

## ANNEX 1 – EFFICIENCY QUANTIFICATION

### Modelling the intraday model, 2020 data

#### COUNTERTRADE MODELLED IN DAY-AHEAD MARKET MODELS

When quantifying the effects of the methodology on other markets market coupling, the successive nature of the actual power markets with varying degrees of market coupling is a challenge because the power market models that Energinet has access to do not allow such successive simulations. For example, the Danish special regulation model is characterized by having a fully coupled day-ahead market and a (roughly speaking) non-coupled countertrade model. Energinet can, however, only model a single degree of market coupling.

Modelling the Danish special regulation model as non-coupled Danish markets would not make sense given the highly coupled nature of the Danish bidding zones while modelling a fully coupled day-ahead market as if this represented the Danish special regulation model would make equally little sense because the actually realized effects of countertrade would in no way be reflected in the modelling results.

The intraday model which allows full market-coupling has close-to the same degree of market coupling as the day-ahead market fits well with the simulation models.

Energinet has access to two relevant models for quantifying the socioeconomic effects of countertrade.

- The Simulation Facility model makes it possible to calculate the socioeconomic effects of changes to the historical power system by rerunning the day-ahead market with the real complexity of the day-ahead market under these changes
- The BID model is based on assumed data on every relevant detail such as fuel prices, technology specific generation capacities, load, interconnection, etc. A simplified mathematical optimization produces a socioeconomically optimal dispatch.

When quantifying the socioeconomic effects of countertrade in either of these models, the purpose is to identify the cost effects of the marginal changes to generation and/or the value effects of marginal changes to load resulting from countertrade.

The key advantage of using the Simulation Facility model is that it allows a perfect match between realized bids in the day-ahead market and realized countertrade. This is not possible in the BID model. There, also the countertrade volume needs to be assumed.

#### INTRODUCING COUNTERTRADE TO THE MODEL

As described, it is not possible to model successive power markets in either model which fundamentally model only the day-ahead market. The effects of countertrade therefore need to be modelled by mimicking the effects of countertrade on other parameters of the models. On the DK1-DE border countertrade results in an import of energy to DK1 which means that less generation is needed on the Danish side of the border to cover demand, either in DK1 or in a bidding zone exporting to DK1 directly or indirectly. A reduction in demand in DK1 would similarly result in less generation in DK1 or less import. As such, countertrade on the DK1-DE border fundamentally corresponds to a reduction in demand in DK1.

Whether or not this reduction in demand is realized in the day-ahead, intraday, or balancing energy market is not important for socioeconomic costs of generation and value of load. It is rather the fact that less generation and/or more load is ultimately needed that has a socioeconomic effect. Obviously, if demand is reduced day-ahead, the day-ahead price will be impacted, but the marginal generation unit is likely to be the same if demand is instead reduced in the intraday time frame or in the balancing time frame<sup>1</sup>. As such, for the socioeconomic assessment, it is unimportant in which time frame demand is reduced. As such, even though the simulations model the day-ahead market, they deliver an assessment of the effects of countertrade on the physics of the system in the form of generation costs and value of load.

The bidding strategies of market participants impact what the day-ahead price will be and by extension which market participants are most likely to deliver the countertrade energy. If consumers for example perfectly forecast countertrade volumes and move their demand from the day-ahead market to the intraday market, the day-ahead price that results from the modelling will be a "best estimate". However, if only 50% of countertrade volumes are forecasted and day-ahead demand adjusted accordingly, the estimated day-ahead price will be too low because the modelling assumed 100% forecasted countertrade. These price effects are associated with distributive effects, i.e. how are consumers, producers, and TSOs impacted by changes in the day-ahead price, and who earns surplus from the sale of countertrade energy but it does not impact the underlying socioeconomic costs of running the power system.

#### HYDRO (STORAGE) EFFECTS

The Simulation Facility model is, however, static in the sense that the bids in the market are not impacted by the changes imposed to the model. This is particularly relevant for hydro-power where the alternative value of hydro resources is the key factor in bidding strategies (as opposed to thermal power plants which have "unlimited" fuel).

<sup>1</sup> Prequalification requirements do play a role but since the effects of these requirements cannot be quantified the requirements are ignored for simplicity here.

A reservoir hydropower plant offering to reduce its generation does so on the basis of the expected future value of the saved water. As such, it is not the water value in the hour with countertrade but in the hour in which the saved water will actually be used that determines the value. In the Simulation Facility, this dynamic cannot be captured. In the BID model, however, the model makes an initial optimization which takes into account expected load, etc. which will tend to capture these dynamic effects, or at least do so better than the Simulation Facility.

When reporting the effects of countertrade on for example generation, the Simulation Facility model will tend to report that countertrade results in a significant reduction in generation in hydrobased Nordic bidding zones, whereas the dynamics in the BID model will imply that although generation is initially reduced in hydrobased Nordic bidding zones, generation is subsequently increased to avoid accumulation of the water that was not used due to countertrade initially.

Further, in the Simulation Facility the use of specific years may introduce a bias in the results if the modelled years are not representative of the future. This can be overcome by selecting the multiple years.

#### IDENTIFYING THE EFFECTS OF COUNTERTRADE

In the Simulation Facility model, the only practical way of implementing changes in demand is to reduce the export capacity in situations with export such that demand from outside DK1 is reduced. To mimic the effects of countertrade on the DK1-DE/LU border, Energinet has reduced export capacity on the DK1-DE/LU border in hours with countertrade to reduce demand in DK1.

The reduced flow to Germany implies that less generation or more load is necessary to maintain a balanced system on the Danish side. On the German side more generation or less load is similarly needed. The Danish and German side are not isolated to the Danish or German bidding zones but rather constitute areas of uncongested bidding zones. Fundamentally, the Danish side is DK1 and all bidding zones to which there is directly or indirectly available export capacity, i.e. if the reference simulation allows export from DK1 to NO2, SE3, and NL, these three bidding zones constitute an uncongested area and are relevant for identifying the socio-economic effect on the Danish side. Similarly so on the German side for other bidding zones.

These uncongested areas may differ from hour to hour. In each hour, however, within the uncongested area on the Danish side in hours with countertrade, generation will decrease and/or load will increase, while on the German side generation will increase and/or load will decrease. A bidding zone like the Netherlands is likely to at times be in the uncongested area on the Danish side and at other times in the uncongested area on the German side. As such it is necessary to make gross calculations of the positive and negative effects on generation and load to identify the effects of the countertrade. For the Danish countertrade model only the negative effects on generation and the positive effects on load are relevant.

The value of countertrade can thus be estimated by calculating the saved generation costs from reduced generation (generator revenue minus producer surplus, i.e. the area under the supply curve) and the extra value from increased generation (total consumer payments plus consumer surplus, i.e. the area under the demand curve).

From the practical results, however, this theoretical approach seems to entail a volume issue which is addressed later.

## CRITICAL ISSUES REGARDING THE SIMULATION FACILITY MODEL

### *Imperfect possibilities for implementing countertrade*

Reducing the export capacity from DK1 to DE to reduce demand is fundamentally an indirect way of modelling countertrade. From a practical perspective, it is, however, the only possible way. This, however, means that the modelled countertrade volume cannot exceed the total export from DK1 to DE.

There are many hours in which the countertrade volume exceeds export on the DK1-DE border. For 2020, a maximum reduction of cross-zonal capacity on the DK1-DE border, will result in a reduction of export flow on that border of 2,9 TWh, roughly 1 TWh short of the total countertrade volume in 2020. As such, only 75 % of the total countertrade volume would be modelled.

The issue could be addressed by reducing cross-zonal capacity on other borders. Doing so could reduce demand in DK1 further but could have unforeseen consequences because it would necessarily be clear on which border to reduce capacity optimally. Fixing the problem of modelling too little countertrade could thus introduce other problems with unknown consequences. Generally speaking, in hours with export to Germany, flow is generally from the Nordic system to the continental system. Reducing flow on the DK1-NL interconnector is thus a possibility to come closer to modelling the full countertrade volume. Including the DK1-NL border increases the modelled countertrade volume to 3.2 TWh. Energinet has chosen to use this implementation.

### *Stochastic results*

The possibility space for the optimization in the Simulation Facility model is too large to allow investigation of all possibilities. Rather the model has a maximum calculation time under which it finds the best solution among the investigated solutions. As such, the Simulation Facility model is a non-deterministic model.

This implies that it is principle not possible to get the same result twice, or by extension that the imposed changes between two simulations will not in every case (hour) result in the theoretical effects, i.e. a reduction in cross-zonal capacity may increase total welfare. This effect becomes more pronounced when only parts of the modelled area are considered. Fundamentally, there is an element of noise in the model.

When the socioeconomic effects are calculated for the Danish side of the border, the results show that for a given reduction in cross-zonal flow of 2.7 TWh on the DK1-DE border, the resulting reduction in generation and increase in demand on the Danish side for the modelled period is 3.6 TWh.

Energinet currently has no way of quantifying the cause of this discrepancy. It can be the result of the stochastic nature of the model, or it can be the result of changes to clearing of e.g. block bids and the like resulting from the change in cross-zonal capacity. This begs the question what to do with this result. In the worst case, the difference is purely noise, implying that use of the 3.6 TWh reduction in generation and increase in demand results in an overestimation of the value of the countertrade energy in the intraday model. In the best case, noise is minimal and the 3.6 TWh really does reflect the effects of countertrade, in which case the estimation is precise.

## Modelling results

For 2020, a total countertrade volume of roughly 3.2 TWh has implemented in the modelling. The simulations have given the following results.

The first table shows that effect on load and generation across the simulated area with particular focus on the Nordic bidding zones

Area	Bidding zone	$\Delta$ load>0	$\Delta$ load<0	$\Delta$ generation >0	$\Delta$ generation <0	Total, down	Total, up	Net effect
DK	DK1	41.284	-1.527	12.127	-351.470	-392.754	13.654	-379.100
	DK2	17.851	-2.778	3.297	-8.934	-26.785	6.075	-20.710
Other nordic	FI	8.680	-1.959	10.295	-62.979	-71.659	12.254	-59.405
	NO1	616	0	4.331	-88.231	-88.847	4.331	-84.515
	NO2	8.132	-1.481	38.924	-845.475	-853.607	40.405	-813.202
	NO3	459	-11	6.572	-119.477	-119.935	6.583	-113.352
	NO4	5.581	-264	8.612	-135.037	-140.619	8.876	-131.742
	NO5	1.621	-122	41.273	-490.568	-492.189	41.394	-450.795
	SE1	9.895	-581	15.255	-268.000	-277.895	15.835	-262.060
	SE2	67.446	-2.791	14.548	-204.420	-271.866	17.338	-254.528
	SE3	51.032	-1.041	3.257	-91.305	-142.337	4.298	-138.038
	SE4	1.704	-288	264	-2.595	-4.299	551	-3.747
Non nordic	All	526.128	-1.666.399	2.363.078	-787.458	-1.313.587	4.029.477	2.715.891
Total		740.428	-1.679.242	2.521.832	-3.455.950	-4.196.378	4.201.073	4.695

Table 1 – Simulated impact on load and generation of modelled countertrade, 2020, MWh

	Total, down	Total, up
Nordic	-2.882.792	171.596
Non-Nordic	-1.313.587	4.029.477
Total	-4.196.378	4.201.073

Table 2 – Simulated impact on load and generation of modelled countertrade, 2020, MWh

It is clear that the total energy response in the simulated system far exceeds the simulated countertrade volume of 3.2 TWh. However, the Nordic energy response is in the similar range as the applied countertrade. Although, theoretically, the calculated energy response for the entire power system should be a consequence of the applied countertrade, Energinet is concerned that the stochastic nature of the Simulation Facility implies that the total energy response is heavily impacted by “random” simulation effects, which if included in the socio-economic assessment would lead to an overestimation of the effect of the intraday model. Further, it makes sense intuitively that the main part of the energy response would come from the Nordic bidding zones since export from DK1 to Germany is generally matched by southbound flow generally. Also, the interconnectors from the Nordic bidding zones to the Netherlands, Germany, Poland, and the Baltics do in case of available capacity in the reference case provide a path for the countertrade energy to “leak” out of the Nordic bidding explaining why the Nordic energy response to the simulated countertrade is less than the simulated countertrade volume.

For these reasons, the socioeconomic effect is only calculated based on the energy response in the Nordic bidding zones.

Bidding zone	Socioeconomic value, EUR
DK1	6.242.204
DK2	558.905
FI	1.283.737
NO1	810.450
NO2	9.031.455
NO3	1.392.021
NO4	1.830.502
NO5	5.494.237
SE1	3.928.545
SE2	3.756.319
SE3	1.803.011
SE4	95.449
Total	36.226.835

Table 3 – Simulated socioeconomic value of reduced generation and increased load in Nordic bidding zones, 2020, EUR

The above results are the “raw” model data. They, however, do not take into account several obvious inconsistencies

- The energy response in the Nordic bidding zones is less than the simulated countertrade volume due to “leaking” outside the Nordic bidding zones so the socioeconomic value calculated for the Nordic bidding zones will underestimate the value of the intraday model.
- The actual countertrade volume (3,9 TWh) is higher than the simulated countertrade volume so the simulated socioeconomic value of the intraday model will underestimate the value of the intraday model.

	Simulated volumes	Actual volumes
Countertrade	3.183.563	3.901.000
Nordic energy response	2.882.792	?
"Leakage" of CT energy	300.771	?

Table 4 - Overview of actual countertrade volumes and simulated countertrade volume, and energy response, 2020, MWh

Based on these volumes, Energinet has simply scaled the simulated value to obtain an estimate of the actual value. The average simulated value is attributed to both the leakage and the “non-simulated countertrade volume”. This scaling is likely to provide an overoptimistic assessment of the value of the intraday model as the value is likely be decreasing with increasing countertrade volumes. Energinet, however, sees no other objective way of correcting for this.

	Simulated socioeconomic value	Socioeconomic value Scaled due to leakage	Socioeconomic value Scaled due to non-simulated countertrade volume
Simulated value	36	36	44
"Leakage" of CT energy	0	4	5
Total	36	40	49

Table 5 – Socioeconomic value, including scaling due to leakage and non-estimated countertrade volumes, 2020, million euro

Based on this, Energinet estimates that the value of the intraday model is likely to lie in the range of 36-51 million euro for 2020. For 2019, based on the same approach, Energinet estimates that the value of the intraday model lies in the range of 40-66 million euro. The lower bound presents the unscaled value whereas the upper bound presents the scaled value taking into account both leakage and non-simulated countertrade.

	2019	2020
Socioeconomic value of intraday model	40-66	36-49

Table 6 – Estimated socioeconomic value of the intraday model for 2019 and 2020, million euro

Based on these a range for the per-unit value of countertrade can be calculated, which is used in the assessment of the special regulation model. Dividing the lower bound estimate of the socioeconomic value by the simulated countertrade volume (in essence assuming zero value of the "leakage" and the non-simulated countertrade volumes), provides a lower bound per-unit estimate. A higher bound estimate can be calculated as the Nordic socioeconomic effect divided by the Nordic energy response (basically assuming that the average value created in the Nordic bidding zones based on the Nordic energy response is representative of value of the leakage and non-simulated countertrade volumes).

	2019	2020
Per-unit estimate	27,2-34,7	11,4-12,6

Table 7 – Per unit estimate of socioeconomic value of the intraday model, EUR/MWh

These per-unit values reflect the generally much lower power prices in 2020 compared to 2019 such that even though the countertrade volume was significantly lower in 2019, the value of countertrade was probably higher.

The underlying tables for 2019 are presented below without commenting which would be identical to the commenting for the 2020 tables.

Area	Bidding zone	$\Delta$ load>0	$\Delta$ load<0	$\Delta$ generation >0	$\Delta$ generation <0	Total, down	Total, up	Net effect
DK	DK1	20.378	-399	7.822	-170.428	-190.805	8.221	-182.585
	DK2	5.439	-1.288	1.732	-8.267	-13.705	3.020	-10.685
Other nordic	FI	3.508	-1.867	10.818	-33.178	-36.686	12.685	-24.001
	NO1	1.444	-64	3.498	-41.757	-43.201	3.562	-39.639
	NO2	15.154	-1.585	27.282	-300.733	-315.887	28.868	-287.019
	NO3	57	-29	7.222	-39.548	-39.605	7.251	-32.353
	NO4	1.797	-264	12.697	-58.420	-60.217	12.960	-47.256
	NO5	3.952	-4	22.625	-232.306	-236.258	22.629	-213.629
	SE1	2.239	-300	12.755	-78.160	-80.399	13.055	-67.344
	SE2	21.057	-4.703	12.029	-74.600	-95.657	16.732	-78.925
	SE3	6.611	-68	3.286	-32.635	-39.246	3.353	-35.893
	SE4	361	-12	55	-209	-570	67	-503
Non nordic	All	488.991	-860.997	1.377.255	-725.618	-1.214.609	2.238.252	1.023.644
Total		570.986	-871.580	1.499.076	-1.795.858	-2.366.845	2.370.656	3.811

Table 8 – Simulated impact on load and generation of modelled countertrade, 2019, MWh

	Total, down	Total, up
<b>Nordic</b>	-1.152.236	132.403
<b>Non-Nordic</b>	-1.214.609	2.238.252
<b>Total</b>	-2.366.845	2.370.656

Table 9 – Simulated impact on load and generation of modelled countertrade, 2019, MWh

Bidding zone	Socioeconomic value, EUR
DK1	4.779.550
DK2	481.218
FI	1.471.311
NO1	1.510.297
NO2	11.990.966
NO3	1.369.940
NO4	2.160.267
NO5	8.821.895
SE1	2.939.453
SE2	3.140.555
SE3	1.259.400
SE4	14.157
Total	39.939.010

Table 10 – Simulated socioeconomic value of reduced generation and increased load in Nordic bidding zones, 2019, EUR

	Simulated volumes	Actual volumes
Countertrade	1.468.258	1.914.000
Nordic energy response	1.152.236	?
"Leakage" of CT energy	316.022	?

Table 11 - Overview of actual countertrade volumes and simulated countertrade volume, and energy response, 2019, MWh

	Simulated value	Socioeconomic value Scaled due to leakage	Socioeconomic value Scaled due to non-simulated countertrade volume
Simulated value	40	40	52
"Leakage" of CT energy	0	11	14
Total	40	51	66

Table 12 – Socioeconomic value, including scaling due to leakage and non-estimated countertrade volumes, 2019, million euro

## The special regulation model

### VALUE ASSESSMENT OF EACH CATEGORY OF SPECIAL REGULATION

Countertrade on the DK1-DE border results in special downward regulation of wind power, thermal generation, and load, and in netting with imbalances in DK1 and the Nordic synchronous area. The total countertrade volume can thus be assigned to these four categories as shown in table 2 earlier.

When assessing the value of the countertrade energy, the derived socio-economic effects of the energy in these categories need to be estimated. This is done below.

As explained, the assessment is based on assumptions made by Energinet because the pay-as-bid pricing does not allow Energinet to assume that bid prices reflect underlying costs. Further, since Energinet only has access to the volume of accepted bids in each category, Energinet needs develop an estimate of the underlying socioeconomic costs.

#### Wind power

For wind power, the socioeconomic effect of downward regulation is a reduction in O&M costs. According to the technology data of the Danish Energy Agency, this corresponds to roughly 3 EUR/MWh for onshore wind turbines resulting from investments in 2015.

	2019	2020
Wind generation	3	3

Table 13 – Value of special regulation from wind power for 2019 and 2020, EUR/MWh

## Load

The use of electric boilers for supplying special regulation in relation to countertrade implies that the special regulation reduces the need for alternative more costly heat generation. For electric boilers, the alternative source of heat may differ significantly, eg. from gas boilers to wood chip boilers, and similarly there is a large variation in DSO-tariffs between DSOs. Energinet has no information regarding this alternative heat generation or the DSO-tariffs underlying the activated bids. This implies that there is a significant uncertainty related to assessing the socioeconomic effect of special regulation from electric boilers.

From a socioeconomic perspective, the cost of operating an electric boiler is the O&M costs and the variable part of tariffs. According, however, to the socioeconomic assumptions for 2019 provided by the Danish Energy Agency, the socioeconomic tariff cost is 16 EUR/MWh for industry.<sup>2</sup> In sum this amounts to roughly 17 EUR/MWh. Assuming the alternative heat generation to come from either a wood chip-fired or gas-fired boiler, the alternative socioeconomic heat generation costs is roughly 25 EUR/MWh as calculated in the below table

EUR/MWh <sub>heat</sub>	2019		2020	
	Wood chip-fired boiler alternative	Gas-fired boiler alternative	Wood chip-fired boiler alternative	Gas-fired boiler alternative
O&M, electric boiler	-1	-1	-1	-1
Tariffs, electric boiler	-3	-3	-3	-3
Saved alternative costs				
- Fuel	24	21	23	24
- O&M	5	1	5	1
- Gas tariff		2		2
- Pollution taxes		5		5
Socioeconomic cost savings from electric boilers	25	24	24	27

Table 14, Value of special regulation from load (socioeconomic cost savings from activation of electric boilers), 2019 and 2020, EUR/MWh

From the table it is clear that the socioeconomic effect depends very little on the alternative heat generation, be it a chip-fired or a gas-fired boiler. For simplicity a socioeconomic effect of special regulation from electric boilers of 25 EUR/MWh for 2019 and 27 EUR/MWh for 2020 is therefore assumed.

By the beginning of 2021, the tax on electricity for heating was reduced significantly from 21 EUR/MWh to 1 EUR/MWh, which has shifted the commercial activation price upwards by this amount. This implies that electric boilers in the Danish system in the future will be activated much more than previously due to “low” day-ahead prices. When assessing the effects of the countertrade model based on historical data, this needs to be taken into account. In practice this implies that the assessment of the intraday model will tend to “underdispatch” the electric

<sup>2</sup> For natural gas, tariffs are described to contain a fixed component resulting in a significantly reduced socioeconomic tariff cost compared to the commercial tariff cost. No similar distinction is apparently made for electricity although the same logically applies here. According to the 2010 report on dynamic tariffs, the variable part of tariffs constitutes only 3-11 EUR/MWh. Given the connection voltage level of electric boilers the lower end of this interval is most likely more relevant.

boilers resulting in a lower calculated effect. Correcting for this effect, however, is simpler under the special regulation model.

Each electric boilers would have been competitive under a certain price. Accepted bids for special regulation from this electric boiler at day-ahead prices below this level should not be attributed the above calculated socioeconomic effect. Rather, they should be attributed an effect similar to that calculated for the intraday model, the logic being that if they were indeed activated for special regulation, this would imply that they had not bid in the day-ahead market according to their costs but had speculated instead in the expectation of earning higher profits by supplying special regulation. This is fundamentally, the same effect as that of other speculators in the intraday market and should thus be attributed the same value. For simplicity, the average of per-MWh-value from the intraday model should therefore attributed to such activations. However, Energinet has no information as to what this “certain” price is making it difficult to assess the impact of this effect.

For simplicity, a range for the socioeconomic effect of the activation of electric boilers is therefore set up. The bounds of the range are set by the average per-MWh value of countertrade as calculated for the intraday model (27-35 EUR/MWh and 11-13 EUR/MWh for 2019 and 2020) and the calculated socioeconomic effect (25 EUR/MWh and 27 EUR/MWh for 2019 and 2020).

This range should be considered “worst” and “best” cases, neither of which is realistic. It is neither the case that all activations of electric boilers for special regulation have had no impact on alternative heat generation costs, nor is it the case that all activations have in fact had the calculated impact. The actual value lies somewhere in between but Energinet has little information making a more precise estimation possible.

	2019	2020
Load, lower bound	25	11
Load, upperbound	35	27

Table 15 - Bounds of value of special regulation from load for 2019 and 2020, EUR/MWh

### *Thermal generation*

For CHPs, there are basically two options for alternative heat generation. Either the heat is supplied by CHP generation at a different time (potentially by the same generation unit) or by non-CHP heat generation.

In the first case, the socioeconomic effect of the postponed generation is the electricity price at this time (assuming the same type of operation, etc.), which must be assumed to be lower than at the time of special regulation (since otherwise the CHP generation would have been planned at this time

In the latter case, the technology supplying the heat determines the socioeconomic effect. In the absence of special regulation, both heat and power will be produced while the alternative heat generation will only generate heat implying that the alternative heat generation will have a higher efficiency leading to socioeconomic cost savings. To determines this effect, it is necessary to know both the technology supplying special regulation (in order to know the cost savings related to stopped CHP generation) and the alternative technology supplying the heat generation.

Energinet only has the information that special regulation has been supplied by thermal generation units. Based on the above, any assessment of the socioeconomic effects of special regulation is highly uncertain. It is the impression of Energinet that special regulation based on thermal power is primarily supplied by central power plants.

Central power plants can supply special regulation by either reducing non-CHP (condensing) generation or CHP generation. Reducing non-CHP generation results in saved generation costs which then equal the socioeconomic effect. This level of costs is unknown to Energinet but the costs cannot be expected to exceed the day-ahead price in the given hour. This is the highest possible socioeconomic effect of special regulation from thermal generation.

Reducing CHP-generation implies that an alternative source of heat is needed. Energinet has no information on what this is in reality. A simple assumption is to assume that the CHP-generation is simply shifted to a later time, fundamentally assuming that the generator has sufficient flexibility through e.g. thermal storage. In the best case, no costs are associated with such shifting of generation. With this simplifying assumption, the lowest possible socioeconomic effect of special regulation from thermal generation is 0 EUR/MWh.

The socioeconomic effect of special regulation from thermal generation is thus assumed to lie in the range between 0 EUR/MWh and the day-ahead price (when activated), roughly 37 EUR/MWh and 37 EUR/MWh for 2019 and 2020.

	2019	2020
Thermal, lower bound	0	0
Thermal, upperbound	37	18

Table 16 - Bounds of value of special regulation from thermal generation for 2019 and 2020, EUR/MWh

This range should be considered “worst” and “best” cases, neither of which is realistic. It is neither the case that all activations of thermal generation for special regulation have just resulted in shifted CHP-generation, nor is it the case that all activations have resulted in reduced non-CHP generation. The actual value lies somewhere in between but Energinet has little information making a more precise estimation possible.

### **Netting**

As described, the value of netting is equal to the value in the intraday model. The calculated ranges presented for the intraday model are used. For 2019 and 2020, this is 27-35 EUR/MWh and 11-13 EUR/MWh.

	2019	2020
Netting, lower bound	27	11
Netting, upperbound	35	13

Table 17 - Bounds of value of netting of countertrade energy with Nordic system imbalance for 2019 and 2020, EUR/MWh

## SUMMARY ESTIMATED EFFECTS

Based on the unit values derived in the previous sections, the volumes from table 2 allows an estimation of the total value of countertrade on the DK1-DE border in the Danish special regulation model. The total value is calculated to be 25-55 mEUR for 2019 and 20-47 million Euro for 2020.

Type	GWh	Unit price, EUR/MWh	Total value, mEUR
Wind	420	3	1
Electric boilers	289	25-35	7-10
Thermal generation	603	0-37	0-23
Netting	602	27-35	16-21
	1,914		<b><u>25-55</u></b>

Table 18 – Socioeconomic value resulting from the Danish special regulation model 2019

Type	GWh	Unit price, EUR/MWh	Total value, mEUR
Wind	1.461	3	4
Electric boilers	517	11-27	6-14
Thermal generation	1.065	0-18	0-19
Netting	853	11-13	10-11
	3.896		<b><u>20-47</u></b>

Table 19 – Socioeconomic value resulting from the Danish special regulation model 2020

Given the average value of countertrade in the intraday model at 11-13 EUR/MWh, it is clear from the table that it is the reduction in wind power that tends to reduce socioeconomic welfare.

The assumptions identify special regulation from electric boilers and thermal generation as potentially having more socioeconomic value than can be realized in the intraday model. For thermal generation this is

Energinet can only identify distortionary taxes and costs as the reason for such higher valuation. Electricity and natural gas tariffs, along with the energy tax on natural gas are the prime candidates for causes of such distortions.

## Comparison of the two models

The below table summarizes the total effect of the intraday model and the special regulation as described above.

	2019	2020
Intraday model	40-66	36-49
Special regulation model	25-55	20-47

Table 20 – Estimated socioeconomic value of the intraday model and the special regulation model for 2019 and 2020, million euro

