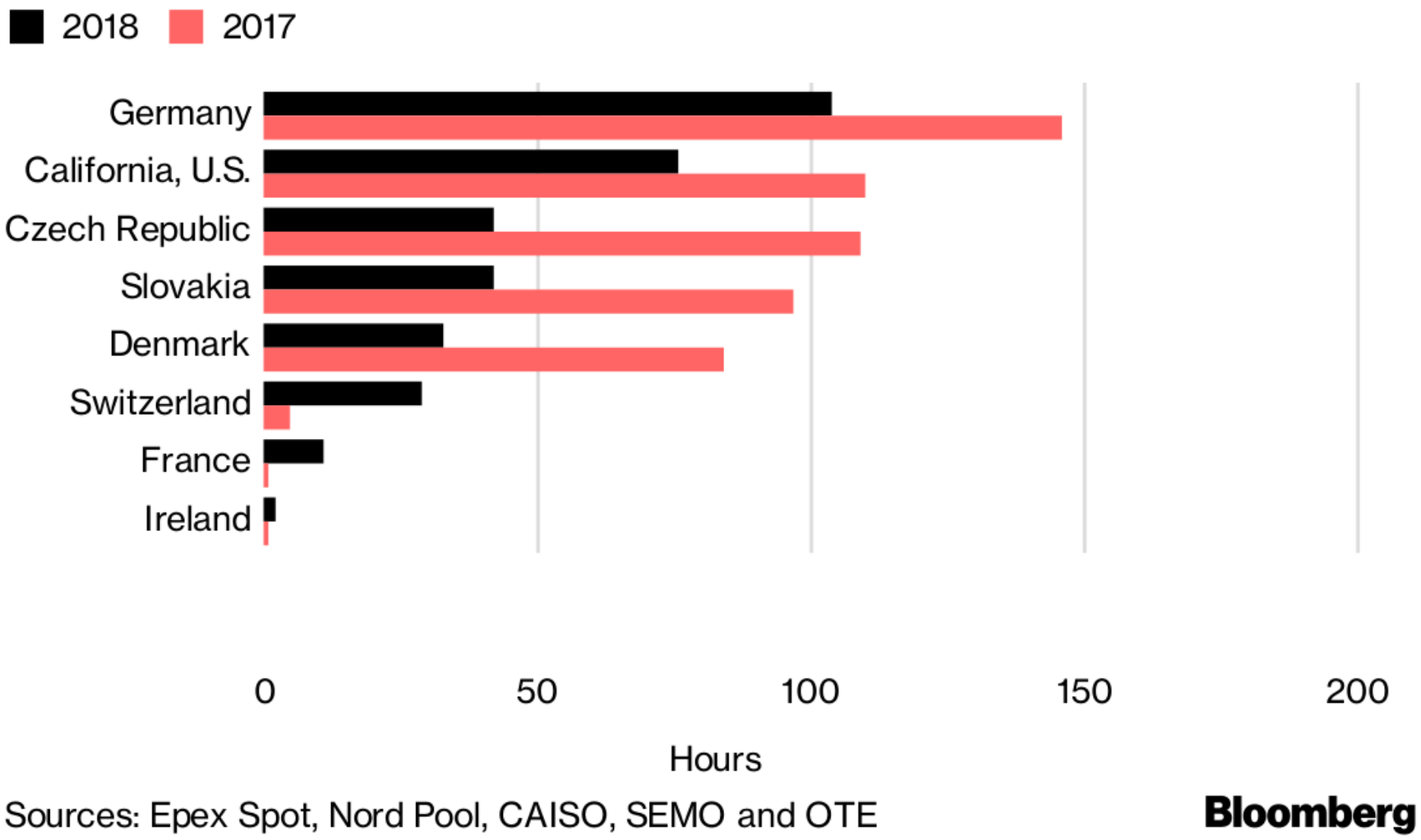
Av **Benedicte Storm Bamvik**

Oppdatert: 6. juli 2020 13:00

Publisert: 6. juli 2020 11:32

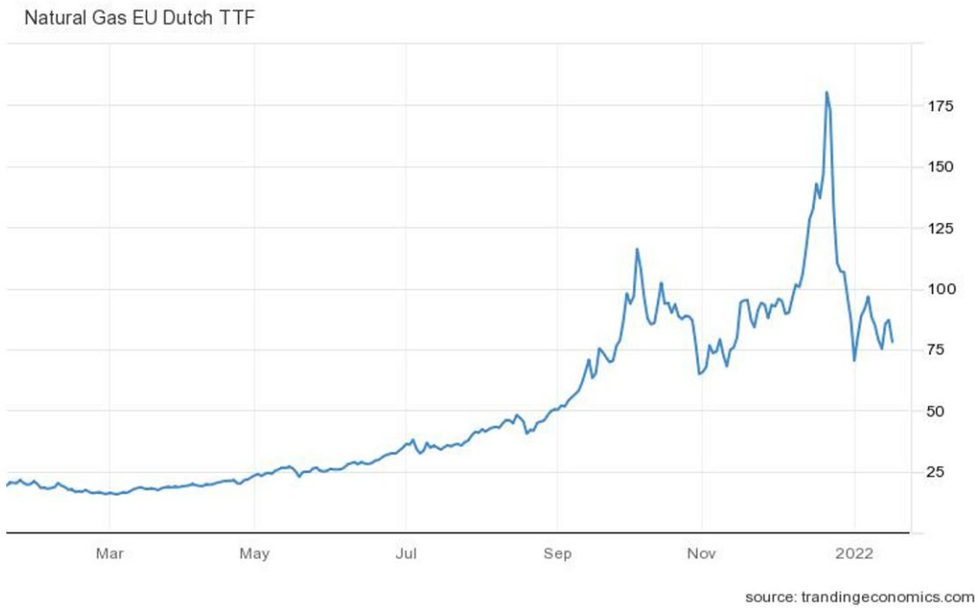
Negative Power Prices

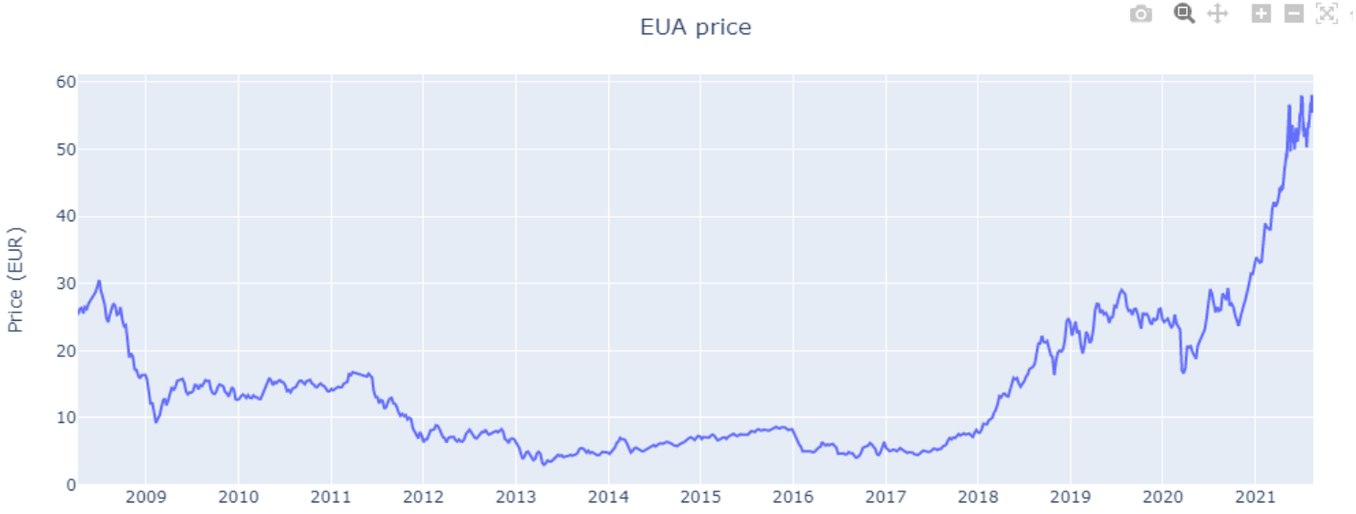
Number of occurrences in day-ahead markets



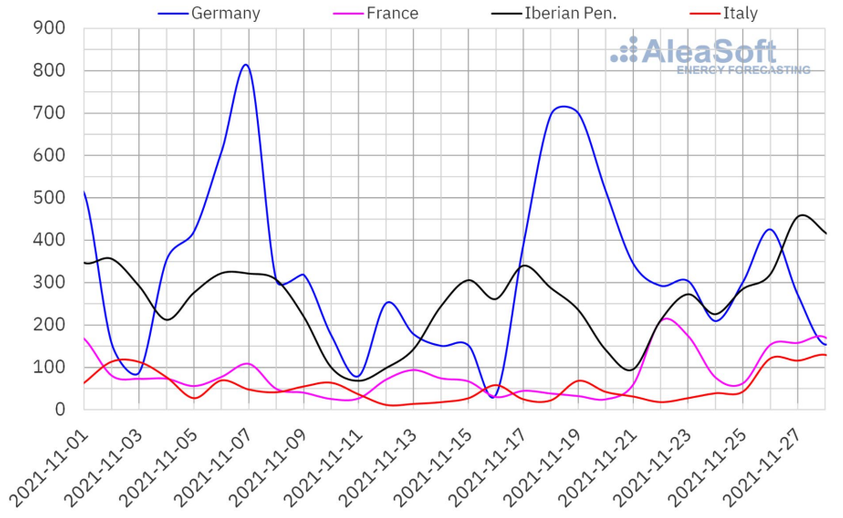
Sources: Epex Spot, Nord Pool, CAISO, SEMO and OTE

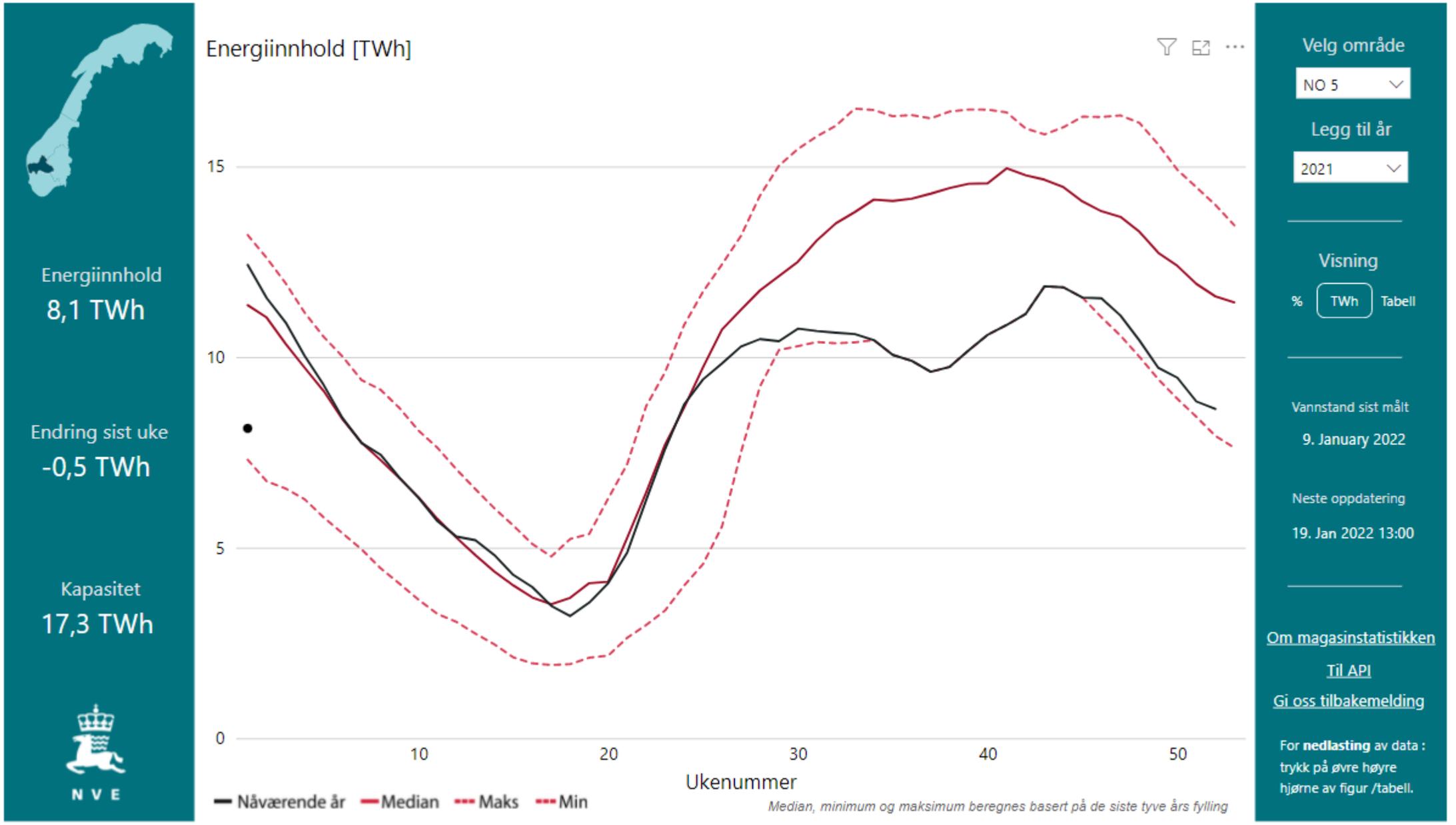
Bloomberg

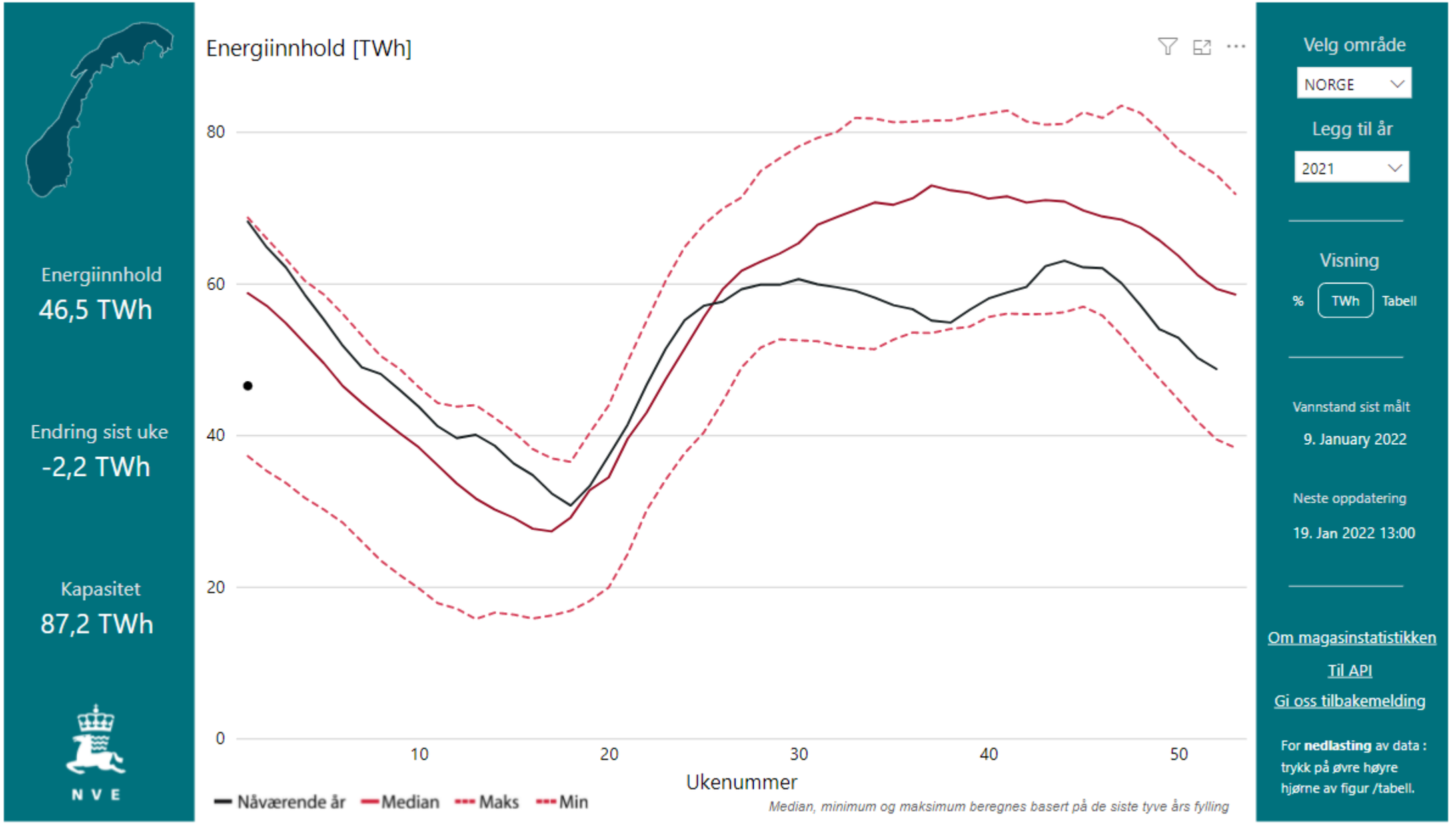




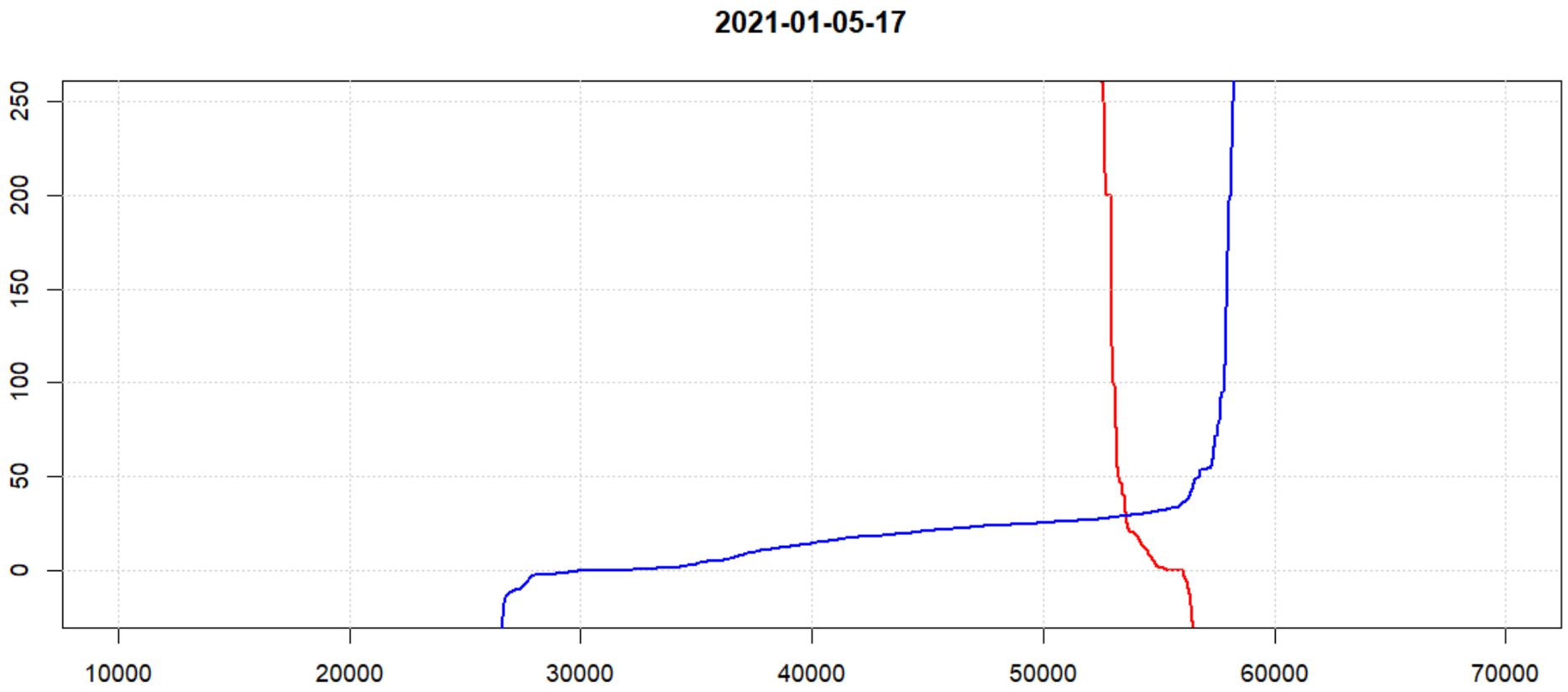
European wind energy production [GWh]

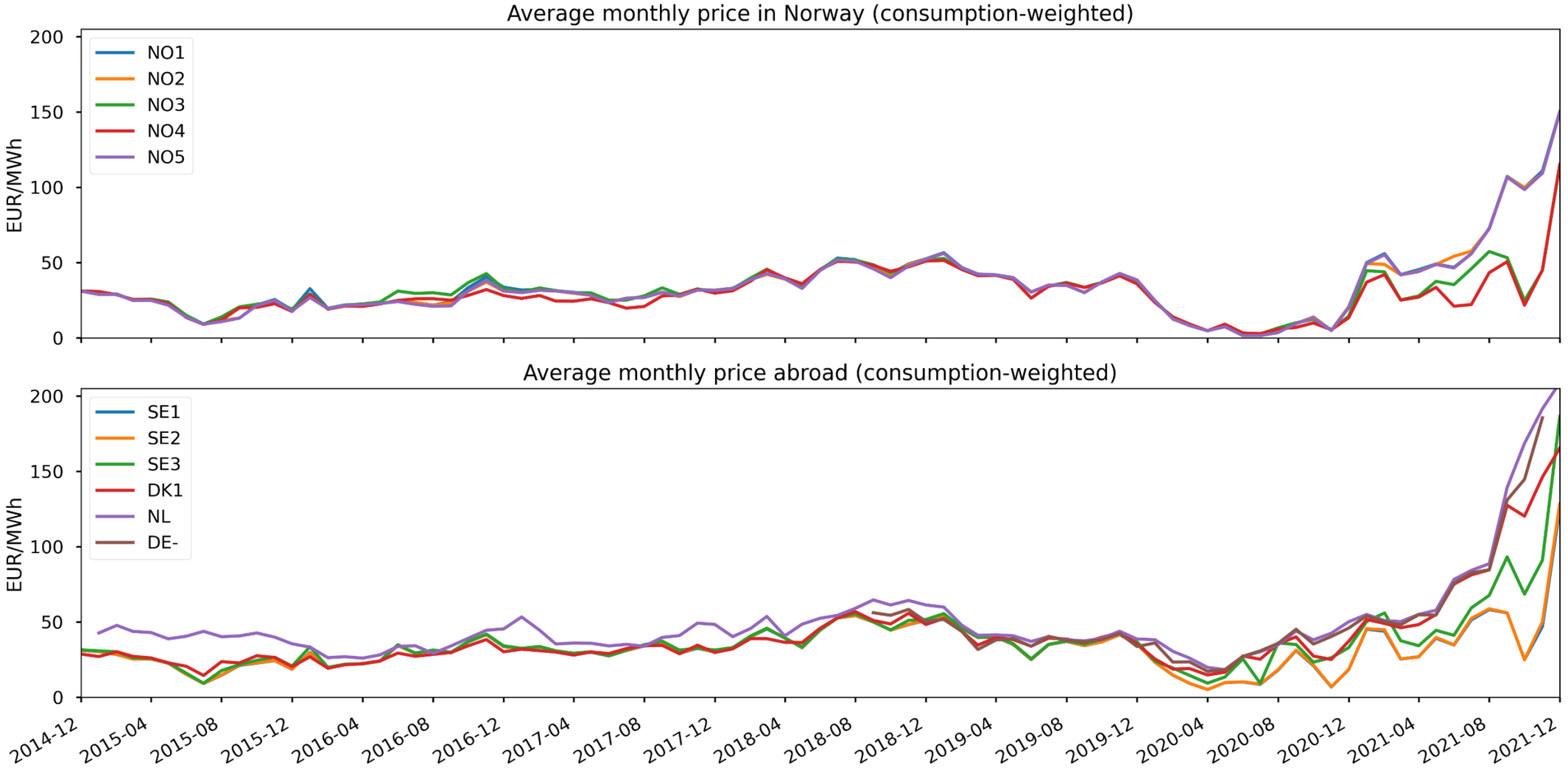


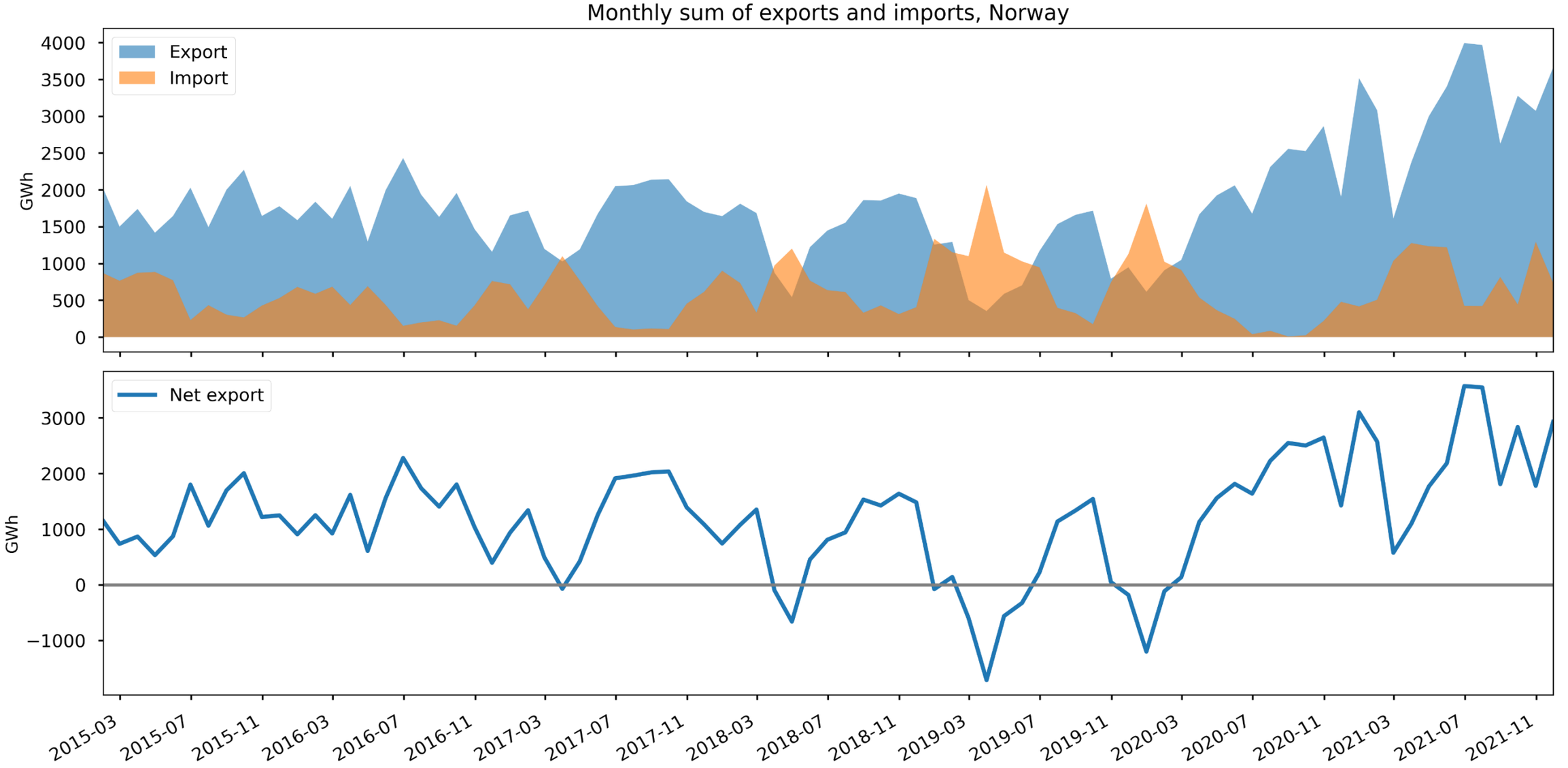

Energiinnhold [TWh]
15
10
5
0
10
20
30
40
50
Ukenummer
Nåværende år
Median
Maks
Min
Median, minimum og maksimum beregnes basert på de siste tyve års fylling
Energiinnhold
8,1 TWh
Endring sist uke
-0,5 TWh
Kapasitet
17,3 TWh
N V E
Velg område
NO 5
Legg til år
2021
Visning
%
TWh
Tabell
Vannstand sist målt
9. January 2022
Neste oppdatering
19. Jan 2022 13:00
Om magasinstatistikken
Til API
Gi oss tilbakemelding
For nedlasting av data : trykk på øvre høyre hjørne av figur /tabell.

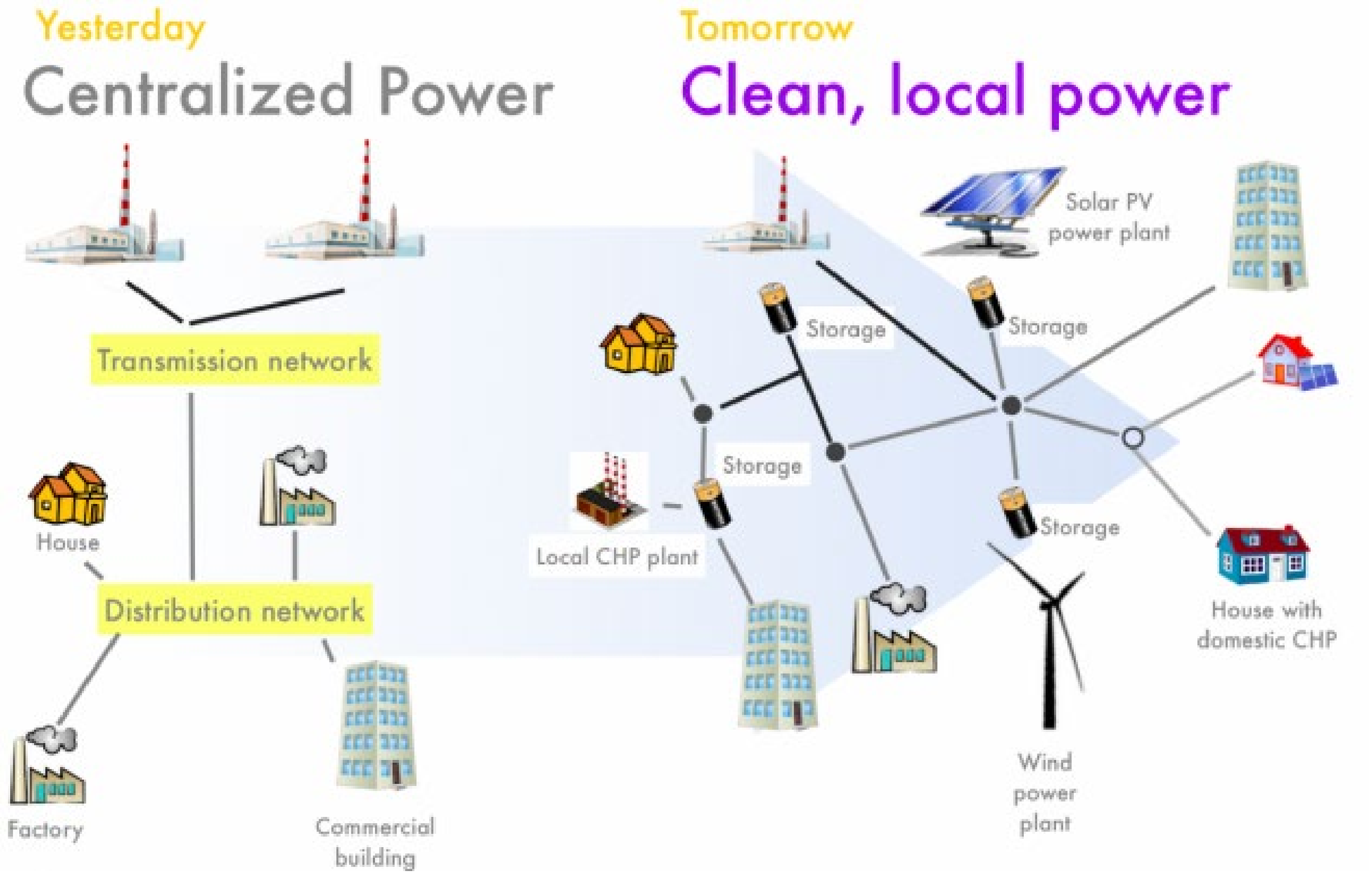

Energiinnhold [TWh]
80
60
40
20
0
10
20
30
40
50
Ukenummer
Nåværende år
Median
Maks
Min
Median, minimum og maksimum beregnes basert på de siste tyve års fylling
Energiinnhold
46,5 TWh
Endring sist uke
-2,2 TWh
Kapasitet
87,2 TWh
NVE
Velg område
NORGE
Legg til år
2021
Visning
%
TWh
Tabell
Vannstand sist målt
9. January 2022
Neste oppdatering
19. Jan 2022 13:00
Om magasinstatistikken
Til API
Gi oss tilbakemelding
For nedlasting av data : trykk på øvre høyre hjørne av figur /tabell.

Nordic bid curves (2021)



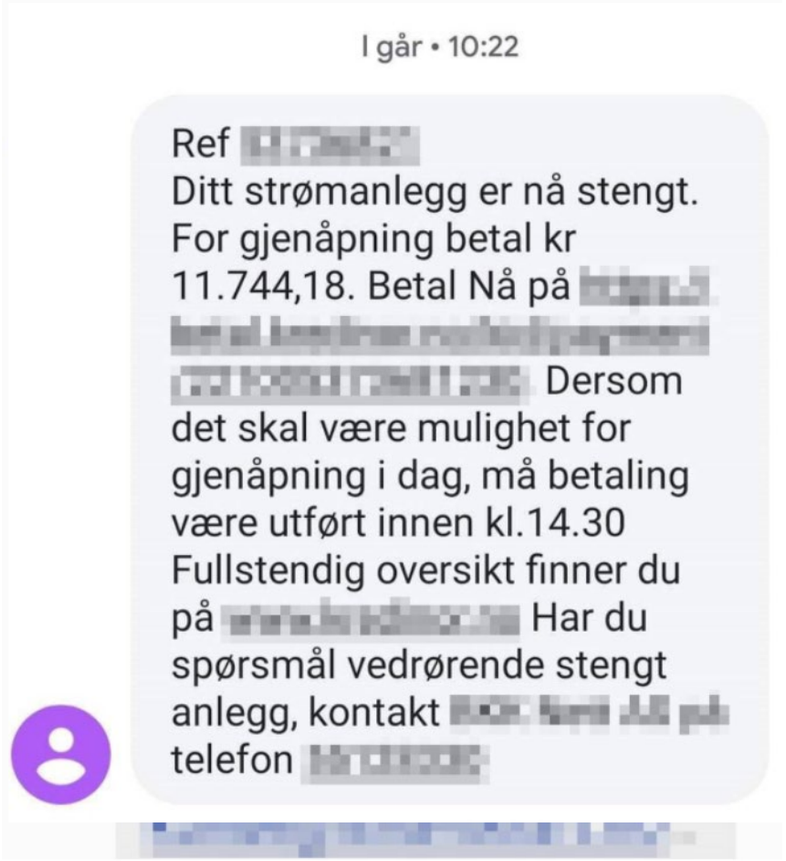

Average monthly price in Norway (consumption-weighted)
NO1
NO2
NO3
NO4
NO5
EUR/MWh
200
150
100
50
0
Average monthly price abroad (consumption-weighted)
SE1
SE2
SE3
DK1
NL
DE-
EUR/MWh
200
150
100
50
0
2014-12
2015-04
2015-08
2015-12
2016-04
2016-08
2016-12
2017-04
2017-08
2017-12
2018-04
2018-08
2018-12
2019-04
2019-08
2019-12
2020-04
2020-08
2020-12
2021-04
2021-08
2021-12


Monthly sum of exports and imports, Norway
Export
Import
GWh
4000
3500
3000
2500
2000
1500
1000
500
0
Net export
GWh
3000
2000
1000
0
−1000
2015-03
2015-07
2015-11
2016-03
2016-07
2016-11
2017-03
2017-07
2017-11
2018-03
2018-07
2018-11
2019-03
2019-07
2019-11
2020-03
2020-07
2020-11
2021-03
2021-07
2021-11



J. Farrell, 2011 (adapted from European Commission)

Clean and affordable



https://www.nrk.no/klima/xl/**elektrifiseri**ng-oker-stromprisen---blir-regningen-rettferdig_-1.15539835

- What is the new normal for electricity prices?
  - Interconnectors
  - Renewables
  - Demand and the green shift
- How to deal with the "affordability" part?
  - Innovations in demand response and contracts
  - Mechanisms to save on the electricity bill for all
  - Keeping incentives to save energy when needed