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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 results 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[1]. 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 are 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 hydropower where the alternative value of hydro resources is the key factor in bidding strategies (as opposed to thermal power plants which have “unlimited” fuel).

[1] 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 socioeconomic 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 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).

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 3.6 TWh. Energinet has chosen to use this implementation even though it implies that less than the full countertrade volume is modelled.

This begs the question how the remaining volume should be handled. The simplest way of handling this issue is to scale the modelled results by the missing volume. Given the decreasing marginal value of energy, this will tend to overestimate the estimated value. Another option would be to reduce the countertrade volume used for calculating the value in the special regulation model. Energinet has therefore chosen to scale the results from the intraday model by the "missing" countertrade volume and use the full countertrade volume

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 matching of 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.

Energinet has chosen to report both figures but has scaled the used results in the best estimate by the countertrade volume-to-system response factor (2.7/3.9).

Modelling results

Bidding zone	Δload positive	Δgeneration negative	Δload negative	Δgeneration positive	Total Δ
NO2	7.575	-670.509	-125	10.260	-667.699
NO5	1.550	-421.163	-20	10.657	-412.036
DK1	28.176	-258.736	-1.584	13.029	-272.300
SE1	7.975	-229.641	-594	13.780	-223.242
SE2	56.143	-179.188	-2.082	12.772	-220.478
SE3	37.331	-82.416	-2.043	3.004	-114.700
NO4	4.426	-112.568	-280	9.054	-107.660
NO3	438	-95.992	-16	6.303	-90.112
NO1	547	-80.694	-3	1.505	-79.732
FI	8.046	-55.815	-2.092	11.040	-50.729
LT	21.820	-9.951	-4.257	7.552	-19.962
DK2	14.716	-8.000	-2.843	2.901	-16.971
NIR	271	-14.400	-485	6.764	-7.421
LV	52	-30.579	-10	23.726	-6.895
LBI	0	-13.039	0	6.698	-6.340
SE4	1.451	-2.441	-268	280	-3.344
EE	381	-3.378	-64	506	-3.190
LRI	0	-514	0	0	-514
SARD	4	-337	-36	231	-73
MALT	6	0	-24	0	18
GREC	48	-228	-270	87	81
GREE	0	-2	-32	65	95
MONT	0	0	-72	124	197
SICI	22	-58	-35	359	314
CNOR	18	-2.593	-166	3.649	1.204
HR	934	-456	-1.639	1.357	1.606
PL	3.221	-1.091	-4.456	1.568	1.711
CSUD	25	-2.375	-77	4.142	1.819
SUD	38	-1.799	-55	5.702	3.920
ROSN	0	-859	0	4.913	4.054
SVIZ	987	-1.981	-2.151	5.348	4.531
BSP	412	-1.140	-2.195	5.815	6.458
ROI	2.068	-13.380	-2.665	25.496	12.713
GB1	49.577	-114.457	-59.233	119.686	14.885
GB2	55.756	-83.541	-97.418	67.766	25.887
NORD	234	-17.419	-826	55.614	38.787
PT	5.443	-29.810	-12.788	68.572	46.107
ES	14.858	-38.855	-35.755	72.148	54.189
BE	45.389	-59.816	-69.028	106.176	69.999
NL	92.919	-106.926	-155.349	175.872	131.375
AT	27.626	-29.332	-109.342	100.280	152.664
FR	68.260	-110.356	-222.968	246.288	290.641
DE/LU	68.430	-72.091	-643.545	938.769	1.441.793
Grand Total	**627.174**	**-2.957.924**	**-1.436.890**	**2.149.859**	**1.651**

Table 1 – Sum of gross changes in load and generation and net change (bidding zones with zero change not reported), MWh

Bidding zone	Δvalue of load	-Δgeneration costs
NO2	105.936	4.823.415
DK1	342.836	4.017.360
NO5	3.951	3.153.417
GB1	851.501	2.580.379
SE1	86.126	2.309.804
SE2	740.014	2.059.439
GB2	1.077.806	1.710.766
NL	1.181.967	1.466.262
FR	1.087.072	1.453.591
NO4	47.082	1.227.619
ES	352.432	1.216.232
AT	910.394	1.042.751
FI	105.138	851.363
SE3	314.584	817.421
NO3	6.063	755.502
NORD	-153.919	686.196
DE/LU	542.076	587.004
PT	66.779	569.773
BE	388.076	541.545
ROI	68.439	446.787
NO1	4.275	417.128
NIR	10.227	387.168
LBI	0	365.358
LV	225	300.057
LT	309.549	210.399
DK2	257.314	160.190
CSUD	-7.047	109.222
CNOR	-6.732	100.271
SUD	610	78.453
SVIZ	38.688	74.677
EE	2.192	69.734
PL	143.567	62.105
SE4	17.436	39.789
BSP	6.876	32.485
ROSN	0	26.283
SARD	583	21.304
HR	30.965	13.917
GREC	1.994	9.521
LRI	0	9.163
SICI	1.031	1.459
GREE	0	84
MALT	104	0
Grand Total	**8.936.212**	**34.805.391**
Sum (EUR)		**43.741.603**
Sum (DKK)		**325.874.940**

Table 2 – Sum of effects on value of load and generation costs (positive is a reduction for making summing easier), EUR, 2020

	Total value 2020, mEUR
Modelled value	43,5
Corrected for 3.6 TWh total response (only)	32,6
Corrected for 3,9 TWh countertrade (only)	62,8
Corrected for both effects	**47,2**

Table 3 – Possible corrections of modelled results

The estimate provided above is the modelled value corrected for both effects.

The special regulation model, 2020 data

VALUE ASSESSMENT OF EACH CATEGORY OF SPECIAL REGULATION

In 2020, countertrade on the DK1-DE border resulted 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 in 2020, 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.

Load

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.[2] 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 29 EUR/MWh.

From its dialogue with market participants, Energinet has the impression that the actual activation price of electric boilers is around 20 EUR/MWh on average. This depends among other things on the alternative heat generation technology. It this is a gas-fired boiler, the activation price will be much higher, most likely in the range of 47 EUR/MWh. If it is a wood chip-fired boiler, the activation price will be lower, most likely in the range of 7 EUR/MWh.

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

2 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.

amount. This implies that electric boilers in the Danish system in the future will be activated much more than previously. When assessing the effects of the countertrade model based on 2020 data, this needs to be taken into account.

In practice this means, that even in the absence of special regulation, the electric boilers would also have been in operation when the day-ahead price was below 20 EUR/MWh, and not below roughly 0 EUR/MWh (as was the case in 2020 given the then tax on electricity for heating). Whether or not the electric boilers would have supplied the same volume of special regulation is unknown, since that question depends on their strategy in the markets. It is thus tricky to describe what the effect of this tax change is.

The focus is the countertrade volume which resulted in special regulation supplied from electric boilers in hours with a day-ahead price below 20 EUR/MWh. In 2020, this amounted to 318,407 MWh.

If the electric boilers in hours had bid their "true" activation price into the day-ahead market, the boilers would have been operating in the day-ahead market (and there have slightly increased the day-ahead price), and thus could not supply special regulation. Another technology would in this case need supply special regulation, most likely wind power in the special regulation model (resulting in low-cost savings).

If the electric boilers had bid into the market below their true activation price, the day-ahead price would be lower, and the electric boilers would still supply special regulation. In either case, the electric boilers are in operation and thus save fuel costs, however, bidding below their true activation price triggers a response in the day-ahead market. This response is the same that would happen in the intraday model, where the electric would initially increase the day-ahead price upon which countertrade would reduce generation (and supply) on the margin.

As such, in hours in 2020 with a day-ahead price below the by 2021 reduced strike price of the electric boilers (assumed to be 20 EUR/MWh), the value of special regulation supplied by the electric boilers is equivalent to that of countertrade in the intraday model.

As such, only parts of the supplied volumes of special regulation from electric boilers should be based on assessment of the socioeconomic costs associated with the electric boiler itself. Assuming that the socioeconomic part of electricity tariffs constitutes roughly 3 EUR/MWh, the socioeconomic operating costs of an electric boilers is assumed to be 4 EUR/MWh.

EUR/MWh_{heat}	Wood chip-fired boiler alternative	Gas-fired boiler alternative
O&M, electric boiler	-1	-1
Tariffs, electric boiler	-3	-3
Saved alternative costs		
- Fuel	23	24
- O&M	5	1
- Gas tariff		2
- Pollution taxes		5
Socioeconomic cost savings from electric boiler	24	27

Table 4, Socioeconomic cost savings from electric boilers, 2020

Assuming a 20/80 ratio between wood chip-fired and gas-fired boilers, the assumed average socioeconomic cost effect of special regulation from electric boilers is roughly 27 EUR/MWh when the day-ahead price is above 20 EUR/MWh.

The average value of special regulation from electric boilers is thus 17 EUR/MWh calculated as the weighted average between the unit value of 27 EUR/MWh and 12 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, in which case Energinet expects the relevant socioeconomic effect to be postponement of CHP generation. Energinet has no information that allows Energinet to calculate what the day-ahead price will be when postponed CHP generation is realized instead. As such, Energinet will use the day-ahead price at the time of special regulation (weighted by the volume of thermal special regulation) to approximate the value of special regulation. This corresponds to roughly 12 EUR/MWh in 2020.

Netting

As described, the value of netting is equal to the value in the intraday model. For simplicity this is estimated to be the average value of countertrade in the intraday model. For 2019 and 2020, this is 25 EUR/MWh and 12 EUR/MWh.

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 42 mEUR for 2020.

Type	GWh	Unit price, EUR/MWh	Total value, mEUR
Wind	1.461	2,7	3,9
Electric boilers	517	17,2	8,9
Thermal generation	1.065	18	19,2
Netting	853	12,1	10,3
	3.896		**42,3**

Table 5 – Socioeconomic value resulting from the Danish special regulation model 2020

Given the average value of countertrade in the intraday model at 12 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 having more socioeconomic value than can be realized in the intraday model, and for parts of the electric boilers, significantly more so. Similarly, for thermal generation, the assumed value is roughly 50 % higher than the average value in the intraday market.

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

Further, to the extent that special regulation from thermal generation is not based on postponement of generation as assumed in above but instead based on speculation (i.e. bidding below marginal costs in the day ahead market to be able to offer downward regulation in the balancing energy market), the estimation will tend to overestimate the value from thermal generation since in this case, the value will most likely be similar to the average value estimated for the intraday model.

Finally, as illustrated in Figure 4 in section 2.3.4. in the Methodology the 2020 average DA price was quite low compared to the previous years, and the countertrade volumes in 2020 was more than doubled from the previous years.

These considerations illustrate that there is a significant degree of uncertainty associated with the assessment of the socioeconomic effects of the Danish special regulation model, and that another year should be used to the assess the socioeconomic effects.

Modelling the intraday model, 2019 data

The average DA-price for 2019 is close to the average DA-price for the previous four years and the countertrade volume requested was gradually increased from 2017 to 2018 to 2019, whereas 2020 volumes were significantly higher. Thus, 2019 is viewed to be a more representative year.

Imperfect possibilities for implementing countertrade

In 2019 there are likewise 2020 many hours in which the countertrade volume exceeds export on the DK1-DE border. For 2019, a maximum reduction of cross-zonal capacity on the DK1-DE border, will result in a reduction of export flow on that border of 1.5 TWh, roughly 0.4 TWh short of the total countertrade volume in 2019. As such, only 80% of the total countertrade volume would be modelled. Energinet will scale the results from the intraday model by the "missing" countertrade volume and use the full countertrade volume

Stochastic results

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 1,5 TWh on the DK1-DE border, the resulting reduction in generation and increase in demand on the Danish side for the modelled period is 2,3 TWh.

Energinet has chosen to report both figures but has scaled the used results in the best estimate by the countertrade volume-to-system response factor (1.5/2.3).

MODELLING RESULTS

Bidding Zone	Δ Total	Δload Negative	Δload Positive	Δ Generation Negative	Δ Generation Positive
NO2	-287.053	-1.605	15.196	-300.784	27.322
NO5	-213.624	-4	3.953	-232.360	22.684
DK1	-182.723	-413	20.445	-170.549	7.858
SE2	-78.938	-4.703	21.067	-74.721	12.146
SE1	-67.342	-300	2.242	-78.244	12.844
NO4	-47.253	-286	1.833	-58.494	12.789
NO1	-39.691	-64	1.447	-41.959	3.649
SE3	-35.905	-68	6.614	-32.855	3.497
NO3	-32.354	-30	66	-39.652	7.334
EE	-26.541	-88	110	-27.207	688
FI	-24.017	-1.926	3.596	-33.284	10.936
LT	-16.567	-3.759	13.696	-9.053	2.423
BE	-11.009	-51.787	52.732	-89.391	79.327
DK2	-10.766	-1.305	5.459	-8.404	1.792
LV	-9.939	-1	75	-23.953	14.088
LBI	-3.172	0	0	-4.051	879
SE4	-506	-12	362	-212	57
GREC	-314	-75	135	-300	46
MALT	9	-21	12	0	0
CNOR	35	-122	3	-1.418	1.335
SARD	42	-12	0	-57	87
SICI	262	-8	3	-44	300
ROI	303	-1.580	1.207	-13.510	13.441
SVIZ	606	-857	727	-1.490	1.967
PT	652	-4.400	2.243	-25.960	24.455
HR	1.160	-710	145	-187	782
ROSN	1.618	0	0	-266	1.884
BSP	1.802	-661	688	-1.314	3.142
GB1	2.171	-91.036	82.304	-128.408	121.847
CSUD	2.429	-42	21	-839	3.246
NIR	2.709	-275	142	-4.124	6.699
SUD	2.953	-117	4	-920	3.761
PL	4.618	-10.659	6.880	-3.702	4.541
NORD	17.705	-297	32	-9.620	27.060
ES	19.074	-17.134	10.952	-28.121	41.014
GB2	56.586	-68.309	44.530	-66.761	99.569
AT	108.853	-75.651	26.045	-22.461	81.708
NL	134.423	-137.360	91.631	-69.105	157.800
FR	136.726	-148.117	78.303	-100.541	167.453
DE/LU	596.021	-247.887	76.885	-93.263	518.283
Grand Total	**3.043**	**-871.682**	**571.785**	**-1.797.586**	**1.500.732**

Table 6 – 2019 sum of gross changes in load and generation and net change (bidding zones with zero change not reported), MWh

Bidding Zone	Δ Value of Load	-Δ Generation Costs
DK1	14.594.768	24.076.225
SE3	10.903.025	11.592.386
BE	-3.172.589	10.367.175
NO2	5.607.743	7.724.501
NO5	2.919.204	5.918.743
SE2	1.653.634	4.885.724
FI	4.865.498	3.995.319
NO1	5.027.939	2.808.966
SE1	1.299.691	2.295.769
DK2	3.282.486	1.680.462
NO3	1.633.600	1.444.018
NO4	868.640	984.360
SE4	2.795.858	952.974
EE	246.503	412.539
LT	574.282	313.825
LV	302.680	256.911
LBI	0	95.052
MONT	99	-390
PL	-51.587	-3.065
GREC	-11.303	-6.626
FRAN	0	-10.212
SICI	-172.508	-34.041
BSP	-76.900	-48.989
ROSN	0	-68.293
SARD	-87.773	-70.896
HR	-79.710	-82.723
NIR	-55.001	-88.660
SUD	-235.398	-135.969
ROI	-185.475	-176.563
CNOR	-319.529	-205.316
CSUD	-464.084	-254.978
SVIZ	-4.733	-264.727
ES	-515.153	-630.533
GB2	-791.202	-746.711
NL	-1.417.184	-1.253.906
AT	-2.195.369	-1.277.153
GB1	-1.709.660	-1.406.433
NORD	-1.730.148	-1.767.576
FR	-3.197.494	-4.349.043
DE/LU	-20.960.995	-22.480.992
Grand Total	**18.941.373**	**44.498.472**
SUM		**63.439.845**

Table 7 – 2019 sum of effects on value of load and generation costs (positive is a reduction for making summing easier), EUR

	Total value, mEUR
Modelled Countertrade (1,5 TWh)	63
Corrected for 2,3 TWh total response (only)	41
Corrected for 1,9 TWh countertrade (only)	80
Corrected for both effects	46.9

Table 8 – Possible corrections of modelled results, 2019

The estimate provided in section 5.6.2.2 is the modelled value corrected for both effects.

The special regulation model, 2019

VALUE ASSESSMENT OF EACH CATEGORY OF SPECIAL REGULATION

In 2019, countertrade on the DK1-DE border resulted 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 9, section 5.6.2.1. in the methodology.

When assessing the value of the countertrade energy in 2019, the derived socioeconomic effects of the energy in these categories need to be estimated.

As already mentioned, 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.

Load

For electric boilers, the alternative source of heat may differ significantly, e.g., 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.[3] 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 29 EUR/MWh.

[3] 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

From dialogue with market participants, Energinet has the impression that the actual activation price of electric boilers is around 20 EUR/MWh on average. This depends among other things on the alternative heat generation technology. It this is a gas-fired boiler, the activation price will be much higher, most likely in the range of 47 EUR/MWh. If it is a wood chip-fired boiler, the activation price will be lower, most likely in the range of 7 EUR/MWh.

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. When assessing the effects of the countertrade model based on 2019 data, this needs to be taken into account.

In practice this means, that even in the absence of special regulation, the electric boilers would also have been in operation when the day-ahead price was below 20 EUR/MWh, and not below roughly 0 EUR/MWh (as was the case in 2019 given the then tax on electricity for heating). Whether or not the electric boilers would have supplied the same volume of special regulation is unknown, since that question depends on their strategy in the markets. It is thus tricky to describe what the effect of this tax change is.

The focus is the countertrade volume which resulted in special regulation supplied from electric boilers in hours with a day-ahead price below 20 EUR/MWh.

If the electric boilers in hours had bid their "true" activation price into the day-ahead market, the boilers would have been operating in the day-ahead market (and there have slightly increased the day-ahead price), and thus could not supply special regulation. Another technology would in this case need supply special regulation, most likely wind power in the special regulation model (resulting in low-cost savings).

If the electric boilers had bid into the market below their true activation price, the day-ahead price would be lower and the electric boilers would still supply special regulation. In either case, the electric boilers are in operation and thus save fuel costs, however, bidding below their true activation price triggers a response in the day-ahead market. This response is the same that would happen in the intraday model, where the electric would initially increase the day-ahead price upon which countertrade would reduce generation (and supply) on the margin.

As such, in hours in 2019 with a day-ahead price below the 2021 reduced strike price of the electric boilers (assumed to be 20 EUR/MWh), the value of special regulation supplied by the electric boilers is equivalent to that of countertrade in the intraday model. The value of the intraday model is 47 million Euro divided by the countertrade volumes in 2019 (1.914 GWh) which gives a value of 24.5 EUR/MWh

As such, only parts of the supplied volumes of special regulation from electric boilers should be based on assessment of the socioeconomic costs associated with the electric boiler itself. Assuming that the socioeconomic part of electricity tariffs constitutes roughly 3 EUR/MWh, the socioeconomic operating costs of an electric boilers is assumed to be 4 EUR/MWh.

here. According to the 2010 report on dynamic tariffs, the variable part of tariffs constitute only 3-11 EUR/MWh. Given the connection voltage level of electric boilers the lower end of this interval is most likely more relevant.

EUR/MWh heat	Wood chip-fired boiler alternative	Gas-fired boiler alternative
O&M, electric boiler	-1	-1
Tariffs, electric boiler	-3	-3
Saved alternative costs		
- Fuel	24	21
- O&M[4]	5	1
- Gas tariff		2
- Pollution taxes		5
Socioeconomic cost savings from electric boiler	25	24

Table 10: Socioeconomic cost savings from electric boiler, 2019

Assuming a 20/80 ratio between wood chip-fired and gas-fired boilers, the assumed average socioeconomic cost effect of special regulation from electric boilers is 24.5 EUR/MWh when the day-ahead price is above 20 EUR/MWh.

The average value of special regulation from electric boilers is thus 24.5 EUR/MWh.

Thermal generation

For combined heat power generators (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, in which case Energinet expects the relevant socioeconomic effect to be postponement of CHP generation. Energinet has no information that allows Energinet to calculate what the day-ahead price will be when postponed CHP generation is realized instead. As such, Energinet will use the day-ahead price at the time of special regulation (weighted by the volume of thermal special regulation) to approximate the value of special regulation. This corresponds to 24.5 EUR/MWh in 2020.

[4] technology_data_catalogue_for_el_and_dh.pdf (ens.dk), s. 320

Netting

The value of netting is equal to the value in the intraday model. For simplicity this is estimated to be the average value of countertrade in the intraday model. For 2019 this is 24.5 EUR/MWh.

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/LU border in the Danish special regulation model. The total value is calculated to be 48 mEUR for 2019.

Type	GWh	Unit price, EUR/MWh	Total value, mEUR
Wind	420	2.7	1.1
Electric boilers	289	24.5	124.5
Thermal generation	603	42	42
Netting	602	24.5	24.5
	1.914		48

Table 11 – Socioeconomic value resulting from the Danish special regulation mode, 2019

Given the average value of countertrade in the intraday model at 24,5 EUR/MWh, it is clear from the table that it is the reduction in wind power that has the potential to reduce socioeconomic welfare, however the value of the intraday CT model is lower than the value of the special regulation model, when using 2019 numbers.

The assumptions identify special regulation from thermal generation as having more socioeconomic value than can be realized in the intraday model.

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

Further, to the extent that special regulation from thermal generation is not based on postponement of generation as assumed in above but instead based on speculation (i.e. bidding below marginal costs in the day-ahead market to be able to offer downward regulation in the balancing energy market), the estimation will tend to overestimate the value from thermal generation since in this case, the value will most likely be similar to the average value estimated for the intraday model.

These considerations illustrate that there is a significant degree of uncertainty associated with the assessment of the socioeconomic effects of the Danish special regulation model.