

Flows and Congestions in Nordic Grids in 2019

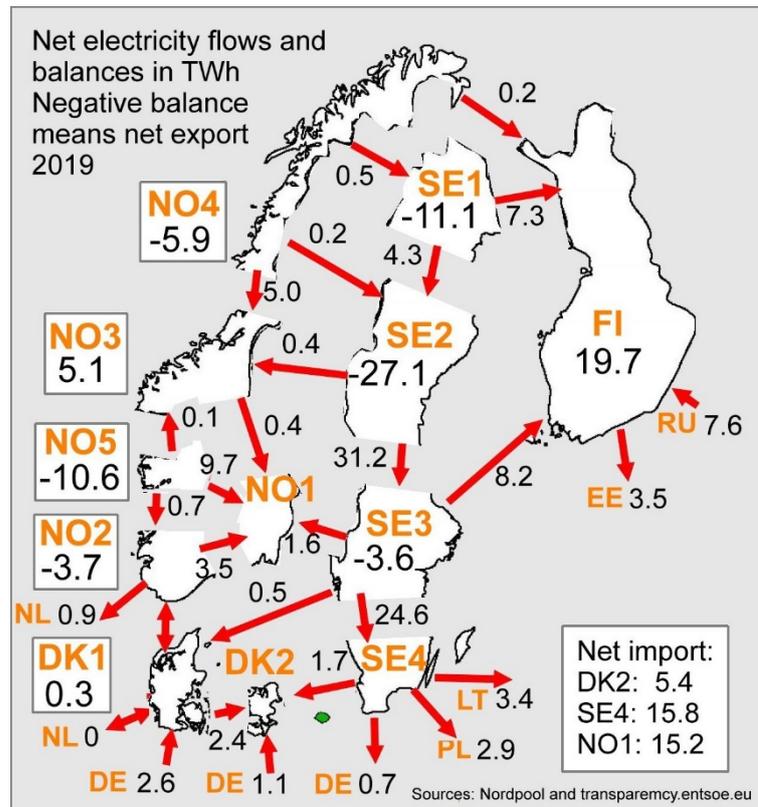


Fig. 1 - Heavy transport from north to south in Sweden

The Nordic flow pattern

The Nordic net flows of electricity in 2019 (fig. 1) are results of the following circumstances:

- Large import to Finland: 19.7 TWh
- Large import to Southern Sweden (SE4) and Eastern Denmark (DK2): 21.2 TWh
- Large surplus in Sweden (net export: 26 TWh)
- Practically zero net balance in Norway (net import: 0.15 TWh)

The main supplying areas exported the following amounts to other price zones in 2019:

- SE2: 27.1 TWh
- SE1: 11.1 TWh
- NO5: 10.6 TWh

It is the purpose of the market arrangements to optimize the dispatch of energy resources and the grid operation. The national Nordic grids have several internal bottlenecks. Keeping each nation as one price zone would require interventions (e.g. redispatch or countertrade) by the transmission system operators (TSOs). The price zones reduce the need for interventions. As a further development, NO4 is about to be divided into NO4 to the north and NO6 to the south.

SE1 and SE2 have identical day-ahead prices, so they are de facto one price zone, and the border between them cannot generate congestion fees.

24.6 TWh were transferred from SE3 to SE4 in 2019. The utilization was 53% the total congestion income was 50 mill. €, and the average congestion fee 2.01 €/MWh.



Fig. 3 - Average exchange was 53% of maximum exchange

Nordpool's Historical Market Data² offers useful hourly information. Fig. 3 shows that the commercial capacity was reduced several times, but utilized by the market to the limit in the peaks. The flow is surprisingly fluctuating, some days with variations from the zero level in the night to maximum capacity later the same day. The capacity was sold out 16% of the hours in 2019 (fig. 2).

The capacity reduction codes are particularly helpful in explaining reasons for capacity limitations, set by the TSO³ (table 4). Normal operation has the code 1010. Codes are missing for 31 March (23 hours).

	Normal	Reduced	No code	Different
	hours	hours	hours	codes
SE2 > SE3	0	8737	23	7
NO1 > NO3	0	8737	23	3
NO3 > NO1	0	8737	23	3
NO2 > DK1	1423	7314	23	10
DK1 > NO2	1586	7151	23	10
SE3 > SE4	1687	7050	23	15
SE3 > NO1	2764	5973	23	17
DK1 > SE3	3141	5596	23	13
DK2 > SE4	3166	5571	23	17
SE2 > NO3	3480	5257	23	12
NO4 > SE1	3704	5033	23	16
SE2 > NO4	4030	4707	23	9

Table 4 - Top 12 list of borders by hours with capacity reductions

The capacity at the border, SE3→SE4, was reduced for 7050 hours in 2019. Fifteen different reasons have been reported in this case (table 5). The causes of reductions can be planned outages or unexpected conditions.

Congestion problems in Sweden

According to the analyses above, the Swedish electricity market seems to serve its users reasonably well in comparison with other European markets. However, we know from other sources that the market participants are less satisfied.

The reason is that the Swedish price zones have internal bottlenecks. In 2019, Entso-e presented an alternative Nordic price zone structure⁴. The idea was to combine SE 3 and SE 4 to a larger SE 3, but with the city of Stockholm as a separate SE 4. The proposal has caused some concern in Sweden. Firstly, because there are real bottlenecks in the border area between SE 3 and SE 4, and secondly, because it might cause higher spot prices in the capital area than elsewhere in Sweden.

	What?	Where
1010	Normal operation	-
1323	Thermal limitation at border	SE3→SE4
1423	Planned outage	SE3→SE4
1433	Planned outage	SE3
1434	Planned outage	SE4
1623	Stability	SE3→SE4
1823	Increased reliability margin	SE3→SE4
2023	Reduced operational reserves	SE3→SE4
2034	Reduced operational reserves	SE4
2223	Step by step restriction	SE3→SE4
2233	Step by step restriction	SE3
2234	Step by step restriction	SE4
2523	Ramping in Elspot	SE3→SE4
2533	Thermal limitation	SE3
2534	Thermal limitation	SE4

Table 5 – SE3-SE4 – The 15 reduction codes in 2019

² <https://www.nordpoolgroup.com/historical-market-data/>

³ TSO: transmission system operator

⁴ ENTSO-E: Bidding Zone Review Region Nordic Region, 26 August 2019

There is reason to worry about the electricity supply to Stockholm. There are CHP stations with a considerable electricity production in the city, but the middle-term preservation of these stations is uncertain. Svenska Kraftnät (SKN) is therefore about to drill a tunnel below Stockholm from north to south in order to reinforce electricity supply to the city area.

There are also problems with the west-coast-corridor within SE3. An agreement between The European Commission and the Swedish TSO, Svenska Kraftnät, from 2009⁵ allowed Sweden to curtail exchanges with Norway and Denmark temporarily:

Svenska Kraftnät has argued that; unlike the other zones of congestion, congestion in the West-Coast-Corridor cannot be managed in an efficient manner through bidding zones and market splitting, because this area does not contain sufficient suitable generation resources to be able to set a market price by itself. However, SvK offered the commitment to alleviate this situation by reinforcing the West-Coast-Corridor section by building and operating a new 400 kV transmission line between Stenkullen and Strömme-Lindome by 30 November 2011.

This exception was still active in 2019. The code, 1624, was used nearly half the year:

- DK2 → SE4: 3536 hours
- SE3 → NO1: 3250 hours
- DK1 → SE3: 3264 hours

Today (3 March 2020) Jens Björn from Fortum announced in second-opinion.se⁶ that the Swedish plans for grid reinforcements are insufficient for serving the future needs of Swedish market participants.

Grid reinforcements are lagging behind

TSOs usually give security criteria a high priority in the continuous operational planning. Capacity for trading is what is left when an acceptable security level has been established. In weak grids, the result can be spot price differences and many congested hours.

The Swedish case demonstrates that severe trade barriers can occur, even when the calculated indicators seem to be reasonable.

Therefore, we cannot set general limits for the indicators, presented in this note: congestion time, congestion fees and utilization of interconnectors. However, congestion times exceeding 50% for HVAC⁷ interconnections or average bottleneck fees exceeding 10 €/MWh should be sufficient reasons for a closer examination of possible reinforcements.

It is important to find the proper balance between new fluctuating production and necessary grid reinforcements. The development of the European transmission systems have lagged behind for some years now. Improved presentations of flows and congestions may help understanding the need for a more balanced long-term planning.

⁵ https://ec.europa.eu/commission/presscorner/detail/en/IP_09_1425

⁶ <https://second-opinion.se/svks-satsningar-for-begransade/>

⁷ HVAC: high voltage alternating current

Nordic borders between price zones

Overview 2019, sorted by utilization

Import/export refers to the second part of the border name.

Borders						
2019	Import	Export	Net imp.	Max imp.	Max exp.	Utilization
	GWh	GWh	GWh	MWh/h	MWh/h	
SE3-FI	8221	57	8164	1203	1134	79%
DE-DK2	2343	1292	1051	600	585	69%
NL-DK1	650	605	46	703	681	69%
LT-SE4	278	3727	-3449	699	734	62%
PL-SE4	187	3077	-2889	597	600	62%
NL-NO2	1467	2359	-892	732	707	60%
DK2-DK1	208	2845	-2637	600	598	58%
RU-FI	7583	0	7583	1506	9	57%
SE1-FI	7592	304	7288	1577	1106	57%
SE4-SE3	77	24721	-24645	1090	5331	53%
SE3-DK1	1844	1381	463	715	720	51%
SE3-SE2	102	31351	-31249	1486	7340	49%
NO2-DK1	3285	3277	8	1533	1619	46%
EE-FI	274	3796	-3523	1016	1016	46%
SE4-DK2	3439	1712	1727	1395	1484	40%
DE-DK1	4080	1681	2399	1792	1454	37%
DE-SE4	565	1306	-741	596	611	35%
SE3-NO1	4618	3052	1566	3025	2348	29%
NO5-NO2	1354	618	736	787	490	29%
SE2-SE1	1130	5420	-4290	2206	2650	28%
SE1-NO4	818	1325	-506	840	912	27%
NO4-FI	243	55	188	144	96	24%
NO4-NO3	5061	63	4997	2525	486	23%
SE2-NO3	1588	1178	411	1574	826	20%
NO5-NO3	737	593	144	774	479	20%
SE2-NO4	186	420	-235	370	295	19%
NO5-NO1	9803	74	9730	6336	536	18%
NO3-NO1	766	345	421	773	497	16%
NO2-NO1	5110	1588	3522	7315	2350	10%

Average spot prices in northern Europe 2019

Spot prices				
2019	Average	Max	Min	St.dev.
	€/MWh	€/MWh	€/MWh	€/MWh
DE	37,68	121,46	-90,01	15,51
DK1	38,50	109,45	-48,29	13,16
DK2	39,84	109,45	-48,29	12,66
EE	45,86	200,03	0,47	15,81
FI	44,04	199,98	0,47	15,27
LT	46,12	200,03	0,12	15,82
NL	41,22	121,46	-9,02	11,25
NO1	39,29	109,45	5,86	8,34
NO2	39,27	109,45	5,86	8,23
NO3	38,54	80,75	1,38	7,87
NO4	38,31	80,75	1,38	7,56
NO5	39,27	109,45	5,86	8,27
NO6	38,54	80,75	1,38	7,87
PL	49,94	115,32	1,18	17,68
SE1	37,94	107,67	0,47	9,87
SE2	37,94	107,67	0,12	9,89
SE3	38,36	109,45	0,47	10,36
SE4	39,81	109,45	0,47	11,28

Exchanges and congestions in Scandinavia 2019

Western Denmark			Source: ENTSO-E						
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
DE-DK1	4080	5332	1681	3428	2399	1792	1454	37%	
DK2-DK1	208	1243	2845	7517	-2637	600	598	58%	
NL-DK1	650	1366	605	7394	46	703	681	20%	
NO2-DK1	3285	4625	3277	4135	8	1533	1619	46%	
SE3-DK1	1844	4422	1381	4338	463	715	720	51%	
Total	10068		9790		278				
Congested									
2019	of which import		of which export		Estimated revenue	Flow against price signals	of which import export		
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	
DE-DK1	2561	1550	1011	20	3,48	130	130	0	
DK2-DK1	1705	67	1638	5	1,80	80	29	51	
NL-DK1	4259	444	3815	4	3,53	46	33	13	
NO2-DK1	5242	2718	2524	49	7,43	251	180	71	
SE3-DK1	4369	2271	2098	17	5,13	432	270	162	
				95	4,80				
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh

Eastern Denmark			Source: ENTSO-E						
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
DK1-DK2	2845	7353	208	1407	2637	598	600	58%	
DE-DK2	2343	5345	1292	3415	1051	600	585	69%	
SE4-DK2	3439	5313	1712	3447	1727	1395	1484	40%	
Total	8627		3212		5415				
Congested									
2019	of which import		of which export		Estimated revenue	Flow against price signals	of which import export		
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	
DK1-DK2	1705	1535	170	5	1,80	80	51	29	
DE-DK2	3488	2477	1011	16	4,41	129	70	59	
SE4-DK2	2443	1717	726	19	3,66	83	38	45	
				40	3,41				
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh

Finland			Source: ENTSO-E						
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
EE-FI	274	1299	3796	7461	-3523	1016	1016	46%	
NO4-FI	243	5471	55	3289	188	144	96	24%	
RU-FI	7583	8591	0	169	7583	1506	9	57%	
SE1-FI	7592	7769	304	991	7288	1577	1106	57%	
SE3-FI	8221	8434	57	326	8164	1203	1134	79%	
Total	23913		4213		19700				
Congested									
2019	of which import		of which export		Estimated revenue	Flow against price signals	of which import export		
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	
EE-FI	957	7	950	14	3,56	9	0	9	
NO4-FI	4541	2908	1633	2	6,56	1027	405	622	
RU-FI	8752	8583	169						
SE1-FI	3335	3333	2	65	8,29	2	0	2	
SE3-FI	3102	3072	30	54	6,49	0	0	0	
				136	6,60				
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh

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Norway 1				Source: ENTSO-E					
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
NO2-NO1	5110	4664	1588	4096	3522	7315	2350	10%	
NO3-NO1	766	5427	345	3333	421	773	497	16%	
NO5-NO1	9803	8224	74	536	9730	6336	536	18%	
SE3-NO1	4618	4814	3052	3946	1566	3025	2348	29%	
Total	20298		5059		15239				
Congested									
2019	of which import		of which export		Estimated revenue	Flow again price signal		of which import export	
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	hours
NO2-NO1	162	71	91	1	0,16	9	9	0	
NO3-NO1	3414	1709	1705	0	-0,18	1454	522	932	
NO5-NO1	84	53	31	1	0,08	7	7	0	
SE3-NO1	3286	2053	1233	23	3,06	11	7	4	
Total				25	0,99				
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh

Norway 2				Source: ENTSO-E					
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
NO1-NO2	1588	2205	5110	6555	-3522	2350	7315	10%	
DK1-NO2	3279	4125	3285	4635	-6	2354	1533	32%	
NL-NO2	1467	3331	2359	5429	-892	732	707	60%	
NO5-NO2	1354	5079	618	3681	736	787	490	29%	
Total	7688		11372		-3684				
Congested									
2019	of which import		of which export		Estimated revenue	Flow again price signal		of which import export	
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	hours
NO1-NO2	162	55	107	1	0,16	9	0	9	
DK1-NO2	5256	2531	2725	49	7,42	254	70	184	
NL-NO2	7232	2784	4448	25	6,57	303	118	185	
NO5-NO2	192	103	89	0	0,07	26	26	0	
Total				75	3,94				
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh

Norway 3				Source: ENTSO-E					
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
NO4-NO3	5061	8240	63	520	4997	2525	486	23%	
NO5-NO3	737	4741	593	4019	144	774	479	20%	
NO1-NO3	345	2846	766	5914	-421	497	773	16%	
SE2-NO3	1588	4557	1178	4203	411	1574	826	20%	
Total	7731		2600		5131				
Congested									
2019	of which import		of which export		Estimated revenue	Flow again price signal		of which import export	
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	hours
NO4-NO3	667	629	38	2	0,39	29	29	0	
NO5-NO3	3427	1886	1541	-2	-1,35	2107	1434	673	
NO1-NO3	3414	1492	1922	0	-0,18	1454	932	522	
SE2-NO3	1581	911	670	6	2,27	11	0	11	
Total				6	0,61				
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh

Annex 3, p.3

Norway 4				Source: ENTSO-E					
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
NO3-NO4	63	519	5061	8241	-4997	486	2525	23%	
FI-NO4	55	2143	243	6617	-188	96	144	24%	
SE1-NO4	818	3540	1325	5220	-506	840	912	27%	
SE2-NO4	186	3617	420	5143	-235	370	295	19%	
Total	1123		7049		-5926				
Congested									
2019	of which import		of which export		Estimated revenue	Flow again price signal		of which import export	
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	hours
NO3-NO4	667	38	629	2	2	0,39	29	0	29
FI-NO4	4539	1031	3508	2	2	6,55	1023	620	403
SE1-NO4	1989	1134	855	3	3	1,35	309	261	48
SE2-NO4	1989	940	1049	1	1	1,94	234	173	61
Total				8	8	0,98			
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh

Norway 5				Source: ENTSO-E					
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
NO1-NO5	74	534	9803	8226	-9730	536	6336	18%	
NO2-NO5	618	3623	1354	5137	-736	490	787	29%	
NO3-NO5	593	4003	737	4757	-144	479	774	20%	
Total	1286		11895		-10609				
Congested									
2019	of which import		of which export		Estimated revenue	Flow again price signal		of which import export	
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	hours
NO1-NO5	84	31	53	1	1	0,08	7	0	7
NO2-NO5	192	86	106	0	0	0,07	26	0	26
NO3-NO5	3427	1533	1894	-2	-2	-1,35	2107	673	1434
				-1	-1	-0,07			
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh

Sweden 1				Source: ENTSO-E					
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
FI-SE1	304	969	7592	7791	-7288	1106	1577	57%	
NO4-SE1	1325	5064	818	3696	506	912	840	27%	
SE2-SE1	1130	2391	5420	6369	-4290	2206	2650	28%	
Total	2759		13830		-11072				
Congested									
2019	of which import		of which export		Estimated revenue	Flow again price signal		of which import export	
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	hours
FI-SE1	3338	2	3336	65	65	8,29	2	2	0
NO4-SE1	1989	760	1229	3	3	1,35	309	48	261
SE2-SE1	0	0	0	0	0	0,00	0	0	0
				68	68	4,12			
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh

Annex 3, p. 4

Sweden 2				Source: ENTSO-E					
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
NO3-SE2	1178	4195	1588	4565	-411	826	1574	20%	
NO4-SE2	420	4498	186	4262	235	295	370	19%	
SE3-SE2	102	238	31351	8522	-31249	1486	7340	49%	
SE1-SE2	5420	6327	1130	2433	4290	2650	2206	28%	
Total	7120		34255		-27135				
Congested									
2019	of which import		of which export		Estimated revenue	Flow again price signal		of which import export	
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	hours
NO3-SE2	1581	670	911	6	6	2,27	11	11	0
NO4-SE2	1989	887	1102	1	1	1,94	234	61	173
SE3-SE2	524	0	524	21	21	0,67	0	0	0
SE1-SE2	0	0	0	0	0	0,00	0	0	0
				29	29	0,69			
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh

Sweden 3				Source: ENTSO-E					
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
DK1-SE3	1381	3701	1844	5059	-463	720	715	51%	
FI-SE3	57	196	8221	8564	-8164	1134	1203	79%	
NO1-SE3	3052	3934	4618	4826	-1566	2348	3025	29%	
SE4-SE3	77	243	24721	8517	-24645	1090	5331	53%	
SE2-SE3	31351	8483	102	277	31249	7340	1486	49%	
Total	35918		39506		-3589				
Congested									
2019	of which import		of which export		Estimated revenue	Flow again price signal		of which import export	
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	hours
DK1-SE3	4373	1722	2651	17	17	5,14	431	161	270
FI-SE3	3105	0	3105	54	54	6,50	0	0	0
NO1-SE3	3286	1233	2053	23	23	3,06	11	4	7
SE4-SE3	1392	7	1385	50	50	2,01	47	2	45
SE2-SE3	524	524	0	21	21	0,67	0	0	0
				165	165	2,19			
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh

Sweden 4				Source: ENTSO-E					
Borders									
2019	Import		Export		Net imp.	Max imp.	Max exp.	Utilization	
	GWh	Hours	GWh	Hours	GWh	MWh/h	MWh/h		
DE-SE4	565	5004	1306	3756	-741	596	611	35%	
DK2-SE4	1712	3421	3439	5339	-1727	1484	1395	40%	
LT-SE4	278	1339	3727	7421	-3449	699	734	62%	
PL-SE4	187	722	3077	8038	-2889	597	600	62%	
SE3-SE4	24721	8480	77	280	24645	5331	1090	53%	
Total	27464		11626		15838				
Congested									
2019	of which import		of which export		Estimated revenue	Flow again price signal		of which import export	
	hours	hours	hours	hours	Mill. €	€/MWh	hours	hours	hours
DE-SE4	5634	2932	2702	12	12	6,58	96	49	47
DK2-SE4	2443	715	1728	19	19	3,66	83	45	38
LT-SE4	3498	98	3400	35	35	8,72	57	12	45
PL-SE4	7998	434	7564	31	31	9,35	917	107	810
SE3-SE4	1392	1382	10	50	50	2,01	47	45	2
				146	146	3,75			
Tolerance:	1,00	€/MWh					Tolerance:	1,00	€/MWh