NWE Day-Ahead Market Coupling Project

Introduction of loss factors on interconnector capacities in NWE Market Coupling

April, 2013

CONTENTS

1. Introduction

The approach in market coupling is to match supply and demand curves in each market area under constrained exchange possibilities and an overall supply/demand equilibrium constraint in order to maximize consumer and producer surplus. This results into a maximum value of aggregated consumer surplus, producer surplus and congestion rents under the constraints given. In the current NWE market coupling context (ITVC) on some interconnectors (e.g. Baltic cable and Britned) a loss factor is included in the allocation and on others not. This means that welfare loss from the losses, i.e. the costs of providing the physical difference between sending end input and receiving end output flows, is taken into account in the market coupling on these interconnectors and on others not.

This analysis reviews the inclusion of loss functionality in the allocation of capacity through market coupling and answers the questions raised by the NWE regulators concerning this issue.

Chapter 2 of this report will be addressing the welfare maximizing in market coupling and the parts of the total welfare that are included in the market coupling.

Chapter 3 describes the quantitative analysis set-up, limitations and welfare results.

Chapter 4 answers the regulators' questions on the basis of a qualitative analysis supplemented by the results of the quantitative analysis.

A detailed description of the quantitative analysis is provided in Appendix III.

Throughout this report the word "exchange" refers to the scheduled exchange of electrical energy over an interconnector unless explicitly stated otherwise. Also the word "flow" is used as an equivalent for this. Where physical flows are meant, this is mentioned explicitly.

Two different welfare concepts are used in this report: total welfare and net coupling welfare.

Net coupling welfare is defined in section 3.1.1. It is the welfare effect that is calculated from the market simulations and it includes the following welfare elements:

- consumer and producer surplus (from the PX order books) and trade income (congestion rent) from all exchanges of power between all bidding zones minus the costs of the losses on DC interconnectors that were not included in the simulation run.

Total welfare is defined in section 2.1. It includes the following welfare elements that are not accounted for in the net coupling welfare:

- Welfare losses induced by exchanges on AC interconnectors, e.g. the costs of losses over AC interconnectors
- Welfare losses induced by all exchanges on the AC network inside the bidding zones, i.e. any variable operating costs due to the exchanges like costs of AC network losses or redispatch costs.

2. Welfare maximisation in market coupling

2.1. Welfare maximisation by exchange between two markets

Let us define total welfare here as the total consumer and producer surplus plus congestion rents in all parts of the electricity market. It also includes the consumer and producer surplus caused by the provision of the grid losses including the losses over the interconnections and it includes the consumer and producer surplus in the ancillary services markets.

An exchange is defined here as the hourly energy exchange over an interconnection between two market areas.

The market coupling algorithm makes sure that all exchanges in the capacity allocation are to the level where either:

a) the modelled marginal welfare loss of the exchange is equal to the modelled marginal welfare gain of the exchange and the exchange is not using all exchange capacity (Figure 1, left side) or
b) the modelled marginal welfare loss of the exchange is smaller than the modelled marginal welfare gain of the exchange and the exchange is using all exchange capacity (Figure 1, right side)

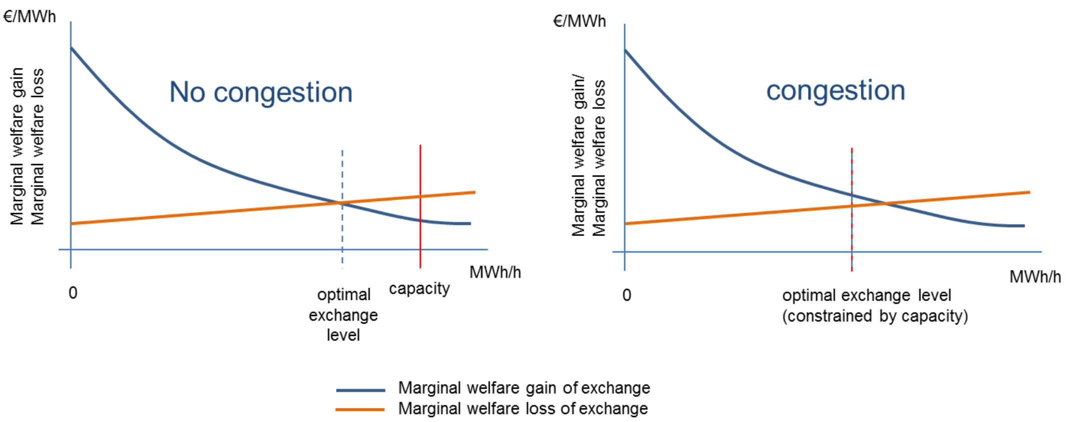

Figure 1: optimal exchange level in capacity allocation

Assuming that the modelled marginal welfare loss and gain in the market coupling are an accurate representation of the marginal total welfare loss and gain, it is known from standard economic theory that this leads to a maximum increase of total welfare by the allocated exchanges.

2.2. Modelling of welfare gains and welfare losses in market coupling

In the market coupling model the price difference between the areas on each side of the interconnection represents the marginal total welfare gain of the exchange.

The loss factor for the exchange times the lowest price on either side of the exchange represents the marginal total welfare loss of the exchange. Where no loss factor is taken into account, no marginal welfare loss of the exchange is taken into account. The next section reviews in how far this is an accurate representation of total marginal welfare loss.

Welfare distribution effects like from TSO-TSO compensation schemes or congestion income sharing are not taken into account throughout this analysis as they are assumed to have no impact on total welfare.

2.3. Welfare losses induced by exchanges on AC and DC interconnections

The marginal welfare loss that is induced by exchanges over interconnections between market areas can conceptually be divided into marginal costs by DC cable exchanges and marginal costs by exchanges over AC interconnections. The marginal costs that are induced by the exchanges can be further divided into marginal costs on the interconnections itself and marginal costs not on the interconnections (e.g. on the grid inside the interconnected areas).

For DC interconnectors the losses over the interconnector induce a marginal cost that can be approximated by a linear loss factor[1] applied to the exchange and multiplied by the lowest market price on either side of the interconnector..

For DC interconnectors, it is assumed that the marginal costs for exchange over the interconnection can be approximated based on a fixed linear loss factor on the exchange. On the other hand, DC interconnector exchanges can also induce marginal costs inside the AC networks of the connected areas.

For AC interconnectors, the relationship between the exchange and the marginal costs over the interconnector is not so clearly to be defined. This is partly due to the non-linear relationship between the AC losses over the interconnector and the exchanges. Another important reason is that the physical flow over an AC interconnector might differ from the commercial exchange over the interconnector as scheduled from market coupling, especially in case of parallel AC network paths. If the marginal costs for exchange over specific AC interconnectors can in principle be expressed by a linear loss factor, then this interconnector should be assigned the respective loss factor accordingly.

The marginal costs incurred by any interconnector exchange (AC or DC) inside the AC network of the connected bidding zones could include for example increase or decrease of internal grid losses and redispatch costs due to internal congestions. This will depend highly on the grid topology and the distribution of load and generation over the grid as well as on the number of flow paths that enable the exchange. As grid topologies are different in different market areas, interconnections generally are meshed and the grid loading pattern changes from hour to hour, the relationship between interconnector exchanges and the marginal costs incurred inside the AC network of the interconnected bidding zones is not obvious. It is assumed that the correlation between an exchange and the marginal cost of the internal grid depends on the grid topology, may include other exchanges and has a more or less random character with a bias depending on the grid topology and market scenarios. For certain topologies a multi-variate correlation may exist between the marginal cost of the internal grid and the exchanges on a set of interconnector. If this multi-variate correlation can be approximated by a linear factor on each of the interconnectors in the set, then all interconnectors in that set should have a marginal cost factor assigned (e.g. a loss factor) in order to ensure overall welfare maximization.

[1] In reality the loss factor deviates from this linear approximation depending on DC technology, power flow, voltage level etc

Marginal welfare loss element	DC interconnector exchange	AC interconnector exchange
Marginal costs on the interconnector	Approximate linear correlation - Different methods to determine correlation (loss factor)	Linear correlation? - Losses not linear to physical flow - Physical flow may deviate from scheduled flow
Marginal costs of the internal grid of a bidding zone	Marginal costs of the internal grid may have a complex correlation with the exchanges on all interconnectors, AC as well as DC. Correlation may differ, may also depend on exchanges on other interconnectors and will have a certain randomness and correlation bias (positive or negative, negligible or not) depending on the grid topology. For certain topologies a multi-variate correlation may exist with the exchanges on a set of interconnectors. If this multi-variate correlation can be approximated by a linear factor on each of the interconnectors in the set, then all interconnectors in that set should have a marginal cost factor assigned (e.g. loss factor).	

Table 1: Marginal welfare losses caused by DC and AC exchanges

Where marginal costs of the grid inside a bidding zone incurred by exchanges with other bidding zones can be higher than the marginal costs incurred on the interconnector itself, there seems no obvious economic argument for activation of only losses on the interconnector as a welfare loss in the allocation or for not including losses on only the interconnector. Vice versa, if it can be made plausible that the marginal costs of flows inside bidding zones incurred by interconnector exchanges are relatively small compared to the marginal costs on the interconnector, this seems a potential economically viable reason to activate only the losses on the interconnector as a welfare loss in the allocation. This does not depend on the kind of interconnector: it is equally applicable for a DC interconnector as well as for an AC interconnector.

2.4. Inclusion of losses in market coupling

.From ENTSO-E investigation on losses it has been concluded that the optimal way to include losses incurred by an exchange in the market coupling algorithm is to include these losses in the overall supply and demand equilibrium constraint. Appendix II describes how this should be represented in the mathematical model of the market coupling. The PCR algorithm is specified according to this model. The ENTSO-E investigation did not make any conclusions on the actual decision to apply a loss factor in the allocation.

Main conclusion from the mathematical modelling is that the price characteristics will slightly change between areas that share an interconnection with a loss factor included[2]:

price on export side <= (1-loss factor)*(price on import side)

This can be rewritten as:

loss factor <= (price on import side – price on export side)/(price on import side)

Where the right side of this inequality will be referred to in the rest of this document as remaining relative price difference.

[2] Note that this property does not hold in case of adverse flows, e.g. due to intertemporal constraints (e.g. ramping constraints, block orders selections)

3. Quantitative Analysis

3.1. Modelling, assumptions and limitations

The quantitative analysis relies on market simulations which help to support some conclusions of the study.

However the modelling relies on assumptions and has some limitations; which makes it difficult to derive direct and definite conclusions from raw numerical results.

The purpose of this chapter is to explain why numerical results should be considered carefully and to show the consequences of modelling assumptions.

Detailed quantitative results including all technical details related to modelling assumptions and limitations can be found in Appendix III.

3.1.1. Net coupling welfare

In chapter 2 of this report it was explained which aspects of the welfare can be modelled in the market coupling. The marginal total welfare gain is assumed to be adequately represented by the price difference in the market coupling. Of the marginal total welfare losses induced by the exchanges only those that are induced by losses on DC cables were included in the market simulations and respective calculations.

The welfare effect that is calculated from the simulations is:

$$consumer\ surplus + producer\ surplus$$

$$+\left\{\sum_{all\ interconnectors}\left(volume_{receiving\ end} * price_{receiving\ end}\right) - \left(volume_{sending\ end} * price_{sending\ end}\right)\right\}$$

$$-\left\{\sum_{\substack{interconnectors\ with\ (part\ of)\\ losses\ not\ included}} losses\ part\ not\ included * \min(price_{receiving\ end}, price_{sending\ end})\right\}$$

Where the producer and consumer surplus are calculated from the supply and demand curves in the order books and the market clearing prices.

This is called the net coupling welfare.

3.1.2. Gross and Net Congestion Rent

The second line of the formula in 3.1.1 represents the congestion income collected from market coupling. This part is called gross congestion rent throughout this report. Note that for interconnectors with losses included in the allocation, the difference between sending end and receiving end volumes are the losses that are included. Because the included losses are added to the system balance constraint, the impact of these losses on the producer surplus is fully taken into account. The second and third line of the formula together are called the Net Congestion Rent.

Gross congestion rents are not comparable between the runs as they contain for each run to a different extent DC cable losses that are procured within the market coupling. Only the Net Congestion Rents are comparable between the runs .

The third line of the formula in 3.1.1 refers to the costs of the losses which are not implicitly procured at the PX through a loss factor. These costs are a welfare loss that is not taken into account in the welfare as calculated by the market coupling algorithm, irrespective if these losses are procured explicitly on a PX (through a demand order) or bilaterally outside the PX (See Appendix VI –(D)).

Marginal total welfare losses induced by exchanges inside the AC network or on AC interconnectors were not included in the simulations. If in practice these would be in absolute value larger than the marginal welfare loss from the losses on the DC cables, the optimality condition for inclusion of a loss factor is not fulfilled. In this case it would not be valid to make any conclusions on total welfare effect from the Market coupling results. In the same case total welfare is likely to be decreased if loss factors on DC cables were included even if the net market coupling result would show an increase.

3.1.3. Simulations overview

Period of simulations and market data

Simulations cover full year 2011; results are available for 363 days (8712 hours)[3]. Market data are historical data from PXs order books. Network data are historical ATCs and ramping limits (except when losses apply).

Network and perimeter

The network is based on ATC interconnection (no flow-based); no tariff applied. Losses are applied only for some cables (see below). The perimeter covers the NWE bidding areas (including PL and Baltic areas).

List of Runs

No loss is applied on AC interconnectors for any run.

- Run #1 – No losses in the market coupling at all (loss factors applied in Run#3 are used to calculate external losses costs) - The output is the reference result in terms of welfare, prices and flow pattern
- Run #2 – Equal Loss Factor in the allocation on all existing DC cables (harmonized case)
- Run #3 – Individual Loss Factor in the allocation on all existing DC cables – These loss factors are assumed to be the actual loss factors which perfectly reflect the losses on the interconnectors
- Run #4 – Individual Loss Factor in the allocation on some DC cables (BritNed, IFA and Baltic)
- Run #5 – Equal Loss Factor in the allocation on some DC cables (BritNed, IFA and Baltic)

[3] The inclusion of the ramping constraint with the flow of last hour previous day made two sessions fail, so that results were available for 363 days (8712 hours) only.

For all runs the costs of the losses which are not included in the market coupling are based on the difference between the actual loss factor in Run#3 and the loss factor which is included in the current run. This is elaborated in Appendix V. under section a.

The only difference between the 5 runs is the modification of DC loss factors which are included in the algorithm. Every other characteristic (e.g. input data, algorithm parameters, network topology for each day) is identical for all runs[4].

Loss Factor Up/Down	Run #1	Run #2	Run #3	Run #4	Run #5
NorNed	0%	2%	4%	0%	0%
Storebælt	0%	2%	1.5%	0%	0%
Skagerak	0%	2%	3.8%	0%	0%
Kontek	0%	2%	2.5%	0%	0%
Kontiskan	0%	2%	2.6%	0%	0%
IFA	0%	2%	2.313%	2.313%	2%
Estlink	0%	2%	5.05% / 5.21%	0%	0%
Fennoskan	0%	2%	2.4%	0%	0%
Baltic	0%	2%	2.4%	2.4%	2%
BritNed	0%	2%	3%	3%	2%
SwePol	0%	2%	2.6%	0%	0%

Table 2: Loss Factor

3.1.4. "Sending end" versus "Receiving end": alterations of ATCs and ramping limits due to losses

Since losses result in a lower flow at the receiving end of the cable than at the sending end of the cable, two options are possible when loss factors apply:

"sending end"

- The historical ATC is considered as the sending end ATC. Therefore the receiving end ATC is lower when losses apply.

Example: Baltic 610MW at sending end results into 595MW at receiving end when a 2.4% loss factor applies.

"receiving end"

- The historical ATC is considered as the receiving end ATC. Therefore the sending end ATC is higher when losses apply.

Example: NorNed 700MW at receiving end results into 729MW at sending end when a 4% loss factor applies.

[4] Though being an input for a given day, the flow of last hour previous day through each interconnection with ramping constraint is an output of the day before and therefore can be different for each run.

The following DC interconnectors are modelled under the sending end option: Baltic, BritNed, and IFA[5].

The other DC interconnectors with losses are modelled under the receiving end option.

3.1.5. Ramping constraints

The following DC interconnectors are subject to a ramping constraint of 600MW[6]:

NorNed; Storebaelt; Skagerak; Kontek; Kontiskan; Baltic; Swepol.

3.1.6. Topology description including SE splitting

The topology of the network takes into account the splitting of SE into 4 bidding areas after Nov 1st.

Until Oct 31, the topology includes:

- SEA virtual bidding area;
- SE is a single bidding area, with one single connection to FI in production, aggregating the DC line between SE and FI and the AC interconnection between SE and FI in the north[7];

The modelling of this topology in the frame of the simulations does not exactly correspond to the historical modelling in production as regards the parallel interconnections between SE and FI. Therefore corresponding results should not be considered as historical results, even for Run#1, but only as possible results if such a configuration were implemented.

After Nov 1st, the topology has changed:

- SEA no longer exists;
- SE has been split into SE1/SE2/SE3/SE4, so that there exists one SE3-FI Fennoskan DC interconnector and one SE1-FI AC interconnector;

Therefore yearly total indicators should not be compared to production yearly totals; the indicators related to these recent bidding areas and corresponding interconnections only concerns two months of simulations (61 days; 1464 hours).

Similarly, indicators related to the "old" topology are calculated and available only for 302 days (7248 hours).

The quantitative analysis always relies on comparisons between runs; no comparison between these different topologies can be envisaged or deduced from the results and such a comparison was never seen as a possible objective of the simulations.

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[5] IFA sending end ATCs are re-calculated from mid-channel reference – see Appendix VII.
[6] Maximum variation (increase or decrease) of flow between two consecutive hours.
[7] The modelling of this configuration is implemented by means of a virtual bidding area between SE and FI – see Appendix VII.

3.2. Consequences and side effects of the modelling

3.2.1. Market data are historical order books for all runs

The modelling frame assumes that historical order books remain identical when losses apply. However it is very unlikely that market members do not take losses into account if they apply; which has the following consequences:

- Numerical results related to prices and net positions should not be considered as a forecast of the evolution of the market if losses apply
- Numerical results related to welfare indicators should not be considered as the effective evolution of welfare if losses apply

Supply curves in order books are kept unchanged for all runs; which has the following consequences[8]:

- The generators which are assumed to provide the losses in the reference case are not known, therefore cannot be modelled in the order books and were kept out of the order books in all runs
- In runs where loss factors are applied the contribution of these generators to the coupling welfare can thus not be taken into account which leads to an underestimated net coupling welfare in all runs where loss factors are applied
- A second effect of these missing generators is that there is a positive price increase bias in all runs where loss factors are applied

3.2.2. "Sending end" modelling

The modelling of some interconnectors under the "sending end" option results in an underestimation of net coupling welfare:

- The effect can be significant: an expected increase of net coupling welfare might turn into a decrease of net coupling welfare; this is observed in particular during hours when the interconnector is congested in the reference Run#1
- The reduction of receiving end ATC turns into reduced receiving end flows when the interconnector was congested without losses included

3.2.3. Calculation of loss costs

In simulation runs where the losses on DC cables are not or partially not included in the market coupling algorithm (e.g. all runs except run#3), the missing losses are assumed to be procured outside the market coupling algorithm. In order to calculate the net coupling welfare the costs of these losses must be approximated and deducted from the market coupling welfare calculated from the simulations.

[8] Please see Appendix VI for technical analysis.

The two following assumptions allow an effective assessment of loss costs for losses not included in the market coupling:

- TSOs buy the lost energy at the Market Clearing Price in the exporting side[9,10]
- The modality of losses procurement by TSOs has no impact on the formation of market prices, whatever the term (forecast and order on the market; or procurement on intra-day / balancing)

3.3. Welfare Results

Net Coupling Welfare is defined in 3.1.1. It is the difference between the Coupling Welfare which is calculated by the coupling algorithm and the External Losses Cost for the part of losses which are assumed to be procured outside the coupling mechanism. In addition, this indicator is corrected to take into account part of the side effects due to the "sending end" modelling[11]. This indicator is the quantity which reflects the effect in total economic welfare given the modelling assumptions (i.e. if the assumptions are not satisfied, then the Net Coupling Welfare does not reflect the effect in total economic welfare).

The table below shows the increase in Net Coupling Welfare for each Run compared to reference Run#1.

RUN	Net Coupling Welfare Increase (€x1000)
2	5 768
3	7 280
4	1 808
5	1 593

Table 3: Increase in Net Coupling Welfare

These variations of Net Coupling Welfare are represented in Figure 2.

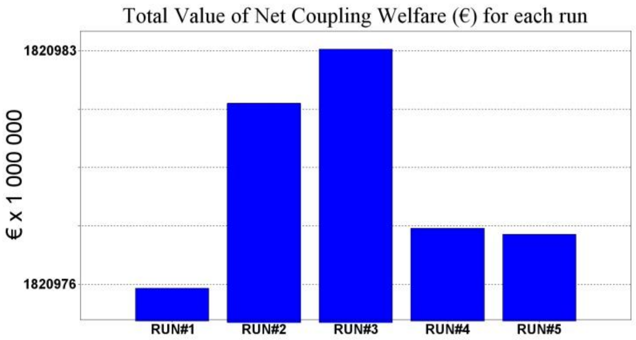


Figure 2: Total value of net coupling welfare for each run

[9] In fact at the side where the lowest market clearing price occurs. This is the export side in case of non-adverse flows, in case of adverse flows this is the import side

[10] Please see Appendix VI for a rationale for this price

[11] Please see Appendix VI for technical presentation.

Observations correspond to expectations[12]:

- Net Coupling Welfare is higher when loss factors included in the algorithm are closer to the actual value;
- Net Coupling Welfare is higher in Run#2 (all DC interconnectors with 2% loss factors included) than in Run#5 (only IFA, Baltic, BritNed with loss factor 2% included);
- Net Coupling Welfare is higher in Run#3 (all DC interconnectors with actual losses included) than in Run#4 (only IFA, Baltic, BritNed with actual losses included);
- Net Coupling Welfare difference between Run#3 and Run#1 is around € 7.3 million;

[12] Please note that this does not mean that if loss factors increase, net coupling welfare also increases

4. Answers to questions from regulators

4.1. Effects on prices and flows in the NWE region

What effects can be expected on prices and flows in the NWE region when a loss functionality is used?

4.1.1. Price/flow characteristics

From the price properties mentioned in section 2.4 the following price/flow characteristics follow:

- The loading factor (flow as percentage of the capacity) is 100% if the remaining relative price difference is larger than the loss factor
- the loading factor is up to 100% if the remaining relative price difference is equal to the loss factor
- the loading factor is 0% if the remaining relative price difference is lower than the loss factor.

The following table shows some examples of resulting loading factors as a function of remaining relative price difference and loss factor.

Remaining relative price difference	Loading factor at a loss factor of				
	N/A or 0%	1%	2%	3%	4%
0,0%	≤100%	0%	0%	0%	0%
1,0%	100%	≤100%	0%	0%	0%
2,0%	100%	100%	≤100%	0%	0%
3,0%	100%	100%	100%	≤100%	0%
4,0%	100%	100%	100%	100%	≤100%

Table 4: Examples of resulting loading factors

In this table N/A stands for not applying a loss factor which is the same as applying a loss factor of 0%.

4.1.2. Synthetic examples

The effects before and after inclusion of a loss factor are now illustrated based on the following scenarios:

A. Scenario A: the remaining relative price difference before the inclusion of the loss factor is larger than or equal the loss factor
B. Scenario B: the remaining relative price difference before the inclusion of the loss factor is positive but smaller than or equal to the loss factor
C. Scenario C: the remaining relative price difference before the inclusion of losses is zero

1. Scenario C1: with an alternative interconnection that has no loss factor applied and before the inclusion of a loss factor has unused capacity larger than or equal to the flow over the interconnector which gets a loss factor applied
2. Scenario C2: with an alternative interconnection that has no loss factor applied and before the inclusion of a loss factor has unused capacity smaller than the flow over the interconnector which gets a loss factor applied

Scenario A:

In this scenario the remaining relative price difference before the inclusion of the loss factor is larger than or equal to the loss factor.

Assuming no adverse flow and a positive loss factor, this scenario can only occur if the interconnection is congested. This means that the loading factor on the interconnection before the inclusion of the losses must have been 100%. In that case it follows from the price/flow properties that the interconnection after inclusion of the loss factor will remain congested. The loading factor will remain 100% and the prices remain the same.

An example of this scenario is illustrated below:

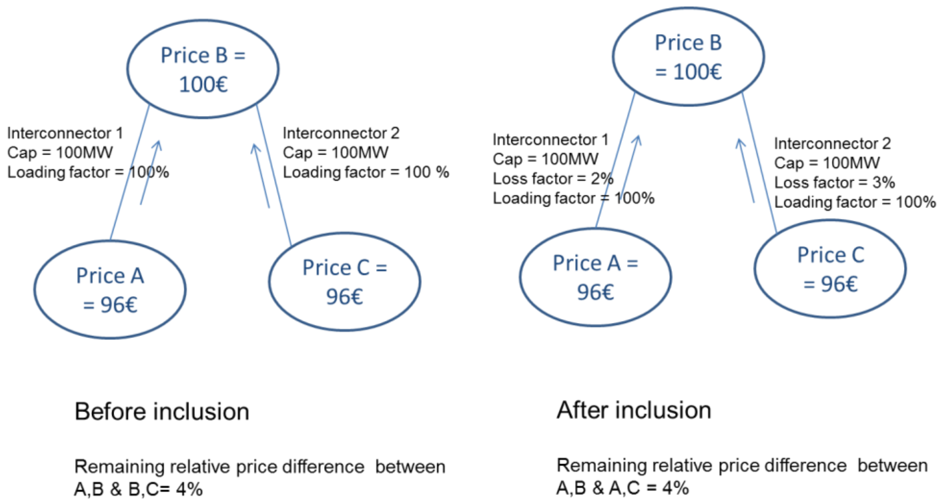


Figure 3: example of scenario A

Scenario B:

In this scenario the remaining relative price difference before the inclusion of the loss factor is positive but smaller than the loss factor.

Assuming no adverse flow and a positive loss factor, this scenario can only occur if the interconnection is congested before the inclusion of losses. This means that the loading factor on the interconnection before the inclusion of the losses must have been 100%. In this case it follows from the price/flow properties that the interconnection after inclusion of the loss factor will have a flow smaller than or equal to the available capacity. Depending on the market scenario, the interconnection may still be congested or not, but the relative remaining price difference will increase to at least the loss factor.

Two examples of this scenario are illustrated.

In the first example the market scenario does not allow for any flows over the interconnections after the loss factors are included and the resulting prices no longer converge:

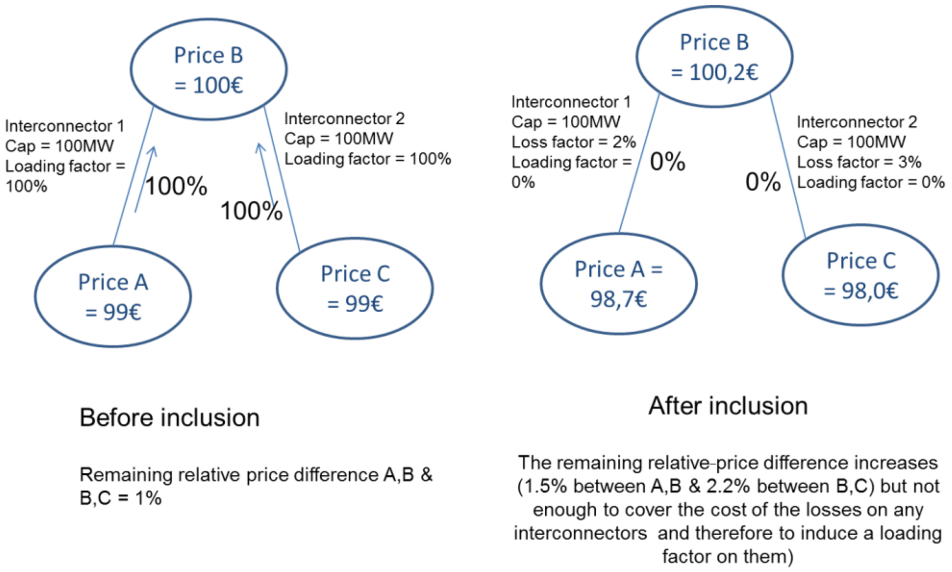


Figure 4: example 1 for scenario B

In the second example the market scenario results in a price difference that allows a flow on the interconnector with the lowest loss factor only:

Figure 5: Example 2 for scenario B

Scenario C:

In this scenario the remaining relative price difference before the inclusion of losses is zero.

In case there are no alternative interconnections the flow after inclusion of a loss factor will reduce or will (under a very specific market scenario) at most remain the same. According to the price/flow characteristics there can only be a flow if the resulting remaining relative price difference is larger than or equal to the loss factor.

In case there is an alternative interconnection two sub scenarios are identified.

Scenario C1:

In this sub scenario there is/are alternative interconnectors which have no loss factor applied and the flow over the interconnector with a loss factor before the loss factor is applied is smaller than or equal to the total unused capacity on the alternative lines. The alternative interconnectors have sufficient unused capacity to fully take over the flow from the interconnector with the loss factor. In this case total exchanged flow over all interconnectors remains the same and the prices remain unchanged. With one alternative interconnector this is illustrated in the following example:

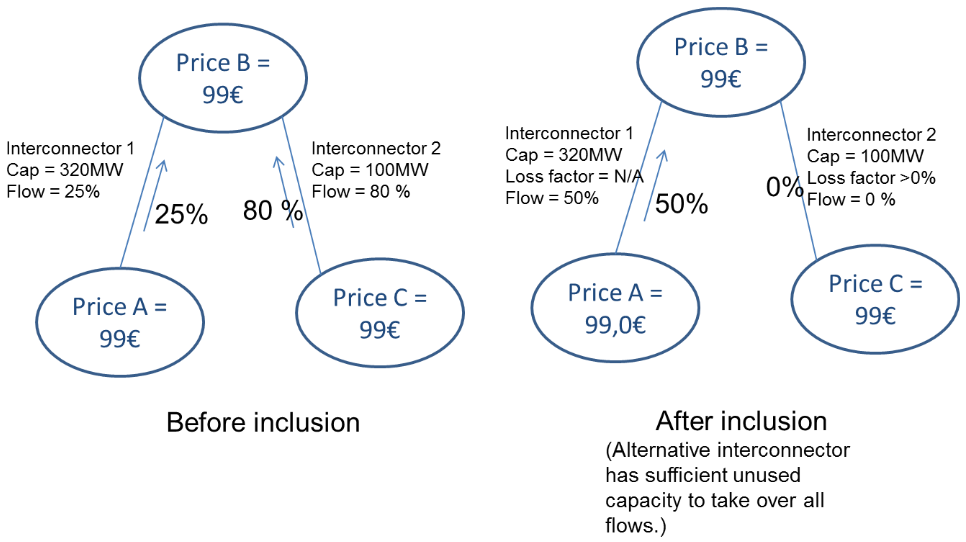


Figure 6: Example of scenario C1

Scenario C2:

In this sub scenario there is/are alternative interconnectors which have no loss factor applied and the flow over the interconnector with a loss factor before the loss factor is applied is larger than the total unused capacity on the alternative lines. The alternative interconnectors have insufficient unused capacity to fully take over the flow from the interconnector with the loss factor. This is illustrated in the following example:

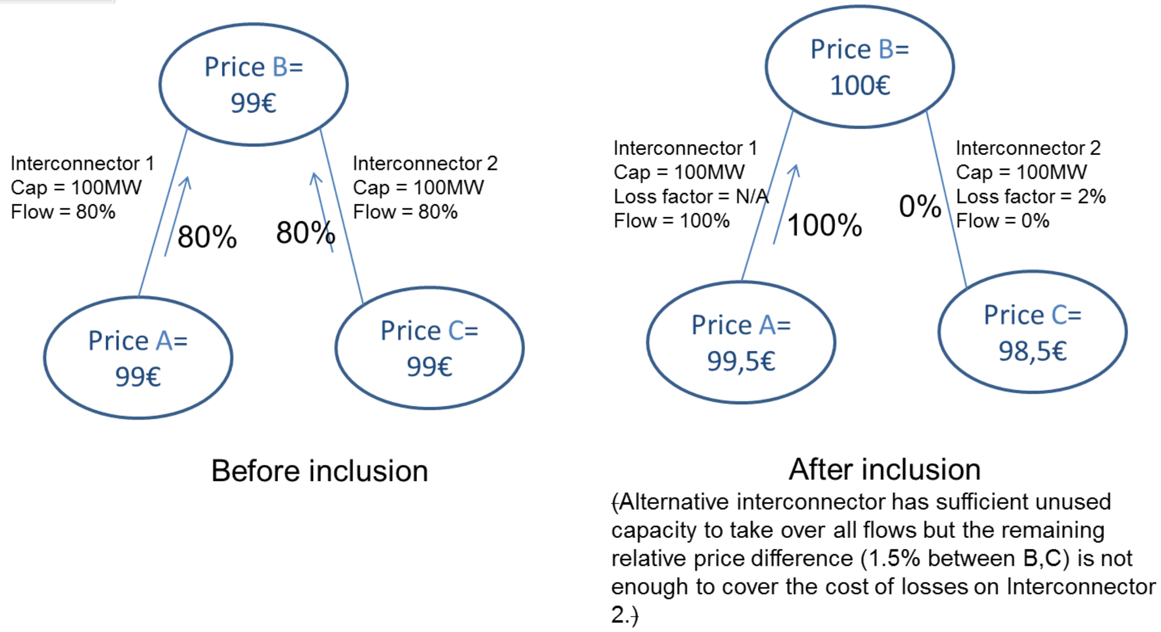


Figure 7: Example of scenario C2

4.1.3. Observed effects on prices from quantitative analysis

Table 5 shows the number of hours with equal prices in the specified regions. Note that when losses are included in the allocation price inequality is no longer equivalent to a congested situation.

Price Convergence	RUN#1 (no loss factors, reference case)	RUN#2 All DC cables with a loss factor of 2%	RUN#3 All DC cables with actual loss factors	RUN#4 Actual loss factors on IFA, Britned and Baltic only	RUN#5 As #4, but with a harmonized loss factor of 2%
#hours with CWE price convergence	5412 – 62.1%	5343 – 61.3%	5243 – 60.2%	5287 – 60.7%	5353 – 61.4%
#hours with Nordic price convergence	2262 – 26.0%	0 – 0%	0 – 0%	2178 – 25.0%	2192 – 25.2%
#hours with Baltic price convergence	7253 – 83.3%	7261 – 83.3%	7296 – 83.8%	7251 – 83.2%	7250 – 83.2%
#hours with CWE-Nordic price convergence	358 – 4.1%	0 – 0%	0 – 0%	279 – 3.2%	285 – 3.3%
#hours with CWE-GB price convergence	3070 – 35.2%	0 – 0%	0 – 0%	0 – 0%	0 – 0%
#hours with full NWE price convergence	9 – 0.1%	0 – 0%	0 – 0%	0 – 0%	0 – 0%

Table 5: Number of hours with price convergence

As expected in regions with at least one internal interconnector with a loss factor included prices can no longer converge. This is observed for the Nordic region and the NWE region as a whole. Although the CWE region does not have any internal interconnectors with a loss factor included some decrease of frequency of regional price convergence is observed due to the inclusion of a loss factor on interconnectors to neighbouring regions (UK, Nordic).

Table 6 shows the change in prices that are observed between run#3 and run#1. This difference is partly due to the inclusion of full actual loss factors on all DC interconnectors in run#3. Some positive bias on the prices is due to the fact that the unknown generator that provides the losses in the reference case (run#1) is not included in the order books when all losses on DC interconnectors are included in the market coupling (see 3.2.1). For this reason the table must be interpreted with caution, especially regarding any conclusions on the average change in prices.

Bidding area	min	1st percentile	Average	stdev	99th percentile	max
GB1/GB2	-8,49	-1,97	0,11	0,85	2,18	10,54
FR	-4,76	-1,35	0,01	0,47	1,35	3,53
BE	-4,76	-1,38	0,01	0,47	1,35	3,53
NL	-3,30	-1,68	0,07	0,66	2,01	7,14
DE	-3,81	-1,45	0,02	0,60	1,59	20,04
DK1	-7,12	-2,85	0,16	1,33	3,47	20,04
DK2	-17,07	-2,25	0,28	1,34	3,66	20,79
NO1	-3,65	-1,19	0,07	0,43	1,70	4,18
NO2	-3,65	-1,32	0,08	0,47	2,01	4,18
NO3	-2,49	-1,21	0,03	0,40	1,34	3,55
NO4	-6,03	-1,21	0,03	0,39	1,30	3,55
NO5	-3,65	-1,13	0,07	0,41	1,69	4,18
SE	-4,06	-1,40	0,04	0,48	1,49	3,55
SE1	-2,55	-1,08	-0,01	0,39	1,23	3,01
SE2	-2,55	-1,08	-0,01	0,39	1,23	3,01
SE3	-4,23	-1,84	0,12	0,70	2,37	5,64
SE4	-17,07	-2,67	-0,02	1,28	2,57	7,99
FI	-11,07	-2,19	0,02	0,87	2,45	9,02
EE	-13,61	-3,89	0,74	3,19	13,84	36,20
PL	-5,48	-1,56	0,23	0,70	2,47	5,51

Table 6: Change in prices from run#1 to run#3

From this table it can be observed that the change in prices stays in absolute sense during 98% of the time within a couple of Euros. Note that all price variations are positively biased due to exclusion of all losses providing generators from the order books.

<u>In summary the following effects can be observed from the simulations:</u>

- Price convergence in regions that have no interconnectors with loss factors included within the region is slightly reduced due to loss factors on interconnectors to or in other regions
    - Full CWE price convergence reduces from 62,1% to 60,2% at most
    - Full Nordic price convergence reduces from to 26% to 0% if all internal Nordic DC lines have a loss factor and to 25,2% at most if loss factors are only on Baltic, IFA and Britned
- prices are differently impacted per bidding area.
- price changes are positive or negative depending on hours
- price changes are small in most hours

- Some hours can show large absolute price changes (>0 or <0)
- Price convergence between bidding areas at cable ends is no longer possible except if a parallel AC route remains

4.1.4. Observed effects on flows from quantitative analysis

The following effects have been observed from the quantitative analysis:

- Flows on interconnectors with a loss factor decrease when losses are included in the coupling mechanism:

The yearly total energy exchange[13] (GWh) over the interconnectors with losses included is as follows:

Run#1	Run#2	Run#3	Run#4	Run#5
34 922	29 868	29 021	33 153	33 445

- Flow reduction can be a reduction to zero, but this is not the most frequent case: in general flows decrease but remain positive (depending on the elasticity of curves):

A duration curve of flows (MW) shows the reduction of flows in Run#3 compared to Run#1 (absolute value of receiving end flows up and down):

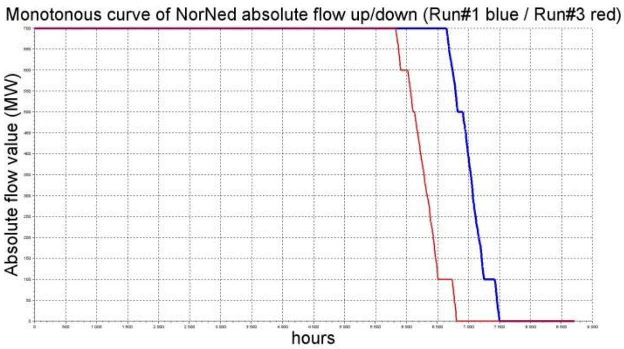


Figure 8: monotonous curve of NorNed absolute flow up/down

- Flows on interconnectors without loss factors tend to be more congested when losses are included on some other interconnectors, depending on their location in the network; this is in line with example C2 from scenario C in the qualitative analysis:

E.g. In Run#1, flow DE->NL is congested in 1190 hours for a total energy exchange of 1 991 GWh during these hours;
In Run#3, flow DE->NL is congested in 1274 hours for a total energy exchange of 2 163 GWh during these hours;

[13] Receiving end values.

- It can happen that flows on an interconnector with losses included increase in average if a merit order selection effect occurs with an interconnector with a higher loss factor also included in the coupling mechanism:

  E.g. in Run#2 the yearly total energy exchange through IFA amounts to 2 199 GWh; however it is 2 457 GWh in Run#3 whereas the loss factor in Run#3 is 2.313%, which is greater than the 2% loss factor in Run#2; This is due to a merit order effect with BritNed which has a loss factor of 3%: in Run#2, the yearly total energy exchange through BritNed amounts to 2 746 GWh; whereas it is only 2 210 GWh in Run#3.

These observations are in line with the qualitative analysis.

4.1.5. Conclusions

<u>Conclusions that can be made from both the qualitative and quantitative analysis</u>

The following conclusions can be made from the qualitative analysis and have been validated by indicators from the quantitative analysis:

- Flows and prices in the NWE region will change in all bidding zones after the inclusion of loss factors
- Total energy exchange over interconnectors with a loss factor applied generally reduce
- Generally convergence of prices on a border with a loss factor on all the interconnectors and no alternative exchange path to the other side can only be to the level where the remaining relative price difference is larger than or equal to the lowest loss factor. This may be relaxed in case of an alternative exchange path under certain market scenarios with sufficient unused capacity over the alternative path
- This conclusion applies to borders with only AC interconnectors, only DC interconnectors as well as to borders with combined AC and DC interconnectors
- Specifically on a border with only DC interconnector and no alternative paths to the other side, prices will no longer converge after loss factors are applied on all interconnectors. If there is no exchange, market scenarios on both sides of the border can then only lead to equal prices by coincidence
- Specifically on a border with both DC and AC interconnectors, no alternative paths between the areas and a loss factor applied only on the DC interconnectors, prices can still converge. This occurs in market scenarios where the capacity of the AC interconnectors alone is sufficient to have the prices fully converge: in this case there is no flow on the DC interconnector. In market scenarios where the capacity of the AC interconnectors is not sufficient for full price convergence, prices can only converge to the level where the remaining relative price difference is equal to the lowest loss factor on any of the DC interconnectors.

<u>Conclusions that can be made from the qualitative analysis only</u>

For the following conclusions, no indicators from the quantitative analysis were available to validate this. Therefore these conclusions can at this point only be qualitative:

- Change in relative remaining price differences is generally limited to the loss factor on each interconnector

- Prices and flows will not change if the lines were already congested and relative price differences were higher than loss factors. Note that this would in practice rarely happen as this can only occur in hours where all interconnectors with a loss factor in the allocation would already have been heavily congested without inclusion of a loss factor.

4.2. Inclusion of loss functionality on a subset of interconnectors

If based on your analysis you would come to such conclusion, please explain why a subset of interconnectors with a loss functionality could be welfare maximizing, compared to introducing the functionality on all cables?

4.2.1. Optimality condition for the inclusion of losses

From the welfare maximization principle described in 2.1 and the modelling aspects of the welfare as described in 2.2 and 2.3 the following optimality condition for the inclusion of losses can be derived:

Inclusion of a loss factor on any interconnector is welfare increasing if the exchange induces marginal welfare losses which are adequately represented through the loss factor and if the exchange does not induce to a larger extent (positive or negative) marginal welfare losses elsewhere in the system which cannot be captured by an adequate loss factor (or a combination of loss factors) within the allocation.

For each interconnector where the total marginal costs of an exchange are mainly caused by the losses induced by the exchange, the introduction of a loss factor would be welfare increasing if external effects can be discarded. They cannot be discarded if, due to the introduction of a loss factor flows are reallocated to parts of the grids with even higher losses as a result or with the need to increase redispatch costs to a level higher than the costs of the losses included in the allocation.

4.2.2. Synthetic examples

Two price areas are coupled by two interconnectors A and B with capacities X respectively 2*X. Before the inclusion of a loss factor on any of the interconnectors, the prices are equal under a total exchange of 2*X: X on A and X on B. Furthermore in this example a flow indeterminacy rule of 50/50 is assumed.

In the first example (Figure 9) the loss factor on interconnector 1 is α and on interconnector 2 $0{,}25\alpha$. Now if a loss factor on interconnector 1 is applied, interconnector 2 takes over all flows and the total losses go down from $1{,}25\alpha X$ to $0{,}5\alpha X$, obviously a welfare gain.

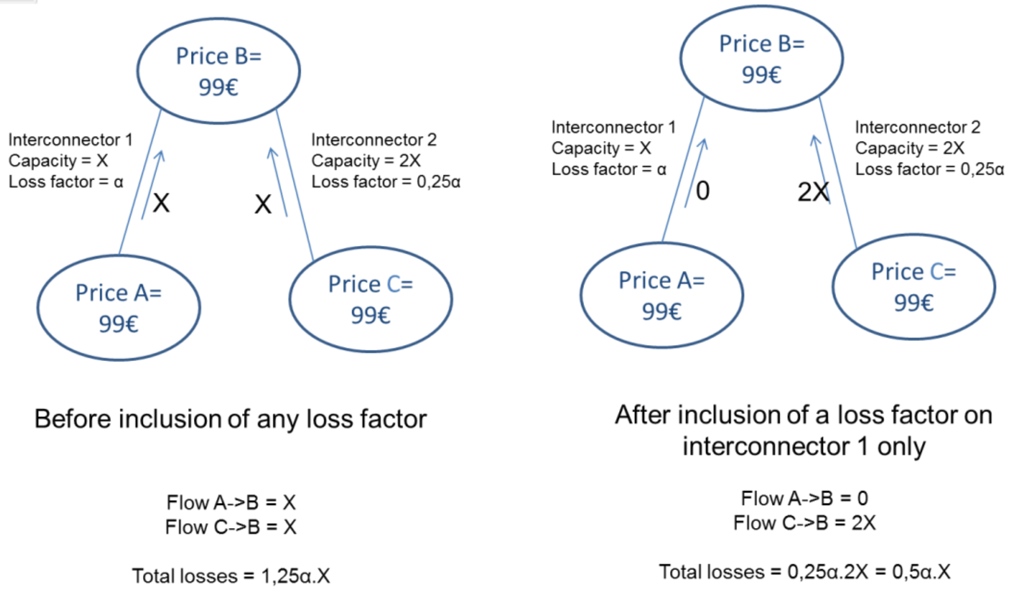


Figure 9: inclusion of losses induces lower losses elsewhere that are not included in the allocation

In the second example interconnector 2 has a higher loss factor (2α) than interconnector 1 (α) and again only the losses over interconnector 1 are included in the allocation. In this example, after the inclusion of a loss factor on only interconnector 1, the total losses increase from 1,25αX to 4αX, obviously a welfare loss (there is no welfare increase due to trade profit as the prices do not change).

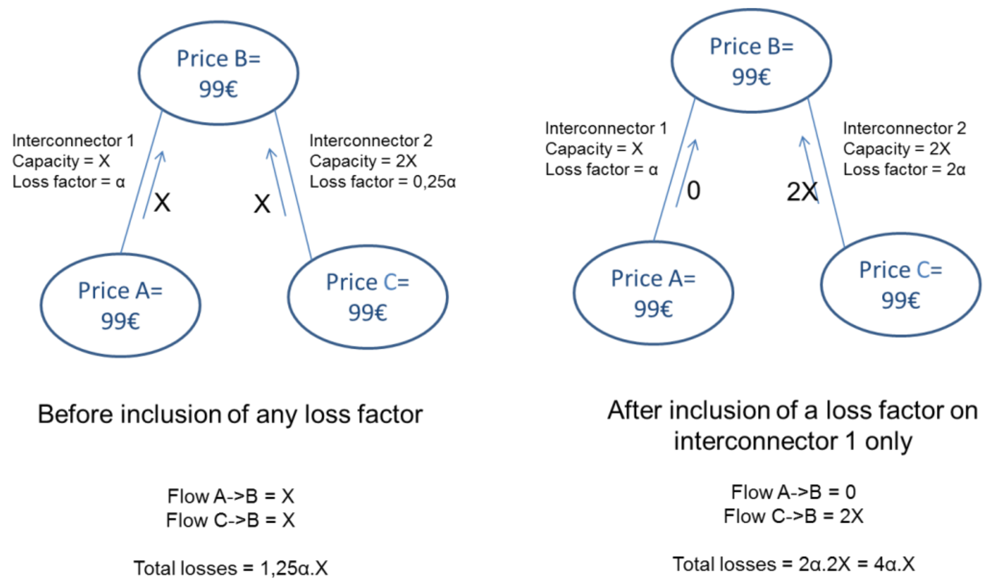


Figure 10: Inclusion of losses induces higher losses elsewhere that are not included in the allocation

The first example demonstrates a situation where the inclusion of a loss factor on a subset of interconnectors leads to a welfare gain compared to not including a loss factor on any interconnector. The second example demonstrates a situation where the inclusion of a loss factor on a subset of interconnectors leads to a welfare loss. The reason for this is the magnitude of the loss factor not included in the allocation versus the loss factor that is included. If a higher loss factor elsewhere is not included, welfare may be lost instead of gained.

4.2.3. Results from quantitative analysis

When losses are applied, a merit order effect is expected, which must result in a re-routing of flows through interconnectors with lower loss factors. This effect could cause a reduction of welfare if the routes with lower loss factors do actually have an External Losses Cost which is not included in the coupling mechanism.

Run#4 and Run#5 give examples of such a situation:

- In Run#4, losses are included only on Baltic, BritNed and IFA with the actual loss factors
- In Run#5, losses are included only on Baltic, BritNed and IFA with a harmonized loss factor of 2%

If we consider the energy exchanges between CWE and Nordic bidding areas (both directions included):

- In Run#1, 15 108 GWh are exchanged: 2 782 GWh through Baltic; 12 326 GWh through DE-DK and NL-NO2 routes
- In Run#4, 14 857 GWh are exchanged: 2 227 GWh through Baltic; 12 630 GWh through DE-DK and NL-NO2 routes
- In Run#5, 14 884 GWh are exchanged: 2 260 GWh through Baltic; 12 624 GWh through DE-DK and NL-NO2 routes

Hence we observe a re-routing effect:

- When losses are included on Baltic, total exchanges between CWE and Nordic bidding areas are reduced; exchanges on Baltic are reduced; whereas exchanges on parallel routes with lower loss factor are increased
- The re-routing effect is a partial re-routing (exchanges through Baltic are not reduced down to zero)
- The increase of exchanges on parallel routes with lower loss factors amounts to 304 GWh in Run#4 compared to Run#1; which does not compensate the reduction of exchanges on Baltic, which amounts to -555 GWh in Run#4 compared to Run#1
- The re-routing effect is stronger when the loss factor which is included is closer to the actual value (which is higher than loss factor in Run #5)

As a result of these energy exchanges, we have the following External Losses Costs:

- Routes through DE-DK and NL-NO2 interconnectors:
  Run#1: total yearly external losses cost is € 27.589 million[14]

- Routes through DE-DK and NL-NO2 interconnectors:
  Run#4: total yearly external losses cost is € 27.919 million

- Routes through DE-DK and NL-NO2 interconnectors:

[14] Throughout this report the point will be used as a decimal separator

Run#5: total yearly external losses cost is € 27.918 million

In other words, external losses costs on parallel routes with losses not included increase because of the re-routing effect when Baltic has losses included.

Note again that welfare losses due to losses on interconnectors without a loss factor included or due to increased losses or other variable operating costs in the internal grid that are not included through any loss factor are not accounted for in the net coupling welfare of the simulations.

4.2.4. Conclusions

Application of the optimality condition leads to the following conclusions.

Assuming that marginal welfare loss by exchanges can be adequately reflected by loss factors on all interconnectors:

- The total welfare always increases if the loss factor is included on a subset of interconnectors with the highest loss factors;
- The highest total welfare increase is obtained if loss factors are included on all interconnectors;
- Total welfare may decrease if an interconnector with a higher loss factor than any of the interconnectors in the subset of interconnectors that have a loss factors included is excluded from this subset;

This applies also to AC interconnectors if the marginal welfare loss of the exchange can be linearly related to the costs of the losses incurred by the exchange. This might especially occur for AC interconnectors which are the only AC interconnection between two market areas. Whether the welfare loss by the exchange over an AC interconnector can be adequately reflected by a loss factor needs to be verified by network analysis.

These conclusions are supported by the quantitative analysis in as far as the impact of marginal welfare losses (caused by exchanges) that are excluded from the market coupling can be neglected.

4.3. Effects on a border with both AC and DC interconnectors

> On a border with both AC and DC interconnectors, what would the effect of a loss functionality on the HVDC cable be on flows? And would there be any effects on prices, that are different from a purely HVDC connected border?

4.3.1. Qualitative analysis by examples

The analysis in 4.1 and 4.2 does not differentiate between AC and DC interconnectors and thus is valid for both kinds of interconnectors.

For a border between two bidding zones with both AC and DC interconnectors the following tables apply before and after the inclusion of a loss factor where it is assumed that the DC interconnectors will get a loss factor applied and the AC interconnectors not. In the tables a loss factor for the DC interconnector of 2% is assumed. The tables show the loading factors for each kind of interconnector at different remaining relevant price differences.

Loading factors before

remaining relative price difference	loss factor	
	AC N/A	DC N/A
0.0%	≤100%	≤100%
1.0%	100%	100%
2.0%	100%	100%
3.0%	100%	100%
4.0%	100%	100%

Loading factors after

remaining relative price difference	loss factor	
	AC 0%	DC 2%
0.0%	≤100%	0
1.0%	100%	0
2.0%	100%	≤100%
3.0%	100%	100%
4.0%	100%	100%

Figure 11:
Loading factors before and after inclusion of a loss factor on a DC interconnection with a loss factor of 2% on a border with both AC and DC interconnections

Basically the total flow between the areas will reduce or remains equal and prices on the AC/DC border can still converge if the allocated flow on the border does not exceed the total AC capacity.

In the following example a border with only DC interconnectors is compared to a border with combined AC and DC interconnectors and it is assumed that a loss factor is applied on only the DC interconnectors. The example assumes a pure DC border with two interconnectors and a loss factor of 1% and 2% respectively. The loss factor of the DC interconnector on the AC/DC border is assumed to be 2%.

AC and DC loading factors after

remaining relative price difference	loss factor	
	AC N/A	DC 2%
0.0%	≤100%	0
1.0%	100%	0
2.0%	100%	≤100%
3.0%	100%	100%
4.0%	100%	100%

DC loading factors after, purely DC

remaining relative price difference	loss factor	
	DC 1%	DC 2%
0.0%	0	0
1.0%	≤100%	0
2.0%	100%	≤100%
3.0%	100%	100%
4.0%	100%	100%

Figure 12:
Loading factors after inclusion of a loss factor on DC interconnections on an AC//DC border (left) compared to a purely DC border (right)

Generally prices on a border with a loss factor on all interconnectors can only converge to the lowest loss factor, unless convergence occurs by coincidence without flow. (Right table)

In case of a combined AC/DC border with a loss factor applied on only the DC interconnector the AC interconnector behaves as an interconnector with a loss factor of 0% applied. (Left table).

A border with both an AC and a DC interconnector can be seen as a particular case of loss factor merit order effects between an interconnector with losses included (here, the DC interconnector) and an interconnector with losses not included (here the AC interconnector). Such a configuration was observed between bidding zones Finland and Sweden during the first 10 months of simulations where the DC interconnector had a parallel route made of one or more AC interconnectors. This case can be generalized to a case with several parallel routes into a bidding zone where one route has an interconnector on the bidding zone border with a loss factor and the other route has an interconnector on the bidding zone border without a loss factor.

The following observations follow from the simulations:

- Flow decreases on the DC interconnector if losses are included; and increase on the AC interconnector;
- The AC interconnector is loaded before the DC interconnector; the DC interconnector is loaded only when the AC interconnector is congested;
- Prices still converge when the AC interconnector is not congested. This would not have been observed if the border would have been a purely DC interconnection and all DC interconnectors would have had a loss factor included;

In particular these effects have been observed from the simulations on the DE-DK1 and SE-FI borders. In case of DE-DK1 the increase of flows on the AC interconnector was prevented in run#2 because the harmonized loss factor on all DC interconnectors prevented any loss factor merit order effects on parallel routes into DE.

Table 7 shows the frequency of equal prices on cable ends for the different simulation runs (the basis for the frequency percentage is the total number of hours that the interconnector links the mentioned bidding areas, for each interconnector).

Interconnection	Price Convergence at Cable Ends	RUN#1	RUN#2	RUN#3	RUN#4	RUN#5
SEA-DK1A	#hours	3651	0	0	3564	3565
	%	50.37%	0.00%	0.00%	49.17%	49.19%
SE-FI	#hours	5438	3784	3790	5439	5436
	%	75.03%	52.21%	52.29%	75.04%	75.00%
DE-DK2	#hours	4828	1	1	4391	4395
	%	55.42%	0.01%	0.01%	50.40%	50.45%
DE-SE	#hours	1351	0	0	1008	1014
	%	18.64%	0.00%	0.00%	13.91%	13.99%
NO2-DK1A	#hours	3847	0	0	3817	3817
	%	44.16%	0.00%	0.00%	43.81%	43.81%
DK1-DK2	#hours	7342	2	1	7260	7267
	%	84.27%	0.02%	0.01%	83.33%	83.41%
SE-PL	#hours	1885	0	0	1861	1866
	%	26.01%	0.00%	0.00%	25.68%	25.75%
EE-FI	#hours	4325	0	0	4330	4329
	%	49.64%	0.00%	0.00%	49.70%	49.69%

Interconnection	Price Convergence at Cable Ends	RUN#1	RUN#2	RUN#3	RUN#4	RUN#5
NL-NO2	#hours	1233	0	0	1028	1030
	%	14.15%	0.00%	0.00%	11.80%	11.82%
FR-GB1	#hours	3879	0	0	0	0
	%	44.52%	0.00%	0.00%	0.00%	0.00%
NL-GB2	#hours	4225	0	0	0	0
	%	48.50%	0.00%	0.00%	0.00%	0.00%
SE3-FI	#hours	1359	979	978	1359	1358
	%	92.83%	66.87%	66.80%	92.83%	92.76%
SE4-PL	#hours	712	0	0	712	711
	%	48.63%	0.00%	0.00%	48.63%	48.57%
DE-SE4	#hours	408	0	0	207	206
	%	27.87%	0.00%	0.00%	14.14%	14.07%
DK1A-SE3	#hours	1253	0	0	1254	1253
	%	85.59%	0.00%	0.00%	85.66%	85.59%

Table 7: Frequency of price convergence at cable ends

From this table the following observations can be derived:

- Generally speaking, as expected, the application of a loss factor on an interconnector prevents price convergence at both ends of the interconnector (e.g. IFA, BritNed); even when the interconnector is not congested, a price difference remains
- Including losses on Baltic only (in addition to IFA, BritNed – Runs#4 and #5) does not prevent price convergence between Germany and Sweden, since parallel routes without losses exist
- When losses are included on all DC interconnectors (Runs#2 and #3), price convergence between SE/SE3 and FI still remains possible in the majority of hours (52% in SE-FI / 67% in SE3/FI) because the northern route is not congested; every hour that price convergence occurs, the Fennoskan interconnector is not loaded at all[15], as expected
- It rarely happens that price convergence occurs despite the application of loss factors (e.g. DE-DK2 in Run#3); this must be considered as due to coincidence instead of the effect of market convergence

4.3.3. Conclusions

The total flow on a border with both AC and DC interconnectors and a loss factor applied on only the DC interconnectors will reduce or remain equal. The magnitude of the change in flow will depend on the loss factors applied, the slope of the demand and supply curves, the interconnector capacities and the price differences.

Under certain conditions the AC interconnectors may take over flow from the DC interconnectors. This occurs when the relative remaining price differences are lower than the loss factors on the DC interconnectors and the AC interconnectors are not congested. The shift in flow (from DC to AC) may substantially influence the marginal operating costs of the impacted AC interconnectors and grid, for

[15] This does not refer to physical flows but to algorithm outputs.

example by increased exchange over alternative AC interconnectors and/or losses and dispatch costs induced in the AC grid. In this case, a loss factor on the AC interconnector may also need to be considered.

Generally area prices on each side of a border with loss factors on all the interconnectors for that border (e.g. a purely DC border with loss factors on all DC lines) can only converge to the lowest loss factor, unless convergence occurs by coincidence (no flow on the interconnectors but equal prices in the areas interconnected).

If the question is generalized to two parallel routes into a bidding zone with on one route an interconnector on the bidding zone border with a loss factor included and on the other route an interconnector on the bidding zone border without a loss factor included then a loss factor merit order effect occurs. The route with the lowest total loss factor takes over some flow from the route with a higher total loss factor (re-routing effect). This effect is countered if the total loss factor on both routes is equalized.

Specifically if one route has a DC interconnector with a loss factor included and the alternative route has at least one AC interconnector without a loss factor and if the alternative route also contains a DC interconnector and that DC interconnector has the same loss factor as the highest loss factor on the parallel route (e.g. through harmonisation of the applied loss factor), then re-routing effects do not occur but the overall exchange between the market areas will be reduced due to the loss factor applied on both routes.

4.4. Discrimination issue between DC and AC interconnectors?

> Since as today also in future losses on the AC grid shall not be considered in the welfare maximization, could introduction for DC interconnectors be a discrimination issue?

This question requires a thorough legal analysis on what should be interpreted as discrimination. This is out of scope of this analysis.

Therefore this question will be treated from an economic perspective alone. Table 1 from section 2.3 gives us the basis for this.

If exchanges on AC interconnectors – just as on DC interconnectors - clearly induce marginal welfare losses due to the operation of the AC interconnector itself (e.g. the losses only on the AC interconnectors) then there is a comparable economic effect on the welfare induced by exchange over AC interconnectors and DC interconnectors. The welfare loss due to losses over the interconnector is then not an economic argument to discriminate on inclusion of loss factors between AC and DC interconnectors. Besides the direct welfare effects on the interconnectors themselves (e.g. due to losses), the operational costs of the AC networks inside the interconnected areas may also vary with the exchanges over the interconnectors (DC and AC). If this is the case this is essentially also a welfare loss which should be included for both kind of interconnectors if feasible.

If the marginal costs induced by exchanges over AC interconnectors are always relatively small compared to the marginal costs induced by exchanges over DC interconnectors, the optimality condition for the inclusion of losses would provide an economical argument to only allow losses on DC interconnectors (in that case the DC interconnectors are a subset of interconnectors with the highest loss factors of all interconnectors).

An exception should be made where the inclusion of a loss factor on a DC cable clearly induces variable operational costs that can be related to the DC cable exchange, e.g. increased losses in the internal AC network because of alternative AC interconnections that take over the flow. If in those cases such internal losses could be modelled as a linear factor of the exchange over the alternative AC interconnection then these losses should also be included in the allocation to ensure a positive welfare effect.

4.5. System price effects

> Would the introduction of a loss functionality on DC interconnectors within the Nordic area have any detrimental effects on e.g. the System price as in the Nordic Market or CfDs?

The prices of CfDs are, as also true for PTRs and FTRs, based on the expectation of future market prices.

According to the price difference characteristic:

$$\text{export price} <= (1\text{-loss factor}) * \text{import price}$$

inclusion of a loss functionality (on any interconnector) is expected to change price differences marginally but limited to the order of magnitude of the loss factor.

This means that prices will be especially affected in areas with interconnectors where a loss factor is applied. As the price difference effects are expected to be marginal, the effects on the Nordic system price or CfD market should also be marginal.

4.6. System security effects

> Would the introduction of a loss functionality on DC interconnectors have detrimental effects in terms of system security on the neighbouring and/or whole AC grid?

Basically, a TSO is responsible to manage the grid security under all circumstances and market designs, and should have sufficient means available to do this under any likely scenario including the implementation of losses in the allocation.

The introduction of loss factors may have increasing as well as decreasing effects on the flows within and between the TSO control areas in the AC network. These effects are limited in volume to the capacity of the interconnectors concerned and only occur in situations where the markets concerned have small or no price differences before the inclusion of losses.

If the flow scenario that occurs after the introduction of the loss factor is significantly different to the situation before (e.g. if before there was always flow, relieving the local AC network and after losses introduction there is less or sometimes no flow which stressed the AC network), then the TSO has the challenge to adapt its means to the new situation. One of those means would be to make use of the interconnector concerned (e.g. in case the reduction or absence of flow stresses the grid) and change the flow on the interconnector to a scenario which no longer stresses the grid.

While introducing loss factors will lead to new load flow situations, the resulting changes will in general be covered by respective security calculations and operational planning measures. Hence, a negative impact on system security is currently not anticipated. However, TSOs will analyse existing security calculations and will adjust the operational planning measures accordingly if necessary.

As a conclusion, there should be no impact on grid security as long as the access to the physical means to manage the grid remains adequate. For example, it may be necessary for the TSOs to change their access to the means to manage the grid. The extent to which this is necessary needs to be quantified by network analysis.

4.7. Other effects

What other effects (if any) are there (positive or negative) with the introduction of a loss functionality?

The introduction of the loss functionality with different losses coefficients linked to each interconnector prevents any potential flow indeterminacies between Nordic and CWE and provides the system with a specific cable usage prioritization rule based on an economic criterion.

In case of multiple interconnectors with a loss factor between two different price areas (e.g. UK price area and CWE price area, where prices in CWE have converged) the interconnector with the lowest loss factor gets an exchange allocated first. As any exchange imposes a financial firmness risk to the interconnector operator, the interconnector operator with the lowest loss factor faces the highest firmness risk. Specifically in situations where the interconnector remains uncongested this higher financial firmness risk is not covered by congestion income.

Two other effects have been identified when loss functionality is introduced. Firstly a single regional or pan-European price will no longer be possible (equal prices can no longer be used to identify the absence of any congestion) and secondly from time to time cross-border exchanges in day ahead price coupling will be reduced on interconnections with a loss factor (and may be increased elsewhere).

4.8. Effects on intraday trading

> If a loss functionality is included for DA without doing the same for ID, what will the effects be on ID trading?

On borders with a loss factor included in day ahead allocation, the allocation may result in a remaining price difference but no congestion.

If this capacity is made available intraday, the intraday market could immediately after intraday market opening cash-out the remaining price difference by an intraday trade.

The following purely synthetic example demonstrates a worst case effect:

- Market A and B have an interconnector of 100 MW with a loss factor of 5%
- Day ahead result of market A is a price of € 100/MWh
- Day ahead result of market B is a price of € 99/MWh
- Day ahead result of the allocation is an exchange of 0 MW over the interconnector (the price difference is too small to compensate for the costs of losses)
- There is an intraday buy order posted in market A of 100 MWh/h @ € 99,90/MWh, just out of day ahead merit
- There is a just out of day ahead merit order supplier in market B that has 100 MWh/h available at € 99,40/MWh.

If the unused day ahead capacity is made available for the intraday market, the market B supplier could immediately hit the intraday buy order in market A of 100 MWh/h at € 99,90/MWh and earn 100*(99,90-99,40) = € 50.

- The resulting intraday exchange would be 100 MWh from market B to market A
- The losses incurred are 5 MWh which would cost the interconnector operator at least € 99,40 /MWh = € 497
- The total welfare effect from this intraday trade would be: +50 – 497 = -€ 447

However, if no loss factor would have been included in the day ahead allocation, the result from the day ahead allocation would have been the same:

100* (99,90-99,40) – 5%.100*99,40 = -€ 447

As a conclusion: in the worst case a positive day ahead welfare effect from inclusion of a loss factor can be reduced by intraday trade if the intraday trading mechanism does not take the loss factor into account but it cannot lead to a negative net welfare effect over both markets. For the worst case to occur the DC interconnector which was not used to "carry" DA flow, must be completely utilised for ID trade.

The absence of gaming effects that shift within merit liquidity from day-ahead to intraday markets is a prerequisite for this conclusion. Intraday capacity is allocated on many borders with a free capacity as of today. Collusion or market power would be necessary to the extent that DA prices on both sides are influenced to equalize prices in DA allocation and use the unused capacity for free in intraday. The same is true if a loss factor is applied be it that prices then only need to be influenced to the extent that price differences in day ahead allocation remain below the loss factor threshold. In theory this may become a bit easier than betting on equal prices.

Vice versa, if the positive effect on the losses of an intraday trade in a direction decreasing the day ahead flow (this would decrease the losses) is not taken into account this may prevent intraday transactions that would have been efficient otherwise.

As a second conclusion: if a loss factor is included in day ahead allocation it should also be included in intraday allocation to maximize the welfare gain. This is why NWE TSOs have requested the inclusion of a loss factor functionality in the intraday allocation mechanism. Without any prejudice to the actual decision to apply a loss factor.

4.9. Implications for the long term market

What would be implications of a loss functionality for the long term market and its products (PTRs, FTRs, CfDs)?

With the introduction of a loss factor it is expected that both the local market price and the regional system price will marginally change. As the price of PTRs, FTRs and CfDs are related to expected market prices, this can only have a marginal effect on the prices for these products.

For PTRs and FTRs there is a second aspect related to the introduction of a loss factor. As prices will no longer fully converge the expected prices of these products could slightly increase. On the other hand, the issuing party (generally a TSO) of the PTR/FTR has a slightly increased financial risk: he would always have to pay out the remaining relative price difference if the definition of the long-term products remained unchanged.

Depending on the long term product, introduction of a loss factor could therefore require a different implementation. As a general principle[16]:

- For PTRs: the nomination right needs to be redefined taking the loss factor into account: the option to nominate includes an obligation to nominate on import and export side in such a way that the difference is always equal to the losses incurred
- For unused PTRs and for FTRs: the right to collect the price difference between the markets concerned has to be defined in such a way that the costs of the losses incurred are not paid out to avoid a welfare transfer between the TSOs on one hand (e.g. the consumers through the tariffs) and the PTR/FTR holder on the other hand. This welfare transfer would be equal to the costs of the losses. Alternatively a minimum price is introduced in the auctioning of these products to cater for the fact

[16] These principles are already applied today on interconnectors where losses are included in an explicit allocation

that there are market results possible with no flow (and thus no congestion income) but a remaining price difference

There are however many implementation aspects which go beyond the scope of this analysis which would need to be studied further. In first glance, the price for the PTRs and FTRs should rise slightly for interconnectors where a loss factor is introduced as there will generally be a relative remaining price difference to be paid out (adverse flows and coincidental situations excepted). This increased price could compensate to some extent for the higher financial risk incurred.

4.10. Important further issues

Please raise any further issues you consider important in your analysis

Regulators have expressed a preference for a harmonized approach to determine the loss factor.

For DC cables in NWE today, different approaches exist to determine the loss factor. Basically there are three variants:

1) The loss factor is based on measurements
2) The loss factor is based on manufacturers specifications
3) A combination of 1) and 2)

And within these variants different methods are applied to find the best fitting linear loss factor. For example for variant 1) the best fit at maximum flow, the best fit at most frequent flow or the best fit at average flow can be used.

The development of a harmonized approach seems appropriate as the (level of the) loss factor could influence the business case of the interconnector, e.g. by the financial firmness risk profile and through other variable operating costs. Therefore NWE TSOs will further consider how this should be solved.

Appendix I - Marginal welfare gain by exchange between markets

Generally the welfare gain in an isolated market is expressed as the consumer surplus plus the producer surplus that is reached at the equilibrium between market demand and market supply. In this equilibrium, consumers are willing to pay for a volume which exactly equals the volume that producers are willing to supply and the price consumers are willing to pay for additional supply is exactly equal to the price for which producers are willing to supply additional demand.

In two coupled markets additional welfare gain can be reached by exchanging energy from the lower priced market to the higher priced market. The figure below shows that with a marginal increase of the exchange the welfare increases marginally with the price difference between the markets.

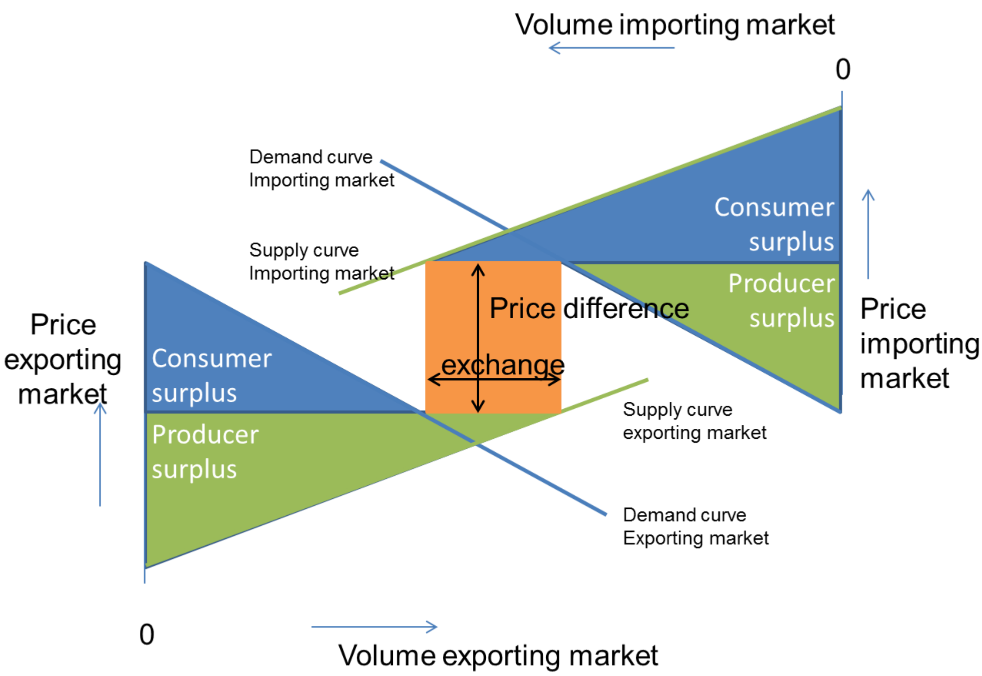


Figure 13: marginal welfare gain by exchange is equal to the price difference

Appendix II - Mathematical Modelling

We express mathematically what market coupling optimizes (the so-called objective function) and what the relevant constraints for inclusion of losses are. For simplicity, we assume two markets and one hour only.

Let:

$D_i(d)$: Demand price in market i for demand volume d

$S_i(s)$: Demand price in market i for supply volume s

$cap_{i,j}^{DC}$: maximum importflow of DC cable between market i and market j

$\alpha_{i,j}^{DC}$: lossfactor on DC cable between market i and market j as a fraction of the exportflow send at side i

$imp_{i,j}^{DC}$: import flow received at side i from DC cable between market i and market j

$exp_{i,j}^{DC}$: export flow send at side i from DC cable between market i and market j

Then the optimization problem for efficient allocation of capacity, including the implicit procurement of losses is:

Objective:

$$\max_{d_i, s_i, imp_{i,j}^{DC}, exp_{i,j}^{DC}} \sum_i \left\{ \int_{d=0}^{d_i} D_i(d) - \int_{s=0}^{s_i} S_i(s) \right\}$$

Subject to:

(1) Capacity constraints: Import flows must not exceed capacity:

$$0 \le imp_{i,j}^{DC} \le cap_{i,j}^{DC}, \qquad \forall_{i,j}$$

(2) DC line balancing constraint: Import flows on side i are equal to exportflows on side j minus the losses:

$$imp_{i,j}^{DC} = \left(1 - \alpha_{j,i}^{DC}\right) * exp_{j,i}^{DC}, \qquad \forall_{i,j}$$

(3) Bidding zone balancing constraints. For each bidding zone, matched supply minus matched demand must equal sum of export flows minus import flows on all DC cables from/to the bidding zone:

$$s_i - d_i = \sum_j \left(exp_{i,j}^{DC} - imp_{i,j}^{DC}\right), \qquad \forall_i$$

(4) System balancing constraint. Sum of matched supplies must equal sum of matched demands plus all losses:

$$\sum_i s_i = \sum_i d_i + \sum_{i,j} \alpha_{i,j}^{DC} * exp_{i,j}^{DC}$$

Constraint (4) is in fact redundant because it is automatically fulfilled if (3) is satisfied for all bidding zones. Constraints (2) and (3) together make:

(5)

$$s_i - d_i = \sum_j \left(exp_{i,j}^{DC} - \left(1 - \alpha_{j,i}^{DC}\right) * exp_{j,i}^{DC}\right), \qquad \forall_i$$

All the rest of the constraints in the mathematical model are in principle unchanged and not handled here.

AII.1. Price properties

As a consequence of the adjusted balancing constraints (5), the price properties of the coupled markets change. From the Kuhn-Tucker conditions (these are the mathematical conditions for an optimal solution to any optimization problem) it can be proven that for an efficient allocation the relative price difference between the coupled markets is at least equal to the loss factor:

price on export side <= (1-loss factor)*(price on import side).

This can also be explained in a more intuitive way: an additional trade including the costs of the losses is profitable for the trader if and only if the trade profit minus the costs of the losses is profitable.

With a marginal export δV (assuming non-adverse flows, i.e. the price on the importing side is larger than on the export side), a price π_i on the import-side and a price π_j on the export side, marginal welfare gain is:

$$\left(\pi_i - \pi_j\right) * \delta V$$

And the marginal losses are:

$$\alpha_{j,i}^{DC} * \delta V$$

As the marginal losses are the volume that does not arrive at the import side, the sales income on the import side is reduced with:

$$\pi_i * \alpha_{j,i}^{DC} * \delta V$$

Which is the marginal welfare loss of the exchange. Now the condition for a positive welfare is that the marginal welfare gain is larger than or equal to the marginal losses:

$$\left(\pi_i - \pi_j\right) * \delta V \geq \pi_i * \alpha_{j,i}^{DC} * \delta V$$

If there is no congestion on the line then the flow (and thus the welfare) will increase until this condition becomes equality:

$$\left(\pi_i - \pi_j\right) * \delta V = \pi_i * \alpha_{j,}^{DC} * \delta V$$

Which is equivalent to:

(6)

$$\pi_j = \left(1 - \alpha_{j,i}^{DC}\right) * \pi_i$$

In other words, prices will converge until the cable is congested or until the remaining price difference exactly compensates the costs of the losses incurred, whichever comes first.

In this paper we refer to the remaining relative price difference as :

$$\frac{\pi_i - \pi_j}{\pi_i}$$

Appendix III - Detailed Quantitative Results

Quantitative results were calculated with a release candidate 3 of the PCR algorithm which might be a different algorithm version from the version which will be used in production from the NWE go-live.
Because of this and because of the assumptions and limitations which are listed in chapter 3, any numerical result should be considered with caution.
Numerical results must be understood with the following usual units: prices are in Euro (€) (unless million € is indicated); flows are in Megawatts (MW); energy is in Megawatt-hour (MWh) or Gig watt-hour (GWh); indicators which are homogeneous to prices (such as welfare indicators) are in Euro (€); non-dimensional indicators (such as the number of hours that an event occurs) do not have any unit. Absolute variations of an indicator (and associated statistical indicators) have the same unit as the indicator; relative variations are non-dimensional and have no unit.

AIII.1. Welfare Results

AIII.1.1. Welfare Indicators

Welfare indicators are the following:

- Producer and Consumer Surplus
- External Losses Cost; loss factors applied in Run#3 are the reference loss factors for the assessment of External Losses Cost; it accounts for losses which are procured explicitly out of the coupling mechanism
- Net Congestion Rent; it is calculated as the difference between energy purchase at the exporting side and energy sales at the importing side; from which the external losses cost is subtracted

Net Congestion Rent = (energy sales – energy purchase) – External Losses Cost

- The term (energy sales – energy purchase) is called gross congestion rent and contains the cost of losses which are implicitly purchased through the coupling mechanism when loss factors are included
- Coupling Welfare; it is the welfare which is optimized in the algorithm; only losses included in the algorithm are taken into account; external losses costs are not subject to this optimization process:

Coupling Welfare = Producer Surplus + Consumer Surplus + gross congestion rent

- Net Coupling Welfare; it is the difference between the Coupling Welfare and the External Losses Cost:

Net Coupling Welfare = Coupling Welfare – External Losses Cost
= Producer Surplus + Consumer Surplus + Net Congestion Rent

In addition, this indicator is corrected to take into account part of the side effects due to the "sending end" modeling[17]; this indicator is the quantity which best reflects the total economic welfare given the modeling assumptions (i.e. if the assumptions are not satisfied, then the Net Coupling Welfare does not reflect the total economic welfare);

17 Please see Appendix VI for technical presentation.

Each of these indicators is defined in Euro (€). Any figure related to these indicators must be understood as a quantity in Euro (€).

AIII.1.2. Expected Results

The following results are expected for each day in the simulation data set:

(a) The closer to the actual value the loss factors included in the algorithm are, the greater the Net Coupling Welfare is;
(b) The closer to the actual value the loss factors included in the algorithm are, the lower the External Losses Cost is;
(c) The greater the loss factors are, the lower the Coupling Welfare is;

The observations below show that these expectations are confirmed on a yearly basis. In addition expectations (b) and (c) are verified for each day: they are inherent to the modeling.

However expectation (a) is not satisfied for some days. The causes of these unexpected results are analyzed in Appendix VIII (modeling limitations and flow indeterminacy solving are the main reasons).

AIII.1.3. Overview of Welfare Results- Yearly Totals

The **yearly totals**[18] for welfare indicators (in Euro - €) are in the table below.

RUN	Producer Surplus	Consumer Surplus	Net Congestion Rent	External Losses Cost	Coupling Welfare	Net Coupling Welfare
1	665 871 349 591	1 154 543 666 654	561 095 087	49 616 853	1 821 025 728 184	1 820 **976 111 331**
2	665 890 947 427	1 154 516 094 837	573 814 804	15 503 539	1 820 996 360 607	1 820 **981 879 178**
3	665 900 350 887	1 154 504 815 569	576 928 597	0	1 820 982 095 052	1 820 **983 391 330**
4	665 873 519 394	1 154 537 567 166	565 535 760	38 255 870	1 821 014 878 190	1 820 **977 918 868**
5	665 873 910 639	1 154 537 944 169	564 827 211	40 448 040	1 821 017 130 059	1 820 **977 704 148**

Table 8: Yearly totals for welfare indicators

[18] Results are available over 363 days only.

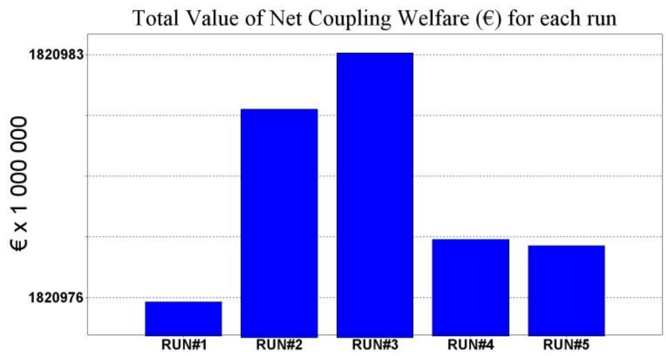


Figure 14: Total Value of Net Coupling Welfare (€) for each run

Observations correspond to expectations:

- Net Coupling Welfare is higher when loss factors included in the algorithm are closer to the actual value;
- Net Coupling Welfare is higher in Run#2 (all DC interconnectors with 2% loss factors included) than in Run#5 (only IFA, Baltic, BritNed with loss factor 2% included);
- Net Coupling Welfare is higher in Run#3 (all DC interconnectors with actual losses included) than in Run#4 (only IFA, Baltic, BritNed with actual losses included);
- Net Coupling Welfare difference between Run#3 and Run#1 is around € 7.3 million;

Net Congestion Rent

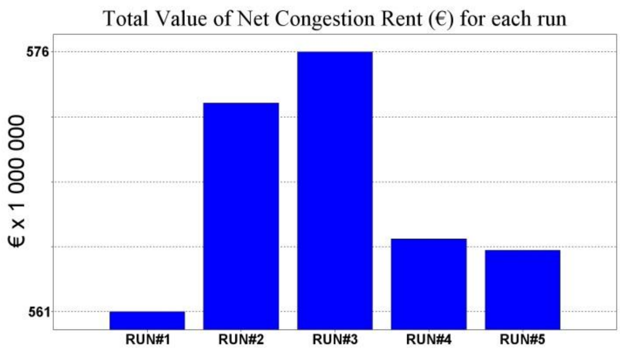


Figure 15: Total Value of Net Congestion Rent (€) for each run

Observations are the following:

- Net Congestion Rent is higher when loss factors are more accurate;
- Net Congestion Rent is higher in Run#2 (all DC interconnectors with 2% loss factors included) than in Run#5 (only IFA, Baltic, BritNed with loss factor 2% included);
- Net Congestion Rent is higher in Run#3 (all DC interconnectors with actual losses included) than in Run#4 (only IFA, Baltic, BritNed with actual losses included);
- Net Congestion Rent difference between Run#3 and Run#1 is € 15.8 million;

External Losses Cost

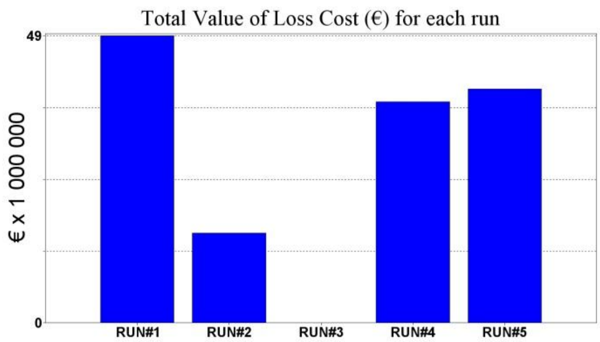


Figure 16: Total Value of Loss Cost (€) for each run

Observations correspond to expectations:

- External Losses Cost is lower when loss factors included are closer to the actual value in Run#3;
- External Losses Cost difference between Run#1 and Run#3 is 49.6 million Euro;

Coupling Welfare (calculated by coupling algorithm)

The Coupling Welfare which is calculated is lower when loss factors increase; and is lower when more DC interconnectors have losses included. This is expected as the application of the general principle that the maximum of an optimization problem gets lower if more constraints applies (when losses are procured outside the coupling mechanism, they do not count as constraints in the optimization process).

AIII.1.4. Analysis of Variations in each day – Each Run compared to Run#1

For each of the 363 days in the sample results, we compare each Run to Run#1 for each welfare indicator and we measure how the indicators vary. **The aim is to check whether the overview of welfare results is confirmed in each day**.

The result is a statistical distribution of day-to-day **absolute variations**:

- The horizontal axis shows the magnitude of the day-to-day absolute variations in Euro (€);
- The vertical axis shows the number of days which a given magnitude is observed;
- A Gaussian curve with same mean and standard deviation shows how close the variations are from a normal distribution; indeed it is important to know whether the difference in yearly indicators between each Run and Run #1 is due to a regular daily difference or due to some special market configurations which occur a few days only;
- The green vertical bar (if any) shows the variation zero point (the left of the bar is the negative variation range; the right of the bar is the positive variation range);

Statistical indicators (in Euro) are calculated:

- The yearly total of absolute variations (which can also be retrieved from the table in welfare result overview);
- The mean μ of the absolute variations;
- The standard deviation σ;
- The median of the absolute variations;
- The minimum and maximum absolute variations;

- The 1st and 99th percentiles[19];

The following observations can be made concerning each Run compared to Run#1 and correspond to expectations:

- External Losses Cost is lower every day when losses are included;
- Coupling Welfare is lower every day when losses are included;

The following observations can be made concerning each Run compared to Run#1; they do not correspond to expectations:

- Net Congestion Rent is higher when losses are included than in Run#1 most days; some days however show a lower Net Congestion Rent (this can be seen as a consequence of modelling limitations – see Appendix VI; however other reasons might exist: for instance, a different selection of block orders might change prices, causing a lower Net Congestion Rent);
- Net Coupling Welfare is higher when losses are included than in Run#1 most days; some days however show a lower Net Coupling Welfare[20];

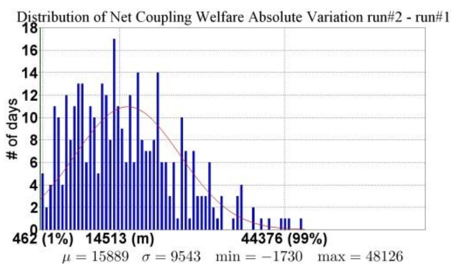
The following observation can be made in addition:

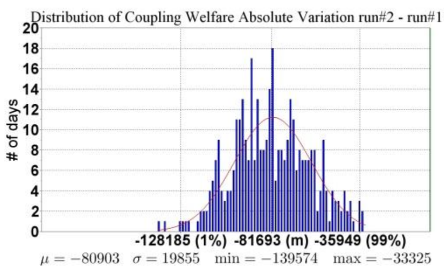
- The difference in yearly Consumer Surplus and yearly Producer Surplus between each Run and Run#1 is the result of an average over the year; for a given day, the difference between each Run and Run#1 can be positive or negative; the distribution of daily variations is close to a normal distribution;

Run#2 (harmonized 2% loss factors on all DC interconnectors) compared to Run#1

Observations from the graphs and table below:

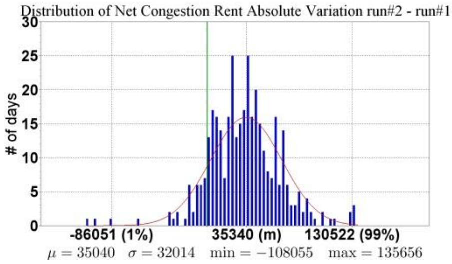
- The Net Coupling Welfare is higher in Run#2 than in Run#1 in almost every day; one day shows a lower Net Coupling Welfare;
- The daily average increase of Net Coupling Welfare is € 15 889;

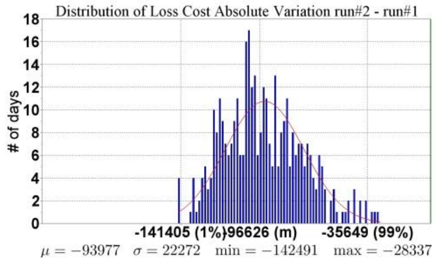


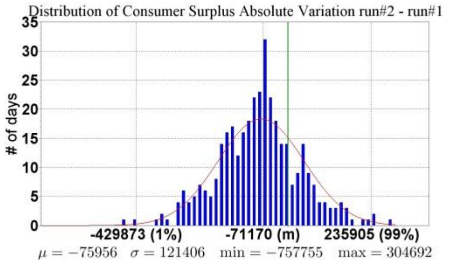


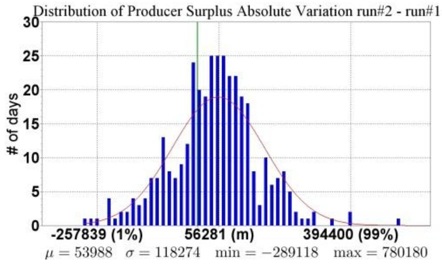
[19] The meaning of the percentiles is the following: 99% of the variations are above the "1st percentile" value; 99% of the variations are below the "99th percentile" value; then 98% of the variations are between the "1st percentile" and the "99th percentile" values.

[20] This is unexpected and reasons are presented in Appendices VI and VIII.









Absolute Daily Variation	RUN	Yearly Total[21]	MU	SIGMA	MEDIAN	MIN	MAX	VALUEAT 1PERCEN T	VALUEAT99 PERCENT
Producer Surplus	2	19 597 835	53 988	118 274	56 281	-289 118	780 180	-257 839	394 400
Consumer Surplus	2	-27 571 818	-75 956	121 406	-71 170	-757 755	304 692	-429 873	235 905
External Losses Cost	2	-34 113 314	-93 977	22 272	-96 626	-142 491	-28 337	-141 405	-35 649
Net Congestion Rent	2	12 719 717	35 040	32 014	35 340	-108 055	135 656	-86 051	130 522
Coupling Welfare	2	-29 367 578	-80 903	19 855	-81 693	-139 574	-33 325	-128 185	-35 949
Net Coupling Welfare	2	5 767 846	15 889	9 543	14 513	-1 730	48 126	462	44 376

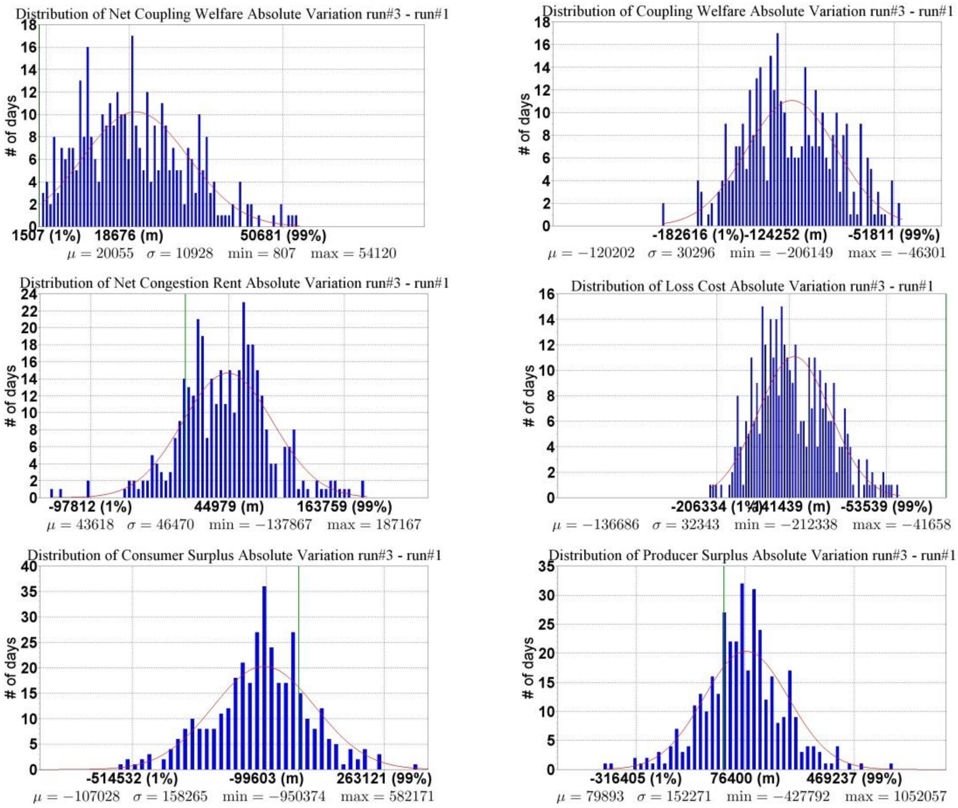
Table 9: Absolute Daily Variation

Run#3 (actual loss factors on all DC interconnectors) compared to Run#1

Observations from the graphs and table below:

- The Net Coupling Welfare is greater every day in Run#3 than in Run#1;
- The daily average increase of Net Coupling Welfare is € 20 055;

[21] The result data contain 363 days. The spread between the yearly total and the mean multiplied by 363 is due to rounding (the quantities in the table have decimals).



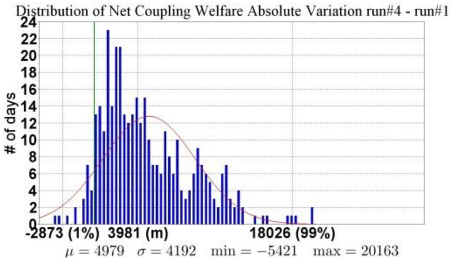
Absolute Daily Variation	RUN	Yearly Total	MU	SIGMA	MEDIAN	MIN	MAX	VALUEAT1PERCENT	VALUEAT99PERCENT
Producer Surplus	3	29 001 295	79 893	152 271	76 400	-427 792	1 052 057	-316 405	469 237
Consumer Surplus	3	-38 851 085	-107 028	158 265	-99 603	-950 374	582 171	-514 532	263 121
External Losses Cost	3	-49 616 854	-136 686	32 343	-141 439	-212 338	-41 658	-206 334	-53 539
Net Congestion Rent	3	15 833 510	43 618	46 470	44 979	-137 867	187 167	-97 812	163 759
Coupling Welfare	3	-43 633 133	-120 202	30 296	-124 252	-206 149	-46 301	-182 616	-51 811
Net Coupling Welfare	3	7 279 998	20 055	10 928	18 676	807	54 120	1 507	50 681

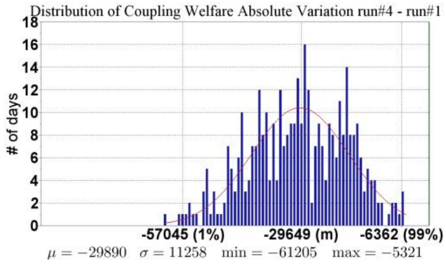
Table 10: Absolute Daily Variation

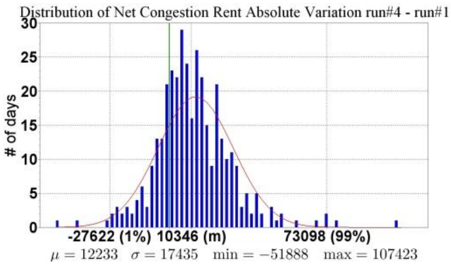
Run#4 (actual loss factors on Baltic, BritNed, IFA only) compared to Run#1

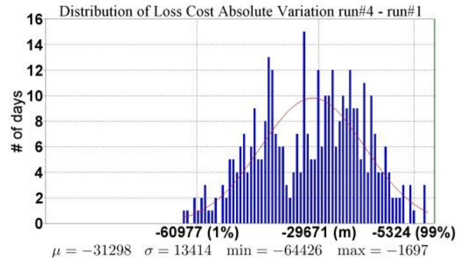
Observations from the graphs and table below:

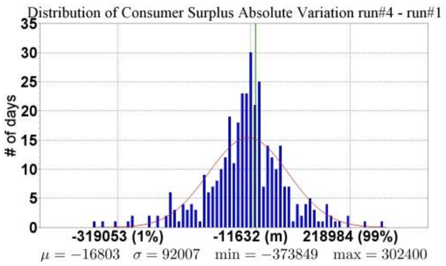
- The Net Coupling Welfare is higher in Run#4 than in Run#1 in almost every day; 20 days show a lower Net Coupling Welfare;
- The daily average increase of Net Coupling Welfare is € 4 979;

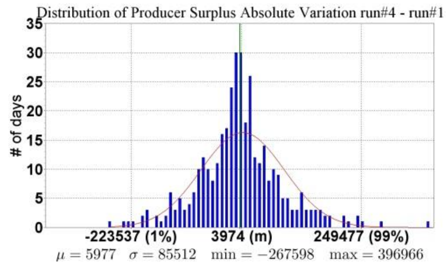












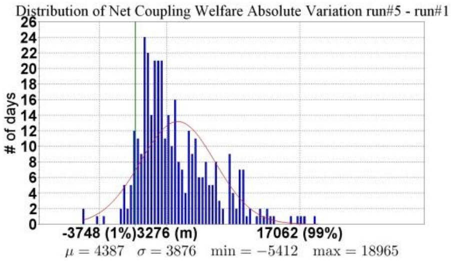
Absolute Daily Variation	RUN	Yearly Total	MU	SIGMA	MEDIAN	MIN	MAX	VALUEAT1PERCENT	VALUEAT99PERCENT
Producer Surplus	4	2 169 802	5 977	85 512	3 974	-267 598	396 966	-223 537	249 477
Consumer Surplus	4	-6 099 488	-16 803	92 007	-11 632	-373 849	302 400	-319 053	218 984
External Losses Cost	4	-11 360 984	-31 298	13 414	-29 671	-64 426	-1 697	-60 977	-5 324
Net Congestion Rent	4	4 440 673	12 233	17 435	10 346	-51 888	107 423	-27 622	73 098
Coupling Welfare	4	-10 849 995	-29 890	11 258	-29 649	-61 205	-5 321	-57 045	-6 362
Net Coupling Welfare	4	1 807 536	4 979	4 192	3 981	-5 421	20 163	-2 873	18 026

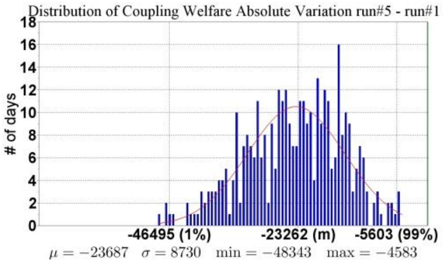
Table 11: Absolute Daily Variation

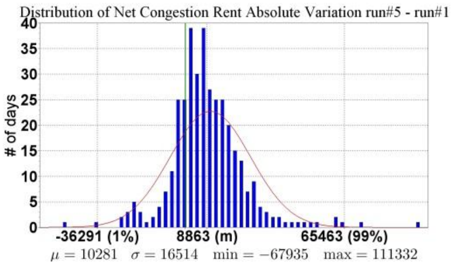
Run#5 (harmonized 2% loss factors on Baltic, BritNed, and IFA only) compared to Run#1

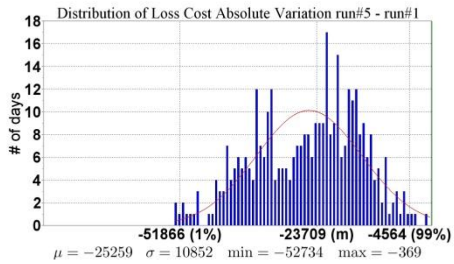
Observations from the graphs and table below:

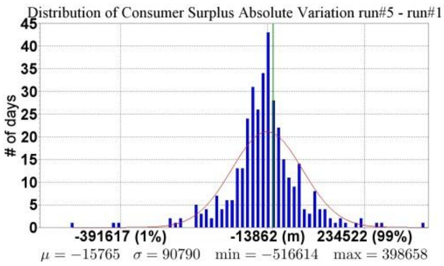
- The Net Coupling Welfare is higher in Run#5 than in Run#1 in almost every day; 22 days show a lower Net Coupling Welfare;
- The daily average increase of Net Coupling Welfare is € 4 387;

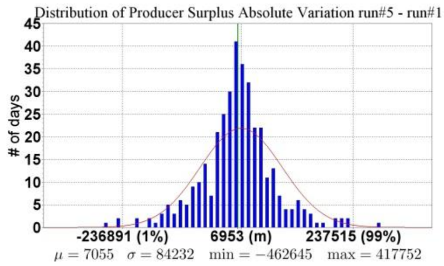












Absolute Daily Variation	RUN	Yearly Total	MU	SIGMA	MEDIAN	MIN	MAX	VALUEAT1PERCENT	VALUEAT99PERCENT
Producer Surplus	5	2 561 048	7 055	84 232	6 953	-462 645	417 752	-236 891	237 515
Consumer Surplus	5	-5 722 485	-15 765	90 790	-13 862	-516 614	398 658	-391 617	234 522
External Losses Cost	5	-9 168 814	-25 259	10 852	-23 709	-52 734	-369	-51 866	-4 564
Net Congestion Rent	5	3 732 124	10 281	16 514	8 863	-67 935	111 332	-36 291	65 463
Coupling Welfare	5	-8 598 126	-23 687	8 730	-23 262	-48 343	-4 583	-46 495	-5 603
Net Coupling Welfare	5	1 592 816	4 387	3 876	3 276	-5 412	18 965	-3 748	17 062

Table 12: Absolute Daily Variation

AIII.1.5. Breakdown of consumer and producer surplus per bidding area

Tables for breakdown of consumer surplus, supplier surplus and total surplus per bidding area can be found in Appendix IV.
Surplus values strongly depend on the price of orders in order books. Without information on supply and demand curves, one cannot derive conclusions from these absolute values. Valid conclusions should rely on the difference between each Run and Run#1.

Surplus values also depend on market clearing prices. The price increase bias when losses are included (see Appendix VI) might explain why producer surplus tends to increase when losses are included whereas consumer surplus tends to decrease.

AIII.1.6. Breakdown of Net Congestion Rent per interconnection

The Net Congestion Rent is calculated per interconnection in each Run. The Net Congestion Rent includes a gross congestion rent (difference between energy sales at receiving end and energy purchase at sending end) and the External Losses Cost.

If an interconnection is subject to ramping constraints or negative ATCs, a **negative gross congestion rent** is obtained when flow is adverse. If an interconnection is subject to losses, a **negative net congestion rent** is obtained when the gross congestion rent is not sufficient to cover External Losses Cost.

Therefore it is interesting to split the Net Congestion Rent into two parts: for a given interconnector, the positive (resp. negative) part is the sum over hours which have a positive (resp. negative) net congestion rent. Some hours have losses cost lower than the gross congestion rent: the interconnection is congested with price difference sufficient to cover losses and the capacity allocation is already optimal. Some hours have losses cost higher than the gross congestion rent: the interconnection is uncongested or the price difference is too small to cover losses (which also includes the case when the gross congestion rent is negative because of adverse flows).

The tables in Appendix IV show the Net Congestion Rent, the positive part and the negative part.

Evolution of Positive Net Congestion Rent when Losses are included

The Net Congestion Rent is the difference between the gross congestion rent and the External Losses Cost; then it is the result of the contribution of these two terms. The positive part concerns the hours which have a gross congestion rent which is greater than External Losses Cost.

When losses are included, the External Losses Cost is reduced (down to zero if the loss factor in the algorithm is the actual loss factor). However a relative price difference generates a positive gross congestion rent only if it is higher than the loss factor: one therefore expects a decreased gross congestion rent on interconnectors with losses when losses are included.

The decrease of gross congestion rent is stronger than the reduction of losses cost: in Run#3 (losses included on all DC interconnectors) compared to Run#1, a reduction of the positive part of the Net Congestion Rent is observed for interconnectors with losses included (except DK1-DK2; see paragraph AIII.2.3 on the interconnection between DE and DK1).

Evolution of Negative Net Congestion Rent when Losses are included

When losses are included, the External Losses Cost on interconnectors with losses is reduced whereas the negative gross congestion rent can increase. The reduction of External Loss Cost is greater, which makes the negative Net Congestion Rent decrease in absolute value. As a result, the Net Congestion Rent increases in Run#3 compared to Run#1 on interconnectors with losses (except EE-FI and Baltic cable).

The EE-FI case is a direct effect the modelling limitations. Let us take the example of day 2 hour 10. In Run#1, the flow EE->FI is congested (365MW) and we have the following prices: p(EE) = € 75.44 and p(FI) = € 88.72; in particular we can check the inequality p(FI).(1-5.21%) > p(EE) which shows that the price difference is sufficient to cover external losses cost. Then the allocation of capacity is already optimal and should not change when losses are included.

In Run#3, because of losses included on Fennoskan, the price in Finland changes: p(FI) = € 86.32, so that we now have p(FI).(1-5.21%) = € 81.82 and the price difference still should be sufficient to cover losses. However we do not re-integrate the producer which procures losses in Run#1 into the supply curves: as shown in Appendix VI under the "receiving end" modelling, this results in a price increase in EE, which is quite significant (as a result of a 5.12% loss factor and of curve elasticity's): we now have p(EE) = € 81.82 and the flow EE->FI is no longer congested though positive.
As a consequence, in Run#1 (day 2; hour 10) we observe a gross congestion rent of € 4849 and an external losses cost of € 1513: the net congestion rent amounts to € 3336. Taking into account the decrease of price in FI when losses are included, the net congestion rent should remain at least equal to € 2460. In Run#3, no external losses cost exists but the uncongested flow generates no congestion rent.

The Baltic cable is modelled under the "sending end" modelling (see Appendix VI). When a "sending end" interconnector is congested a correction should be applied to the net congestion rent. In the document, this correction was applied to net coupling welfare; but net congestion rent was kept uncorrected. This correction amounts to € 520 526 (resp. € 141 284) until Oct 31 (resp. after Nov 1st): the total correction is € 661 810[22].Then we have the following results:

- *Baltic cable - Net Congestion Rent Run#3 variation compared to Run#1 before correction: -€ 2806;*
- *Baltic cable – Corrected Net Congestion Rent Run#3 variation compared to Run#1: € 659 004;*

We then observe that the correction allows to observe an increase of € 659 004 in the Net Congestion Rent in Run#3 compared to Run#1. The need for this correction in order to retrieve expected results can be seen as an illustration of the imperfection of the sending end modelling.

The contribution of the negative part of the gross congestion rent and of the External Losses Cost is illustrated below on an example.

(i) Contribution of negative gross congestion rent

As an example, let us first focus on the negative gross congestion rent of NorNed (4% of losses in Run#3). Assessing this negative gross congestion rent is equivalent to count adverse flows (adverse flows exist because ramping constraints are applied):

- in Run#1, NorNed has 71 hours with adverse flows; which result into -€ 10 823 negative gross congestion rent;
- in Run#3, NorNed has 243 hours with adverse flows; which result into -€ 23 757 negative gross congestion rent;

An adverse flow is understood here as a flow which generates a negative gross congestion rent. When losses are applied, even a flow in the direction of prices can be adverse if the price difference is not sufficient to cover losses. Such adverse flows in the direction of prices but with not sufficient price difference occur in 207 hours (out of a total of 243 hours with adverse flows) in Run#3.

As an example, Run#3 - Jan 11 – h19 shows a flow NL->NO2 of 104MW with price (NL) = € 71,80 and price(NO2) = € 74,10. The flow is in the direction of prices but the price difference is not sufficient to cover losses ((74.10 - 71.80)/74.10 = 0.031 is not greater than loss factor = 0.04). Then this flow generates a negative congestion rent of -€ 69.

(ii) Contribution of External Losses Cost

Now let us consider the External Losses Cost of NorNed: this cost is zero when losses are applied with the actual rate of 4% in Run#3.

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[22] This correction is not an exact correction of the modelling side effect; only an approximation of an error term in the equation of net congestion rent under the sending end modelling.

External Losses Cost of NorNed amounts to a yearly total of € 8.3 million in Run#1 with no losses included. This cost is counted negatively in the Net Congestion Rent. The sum of External Losses Cost Run#1 over hours when the Net Congestion Rent is negative amounts to € 1.603 million; the sum of gross congestion rent over the same hours is € 0.312 million only; which explains the negative Net Congestion Rent of -€ 1.291 million in Run#1 for NorNed.

AIII.2. Flow Results

AIII.2.1. Flow Indicators

Each interconnector has two directions which are arbitrarily denoted up and down; a flow in a given direction can be seen at the sending end (injection point; denoted "in") and at the receiving end (off-take point; denoted "out"). The following indicators are calculated (for each interconnector and each run):

UPINNCG: sum of **sending** end flows in **up** direction over hours when **no** congestion occurs
UPOUTNCG: sum of **receiving** end flows in **up** direction over hours when **no** congestion occurs
DOWNINNCG: sum of **sending** end flows in **down** direction over hours when **no** congestion occurs
DOWNOUTNCG: sum of **receiving** end flows in **down** direction over hours when **no** congestion occurs

UPINCG: sum of **sending** end flows in **up** direction over hours when congestion occurs
UPOUTCG: sum of **receiving** end flows in **up** direction over hours when congestion occurs
DOWNINCG: sum of **sending** end flows in **down** direction over hours when congestion occurs
DOWNOUTCG: sum of **receiving** end flows in **down** direction over hours when congestion occurs

NBHCGUP: number of hours when the interconnector is congested in the **up** direction
NBHCGDOWN: number of hours when the interconnector is congested in the **down** direction
NBHCGTOTAL: number of hours when the interconnector is congested whatever the direction: sum of NBHCGUP and NBHCGDOWN[23]

NBHNCGdPUP: number of hours when the interconnector is **not congested** in the **up** direction although a price difference[24] occurs in the **up** direction
NBHNCGdPDOWN: number of hours when the interconnector is **not congested** in the **down** direction although a price difference occurs in the **down** direction
NBHNCGdPTOTAL: sum of NBHNCGdPUP and NBHNCGdPDOWN

NBHRMPUP: number of hours when the ramping-up[25] constraint is activated
NBHRMPDOWN: number of hours when the ramping-down[25] constraint is activated
NBHRMPTOTAL: sum of NBHRMPUP and NBHRMPDOWN

NBHrFL[26]: number of hours when the flow is reduced compared to the reference run

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[23] If the capacity is zero, a flow equal to zero is considered congested; so that congestion can occur both up and down in the same hour; then the sum of hours can exceed the total number of hours (8712 hours in the sample results).
[24] The price difference is counted as MCP(B) – MPC(A), without the taking into account of the loss factor.
[25] This is not directional and refers to the sign of flow variation: ramping-up (resp. –down) constraints the increase (resp. decrease) of flow between consecutive hours. The ramping constraint is considered activated when the difference of flows between consecutive hours is equal to the ramping limit.

NBHzFL: number of hours when the flow is zero in the current run and is not zero in the reference run

The tables with indicator numerical values are provided in Appendix IV.

[26] This indicator is calculated only for interconnectors subject to loss factor for some runs.

AIII.2.2. Observations from Flow Results

- Flows[27] on interconnectors with a loss factor decrease when losses are included in the coupling mechanism[28]

  The yearly total energy exchange[29] (GWh) over the interconnectors with losses included is the following:

Run#1	*Run#2*	*Run#3*	*Run#4*	*Run#5*
34 922	*29 868*	*29 021*	*33 153*	*33 445*

- Reduction in flows can be a reduction down to zero, but this is not the most frequent case: flows generally decrease but remain positive (depending on the elasticity of curves)

  A duration curve of flows (MW) shows the reduction of flows in Run#3 compared to Run#1 (absolute value of receiving end flows up and down):

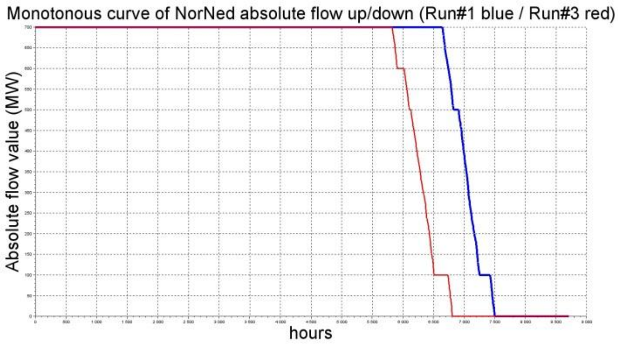

Table 13: Duration curve of NorNed absolute flow up/down

- Flows on some interconnectors without loss factors tend to be more congested when losses are included on some other interconnectors, depending on their location in the network;

  E.g. In Run#1, flow DE->NL is congested in 1190 hours for a total energy exchange of 1 991 GWh during these hours;
  In Run#3, flow DE->NL is congested in 1274 hours for a total energy exchange of 2 163 GWh during these hours;

- It can happen that flows increase on average on an interconnector with losses included if a merit order effect occurs with an interconnector with a higher loss factor also included in the coupling mechanism;

  E.g. In Run#2 the yearly total energy exchange through IFA amounts to 2 199 GWh; however it is 2 457 GWh in Run#3 whereas the loss factor in Run#3 is 2.313%, which is greater than the 2% loss factor in Run#2.
  This is due to a merit order effect with BritNed which has a loss factor of 3%: in Run#2, the yearly total energy exchange through BritNed amounts to 2 746 GWh; whereas it is only 2 210 GWh in Run#3.

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[27] Strictly speaking, receiving end flows decrease; whereas sending end flows might increase up to the loss factor, depending on curve elasticity's.

[28] This can be not satisfied when ramping constraints are activated: in such case, the flow without losses included can be lower than when losses are included because ramping constraints do not allow greater flow values. E.g. NorNed has 80 hours in the year with flow Run#3 greater than flow Run#1; 8632 hours have a decrease flow in Run#3 compared to Run#1.

[29] Receiving end values.

AIII.2.3. Example: analysis of the DE-DK1 interconnection

The DE-DK1 example shows the merit order effect in a complex topology: when losses are applied, flows on an AC interconnector without losses can increase (resp. decrease) if it is part of a route which is higher (resp. lower) in the merit order.

When all interconnectors have losses included with the same loss factor (Run#2 – harmonized loss factor of 2%), every route between CWE and Nordic bidding areas passes through at least one interconnector with losses; therefore all routes have the same external losses cost and no merit order is observed.

Compared to Run#1, Run#2 even shows a reduction of flows through DE-DK1. This is a direct consequence of reduction of exchanges between CWE and Nordic bidding areas when losses are applied as well as the effect of the equivalence of each route between CWE and Nordic bidding areas.

> *Run#1 shows a yearly total energy exchange of 15 108 GWh in both directions from Nordic into CWE bidding areas and from CWE into Nordic bidding areas;*
> *Run#2 shows a yearly total energy exchange of 14 426 GWh in both direction from Nordic into CWE bidding areas and from CWE into Nordic bidding areas;*
>
> *Run#1 - DE-DK1 shows a yearly total energy exchange up[30] and down 4 108 GWh;*
> *Run#2 - DE-DK1 shows a yearly total energy exchange up and down of 4 097 GWh;*

In Run#3, actual loss factors are used and the route through DE-DK1-DK2 bears the loss factor of Storebaelt only (1.5%), which is lower than the other loss factors. Then a merit order effect occurs and this route is prioritized. Hence we observe an increase of flows through DE-DK1 in Run#3 compared to Run#1; even though total energy exchange between CWE and Nordic bidding areas is even lower in Run#3 than in Run#2 as can be observed below:

> *Run#1 shows a yearly total energy exchange of 15 108 GWh from Nordic into CWE bidding areas and from CWE into Nordic bidding areas*
> *Run#3 shows a yearly total energy exchange of 14 171 GWh from Nordic into CWE bidding areas and from CWE into Nordic bidding areas*
>
> *Run#1 - DE-DK1 shows a yearly total energy exchange up and down of 4 108 GWh*
> *Run#3 - DE-DK1 shows a yearly total energy exchange up and down of 4 565 GWh*

AIII.2.4. Analysis of re-routing effects when loss factors are included

When losses are applied, a merit order effect is expected, which must result in a re-routing of flows through interconnectors with lower loss factors.

This effect could cause a reduction of welfare if the routes with lower loss factors do actually have an External Losses Cost which is not included in the coupling mechanism.

Run#4 and Run#5 give examples of such a situation:
- In Run#4, losses are included only on Baltic, BritNed and IFA with the actual loss factors
- In Run#5, losses are included only on Baltic, BritNed and IFA with a harmonized loss factor of 2%

[30] Up (resp. down) refers to the DE->DK1 (resp. DK1->DE) direction; up/down definition are arbitrary and do not modify the example.

If we consider the energy exchanges between CWE and Nordic bidding areas (both directions included):

- In Run#1, 15 108 GWh are exchanged: 2 782 GWh through Baltic; 12 326 GWh through DE-DK and NL-NO2 routes;
- In Run#4, 14 857 GWh are exchanged: 2 227 GWh through Baltic; 12 630 GWh through DE-DK and NL-NO2 routes;
- In Run#5, 14 884 GWh are exchanged: 2 260 GWh through Baltic; 12 624 GWh through DE-DK and NL-NO2 routes;

Hence we observe a re-routing effect:

- When losses are included on Baltic, total exchanges between CWE and Nordic bidding areas are reduced; exchanges on Baltic are reduced; whereas exchanges on parallel routes with lower loss factor are increased;
- The re-routing effect is a partial re-routing (exchanges through Baltic are not reduced down to zero);
- The increase of exchanges on parallel routes with lower loss factors amounts to 304 GWh in Run#4 compared to Run#1; which does not compensate the reduction of exchanges on Baltic, which amounts to -555 GWh in Run#4 compared to Run#1
- The re-routing effect is stronger when the loss factor which is included is closer to the actual value;

As a result of these energy exchanges, we have the following External Losses Costs:

- Routes through DE-DK and NL-NO2 - Run#1: total yearly external losses cost is € 27.589 million;
- Routes through DE-DK and NL-NO2 - Run#4: total yearly external losses cost is € 27.919 million;
- Routes through DE-DK and NL-NO2 - Run#5: total external yearly losses cost is € 27.918 million;

In other words, external losses cost on parallel routes with losses not included increase because of the re-routing effect when Baltic has losses included.

AIII.3. Net Position Results

AIII.3.1. Net Position Indicators

For each bidding area and each run, the net position indicators are calculated and numerical values are provided in Appendix IV:

Total Pos NP: sum of net position for hours which have a positive net position
Total Neg NP: sum of net position for hours which have a negative net position
Total NP: sum of Total Pos NP and Total Neg NP

CWE NP: sum of net positions of CWE bidding areas
Nordic NP: sum of net positions of Nordic[31] bidding areas

For each CWE bidding area, a NWE-Net Position is calculated as follows for each hour:

$$\text{Hourly NWE-NP} = NP - Flow_{ExportedToNonCWE} + Flow_{ImportedFromNonCWE}$$

[31] Only bidding areas in Sweden, Norway, Denmark and Finland.

The NWE-NP indicator is the sum of the hourly NWE-NP. This NWE-Net Position represents the net position of the CWE bidding areas after correction of the exchanges from/to other non-CWE bidding areas.

AIII.3.2. Observations from Yearly Total Net Position Results

Below are some significant observations from the Net Position results:

- Yearly net positions of GB1 and GB2 are importing. They vary significantly when losses are included: in Run#3 compared to Run#1, GB1 (resp. GB2) importing net position experiences a 32% (resp. 6%) reduction. Both the importing and exporting part of the net position of GB1 and GB2 experience a decrease (in absolute values) when losses are included. This effect is stronger when losses are included at the actual loss factor than when they are included at the 2% loss factor: with the harmonized loss factor, GB1 (resp. GB2) importing net position decrease rate is below 20% (resp. 4%). These variations reflect the connection between GB and the rest of the network through routes on which losses are applied: no parallel route without losses exists.

- In Run#2 (all DC interconnectors with 2% losses included), the GB1 (resp. GB2) importing net position decrease rate is 19% (resp. 3.7%) (Compared to Run#1) whereas it is only 17.4% (resp. 3.1%) in Run#5 (only Baltic, BritNed, IFA with 2% loss factor included).
  Similarly in Run#3 (all DC interconnectors with actual losses included), the GB1 (resp. GB2) importing net position decrease rate is 32% (resp. 6%) (Compared to Run#1) whereas it is only 26% (resp. 5%) in Run#4 (only Baltic, BritNed, IFA with actual loss factor included).
  This comparison between Run#2 and Run#5 (resp. Run#3 and Run#4) reflects the following fact: when losses are less included in the rest of the network, the system is less constrained and GB can import more energy.

- In Run#2 (resp. Run#3) which has a loss factor included on Fennoskan and Estlink, the exporting part of the FI net position decreases by 2.4% (resp. 2.9%)(compared to Run#1) and the importing part of the FI net position decreases by 0.4% (resp. 0.7%). This reflects how exchanges from/to FI are impacted by losses included on Fennoskan and Estlink: greater loss factors tend to result into a reduction of both importing and exporting exchanges.
  On the other hand in Run#4 (resp. Run#5) which has a loss factor on Baltic cable only (and on IFA and BritNed which are far from FI), the exporting part of the FI net position increases by 0.04% (resp. 0.05%)(compared to Run#1) and the importing part of the FI net position increases by 0.15% (resp. 0.14%). This reflects how the exchanges from/to FI tend to slightly compensate the decrease of exchange due to losses included on Baltic.

- In all runs, the yearly net position of DE is exporting towards other CWE bidding areas (DE - NWE NP is positive). This DE exporting net position towards other CWE bidding areas increases by 15% (resp. 49%) in Run#2 (resp. Run#3) (compared to Run#1) when losses are included on all DC interconnectors. This results from the demand of energy coming from Nordic bidding areas into other CWE bidding areas, especially into NL, which cannot be satisfied as much as in Run#1.
  In Run#4 (resp. Run#5) the DE exporting net position towards other CWE bidding areas is reduced by 12% (resp. 8%) (Compared to Run#1) when losses are included only on Baltic, BritNed and IFA. These

results from a merit order effect: demand of energy can flow from Nordic bidding areas through routes without losses included.

AIII.4. Price Results

AIII.4.1. Price Indicators

The following indicators are calculated for each Run:

- percentage of hours with CWE convergence of prices;
- percentage of hours with Nordic[32] convergence of prices;
- percentage of hours with Baltic[33] convergence of prices;
- percentage of hours with price convergence between CWE and Nordic bidding areas;
- percentage of hours with price convergence between CWE and GB bidding areas;
- percentage of hours with converging prices between bidding areas at line ends;
- percentage of hours with full convergence of prices;

Number of hours and percentage of hours are non-dimensional indicators.

The analysis of price convergence relies on the definition of price convergence as price equality. These results into quite low rates of price convergence which do not reflect whether prices have converged as much as possible given the applied loss factors. Changing the definition of price convergence into the following equality: [MCPexporting = (1 – loss factor).MCPimporting] would result in greater price convergence rates.
This definition is equivalent to usual price convergence when the loss factor is zero.

In addition, for each bidding area, the hourly absolute variations of prices (in Euro) is provided for each Run compared to Run#1 (i.e. for each hour in the sample results, the price difference between Run#1 and the current Run). The indicators (in Euro) are the following:

- mean of the hourly price differences between current Run and Run#1;
- standard deviation;
- minimum and maximum absolute hourly price differences;
- median, "1st percentile", "99th percentile"[34];

AIII.4.2. Price Convergence between bidding areas

The table below shows the occurences of price convergence between bidding areas in each Run. We observe the following:

[32] Only bidding areas in Sweden, Norway, Denmark and Finland.
[33] Only EE; ELE; ELI bidding areas.
[34] The meaning of the percentiles is the following: 99% of the variations are above the "1st percentile" value; 99% of the variations are below the "99th percentile" value; then 98% of the variations are between the "1st percentile" and the "99th percentile" values.

(i) Price convergence in CWE is slightly reduced when loss factors are included (Run#1 shows a convergence rate of 62.1%, which is reduced to 60.2% in Run#3); this reduction is maximal but remains small when losses are included with the actual loss factors (Run#3 and Run#4 compared to Run#1);

(ii) The convergence of Nordic prices is hardly impacted by a loss factor included on Baltic cable[35] (Run#4 and Run#5 compared to Run#1); Run#2 and Run#3 show an example of the configuration which has losses included on interconnectors in the middle of a set of bidding areas, leaving no remaining parallel route without losses included; in such a case, prices can no longer converge in any hour;

(iii) The impact of losses on the convergence of Baltic prices is negligible;

(iv) Run#1 shows a rare occurrence of convergence of CWE and Nordic prices; the inclusion of losses on Baltic cable results in a small reduction of the CWE-Nordic convergence rate;

(v) The convergence of CWE and GB prices occurs in 35.2% of hours when no losses are included; losses inclusion on IFA and BritNed (Run#2-5) prevents CWE-GB price convergence;

(vi) Run#1 shows a rare occurence of full NWE price convergence; including losses again results in the particular case when no parallel routes without losses exist: prices cannot convergence any more;

Price Convergence	RUN#1	RUN#2	RUN#3	RUN#4	RUN#5
#hours with CWE price convergence	5412 – 62.1%	5343 – 61.3%	5243 – 60.2%	5287 – 60.7%	5353 – 61.4%
#hours with Nordic price convergence	2262 – 26.0%	0 – 0%	0 – 0%	2178 – 25.0%	2192 – 25.2%
#hours with Baltic price convergence	7253 – 83.25%	7261 – 83.34%	7296 – 83.75%	7251 – 83.23%	7250 – 83.22%
#hours with CWE-Nordic price convergence	358 – 4.11%	0 – 0%	0 – 0%	279 – 3.20%	285 – 3.27%
#hours with CWE-GB price convergence	3070 – 35.2%	0 – 0%	0 – 0%	0 – 0%	0 – 0%
#hours with full NWE price convergence	9 – 0.1%	0 – 0%	0 – 0%	0 – 0%	0 – 0%

Table 14: Price Convergence

AIII.4.3. Price Convergence at the ends of interconnections

For each interconnection, the table in Appendix IV shows price convergence between the two bidding areas which are linked by the interconnection. We observe the following:

(i) Generally speaking, as expected, the application of a loss factor on an interconnector prevents price convergence at both ends of the interconnector (e.g. IFA, BritNed); even when markets have converged, a price difference remains;

(ii) Including losses on Baltic only (in addition to IFA, BritNed – Runs#4 and #5) do not prevent price convergence between Germany and Sweden, since parallel routes without losses exist;

(iii) When losses are included on all DC interconnectors (Runs#2 and #3), convergence between SE/SE3 and FI still remains possible in the majority of hours (52% in SE-FI / 67% in SE3/FI)

[35] Reference run is still Run#1 without any losses included; independently from the current inclusion of losses on interconnections which take part in a price or volume coupling mechanism.

because the northern route is not congested; every hour that price convergence occurs, the Fennoskan interconnector is not loaded at all[36], as expected;

(iv) It rarely happens that price convergence occurs despite the application of loss factors (e.g. DE-DK2 in Run#3); this must be considered as due to coincidence instead of the effect of market convergence;

AIII.4.4. Analysis of Hourly Price Variations– Each Run compared to Run#1

The analysis should be run per bidding area for each Run; as a general result, variation distributions have a high peak around the mean, which is close to zero in general. Long tails show rare occurrences of greater variation values over a quite large range of values (up to a few Euros). More important variations are observed in some bidding areas (e.g. DE, DK) for some runs (up to -€ 17.40 / +€ 36.20).

Let us focus on the question on the change in price difference between the ends of the interconnectors when losses are included. The question is whether a price difference lower than the loss factor (possibly zero) in the reference Run#1 without losses included turns into a price difference greater or equal than the loss factor in the current Run with losses included.

For each interconnector with losses and each run, a table in Appendix IV shows the number of hours:

- which have a relative price difference in Run#1 lower than the loss factor of the current Run;
- and which have a relative price difference in the current Run greater than the loss factor;
- The percentage is calculated over the sum of hours with a price difference in Run#1 lower than the loss factor of the current Run;

These hours show a change in relative price difference when losses are included which is not limited to the loss factor.

Similarly, a table shows the number of hours:

- which have a relative price difference in Run#1 lower than the loss factor of the current Run;
- and which have a relative price difference in the current Run equal to the loss factor;
- The percentage is calculated over the sum of hours with a price difference in Run#1 lower than the loss factor of the current Run;

Last, a table shows the number of hours:

- which have a relative price difference in Run#1 lower than the loss factor of the current Run;
- and which have a relative price difference in the current Run lower than the loss factor;
- The percentage is calculated over the sum of hours with a price difference in Run#1 lower than the loss factor of the current Run;

These hours with a price difference lower than the loss factor when losses are included can occur if the flow is zero on the interconnector with losses included.

[36] This does not refer to physical flows but to algorithm outputs.

Appendix IV - Quantitative Results - Tables and Graphs

Breakdown of consumer surplus and supplier surplus per bidding area

Consumer and surplus breakdown are given as yearly totals in Euro (€) in each Run. Yearly totals are the sum over the 363 days of result, except when the bidding area exists less days in the result data set (then yearly totals cover the period it exists only).

The following table shows the breakdown of **producer** surplus per bidding area.
Example. In Run#1, the yearly total producer surplus of FR is € 54 111 493 326; this value depends on the price in supply curve (especially price taking orders) and on the market clearing price: in itself, this absolute value should not lead to any interpretation; what can be analyzed is the variation of this surplus in the other runs.

Producer Surplus	Run#1	Run#2	Run#3	Run#4	Run#5
FR	54 111 493 326	54 111 706 974	54 111 516 396	54 111 103 937	54 111 350 901
DE	531 955 998 326	531 963 445 737	531 964 944 850	531 958 777 483	531 958 730 685
EE	114 980 430	116 605 272	118 631 417	114 954 110	114 958 833
ELE	0	0	0	0	0
ELI	7 601 086	7 685 705	7 794 998	7 602 524	7 602 170
DK1	2 436 531 781	2 436 382 264	2 437 338 803	2 436 448 599	2 436 569 846
DK2	1 659 935 793	1 662 640 169	1 662 805 773	1 659 752 044	1 659 811 791
FI	7 563 166 286	7 561 953 014	7 562 216 395	7 563 183 779	7 563 221 042
NO1	3 959 146 399	3 960 120 924	3 960 780 947	3 958 975 606	3 959 052 929
NO2	2 571 028 344	2 572 056 225	2 572 959 876	2 570 853 521	2 570 909 194
NO3	645 508 869	645 637 768	645 741 436	645 431 401	645 448 311
NO4	852 489 257	852 724 094	852 857 726	852 425 813	852 441 632
NO5	880 576 616	880 927 876	881 192 504	880 535 582	880 554 094
PL	993 493	979 622	976 211	989 915	990 057
GB1	671 283 219	671 896 911	672 310 368	672 128 823	671 822 102
BE	12 678 780 431	12 678 838 897	12 678 795 405	12 678 717 459	12 678 755 112
GB2	30 257 693	30 129 819	30 100 362	30 085 565	30 122 710
NL	23 845 620 321	23 846 885 520	23 847 323 897	23 846 500 396	23 846 325 791
Topology until Oct 31					
SE	17 954 817 950	17 958 547 651	17 959 524 102	17 954 342 998	17 954 491 720
Topology after Nov 1					
SE1	297 673 262	297 562 916	297 654 076	297 650 130	297 653 063
SE2	749 723 176	749 470 494	749 637 812	749 669 160	749 675 857
SE3	2 678 346 449	2 679 369 415	2 679 844 455	2 678 156 340	2 678 174 600
SE4	205 397 083	205 380 161	205 403 080	205 234 209	205 248 200

Table 15: Producer Surplus

The following table shows the breakdown of **consumer** surplus per bidding area.

Consumer Surplus	Run#1	Run#2	Run#3	Run#4	Run#5
FR	72 282 477 019	72 281 921 159	72 281 916 545	72 282 235 861	72 282 179 303
DE	478 284 652 269	478 276 153 814	478 274 106 887	478 280 880 563	478 281 105 062
EE	4 468 038 514	4 467 206 275	4 466 175 039	4 468 047 658	4 468 045 923
ELE	1 530 593 016	1 530 455 295	1 530 365 097	1 530 611 157	1 530 605 933
ELI	0	0	0	0	0
DK1	28 585 444 291	28 584 754 280	28 583 403 352	28 585 488 964	28 585 296 400
DK2	23 994 549 049	23 991 228 593	23 990 910 234	23 994 777 562	23 994 687 696
FI	82 282 253 399	82 281 662 100	82 280 936 797	82 282 278 166	82 282 227 836
NO1	55 983 189 333	55 981 906 715	55 981 001 821	55 983 298 593	55 983 231 979
NO2	27 168 034 980	27 167 135 436	27 166 345 309	27 168 153 458	27 168 105 662
NO3	20 250 421 443	20 250 018 615	20 249 859 061	20 250 486 309	20 250 466 679
NO4	16 737 657 417	16 737 418 578	16 737 330 392	16 737 696 431	16 737 683 929
NO5	15 549 703 892	15 549 308 323	15 548 999 955	15 549 718 567	15 549 697 653
PL	8 275 125	7 772 560	7 612 529	8 316 389	8 315 107
GB1	10 822 334 710	10 820 315 471	10 819 553 356	10 819 758 998	10 820 400 242
BE	19 270 881 932	19 270 762 801	19 270 793 303	19 270 834 982	19 270 807 447
GB2	199 637 042	199 126 439	198 927 072	198 963 971	199 150 873
NL	65 021 122 949	65 019 568 211	65 018 952 769	65 020 376 594	65 020 457 760
Topology until Oct 31					
SE	187 741 846 022	187 737 995 807	187 737 060 510	187 742 114 938	187 742 007 039
Topology after Nov 1					
SE1	3 280 632 182	3 280 681 120	3 280 643 238	3 280 645 614	3 280 644 648
SE2	4 541 918 279	4 541 987 445	4 541 929 873	4 541 938 047	4 541 936 315
SE3	28 547 706 076	28 546 257 841	28 545 620 175	28 547 975 328	28 547 944 960
SE4	7 992 297 716	7 992 457 957	7 992 372 256	7 992 969 014	7 992 945 723

Table 16: Consumer Surplus

The following table shows the breakdown of **total** surplus per bidding area (sum of consumer and supplier surplus).

Total Surplus	Run#1	Run#2	Run#3	Run#4	Run#5
FR	126 393 970 345	126 393 628 133	126 393 432 941	126 393 339 798	126 393 530 204
DE	1 010 240 650 595	1 010 239 599 551	1 010 239 051 737	1 010 239 658 045	1 010 239 835 746
EE	4 583 018 944	4 583 811 547	4 584 806 456	4 583 001 768	4 583 004 757
ELE	1 530 593 016	1 530 455 295	1 530 365 097	1 530 611 157	1 530 605 933
ELI	7 601 086	7 685 705	7 794 998	7 602 524	7 602 170
DK1	31 021 976 072	31 021 136 543	31 020 742 155	31 021 937 563	31 021 866 246
DK2	25 654 484 841	25 653 868 763	25 653 716 007	25 654 529 606	25 654 499 488
FI	89 845 419 684	89 843 615 114	89 843 153 191	89 845 461 944	89 845 448 878
NO1	59 942 335 732	59 942 027 639	59 941 782 768	59 942 274 199	59 942 284 907
NO2	29 739 063 324	29 739 191 661	29 739 305 185	29 739 006 979	29 739 014 856
NO3	20 895 930 313	20 895 656 383	20 895 600 497	20 895 917 710	20 895 914 991
NO4	17 590 146 674	17 590 142 671	17 590 188 118	17 590 122 244	17 590 125 561
NO5	16 430 280 509	16 430 236 199	16 430 192 459	16 430 254 149	16 430 251 747
PL	9 268 618	8 752 181	8 588 739	9 306 304	9 305 164
GB1	11 493 617 929	11 492 212 382	11 491 863 724	11 491 887 821	11 492 222 344

BE	31 949 662 362	31 949 601 698	31 949 588 708	31 949 552 441	31 949 562 559
GB2	229 894 735	229 256 258	229 027 434	229 049 536	229 273 583
NL	88 866 743 270	88 866 453 732	88 866 276 666	88 866 876 991	88 866 783 551
Topology until Oct 31					
SE	205 696 663 972	205 696 543 458	205 696 584 612	205 696 457 936	205 696 498 759
Topology after Nov 1					
SE1	3 578 305 444	3 578 244 037	3 578 297 313	3 578 295 744	3 578 297 710
SE2	5 291 641 455	5 291 457 939	5 291 567 684	5 291 607 208	5 291 612 172
SE3	31 226 052 525	31 225 627 255	31 225 464 630	31 226 131 668	31 226 119 560
SE4	8 197 694 800	8 197 838 119	8 197 775 335	8 198 203 223	8 198 193 923

Table 17: Total Surplus

Congestion Rent Tables

Congestion rent breakdowns are given as yearly totals in Euro (€) in each Run. Yearly totals are the sum over the 363 days of result, except when the interconnector exists less days in the result data set (then yearly totals cover the period it exists only).

The congestion rents below are calculated on the basis of unrounded prices and flows; then they do not exactly correspond to effective congestion rents which would result from the operational coupling process. The Net Congestion Rent is split into a positive and a negative part: the sum of these two parts might not be exactly equal to the Net Congestion Rent because of rounding (calculated figures have decimals, whereas figures below are rounded).

Below are the yearly totals of **gross** congestion rent for each interconnector.
Example. DE-DK2 is subject to ramping constraints and has losses included (for some runs); in Run#1, the yearly total gross congestion rent is € 18 718 028.

Total Gross Congestion Rent	Ramping / Neg. ATC	Run#1	Run#2	Run#3	Run#4	Run#5
DE-FR		75 052 596	75 359 931	75 613 263	75 377 712	75 308 303
DK1A-DK1	Ramping	770 792	793 884	818 860	801 257	798 097
NO2-NO1		8 084 509	7 998 653	7 811 554	8 112 837	8 115 444
DE-DK1		21 622 895	21 304 556	21 062 020	21 777 966	21 709 836
DE-DK2	Ramping Losses	18 718 028	16 257 922	15 539 560	18 959 074	18 907 771
NO1-NO5		2 877 866	2 890 238	2 880 169	2 861 820	2 866 466
NO2-NO5		3 427 770	3 400 642	3 352 071	3 423 501	3 426 494
NO2-DK1A	Ramping Losses	67 575 750	63 375 135	59 827 595	67 597 825	67 673 246
NO1-NO3	NegativeATC	174 410	176 083	172 121	169 565	169 837
NO3-NO4		1 106 569	1 086 455	1 084 257	1 102 291	1 102 842
DK1-DK2	Ramping Losses	3 997 961	3 140 887	3 680 014	3 942 805	3 927 068
EE-FI	Losses	19 357 172	16 833 130	13 201 301	19 349 235	19 353 044
EE-ELI		39 199	39 285	41 450	39 199	39 199
EE-ELE		47 204 014	46 914 609	46 594 812	47 206 248	47 207 116
FI-NO4		0	0	0	0	0
NL-NO2	Ramping Losses	75 077 070	71 403 858	67 758 763	75 266 447	75 228 365
FR-BE		549 999	547 719	538 127	539 966	545 381
BE-NL		45 074 790	45 610 298	45 900 311	45 667 628	45 483 779
NL-DE		17 634 224	17 089 323	16 917 954	16 852 847	17 138 201
GB2-GB1		0	0	0	0	0
FR-GB1	Losses	9 495 549	8 306 873	8 285 040	8 301 799	8 322 893

NL-GB2	Losses	14 238 321	12 156 701	11 194 973	11 336 612	12 229 708
Topology Until Oct 31						
SEA-DK2		33 350 919	33 142 329	33 511 855	33 491 414	33 522 614
SEA-DK1A	Ramping Losses	16 772 473	15 245 738	14 976 996	16 837 158	16 872 241
NO1-SEA		20 597 872	20 574 424	20 962 885	20 524 522	20 539 724
SE-SEA		140 613	143 496	136 136	146 188	145 866
SE-FI	Losses	8 839 607	8 105 072	7 938 363	8 852 687	8 853 680
NO3-SE		2 382 443	2 222 629	2 187 359	2 368 066	2 372 869
SE-FIA		20 391 397	22 132 820	22 394 755	20 412 527	20 417 124
DE-SE	Ramping Losses	21 758 827	19 902 414	19 564 222	19 522 285	19 893 904
NO4-SE		2 612 870	2 480 353	2 442 068	2 600 960	2 603 636
SE-PL	Ramping Losses	8 390 175	7 625 531	7 383 460	8 400 016	8 399 045
Topology After Nov 1						
NO1-SE3		3 421 862	3 568 232	3 665 841	3 402 294	3 404 951
NO3-SE2		383 923	368 972	368 002	381 437	381 637
NO4-SE1		1 105 517	1 078 132	1 082 068	1 099 816	1 100 587
NO4-SE2		197 428	192 787	193 463	196 428	196 566
SE1-FI		553 563	699 979	749 704	565 004	565 266
SE1-SE2		0	0	0	0	0
SE2-SE3		7 336 333	8 350 430	8 510 311	7 251 269	7 262 462
SE3-FI	Losses	555 312	484 876	464 966	547 242	547 578
SE3-SE4		20 906 290	20 379 891	20 305 076	20 209 701	20 218 027
SE4-DK2		356 866	389 254	475 267	376 208	373 915
SE4-PL	Ramping Losses	1 949 269	1 696 862	1 613 007	1 962 198	1 966 282
DE-SE4	Ramping Losses	5 903 733	5 243 959	5 096 333	5 239 127	5 364 562
DK1A-SE3	Ramping Losses	725 163	603 979	632 241	718 447	719 625

Table 18: Total Gross Congestion Rent

Below are the yearly totals of **Net Congestion Rent** for each interconnector.

Total Net Congestion Rent	Ramping / Neg. ATC	Run#1	Run#2	Run#3	Run#4	Run#5
DE-FR		75 052 596	75 359 931	75 613 263	75 377 712	75 308 303
DK1A-DK1	Ramping	770 792	793 884	818 860	801 257	798 097
NO2-NO1		8 084 509	7 998 653	7 811 554	8 112 837	8 115 444
DE-DK1		21 622 895	21 304 556	21 062 020	21 777 966	21 709 836
DE-DK2	Ramping Losses	14 771 881	15 522 881	15 539 560	14 767 385	14 719 465
NO1-NO5		2 877 866	2 890 238	2 880 169	2 861 820	2 866 466
NO2-NO5		3 427 770	3 400 642	3 352 071	3 423 501	3 426 494
NO2-DK1A	Ramping Losses	56 965 726	58 780 981	59 827 595	56 987 184	57 061 681
NO1-NO3	NegativeATC	174 410	176 083	172 121	169 565	169 837
NO3-NO4		1 106 569	1 086 455	1 084 257	1 102 291	1 102 842
DK1-DK2	Ramping Losses	2 525 567	3 547 208	3 680 014	2 445 733	2 433 490
EE-FI	Losses	14 472 006	13 848 582	13 201 301	14 464 974	14 468 682
EE-ELI		39 199	39 285	41 450	39 199	39 199
EE-ELE		47 204 014	46 914 609	46 594 812	47 206 248	47 207 116
FI-NO4		0	0	0	0	0
NL-NO2	Ramping	66 777 660	67 402 665	67 758 763	66 983 813	66 939 457

	Losses					
FR-BE		549 999	547 719	538 127	539 966	545 381
BE-NL		45 074 790	45 610 298	45 900 311	45 667 628	45 483 779
NL-DE		17 634 224	17 089 323	16 917 954	16 852 847	17 138 201
GB2-GB1		0	0	0	0	0
FR-GB1	Losses	6 040 834	7 939 666	8 285 040	8 301 799	7 955 989
NL-GB2	Losses	8 961 569	10 727 620	11 194 973	11 336 612	10 800 881
Topology Until Oct 31						
SEA-DK2		33 350 919	33 142 329	33 511 855	33 491 414	33 522 614
SEA-DK1A	Ramping Losses	13 917 587	14 675 317	14 976 996	13 910 765	13 948 807
NO1-SEA		20 597 872	20 574 424	20 962 885	20 524 522	20 539 724
SE-SEA		140 613	143 496	136 136	146 188	145 866
SE-FI	Losses	5 771 964	7 893 541	7 938 363	5 742 726	5 751 435
NO3-SE		2 382 443	2 222 629	2 187 359	2 368 066	2 372 869
SE-FIA		20 391 397	22 132 820	22 394 755	20 412 527	20 417 124
DE-SE	Ramping Losses	19 519 213	19 552 819	19 564 222	19 522 285	19 592 397
NO4-SE		2 612 870	2 480 353	2 442 068	2 600 960	2 603 636
SE-PL	Ramping Losses	6 843 720	7 287 171	7 383 460	6 852 518	6 851 663
Topology After Nov 1						
NO1-SE3		3 421 862	3 568 232	3 665 841	3 402 294	3 404 951
NO3-SE2		383 923	368 972	368 002	381 437	381 637
NO4-SE1		1 105 517	1 078 132	1 082 068	1 099 816	1 100 587
NO4-SE2		197 428	192 787	193 463	196 428	196 566
SE1-FI		553 563	699 979	749 704	565 004	565 266
SE1-SE2		0	0	0	0	0
SE2-SE3		7 336 333	8 350 430	8 510 311	7 251 269	7 262 462
SE3-FI	Losses	261 478	458 059	464 966	254 327	254 246
SE3-SE4		20 906 290	20 379 891	20 305 076	20 209 701	20 218 027
SE4-DK2		356 866	389 254	475 267	376 208	373 915
SE4-PL	Ramping Losses	1 450 320	1 585 296	1 613 007	1 459 563	1 463 570
DE-SE4	Ramping Losses	5 138 536	5 120 644	5 096 333	5 239 127	5 261 371
DK1A-SE3	Ramping Losses	319 498	536 948	632 241	308 277	307 836

Table 19: Total Net Congestion Rent

Below are the yearly totals of the **Positive** part of **Net Congestion Rent** for each interconnector.
Example. In Run#1, the sum of DE-FR congestion rent over hours when this congestion rent is positive amounts to € 75 052 596.

Positive Net Congestion Rent	Ramping / Neg. ATC	Run#1	Run#2	Run#3	Run#4	Run#5
DE-FR		75 052 596	75 359 931	75 613 263	75 377 712	75 308 303
DK1A-DK1	Ramping	852 962	895 297	940 679	894 180	889 187
NO2-NO1		8 084 509	7 998 653	7 811 554	8 112 837	8 115 444
DE-DK1		21 622 895	21 304 556	21 062 020	21 777 966	21 709 836
DE-DK2	Ramping Losses	16 596 627	15 859 598	15 539 562	16 549 467	16 552 746
NO1-NO5		2 877 866	2 890 238	2 880 169	2 861 820	2 866 466
NO2-NO5		3 427 770	3 400 642	3 352 071	3 423 501	3 426 494
NO2-DK1A	Ramping Losses	61 333 549	60 482 188	59 886 838	61 346 602	61 421 897
NO1-NO3	NegativeATC	950 978	960 510	970 818	945 520	945 793

NO3-NO4		1 106 569	1 086 455	1 084 257	1 102 291	1 102 842
DK1-DK2	Ramping Losses	3 616 829	3 547 208	3 680 017	3 545 534	3 532 393
EE-FI	Losses	16 400 102	15 036 830	13 201 302	16 399 582	16 400 564
EE-ELI		39 199	39 285	41 450	39 199	39 199
EE-ELE		47 204 014	46 914 609	46 594 812	47 206 248	47 207 116
FI-NO4		0	0	0	0	0
NL-NO2	Ramping Losses	68 069 048	67 908 525	67 782 521	68 132 270	68 116 706
FR-BE		549 999	547 719	538 127	539 966	545 381
BE-NL		45 074 790	45 610 298	45 900 311	45 667 628	45 483 780
NL-DE		17 634 224	17 089 323	16 917 955	16 852 847	17 138 202
GB2-GB1		0	0	0	0	0
FR-GB1	Losses	8 322 802	8 161 560	8 285 042	8 301 801	8 177 724
NL-GB2	Losses	11 640 877	11 351 711	11 194 974	11 336 613	11 425 513
Topology Until Oct 31						
SEA-DK2		33 350 919	33 142 329	33 511 855	33 491 414	33 522 614
SEA-DK1A	Ramping Losses	15 189 185	14 889 809	14 977 532	15 213 683	15 255 549
NO1-SEA		20 597 872	20 574 424	20 962 885	20 524 522	20 539 724
SE-SEA		140 613	143 496	136 137	146 188	145 866
SE-FI	Losses	8 048 153	7 977 413	7 938 364	8 060 152	8 060 607
NO3-SE		2 382 443	2 222 629	2 187 359	2 368 066	2 372 869
SE-FIA		20 391 397	22 132 820	22 394 755	20 412 527	20 417 124
DE-SE	Ramping Losses	20 009 877	19 616 892	19 564 749	19 522 875	19 611 629
NO4-SE		2 612 870	2 480 353	2 442 068	2 600 960	2 603 636
SE-PL	Ramping Losses	7 456 776	7 418 280	7 383 461	7 464 781	7 463 857
Topology After Nov 1						
NO1-SE3		3 421 862	3 568 232	3 665 841	3 402 294	3 404 951
NO3-SE2		383 923	368 972	368 002	381 437	381 637
NO4-SE1		1 105 517	1 078 132	1 082 068	1 099 816	1 100 587
NO4-SE2		197 428	192 787	193 463	196 428	196 566
SE1-FI		553 563	699 979	749 704	565 004	565 266
SE1-SE2		0	0	0	0	0
SE2-SE3		7 336 333	8 350 430	8 510 311	7 251 269	7 262 462
SE3-FI	Losses	497 625	476 199	464 966	490 273	490 470
SE3-SE4		20 906 290	20 379 891	20 305 076	20 209 701	20 218 027
SE4-DK2		356 866	389 254	475 267	376 208	373 915
SE4-PL	Ramping Losses	1 694 075	1 639 352	1 613 007	1 707 523	1 709 060
DE-SE4	Ramping Losses	5 367 985	5 156 835	5 096 691	5 239 440	5 277 894
DK1A-SE3	Ramping Losses	635 553	585 292	632 314	628 072	629 350

Table 20: Positive Net Congestion Rent

Below are the yearly totals of the Negative part of Net Congestion Rent for each interconnector.
Example. In Run#1, the sum of DE-FR congestion rent over hours when this congestion rent is negative amounts to 0€; which is expected since no adverse flow occurs on this interconnection.

Negative Net Congestion Rent	Ramping / Neg. ATC	Run#1	Run#2	Run#3	Run#4	Run#5
DE-FR		0	0	0	0	0
DK1A-DK1	Ramping	-82 170	-101 413	-121 820	-92 923	-91 089
NO2-NO1		0	0	0	0	0

DE-DK1		0	0	0	0	0
DE-DK2	Ramping Losses	-1 824 747	-336 717	0	-1 782 082	-1 833 281
NO1-NO5		0	0	0	0	0
NO2-NO5		0	0	0	0	0
NO2-DK1A	Ramping Losses	-4 367 823	-1 701 207	-59 243	-4 359 418	-4 360 216
NO1-NO3	NegativeATC	-776 568	-784 427	-798 697	-775 955	-775 956
NO3-NO4		0	0	0	0	0
DK1-DK2	Ramping Losses	-1 091 262	0	-3	-1 099 800	-1 098 903
EE-FI	Losses	-1 928 096	-1 188 248	0	-1 934 608	-1 931 882
EE-ELI		0	0	0	0	0
EE-ELE		0	0	0	0	0
FI-NO4		0	0	0	0	0
NL-NO2	Ramping Losses	-1 291 389	-505 860	-23 757	-1 148 457	-1 177 249
FR-BE		0	0	0	0	0
BE-NL		0	0	0	0	0
NL-DE		0	0	0	0	0
GB2-GB1		0	0	0	0	0
FR-GB1	Losses	-2 281 968	-221 894	0	0	-221 735
NL-GB2	Losses	-2 679 308	-624 091	0	0	-624 631
Topology Until Oct 31						
SEA-DK2		0	0	0	0	0
SEA-DK1A	Ramping Losses	-1 271 598	-214 492	-536	-1 302 919	-1 306 743
NO1-SEA		0	0	0	0	0
SE-SEA		0	0	0	0	0
SE-FI	Losses	-2 276 190	-83 873	0	-2 317 426	-2 309 172
NO3-SE		0	0	0	0	0
SE-FIA		0	0	0	0	0
DE-SE	Ramping Losses	-490 664	-64 073	-527	-590	-19 232
NO4-SE		0	0	0	0	0
SE-PL	Ramping Losses	-613 057	-131 109	0	-612 263	-612 194
Topology After Nov 1						
NO1-SE3		0	0	0	0	0
NO3-SE2		0	0	0	0	0
NO4-SE1		0	0	0	0	0
NO4-SE2		0	0	0	0	0
SE1-FI		0	0	0	0	0
SE1-SE2		0	0	0	0	0
SE2-SE3		0	0	0	0	0
SE3-FI	Losses	-236 147	-18 140	0	-235 946	-236 224
SE3-SE4		0	0	0	0	0
SE4-DK2		0	0	0	0	0
SE4-PL	Ramping Losses	-243 755	-54 056	0	-247 960	-245 490
DE-SE4	Ramping Losses	-229 449	-36 192	-358	-313	-16 524
DK1A-SE3	Ramping Losses	-316 054	-48 344	-72	-319 795	-321 514

Table 21: Negative Net Congestion Rent

Flow Result Table

The table below shows flow indicators (totals over the sample results i.e. 363 days for most interconnections). Flows are in MW (but can be seen as energy in MWh if we consider that flow values are hourly values). Number of hours is non-dimensional indicators.
In the table below, an interconnection is always defined by two bidding areas bd1 and bd2; by definition, the up direction is from bd1 to bd2 and the down direction is from bd2 to bd1 (this definition is arbitrary and does not change the conclusions which can be derived from the results).

Example. SE-FI has a direction up which is from SE to FI; and a direction down which is from SE to FI. In Run#3, the yearly total (counted over hours the interconnection exists i.e. here until Oct 31) of flow SE->FI over hours when the direction up (SE->FI) is not congested amounts to 240 085MW "in" (i.e. seen from the sending end side i.e. from SE) and to 234 323MW "out" (i.e. seen from the receiving end side i.e. from FI). In Run#3, the direction SE->FI is congested during 1656 hours; 856 hours have the direction up not congested although the SE price is lower than the FI price; 4068 hours experience a reduction of sending end flow SE->FI or FI->SE compared to Run#1; in 2568 hours, this reduction is a reduction down to zero.

Example. In Run#1, the interconnection DK1A-DK1 experience 318 hours with an increase of flow which is equal to the ramping-up constraint; and 261 hours with a decrease of flow which is equal to the ramping-down constraint. The yearly total of flow DK1->DK1A over hours when the direction down (DK1->DK1A) is congested amounts to 113 400MW (seen both from DK1 sending end or DK1A receiving end).

LINE	RUN	UPIN-NCG	UPOUT-NCG	DOWNIN-NCG	DOWNOUT-NCG	UPIN-CG	UPOUT-CG	DOWNIN-CG	DOWNOUT-CG	NBH-CG-UP	NBH-CG-DOWN	NBH-CG-TOTAL	NBH-NCG-dP-UP	NBH-NCG-dP-DOWN	NBH-NCG-dp-TOTAL	NBH-RMP-UP	NBH-RMP-DOWN	NBH-RMP-TOTAL	NBH-rF-L	NBH-zF-L
DE-FR	1	2 727 121	2 727 121	2 483 211	2 483 211	1 986 813	1 986 813	4 561 427	4 561 427	928	2 632	3 560	0	0	0	0	0	0	0	0
	2	2 723 538	2 723 538	2 452 059	2 452 059	2 027 859	2 027 859	4 627 792	4 627 792	943	2 670	3 613	0	0	0	0	0	0	0	0
	3	2 747 968	2 747 968	2 424 182	2 424 182	2 069 190	2 069 190	4 693 455	4 693 455	965	2 710	3 675	0	0	0	0	0	0	0	0
	4	2 744 641	2 744 641	2 436 342	2 436 342	2 040 300	2 040 300	4 674 899	4 674 899	953	2 697	3 650	0	0	0	0	0	0	0	0
	5	2 725 076	2 725 076	2 463 427	2 463 427	2 010 021	2 010 021	4 612 936	4 612 936	937	2 661	3 598	0	0	0	0	0	0	0	0
DK1A-DK1	1	3 131 303	3 131 303	3 064 186	3 064 186	1 957 720	1 957 720	113 400	113 400	1 507	70	1 577	126	149	275	318	261	579	0	0
	2	4 761 997	4 761 997	2 959 270	2 959 270	22 600	22 600	90 390	90 390	42	55	97	219	258	477	277	229	506	0	0
	3	4 362 697	4 362 697	2 789 074	2 789 074	20 300	20 300	49 990	49 990	39	30	69	399	438	837	268	208	476	0	0
	4	3 137 744	3 137 744	3 066 922	3 066 922	2 012 300	2 012 300	113 650	113 650	1 556	71	1 627	156	192	348	302	270	572	0	0
	5	3 140 557	3 140 557	3 069 169	3 069 169	2 005 050	2 005 050	112 350	112 350	1 551	70	1 621	156	191	347	307	268	575	0	0
SEA-DK2	1	1 128 169	1 128 169	409 729	409 729	1 919 489	1 919 489	1 086 723	1 086 723	2 617	1 695	4 312	0	0	0	0	0	0	0	0
	2	1 160 697	1 160 697	399 525	399 525	1 957 297	1 957 297	1 068 469	1 068 469	2 669	1 675	4 344	0	0	0	0	0	0	0	0
	3	803 988	803 988	473 555	473 555	2 651 954	2 651 954	1 165 112	1 165 112	3 272	1 793	5 065	0	0	0	0	0	0	0	0
	4	1 154 215	1 154 215	437 615	437 615	1 999 773	1 999 773	1 113 524	1 113 524	2 696	1 728	4 424	0	0	0	0	0	0	0	0
	5	1 153 659	1 153 659	438 123	438 123	2 002 765	2 002 765	1 112 762	1 112 762	2 699	1 728	4 427	0	0	0	0	0	0	0	0
SEA-DK1A	1	434 207	434 207	140 309	140 309	1 000 950	1 000 950	664 462	664 462	2 278	2 383	4 661	1	0	1	20	14	34	0	0
	2	421 993	413 553	101 883	99 846	875 571	858 060	569 232	557 847	2 026	2 129	4 155	2 051	1 272	3 323	17	8	25	1 824	751
	3	375 876	366 103	101 933	99 283	1 015 344	988 945	551 963	537 612	2 239	2 076	4 315	1 840	1 316	3 156	28	16	44	1 897	1 126
	4	426 139	426 139	144 492	144 492	1 058 370	1 058 370	671 327	671 327	2 377	2 400	4 777	1	0	1	21	16	37	283	49
	5	430 014	430 014	144 445	144 445	1 050 770	1 050 770	672 374	672 374	2 363	2 402	4 765	1	0	1	20	18	38	268	46
NO1-SEA	1	1 381 679	1 381 679	1 063 144	1 063 144	2 421 770	2 421 770	1 180 698	1 180 698	2 004	1 451	3 455	0	0	0	0	0	0	0	0
	2	1 394 987	1 394 987	981 338	981 338	2 513 550	2 513 550	1 279 154	1 279 154	2 088	1 538	3 626	0	0	0	0	0	0	0	0
	3	1 316 018	1 316 018	913 345	913 345	3 018 835	3 018 835	1 450 639	1 450 639	2 401	1 681	4 082	0	0	0	0	0	0	0	0
	4	1 369 655	1 369 655	1 060 137	1 060 137	2 403 210	2 403 210	1 170 335	1 170 335	1 988	1 442	3 430	0	0	0	0	0	0	0	0
	5	1 366 240	1 366 240	1 061 554	1 061 554	2 408 920	2 408 920	1 171 810	1 171 810	1 992	1 444	3 436	0	0	0	0	0	0	0	0
SE-SEA	1	2 601 784	2 601 784	2 058 257	2 058 257	128 458	128 458	50 000	50 000	392	10	402	0	0	0	0	0	0	0	0
	2	2 625 053	2 625 053	2 095 448	2 095 448	207 221	207 221	95 000	95 000	433	19	452	0	0	0	0	0	0	0	0
	3	2 617 700	2 617 700	2 070 073	2 070 073	208 105	208 105	155 000	155 000	433	31	464	0	0	0	0	0	0	0	0
	4	2 692 240	2 692 240	2 045 874	2 045 874	132 779	132 779	50 000	50 000	397	10	407	0	0	0	0	0	0	0	0
	5	2 690 790	2 690 790	2 044 546	2 044 546	131 464	131 464	50 000	50 000	395	10	405	0	0	0	0	0	0	0	0
SE-FI	1	185 860	185 860	243 766	243 766	1 222 100	1 222 100	972 400	972 400	2 846	2 392	5 238	0	0	0	0	0	0	0	0
	2	229 809	225 213	205 356	201 249	590 172	578 369	209 253	205 068	1 676	997	2 673	832	939	1 771	0	0	0	4 047	2 529
	3	240 085	234 323	199 070	194 292	581 016	567 072	200 991	196 167	1 656	981	2 637	856	951	1 807	0	0	0	4 068	2 568
	4	184 681	184 681	235 830	235 830	1 218 800	1 218 800	1 004 850	1 004 850	2 840	2 451	5 291	0	0	0	0	0	0	614	317
	5	174 440	174 440	234 536	234 536	1 236 950	1 236 950	999 350	999 350	2 873	2 441	5 314	0	0	0	0	0	0	580	311
NO2-NO1	1	4 245 083	4 245 083	1 554 594	1 554 594	3 093 400	3 093 400	16 700	16 700	1 240	16	1 256	0	0	0	0	0	0	0	0
	2	4 435 924	4 435 924	1 591 519	1 591 519	3 112 800	3 112 800	14 700	14 700	1 247	14	1 261	0	0	0	0	0	0	0	0
	3	4 837 394	4 837 394	1 417 636	1 417 636	2 949 200	2 949 200	4 700	4 700	1 181	4	1 185	0	0	0	0	0	0	0	0
	4	4 214 512	4 214 512	1 572 456	1 572 456	3 123 800	3 123 800	17 700	17 700	1 252	17	1 269	0	0	0	0	0	0	0	0
	5	4 211 047	4 211 047	1 572 186	1 572 186	3 126 000	3 126 000	17 700	17 700	1 253	17	1 270	0	0	0	0	0	0	0	0
NO3-SE	1	318 869	318 869	1 669 753	1 669 753	253 400	253 400	1 094 000	1 094 000	576	1 325	1 901	0	0	0	0	0	0	0	0
	2	322 075	322 075	1 684 004	1 684 004	245 000	245 000	1 064 500	1 064 500	562	1 296	1 858	0	0	0	0	0	0	0	0
	3	324 125	324 125	1 681 936	1 681 936	245 000	245 000	1 064 800	1 064 800	562	1 296	1 858	0	0	0	0	0	0	0	0
	4	317 120	317 120	1 675 081	1 675 081	252 200	252 200	1 089 800	1 089 800	574	1 321	1 895	0	0	0	0	0	0	0	0
	5	317 096	317 096	1 673 428	1 673 428	252 800	252 800	1 090 800	1 090 800	575	1 322	1 897	0	0	0	0	0	0	0	0

LINE	RUN	UPIN-NCG	UPOUT-NCG	DOWNIN-NCG	DOWNOUT-NCG	UPIN-CG	UPOUT-CG	DOWNIN-CG	DOWNOUT-CG	NBH-CG-UP	NBH-CG-DOWN	NBH-CG-TOTAL	NBH-NCG-dP-UP	NBH-NCG-dP-DOWN	NBH-NCG-dp-TOTAL	NBH-RMP-UP	NBH-RMP-DOWN	NBH-RMP-TOTAL	NBH-rF-L	NBH-zF-L
SE-FIA	1	1 261 321	1 261 321	1 066 167	1 066 167	1 742 991	1 742 991	787 110	787 110	1 478	835	2 313	0	0	0	0	0	0	0	0
	2	1 134 125	1 134 125	1 222 668	1 222 668	2 463 380	2 463 380	1 370 804	1 370 804	2 054	1 410	3 464	0	0	0	0	0	0	0	0
	3	1 145 874	1 145 874	1 213 902	1 213 902	2 469 202	2 469 202	1 360 119	1 360 119	2 058	1 400	3 458	0	0	0	0	0	0	0	0
	4	1 271 692	1 271 692	1 065 596	1 065 596	1 744 530	1 744 530	764 280	764 280	1 477	809	2 286	0	0	0	0	0	0	0	0
	5	1 280 579	1 280 579	1 073 571	1 073 571	1 726 449	1 726 449	762 725	762 725	1 463	810	2 273	0	0	0	0	0	0	0	0
DE-DK1	1	597 367	597 367	612 371	612 371	827 766	827 766	2 070 344	2 070 344	1 136	4 051	5 187	0	0	0	0	0	0	0	0
	2	580 551	580 551	709 016	709 016	796 987	796 987	2 009 630	2 009 630	1 101	3 990	5 091	0	0	0	0	0	0	0	0
	3	549 550	549 550	648 438	648 438	1 115 944	1 115 944	2 250 691	2 250 691	1 508	4 288	5 796	0	0	0	0	0	0	0	0
	4	584 916	584 916	591 493	591 493	882 001	882 001	2 169 873	2 169 873	1 207	4 196	5 403	0	0	0	0	0	0	0	0
	5	588 761	588 761	591 571	591 571	877 253	877 253	2 164 827	2 164 827	1 201	4 191	5 392	0	0	0	0	0	0	0	0
DE-DK2	1	417 537	417 537	506 416	506 416	862 200	862 200	1 506 870	1 506 870	1 783	3 010	4 793	85	63	148	121	153	274	0	0
	2	402 174	394 130	532 329	521 682	809 676	793 482	1 353 368	1 326 301	1 669	2 699	4 368	2 111	2 582	4 693	82	112	194	2 358	529
	3	346 000	337 350	495 689	483 297	547 350	533 666	1 263 909	1 232 311	1 236	2 533	3 769	2 539	2 755	5 294	52	85	137	3 836	1 491
	4	407 731	407 731	486 867	486 867	900 000	900 000	1 690 275	1 690 275	1 846	3 325	5 171	121	80	201	141	163	304	510	45
	5	404 607	404 607	485 336	485 336	903 600	903 600	1 688 820	1 688 820	1 852	3 322	5 174	119	80	199	142	166	308	476	42
DE-SE	1	37 865	37 865	85 328	85 328	570 694	570 694	1 342 988	1 342 988	3 290	4 421	7 711	34	45	79	86	84	170	0	0
	2	26 008	25 487	93 307	91 441	531 785	521 149	1 276 730	1 251 195	3 188	4 306	7 494	392	470	862	71	76	147	619	280
	3	29 286	28 584	102 236	99 782	543 171	530 135	1 276 768	1 246 126	3 204	4 309	7 513	375	466	841	73	81	154	578	285
	4	19 935	19 457	93 399	91 157	464 969	453 810	1 079 768	1 053 854	3 013	3 959	6 972	221	421	642	64	64	128	1 194	768
	5	19 217	18 832	91 236	89 411	471 054	461 633	1 095 718	1 073 804	3 028	3 987	7 015	202	393	595	64	69	133	1 144	728
NO1-NO5	1	266 195	266 195	1 264 889	1 264 889	100 100	100 100	1 210 050	1 210 050	212	2 024	2 236	0	0	0	0	0	0	0	0
	2	260 404	260 404	1 270 898	1 270 898	97 600	97 600	1 227 200	1 227 200	207	2 048	2 255	0	0	0	0	0	0	0	0
	3	258 899	258 899	1 237 499	1 237 499	94 700	94 700	1 278 900	1 278 900	202	2 124	2 326	0	0	0	0	0	0	0	0
	4	265 824	265 824	1 269 615	1 269 615	99 800	99 800	1 208 550	1 208 550	211	2 022	2 233	0	0	0	0	0	0	0	0
	5	267 444	267 444	1 269 619	1 269 619	99 800	99 800	1 208 550	1 208 550	211	2 022	2 233	0	0	0	0	0	0	0	0
NO2-NO5	1	352 608	352 608	297 302	297 302	825 650	825 650	771 150	771 150	1 472	2 642	4 114	0	0	0	0	0	0	0	0
	2	364 664	364 664	303 979	303 979	810 550	810 550	762 000	762 000	1 446	2 609	4 055	0	0	0	0	0	0	0	0
	3	367 115	367 115	327 518	327 518	788 950	788 950	724 450	724 450	1 403	2 513	3 916	0	0	0	0	0	0	0	0
	4	354 312	354 312	294 264	294 264	829 650	829 650	773 950	773 950	1 480	2 642	4 122	0	0	0	0	0	0	0	0
	5	353 617	353 617	295 165	295 165	829 300	829 300	772 350	772 350	1 478	2 638	4 116	0	0	0	0	0	0	0	0
NO2-DK1A	1	636 747	636 747	521 681	521 681	3 111 930	3 111 930	2 101 500	2 101 500	3 802	2 641	6 443	42	25	67	245	188	433	0	0
	2	726 576	712 044	510 245	500 040	2 740 182	2 685 378	1 924 230	1 885 745	3 322	2 412	5 734	1 828	1 579	3 407	122	98	220	2 674	664
	3	736 908	708 905	449 972	432 873	2 180 021	2 097 180	1 711 409	1 646 375	2 683	2 160	4 843	2 455	1 842	4 297	156	104	260	3 884	1 691
	4	641 255	641 255	521 686	521 686	3 116 430	3 116 430	2 093 800	2 093 800	3 807	2 633	6 440	38	26	64	239	189	428	584	55
	5	637 490	637 490	523 909	523 909	3 120 380	3 120 380	2 091 850	2 091 850	3 811	2 631	6 442	38	26	64	237	182	419	582	51
NO1-NO3[37]	1	0	0	0	0	445 550	445 550	480 150	480 150	5 157	5 169	10 326	0	0	0	0	0	0	0	0
	2	0	0	0	0	445 550	445 550	480 150	480 150	5 157	5 169	10 326	0	0	0	0	0	0	0	0
	3	0	0	0	0	445 550	445 550	480 150	480 150	5 157	5 169	10 326	0	0	0	0	0	0	0	0
	4	0	0	0	0	445 550	445 550	480 150	480 150	5 157	5 169	10 326	0	0	0	0	0	0	0	0
	5	0	0	0	0	445 550	445 550	480 150	480 150	5 157	5 169	10 326	0	0	0	0	0	0	0	0

[37] Flows on this interconnection are forced to a given value (possibly zero) every hour by means of negative ATCs; non-relevant figures are greyed.

LINE	RUN	UPIN-NCG	UPOUT-NCG	DOWNIN-NCG	DOWNOUT-NCG	UPIN-CG	UPOUT-CG	DOWNIN-CG	DOWNOUT-CG	NBH-CG-UP	NBH-CG-DOWN	NBH-CG-TOTAL	NBH-NCG-dP-UP	NBH-NCG-dP-DOWN	NBH-NCG-dp-TOTAL	NBH-RMP-UP	NBH-RMP-DOWN	NBH-RMP-TOTAL	NBH-rF-L	NBH-zF-L
NO3-NO4[38]	1	10 953	10 953	2 051 568	2 051 568	10 100	10 100	455 200	455 200	7 530	611	8 141	0	0	0	0	0	0	0	0
	2	10 603	10 603	2 060 310	2 060 310	9 600	9 600	445 850	445 850	7 523	600	8 123	0	0	0	0	0	0	0	0
	3	10 792	10 792	2 059 189	2 059 189	9 700	9 700	447 000	447 000	7 525	602	8 127	0	0	0	0	0	0	0	0
	4	11 019	11 019	2 054 026	2 054 026	10 100	10 100	449 950	449 950	7 530	605	8 135	0	0	0	0	0	0	0	0
	5	10 981	10 981	2 053 390	2 053 390	10 100	10 100	451 750	451 750	7 530	607	8 137	0	0	0	0	0	0	0	0
NO4-SE	1	444 843	444 843	568 241	568 241	529 500	529 500	417 016	417 016	1 160	655	1 815	0	0	0	0	0	0	0	0
	2	451 462	451 462	566 272	566 272	524 850	524 850	401 566	401 566	1 150	632	1 782	0	0	0	0	0	0	0	0
	3	450 784	450 784	568 277	568 277	528 100	528 100	404 016	404 016	1 154	636	1 790	0	0	0	0	0	0	0	0
	4	440 055	440 055	567 752	567 752	528 900	528 900	414 216	414 216	1 157	651	1 808	0	0	0	0	0	0	0	0
	5	441 270	441 270	568 450	568 450	529 250	529 250	414 216	414 216	1 158	651	1 809	0	0	0	0	0	0	0	0
DK1-DK2	1	997 985	997 985	146 091	146 091	767 560	767 560	11 050	11 050	1 955	390	2 345	55	75	130	34	58	92	0	0
	2	942 337	923 490	113 335	111 068	536 744	526 009	12 087	11 845	1 508	390	1 898	4 617	2 591	7 208	7	22	29	3 419	945
	3	1 040 746	1 025 134	498 125	490 654	956 350	942 005	208 343	205 218	2 228	728	2 956	3 858	2 280	6 138	70	78	148	2 423	743
	4	1 014 505	1 014 505	157 325	157 325	770 240	770 240	10 450	10 450	1 957	389	2 346	72	97	169	47	68	115	700	160
	5	1 008 518	1 008 518	157 738	157 738	771 610	771 610	10 450	10 450	1 959	389	2 348	71	96	167	48	70	118	696	147
SE-PL	1	374 054	374 054	40 861	40 861	643 527	643 527	228 453	228 453	3 294	4 423	7 717	6	10	16	3	9	12	0	0
	2	376 068	368 547	35 469	34 759	598 751	586 776	220 042	215 641	3 171	4 360	7 531	1 637	442	2 079	1	3	4	1 557	212
	3	387 491	377 417	34 989	34 079	573 283	558 378	215 945	210 330	3 113	4 339	7 452	1 697	455	2 152	1	3	4	1 689	281
	4	372 896	372 896	39 274	39 274	646 071	646 071	229 528	229 528	3 303	4 427	7 730	7	11	18	4	9	13	333	21
	5	373 695	373 695	39 401	39 401	644 730	644 730	229 834	229 834	3 300	4 428	7 728	7	11	18	4	9	13	327	17
EE-FI	1	420 896	420 896	299 124	299 124	1 235 996	1 235 996	156 285	156 285	3 994	792	4 786	0	0	0	0	0	0	0	0
	2	458 711	449 536	292 098	286 256	1 182 356	1 158 709	149 049	146 068	3 778	763	4 541	2 584	1 983	4 567	0	0	0	2 405	166
	3	511 303	484 664	285 625	271 201	1 090 164	1 033 366	142 591	135 390	3 422	733	4 155	2 925	2 030	4 955	0	0	0	3 317	446
	4	422 048	422 048	299 923	299 923	1 233 881	1 233 881	155 935	155 935	3 988	791	4 779	0	0	0	0	0	0	286	9
	5	422 220	422 220	299 414	299 414	1 233 866	1 233 866	156 285	156 285	3 988	792	4 780	0	0	0	0	0	0	277	9
EE-ELI[39]	1	0	0	552 897	552 897	0	0	8 350	8 350	8 712	24	8 736	0	0	0	0	0	0	0	0
	2	0	0	557 854	557 854	0	0	8 350	8 350	8 712	24	8 736	0	0	0	0	0	0	0	0
	3	0	0	563 819	563 819	0	0	9 100	9 100	8 712	26	8 738	0	0	0	0	0	0	0	0
	4	0	0	552 916	552 916	0	0	8 350	8 350	8 712	24	8 736	0	0	0	0	0	0	0	0
	5	0	0	552 876	552 876	0	0	8 350	8 350	8 712	24	8 736	0	0	0	0	0	0	0	0
EE-ELE[40]	1	1 417 514	1 417 514	0	0	655 984	655 984	0	0	1 435	8 712	10 147	0	0	0	0	0	0	0	0
	2	1 425 561	1 425 561	0	0	646 088	646 088	0	0	1 417	8 712	10 129	0	0	0	0	0	0	0	0
	3	1 442 165	1 442 165	0	0	627 508	627 508	0	0	1 381	8 712	10 093	0	0	0	0	0	0	0	0
	4	1 416 988	1 416 988	0	0	656 864	656 864	0	0	1 437	8 712	10 149	0	0	0	0	0	0	0	0
	5	1 416 933	1 416 933	0	0	656 864	656 864	0	0	1 437	8 712	10 149	0	0	0	0	0	0	0	0

[38] Low values of flows in the up direction (from NO3 to NO4) are due to frequent zero up capacity; non-relevant figures are greyed.
[39] Capacities up (from EE to ELI) are always zero; which artificially makes the line congested in the up direction; non-relevant figures are greyed.
[40] Capacities down (from ELE to EE) are always zero; which artificially makes the line congested in the down direction; non-relevant figures are greyed.

LINE	RUN	UPIN-NCG	UPOUT-NCG	DOWNIN-NCG	DOWNOUT-NCG	UPIN-CG	UPOUT-CG	DOWNIN-CG	DOWNOUT-CG	NBH-CG-UP	NBH-CG-DOWN	NBH-CG-TOTAL	NBH-NCG-dP-UP	NBH-NCG-dP-DOWN	NBH-NCG-dp-TOTAL	NBH-RMP-UP	NBH-RMP-DOWN	NBH-RMP-TOTAL	NBH-rF-L	NBH-zF-L
FI-NO4[41]	1	0	0	0	0	0	0	0	0	8 712	8 712	17 424	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	8 712	8 712	17 424	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	8 712	8 712	17 424	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	8 712	8 712	17 424	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	8 712	8 712	17 424	0	0	0	0	0	0	0	0
NL-NO2[42]	1	129 125	129 125	141 999	141 999	1 346 100	1 346 100	3 307 800	3 307 800	3 136	5 939	9 075	116	153	269	200	226	426	0	0
	2	146 787	143 851	174 280	170 795	1 293 768	1 267 893	3 179 748	3 116 153	3 025	5 667	8 692	616	617	1 233	181	216	397	937	306
	3	153 524	147 383	182 102	174 818	1 239 300	1 189 728	3 009 625	2 889 240	2 913	5 342	8 255	736	934	1 670	193	223	416	1 471	693
	4	134 774	134 774	146 121	146 121	1 344 700	1 344 700	3 291 000	3 291 000	3 134	5 915	9 049	140	170	310	201	229	430	357	57
	5	132 277	132 277	145 141	145 141	1 346 100	1 346 100	3 295 900	3 295 900	3 136	5 922	9 058	141	172	313	199	230	429	329	55
FR-BE	1	5 090 240	5 090 240	895 280	895 280	48 979	48 979	8 936	8 936	61	9	70	0	0	0	0	0	0	0	0
	2	5 167 645	5 167 645	927 339	927 339	49 311	49 311	10 391	10 391	61	10	71	0	0	0	0	0	0	0	0
	3	5 234 947	5 234 947	977 214	977 214	64 364	64 364	10 391	10 391	68	10	78	0	0	0	0	0	0	0	0
	4	5 210 066	5 210 066	984 232	984 232	60 690	60 690	8 936	8 936	66	9	75	0	0	0	0	0	0	0	0
	5	5 151 829	5 151 829	926 438	926 438	50 721	50 721	10 391	10 391	62	10	72	0	0	0	0	0	0	0	0
BE-NL	1	1 997 680	1 997 680	1 210 163	1 210 163	2 895 665	2 895 665	534 302	534 302	2 439	447	2 886	0	0	0	0	0	0	0	0
	2	1 959 974	1 959 974	1 187 067	1 187 067	3 003 984	3 003 984	587 671	587 671	2 529	489	3 018	0	0	0	0	0	0	0	0
	3	1 922 078	1 922 078	1 179 921	1 179 921	3 122 776	3 122 776	646 586	646 586	2 627	534	3 161	0	0	0	0	0	0	0	0
	4	1 937 541	1 937 541	1 194 102	1 194 102	3 085 224	3 085 224	648 775	648 775	2 598	537	3 135	0	0	0	0	0	0	0	0
	5	1 968 088	1 968 088	1 199 406	1 199 406	2 986 579	2 986 579	582 698	582 698	2 515	486	3 001	0	0	0	0	0	0	0	0
NL-DE	1	2 608 596	2 608 596	4 089 389	4 089 389	786 251	786 251	1 991 168	1 991 168	320	1 190	1 510	0	0	0	0	0	0	0	0
	2	2 650 621	2 650 621	4 059 215	4 059 215	728 520	728 520	2 056 876	2 056 876	298	1 224	1 522	0	0	0	0	0	0	0	0
	3	2 670 684	2 670 684	4 047 663	4 047 663	714 200	714 200	2 162 711	2 162 711	292	1 274	1 566	0	0	0	0	0	0	0	0
	4	2 654 939	2 654 939	4 014 256	4 014 256	713 647	713 647	1 992 581	1 992 581	292	1 192	1 484	0	0	0	0	0	0	0	0
	5	2 650 133	2 650 133	4 050 104	4 050 104	737 538	737 538	2 004 707	2 004 707	302	1 199	1 501	0	0	0	0	0	0	0	0
FR-GB1	1	675 812	675 812	714 110	714 110	1 033 536	1 033 536	380 437	380 437	4 655	974	5 629	0	0	0	0	0	0	0	0
	2	550 508	539 498	540 986	530 166	854 538	837 447	297 749	291 794	4 238	848	5 086	1 896	1 801	3 697	0	0	0	3 357	1 063
	3	559 324	546 387	609 368	595 273	969 152	946 736	377 649	368 914	4 382	928	5 310	1 753	1 718	3 471	0	0	0	2 762	1 065
	4	566 709	553 601	610 491	596 370	971 056	948 595	373 270	364 636	4 389	928	5 317	1 744	1 720	3 464	0	0	0	2 759	1 054
	5	546 620	535 688	539 561	528 770	859 499	842 309	296 919	290 981	4 245	849	5 094	1 891	1 797	3 688	0	0	0	3 355	1 057
NL-GB2	1	619 946	619 946	572 884	572 884	1 575 170	1 575 170	628 083	628 083	2 837	1 259	4 096	0	0	0	0	0	0	0	0
	2	522 308	511 862	410 181	401 977	1 373 692	1 346 218	495 572	485 661	2 555	1 095	3 650	1 854	1 413	3 267	0	0	0	3 087	921
	3	409 136	396 862	270 801	262 677	1 207 924	1 171 686	389 978	378 279	2 307	959	3 266	2 094	1 557	3 651	0	0	0	3 592	1 899
	4	411 703	399 352	266 138	258 154	1 221 199	1 184 563	389 371	377 690	2 324	957	3 281	2 104	1 531	3 635	0	0	0	3 571	1 887
	5	529 861	519 264	408 942	400 763	1 372 564	1 345 113	492 718	482 864	2 552	1 092	3 644	1 873	1 399	3 272	0	0	0	3 102	915
NO1-SE3	1	311 809	311 809	206 422	206 422	439 850	439 850	151 606	151 606	333	125	458	0	0	0	0	0	0	0	0
	2	402 980	402 980	195 648	195 648	489 515	489 515	160 186	160 186	370	129	499	0	0	0	0	0	0	0	0
	3	489 737	489 737	210 550	210 550	568 545	568 545	179 831	179 831	424	140	564	0	0	0	0	0	0	0	0
	4	309 739	309 739	209 808	209 808	438 605	438 605	149 386	149 386	332	123	455	0	0	0	0	0	0	0	0

[41] The FI-NO4 interconnection exists in the data but always with zero capacities up and down; non-relevant data are greyed.

[42] Capacities are sometimes zero; which artificially makes the line congested; non-relevant figures are greyed.

	5	309 530	309 530	209 186	209 186	438 605	438 605	149 386	149 386	332	123	455	0	0	0	0	0	0	0	0
LINE	RUN	UPIN-NCG	UPOUT-NCG	DOWNIN-NCG	DOWNOUT-NCG	UPIN-CG	UPOUT-CG	DOWNIN-CG	DOWNOUT-CG	NBH-CG-UP	NBH-CG-DOWN	NBH-CG-TOTAL	NBH-NCG-dP-UP	NBH-NCG-dP-DOWN	NBH-NCG-dp-TOTAL	NBH-RMP-UP	NBH-RMP-DOWN	NBH-RMP-TOTAL	NBH-rF-L	NBH-zF-L
NO3-SE2	1	180 631	180 631	84 675	84 675	119 400	119 400	81 000	81 000	241	123	364	0	0	0	0	0	0	0	0
	2	181 559	181 559	90 510	90 510	111 600	111 600	71 000	71 000	228	113	341	0	0	0	0	0	0	0	0
	3	181 582	181 582	91 430	91 430	112 200	112 200	71 000	71 000	229	113	342	0	0	0	0	0	0	0	0
	4	181 313	181 313	85 165	85 165	117 600	117 600	81 000	81 000	238	123	361	0	0	0	0	0	0	0	0
	5	182 791	182 791	85 135	85 135	116 400	116 400	81 000	81 000	236	123	359	0	0	0	0	0	0	0	0
NO4-SE1	1	88 532	88 532	41 133	41 133	495 500	495 500	70 200	70 200	779	156	935	0	0	0	0	0	0	0	0
	2	93 578	93 578	40 855	40 855	490 150	490 150	73 350	73 350	771	163	934	0	0	0	0	0	0	0	0
	3	92 769	92 769	39 668	39 668	492 100	492 100	73 350	73 350	774	163	937	0	0	0	0	0	0	0	0
	4	88 869	88 869	40 331	40 331	494 150	494 150	70 650	70 650	777	157	934	0	0	0	0	0	0	0	0
	5	89 918	89 918	40 862	40 862	493 500	493 500	70 200	70 200	776	156	932	0	0	0	0	0	0	0	0
NO4-SE2	1	3 216	3 216	4 968	4 968	129 200	129 200	11 500	11 500	1 000	48	1 048	0	0	0	0	0	0	0	0
	2	3 597	3 597	3 701	3 701	129 350	129 350	12 500	12 500	1 001	52	1 053	0	0	0	0	0	0	0	0
	3	3 778	3 778	4 067	4 067	129 350	129 350	12 000	12 000	1 001	50	1 051	0	0	0	0	0	0	0	0
	4	3 104	3 104	4 974	4 974	129 200	129 200	11 750	11 750	1 000	49	1 049	0	0	0	0	0	0	0	0
	5	3 155	3 155	4 989	4 989	129 200	129 200	11 750	11 750	1 000	49	1 049	0	0	0	0	0	0	0	0
SE1-FI	1	726 226	726 226	1 692	1 692	259 216	259 216	0	0	180	0	180	0	0	0	0	0	0	0	0
	2	739 245	739 245	104 110	104 110	263 549	263 549	8 315	8 315	183	7	190	0	0	0	0	0	0	0	0
	3	744 720	744 720	102 421	102 421	272 194	272 194	5 940	5 940	189	5	194	0	0	0	0	0	0	0	0
	4	723 993	723 993	1 525	1 525	263 491	263 491	0	0	183	0	183	0	0	0	0	0	0	0	0
	5	723 643	723 643	1 510	1 510	263 491	263 491	0	0	183	0	183	0	0	0	0	0	0	0	0
SE1-SE2	1	1 559 789	1 559 789	37 203	37 203	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	1 669 993	1 669 993	59 858	59 858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	1 656 729	1 656 729	60 574	60 574	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	1 556 647	1 556 647	37 553	37 553	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	1 557 471	1 557 471	37 532	37 532	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SE2-SE3	1	4 658 791	4 658 791	14 497	14 497	1 999 900	1 999 900	0	0	330	0	330	0	0	0	0	0	0	0	0
	2	4 715 664	4 715 664	37 291	37 291	2 048 300	2 048 300	0	0	338	0	338	0	0	0	0	0	0	0	0
	3	4 714 578	4 714 578	36 806	36 806	2 036 200	2 036 200	0	0	336	0	336	0	0	0	0	0	0	0	0
	4	4 653 400	4 653 400	14 481	14 481	1 999 900	1 999 900	0	0	330	0	330	0	0	0	0	0	0	0	0
	5	4 654 308	4 654 308	14 486	14 486	1 999 900	1 999 900	0	0	330	0	330	0	0	0	0	0	0	0	0
SE2-FI	1	51 957	51 957	191 773	191 773	4 500	4 500	62 400	62 400	41	137	178	0	0	0	0	0	0	0	0
	2	26 305	25 778	72 530	71 079	510	500	45 543	44 632	36	110	146	128	266	394	0	0	0	656	391
	3	27 429	26 771	73 041	71 288	512	500	41 409	40 415	36	105	141	133	267	400	0	0	0	647	406
	4	51 478	51 478	192 787	192 787	4 500	4 500	60 750	60 750	41	134	175	0	0	0	0	0	0	128	2
	5	51 751	51 751	192 382	192 382	4 500	4 500	61 300	61 300	41	135	176	0	0	0	0	0	0	122	2
SE3-SE4	1	2 957 319	2 957 319	7 863	7 863	1 864 970	1 864 970	0	0	472	0	472	0	0	0	0	0	0	0	0
	2	2 720 345	2 720 345	6 714	6 714	2 199 090	2 199 090	0	0	548	0	548	0	0	0	0	0	0	0	0
	3	2 578 545	2 578 545	12 499	12 499	2 432 310	2 432 310	0	0	603	0	603	0	0	0	0	0	0	0	0
	4	2 975 381	2 975 381	7 181	7 181	1 832 970	1 832 970	0	0	465	0	465	0	0	0	0	0	0	0	0
	5	2 992 762	2 992 762	7 197	7 197	1 817 470	1 817 470	0	0	461	0	461	0	0	0	0	0	0	0	0
SE4-DK2	1	655 506	655 506	84 197	84 197	39 800	39 800	20 281	20 281	49	25	74	0	0	0	0	0	0	0	0
	2	754 071	754 071	70 673	70 673	54 600	54 600	24 603	24 603	69	29	98	0	0	0	0	0	0	0	0
	3	715 451	715 451	94 280	94 280	204 700	204 700	28 631	28 631	185	34	219	0	0	0	0	0	0	0	0
	4	718 925	718 925	85 779	85 779	55 900	55 900	23 719	23 719	63	29	92	0	0	0	0	0	0	0	0
	5	717 345	717 345	84 445	84 445	55 900	55 900	24 590	24 590	63	30	93	0	0	0	0	0	0	0	0
SE4-PL	1	183 678	183 678	10 831	10 831	247 800	247 800	9 788	9 788	735	1 096	1 831	1	8	9	5	4	9	0	0

	2	185 895	182 177	8 218	8 054	234 192	229 508	9 148	8 965	704	1 092	1 796	625	131	756	3	4	7	517	38
	3	185 797	180 967	8 258	8 043	229 535	223 567	8 570	8 347	692	1 090	1 782	637	133	770	2	4	6	556	51
	4	185 336	185 336	10 693	10 693	249 600	249 600	9 584	9 584	738	1 094	1 832	1	8	9	5	4	9	114	0
	5	184 779	184 779	10 757	10 757	250 200	250 200	9 584	9 584	739	1 094	1 833	1	8	9	5	4	9	116	0
DE-SE4	1	4 078	4 078	50 740	50 740	29 543	29 543	661 040	661 040	140	1 141	1 281	10	11	21	29	33	62	0	0
	2	3 031	2 970	52 091	51 050	22 087	21 645	643 350	630 483	123	1 112	1 235	75	196	271	28	33	61	183	46
	3	4 947	4 828	54 632	53 321	22 132	21 601	649 450	633 863	122	1 122	1 244	77	185	262	28	27	55	161	48
	4	2 690	2 625	80 314	78 386	16 582	16 184	524 590	512 000	103	914	1 017	23	260	283	32	28	60	431	179
	5	2 108	2 065	79 863	78 266	17 366	17 019	529 470	518 881	105	922	1 027	22	252	274	34	25	59	422	177
DK1A-SE3	1	91 742	91 742	137 431	137 431	31 054	31 054	140 920	140 920	115	302	417	0	0	0	7	9	16	0	0
	2	48 715	47 740	128 295	125 729	6 814	6 678	103 359	101 292	82	234	316	541	668	1 209	2	6	8	732	265
	3	51 204	49 872	98 506	95 945	26 407	25 720	184 540	179 742	108	368	476	505	543	1 048	1	3	4	639	361
	4	90 998	90 998	133 703	133 703	33 200	33 200	149 080	149 080	121	314	435	0	0	0	6	11	17	164	24
	5	92 377	92 377	133 935	133 935	32 866	32 866	149 320	149 320	120	316	436	0	0	0	8	10	18	158	26
LINE	RUN	UPIN-NCG	UPOUT-NCG	DOWNIN-NCG	DOWNOUT-NCG	UPIN-CG	UPOUT-CG	DOWNIN-CG	DOWNOUT-CG	NBH-CG-UP	NBH-CG-DOWN	NBH-CG-TOTAL	NBH-NCG-dP-UP	NBH-NCG-dP-DOWN	NBH-NCG-dp-TOTAL	NBH-RMP-UP	NBH-RMP-DOWN	NBH-RMP-TOTAL	NBH-rF-L	NBH-zF-L

Table 22: Flow Indicators

Net Position Table

The table below shows the yearly sum of net positions in MWh for each bidding area. The Total Pos NP (resp. Total Neg NP) represents the total exporting (resp. importing) net position over hours which have an exporting (resp. importing) net position. The Total NP represents the sum of exporting and importing net positions: it is positive (resp. negative) when yearly net position is exporting (resp. negative).

The table allows seeing whether a bidding area is exporting or importing on a yearly basis because it follows the same trend every hour or because exporting and importing net positions are balanced over the year.

Example. In Run#1, the sum over hours when FR is exporting amounts to 11 672 025MWh exporting exchanges; similarly, FR imports 4 491 516MWh over the other hours. The total yearly exchange amounts to an exporting net position of 7 180 509MWh; FR exports 11 004 354MWh to other CWE bidding areas and imports 4 438 647MWh from other CWE bidding areas.

BIDDINGAREA	Net Position	RUN#1	RUN#2	RUN#3	RUN#4	RUN#5
FR	Total Pos NP	11 672 025	11 663 264	11 645 067	11 641 248	11 656 884
	Total Neg NP	-4 491 516	-4 472 498	-4 468 592	-4 460 602	-4 463 528
	Total NP	7 180 509	7 190 765	7 176 475	7 180 647	7 193 356
FR-NWE NP	Total Pos NP	11 004 354	11 113 876	11 244 221	11 236 946	11 107 705
	Total Neg NP	-4 438 647	-4 506 196	-4 632 035	-4 633 058	-4 500 718
	Total NP	6 565 707	6 607 680	6 612 186	6 603 888	6 606 987
DE	Total Pos NP	8 711 106	8 705 685	8 694 592	8 694 687	8 705 965
	Total Neg NP	-11 845 148	-11 715 688	-11 659 029	-11 777 816	-11 787 041
	Total NP	-3 134 042	-3 010 004	-2 964 437	-3 083 129	-3 081 076
DE-NWE NP	Total Pos NP	8 925 833	8 947 155	9 003 023	8 876 677	8 895 861
	Total Neg NP	-8 570 827	-8 538 659	-8 478 012	-8 564 724	-8 569 987
	Total NP	355 005	408 496	525 011	311 952	325 874
EE	Total Pos NP	2 728 650	2 728 678	2 705 378	2 727 359	2 727 668
	Total Neg NP	-14 917	-14 491	-13 749	-14 702	-14 710
	Total NP	2 713 733	2 714 187	2 691 629	2 712 657	2 712 959
ELE	Total Pos NP	0	0	0	0	0
	Total Neg NP	-2 073 498	-2 071 649	-2 069 673	-2 073 852	-2 073 797
	Total NP	-2 073 498	-2 071 649	-2 069 673	-2 073 852	-2 073 797
ELI	Total Pos NP	561 247	566 204	572 919	561 266	561 226
	Total Neg NP	0	0	0	0	0
	Total NP	561 247	566 204	572 919	561 266	561 226
SE1	Total Pos NP	2 034 653	2 031 988	2 033 846	2 034 037	2 034 226
	Total Neg NP	-1 017	-1 006	-990	-1 022	-1 019
	Total NP	2 033 636	2 030 982	2 032 857	2 033 015	2 033 207
SE2	Total Pos NP	4 871 304	4 868 143	4 869 403	4 871 397	4 871 111
	Total Neg NP	0	0	0	0	0
	Total NP	4 871 304	4 868 143	4 869 403	4 871 397	4 871 111
SE3	Total Pos NP	296 282	296 379	296 402	296 291	296 281
	Total Neg NP	-2 561 842	-2 558 653	-2 556 227	-2 562 065	-2 561 949
	Total NP	-2 265 560	-2 262 274	-2 259 825	-2 265 774	-2 265 668

SE4	Total Pos NP	0	0	0	0	0
	Total Neg NP	-3 134 580	-3 125 433	-3 124 520	-3 135 088	-3 133 939
	Total NP	-3 134 580	-3 125 433	-3 124 520	-3 135 088	-3 133 939
DK1	Total Pos NP	3 228 486	3 223 013	3 230 687	3 225 216	3 225 661
	Total Neg NP	-2 273 936	-2 260 675	-2 239 760	-2 283 269	-2 287 425
	Total NP	954 549	962 338	990 927	941 946	938 236
DK2	Total Pos NP	415 019	426 250	426 396	415 088	415 212
	Total Neg NP	-3 431 908	-3 415 637	-3 413 001	-3 430 823	-3 430 952
	Total NP	-3 016 889	-2 989 388	-2 986 605	-3 015 735	-3 015 740
DK1A	Total Pos NP	0	0	0	0	0
	Total Neg NP	0	0	0	0	0
	Total NP	0	0	0	0	0
SE	Total Pos NP	7 254 644	7 260 902	7 254 200	7 248 158	7 249 483
	Total Neg NP	-1 519 408	-1 480 604	-1 474 100	-1 511 226	-1 511 384
	Total NP	5 735 236	5 780 298	5 780 100	5 736 931	5 738 099
SEA	Total Pos NP	0	0	0	0	0
	Total Neg NP	0	0	0	0	0
	Total NP	0	0	0	0	0
FI	Total Pos NP	2 115 606	2 064 086	2 054 473	2 116 441	2 116 636
	Total Neg NP	-5 445 951	-5 422 764	-5 408 051	-5 454 060	-5 453 452
	Total NP	-3 330 345	-3 358 678	-3 353 578	-3 337 619	-3 336 816
FIA	Total Pos NP	0	0	0	0	0
	Total Neg NP	0	0	0	0	0
	Total NP	0	0	0	0	0
NO1	Total Pos NP	3 508 728	3 508 257	3 508 897	3 502 645	3 504 329
	Total Neg NP	-9 465 923	-9 440 750	-9 431 784	-9 466 398	-9 465 656
	Total NP	-5 957 195	-5 932 492	-5 922 888	-5 963 753	-5 961 326
NO2	Total Pos NP	9 771 226	9 848 694	9 914 570	9 759 659	9 763 013
	Total Neg NP	-794 162	-773 698	-753 921	-795 910	-795 675
	Total NP	8 977 065	9 074 996	9 160 650	8 963 748	8 967 338
NO3	Total Pos NP	297 191	293 604	293 924	295 877	296 164
	Total Neg NP	-4 805 435	-4 794 742	-4 791 280	-4 806 948	-4 806 899
	Total NP	-4 508 244	-4 501 137	-4 497 355	-4 511 071	-4 510 735
NO4	Total Pos NP	3 798 552	3 808 572	3 812 296	3 792 609	3 794 718
	Total Neg NP	-735 103	-727 873	-731 096	-735 145	-734 833
	Total NP	3 063 449	3 080 699	3 081 200	3 057 464	3 059 885
NO5	Total Pos NP	3 346 909	3 360 578	3 370 511	3 342 997	3 343 624
	Total Neg NP	-1 348 070	-1 329 719	-1 311 808	-1 346 204	-1 348 101
	Total NP	1 998 838	2 030 859	2 058 703	1 996 793	1 995 523
PL	Total Pos NP	289 933	272 877	267 761	289 079	289 577
	Total Neg NP	-1 449 059	-1 367 008	-1 340 328	-1 453 903	-1 453 403
	Total NP	-1 159 125	-1 094 131	-1 072 566	-1 164 825	-1 163 827
GB1	Total Pos NP	1 573 248	1 378 850	1 340 364	1 331 451	1 375 240
	Total Neg NP	-1 957 831	-1 690 398	-1 603 219	-1 615 592	-1 692 994
	Total NP	-384 583	-311 548	-262 855	-284 141	-317 755
BE	Total Pos NP	2 025 402	2 016 983	2 016 108	2 010 899	2 014 259

	Total Neg NP	-3 111 526	-3 106 990	-3 109 468	-3 108 598	-3 107 417
	Total NP	-1 086 124	-1 090 007	-1 093 361	-1 097 700	-1 093 158
GB2	Total Pos NP	676 481	639 181	629 488	626 827	637 280
	Total Neg NP	-1 900 848	-1 818 170	-1 780 508	-1 789 528	-1 823 759
	Total NP	-1 224 367	-1 178 989	-1 151 020	-1 162 702	-1 186 479
NL	Total Pos NP	1 538 705	1 565 033	1 578 042	1 570 443	1 561 976
	Total Neg NP	-8 353 719	-8 329 233	-8 317 007	-8 349 171	-8 345 545
	Total NP	-6 815 014	-6 764 200	-6 738 966	-6 778 728	-6 783 569
NL-NWE NP	Total Pos NP	2 563 413	2 542 916	2 518 457	2 524 895	2 548 897
	Total Neg NP	-8 398 002	-8 469 084	-8 562 293	-8 343 035	-8 388 600
	Total NP	-5 834 589	-5 926 169	-6 043 836	-5 818 140	-5 839 703
CWE NP	Total Pos NP	5 010 852	4 942 630	4 896 045	4 967 052	4 980 326
	Total Neg NP	-8 865 523	-8 616 075	-8 516 333	-8 745 962	-8 744 774
	Total NP	-3 854 671	-3 673 445	-3 620 289	-3 778 910	-3 764 447
Nordic NP	Total Pos NP	10 798 554	10 780 780	10 814 558	10 706 387	10 719 510
	Total Neg NP	-5 377 290	-5 121 867	-4 985 491	-5 334 132	-5 340 335
	Total NP	5 421 264	5 658 913	5 829 067	5 372 256	5 379 175

Table 23: Bidding area

Price Convergence Table - Price Convergence at the ends of interconnectors

Example. In Run#1, prices in SEA and DK2 are equal in 3436 hours; which represents 47.41% of the hours which both bidding areas exist.

Interconnection	Price Convergence at Cable Ends	RUN#1	RUN#2	RUN#3	RUN#4	RUN#5
DE-FR	#hours	5557	5487	5408	5431	5502
	%	63.79%	62.98%	62.08%	62.34%	63.15%
DK1A-DK1	#hours	8372	8178	7814	8290	8292
	%	96.10%	93.87%	89.69%	95.16%	95.18%
SEA-DK2	#hours	3437	2965	2185	3327	3329
	%	47.42%	40.91%	30.15%	45.90%	45.93%
SEA-DK1A	#hours	3651	0	0	3564	3565
	%	50.37%	0.00%	0.00%	49.17%	49.19%
NO1-SEA	#hours	3970	3678	3166	3973	3971
	%	54.77%	50.75%	43.68%	54.82%	54.79%
SE-SEA	#hours	7150	7146	7142	7141	7142
	%	98.65%	98.59%	98.54%	98.52%	98.54%
SE-FI	#hours	5438	3784	3790	5439	5436
	%	75.03%	52.21%	52.29%	75.04%	75.00%
NO2-NO1	#hours	7713	7710	7723	7700	7699
	%	88.53%	88.50%	88.65%	88.38%	88.37%
NO3-SE	#hours	6345	6381	6386	6351	6350
	%	87.54%	88.04%	88.11%	87.62%	87.61%
SE-FIA	#hours	5438	3784	3790	5439	5436
	%	75.03%	52.21%	52.29%	75.04%	75.00%
FIA-FI	#hours	7248	7248	7248	7248	7248

	%	100.00%	100.00%	100.00%	100.00%	100.00%
DE-DK1	#hours	4420	3878	2916	4154	4154
	%	50.73%	44.51%	33.47%	47.68%	47.68%
DE-DK2	#hours	4828	1	1	4391	4395
	%	55.42%	0.01%	0.01%	50.40%	50.45%
DE-SE	#hours	1351	0	0	1008	1014
	%	18.64%	0.00%	0.00%	13.91%	13.99%
NO1-NO5	#hours	7161	7158	7151	7162	7161
	%	82.20%	82.16%	82.08%	82.21%	82.20%
NO2-NO5	#hours	6333	6345	6376	6323	6321
	%	72.69%	72.83%	73.19%	72.58%	72.56%
NO2-DK1A	#hours	3847	0	0	3817	3817
	%	44.16%	0.00%	0.00%	43.81%	43.81%
NO1-NO3	#hours	4784	4387	3851	4789	4789
	%	54.91%	50.36%	44.20%	54.97%	54.97%
NO3-NO4	#hours	7891	7907	7910	7898	7897
	%	90.58%	90.76%	90.79%	90.66%	90.65%
NO4-SE	#hours	6129	6169	6170	6135	6134
	%	84.56%	85.11%	85.13%	84.64%	84.63%
DK1-DK2	#hours	7342	2	1	7260	7267
	%	84.27%	0.02%	0.01%	83.33%	83.41%
SE-PL	#hours	1885	0	0	1861	1866
	%	26.01%	0.00%	0.00%	25.68%	25.75%
EE-FI	#hours	4325	0	0	4330	4329
	%	49.64%	0.00%	0.00%	49.70%	49.69%
EE-ELI	#hours	8688	8688	8686	8688	8688
	%	99.72%	99.72%	99.70%	99.72%	99.72%
EE-ELE	#hours	7278	7296	7332	7276	7276
	%	83.54%	83.75%	84.16%	83.52%	83.52%
FI-NO4	#hours	5513	4197	4203	5524	5522
	%	63.28%	48.17%	48.24%	63.41%	63.38%
NL-NO2	#hours	1233	0	0	1028	1030
	%	14.15%	0.00%	0.00%	11.80%	11.82%
FR-BE	#hours	8663	8662	8655	8658	8661
	%	99.44%	99.43%	99.35%	99.38%	99.41%
BE-NL	#hours	6055	5916	5780	5808	5935
	%	69.50%	67.91%	66.35%	66.67%	68.12%
NL-DE	#hours	7528	7526	7477	7559	7546
	%	86.41%	86.39%	85.82%	86.77%	86.62%
GB2-GB1	#hours	8712	8712	8712	8712	8712
	%	100.00%	100.00%	100.00%	100.00%	100.00%
FR-GB1	#hours	3879	0	0	0	0
	%	44.52%	0.00%	0.00%	0.00%	0.00%
NL-GB2	#hours	4225	0	0	0	0
	%	48.50%	0.00%	0.00%	0.00%	0.00%
NO1-SE3	#hours	1028	978	900	1028	1028

	%	70.22%	66.80%	61.48%	70.22%	70.22%
NO3-SE2	#hours	1216	1229	1229	1219	1221
	%	83.06%	83.95%	83.95%	83.27%	83.40%
NO4-SE1	#hours	968	981	980	974	975
	%	66.12%	67.01%	66.94%	66.53%	66.60%
NO4-SE2	#hours	968	981	980	974	975
	%	66.12%	67.01%	66.94%	66.53%	66.60%
SE1-FI	#hours	1408	1274	1270	1406	1406
	%	96.17%	87.02%	86.75%	96.04%	96.04%
SE1-SE2	#hours	1464	1464	1464	1464	1464
	%	100.00%	100.00%	100.00%	100.00%	100.00%
SE2-SE3	#hours	1343	1126	1128	1343	1342
	%	91.73%	76.91%	77.05%	91.73%	91.67%
SE3-FI	#hours	1359	979	978	1359	1358
	%	92.83%	66.87%	66.80%	92.83%	92.76%
SE3-SE4	#hours	1056	917	863	1062	1062
	%	72.13%	62.64%	58.95%	72.54%	72.54%
SE4-DK2	#hours	1405	1378	1245	1391	1390
	%	95.97%	94.13%	85.04%	95.01%	94.95%
SE4-PL	#hours	712	0	0	712	711
	%	48.63%	0.00%	0.00%	48.63%	48.57%
DE-SE4	#hours	408	0	0	207	206
	%	27.87%	0.00%	0.00%	14.14%	14.07%
DK1A-SE3	#hours	1253	0	0	1254	1253
	%	85.59%	0.00%	0.00%	85.66%	85.59%

Table 24: Interconnection

Table of Hourly Price Variations for each Run compared to Run#1

Run#2 compared to Run#1

Example. In Run#2, in FR, at least one hour experiences a decrease of price compared to Run #1 which amounts to € 4.7582 in absolute value; this amount is the minimum absolute variation which is observed. At least one hour experiences an increase of price compared to Run#1 which amounts to € 3.6144, which is the maximum absolute variation which is observed. On average, in the same given hour, prices in Run#2 are greater of € 0.0096 than in Run#1. In 98% of hours, the change in price in Run#2 compared to Run#1 remains between -€ 1.0473 and € 1.1069.

Bidding area	mean	sigma	min	max	median	1st percentile	99th percentile
FR	0.0096	0.3802	-4.7582	3.6144	0.0000	-1.0473	1.1069
DE	0.0396	0.4867	-3.7911	17.4891	0.0134	-1.0899	1.1785
EE	0.3344	1.8814	-14.8300	23.4469	0.0140	-1.9899	10.6406
ELE	0.2679	1.8413	-14.8300	23.4469	0.0058	-1.9399	10.6406
ELI	0.3344	1.8814	-14.8300	23.4469	0.0140	-1.9899	10.6406

SE1	-0.0298	0.3055	-2.2071	1.4681	0.0138	-0.9132	0.8498
SE2	-0.0298	0.3055	-2.2071	1.4681	0.0138	-0.9132	0.8498
SE3	0.0836	0.5745	-3.8610	5.3110	0.0325	-1.5438	1.7170
SE4	-0.0371	1.1369	-17.3987	4.3675	0.0199	-2.2101	2.2079
DK1	0.0638	1.1629	-4.3906	19.6639	0.0242	-2.6482	3.0138
DK2	0.2450	1.1969	-17.3987	18.5400	0.0654	-1.8430	3.1199
DK1A	0.0602	1.3489	-58.8097	19.6639	0.0274	-2.6792	2.8740
SE	0.0298	0.3913	-3.1770	3.0609	0.0211	-1.1782	1.2031
SEA	0.0249	0.5343	-4.3684	17.4457	0.0202	-1.2965	1.2633
FI	0.0049	0.5648	-2.7147	7.1231	0.0177	-1.4871	1.4474
NO1	0.0409	0.2932	-4.3617	3.2611	0.0234	-0.8348	1.0316
NO2	0.0440	0.3119	-4.3617	3.2611	0.0247	-0.8894	1.1553
NO3	0.0222	0.3291	-2.5169	3.0609	0.0110	-1.0156	1.1240
NO4	0.0219	0.3270	-5.8332	3.0609	0.0085	-1.0154	1.0979
NO5	0.0381	0.2799	-4.3617	3.2611	0.0045	-0.8105	1.0136
PL	0.1724	0.5553	-5.4828	5.0062	0.0007	-1.2598	2.0236
GB	0.0714	0.6917	-8.4873	10.5338	0.0018	-1.6012	1.6737
BE	0.0086	0.3826	-4.7582	3.6144	0.0000	-1.0565	1.1127
NL	0.0498	0.4943	-3.5012	5.6074	0.0112	-1.1859	1.3232

Table 25: Run #2 compared to Run #1

Run#3 compared to Run#1

Bidding area	mean	sigma	min	max	median	1st percentile	99th percentile
FR	0.0071	0.4646	-4.7582	3.5328	0.0000	-1.3468	1.3455
DE	0.0508	0.5989	-3.8103	20.0405	0.0187	-1.4463	1.5932
EE	0.7444	3.1932	-13.6104	36.1958	0.0333	-3.8927	13.8373
ELE	0.6083	3.0697	-13.6104	36.1958	0.0060	-3.8030	13.8373
ELI	0.7437	3.1930	-13.6104	36.1958	0.0331	-3.8927	13.8373
SE1	-0.0086	0.3922	-2.5512	3.0121	0.0246	-1.0831	1.2252
SE2	-0.0086	0.3922	-2.5512	3.0121	0.0246	-1.0831	1.2252
SE3	0.1227	0.7042	-4.2343	5.6582	0.0542	-1.8392	2.3649
SE4	-0.0168	1.2775	-17.0728	7.9881	0.0355	-2.6655	2.5742
DK1	0.1580	1.3322	-7.1243	20.0405	0.0580	-2.8469	3.4679
DK2	0.2821	1.3440	-17.0728	20.7904	0.1589	-2.2488	3.6607
DK1A	0.1564	1.5231	-58.6591	20.0405	0.0691	-2.8891	3.5718
SE	0.0399	0.4784	-4.0598	3.5467	0.0280	-1.3968	1.4863
SEA	0.0316	0.5731	-5.1834	14.6563	0.0267	-1.5864	1.5198
FI	0.0173	0.8673	-11.0697	9.0243	0.0220	-2.1923	2.4520
NO1	0.0698	0.4312	-3.6521	4.1810	0.0366	-1.1939	1.6947
NO2	0.0808	0.4758	-3.6521	4.1810	0.0404	-1.3215	2.0089
NO3	0.0338	0.3989	-2.4851	3.5467	0.0133	-1.2075	1.3346
NO4	0.0320	0.3893	-6.0329	3.5467	0.0105	-1.2077	1.3040
NO5	0.0681	0.4090	-3.6521	4.1810	0.0048	-1.1338	1.6920
PL	0.2294	0.6959	-5.4837	5.5075	0.0004	-1.5644	2.4710
GB	0.1074	0.8536	-8.4873	10.5357	0.0027	-1.9712	2.1832

BE	0.0056	0.4699	-4.7582	3.5328	0.0000	-1.3791	1.3511
NL	0.0704	0.6582	-3.3000	7.1400	0.0168	-1.6767	2.0085

Table 26: Run #3 compared to Run #1

Run#4 compared to Run#1

Bidding area	mean	sigma	min	max	median	1st percentile	99th percentile
FR	-0.0027	0.3978	-4.7582	3.6144	0.0000	-1.2046	1.2384
DE	0.0148	0.4167	-3.4894	3.1125	0.0000	-1.2147	1.3320
EE	-0.0035	0.1542	-4.6300	4.9244	0.0000	-0.5123	0.2811
ELE	-0.0031	0.1480	-4.6300	4.9244	0.0000	-0.4470	0.2183
ELI	-0.0035	0.1542	-4.6300	4.9244	0.0000	-0.5123	0.2811
SE1	-0.0090	0.0953	-1.2321	0.5264	0.0000	-0.4148	0.2911
SE2	-0.0090	0.0953	-1.2321	0.5264	0.0000	-0.4148	0.2911
SE3	-0.0189	0.1849	-1.9844	2.0119	0.0000	-0.8081	0.3379
SE4	-0.1477	0.5086	-3.9495	3.9443	0.0000	-2.0616	0.4463
DK1	-0.0047	0.4368	-3.4894	24.6228	0.0000	-1.0068	1.0430
DK2	-0.0174	0.4456	-3.9495	24.6228	0.0000	-1.4098	1.1500
DK1A	-0.0036	0.4274	-2.4184	24.6228	0.0000	-0.9667	1.0216
SE	-0.0077	0.1803	-1.9490	2.8118	0.0000	-0.7946	0.5077
SEA	-0.0062	0.1783	-1.9490	2.8118	0.0000	-0.7721	0.5312
FI	-0.0033	0.1900	-1.9490	5.7168	0.0000	-0.6675	0.4848
NO1	-0.0061	0.1277	-1.9490	1.9401	0.0000	-0.5494	0.3462
NO2	-0.0075	0.1264	-1.9490	1.9401	0.0000	-0.5494	0.3378
NO3	-0.0074	0.1556	-1.9490	2.8118	0.0000	-0.6796	0.3904
NO4	-0.0071	0.1530	-1.9490	2.8118	0.0000	-0.6675	0.3818
NO5	-0.0031	0.1176	-1.9490	1.9401	0.0000	-0.4651	0.3379
PL	-0.0204	0.1914	-3.6056	2.2800	0.0000	-0.9239	0.2389
GB	0.0993	0.8230	-8.4873	10.5357	0.0026	-1.7216	1.9504
BE	-0.0033	0.4003	-4.7582	3.6144	0.0000	-1.2273	1.2440
NL	0.0294	0.4953	-3.4894	5.6074	0.0000	-1.3485	1.6700

Table 27: Run#4 compared to Run#1

Run#5 compared to Run#1

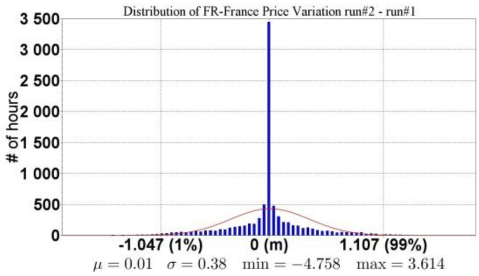
Bidding area	mean	sigma	min	max	median	1st percentile	99th percentile
FR	0.0011	0.3379	-4.7582	2.5685	0.0000	-1.0225	1.0622
DE	0.0149	0.3666	-3.5224	13.1177	0.0000	-1.0056	1.0523
EE	-0.0027	0.1338	-2.7200	4.9241	0.0000	-0.4264	0.2240
ELE	-0.0021	0.1287	-2.7200	4.9241	0.0000	-0.3606	0.1778
ELI	-0.0027	0.1338	-2.7200	4.9241	0.0000	-0.4264	0.2240
SE1	-0.0084	0.0886	-1.0377	0.4677	0.0000	-0.3816	0.2122
SE2	-0.0084	0.0886	-1.0377	0.4677	0.0000	-0.3816	0.2122
SE3	-0.0170	0.1671	-1.6599	2.2455	0.0000	-0.8956	0.2878
SE4	-0.1417	0.5617	-11.0008	3.2832	0.0000	-2.0244	0.4210
DK1	0.0059	0.5194	-3.5224	24.6223	0.0000	-0.8677	0.9015
DK2	-0.0099	0.5334	-11.0008	24.6223	0.0000	-1.1956	0.9706

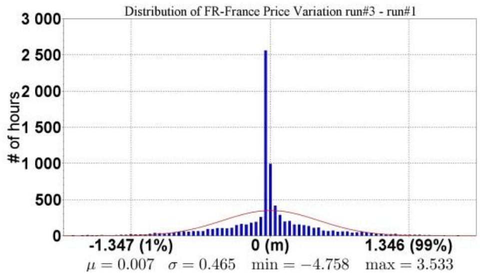
DK1A	0.0070	0.5132	-2.1546	24.6223	0.0000	-0.8467	0.8715
SE	-0.0053	0.1529	-1.5208	2.8118	0.0000	-0.6585	0.4413
SEA	-0.0037	0.1505	-1.5208	2.8118	0.0000	-0.6254	0.4668
FI	-0.0013	0.1697	-1.5208	5.7168	0.0000	-0.5501	0.4063
NO1	-0.0032	0.1074	-1.5208	1.9401	0.0000	-0.4219	0.3064
NO2	-0.0047	0.1068	-1.5208	1.9401	0.0000	-0.4228	0.2927
NO3	-0.0054	0.1329	-1.5208	2.8118	0.0000	-0.5588	0.3524
NO4	-0.0053	0.1305	-1.5208	2.8118	0.0000	-0.5509	0.3383
NO5	-0.0010	0.0992	-1.5208	1.9401	0.0000	-0.3693	0.2914
PL	-0.0178	0.1777	-5.4838	2.2575	0.0000	-0.8458	0.2100
GB	0.0669	0.6740	-8.4873	10.5338	0.0018	-1.3874	1.4774
BE	0.0006	0.3397	-4.7582	2.5685	0.0000	-1.0257	1.0663
NL	0.0243	0.3951	-3.5224	5.6074	0.0000	-1.0509	1.2244

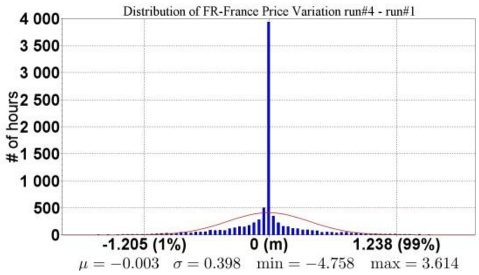
Table 28: Run#5 compared to Run#1

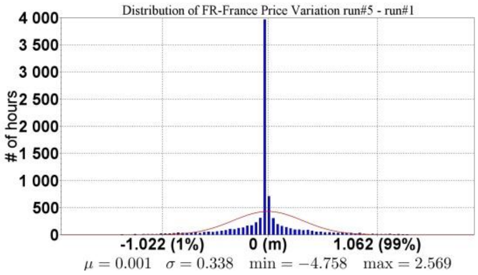
Graphs of Hourly Price Variations for each Run compared to Run#1 – per bidding area

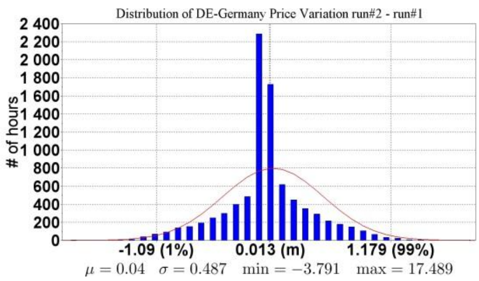
Example. In Run#2, in FR, at least one hour experiences a decrease of price compared to Run #1 which amounts to € 4.758 in absolute value; this amount is the minimum absolute variation which is observed. At least one hour experiences an increase of price compared to Run#1 which amounts to € 3.614, which is the maximum absolute variation which is observed. On average, in the same given hour, prices in Run#2 are greater of € 0.01 than in Run#1. In 98% of hours, the change in price in Run#2 compared to Run#1 remains between -€ 1.047and € 1.107. Almost 3500 hours experience a price change around 0€ in Run#2 compared to Run#1. The distribution of price changes does not look as a normal distribution.

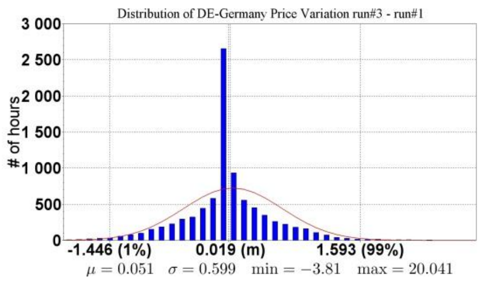


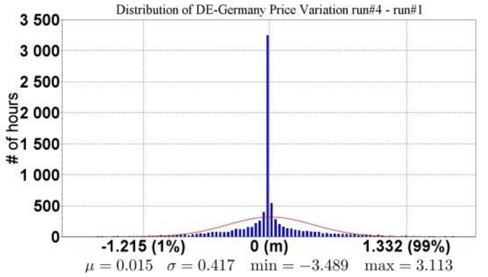




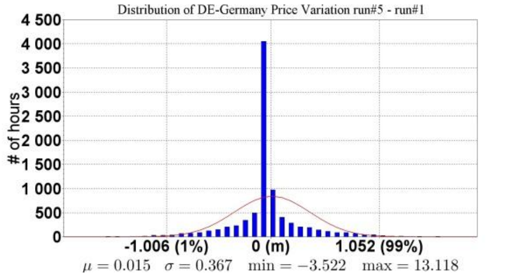




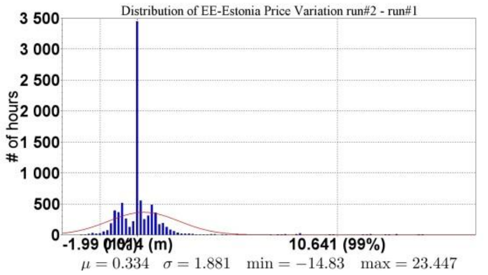




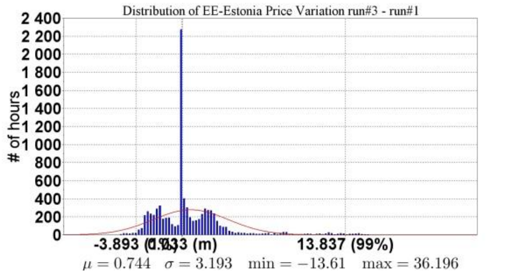
Distribution of DE-Germany Price Variation run#4 - run#1
# of hours
-1.215 (1%)
0 (m)
1.332 (99%)
$\mu = 0.015 \quad \sigma = 0.417 \quad \min = -3.489 \quad \max = 3.113$



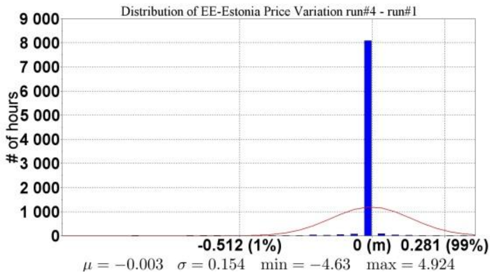
Distribution of DE-Germany Price Variation run#5 - run#1
# of hours
-1.006 (1%)
0 (m)
1.052 (99%)
$\mu = 0.015 \quad \sigma = 0.367 \quad \min = -3.522 \quad \max = 13.118$



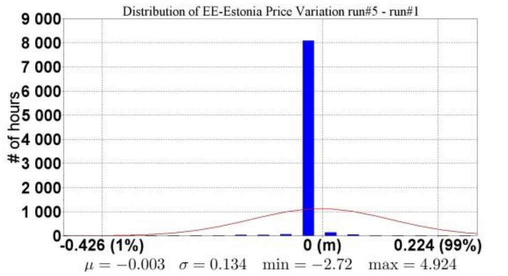
Distribution of EE-Estonia Price Variation run#2 - run#1
# of hours
10.641 (99%)
$\mu = 0.334 \quad \sigma = 1.881 \quad \min = -14.83 \quad \max = 23.447$



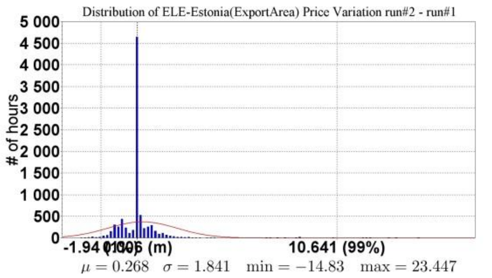
Distribution of EE-Estonia Price Variation run#3 - run#1
# of hours
13.837 (99%)
$\mu = 0.744 \quad \sigma = 3.193 \quad \min = -13.61 \quad \max = 36.196$



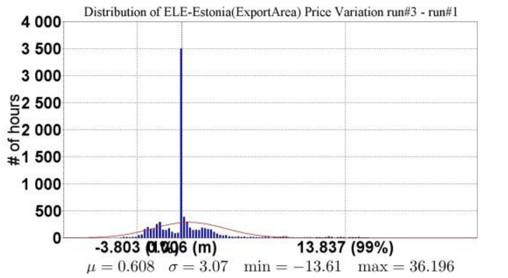
Distribution of EE-Estonia Price Variation run#4 - run#1
# of hours
-0.512 (1%)
0 (m)
0.281 (99%)
$\mu = -0.003 \quad \sigma = 0.154 \quad \min = -4.63 \quad \max = 4.924$



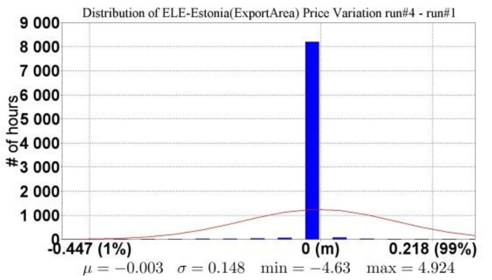
Distribution of EE-Estonia Price Variation run#5 - run#1
# of hours
-0.426 (1%)
0 (m)
0.224 (99%)
$\mu = -0.003 \quad \sigma = 0.134 \quad \min = -2.72 \quad \max = 4.924$



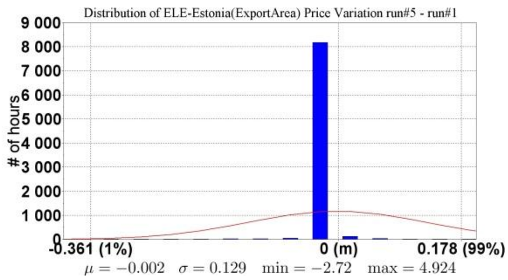
Distribution of ELE-Estonia(ExportArea) Price Variation run#2 - run#1
# of hours
10.641 (99%)
$\mu = 0.268 \quad \sigma = 1.841 \quad \min = -14.83 \quad \max = 23.447$



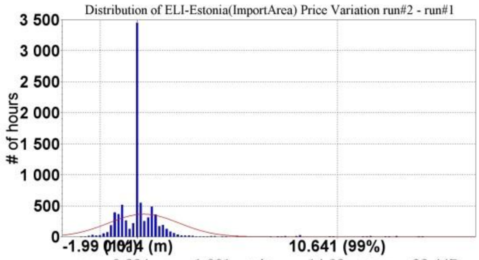
Distribution of ELE-Estonia(ExportArea) Price Variation run#3 - run#1
# of hours
13.837 (99%)
$\mu = 0.608 \quad \sigma = 3.07 \quad \min = -13.61 \quad \max = 36.196$



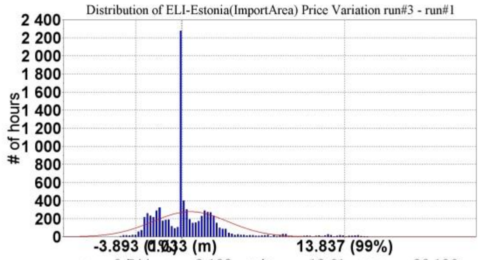
Distribution of ELE-Estonia(ExportArea) Price Variation run#4 - run#1
# of hours
0 (m)
0.218 (99%)
$\mu = -0.003 \quad \sigma = 0.148 \quad \min = -4.63 \quad \max = 4.924$



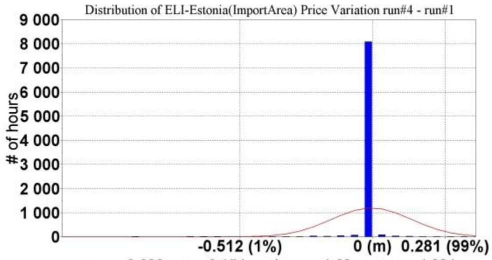
Distribution of ELE-Estonia(ExportArea) Price Variation run#5 - run#1
# of hours
0 (m)
0.178 (99%)
$\mu = -0.002 \quad \sigma = 0.129 \quad \min = -2.72 \quad \max = 4.924$



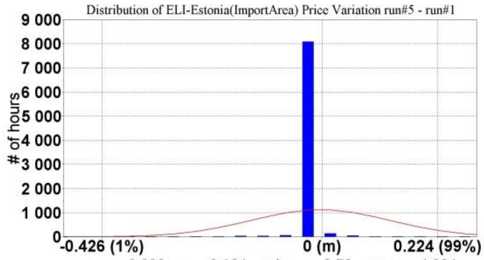
$\mu = 0.334 \quad \sigma = 1.881 \quad \min = -14.83 \quad \max = 23.447$



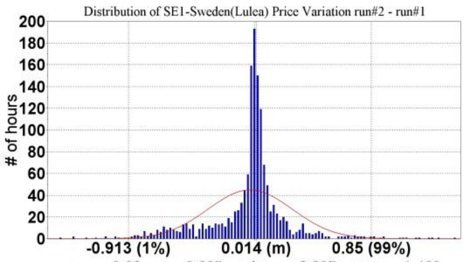
$\mu = 0.744 \quad \sigma = 3.193 \quad \min = -13.61 \quad \max = 36.196$



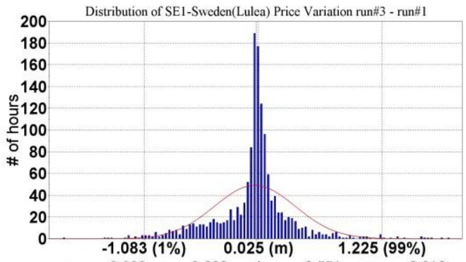
$\mu = -0.003 \quad \sigma = 0.154 \quad \min = -4.63 \quad \max = 4.924$



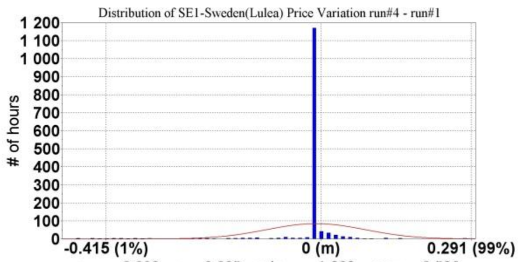
$\mu = -0.003 \quad \sigma = 0.134 \quad \min = -2.72 \quad \max = 4.924$



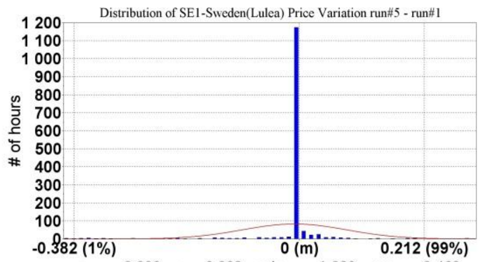
$\mu = -0.03 \quad \sigma = 0.305 \quad \min = -2.207 \quad \max = 1.468$



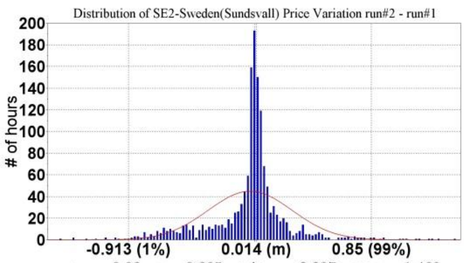
$\mu = -0.009 \quad \sigma = 0.392 \quad \min = -2.551 \quad \max = 3.012$



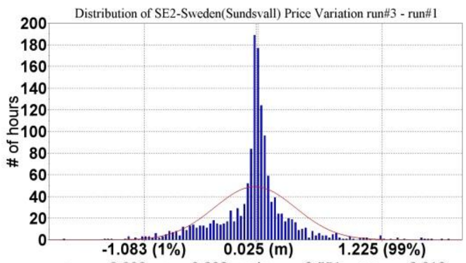
$\mu = -0.009 \quad \sigma = 0.095 \quad \min = -1.232 \quad \max = 0.526$



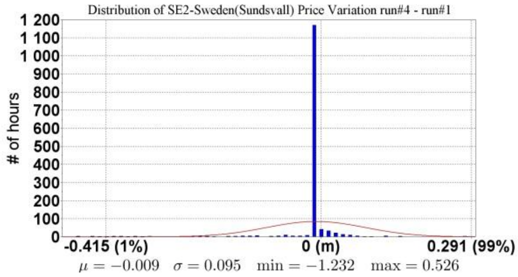
$\mu = -0.008 \quad \sigma = 0.089 \quad \min = -1.038 \quad \max = 0.468$

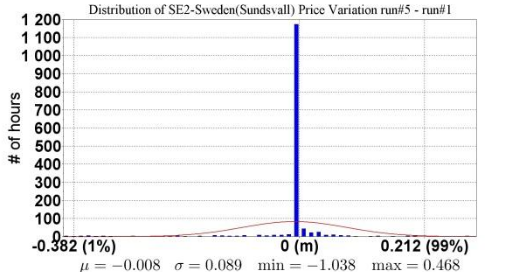


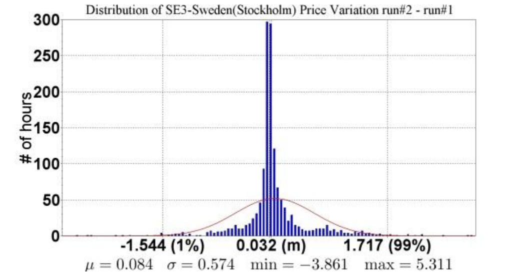
$\mu = -0.03 \quad \sigma = 0.305 \quad \min = -2.207 \quad \max = 1.468$

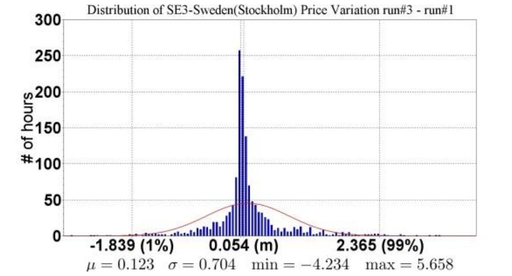


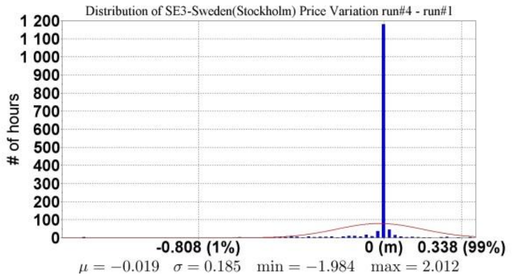
$\mu = -0.009 \quad \sigma = 0.392 \quad \min = -2.551 \quad \max = 3.012$

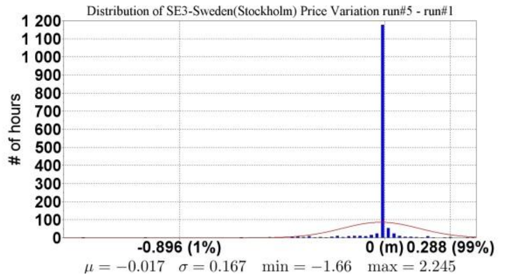

Distribution of SE2-Sweden(Sundsvall) Price Variation run#4 - run#1
# of hours
-0.415 (1%)
0 (m)
0.291 (99%)
μ = −0.009 σ = 0.095 min = −1.232 max = 0.526

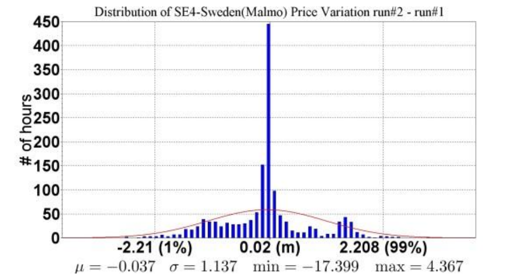

Distribution of SE2-Sweden(Sundsvall) Price Variation run#5 - run#1
# of hours
-0.382 (1%)
0 (m)
0.212 (99%)
μ = −0.008 σ = 0.089 min = −1.038 max = 0.468

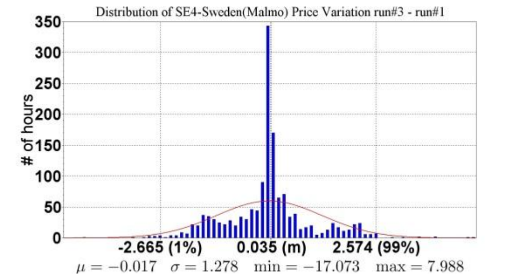

Distribution of SE3-Sweden(Stockholm) Price Variation run#2 - run#1
# of hours
-1.544 (1%)
0.032 (m)
1.717 (99%)
μ = 0.084 σ = 0.574 min = −3.861 max = 5.311

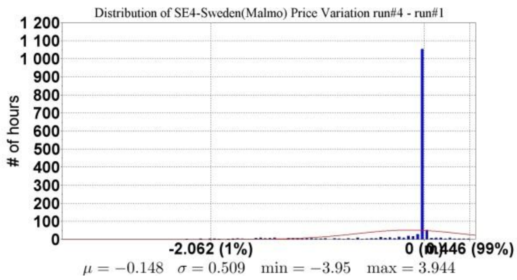

Distribution of SE3-Sweden(Stockholm) Price Variation run#3 - run#1
# of hours
-1.839 (1%)
0.054 (m)
2.365 (99%)
μ = 0.123 σ = 0.704 min = −4.234 max = 5.658

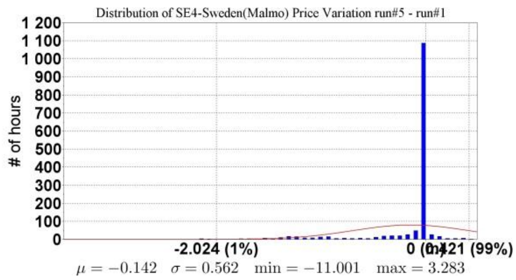

Distribution of SE3-Sweden(Stockholm) Price Variation run#4 - run#1
# of hours
-0.808 (1%)
0 (m)
0.338 (99%)
μ = −0.019 σ = 0.185 min = −1.984 max = 2.012

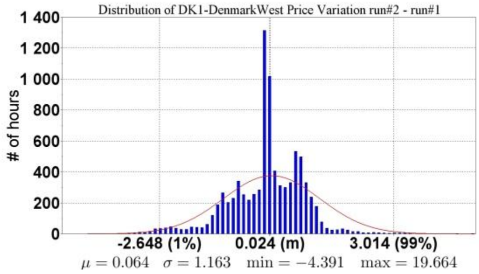

Distribution of SE3-Sweden(Stockholm) Price Variation run#5 - run#1
# of hours
-0.896 (1%)
0 (m)
0.288 (99%)
μ = −0.017 σ = 0.167 min = −1.66 max = 2.245

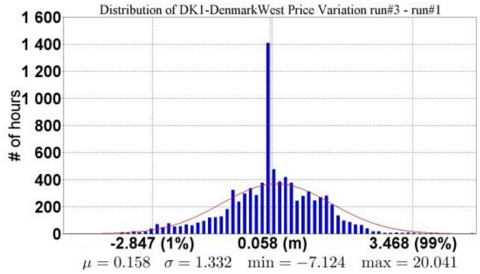

Distribution of SE4-Sweden(Malmo) Price Variation run#2 - run#1
# of hours
-2.21 (1%)
0.02 (m)
2.208 (99%)
μ = −0.037 σ = 1.137 min = −17.399 max = 4.367

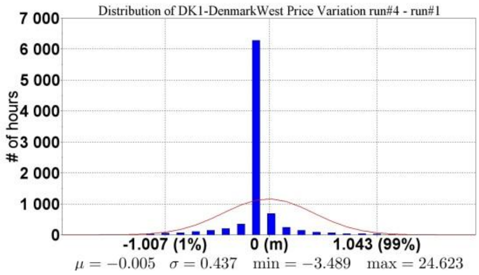

Distribution of SE4-Sweden(Malmo) Price Variation run#3 - run#1
# of hours
-2.665 (1%)
0.035 (m)
2.574 (99%)
μ = −0.017 σ = 1.278 min = −17.073 max = 7.988

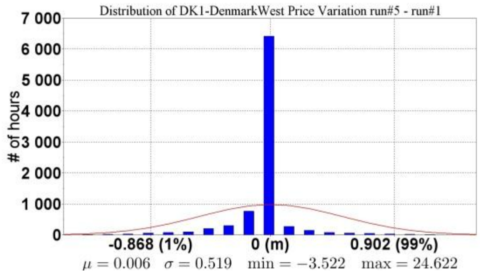

Distribution of SE4-Sweden(Malmo) Price Variation run#4 - run#1
# of hours
-2.062 (1%)
0.446 (99%)
μ = −0.148 σ = 0.509 min = −3.95 max = 3.944

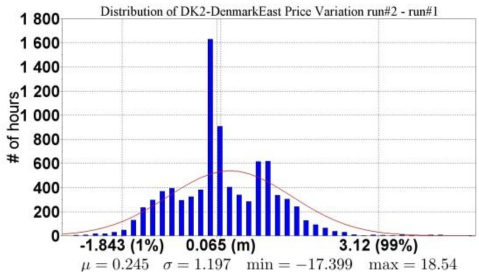

Distribution of SE4-Sweden(Malmo) Price Variation run#5 - run#1
# of hours
-2.024 (1%)
0.421 (99%)
μ = −0.142 σ = 0.562 min = −11.001 max = 3.283

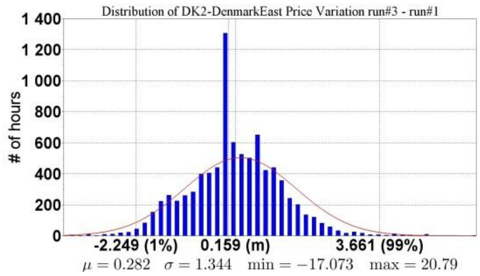

Distribution of DK1-DenmarkWest Price Variation run#2 - run#1
# of hours
-2.648 (1%)
0.024 (m)
3.014 (99%)
$\mu = 0.064$ $\sigma = 1.163$ $\min = -4.391$ $\max = 19.664$

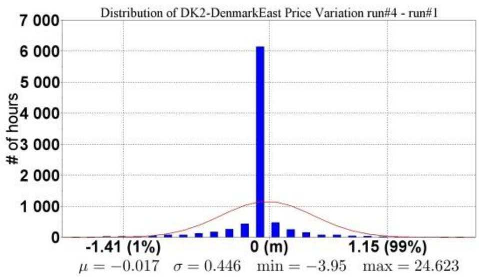

Distribution of DK1-DenmarkWest Price Variation run#3 - run#1
# of hours
-2.847 (1%)
0.058 (m)
3.468 (99%)
$\mu = 0.158$ $\sigma = 1.332$ $\min = -7.124$ $\max = 20.041$

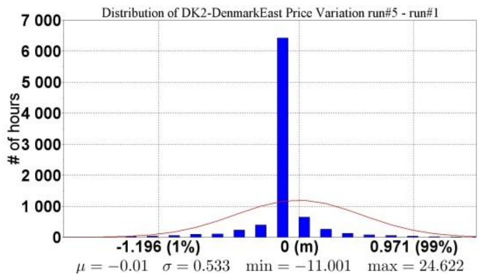

Distribution of DK1-DenmarkWest Price Variation run#4 - run#1
# of hours
-1.007 (1%)
0 (m)
1.043 (99%)
$\mu = -0.005$ $\sigma = 0.437$ $\min = -3.489$ $\max = 24.623$

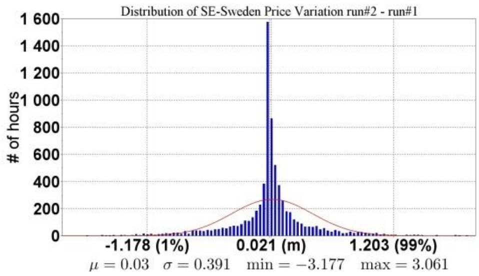

Distribution of DK1-DenmarkWest Price Variation run#5 - run#1
# of hours
-0.868 (1%)
0 (m)
0.902 (99%)
$\mu = 0.006$ $\sigma = 0.519$ $\min = -3.522$ $\max = 24.622$

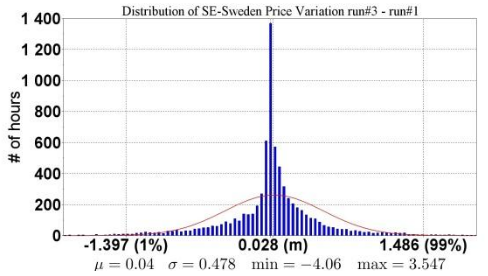

Distribution of DK2-DenmarkEast Price Variation run#2 - run#1
# of hours
-1.843 (1%)
0.065 (m)
3.12 (99%)
$\mu = 0.245$ $\sigma = 1.197$ $\min = -17.399$ $\max = 18.54$

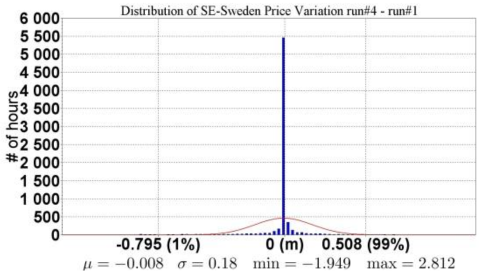

Distribution of DK2-DenmarkEast Price Variation run#3 - run#1
# of hours
-2.249 (1%)
0.159 (m)
3.661 (99%)
$\mu = 0.282$ $\sigma = 1.344$ $\min = -17.073$ $\max = 20.79$

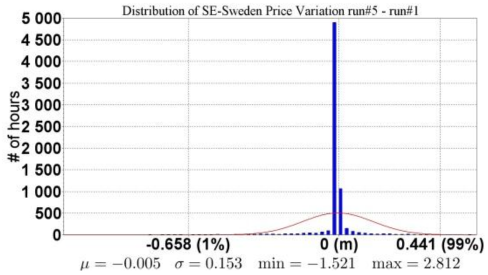

Distribution of DK2-DenmarkEast Price Variation run#4 - run#1
# of hours
-1.41 (1%)
0 (m)
1.15 (99%)
$\mu = -0.017$ $\sigma = 0.446$ $\min = -3.95$ $\max = 24.623$

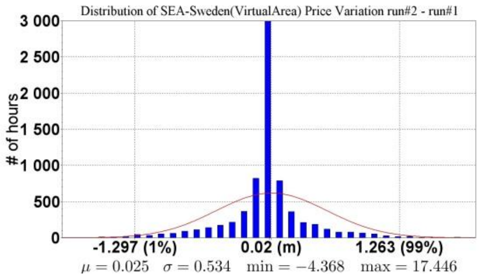

Distribution of DK2-DenmarkEast Price Variation run#5 - run#1
# of hours
-1.196 (1%)
0 (m)
0.971 (99%)
$\mu = -0.01$ $\sigma = 0.533$ $\min = -11.001$ $\max = 24.622$

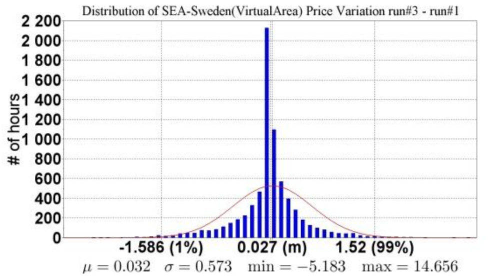

Distribution of SE-Sweden Price Variation run#2 - run#1
# of hours
-1.178 (1%)
0.021 (m)
1.203 (99%)
$\mu = 0.03 \quad \sigma = 0.391 \quad \min = -3.177 \quad \max = 3.061$

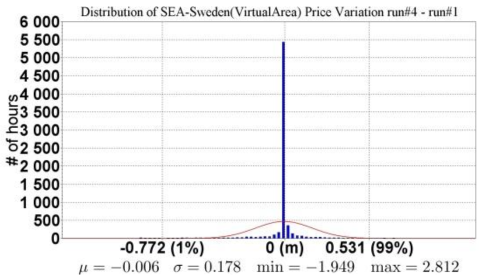

Distribution of SE-Sweden Price Variation run#3 - run#1
# of hours
-1.397 (1%)
0.028 (m)
1.486 (99%)
$\mu = 0.04 \quad \sigma = 0.478 \quad \min = -4.06 \quad \max = 3.547$

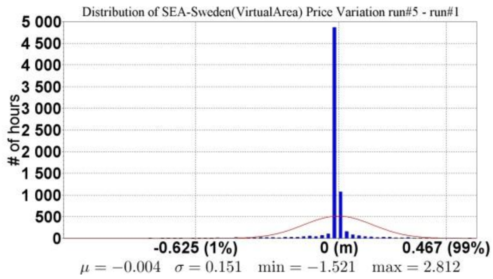

Distribution of SE-Sweden Price Variation run#4 - run#1
# of hours
-0.795 (1%)
0 (m)
0.508 (99%)
$\mu = -0.008 \quad \sigma = 0.18 \quad \min = -1.949 \quad \max = 2.812$

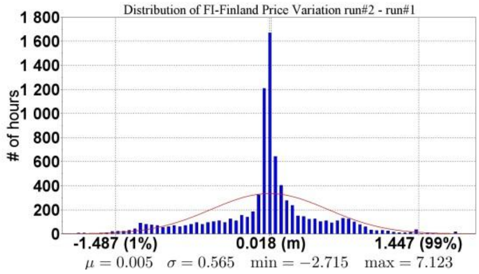

Distribution of SE-Sweden Price Variation run#5 - run#1
# of hours
-0.658 (1%)
0 (m)
0.441 (99%)
$\mu = -0.005 \quad \sigma = 0.153 \quad \min = -1.521 \quad \max = 2.812$

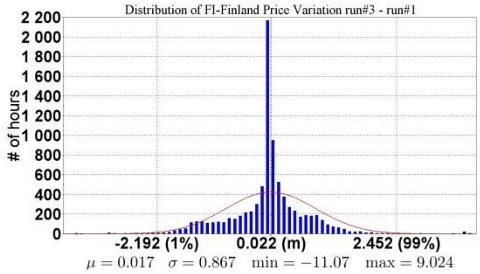

Distribution of SEA-Sweden(VirtualArea) Price Variation run#2 - run#1
# of hours
-1.297 (1%)
0.02 (m)
1.263 (99%)
$\mu = 0.025 \quad \sigma = 0.534 \quad \min = -4.368 \quad \max = 17.446$

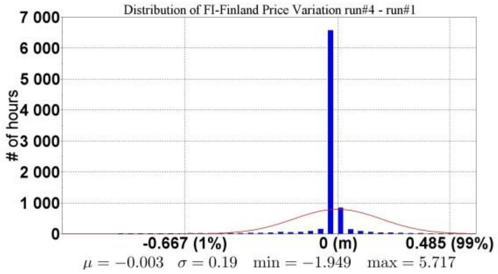

Distribution of SEA-Sweden(VirtualArea) Price Variation run#3 - run#1
# of hours
-1.586 (1%)
0.027 (m)
1.52 (99%)
$\mu = 0.032 \quad \sigma = 0.573 \quad \min = -5.183 \quad \max = 14.656$

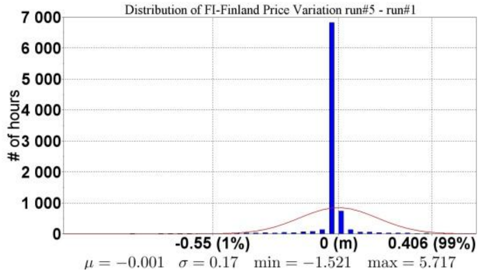

Distribution of SEA-Sweden(VirtualArea) Price Variation run#4 - run#1
# of hours
-0.772 (1%)
0 (m)
0.531 (99%)
$\mu = -0.006 \quad \sigma = 0.178 \quad \min = -1.949 \quad \max = 2.812$

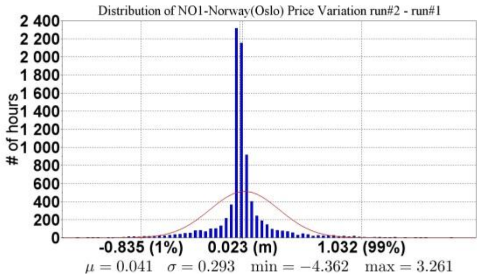

Distribution of SEA-Sweden(VirtualArea) Price Variation run#5 - run#1
# of hours
-0.625 (1%)
0 (m)
0.467 (99%)
$\mu = -0.004 \quad \sigma = 0.151 \quad \min = -1.521 \quad \max = 2.812$

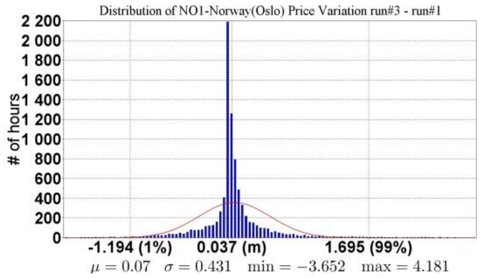

Distribution of FI-Finland Price Variation run#2 - run#1
# of hours
-1.487 (1%)
0.018 (m)
1.447 (99%)
$\mu = 0.005 \quad \sigma = 0.565 \quad \min = -2.715 \quad \max = 7.123$

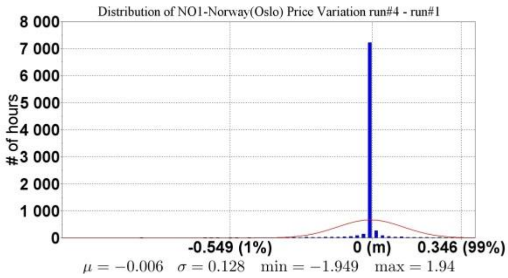

Distribution of FI-Finland Price Variation run#3 - run#1
# of hours
-2.192 (1%)
0.022 (m)
2.452 (99%)
$\mu = 0.017 \quad \sigma = 0.867 \quad \min = -11.07 \quad \max = 9.024$

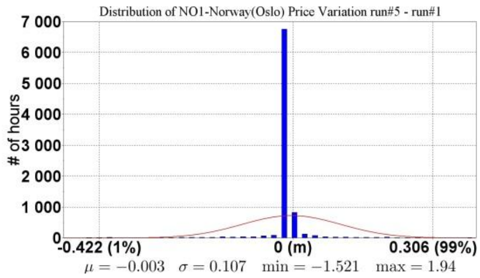

Distribution of FI-Finland Price Variation run#4 - run#1
# of hours
-0.667 (1%)
0 (m)
0.485 (99%)
$\mu = -0.003 \quad \sigma = 0.19 \quad \min = -1.949 \quad \max = 5.717$

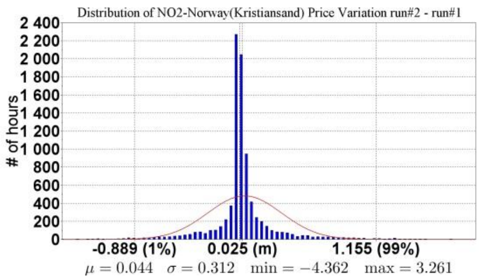

Distribution of FI-Finland Price Variation run#5 - run#1
# of hours
-0.55 (1%)
0 (m)
0.406 (99%)
$\mu = -0.001 \quad \sigma = 0.17 \quad \min = -1.521 \quad \max = 5.717$

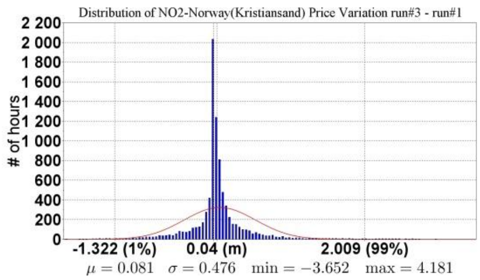

Distribution of NO1-Norway(Oslo) Price Variation run#2 - run#1
# of hours
-0.835 (1%)
0.023 (m)
1.032 (99%)
$\mu = 0.041 \quad \sigma = 0.293 \quad \min = -4.362 \quad \max = 3.261$

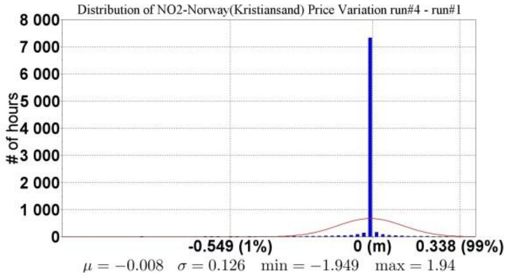

Distribution of NO1-Norway(Oslo) Price Variation run#3 - run#1
# of hours
-1.194 (1%)
0.037 (m)
1.695 (99%)
$\mu = 0.07 \quad \sigma = 0.431 \quad \min = -3.652 \quad \max = 4.181$

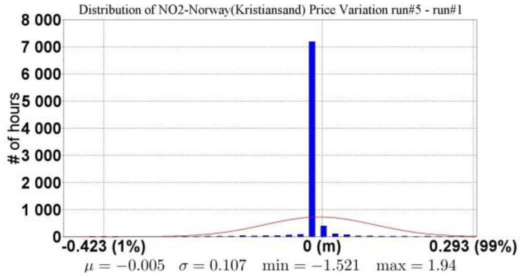

Distribution of NO1-Norway(Oslo) Price Variation run#4 - run#1
# of hours
-0.549 (1%)
0 (m)
0.346 (99%)
$\mu = -0.006 \quad \sigma = 0.128 \quad \min = -1.949 \quad \max = 1.94$

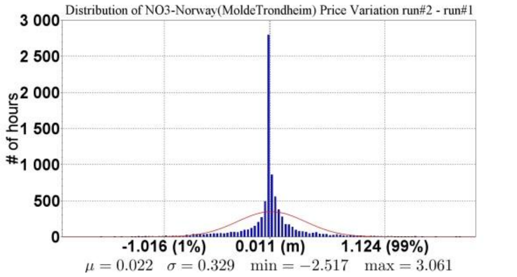

Distribution of NO1-Norway(Oslo) Price Variation run#5 - run#1
# of hours
-0.422 (1%)
0 (m)
0.306 (99%)
$\mu = -0.003 \quad \sigma = 0.107 \quad \min = -1.521 \quad \max = 1.94$

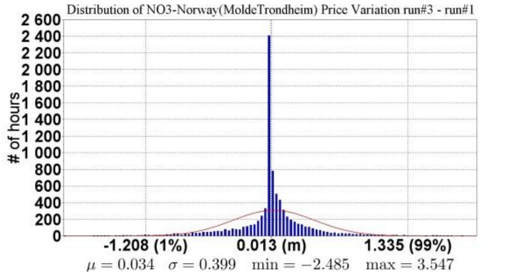

Distribution of NO2-Norway(Kristiansand) Price Variation run#2 - run#1
# of hours
-0.889 (1%)
0.025 (m)
1.155 (99%)
$\mu = 0.044 \quad \sigma = 0.312 \quad \min = -4.362 \quad \max = 3.261$

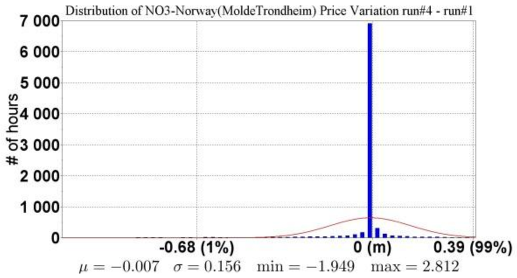

Distribution of NO2-Norway(Kristiansand) Price Variation run#3 - run#1
# of hours
-1.322 (1%)
0.04 (m)
2.009 (99%)
$\mu = 0.081 \quad \sigma = 0.476 \quad \min = -3.652 \quad \max = 4.181$

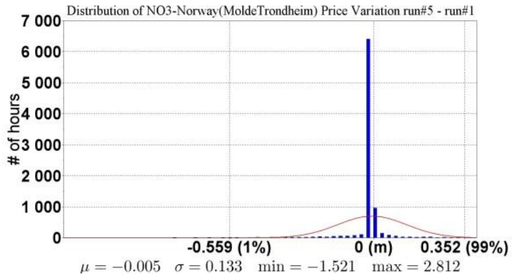

Distribution of NO2-Norway(Kristiansand) Price Variation run#4 - run#1
# of hours
-0.549 (1%)
0 (m)
0.338 (99%)
μ = −0.008 σ = 0.126 min = −1.949 max = 1.94

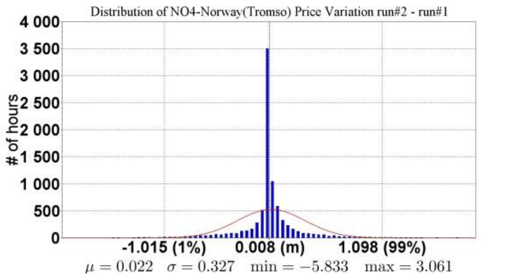

Distribution of NO2-Norway(Kristiansand) Price Variation run#5 - run#1
# of hours
-0.423 (1%)
0 (m)
0.293 (99%)
μ = −0.005 σ = 0.107 min = −1.521 max = 1.94

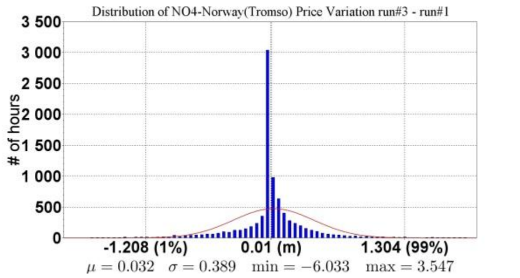

Distribution of NO3-Norway(MoldeTrondheim) Price Variation run#2 - run#1
# of hours
-1.016 (1%)
0.011 (m)
1.124 (99%)
μ = 0.022 σ = 0.329 min = −2.517 max = 3.061

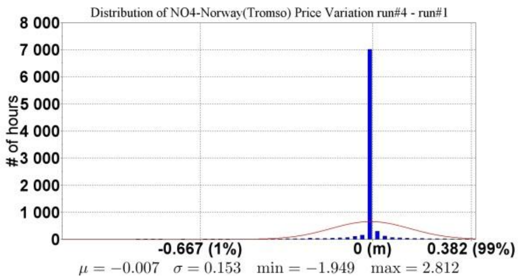

Distribution of NO3-Norway(MoldeTrondheim) Price Variation run#3 - run#1
# of hours
-1.208 (1%)
0.013 (m)
1.335 (99%)
μ = 0.034 σ = 0.399 min = −2.485 max = 3.547

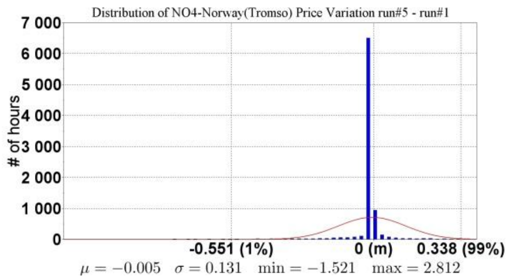

Distribution of NO3-Norway(MoldeTrondheim) Price Variation run#4 - run#1
# of hours
-0.68 (1%)
0 (m)
0.39 (99%)
μ = −0.007 σ = 0.156 min = −1.949 max = 2.812

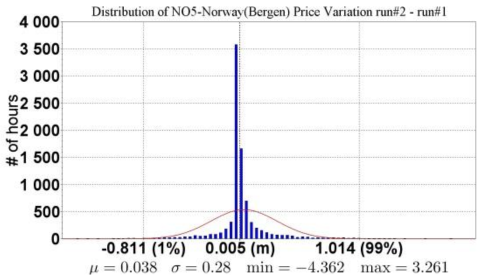

Distribution of NO3-Norway(MoldeTrondheim) Price Variation run#5 - run#1
# of hours
-0.559 (1%)
0 (m)
0.352 (99%)
μ = −0.005 σ = 0.133 min = −1.521 max = 2.812

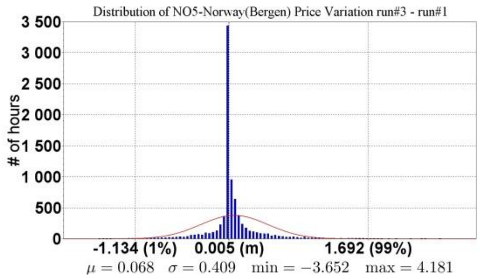

Distribution of NO4-Norway(Tromso) Price Variation run#2 - run#1
# of hours
-1.015 (1%)
0.008 (m)
1.098 (99%)
μ = 0.022 σ = 0.327 min = −5.833 max = 3.061

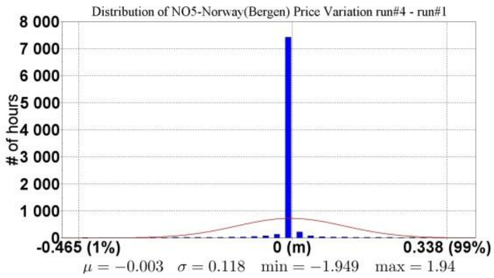

Distribution of NO4-Norway(Tromso) Price Variation run#3 - run#1
# of hours
-1.208 (1%)
0.01 (m)
1.304 (99%)
μ = 0.032 σ = 0.389 min = −6.033 max = 3.547

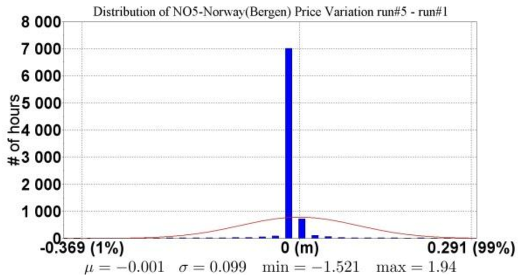

Distribution of NO4-Norway(Tromso) Price Variation run#4 - run#1
# of hours
-0.667 (1%)
0 (m)
0.382 (99%)
μ = −0.007 σ = 0.153 min = −1.949 max = 2.812

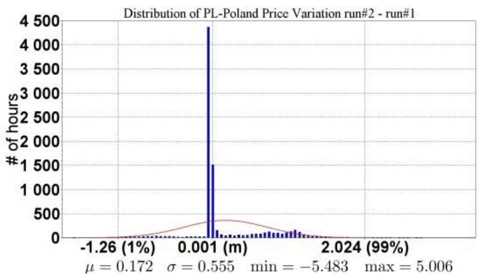

Distribution of NO4-Norway(Tromso) Price Variation run#5 - run#1
# of hours
-0.551 (1%)
0 (m)
0.338 (99%)
μ = −0.005 σ = 0.131 min = −1.521 max = 2.812

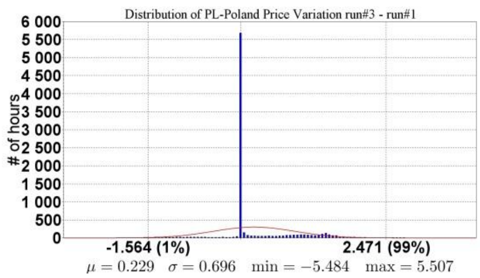

Distribution of NO5-Norway(Bergen) Price Variation run#2 - run#1
# of hours
-0.811 (1%)
0.005 (m)
1.014 (99%)
$\mu = 0.038$ $\sigma = 0.28$ min $= -4.362$ max $= 3.261$

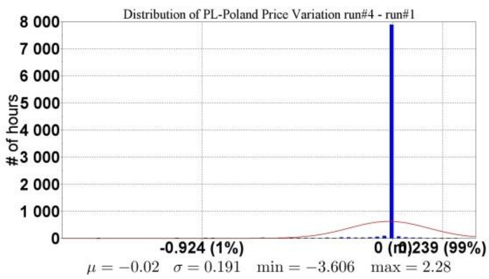

Distribution of NO5-Norway(Bergen) Price Variation run#3 - run#1
# of hours
-1.134 (1%)
0.005 (m)
1.692 (99%)
$\mu = 0.068$ $\sigma = 0.409$ min $= -3.652$ max $= 4.181$

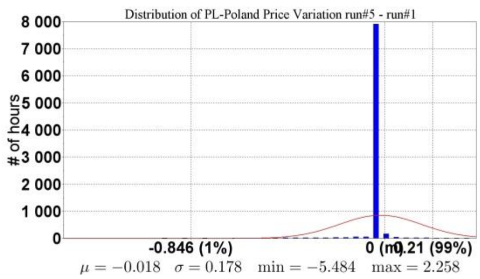

Distribution of NO5-Norway(Bergen) Price Variation run#4 - run#1
# of hours
-0.465 (1%)
0 (m)
0.338 (99%)
$\mu = -0.003$ $\sigma = 0.118$ min $= -1.949$ max $= 1.94$

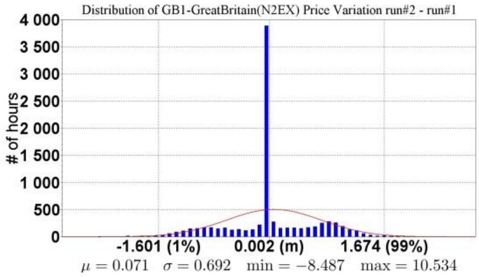

Distribution of NO5-Norway(Bergen) Price Variation run#5 - run#1
# of hours
-0.369 (1%)
0 (m)
0.291 (99%)
$\mu = -0.001$ $\sigma = 0.099$ min $= -1.521$ max $= 1.94$

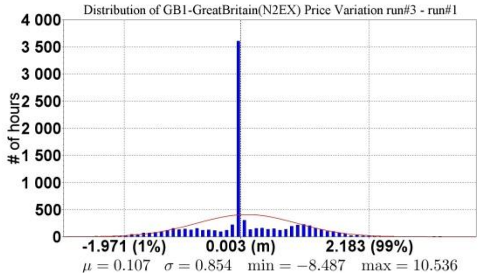

Distribution of PL-Poland Price Variation run#2 - run#1
# of hours
-1.26 (1%)
0.001 (m)
2.024 (99%)
$\mu = 0.172$ $\sigma = 0.555$ min $= -5.483$ max $= 5.006$

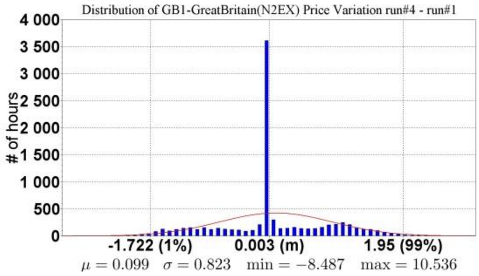

Distribution of PL-Poland Price Variation run#3 - run#1
# of hours
-1.564 (1%)
2.471 (99%)
$\mu = 0.229$ $\sigma = 0.696$ min $= -5.484$ max $= 5.507$

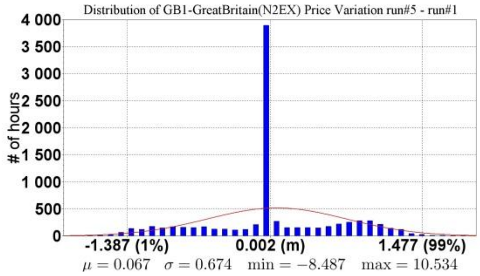

Distribution of PL-Poland Price Variation run#4 - run#1
# of hours
-0.924 (1%)
0 (m)0.239 (99%)
$\mu = -0.02$ $\sigma = 0.191$ min $= -3.606$ max $= 2.28$

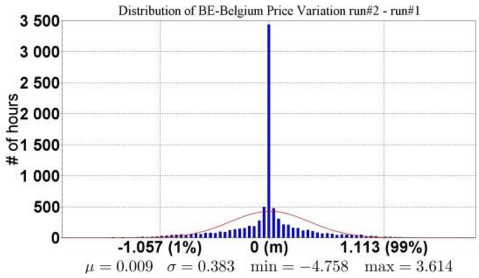

Distribution of PL-Poland Price Variation run#5 - run#1
# of hours
-0.846 (1%)
0 (m)0.21 (99%)
$\mu = -0.018$ $\sigma = 0.178$ min $= -5.484$ max $= 2.258$

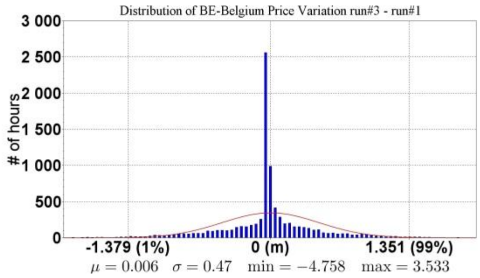

Distribution of GB1-GreatBritain(N2EX) Price Variation run#2 - run#1
# of hours
-1.601 (1%)
0.002 (m)
1.674 (99%)
μ = 0.071 σ = 0.692 min = −8.487 max = 10.534

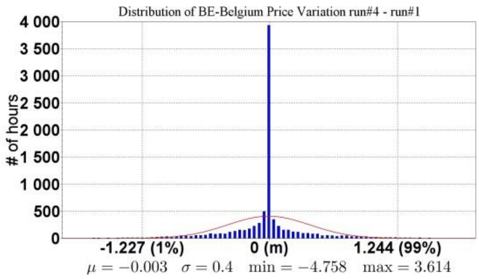

Distribution of GB1-GreatBritain(N2EX) Price Variation run#3 - run#1
# of hours
-1.971 (1%)
0.003 (m)
2.183 (99%)
μ = 0.107 σ = 0.854 min = −8.487 max = 10.536

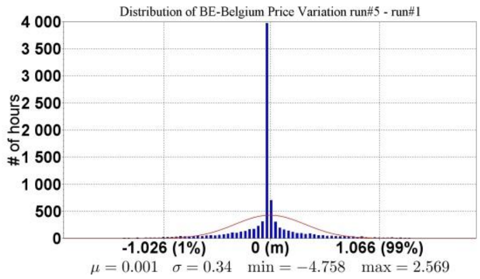

Distribution of GB1-GreatBritain(N2EX) Price Variation run#4 - run#1
# of hours
-1.722 (1%)
0.003 (m)
1.95 (99%)
μ = 0.099 σ = 0.823 min = −8.487 max = 10.536

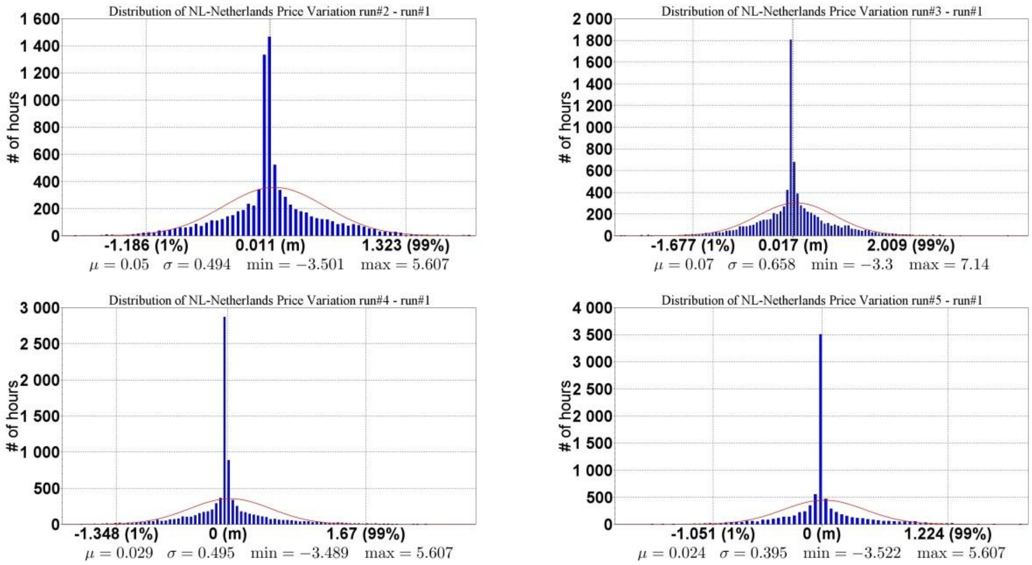

Distribution of GB1-GreatBritain(N2EX) Price Variation run#5 - run#1
# of hours
-1.387 (1%)
0.002 (m)
1.477 (99%)
μ = 0.067 σ = 0.674 min = −8.487 max = 10.534


Distribution of BE-Belgium Price Variation run#2 - run#1
# of hours
-1.057 (1%)
0 (m)
1.113 (99%)
μ = 0.009 σ = 0.383 min = −4.758 max = 3.614


Distribution of BE-Belgium Price Variation run#3 - run#1
# of hours
-1.379 (1%)
0 (m)
1.351 (99%)
μ = 0.006 σ = 0.47 min = −4.758 max = 3.533


Distribution of BE-Belgium Price Variation run#4 - run#1
# of hours
-1.227 (1%)
0 (m)
1.244 (99%)
μ = −0.003 σ = 0.4 min = −4.758 max = 3.614


Distribution of BE-Belgium Price Variation run#5 - run#1
# of hours
-1.026 (1%)
0 (m)
1.066 (99%)
μ = 0.001 σ = 0.34 min = −4.758 max = 2.569



Tables of Price Differences – Number of hours the relative price difference is greater / equal / lower than the loss factor whereas it was lower than the loss factor in the reference Run#1

Number of hours which have a relative price difference in Run#1 lower than loss factor and in current Run greater than loss factor:

Example. Between NL-NO2, 94 hours experience a price difference in Run#2 which is greater than Run#2 loss factor (i.e. 2%), whereas the price difference in Run#1 is lower than Run#2 loss factor (i.e. 2%). These hours represent 5.90% of hours which have a price difference in Run#1 lower than Run#2 loss factor (i.e. 2%).

Interconnector	dp "greater"	Run#2	Run#3	Run#4	Run# 5
NL-NO2	#hours	94	190	229	223
	%	5.90%	9.85%	18.59%	18.10%
DK1-DK2	#hours	40	1 609	104	98
	%	0.53%	21.49%	1.42%	1.34%
NO2-DK1A	#hours	144	243	47	44
	%	3.45%	5.49%	1.22%	1.14%
DE-DK2	#hours	69	200	472	462
	%	1.33%	3.78%	9.79%	9.58%
SEA-DK1A	#hours	59	772	94	91
	%	1.54%	19.85%	2.58%	2.49%
FR-GB1	#hours	51	855	856	48
	%	1.20%	19.82%	19.84%	1.13%
EE-FI	#hours	25	2 440	7	5
	%	0.56%	51.13%	0.16%	0.12%
SE-FI	#hours	23	23	4	4
	%	0.41%	0.41%	0.07%	0.07%
DE-SE	#hours	79	804	41	29
	%	4.79%	46.58%	2.38%	1.76%
NL-GB2	#hours	74	88	69	54
	%	1.57%	1.78%	1.39%	1.15%
SE-PL	#hours	51	64	32	26
	%	2.33%	2.79%	1.70%	1.38%
DK1A-SE3	#hours	2	228	1	1
	%	0.16%	17.94%	0.08%	0.08%
SE3-FI	#hours	2	2	1	1
	%	0.15%	0.15%	0.07%	0.07%
DE-SE4	#hours	15	265	9	11
	%	3.23%	56.03%	1.90%	2.37%
SE4-PL	#hours	15	19	3	4
	%	1.95%	2.41%	0.42%	0.56%

Table 29: Interconnector

Number of hours which have a relative price difference in Run#1 lower than loss factor and in current Run equal to loss factor:

Interconnector	dp "equal"	Run#2	Run#3	Run#4	Run# 5
NL-NO2	#hours	1 240	511	1 003	1 009
	%	77.89%	26.49%	81.41%	81.90%
DK1-DK2	#hours	6 966	5 480	7 236	7 242
	%	92.36%	73.19%	98.58%	98.66%
NO2-DK1A	#hours	3 786	1 931	3 797	3 800
	%	90.60%	43.62%	98.78%	98.86%
DE-DK2	#hours	4 772	2 642	4 350	4 360
	%	91.86%	49.95%	90.21%	90.42%
SEA-DK1A	#hours	3 386	1 527	3 556	3 559
	%	88.50%	39.25%	97.42%	97.51%
FR-GB1	#hours	3 496	2 613	2 619	3 509
	%	82.10%	60.57%	60.71%	82.41%
EE-FI	#hours	4 293	1 852	4 316	4 318
	%	95.59%	38.81%	99.84%	99.88%
SE-FI	#hours	1 575	1 550	5 431	5 431
	%	28.30%	27.75%	99.93%	99.93%
DE-SE	#hours	1 311	303	319	315
	%	79.55%	17.56%	18.48%	19.11%
NL-GB2	#hours	3 821	1 694	1 712	3 843
	%	81.06%	34.22%	34.59%	81.52%
SE-PL	#hours	1 829	1 822	1 853	1 859
	%	83.40%	79.32%	98.30%	98.62%
DK1A-SE3	#hours	1 190	537	1 252	1 252
	%	94.07%	42.25%	99.92%	99.92%
SE3-FI	#hours	320	312	1 358	1 358
	%	23.32%	22.74%	99.93%	99.93%
DE-SE4	#hours	430	143	211	204
	%	92.67%	30.23%	44.61%	43.97%
SE4-PL	#hours	704	702	708	707
	%	91.55%	88.86%	99.58%	99.44%

Table 30: Interconnector

Number of hours which have a relative price difference in Run#1 lower than loss factor and in current Run still lower than loss factor:

Interconnector	dp "lower"	Run#2	Run#3	Run#4	Run# 5
NL-NO2	#hours	258	1 228	0	0
	%	16.21%	63.66%	0.00%	0.00%
DK1-DK2	#hours	536	398	0	0
	%	7.11%	5.32%	0.00%	0.00%
NO2-DK1A	#hours	249	2 253	0	0
	%	5.96%	50.89%	0.00%	0.00%
DE-DK2	#hours	354	2 447	0	0
	%	6.81%	46.27%	0.00%	0.00%
SEA-DK1A	#hours	381	1 591	0	0
	%	9.96%	40.90%	0.00%	0.00%
FR-GB1	#hours	711	846	839	701
	%	16.70%	19.61%	19.45%	16.46%
EE-FI	#hours	173	480	0	0
	%	3.85%	10.06%	0.00%	0.00%
SE-FI	#hours	3 967	4 012	0	0
	%	71.28%	71.84%	0.00%	0.00%
DE-SE	#hours	258	619	1 366	1 304
	%	15.66%	35.86%	79.14%	79.13%
NL-GB2	#hours	819	3 168	3 169	817
	%	17.37%	64.00%	64.02%	17.33%
SE-PL	#hours	313	411	0	0
	%	14.27%	17.89%	0.00%	0.00%
DK1A-SE3	#hours	73	506	0	0
	%	5.77%	39.81%	0.00%	0.00%
SE3-FI	#hours	1 050	1 058	0	0
	%	76.53%	77.11%	0.00%	0.00%
DE-SE4	#hours	19	65	253	249
	%	4.09%	13.74%	53.49%	53.66%
SE4-PL	#hours	50	69	0	0
	%	6.50%	8.73%	0.00%	0.00%

Table 31: Interconnector

Appendix V - Quantitative Indicators

The indicators below are calculated from simulation outputs. Output values being unrounded, the indicators were calculated with decimals and rounded for the presentation of results. It can happen that they differ from indicators which would be calculated from published rounded prices and flows.

a. Welfare Indicators

Let us denote:

- CW the coupling welfare which is optimized by the coupling algorithm (which includes some losses costs modeled via the linear loss factor);
- LC the total external losses cost (including additional energy production) which is not considered in the implicit allocation calculated by the algorithm[43];
- NCW the net coupling welfare;

Theoretically, the net coupling welfare encompasses the surplus of every party, including the producer surplus of the producer who procures energy for losses when losses are procured out of the coupling mechanism.

In practice, we consider a calculated net coupling welfare NCWc which is defined as follows: NCWc = CW – LC; we still call this quantity net coupling welfare and we generally omit the ‘c’ though this is not strictly correct.

The coupling welfare is the sum of producer and consumer surplus and gross congestion rents over all bidding areas and interconnections:

$$CW = \Sigma\ PS + \Sigma\ CS + \Sigma\ CR.$$

Producer and consumer surplus represent the gain compared to the willingness to pay and are directly output by the coupling algorithm.

Gross congestion rent is calculated for each interconnection as the difference between the amounts for energy sales at one end and energy purchase at the other end of the interconnection:

$$CR = MCP_{Importing}.Flow_{ReceivingEnd} - MCP_{Exporting}.Flow_{SendingEnd}.$$

For each interconnector and each run#n, the hourly loss costs are calculated as follows:

$$LC = (\text{loss factor run\#3} - \text{loss factor run\#n})/(1 - \text{loss factor run\#3}).MCP_{Exporting}{*}Flow_{SendingEnd}$$

Case of adverse flows (due to ramping or negative ATCs): losses should be procured at the importing side (cheapest price) leading to the following formula:

$$LC = (\text{loss factor run\#3} - \text{loss factor run\#n}).MCP_{Importing}{*}Flow_{SendingEnd}$$

---

[43] Theoretically, LC = DC LC + AC LC is the sum of losses supported by DC cables and losses supported by the AC part of the network; AC LC is assumed to be constant and is not considered further in the comparison analysis of different runs.

Example:

- If run #3 has a loss factor of 3%, if run #1 results in a flow of 100MW, then 3MW losses must be compensated;
- If run #3 has a loss factor of 3%, if run #2 has a loss factor of 2% and results in a flow of 100MW, then 1MW extra-losses must be compensated;

The calculation of loss cost as above relies on the following assumptions:

- The linear loss factor for run #3 exactly reflects the losses to be taken into account for the assessment of the loss costs i.e. every loss cost is included in the linear loss factor used in run #3 whatever the flow; in particular, the assessment of LC will not use the parabolic formulae as functions of actual physical flows;
- The cable operator buys the lost energy at the Market Clearing Price in the cheapest side (see Annex 4 for a rationale for this price);
- The modality of losses procurement by cable operators has no impact on the formation of market prices, whatever the term (forecast and order on the market; or procurement on intra-day / balancing);

b. Flow Indicators

Each interconnector has two directions arbitrarily denoted up and down; a flow in a given direction can be seen at the sending end (injection point; denoted "in") and at the receiving end (off-take point; denoted "out"). The following indicators are calculated (for each interconnector and each run):

UPINNCG: sum of **sending** end flows in **up** direction over hours when **no** congestion occurs
UPOUTNCG: sum of **receiving** end flows in **up** direction over hours when **no** congestion occurs
DOWNINNCG: sum of **sending** end flows in **down** direction over hours when **no** congestion occurs
DOWNOUTNCG: sum of **receiving** end flows in **down** direction over hours when **no** congestion occurs

UPINCG: sum of **sending** end flows in **up** direction over hours when congestion occurs
UPOUTCG: sum of **receiving** end flows in **up** direction over hours when congestion occurs
DOWNINCG: sum of **sending** end flows in **down** direction over hours when congestion occurs
DOWNOUTCG: sum of **receiving** end flows in **down** direction over hours when congestion occurs

NBHCGUP: number of hours when the interconnector is congested in the **up** direction
NBHCGDOWN: number of hours when the interconnector is congested in the **down** direction
NBHCGTOTAL: number of hours when the interconnector is congested whatever the direction: sum of NBHCGUP and NBHCGDOWN

NBHNCGdPUP: number of hours when the interconnector is **not congested** in the **up** direction although a price difference occurs in the **up** direction

NBHNCGdPDOWN: number of hours when the interconnector is **not congested** in the **down** direction although a price difference occurs in the **down** direction
NBHNCGdPTOTAL: sum of NBHNCGdPUP and NBHNCGdPDOWN

NBHRMPUP: number of hours when the ramping-up[44] constraint is activated
NBHRMPDOWN: number of hours when the ramping-down constraint is activated
NBHRMPTOTAL: sum of NBHRMPUP and NBHRMPDOWN

NBHrFL[45]: number of hours when the flow is reduced compared to the reference run.
NBHzFL: number of hours when the flow is zero in the current run and is not zero in the reference run.

c. Net Position Indicators

For each biddinga area and each run, the net position indicators are calculated:

Total Pos NP: sum of net position for hours when net position is positive
Total Neg NP: sum of net position for hours when net position is negative
Total NP: sum of Total Pos NP and Total Neg NP

CWE NP: sum of net positions of CWE bidding areas for each hour
Nordic NP: sum of net positions of Nordic[46] bidding areas for each hour

For each CWE bidding area, a NWE-NP is calculated as follows for each hour:

$$\text{NWE-NP} = \text{NP} - \text{Flow}_{\text{ExportedToNonCWE}} + \text{Flow}_{\text{ImportedFromNonCWE}}$$

The NWE-NP indicator is the sum of the hourly NWE-NP. This NWE-Net Position represents the net position of the CWE bidding areas after correction of the exchanges from/to other non-CWE bidding areas.

d. Price Indicators

The following indicators are calculated for each Run:

- percentage of hours with CWE convergence of prices
- percentage of hours with Nordic47 convergence of prices
- percentage of hours with Baltic48 convergence of prices
- percentage of hours with price convergence between CWE and Nordic bidding areas
- percentage of hours with price convergence between CWE and GB bidding areas
- percentage of hours with converging prices between bidding areas at line ends
- percentage of hours with full convergence of prices

[44] This is not directional and refers to the sign of flow variation: ramping-up (resp. –down) constraint limits the increase (resp. decrease) of flow from one hour to another.
[45] This indicator is calculated only for interconnectors subject to loss factor for some runs.
[46] Only bidding areas in Sweden, Norway, Denmark and Finland.
[47] Only bidding areas in Sweden, Norway, Denmark and Finland.
[48] Only EE; ELE; ELI bidding areas.

Appendix VI - Modelling Assumptions of the Quantitative Analysis

The focus of this section is the proof of the following statement:

If an interconnection is congested before the inclusion of losses in the coupling mechanism with a relative price difference higher than the loss factor, then the procurement of losses outside the market is already optimal.

Moreover, in these congested configurations with a relative price difference higher than the loss factor, the modelling assumptions of the study have as a consequence an underestimation of the total welfare when losses are included in the coupling mechanism.

Preliminary observations can be made in regards with this statement:

(i) The gain in total welfare due to the inclusion of losses in the coupling mechanism comes from non congested cases or from congested cases with a relative price difference lower than the loss factor: in such cases, the flow is non optimal; this sub-optimality is corrected by the inclusion of losses in the optimization process;

(ii) For the limit case of an interconnection which is always congested with a relative price difference higher than the loss factor, the net coupling welfare which is calculated in the frame of the study is lower when losses are included in the coupling mechanism, instead of being equal to the case when losses are not included; this is contrary to the theory and should be taken as a limit of the study;

(iii) In practice, two effects are in competition when losses are included in the coupling mechanism: (a) an increase of net coupling welfare for non congested cases or congested cases with a relative price difference lower than the loss factor; (b) a decrease of net coupling welfare for congested cases with a relative price difference higher than the loss factor;
Because hours in a given day are interdependent (in particular, a welfare compensation between hours can occur; making one hour with less welfare so that the sum of hours has a higher welfare), it is not possible to split these effects and to calculate the net coupling welfare corresponding to one effect only;

Now assume two bidding areas A and B. We assume that the supply and demand curves are locally linear at the neighbourhood of the equilibrium and that the price is not determined by the selection of block orders (i.e. the block selection remains constant and coherent with small price changes and block orders can be considered as mixed in the supply and demand curves).

Before the inclusion of losses, we assume that maket A is exporting and that the interconnection is congested with a relative price difference higher than the loss factor.

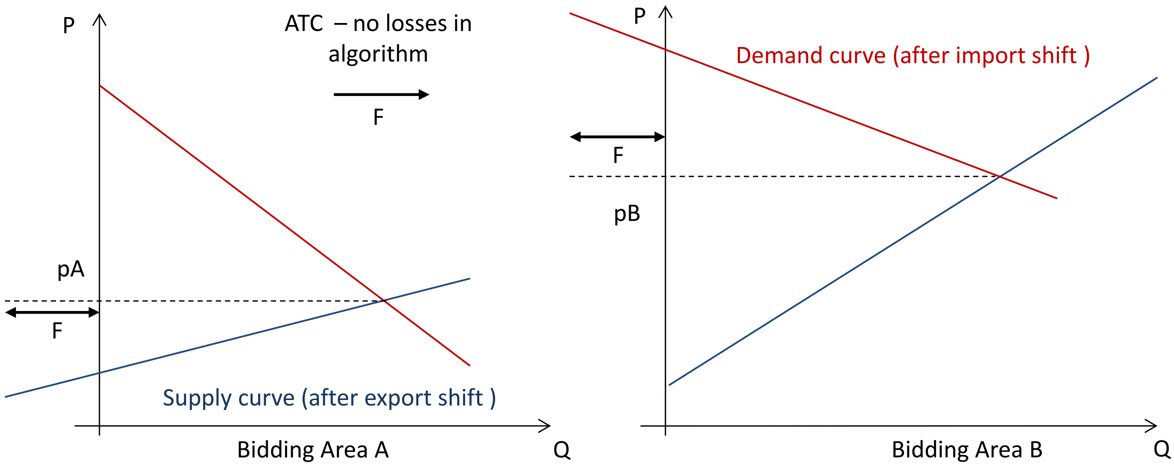


Figure 17: Bidding Area A and B

The exported quantity F from A is equal to the imported quantity into B and to the ATC.

We also assume that losses are procured outside the coupling mechanism at an energy producer located in A, which will be called the Losses Producer. Losses are produced at a marginal production cost denoted pLoss and bought by the TSO at a price denoted pLC. We denote the quantity of energy losses δF (which is equal to a fraction of F given by the loss factor).

Then the loss cost and the gross congestion rent of the TSO are:

LC = δF.pLC,

CR = F(pB – pA).

The surplus of the Losses Producer is LPS = δF.(pLC – pLoss). We can visualise the surplus of consumers and producers, which we denote CS and PS:

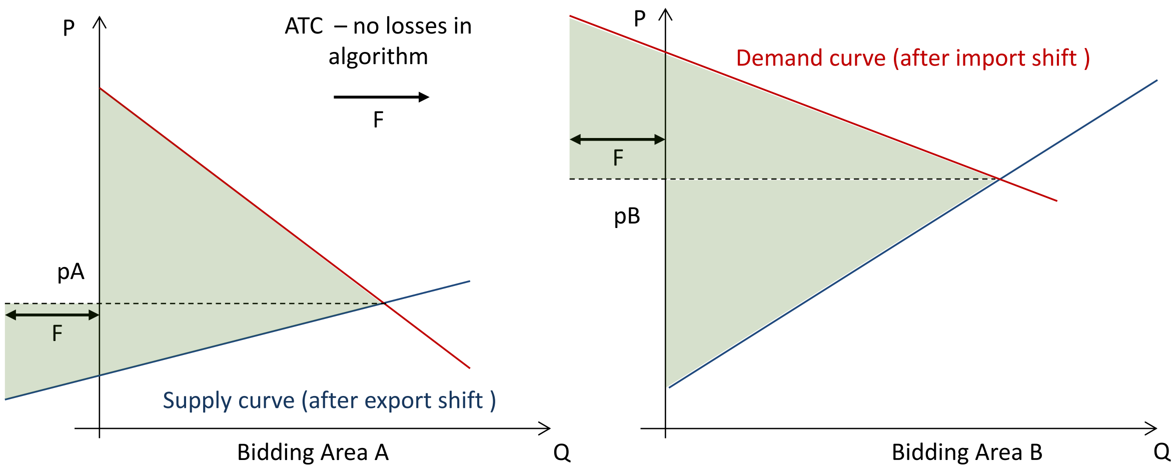


Figure 18: Bidding area A and B

Then we define the coupling welfare as the welfare which is calculated by the coupling mechanism:

CW = (CSA + PSA) + (CSB + PSB) + CR;

and the **net coupling welfare** as the coupling welfare corrected by the loss procurement:

NCW = CW – LC + LPS.

Since we have no mean to assess the Losses Producer Surplus, let us denote the **net coupling welfare which can be calculated**:

NCWc = CW – LC.

(A) "receiving end" modelling

Now assume that the losses are included in the coupling mechanism and that the interconnection has been modeled under the so-called "receiving end" methodology. This means that the receiving end ATC remains constant when losses are applied. The consequence is that the sending ATC must be increased of the losses quantity δF.

We also assume that the Loss Producer now offers the loss energy quantity δF to the market.

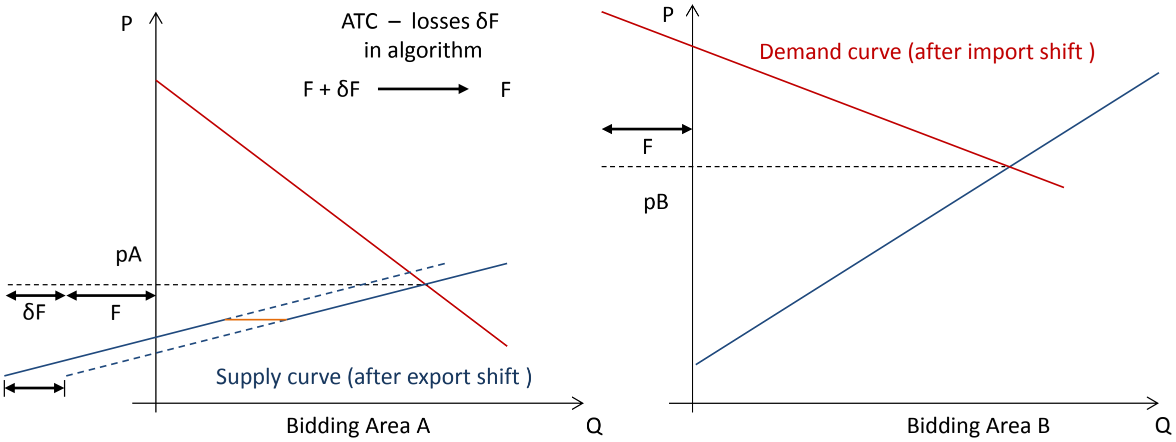


Figure 19: that the Loss Producer now offers the loss energy quantity δF to the market

Then we observe that prices are unchanged; the interconnecion is still congested; and the surplus of consumers and producers who were in the market before remains unchanged as can be visualised below:

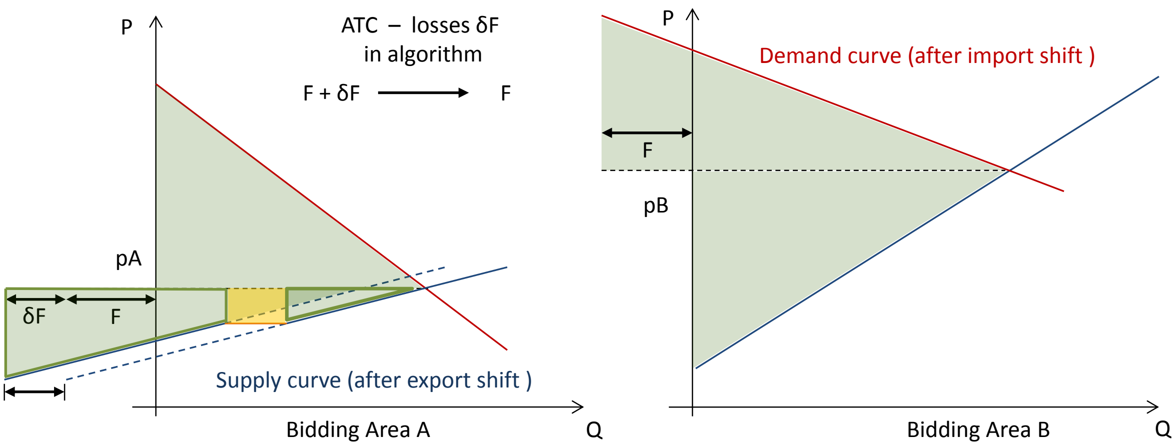


Figure 20: the market before remains unchanged

The surplus of the Loss Producer is then:

LPS' = δF.(pA – pLoss);

and the gross congestion rent of the TSO becomes:

CR' = F.pB – (F + δF).pA = CR – δF.pA.

If we assume that losses are purchased at market clearing price pA when they are not included in the coupling mechanism i.e. pLC = pA, then we obtain:

LPS' = LPS and CR' = CR – LC,

which reflects that losses are implicitly purchased by the TSO in deduction of its congestion rent.
For this reason, the following assumption is made in the frame of the study:

When losses are not included in the coupling mechanism, it is assumed that the price for loss procurement is the market clearing price at the exporting side.

N.B. This assumption holds when losses are not fully included in the coupling mechanism i.e. when part of the losses are included in the coupling mechanism and part of the losses must be purchased out of the coupling mechanism: for that part, the procurement price is assumed to be the exporting market price (importing market price if flow is adverse).

Then we can calculate the coupling welfare:

CW' = (CSA + PSA)' + (CSB + PSB)'+ CR'
= (CSA + PSA) + (CSB + PSB) + LPS' + CR – LC
= (CSA + PSA) + (CSB + PSB) + LPS + CR – LC,

which gives: CW' = NCW.

Since neither Losses Producer surplus nor Losses Costs remain out of the coupling mechanism, we obtain:

NCW' = CW' = NCW,

which is the first part of the statement to proove.

Now let us consider that simulations did not include the offer of the Losses Producer in the supply curve when losses are included in the algorithm. On the drawing, the orange order disappears and we can see that the price in A will increase of δpA[49]:

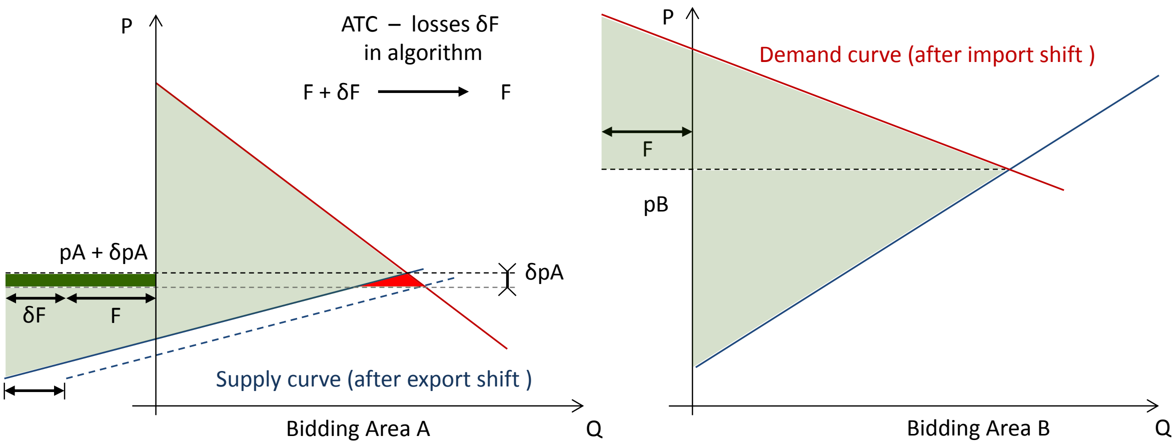


Figure 21: the price in A will increase of δpA

[49] Here we assume that the relative price difference between pB and pA + δpA is still higher than the loss factor.

The surplus of consumers and producers in B is unchanged and the surplus of consumers and producers in A is decreased of the area in red[50] and increased of the area in dark green:

$$(CSA + PSA)' = (CSA + PSA) - 1/2.\delta F.\delta pA + (F + \delta F).\delta pA$$
$$= (CSA + PSA) + 1/2.\delta F.\delta pA + F.\delta pA.$$

The gross congestion rent now becomes:

$$CR' = F.pB - (F + \delta F).(pA + \delta pA)$$
$$= F.pB - F.pA - \delta F.pA - (F + \delta F).\delta pA$$
$$= CR - LC - (F + \delta F).\delta pA.$$

Hence the calculation of the coupling welfare:

$$CW' = CW - LC - 1/2\ .\delta F.\delta pA.$$

No losses are procured out of the coupling mechanism hence $LC' = 0$. If we assume that the Loss Producer can offer its energy outside the coupling mechanism at market clearing price, then we still have $LPS' = LPS$ and we obtain:

$$NCW' = CW' - LC' + LPS'$$
$$= CW - LC + LPS - 1/2\ .\delta F.\delta pA$$

which gives: $NCW' = NCW - 1/2\ .\delta F.\delta pA < NCW$.

In addition we have $NCWc' = NCW' - LC'$, which gives $NCWc' = NCWc - 1/2\ .\delta F.\delta pA < NCWc$.
The last equality shows an underestimation of calculated net coupling welfare which is inherent to the modelling.

Remark on the price bias when the receiving end modelling is applied:

(i) When the Losses Producer is re-integrated in the supply curve, prices in A and B do not change under the receiving end modelling;

(ii) When the Losses Producer is not re-integrated in the supply curve, price B is steady but price A increases of δpA; this price increase δpA depends on curve elasticities in bidding area A (it can be zero up to infinity);

Remark on the evolution of the net congestion rent when the receiving end modelling is applied:

(i) When the Losses Producer is re-integrated in the supply curve, we have $CR' = CR - LC$ and $LC' = 0$; then we observe that the net congestion rent is given by $NCR = CR - LC$ and $NCR' = CR' - LC'$; hence we obtain $NCR' = NCR$ in other words the receiving end model keeps the net congested rent unchanged in congested configurations;

(ii) When the Losses Producer is not re-integrated in the supply curve, we obtain similarly $NCR' = CR' - LC' = CR - LC - (F + \delta F).\delta pA = NCR - (F + \delta F).\delta pA$; which reflects a decrease of net congestion rent due to the price increase in bidding area A;

(B) "sending end" modelling

Now assume that the losses are included in the coupling mechanism and that the interconnection has been modeled under the so-called "sending end" methodology. This means that the sending end ATC remains constant when losses are applied. The consequence is that the receiving ATC is decreased of the losses quantity δF.

[50] Here we use the assumption that the supply and demand curves in A are locally linear at the neighbourhood of the equilibrium and that the price in A is not determined by the block selection.

We also assume that the Losses Producer now offers the losses energy quantity δF to the market. We can see that the price in A decreases: pA' = pA – δpA; and the price in B increases: pB' = pB + δpB.

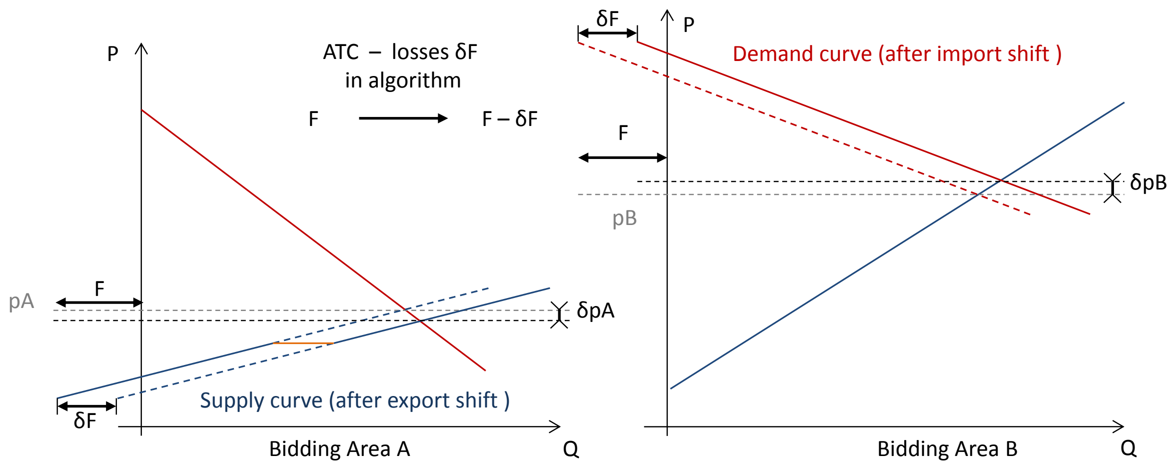


Figure 22: The Losses Producer offers the losses energy quantity

The interconnection remains congested since the price difference increases. No losses costs are procured out of the coupling mechanism, then we have LC' = 0; we also have LPS'_{ext} = 0 since the orange order is integrated to the supply curve. We can calculate the gross congestion rent as the difference between purchased and sold energy:

CR' = (F – δF).(pB + δpB) – F.(pA – δpA)

= CR – δF.(pB + δpB) + F.δpA + F.δpB

The surplus of consumers and producers can be visualised as follows[51]:

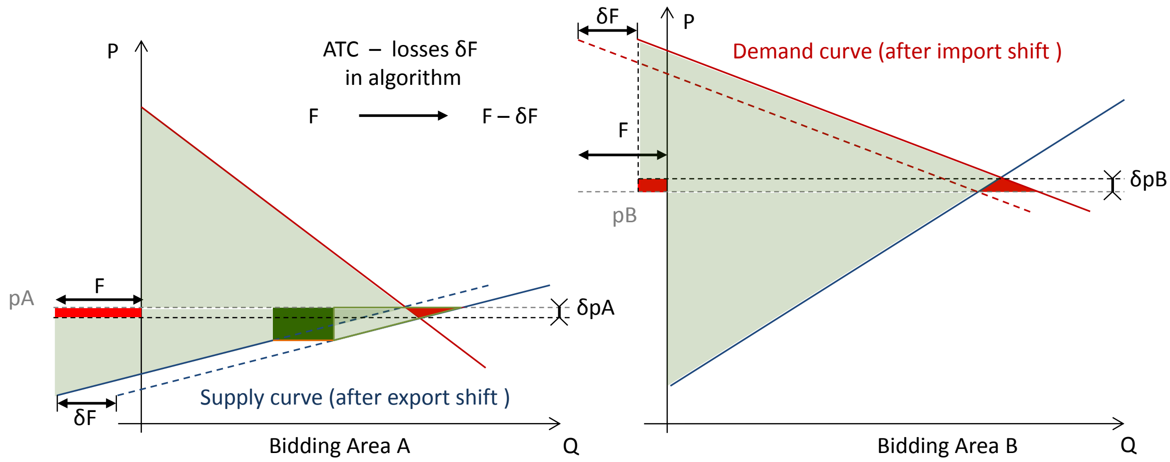


Figure 23: the difference between purchased and sold energy

[51] In the following we use the assumption that the supply and demand curves in A are locally linear at the neighbourhood of the equilibrium and that the prices in A and B are not determined by the block selection.

The surplus can be calculated by the addition of dark green areas and substraction of red areas:

$(CSA + PSA)' = (CSA + PSA) - F.\delta pA - 1/2.\delta F.\delta pA + \delta F.(pA - pLoss)$
$(CSB + PSB)' = (CSB + PSB) - (F - \delta F).\delta pB - 1/2.\delta F.\delta pB$
$= (CSB + PSB) - F.\delta pB + 1/2.\delta F.\delta pB$

Then the coupling welfare can be calculated:

$CW' = CW + LPS - \delta F.pB - 1/2.\delta F.(\delta pA + \delta pB)$

Since no losses cost and no external Losses Producer surplus exist, we obtain:

$NCW' = CW' = NCW - \delta F.(pB - pA) - 1/2.\delta F.(\delta pA + \delta pB)$,

hence we get **NCW' < NCW** since $pB - pA > 0$. The last inequality reflects **the inherent limitation of the "sending end" modelling**. In congested configurations, the interconnection which are simulated under this modelling will return a net coupling welfare which is sub-optimal at least of the quantity equal to $\delta F.(pB - pA)$.

Now let us consider that simulations did not include the offer of the Losses Producer in the supply curve when losses are included in the algorithm. On the drawing, the orange order disappears and the price in A remains unchanged.

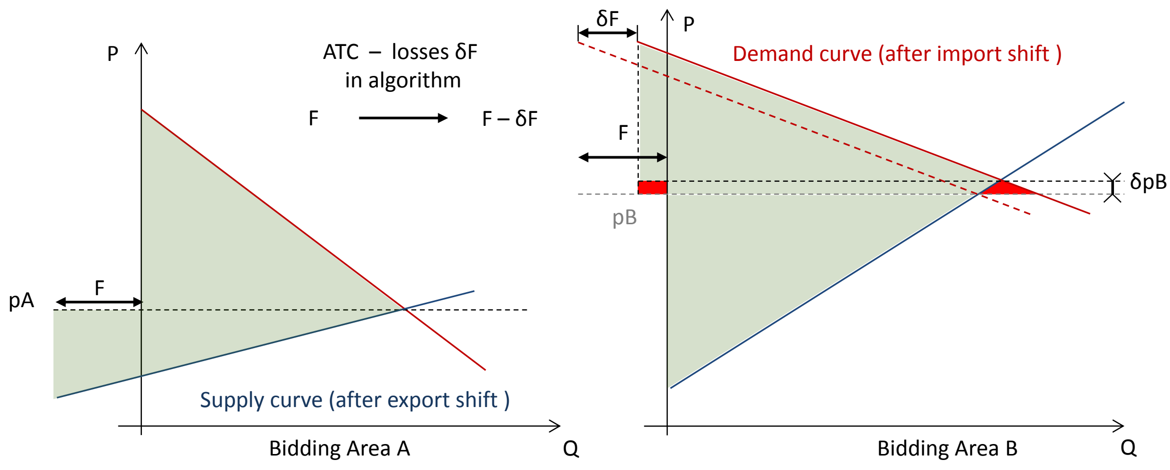


Figure 24: the orange order disappears and the price in A remains unchanged

Then we have an external surplus of Losses Producer $LPS' = \delta F.(pA - pLoss)$ and we have:

$(CSA + PSA)' = (CSA + PSA)$
$(CSB + PSB)' = (CSB + PSB) - F.\delta pB + 1/2.\delta F.\delta pB$

And the gross congestion rent becomes:

$CR' = (F - \delta F).(pB + \delta pB) - F.pA = CR - \delta F.pB - \delta F.\delta pB + F.\delta pB$

Again we sum the surplus and the gross congestion rent to obtain the coupling welfare:

$CW' = CW - \delta F.pB - 1/2.\delta F.\delta pB$.

We remark that no external losses cost remains ($LC' = 0$) and we obtain the net coupling welfare:

$NCW' = CW' + LPS' = CW + LPS - LC - \delta F.(pB - pA) - 1/2.\delta F.\delta pB$,

which results into $NCW' < NCW$. The calculated net coupling welfare now reads:

$NCWc' = CW' = CW - LC - \delta F.(pB - pA) - 1/2.\delta F.\delta pB$,

which can be written:

$NCWc' = NCWc - \delta F.(pB - pA) - 1/2.\delta F.\delta pB$.

Here we have again **NCWc' < NCWc** since pB – pA > 0, the difference being at least equal to the quantity given by δF.(pB – pA).

This last inequality concludes the proof of the limitations of the calculation of net coupling welfare under the frame of this modelling.

Remark on the price bias when the sending end modelling is applied:

(iii) When the Losses Producer is re-integrated in the supply curve, price in A (resp. B) decreases (resp. increases);

(iv) When the Losses Producer is not re-integrated in the supply curve, price A is steady but price B increases of δpB; this price increase δpB depends on curve elasticities in bidding area B (it can be zero up to infinity);

Remark on the evolution of the net congestion rent when the sending end modelling is applied:

(iii) When the Losses Producer is re-integrated in the supply curve, we have the equality on the gross congestion rent: CR' = CR – LC – δF.(pB – pA) – δF.δpB + F.δpA + F.δpB and LC' = 0; then we observe that the net congestion rent is given by NCR = CR – LC and NCR' = CR' – LC'; hence we obtain NCR' = NCR – δF.(pB – pA) – δF.δpB + F.δpA + F.δpB; in other words the sending end model can result into a positive or negative variation of congestion rent depending on the weight of the different terms;

(iv) When the Losses Producer is not re-integrated in the supply curve, we obtain similarly NCR' = CR' – LC' = CR – LC – δF.(pB – pA) – δF.δpB + F.δpB = NCR – δF.(pB – pA) – δF.δpB + F.δpB; in other words the sending end model can result into a positive or negative variation of congestion rent depending on the weight of the different terms.

(C) Correction of part of the side effects of "sending end" modelling

For interconnectors subject to "sending end" modelling (Baltic, BritNed, IFA), part of the decrease of net coupling welfare is corrected in the numerical results by means of the addition of the term δF.(pB – pA) to the raw net coupling welfare.

Let us denote NCWc the calculated net coupling welfare as defined above as CW – LC (difference between coupling welfare and external losses cost). In case a "sending end" interconnector is congested in reference Run#1 (without losses included) with a price difference greater than the loss factor of the current run, a corrected net coupling welfare is calculated as follows in each hour of current run:

CNCWc = NCWc + δF.(pB#1 – pA#1),

where:

- δF is the energy lost in current run when loss factor is included (it is the difference between the flow "in" and the flow "out");
- (pB#1 – pA#1) is the price difference in reference Run#1.

This CNCWc quantity is called Net Coupling Welfare throughout the report, instead of "Corrected calculated Net Coupling Welfare".

N.B. This correction is only an approximation. In particular the term 1/2.δF.δpB is neglected. In addition, this correction assumes as marginal the other reasons why prices and flows can change (e.g. impact of losses on other interconnectors; impact of block order selection; impact of interdependency between hourly results). In other words, the correction corresponds to a pair of bidding areas connected by a single interconnector with the assumptions we made concerning the liquidity of the markets and the local linearity of supply and demand curves whereas it is applied in the frame of a complex topology with historical order books.

(D) Procurement of losses: outside the coupling mechanism versus via day-ahead order on the market

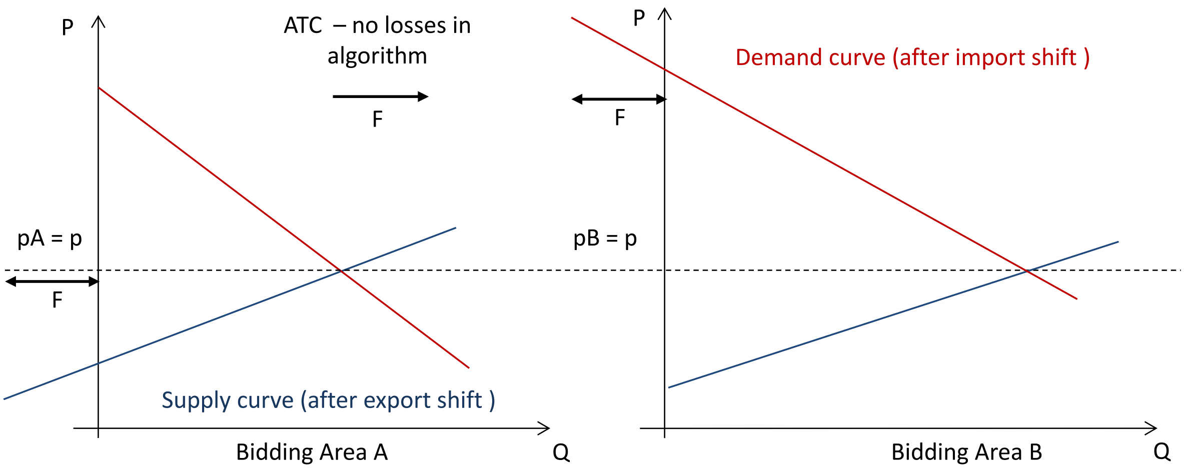
On day-ahead market

Let us consider that no losses are included in algorithm (which corresponds to Run#1). Assume a non congested configuration. Then the gross congestion rent is zero.

TSO purchases for losses on the day-ahead market: the cost for the procurement must be deducted from the gross congestion rent. The net congestion rent is negative:

NCR = – LC = – qLosses.p,

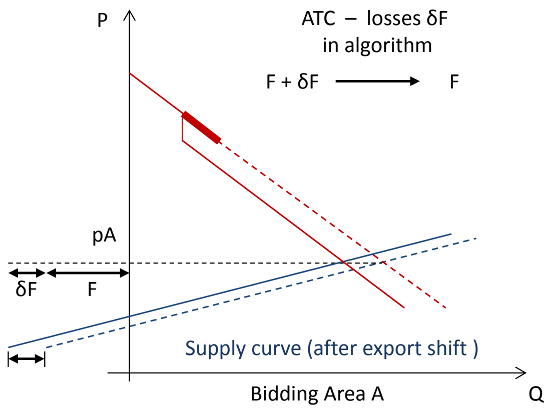
where p = pA = pB and qLosses is the quantity of energy losses.



Then the net coupling welfare can be calculated as follows:

NCW = CS + PS + NCR
= CS + PS – LC
= CW – qLosses.p

When losses are included in the algorithm, the TSO buy order should be removed from the demand curve in the simulations. Since demand curves in Run#3 are kept unchanged, a increase of price pA' = pA + δpA is observed at the exporting side when the interconnector is a "receiving end" interconnector. The graph belows shows the exporting bidding area when losses are included in the algorithm (the dashed red curve is the actual curve in simulations whereas the plain red curve is the theoretical one without the TSO buy order; the dotted blue curve is the supply curve before the inclusion of losses, the plain blue curve is the supply curve when the sending end ATC has been increased).

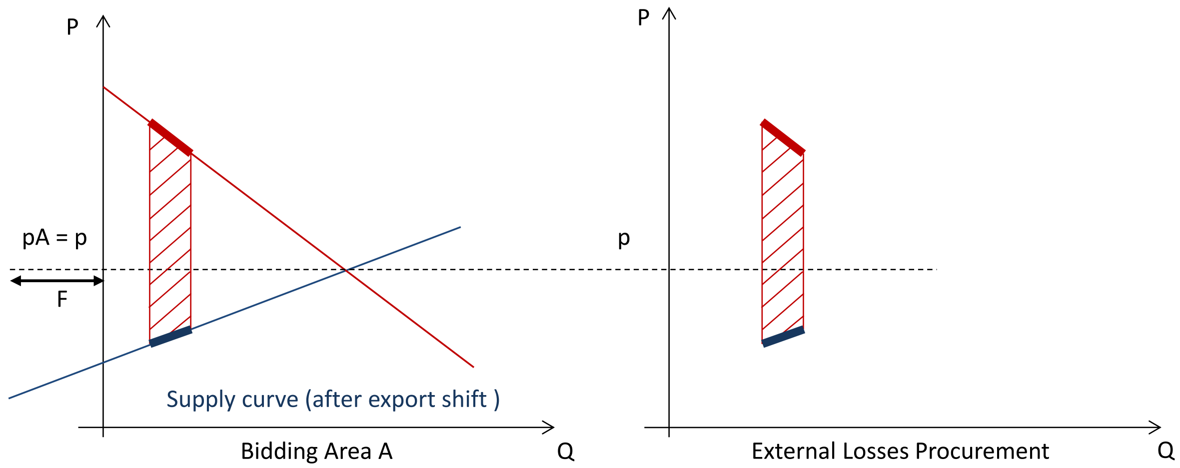


This non removal of the TSO buy order from the demand curve is equivalent to the non addition of the Losses Generator into the supply curve when losses are procured externally: price bias and welfare effects are identical.

Outside the coupling mechanism

We still consider that no losses are included in algorithm (which corresponds to Run#1) and we still consider a non congested configuration.

Now we assume that losses are procured externally[52]. Then the TSO buy order is removed from the day-ahead market and the corresponding Losses Generator sell order (against which the TSO buy order is matched) is removed.



It is assumed that the procurement price for losses is the market price, which is unchanged. Then the surplus of the TSO and of the Losses Generator remain identical compared to the case when the losses procurement is made on the day-ahead market.

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[52] The example shows a TSO buy order at a given price (which can be any price); it remains correct if the TSO order is a price taking order.

The net congestion rent is still negative: NCR = – LC = – qLosses.p
The coupling welfare CW' can be calculated as:

CW' = CW – TSO surplus – Losses Generator surplus

Then the net coupling welfare NCW' is:

NCW' = CW' + TSO surplus + Losses Generator surplus + NCR
= CW – qLosses.p
= NCW

In other words, the net coupling welfare is identical whatever the mode for losses procurement: either on the day-ahead market or outside the coupling mechanism.

Appendix VII - Market Simulation Framework - Description of Runs

Period of simulations

Simulations cover full year 2011[53]. Market data are historical data from PXs order books. Network data are historical ATCs and ramping limits (except when losses apply).

Modeling

The network is based on ATC interconnection (no Flow-Based); no tariff applied. Losses are applied only for some cables (see below). The perimeter covers the NWE bidding areas (including PL and Baltic areas).

List of Runs

No loss is applied on AC interconnectors for any run.

- Run #1 – No losses in the market coupling at all (loss factors applied in Run#3 are used to calculate external losses costs) - The output is the reference result in terms of welfare, prices and flow pattern
- Run #2 – Equal Loss Factor on all existing DC cables (harmonized case)
- Run #3 – Individual Loss Factor on all existing DC cables – These loss factors are assumed to be the actual loss factors which perfectly reflect the losses on the interconnectors
- Run #4 – Individual Loss Factor on some DC cables (BritNed, IFA and Baltic)
- Run #5 – Equal Loss Factor in some DC cables (BritNed, IFA and Baltic)

The only differences between the 5 runs are the modification of loss factors for DC (including the impact on ATC and ramping limit values considered by the algorithm). Every other run feature (e.g. input data, algorithm parameters, network topology for each day) is identical for all runs[54].

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[53] The inclusion of the ramping constraint with the flow of last hour previous day made two sessions fail, so that results were available for 363 days (8712 hours) only.

[54] Though being an input for a given day, the flow of last hour previous day through each interconnection with ramping constraint is an output of the day before and therefore can be different for each run.

Loss Factor Up/Down	Run #1	Run #2	Run #3	Run #4	Run #5
NorNed	0%	2%	4%	0%	0%
Storebælt	0%	2%	1.5%	0%	0%
Skagerak	0%	2%	3.8%	0%	0%
Kontek	0%	2%	2.5%	0%	0%
Kontiskan	0%	2%	2.6%	0%	0%
IFA	0%	2%	2.313%	2.313%	2%
Estlink[55]	0%	2%	5.05% / 5.21%	0%	0%
Fennoskan	0%	2%	2.4%	0%	0%
Baltic	0%	2%	2.4%	2.4%	2%
BritNed	0%	2%	3%	3%	2%
SwePol	0%	2%	2.6%	0%	0%

Table 32: Loss Factor Up/Down

	Ramping constraints (MW)	Cable end to be considered for ATC and ramping	Until Oct 31	After Nov 1
NorNed	600	Receiving end	NL-NO2	idem
Storebælt	600	Receiving end	DK1-DK2	idem
Skagerak	600	Receiving end	NO2-DK1A	idem
Kontek	600	Receiving end	DE-DK2	idem
Kontiskan	600	Receiving end	SEA-DK1A	DK1A-SE3
IFA	0	Sending end	FR-GB1	idem
Estlink	0	Receiving end	EE-FI	idem
Fennoskan	0	Receiving end	SE-FI	SE3-FI
Baltic	600	Sending end	DE-SE	DE-SE4
BritNed	0	Sending end	NL-GB2	idem
SwePol	600	Receiving end	SE-PL	SE4-PL

Table 33

For cables with "receiving end reference", historical ATCs and ramping limits are receiving end values. In order to be used as algorithm inputs, sending end values are re-calculated from historical data as follows:

Algorithm input value = Historical value / (1 - loss factor), rounded down to tick size (1MW).

For Baltic and BritNed cables, historical values are used as such by the algorithm, without alteration (so that for instance historical 600MW ramping results into 586MW receiving end ramping).

[55] Estlink loss factor is directional: up is from FI / down is to FI (for ramping values, which are not directional, loss factor down is used)

For IFA, sending end values are re-calculated from historical values with “mid-channel” reference, independently from the applied loss factor, as follows:

Algorithm input value = Historical value. (1 + 1.17%), rounded down to tick size (1 MW).

Topology Changes

Until Oct 31, the topology includes:

- SEA virtual bidding area
- SE is a single bidding area, with one single connection to FI in production, aggregating the DC line between SE and FI and the AC interconnection between SE and FI in the north

After Nov 1st, the topology has changed:

- SEA no longer exists
- SE has been split into SE1/SE2/SE3/SE4, so that there exists one SE3-FI DC Fennoskan line and one AC SE1-FI line

As a consequence, the production configuration until Oct 31 cannot be used for assessing the impact of the inclusion of losses.

Cumulative ramping limits and cumulative ATCs are represented by means of virtual bidding areas: e.g. cumulative ramping between DK1-DK1A (of 600 MW) is included for the cumulative ramping limit representation of the combination of DK-NO and DK-SE lines.

GB consists of two bidding areas (no virtual areas), of which one is linked to FR (via IFA) and the other is linked to NL (via BritNed). A virtual line with infinite capacity is placed in between the two.

After Nov 1st

Historical configuration can be used (interconnections in red have losses for some runs).

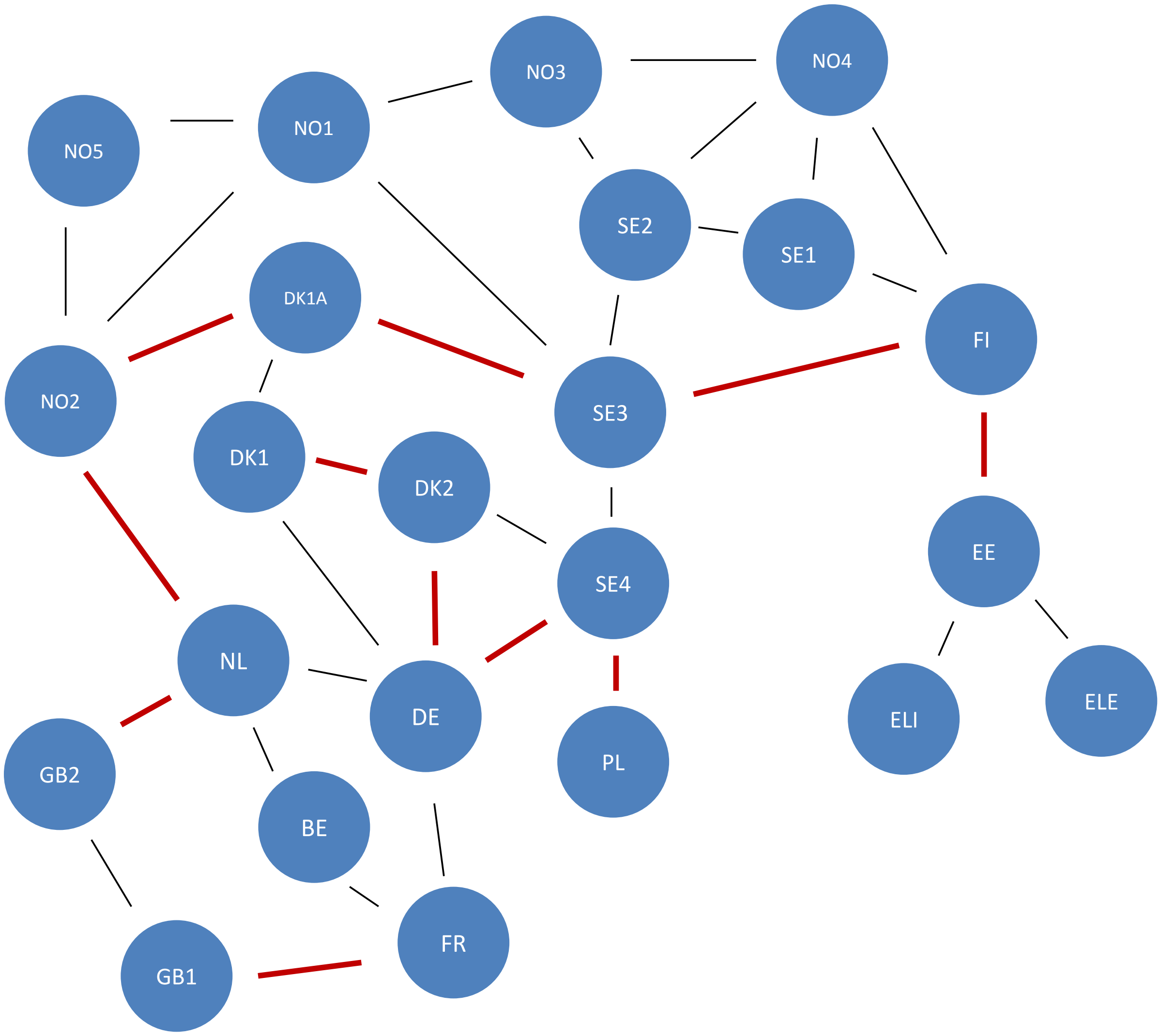

Figure 25: After Nov 1st

Until Oct 31

The historical configuration is not relevant. An alternative configuration is described below; this configuration is not the historical configuration and do not correspond either to the historical configuration after Nov 1st.

SE and FI are linked via two lines, representing the AC and the DC parts of the historical interconnector. The DC line has a constant capacity of 550MW up and down, except days when an outage occurred: 15.2 - 16.2 / 11.4 - 20.4 / 13.5 - 15.5 / 2.8 - 5.8 - 8.8 - 13.8 / 17.9

For these days, the DC capacity is zero up and down. The AC line has the rest of the capacity:

AC capacity SE-FIA = historical SE-FI capacity – DC capacity

The SE-FI alternative configuration is the only occurrence of an AC line in parallel with a DC line with losses.

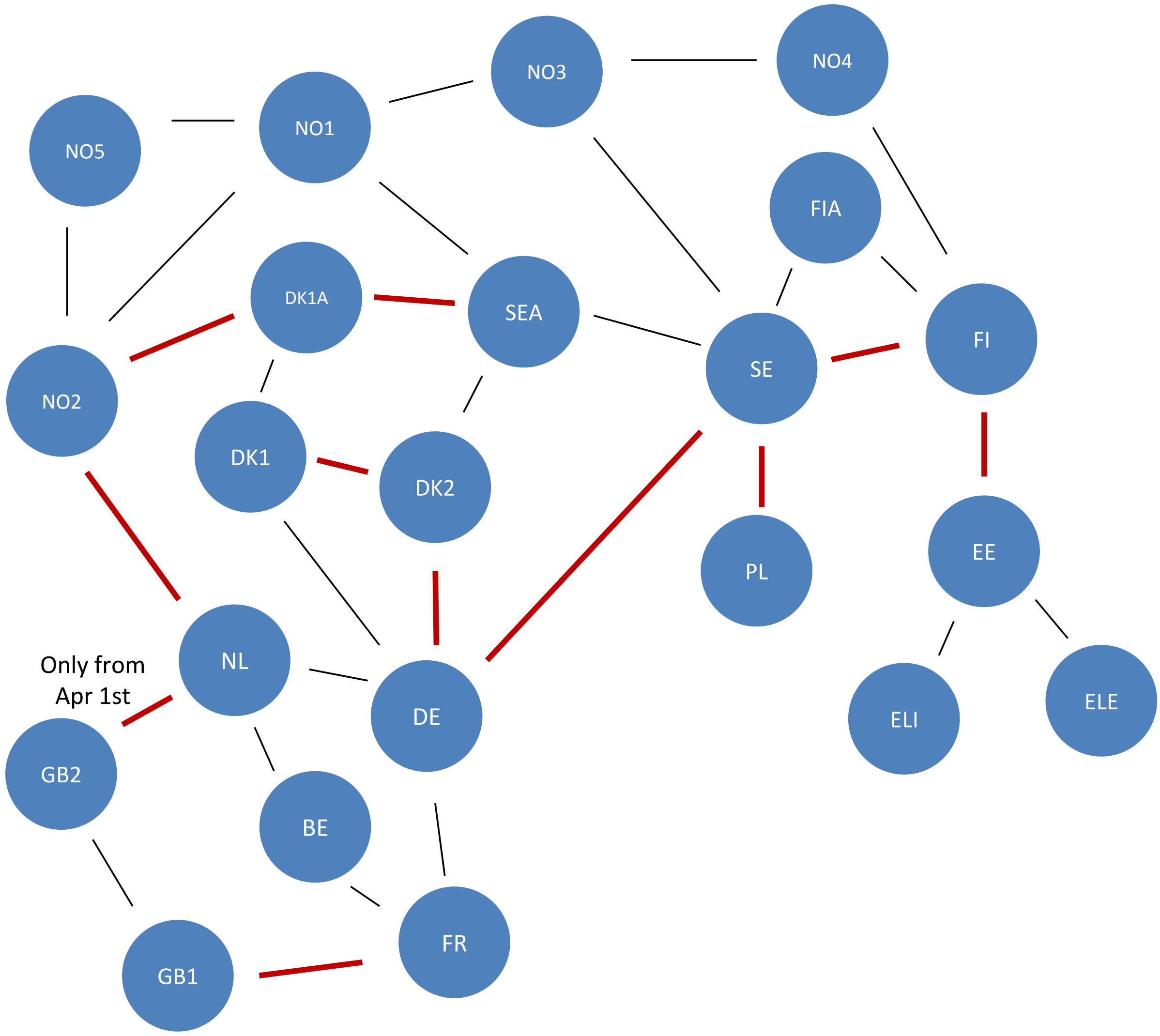

Figure 26: Until Oct 31

Appendix VIII - Explanation on Hours with Unexpected Effects

The calculation of the Net Coupling Welfare before correction of part of the sending end side effects leads to the following observations:

- The average net coupling welfare[56] is lower in Run#4 than in Run#5, which was not expected;
- For some days, the comparison between the results with losses included and results with no losses included shows a decrease of net coupling welfare when losses are included;
  E.g. Run#4 shows less net coupling welfare for Jan 1 than Run#1;
- This decrease was not expected and the occurrence of the observation (188 days out of 363 with less net coupling welfare in Run#4 than in Run#1) makes a need for some investigations;
- It must be noticed that the net coupling welfare remains higher in average when losses are (even partly) included in the algorithm, compared to reference Run#1;

The paragraphs below aims at explaining why such results are observed and why the main results of the study remain valid despite these unexpected observations.

Analysis of an example – Session 1 (Jan 1)

Overview

The quantities below are homogeneous to welfare; the unit is Euro (€).

Session 1 (Jan 1)	Run#1	Run#4	Variation #4 - #1
Coupling Welfare	5 532 876 242	5 532 862 339	-13 903
External Losses Cost	100 631	98 862	-1 769
Net Coupling Welfare	5 532 775 611	5 532 763 477	-12 134

Table 34: Session 1 (Jan 1)

Since Run#4 has losses included, it is expected that the coupling welfare is higher in Run#1, which is verified. We expect External Losses Cost to be higher in Run#1 since this Run#1 has no losses taken into account in the algorithm; whereas some losses are included in the coupling mechanism in Run#4; which is verified.

But the gain of 1 769€ in external losses costs is not sufficient to compensate the decrease of coupling welfare between Run#1 to Run#4: Run#1 has a higher net coupling welfare than Run#4.

Formation of External Losses Cost

When we compare Run#4 to Run#1, the gain in external losses costs of € 1 769 should (at least for a significant part) come from interconnections for which we have losses included in Run#4 and not in Run#1:

- FR-GB1 shows a decrease in external losses costs by € 2 297;
- DE-SE shows a decrease in external losses costs by € 3 478;

[56] In this Appendix, net coupling welfare refers to the uncorrected net coupling welfare

Therefore there must be interconnectors which have no losses included in Run#4 and yet with a higher external losses cost in Run#4. This is not theoretically impossible.

(a) For instance the direction NL->NO2 / session 1 – hour 2 is congested at 700MW both in Run#1 and Run#4; we have the following prices in NL for session 1 – hour 2: Run#1: 56.25€ / Run#4: 57.08€. Hence we can see that the external losses cost will increase by 4%*700*(57.08 – 56.25) = € 23.24;

(b) Another reason could be that the flows on lines FR-GB1 and DE-SE in Run#1 are re-routed to another route with higher losses, because these higher losses are not included in the coupling mechanism in Run#4. This does not occur: FR-GB1 has no parallel route and DE-SE interconnector is congested before and after the inclusion of losses.

We observe that the SE-FI interconnector shows a higher external losses cost in Run#4 than in Run#1:

SE-FI (Jan 1)	Run#1	Run#4	Variation #4 - #1
External Losses Cost (€)	17 501	21 433	3 932

Table 35: SE-FI (Jan 1)

This value of € 3 932 contributes to a lower net coupling welfare in Run#4.

Now in order to explain this variation of external losses cost for on SE-FI, let us consider, as an example, hour h16 of Jan 1. In the drawing below, the link via FIA represents the northern AC interconnection.

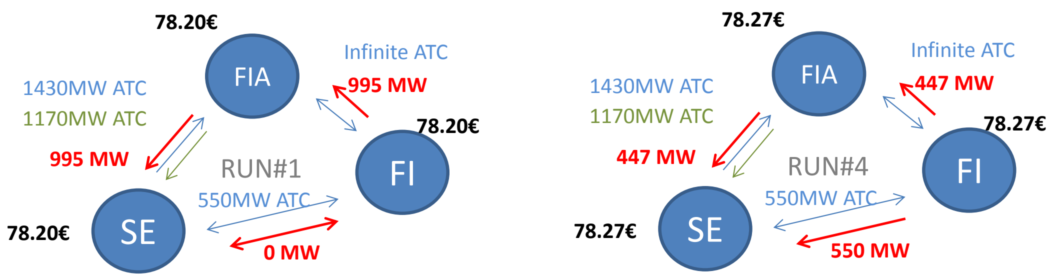

Figure 27: variation of external losses cost for on SE-FI

We can see that prices slightly vary from Run#1 to Run#4. Total flow FI->SE slightly changes from 995MW into 997MW. However the flow indeterminacy is solved completely differently despite identical cost coefficients in Run#1 and Run#4. The discrepancy in flow indeterminacy can be observed for other hours (e.g. h9, h10, h11, h13, h14, h15, h20, h21); on some other hours, the direct route is preferred for both runs; on other hours, the indirect route via FIA is preferred for both runs.
This explains why SE-FI has external losses costs in Run#4 (which corresponds to a 550MW flow in h16 for instance) which cannot be observed in Run#1 (where the flow is zero in h16). More generally speaking, except when both routes are congested, the values of flows seem completely arbitrary[57]; only the sum reflects the net position of FI.

[57] For further simulations, a tuning of cost coefficients should solve the issue.

Impact of modelling assumptions

Theoretically, when an interconnector is congested, including losses in the coupling mechanism should not modify the surplus of producers and consumers.
In the frame of the simulations, we know from Appendix VI that for a congested "receiving end" interconnector, the surplus of producers and consumers slightly **in**creases; which is compensated by a **de**crease in the net congestion rent; which results in an **under**estimation of net coupling welfare.

For a congested "sending end" interconnector, the surplus of producers and consumers slightly **de**creases; which turns out into an even larger underestimation of total welfare.

For session 1 (Jan 1), we observe the following values in Euro (€):

Session 1	Run#1	Run#4	Variation #4 - #1
Producer Surplus	2 332 115 494	2 332 132 625	+17 131
Consumer Surplus	3 193 369 948	3 193 345 258	-24 690
Total Surplus	5 525 485 442	5 525 477 883	-7 559
Gross Congestion Rent	7 390 800	7 384 456	-6 344
Coupling Welfare	5 532 876 242	5 532 862 339	-13 903

Table 36: Session 1

In session 1, the DE-SE interconnector is always congested for Run#1 and Run#4. Same for FR-GB1 (except hours 1 and 2). Then we expect the modeling side effect which is recalled above to occur: it can be partly quantified by means of the term δF. (pB – pA):

- which amounts to 1 326€ in FR-GB1;
- which amounts to 7 430€ in DE-SE;

If we sum the different effects which we have focused on, we retrieve the expected variation of total welfare as follows:

Side Effect (€)	Impact
Artificial External Losses Cost due to flow indeterminacy solving	3 932
Impact of modelling assumption ("sending end")	8 756
Total Gain to reintegrate in Net Coupling Welfare Run#4	12 688
Variation of Net Coupling Welfare #4 –#1 after correction	+554

Table 37: Side Effect (€)

Comparison between Run#4 and Run#5

Let us summarize the raw output values (in Euro - €) of external losses cost, coupling welfare and net coupling welfare for session 1 (Jan 1) and Runs #1; #4; #5.

Session 1	Run#1	Run#4	Run#5
Producer Surplus	2 332 115 494	2 332 132 625	2 332 143 124
Consumer Surplus	3 193 369 948	3 193 345 258	3 193 336 092
Total Surplus	5 525 485 442	5 525 477 883	5 525 479 216
Gross Congestion Rent	7 390 800	7 384 456	7 385 225
Coupling Welfare	5 532 876 242	5 532 862 339	5 532 864 441

External Losses Cost	100 631	98 862	95 634
Net Coupling Welfare	5 532 775 611	5 532 763 477	5 532 768 807

Table 38: Summary of Session 1 results

If we apply the same methodology as before to Run#5 (still session 1 – Jan 1):

- The gain in external losses cost compared to Run#1 is slightly above the contribution of external losses cost gain of FR-GB1 and DE-SE interconnectors;
- Flow indeterminacy artificial losses cost exists but is negligible (due to compensation between hours)
- No interconnector shows a significant increase of external losses cost in Run#5 compared to Run#1
- The part of the impact of the "sending end" modeling which we can quantify amounts to € 6 192 (resp. € 1 147) for DE-SE (resp. FR-GB1);

We can summarize the corrections in the following table:

Side Effect (€)	Impact – Run#4	Impact – Run#5
Artificial External Losses Cost due to flow indeterminacy solving	3 932	0
Impact of modelling assumption ("sending end")	8 756	7 339
Total Gain of to reintegrate in Net Coupling Welfare Run#4	12 688	7 339
Variation of Net Coupling Welfare #4/5 –#1 after correction	+554	+535

Table 39: Corrections for Side Effects (€)

Conclusion

On an example, it was possible to quantify the different limitations of the model and to retrieve the expected direction of the variation of net coupling welfare in Run#1; Run#4; and Run#5.

It must be noticed that the correction made is only an approximation: it focuses on significant side effects but other effects might exist.

Other possible side effects explaining a decrease of net coupling welfare when losses are included

The previous paragraphs emphasized two reasons why net coupling welfare can decrease when losses are included in the coupling mechanism:

- the limitations of the modeling (especially the "sending end" modeling of interconnectors);
- the calculation of flows in case of indeterminacy which is not robust to small flow variations;

Several other causes might explain the decrease of net coupling welfare when losses are included:

(a) Impact of ramping with flow last hour previous day;
(b) Re-routing of flows to an interconnector with a higher loss factor which is not included in the coupling mechanism;
(c) Changes in prices and flows due to the selection of fill-or-kill block orders;
(d) Slight change in the performance of the algorithm when losses are included, leading to a calculated coupling welfare less close to optimality;

In the frame of the study, no element is available to analyse the impact of the two last possible causes (c) and (d).

All these effects can impact the expected increase of net coupling welfare when losses are included.

On average, the effect of net coupling welfare increase in uncongested hours is stronger than the side effects which tend to decrease net coupling welfare when an interconnector is congested with no losses included.

Appendix IX - Losses and Limit Prices Explained

The inclusion of losses in the algorithm imposes a constraint on the price difference between the exchanging bidding areas. This price difference holds whatever the prices in the bidding areas, including negative and extreme prices.

The inclusion of losses does not interfere with other algorithm processes aiming at managing the extreme price situation (e.g. local matching, curtailment sharing); for instance it is not possible to relax the loss factor in order to facilitate a trade so that the curtailment is avoided.

The extreme price range holds in the common currency; it might be possible that the conversion into a local currency exceeds the price limit, but this is managed at the level of the local trading system (not in the coupling algorithm).

Example. Assume a price of -200€ in NO2. This price and the corresponding flows satisfy the losses constraint (i.e. price difference; energy quantity at exporting / importing ends of the interconnections). It might be that the NOK price results into an equivalent of -200,01€ at the hour of settlement, because of the conversion rate agreed between Nord Pool Spot and market participants and because of the process which are implemented in the trading system. Then the price difference in NOK / DKK / SEK might not exactly reflect the loss factor whereas the price difference in € exactly[58] reflects the loss factor in the outputs of the algorithm.

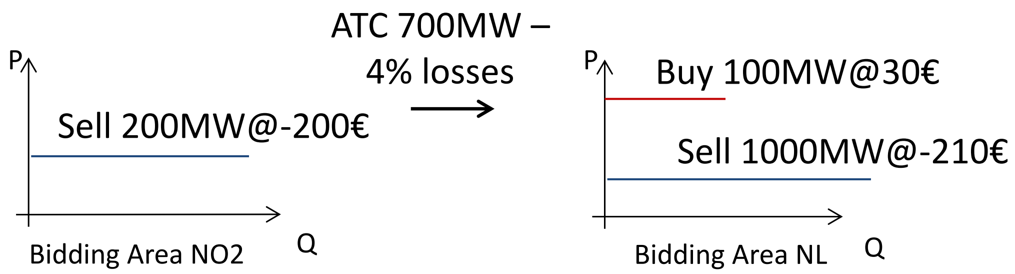

Figure 28: Example 1 – Uncongested case – Price difference not sufficient to cover losses

The coupling result is the following:

- NL price is -€ 210
- NO2 price is -€ 200 higher than NL
- The price difference is not sufficient to cover 4% losses
- No flow is possible from NO2 to NL

This is an uncongested situation. In order to convey 1MW from NO2 to NL, the TSO should purchase 1MW@- € 200 (i.e. would receive + € 200 cash) and should sell 0.96MW@- € 208 (i.e. would pay +€ 200 cash); since the interconnector is uncongested, we check that the cash flow of the TSO would be zero.

[58] Before rounding; when prices are rounded for publications by PXs, a small difference might appear.

Selling 0.96MW@- € 208 in NL is not possible because there is a more competitive sell order 1000MW@-€ 210 and a low demand. Hence no flow is possible.

We observe pNO2 > pNL. (1-loss factor), numerically -200 > -210*0.96 = -201.6; which explains why a flow from NO2 to NL is not possible.

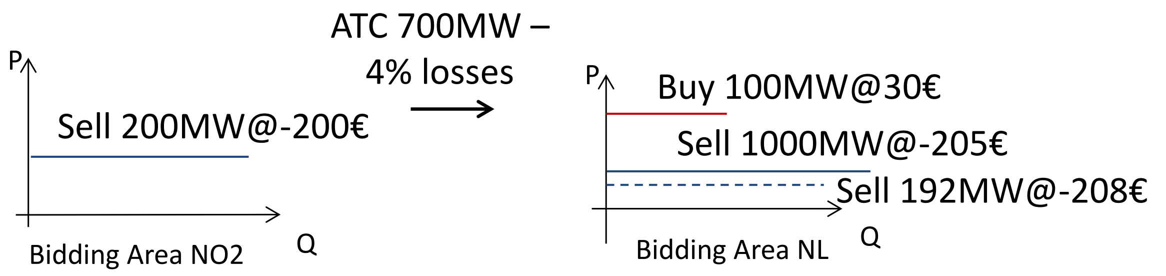

Figure 29: Example 2 – Uncongested case – Price difference sufficient to cover losses

The coupling result is the following:

- NL price is -€ 208;
- NO2 price is -€ 200
- The price difference covers 4% losses
- Flow NO2 to NL of 200MW

This is an uncongested situation. In order to convey 1MW from NO2 to NL, the TSO should purchase 1MW@- € 200 (i.e. would receive + € 200 cash) and should sell 0.96MW@- € 208 (i.e. would pay + € 200 cash); since the interconnector is uncongested, we observe that the cash flow of the TSO is zero.

Selling 0.96MW@- € 208 in NL is welfare maximizing because local NL sell order is @- € 205.

We observe p_{NO2} = p_{NL}. (1-loss factor), numerically -200 = -208*0.96 (after rounding); which reflects the fact that a flow from NO2 to NL exists and is not congested. We also observe that allowing capacity made the NL price decrease from - € 205 (isolated price) to - € 208.

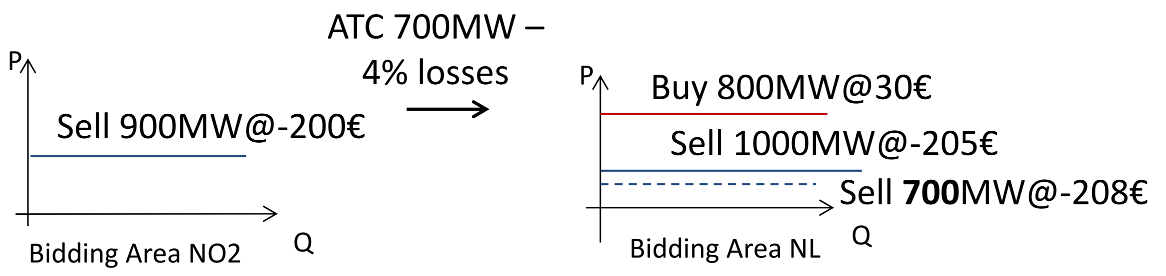

Figure 30: Example 3 – Congested case – Price difference higher than loss factor – positive congestion rent

The coupling result is the following:

- NL price is - € 205
- NO2 price is - € 200
- The price difference covers 4% losses

- Flow NO2 to NL of 700MW is congested

This is a congested situation. In order to convey 1MW from NO2 to NL, the TSO should purchase 1MW@-€ 200 (i.e. would receive + € 200 cash) and should sell 0.96MW@-€ 208 (i.e. would pay + € 200 cash); since the interconnector is congested, the sending end flow is 729MW and we observe a positive congestion rent CR = 700*(-205) – 729*(-200) = € 2300.

Selling 0.96MW@- € 208 in NL is welfare maximizing because local NL sell order is @- € 205.

We observe $p_{NO2} < p_{NL}$. (1 - loss factor), numerically -200 < -205*0.96 = - € 197; which reflects the fact that a flow from NO2 to NL exists and is actually congested.