
CHP in a windy system

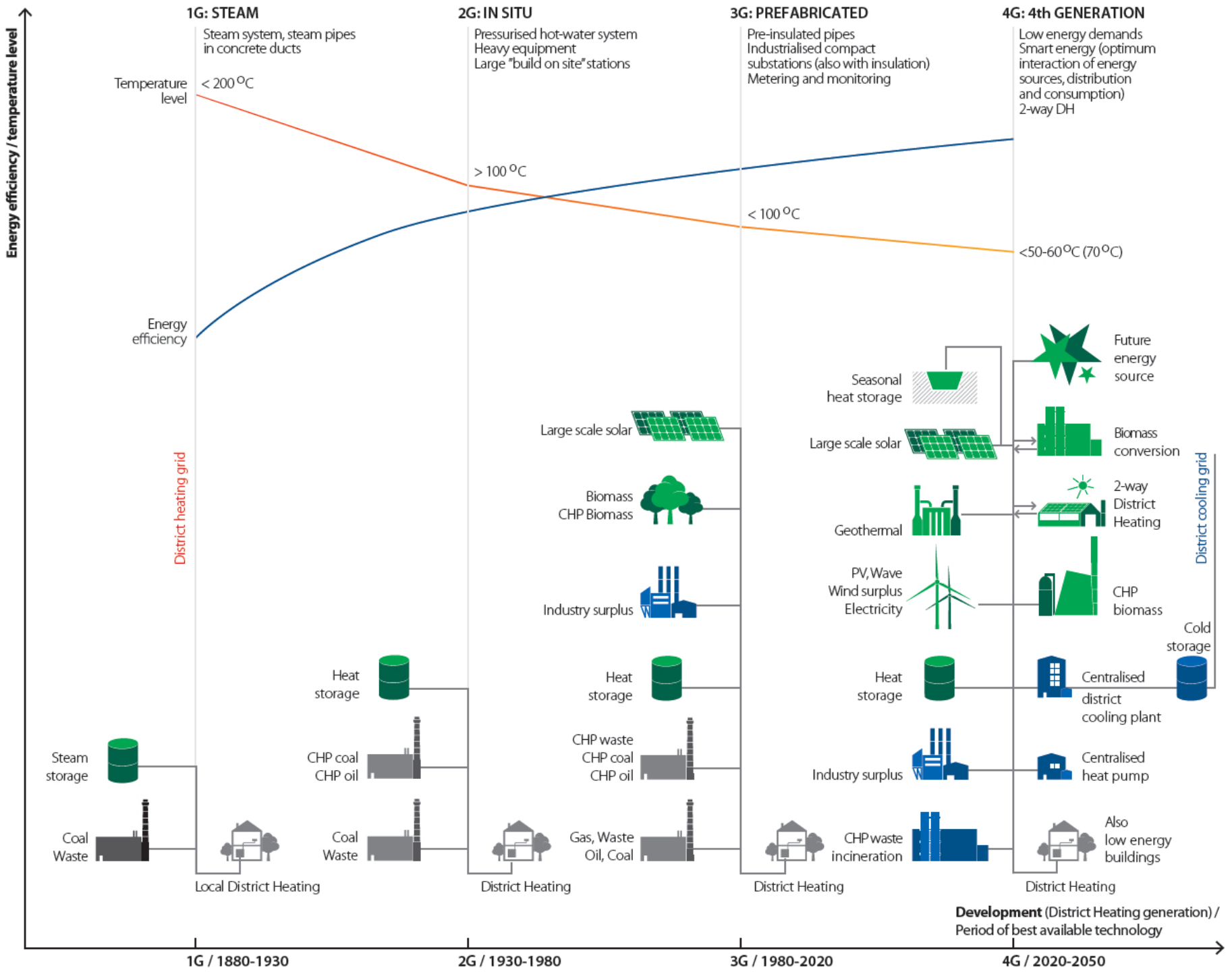
Fabian Levihn

R&D Manager at Fortum Värme

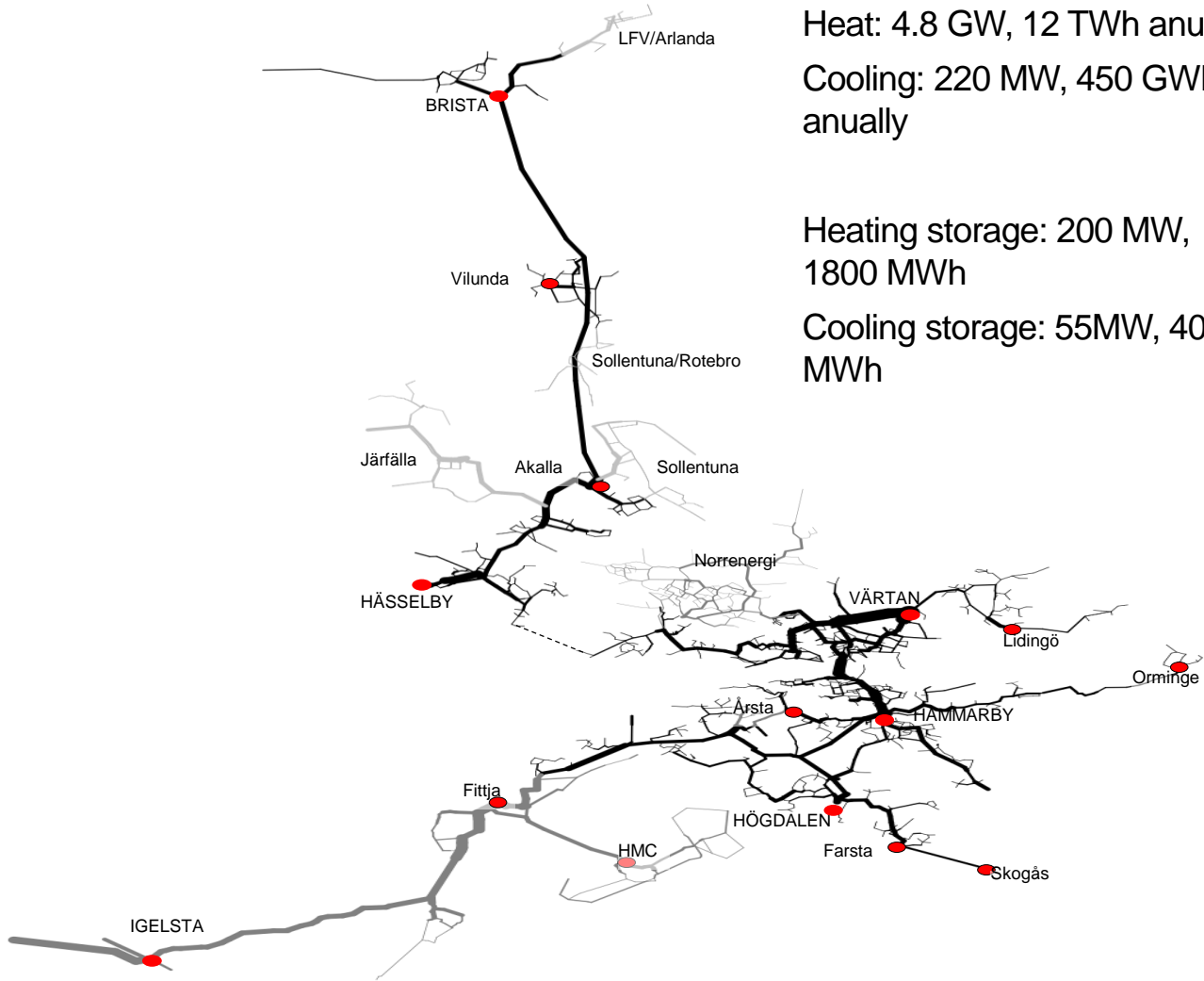
Research fellow at the Royal Institute of Technology (KTH)

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Stockholm district heating network



Heat: 4.8 GW, 12 TWh annually

Cooling: 220 MW, 450 GWh annually

Heating storage: 200 MW, 1800 MWh

Cooling storage: 55MW, 400 MWh

4 larger utilities cooperate:

-Fortum Värme

-Söderenergi

-Norrenergi

-E.On.

68°C normal supply

60°C in low temp areas

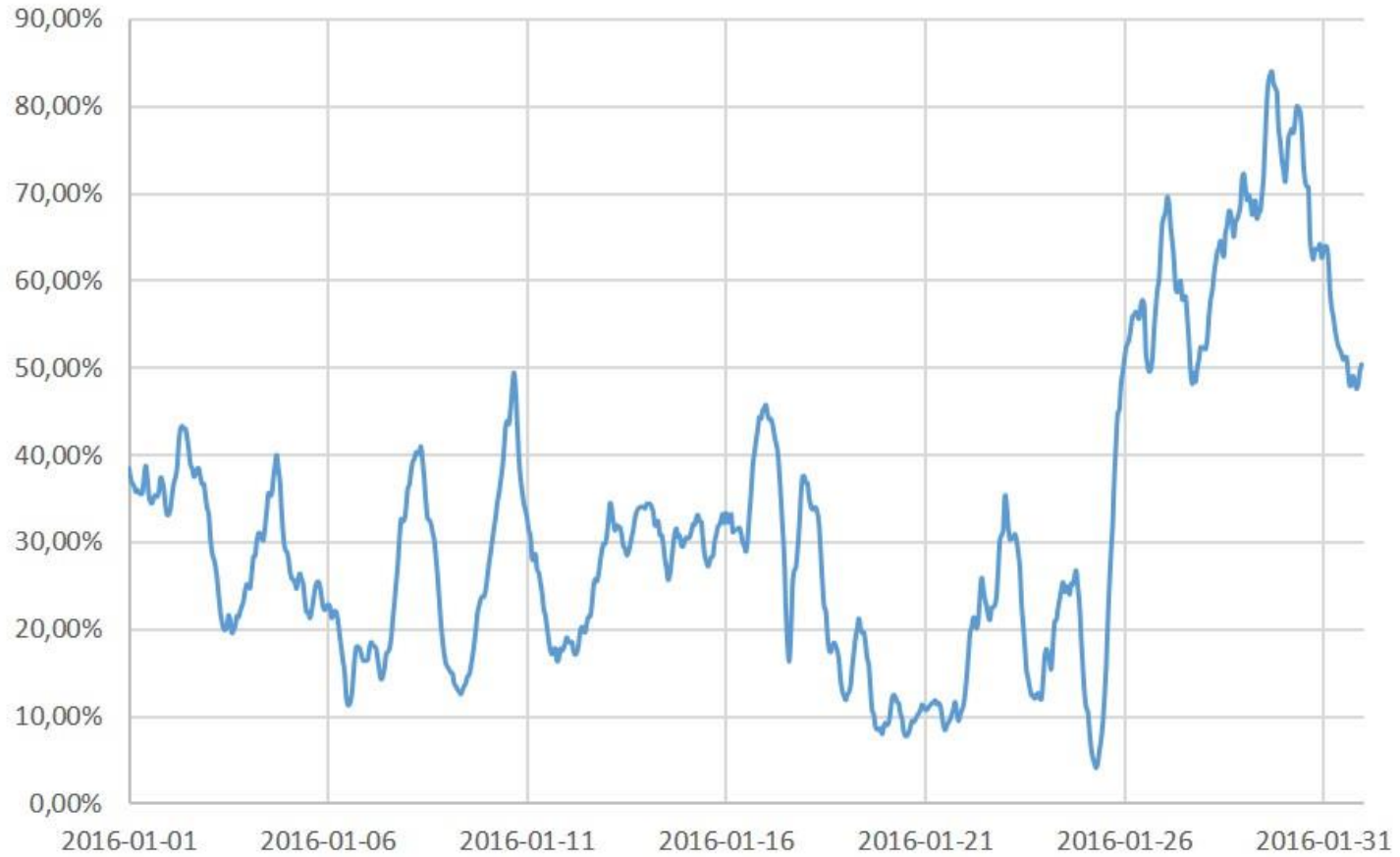
115°C along distributional highways.

41°C average return temp

Maximum allowed Δt in distribution during 2015 was 78°C

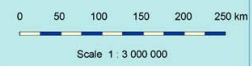
Network losses about 9%

Wind power production as share of installed capacity in Sweden during January 2016



Interconnected network of Northern Europe

01.07.2010



Legend

Lines:

- 750 kV transmission line
- 500 kV transmission line
- 380-400 kV transmission line
- 300-330 kV transmission line
- 220 kV transmission line
- 132-150 kV transmission line
- DC-line
- Interconnection for voltage < 220 kV

Voltage

- Temporary voltage
- One circuit (diff. colours)
- Under construction (diff. colours)
- Double circuit (diff. colours)
- Double circuit with 1 circuit mounted (diff. colours)
- >=3 circuits (diff. colours)

Plants and stations:

- Hydro Power Plant
- Wind Farm
- Thermal Power Plant
- Substation
- Substations + power plants
- Converter station
- Converter station back-to-back
- Under construction

Power systems

- Power systems in ENTSO-E
- Other

The map shows

The existing high-voltage lines and those under construction (same for power plants and substations with towers designed for voltages of a) 220 kV and higher b) 110 kV to 160 kV in the areas of Cyprus, Denmark, Israel/PA and Norway and c) 110 kV to 150 kV if these lines cross national frontiers.

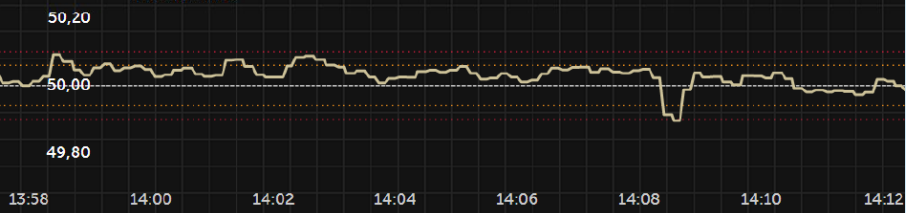
If the operation voltage differs from that indicated by the colour, this voltage is given alongside the line.

Lines with more than 2 circuits bear a numeral in *italics* that is explained hereinafter. The first numeral indicates the number of circuits and the voltage at the final stage of construction (depending on the design of towers), the numerals in brackets indicate the number of circuits and the voltage at the present stage of construction.

1	1 x 380 + 2 x 220	21	4 x 380 (1 x 220)
2	2 x 380 + 2 x 220	22	4 x 380 (2 x 220)
3	3 x 380	23	4 x 380 (3 x 220)
4	4 x 380	24	4 x 380 (1 x 380)
5	4 x 380 + 2 x 220	25	4 x 380 (2 x 380)
6	2 x 380 + 1 x 220	26	4 x 380 (3 x 380)
7	3 x 380 + 2 x 220	27	4 x 380 (1 x 380 + 1 x 220)
8	2 x 380 + 2 x 220 (1 x 380)	28	4 x 380 (1 x 380 + 2 x 220)
9	2 x 380 + 2 x 220 (2 x 380)	29	2 x 220 (1 x 220)
10	2 x 380 + 4 x 220 (4 x 220)	30	4 x 380 (2 x 380 + 1 x 220)
11	2 x 380 + 2 x 220 (2 x 220)	31	4 x 380 (2 x 380 + 1 x 220)
12	2 x 380 + 2 x 220 (2 x 220)	32	4 x 380 (3 x 380 + 1 x 220)
13	2 x 380 + 2 x 220 (2 x 220)	33	4 x 380 + 2 x 220 (3 x 380 + 1 x 220)
14	2 x 380 + 2 x 220 (4 x 220)	34	4 x 380 + 2 x 220 (3 x 380 + 2 x 220)
15	2 x 380 + 2 x 220 (1 x 380 + 1 x 220)	35	3 x 220
16	2 x 380 + 2 x 220 (1 x 380 + 2 x 220)	36	2 x 220 (1 x 220)
17	1 x 380 + 2 x 220 (1 x 380 + 1 x 220)	37	4 x 220 (2 x 220)
18	1 x 380 + 2 x 220 (1 x 380 + 1 x 220)	38	4 x 220 (3 x 220)
19	1 x 380 + 2 x 220 (1 x 380 + 1 x 220)	39	4 x 220 (3 x 220)
20	1 x 380 + 2 x 220 (1 x 220)	40	4 x 220

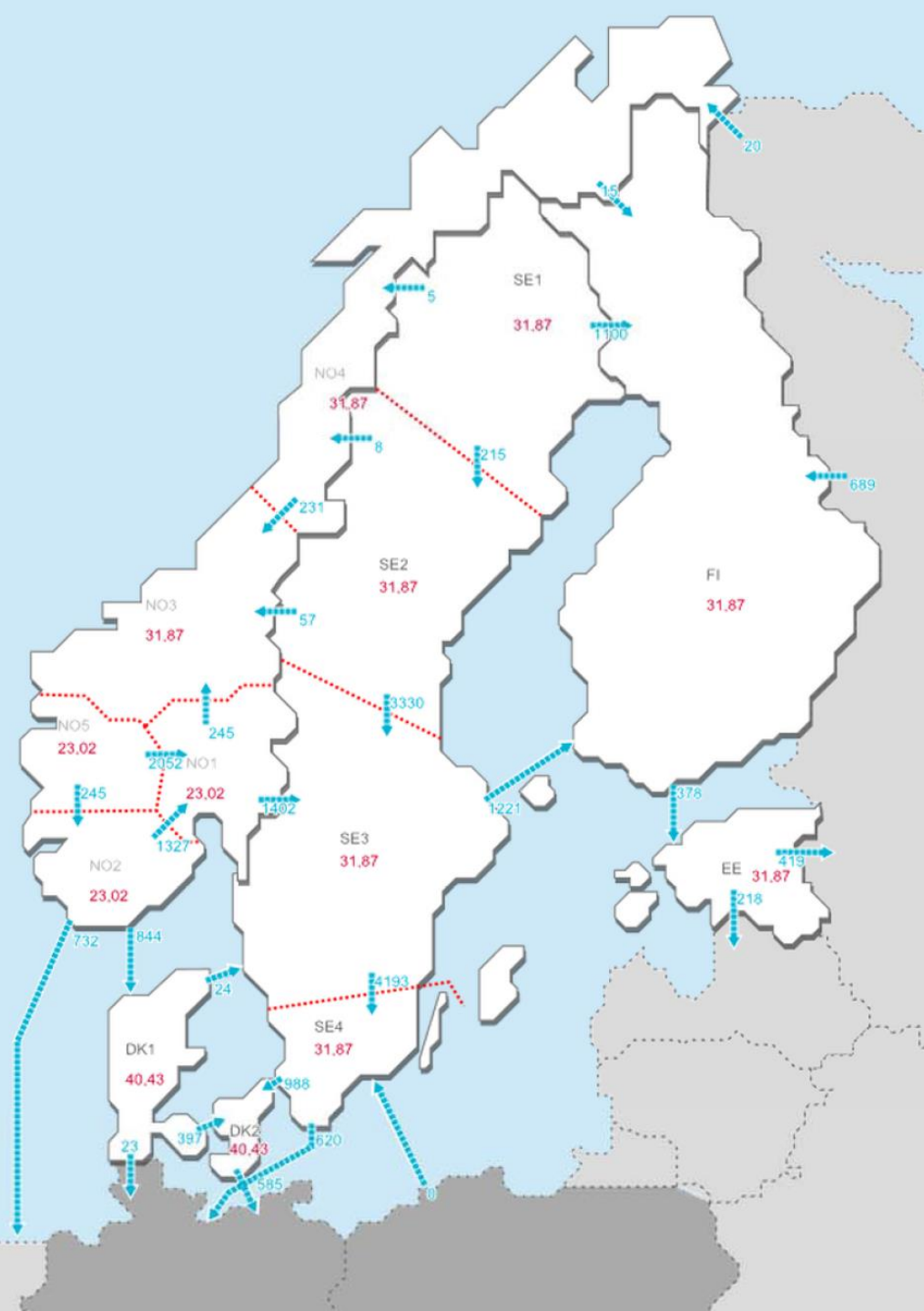


FREKVENNS

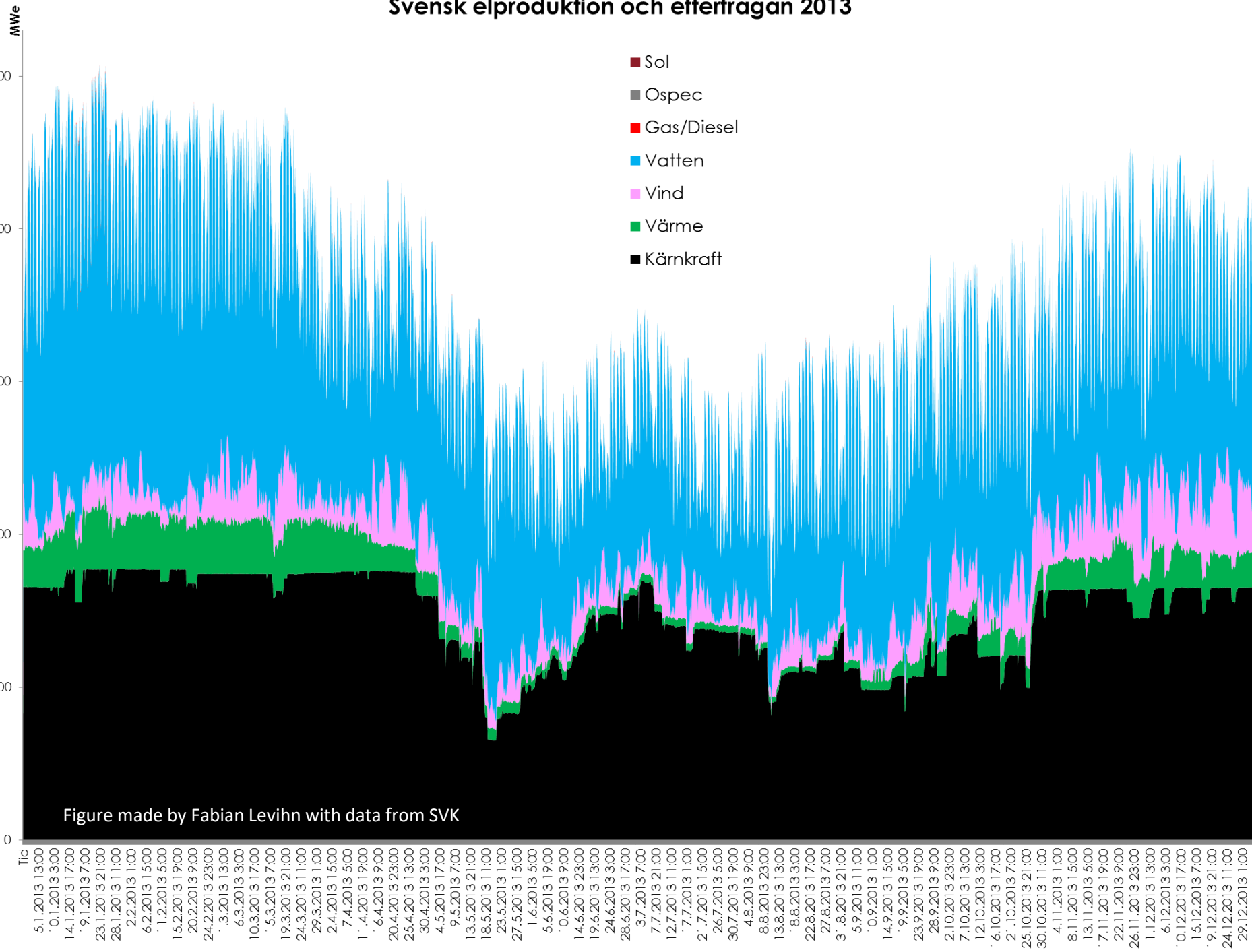


	SE	DK	NO	FI	EE	Total
PRODUKSJON	20 174	3 608	17 731	7 720	1 349	50 581
Kjernekraft	7 924	-	-	2 762	-	10 686
Vann	9 117	-	17 247	1 578	-	27 941
Varme	788	2 728	287	3 087	1 176	8 066
Vind	1 921	879	196	233	174	3 403
Annet	425	-	-	60	-	485
FORBRUK	16 366	4 655	14 898	10 247	1 073	47 240
NETTO UTVEKSLING	-3 808	1 048	-2 833	2 528	-276	-3 342

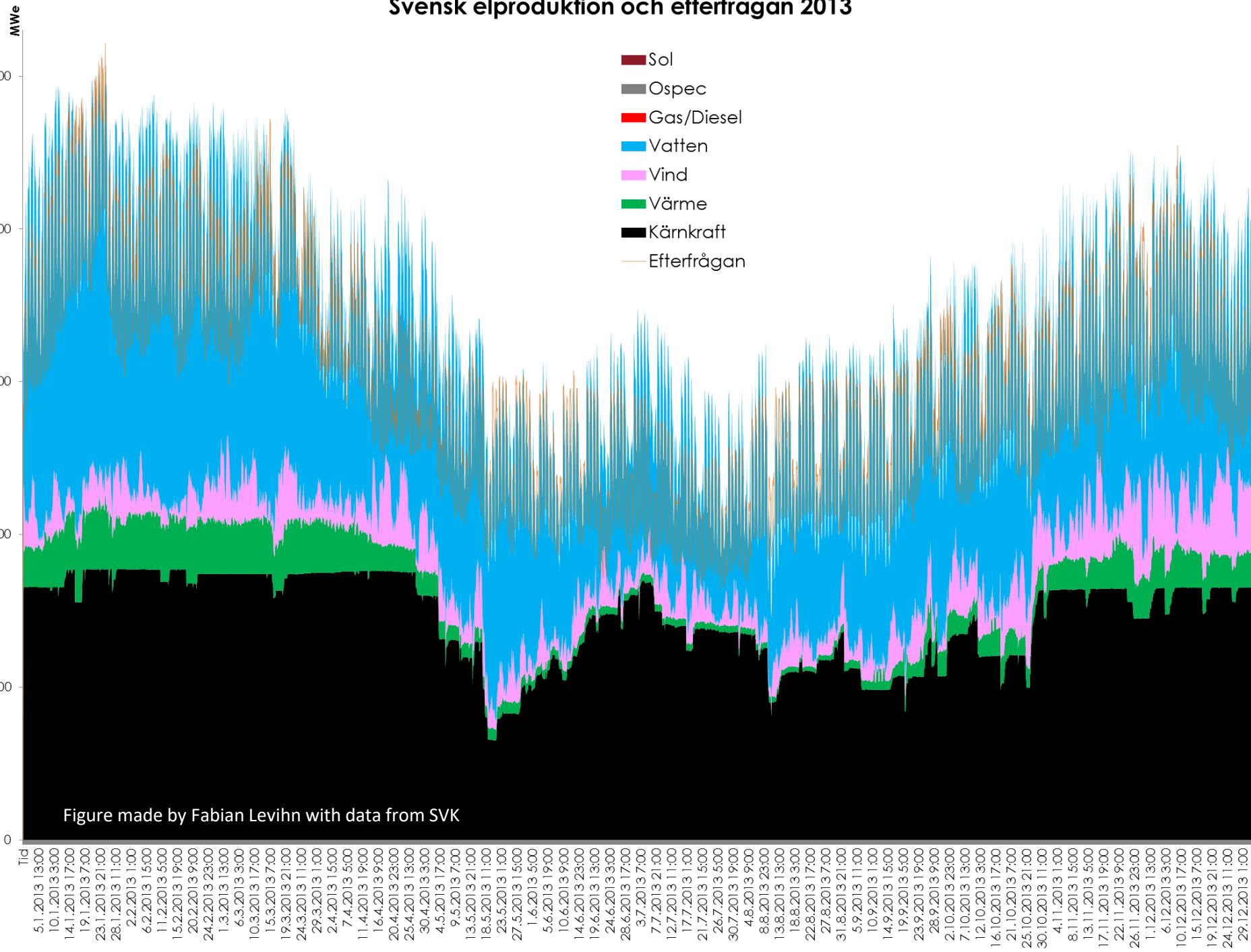
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Svensk elproduktion och efterfrågan 2013



Svensk elproduktion och efterfrågan 2013



2013-01-23 t.o.m. 2013-01-25

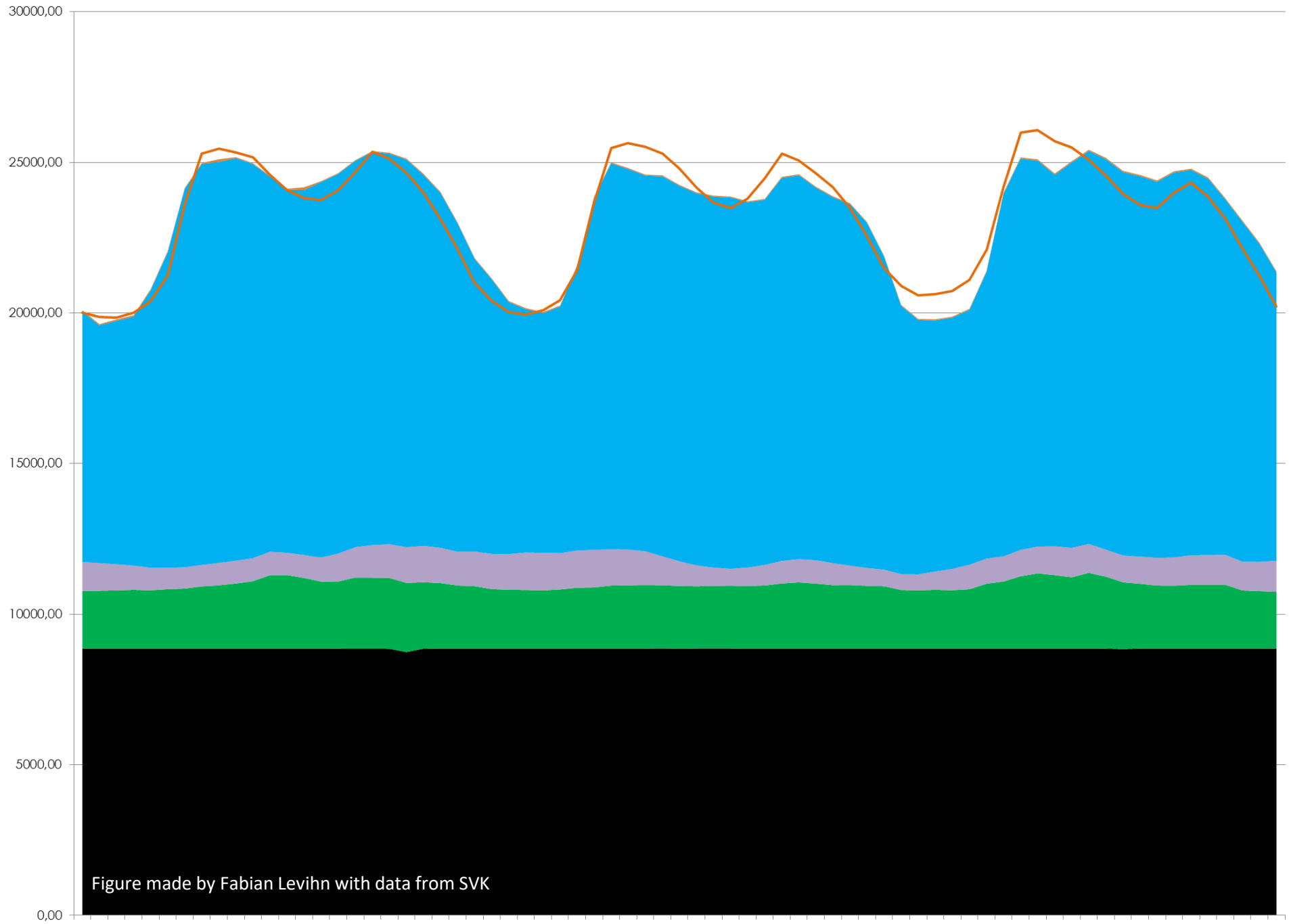
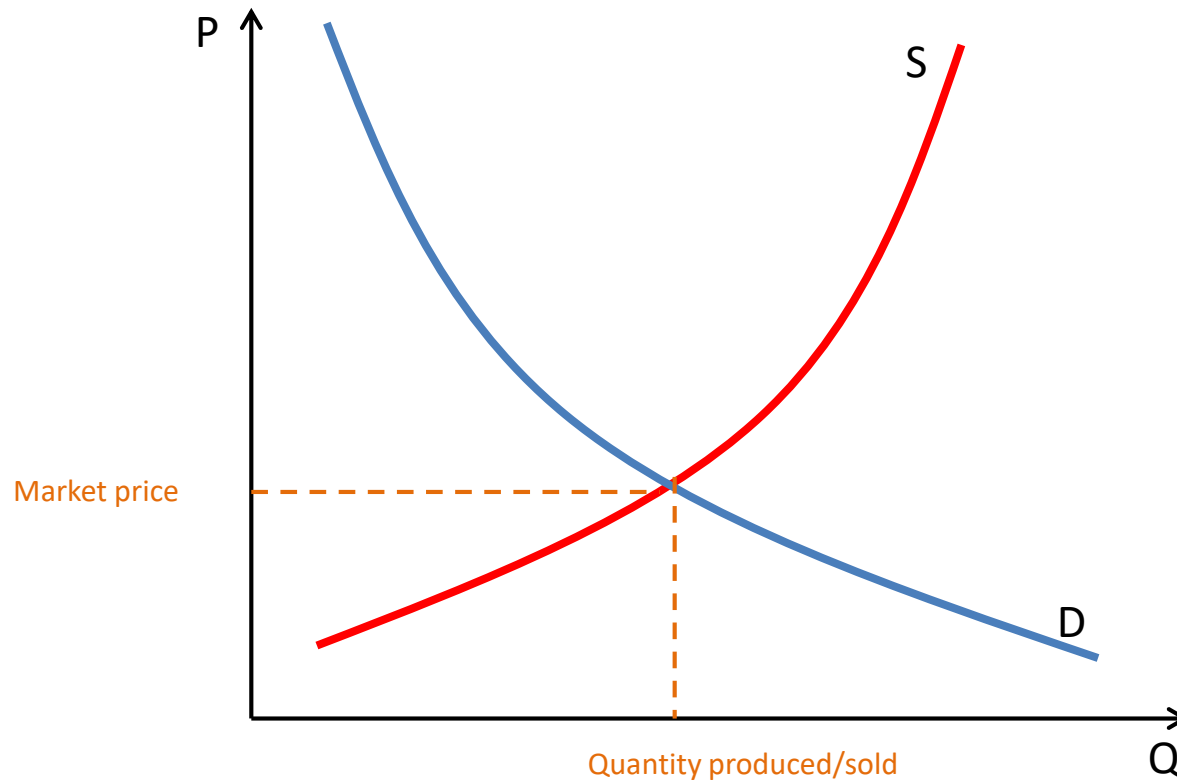
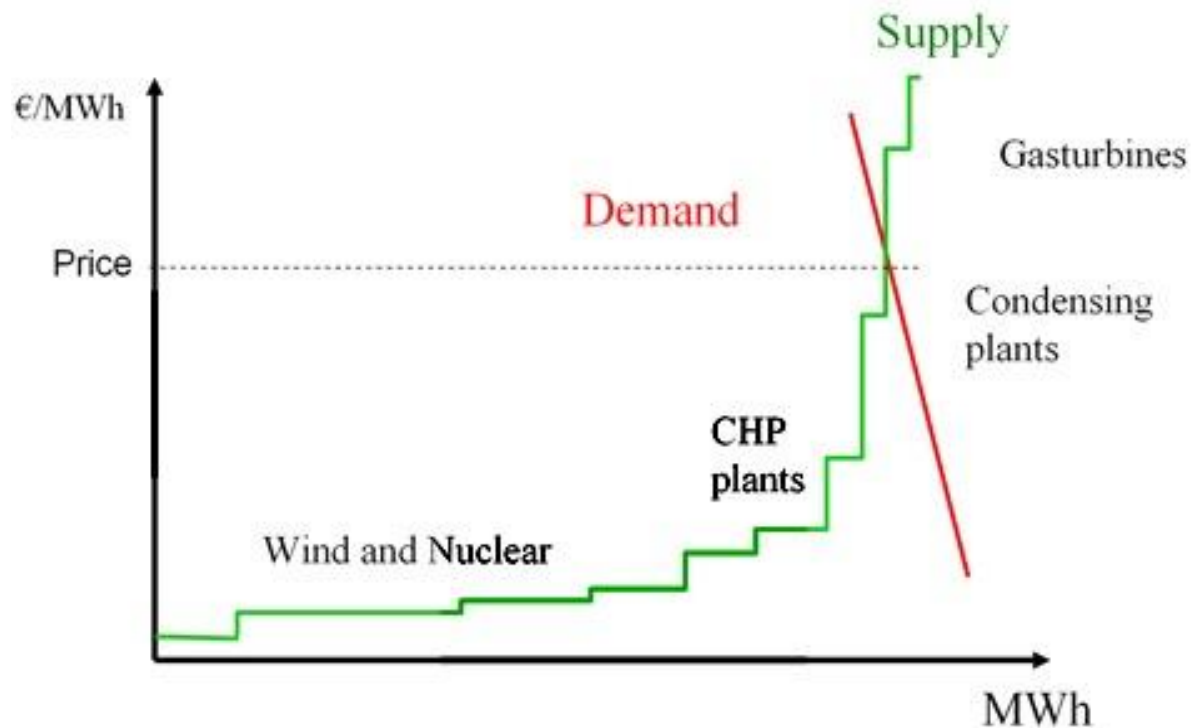


Figure made by Fabian Levihn with data from SVK

Supply and Demand



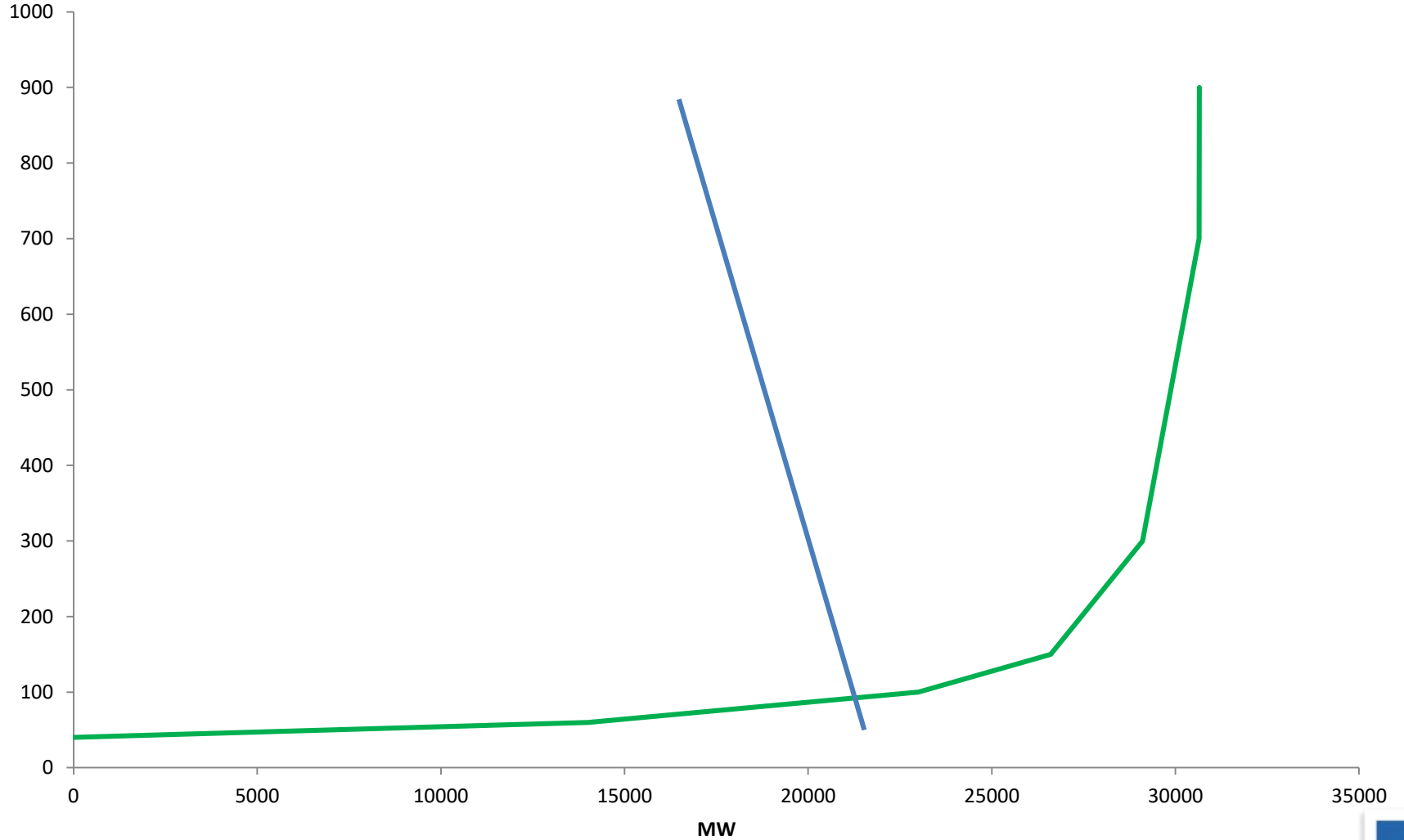
Bottom-up supply curve



Electric power, supply curve

SEK/MW

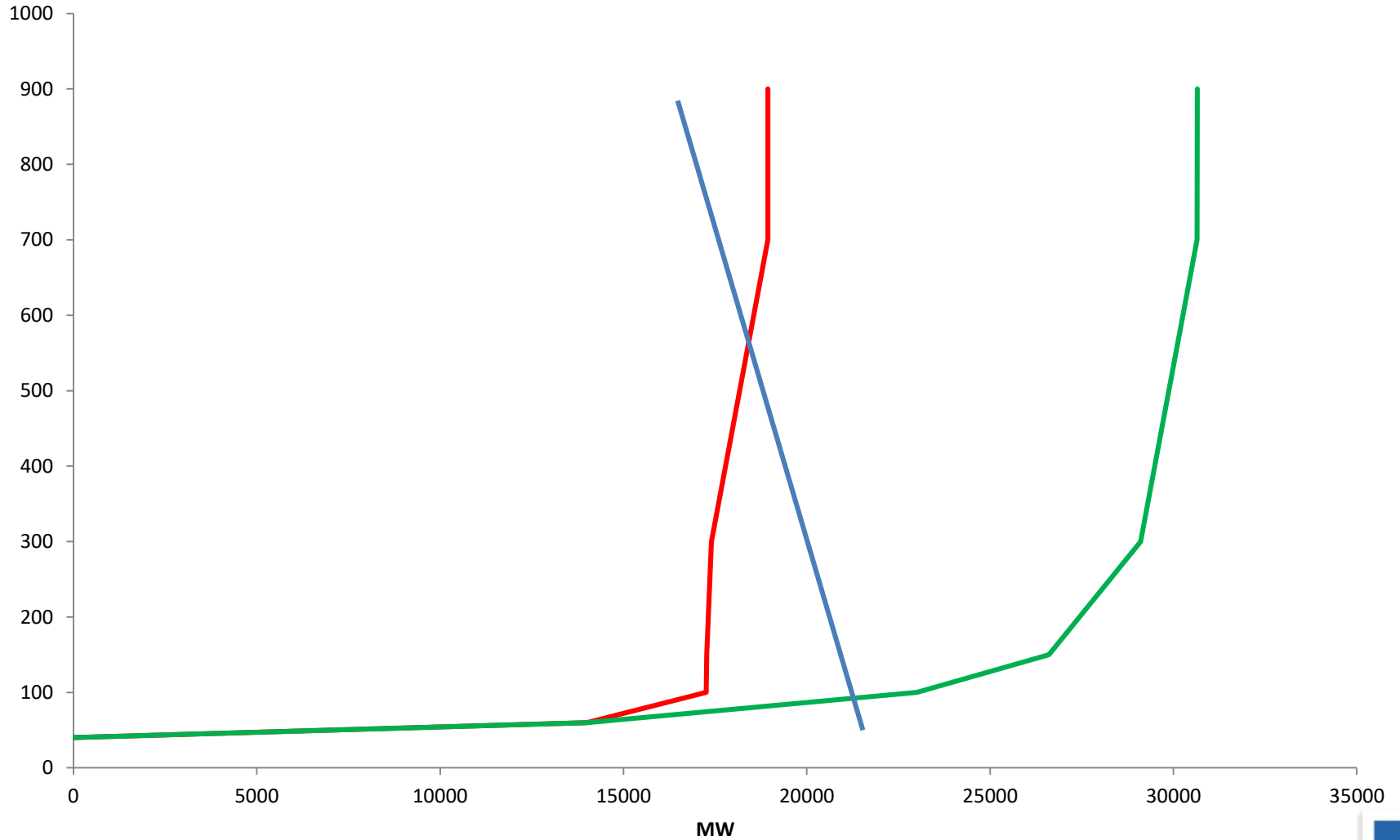
— High renewables



Electric power, supply curve

SEK/MW

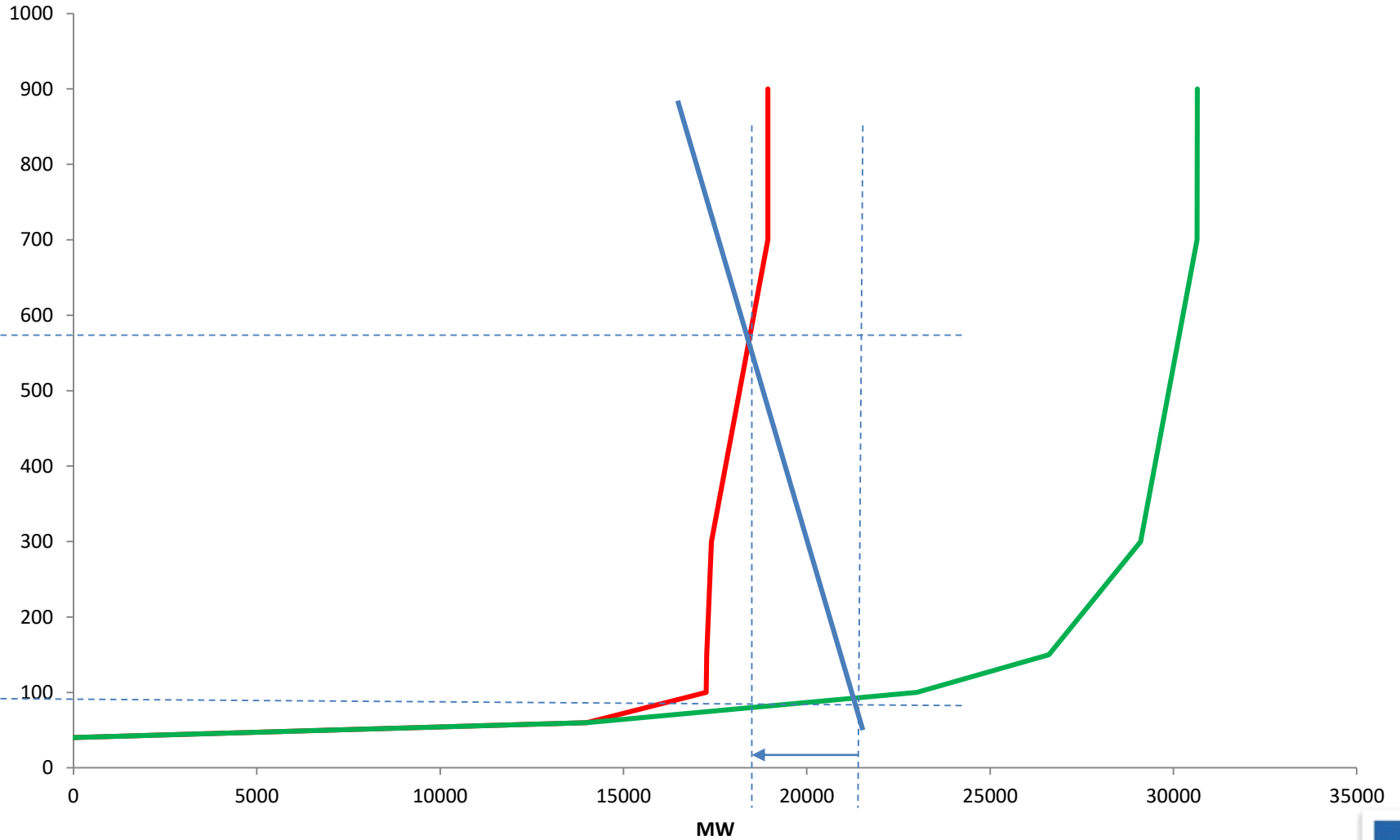
— Nuclear/CHP revision, low renewable — High renewables



Electric power, supply curve

SEK/MW

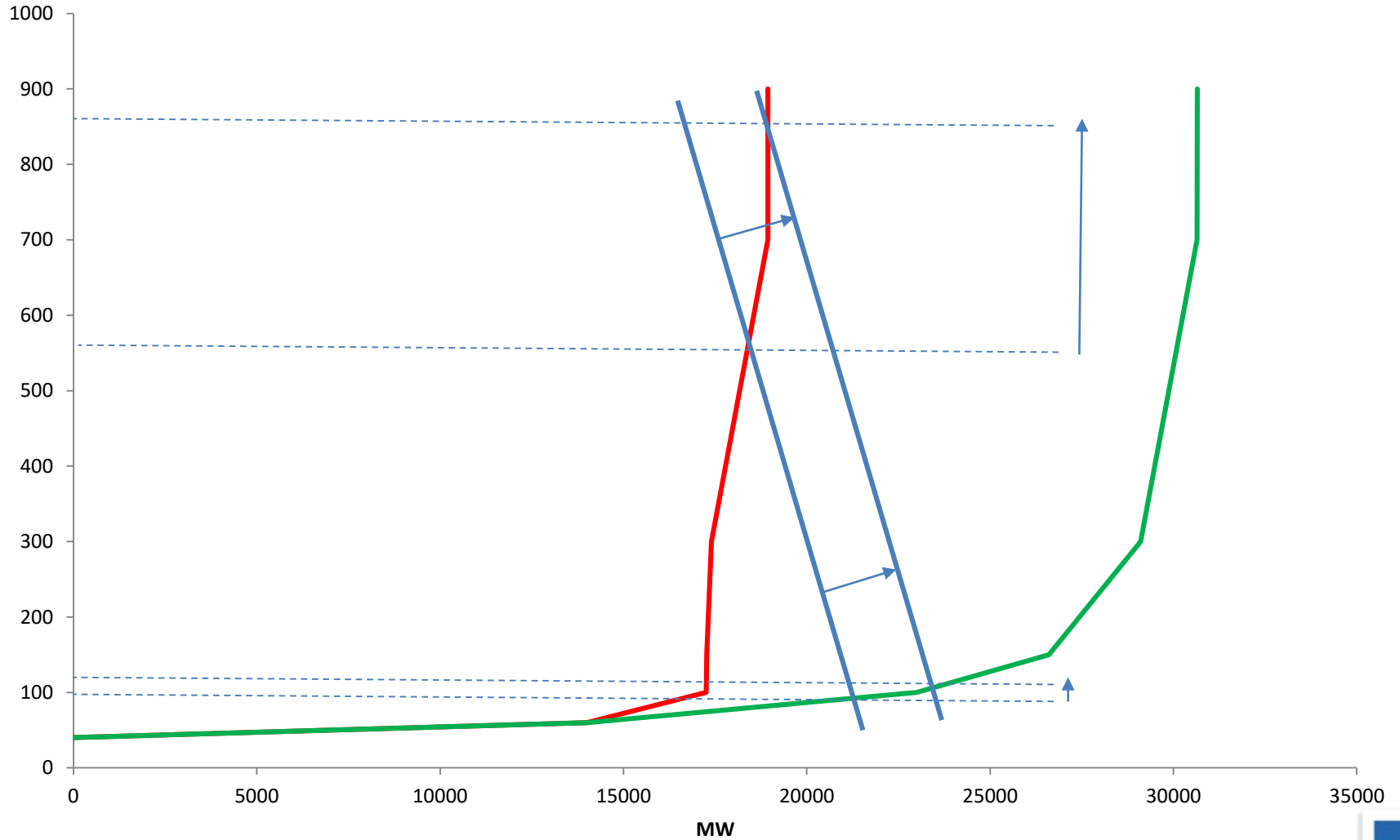
— Nuclear/CHP revision, low renewable — High renewables



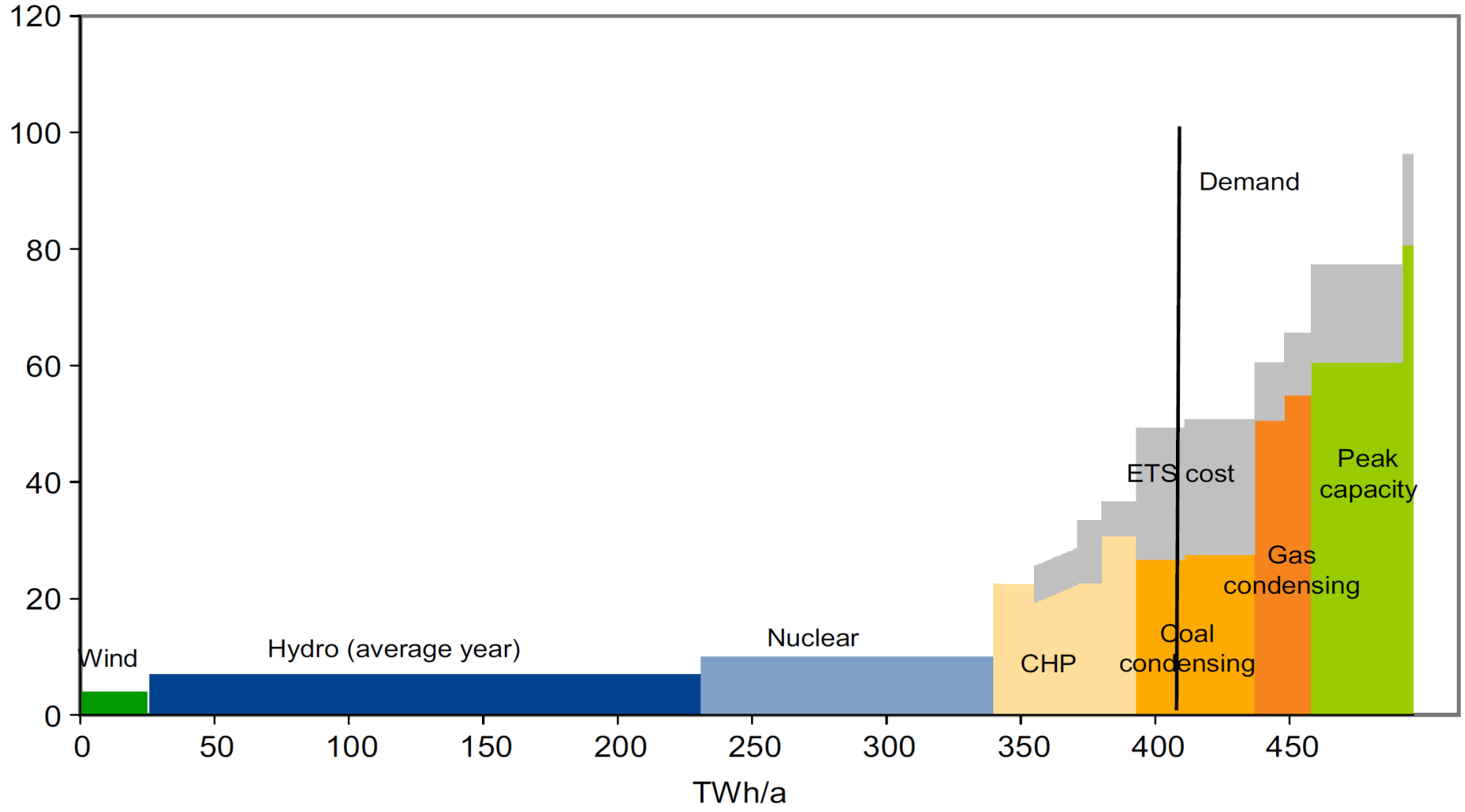
Electric power, supply curve

SEK/MW

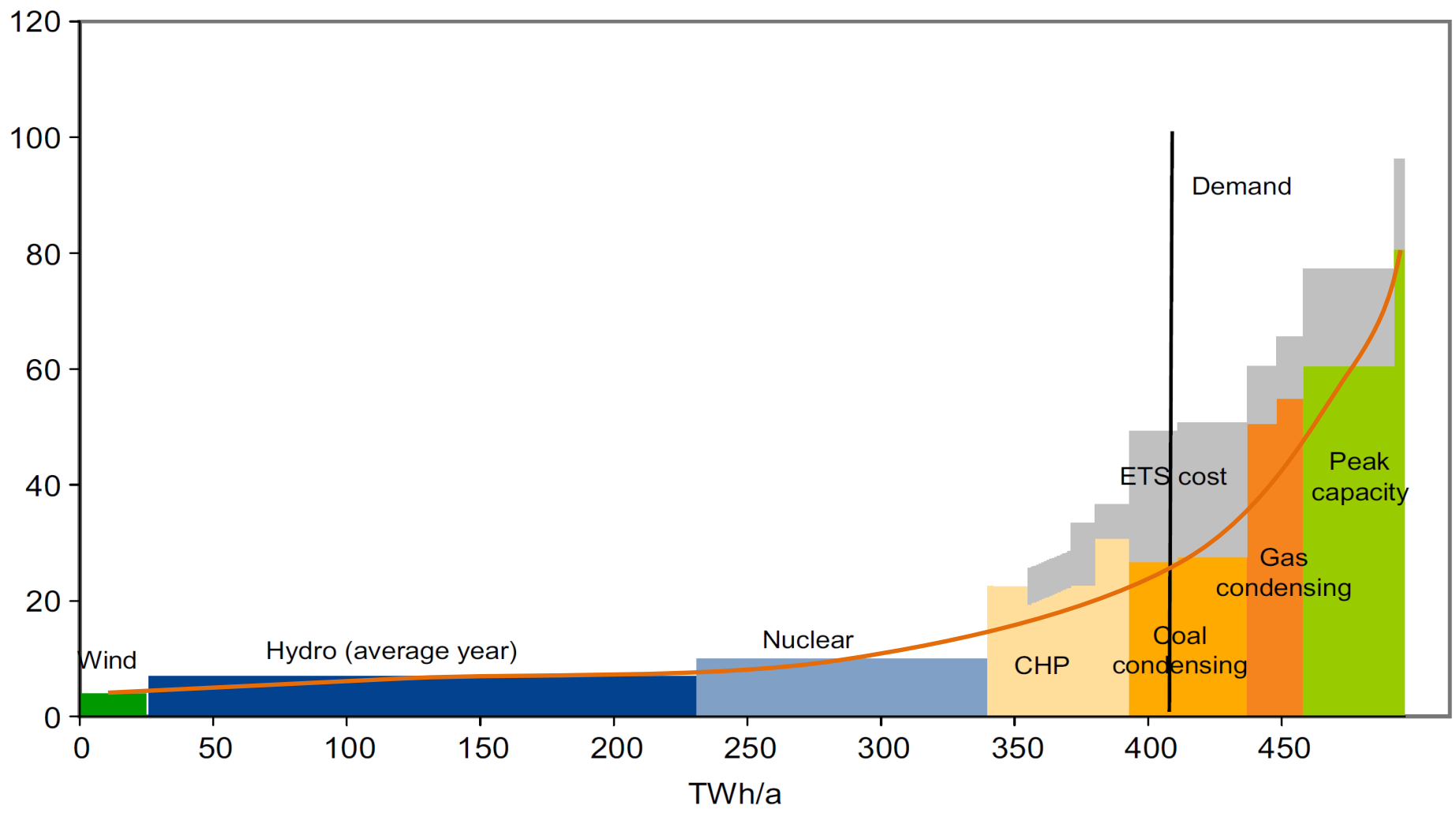
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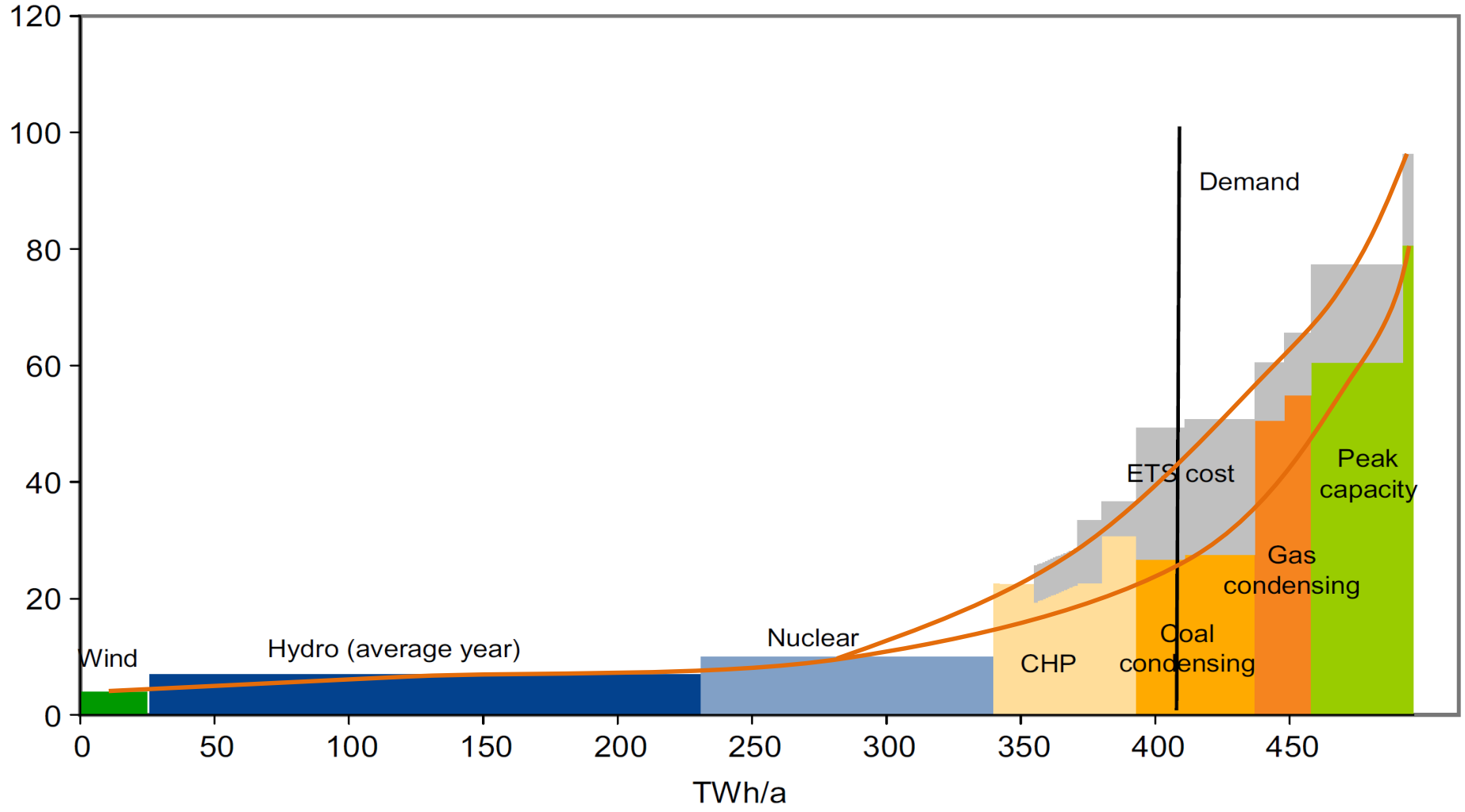
EUR/MWh



EUR/MWh



EUR/MWh

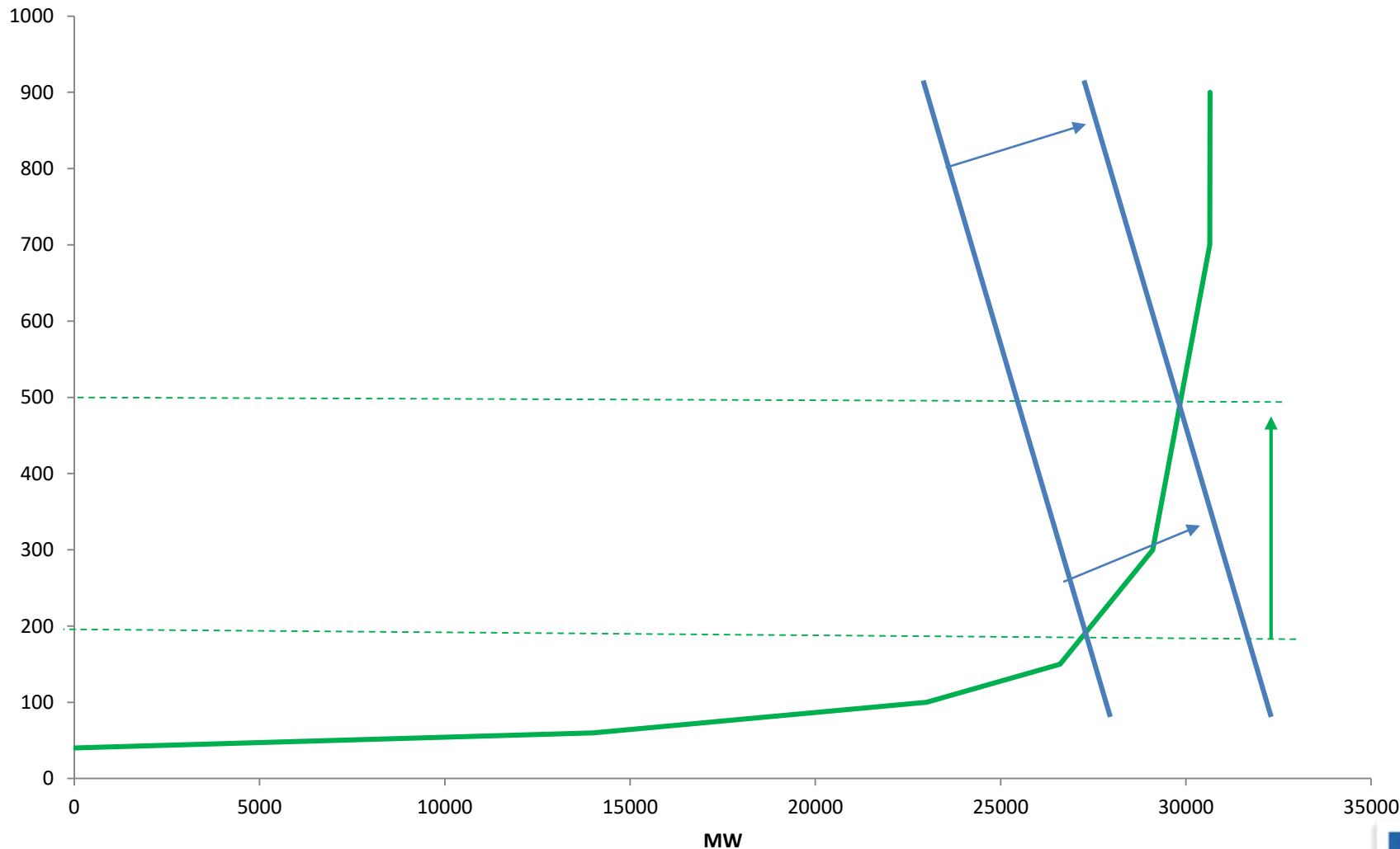


Electric power, supply curve

Influence of EU ETS on spot price

SEK/MW

— High renewables

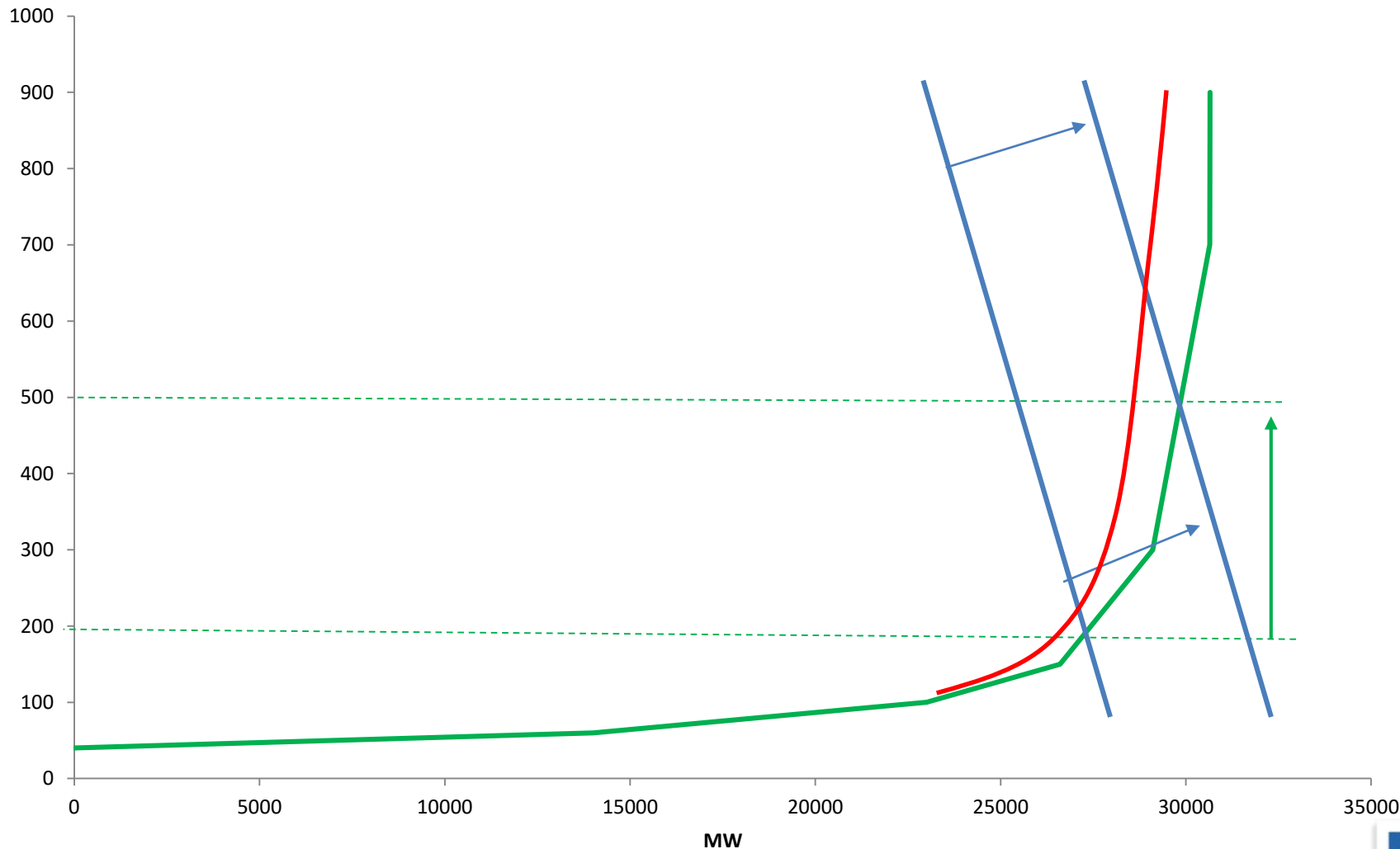


Electric power, supply curve

Influence of EU ETS on spot price

SEK/MW

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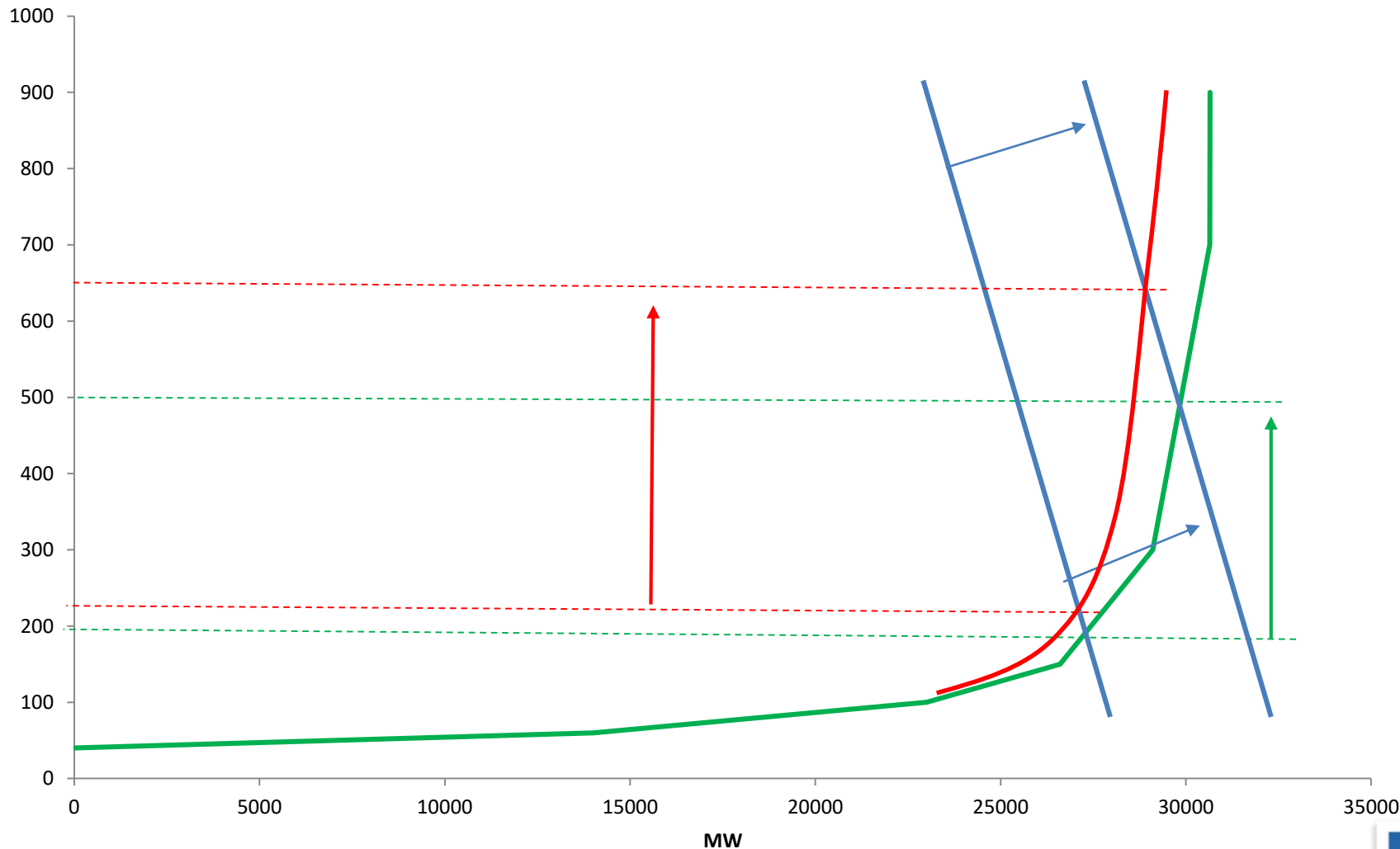


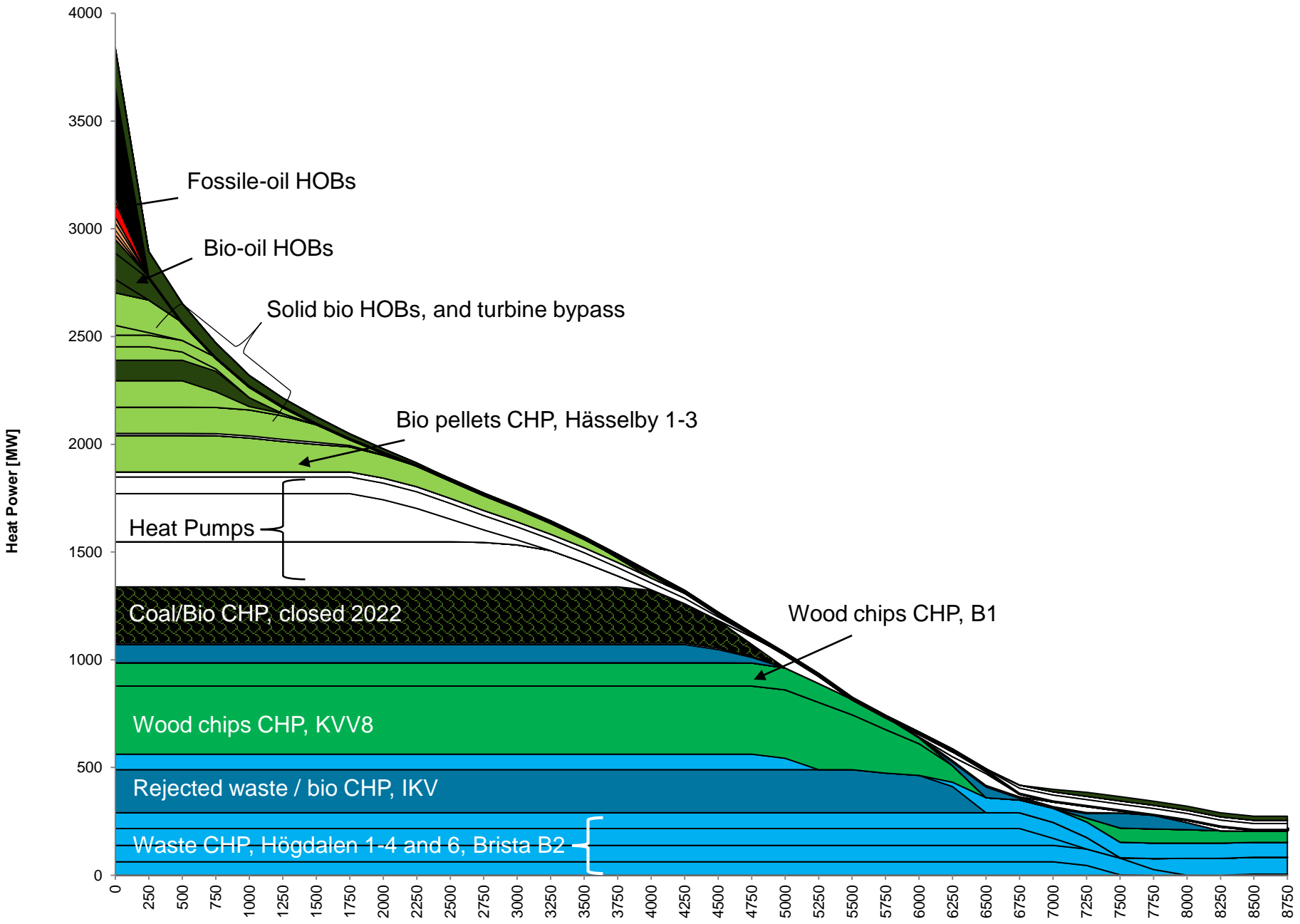
Electric power, supply curve

Influence of EU ETS on spot price

SEK/MW

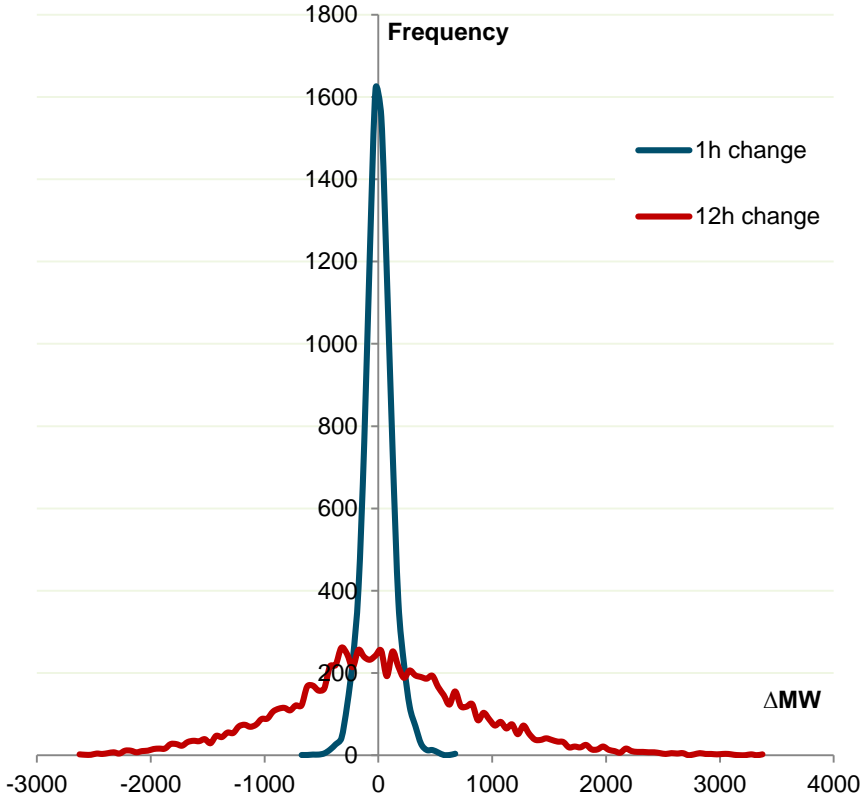
— High renewables



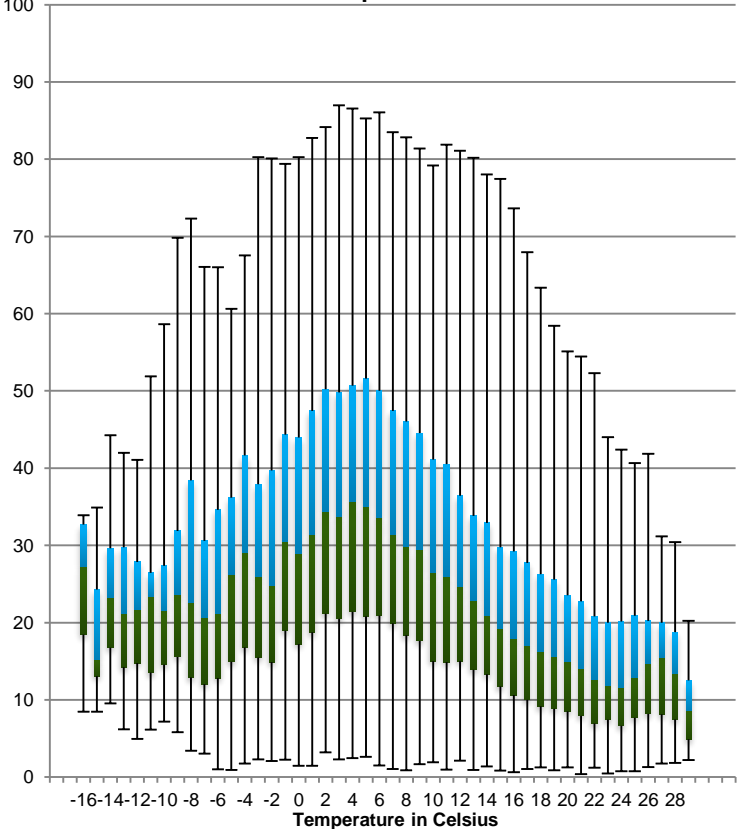


Wind power and CHP, general boundary conditions

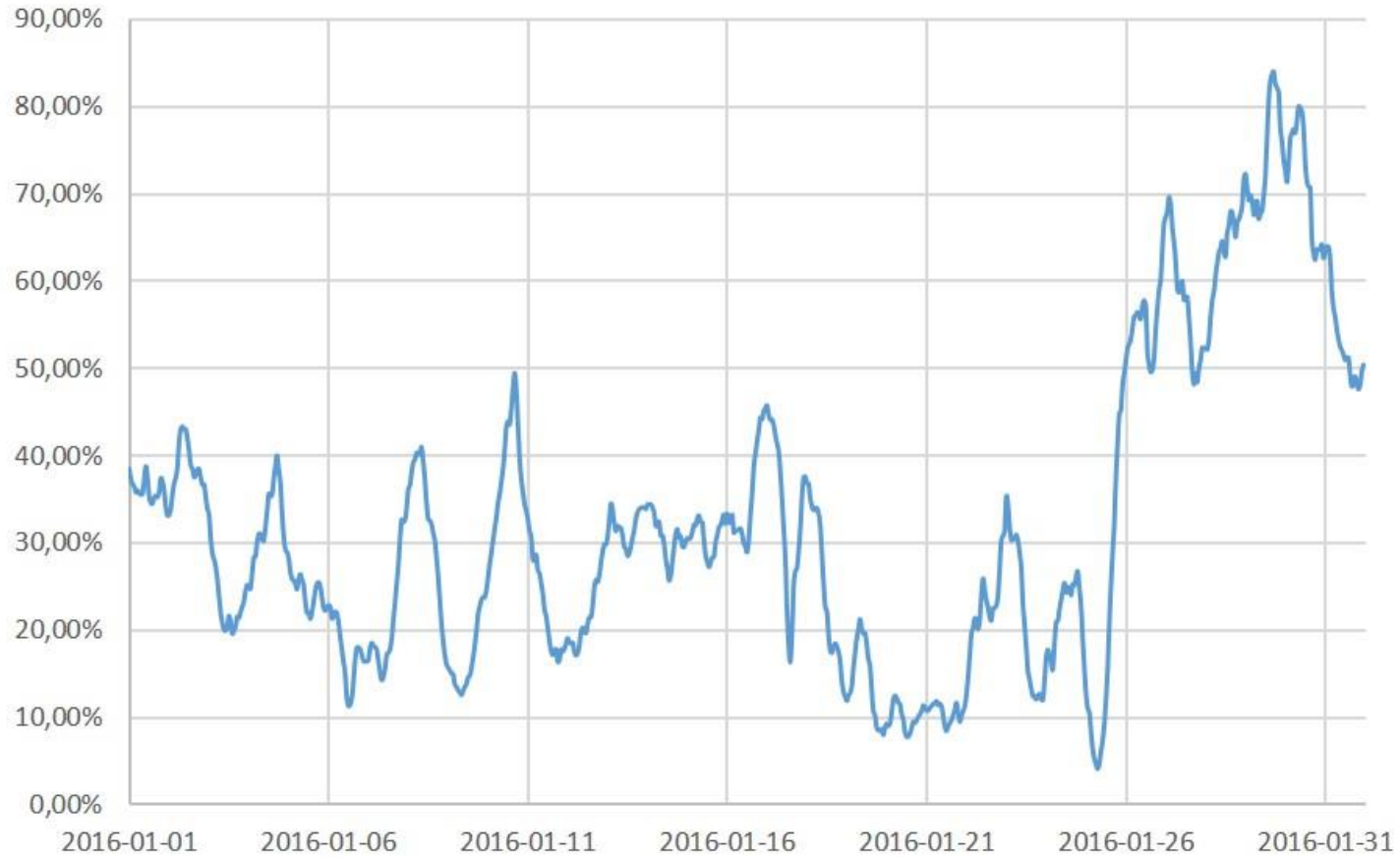
Acceleration of wind power



Share of installed capacity windpower in relation to air temperature in Stockholm



Wind power production as share of installed capacity in Sweden during January 2016

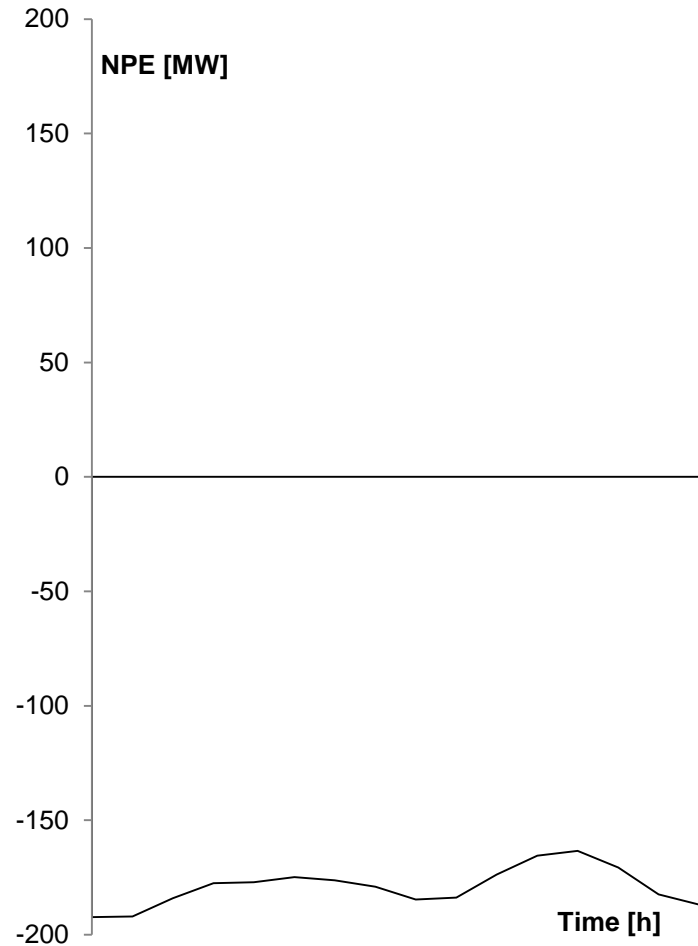


NPE – Net Power Export

NPE describes if we are a net producer or net consumer of electric power.

Theoretically, NPE in our system could range from -594 to +586 MW of electric power.

Basically, NPE is calculated by adding production to the consumption of electric power.

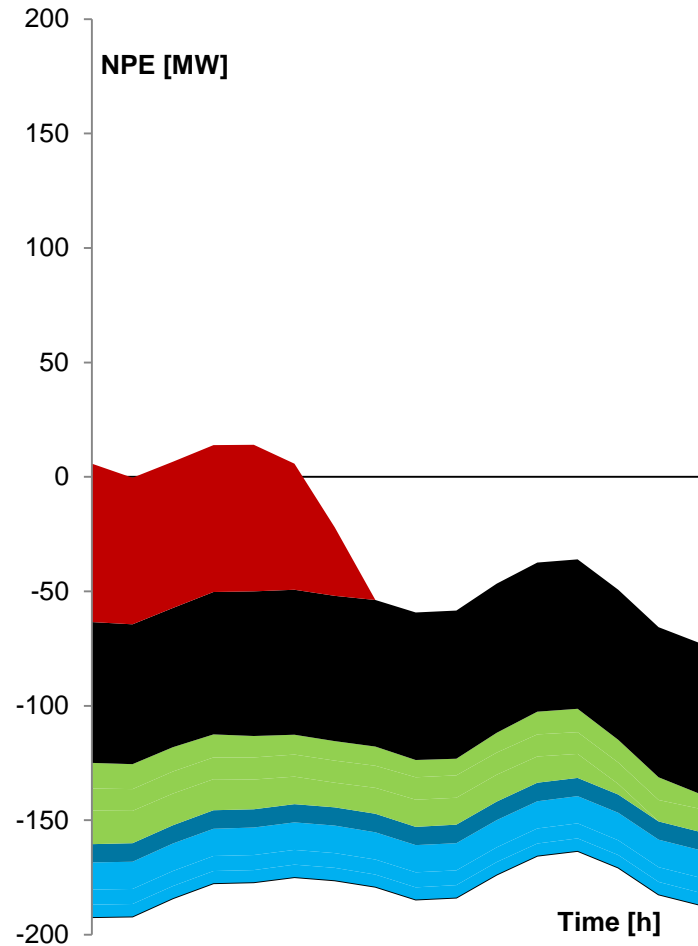


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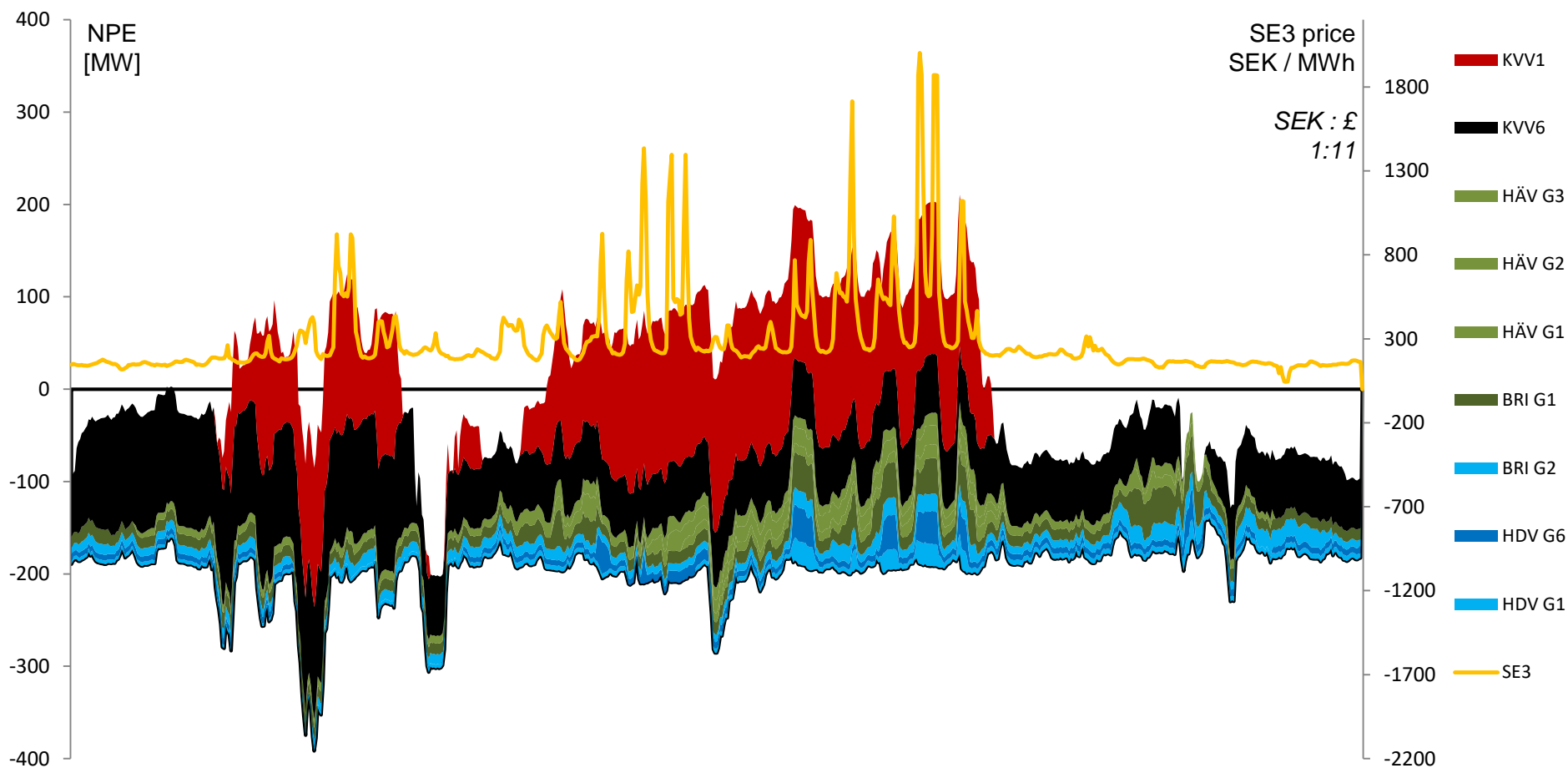
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NPE and electricity spot price during January 2016



Slutsatser

- Många faktorer talar för att lönsamheten i flexibilitet ökar i framtiden
- Kraftvärme/värmepumps combo är troligtvis väl anpassat för framtiden
- Termiska lager konkurrenskraftigt mot andra alternativ och bryter tidsberoendet mellan el och värmeproduktion/konsumtion
- MEN kan vara svårt med lönsamhet på kort sikt, även om konkurrenskraftiga alternativ är få.
- → behov av fungerande marknadsmodeller

