Offshore Wind Study: Explanatory note for 2030 Future of the Algorithm

SDAC

23 April 2023

1 Introduction

This document aims at providing background and observations to the results of the Offshore Wind Study in the framework of the 2030 Future of the Algorithm research performed by N-side based on input by the SDAC MSD. This document targets especially parties that were not involved in the technical discussions on SDAC MSD level (e.g. SDAC MCSC, NRAs, ACER, EC, other TSOs and NEMOs' representatives). The original study can be found in the annex of this document.

Disclaimer:

- Through the research addressed in this document, SDAC MSD members together with N-side are investigating potential evolutions of the market coupling algorithm towards 2030. This first study regarding offshore wind aims to assess the technical feasibility of the offshore wind concept. The study's setup has some important limits which do not allow full market assessment to be provided. These limits include assumptions made on non-formalized offshore wind farm topologies in the North and Baltic Sea, only a limited number of OBZs being modelled, and a lack of knowledge of the UK market coupling leading to a complete exclusion of UK interconnectors in the study even when the expectation is for a UK interconnector to be present in 2030. The latter makes the results for the Belgian Offshore Bidding Zone (OBZ) in this study not representative to the real situation. Therefore, this study should solely be considered as a performance assessment on the technical capability of Euphemia to incorporate OBZs, complemented with a limited number of trends observed in the results. It is in no way fit as a cost-benefit analysis for the introduction of OBZs, nor as a basis for investment decisions for hybrid projects. This is in line with previous communications regarding the scope of the 2030 Future of algorithm stream.

2 CONTEXT

In 2022, SDAC MSD, in discussion with its member TSOs and NEMOs, as well as the NRAs and ACER, performed an exercise to identify new research and development topics for the evolution of the market coupling algorithm towards 2030 ("2030 Future of the Algorithm"). Among others, the Offshore Bidding Zone (OBZ) concept was selected as one of the topics to undergo further quantitative assessment, subject to network/security requirements. As a result, SDAC MSD requested N-side to perform a study over the course of October and December 2022 to assess the impact of introducing OBZs into the algorithm. SDAC MSD provided the input for the case analysed in the N-side study.

As offshore wind farms are important European targets (I.e., in line with the target of 300 GW by 2050 according to the European strategy for offshore), it is important to consider their efficient integration into the electricity system and market. One of the key enablers from the system perspective going forward are so-called hybrid projects, where wind generation will be connected to two or more interconnectors to different countries (and hence bidding zones). Rather than integrating this wind capacity in either of the connected bidding zones, the definition of a separate "Offshore Bidding Zone" (OBZ) is expected to deliver a better (i.e., more welfare-optimal) usage of both generation and interconnection infrastructure. However, this would increase the number of bidding zones considered in SDAC and, in addition, these bidding zones would have a different character than the ones that are in SDAC today (I.e., likely only renewable generation to constitute local offers without local demand). Hence, it seems prudent at this stage to assess the technical feasibility of introducing these OBZs in Euphemia.

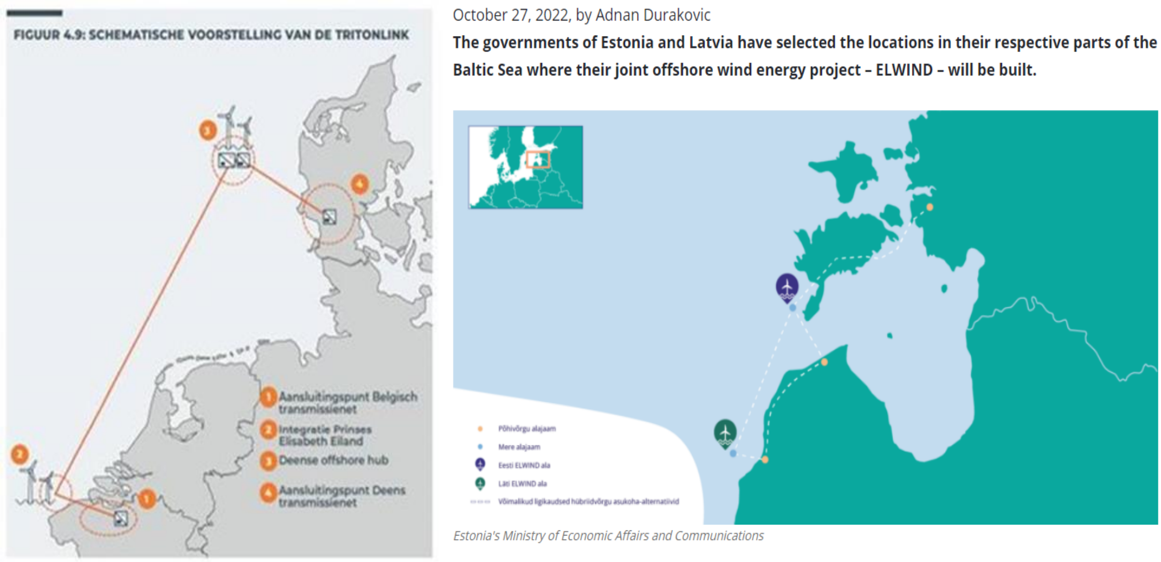


Figure 1: illustration of Offshore wind park planned on the Baltic and North Sea

3 OBJECTIVE AND ASSUMPTIONS

The main objective of the offshore wind study was to assess the effect of offshore wind on the market results and on the performance of the algorithm. This study provides a first insight into the usage of offshore wind farms when connected to the Bidding Zones (BZ) with NTC capacities.

In this study the goal was not to perform a complete market assessment in the view of the challenges of constructing relevant future scenarios. A "mini" market impact assessment has hence been performed, besides the assessment of the impact on performance.

Connection to the UK were not modelled and not considered into study.

The following basic assumptions apply to the model used to obtain the results:

Starting model
- The current market model was used, where offshore wind farms volume where added with 0 marginal cost
Modelling of offshore wind farms
- Modelled as a separate bidding zones (BZ) connected to the neighboring BZ(s) - NTC capacity calculation used in the connection between OBZs and BZs
MTU resolution
- 60 minute MTU

4 SCOPE

Use case considered for the offshore wind study
Input data provided by SDAC MSD - Order books for current topology: 4 months period of historical order books were used, March and September 2021 and 2022 - Order books for OBZ were assumed with only sales volumes - Topology: Current production topology with added OBZ and connections to OBZs
Number of offshore BZs - Total number of OBZs: 6 - where Hybrid OBZs: 4, of which 2 OBZ are connected to each other
Order book scenarios - Offshore bidding zone: only curve orders used - Onshore/offshore wind farm, marginal cost of 0 € with bid prices 0, 5, 10, 15 - Offshore wind farm volumes were estimated based on the foreseen additional wind power capacity in 2030 - Offshore order volumes were formulated based on the estimation of the capacity factors, which were based on historical data
Scenario definition - 2 scenarios: - 1. Reference scenario, where offshore wind farm volume is added to the current production topology (Home market Scenario) - 2. OBZ Scenario, where offshore wind farm volume is added to the offshore bidding zones
Key Performance Indicators - Time To First Solution (TTFS) in relation to number of offshore BZs - Usage of Offshore Windfarms in scenario 1 and 2 - Impact to home market BZs prices by OBZs in scenario 1 and 2 - How often OBZ price is linked to Home Market BZ price - How often OBZ get own price - How much OBZ lines are used for supply - How much OBZ lines are used for transit - How often home market BZ is congested due the OBZ

5 OUTCOMES AND CONCLUSIONS

Observations on algorithm performance

When looking at the integration of OBZs to the market coupling algorithm, it seems not to have significant impact to the Time to Find First Solution (TTFS). The test was performed with the 60-minute MTU context, but the same impact is foreseen for full 15-minute MTU contexts. In the Home Market scenario, TTFS was in average 1:34 min for the testing period, there was one case, where TTFS was appx 4:00 min. In the OBZ scenario, average TTFS was 1:31 min and all cases were solved below 3:30 min. This "mini"-study indicates that adding OBZ will not increase performance time especially when NTC capacity calculation is used. It should be noted that for the future, as more OBZs are expected, new test should be run in order to confirm feasibility of the algorithm performance.

OBZs had only sales curve order used, no block orders, which is a prerequisite if offshore wind farms are modelled as own bidding zones. If other product types are allowed, that would increase complexity for algorithm to find solutions and therefore could lead time increased for finding first solution.

Observations on offshore wind farm usage

In case offshore wind farms are modelled as a separate OBZ, accepted wind generation is less than in the scenario where offshore wind farm's volume is included directly to the home market order books. However, in case offshore wind farms are included in the home market order books, it can lead to the infeasible outcomes as in real case the capacity between the offshore wind farm and home market BZ will limit the usage of the offshore wind farm and therefore, for example, more dispatching would be required. In case offshore wind farms are modelled as own OBZs, more realistic volume is accepted from OBZ because the interconnector capacity will set the limit for wind farm volume. In this study this was seen especially in the case of OBZ connected to Germany and Denmark 1, where offshore wind power is expected to be higher compared to the assumed interconnector capacity.

This study puts importance of the dimensioning of the interconnector capacity between offshore wind farms and home market BZ, which needs to be based on the realistic wind farm capacity and its expected capacity factors.

Observations on offshore wind farm impact to the prices

When offshore wind farms volumes are offered in its own OBZ, home market BZ prices are increased compared to the scenario where offshore wind farm volume is offered directly to the home market BZ. This is a natural outcome, as in the scenario where the offshore wind farm is virtually located in the home market BZ, it neglects the capacity between the offshore wind farm and home market BZ. In addition, offshore wind farm generation is expected to offer with marginal cost of 0 €/MWh, which leads to the situation that in the home market BZ a lot of low-cost production is accepted.

In this study, OBZ interconnector capacity is high between Belgium and OBZ (5,5 GW). In case offshore wind farm volume is offered in the OBZ, the price in Belgium BZ is seen to be lower in more cases than if offshore wind farm volume is virtually added to the Belgium BZ. In case interconnector capacity is estimated smaller than the expected production in OBZ, like in Denmark 1, Denmark 1 BZ price is higher when offshore wind farm volume is offered in the OBZ and not directly to the Denmark 1 BZ in all simulated cases.

Dimensioning of interconnector capacity is also crucial when comparing the OBZ scenario price to the home market BZ price. In case interconnector capacity is estimated to be high enough to cover offshore wind farm production home market BZ and OBZ will have same prices almost all the time. In this study, in case of Belgium and OBZ, there were no price differences foreseen between Belgium BZ and OBZ. But in case OBZ connected to the Germany and Denmark 2, price difference was seen almost in all simulated hours and that OBZ had also own price in some hours.

Observations on offshore wind farm impact to the flows between OBZ and home market BZ

In case there is possibility to transit flows through OBZ to the connected BZs, transit is foreseen as a part of the flow optimisation in the algorithm. In this study most of the transit was seen on the OBZ connected to Denmark 1 and Germany and OBZ connected to the Estonia and Latvia. Introducing OBZ and adding new connections to the home market BZs will increase capacity between those BZs, even though the route for the flow will be longer than directly connected BZs.

In the Baltic region flow from Estonia to Latvia through OBZ were in 22,99% of the simulated hours. Transit flow from Denmark 1 to Germany was also seen through OBZ in 32,4% of hours. By allowing transit flow through OBZ, it will equalise the price differences between adjacent BZs.

Conclusion on the outcomes of the study:

- In this study it was shown that adding OBZs will probably not have an impact on the performance. However, when more OBZs are added, new simulations are to be performed to investigate impact to the performance.

- It is important to dimension the OBZ interconnector capacity in relation to expected offshore wind generation at the OBZ.

- If offshore wind production is offered to the home market BZ, it can artificially lower the home market BZ price as the capacity of the offshore wind farm and home market BZ is not considered and it may require re-dispatching to cover the generation from OBZ at the home market BZ.

Euphemia Lab

2030 Future of the Algorithm – Offshore Bidding Zones

Tuesday April 4, 2023

Offshore bidding zone study overview

Objective: Assess the market and algorithm performance impacts of introducing offshore bidding zones in SDAC.
The market impact assessment is minimal in view of the challenges of constructing relevant future scenarios, or data preparation more generally. A "mini" market impact assessment has hence been performed, besides the assessment of the impact on performances.

Cases investigated & simulated:
- A "simple" use case with some simplifications & assumptions has been investigated.
  - Some offshore wind farms in North Sea and Baltic Sea connected via Hybrid interconnections to the continent.
  - Capacity calculation with NTC approach: OBZ are connected to their home markets via ATC lines.
- Comparison of the inclusion of offshore wind production in offshore BZs versus home markets.

Note:
- Offshore Wind Developments are important European targets which will have large impacts. The implications of this topic are much broader than the current scope of the use case which is investigated in this study.
- Performing a full market impact assessment is out of scope of the present study, though it is understood that such a detailed impact analysis would be valuable for various stakeholders. Such a detailed impact analysis can be an interesting extension of the present study.

Detailed questions addressed in the report

1. Performance: Time to First Solution. What is the performance impact of adding Offshore Bidding Zones (OBZ) in SDAC ?
2. What is the usage of wind farms in the different scenarios?
3. How are the prices of the “adjacent” home market (HM) bidding zones impacted by the OBZ?
4. Is the price of OBZ linked to the HM price/ how often the OBZ has its own price (different from the price in the HM bidding zone)?
5. How much of the OBZ lines are used for supply of offshore wind generation, how much are used for transit?
6. Are there more frequent (or less) situations with “congestion” (price differences) between “adjacent” HM BZs due to the Offshore Wind Parks?

Description of the scenarios

- Data: historical data altered as specified in Scenario 1 and Scenario 2 below.
  - 2021: March and September.
  - 2022: March and September.

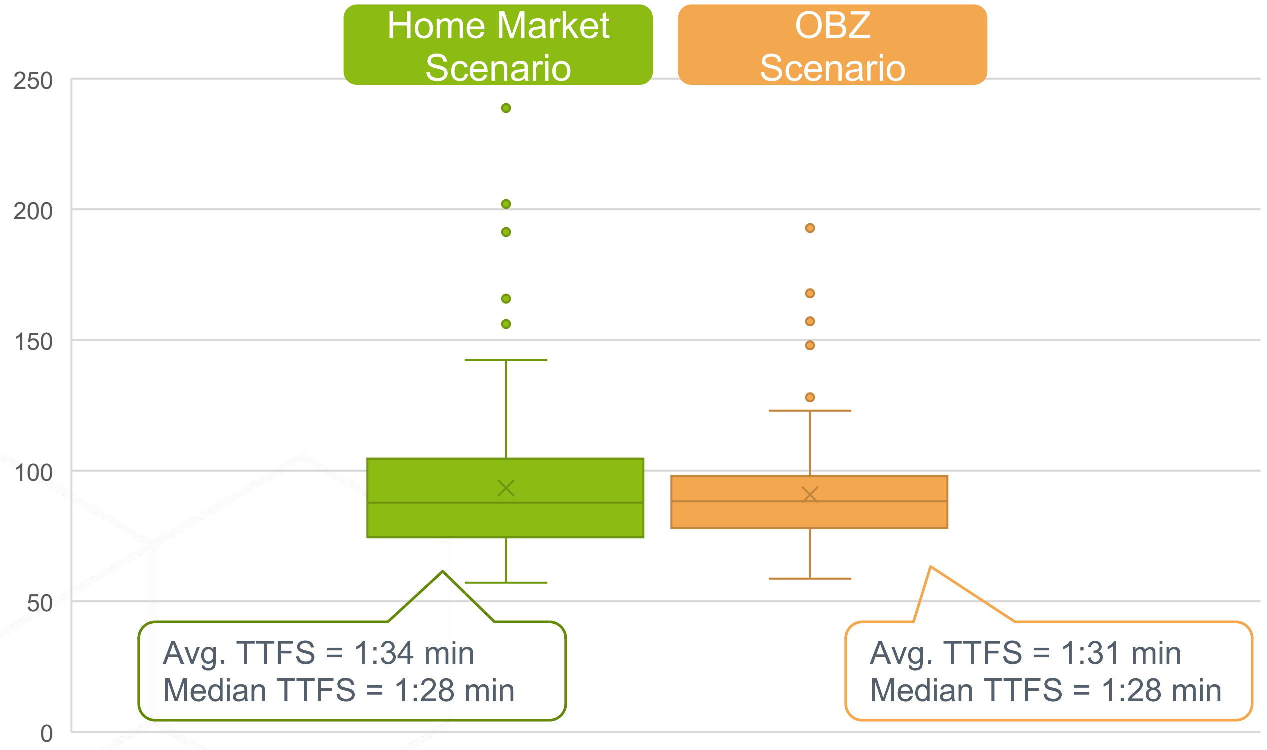
- Scenario 1 (home markets scenario):
  - Topology: as the historical one.
  - Order books: Additions in the “home markets” (historical bidding zones) of new bids representing additional offshore and onshore wind generation following the methodology described in Appendix A.

- Scenario 2 (offshore bidding zones scenario)
  - Topology: addition of Offshore Bidding Zones as on the diagram in Appendix B.
  - Order books: Additions of new bids representing additional offshore and onshore wind generation

    → the bids representing offshore wind generation are now located in the offshore bidding zones.

1. Performances: Introducing separating offshore bidding zones have a negligible impact

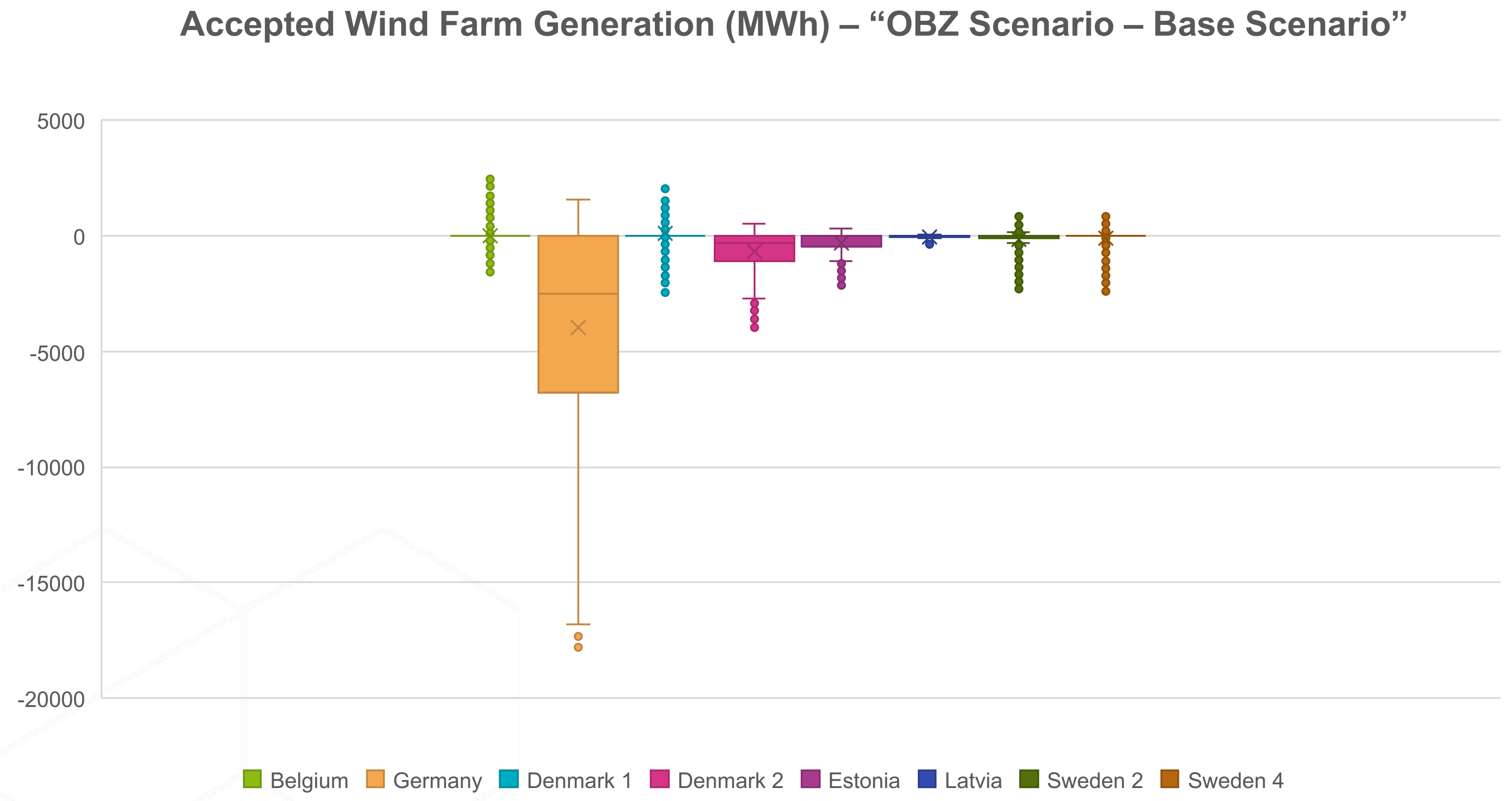
Time to the First Solution for the Home Market and Offshore Bidding Zone Scenarios



Statistics over March 2021, September 2021, March 2022 and September 2022

- There is no significant performance difference between locating offshore wind generation in offshore bidding zones, or locating that same generation in the “parent” home market bidding zones.
- The performance impact should be similar in a 15’ MTU context.

2. What is the usage of wind farms in the different scenarios?

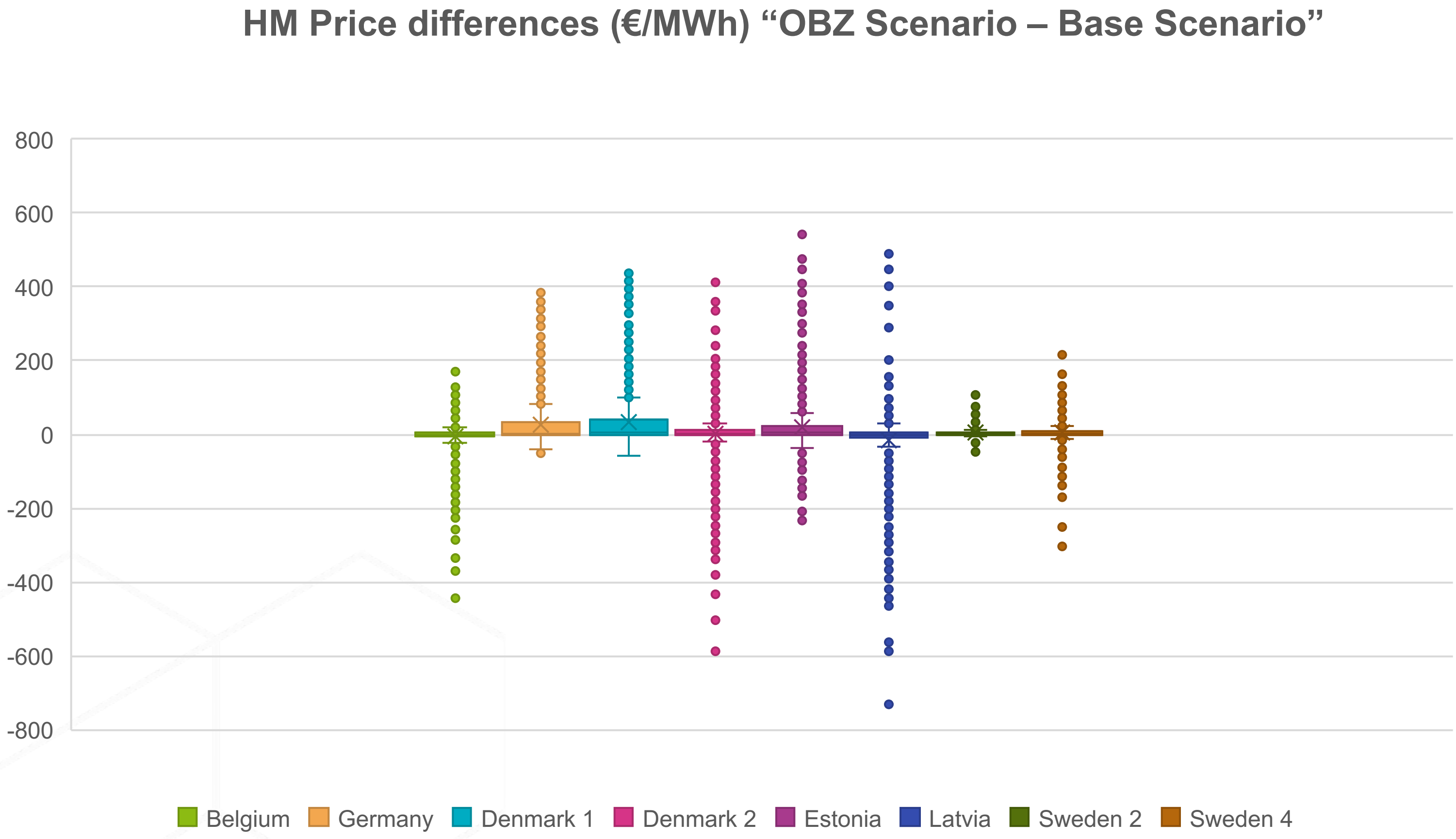


Statistics over March 2021, September 2021, March 2022 and September 2022

This KPI shows concretely the importance of properly dimensioning the interconnector capacity according to (a) the wind farm capacity *and (b) the expected capacity factors*.

- Most of the time, less wind generation is accepted in the Offshore Bidding Zone scenario, due to the capacity limit on the line connecting the OBZ to the HM.
- The base scenario where all the offshore wind generation is virtually located in the home market bidding zone leads to many infeasible outcomes that would require redispatch in practice, because the wind generation exceeds the capacity of the interconnector between the OBZ and the HM BZ.
- The effect is more important in Germany due to the assumptions of a very large offshore wind generation in the future (see scenario description) and assumptions on the interconnector capacity certainly underestimating the needs which depend on wind farm dimensioning *and expected capacity factors.*

3. How are prices of the "adjacent" HM bidding zone impacted by the OBZ?



Statistics over March 2021, September 2021, March 2022 and September 2022

Locating offshore wind farm generation in offshore bidding zones tend to increase the market price in the adjacent HM bidding zone, compared to the case where this wind farm generation is virtually located in the HM bidding zone.

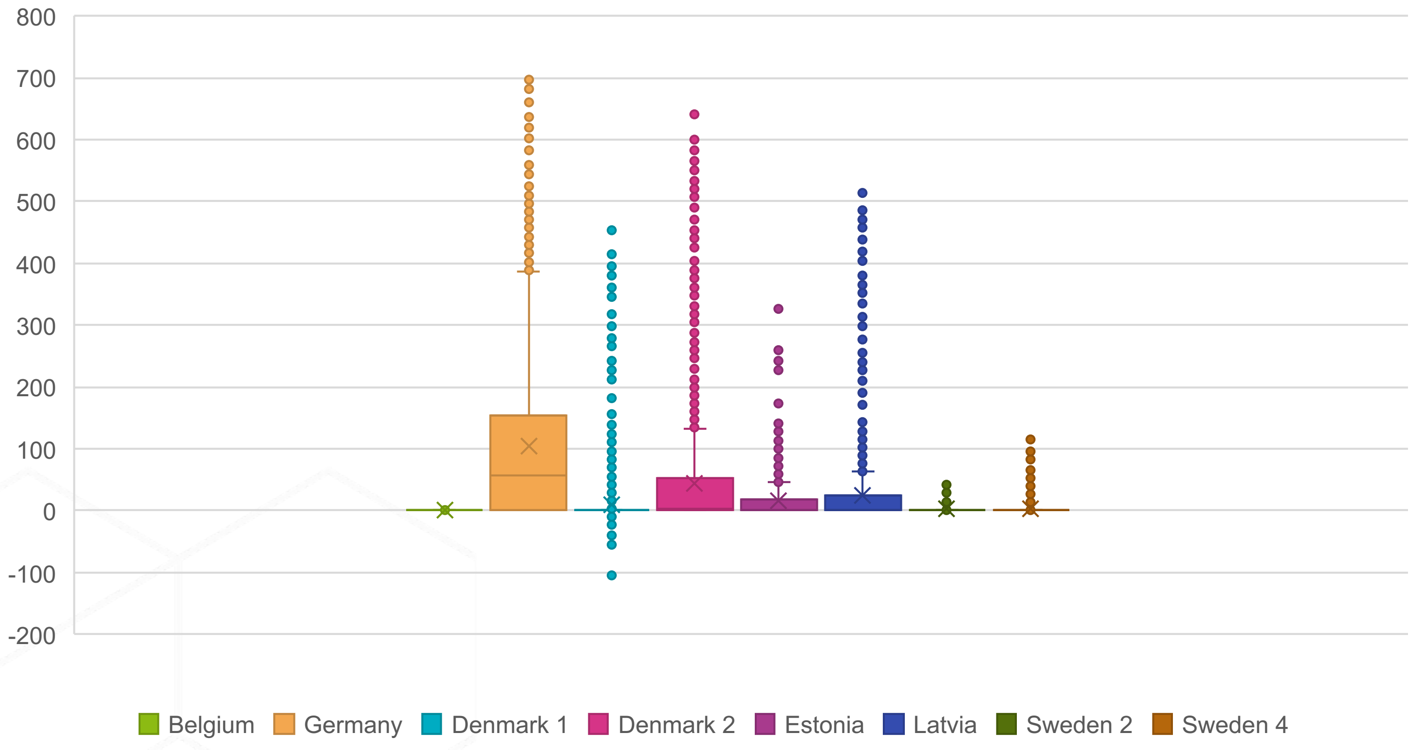
The intuitive reason is that by locating the wind generation in the HM bidding zone and overlooking interconnector capacity limits, more very cheap wind generation is accepted (with a marginal cost set to 0€/MWh in the simulations), mechanically decreasing the market price of that bidding zone.

The largest differences are observed during summer 2022.

Besides offshore wind generation, price differences are also due to the change in the topology. For example, DK2 is connected to DE via OBZ interconnectors in the OBZ scenario, and this sometimes leads to price convergence between Denmark and Germany.

4. Is the price of OBZ linked to the home market price/ how often the OBZ has its own price (different from the price in the mainland bidding zone)?

Price differences (€/MWh) between the OBZ and the HM BZ in the "OBZ Scenario"

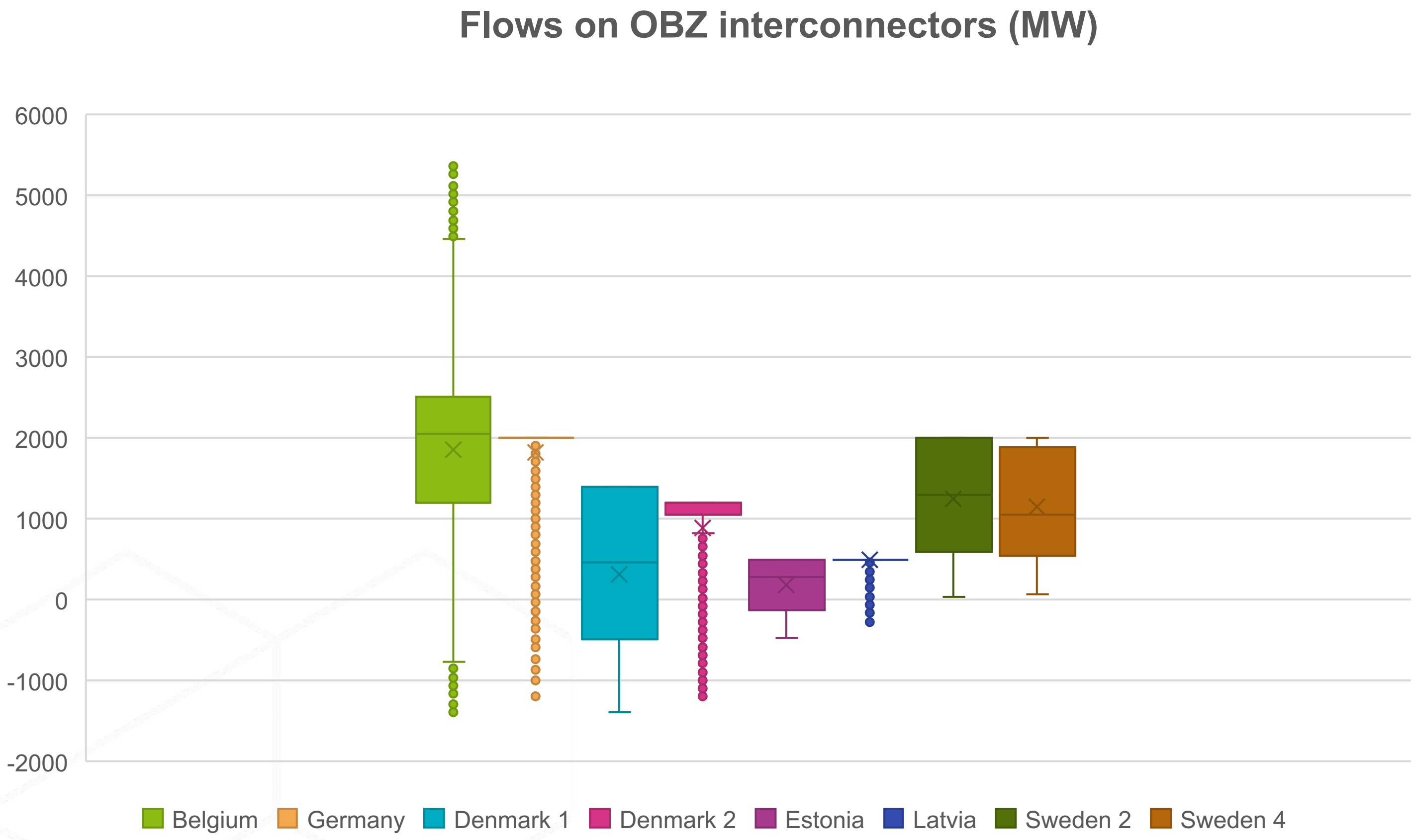


Statistics over March 2021, September 2021, March 2022 and September 2022

Prices differences are due to a suboptimal dimensioning of the OBZ interconnectors compared to the actual offshore wind generation.

Such a curtailment almost never occurs for Belgium, while it is almost systematically the case for Germany and Denmark 2, due to the assumptions on the interconnectors connecting the offshore bidding zone (see topology in Appendix B) not in line with the projections of future offshore wind generation.

5. How much of the OBZ lines are used for supply of offshore wind generation, how much are used for transit?



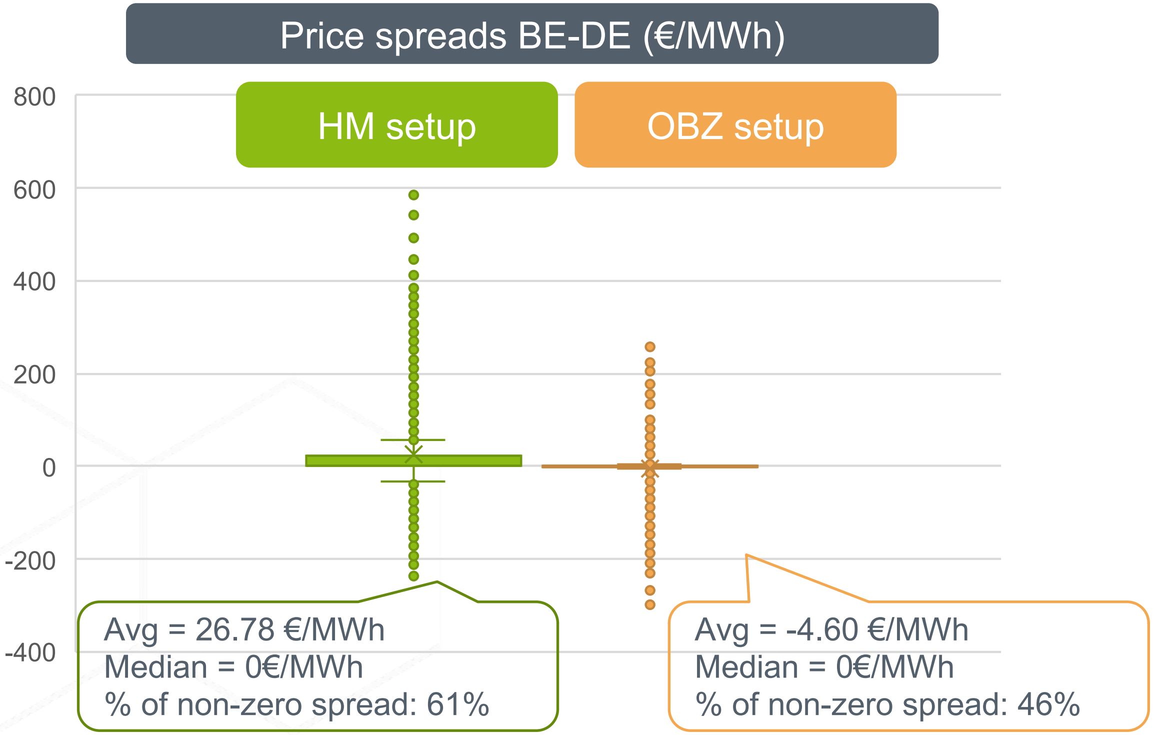
Statistics over March 2021, September 2021, March 2022 and September 2022

- Flows from Home Markets to Offshore Bidding Zones exactly correspond to transit flows, since there is no demand located in OBZs: any flow from a HM to an OBZ should be redirected from that OBZ to the other HMs connected to that OBZ.
- These transit flows from HM to OBZ correspond on the chart to the negative flow values: a negative flow on an OBZ interconnector means a flow from the HM to the OBZ (sign convention used in the simulations).
- Due to the topology (see Appendix B), such transit flows cannot occur in relation to SE2 and SE4.
- For the other HM BZ, the statistics are as follows (percentage = (transit flows / total flows in absolute value)100):

	Belgium	Germany	Denmark 1	Denmark 2	Estonia	Latvia
% transit flows	3.26%	0.94%	32.40%	7.81%	22.99%	0.15%

6. Are there more frequent (or less) situations with “congestion” (price differences) between “adjacent” HM BZs due to the Offshore Wind Parks?

- As a proxy to measure congestion in adjacent HM BZs, we consider price spreads between Germany and Belgium, since a price difference necessarily means that congestion occurs.
- A more detailed analysis will be provided with the final delivery of the study end of March.



Statistics over March 2021, September 2021, March 2022 and September 2022

- Price convergence occurs more often in the OBZ scenario, due to the extra cross-zonal capacity made available by the OBZ interconnectors: via the OBZ interconnectors, BE is connected to DK1 and DE is connected do DK2, overall increasing the interconnection capacity between BE and DE (but not only).
- Price formation is also impacted by the fact that more offshore wind volumes can be accepted in the HM scenario because OBZ interconnector capacities are then neglected (even though redispatch may be needed in that case): disentangling both effects would require for example to run simulations with the new OBZ interconnectors but exactly the same order books on both sides (with all the offshore wind generation located in the HMs).

Conclusions

Adding **Offshore Bidding Zones (OBZ)** has essentially **no impact on the performances of the algorithm**. Adding **even more OBZ** in the future is also **expected to have a negligible impact on performances**.

Relying on the **Home Market (HM) approach** (i.e. virtually locating all the offshore wind generation in the home market bidding zone) **requires well dimensioned interconnectors**. Otherwise, **dispatches may overestimate the offshore wind generation that can flow through the interconnectors and require large amounts of redispatch**.

In terms of Market Impact, accordingly,

- the **HM approach can artificially lower market prices both in the HM and adjacent bidding zones**, by leading to **higher acceptances of wind generation bids compared to what is physically feasible in terms of transmission capacity**.
- **In the OBZ approach, market price differences between the HM and the OBZ directly depends on the dimensioning of the interconnector**: if the interconnector has sufficient capacity compared to the installed capacity in the OBZ, prices differences will be null or most of the time low.

Transit flows can take place where the interconnectors between OBZ and HM are used to transmit electricity between HMs. This shows that **dimensioning of interconnectors, besides taking into consideration the expected installed wind generation capacity in the OBZ, could also consider broader transmission capacity needs within a CCR**.

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Appendix A: High-level methodology to build the offshore (& onshore) wind order books

- New Offshore Wind Bids have been generated based on an estimation of the *additional* offshore wind generation capacity expected by 2023, and an estimation of capacity factors (percentage of usage of that capacity) based on historical data.
- New Onshore Wind Bids (placed in home markets in all scenarios) have been generated based on the same principles.
- All wind generation bids have zero marginal costs.
- To build these order books, three components have hence been required: (a) capacity factor estimations, (b) estimation of the additional onshore wind generation capacity by 2030, (c) estimation of the additional offshore wind generation capacity by 2030. How these figures have been estimated is described below.
- Capacity factor estimations
    - Historical onshore and offshore wind generation capacities and actual generations have been retrieved from the ENTSO-E Transparency platform.
    - For each MTU of each business day in scope, offshore and onshore capacity factors have been computed by dividing the actual generation by the generation capacity.
    - For bidding zones for which no offshore capacity could be computed (because of the absence of historical offshore wind generation), the capacity factor has been computed by "scaling up" the onshore capacity factor according to a scaling factor of 56/30 = 1.866.., based on the table provided by MSD reproduced at the end of this report.

- Additional onshore wind generation capacity by 2030 has been estimated by projecting the current onshore wind generation capacity according to a constant growth rate based on the historical growth rate observed in the ENTSO-E data, and subtracting the current capacity.

- Additional offshore wind generation capacity by 2030 has been estimated based on information provided in *Offshore wind vessel availability until 2030: Baltic Sea and Polish perspective,* H-BLIX & Wind Europe, June 2022, available online: https://windeurope.org/wp-content/uploads/files/policy/topics/offshore/Offshore-wind-vessel-avaiability-until-2030-report-june-2022.pdf

Appendix B: Topology alterations of the OBZ scenario

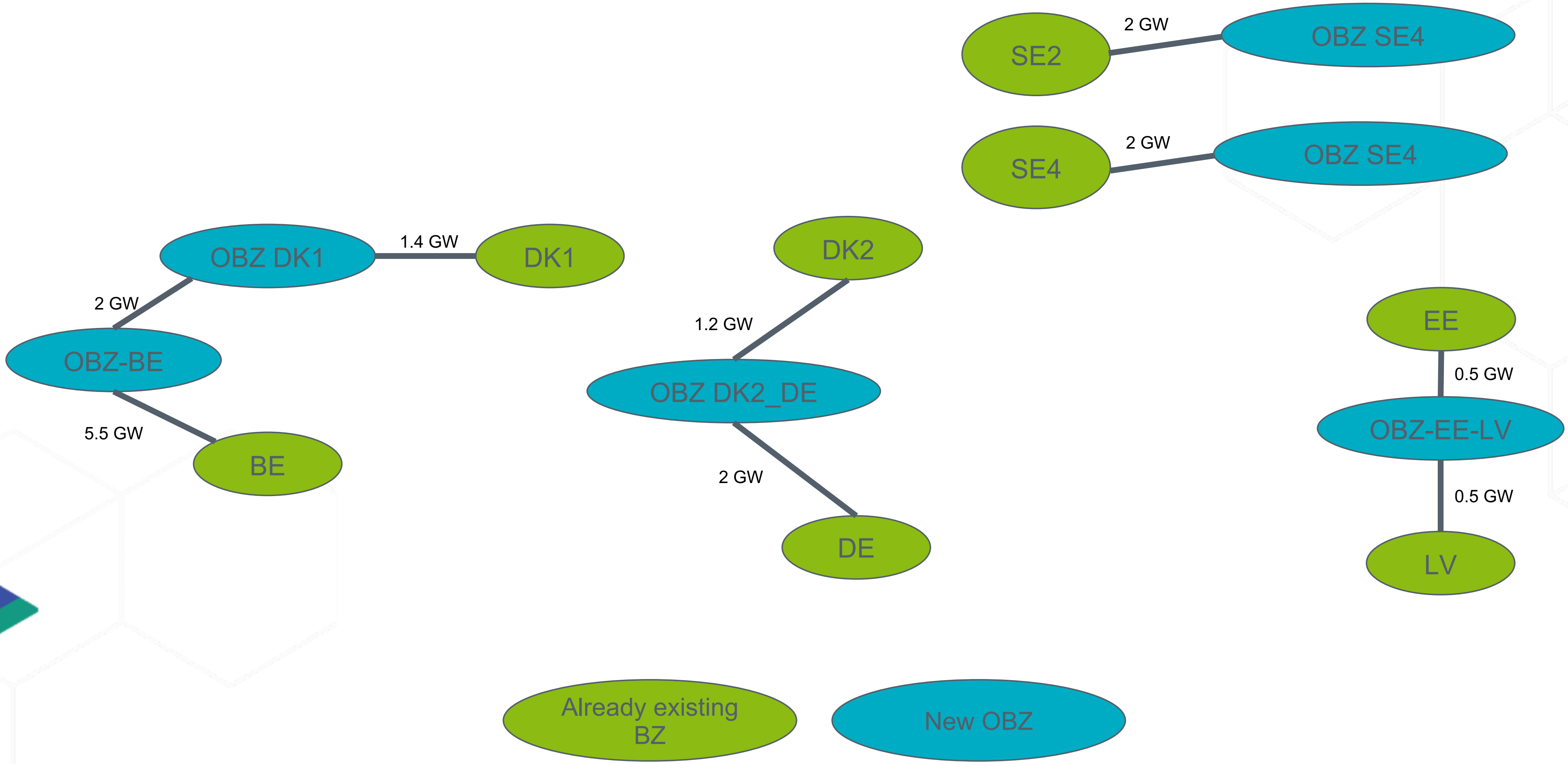

Table to compute the scaling factor to obtain an offshore capacity factor from an onshore capacity factor when the offshore capacity factor is missing

Table B.4a ▷ Technology costs in selected regions in the Stated Policies Scenario

	Capital costs (USD/kW)			Capacity factor (%)			Fuel, CO_2, O&M (USD/MWh)			LCOE (USD/MWh)			VALCOE (USD/MWh)		
	2021	2030	2050	2021	2030	2050	2021	2030	2050	2021	2030	2050	2021	2030	2050
United States															
Nuclear	5 000	4 800	4 500	90	90	90	30	30	30	105	100	95	105	100	95
Coal	2 100	2 100	2 100	35	15	n.a.	25	25	25	95	210	n.a.	95	210	n.a.
Gas CCGT	1 000	1 000	1 000	55	40	20	35	40	40	60	70	110	60	70	80
Solar PV	1 090	710	510	21	22	23	10	10	10	50	30	25	60	50	60
Wind onshore	1 380	1 310	1 250	42	43	44	10	10	10	35	30	30	40	40	45
Wind offshore	4 040	2 460	1 820	42	46	49	35	20	15	120	70	50	120	75	60
European Union															
Nuclear	6 600	5 100	4 500	80	80	80	35	35	35	140	120	105	140	120	105
Coal	2 000	2 000	2 000	40	20	n.a.	115	130	140	180	255	n.a.	165	215	n.a.
Gas CCGT	1 000	1 000	1 000	20	10	n.a.	100	120	130	155	270	n.a.	135	220	n.a.
Solar PV	810	530	410	14	14	14	10	10	10	50	35	30	60	80	80
Wind onshore	1 590	1 510	1 450	29	30	30	15	15	15	55	50	45	65	60	60
Wind offshore	3 040	2 000	1 500	51	56	59	15	10	10	60	40	30	60	45	40
China															
Nuclear	2 800	2 800	2 500	80	80	80	25	25	25	65	65	60	65	65	60
Coal	800	800	800	60	50	35	60	60	70	75	80	95	75	70	50
Gas CCGT	560	560	560	35	25	20	95	105	115	115	130	140	100	110	105
Solar PV	630	410	300	17	18	19	10	5	5	35	20	15	45	50	60
Wind onshore	1 160	1 090	1 050	26	27	28	15	10	10	45	40	40	50	50	50
Wind offshore	2 860	1 840	1 380	33	39	43	25	15	10	100	55	40	100	60	35
India															
Nuclear	2 800	2 800	2 800	75	85	90	30	30	30	75	65	65	75	65	65
Coal	1 200	1 200	1 200	65	75	75	40	35	35	60	55	50	60	55	45
Gas CCGT	700	700	700	40	50	45	75	85	85	95	100	105	95	90	85
Solar PV	590	380	270	20	21	22	5	5	5	35	20	15	40	35	55
Wind onshore	930	880	830	26	28	30	10	10	10	45	40	35	50	45	45
Wind offshore	2 780	1 820	1 300	33	37	39	25	15	10	120	75	50	120	80	60

Notes: O&M = operation and maintenance; LCOE = levelised cost of electricity; VALCOE = value-adjusted LCOE; kW = kilowatt; MWh = megawatt-hour; CCGT = combined-cycle gas turbine. Cost components, LCOE and VALCOE figures are rounded. Lower values for VALCOE indicate improved competitiveness.

Sources: IEA analysis; IRENA Renewable Costing Alliance; (IRENA, 2022).

Source: Table B.4a in *World Energy Outlook 2022, International Energy Agency, available online:* https://iea.blob.core.windows.net/assets/7e42db90-d8ea-459d-be1e-1256acd11330/WorldEnergyOutlook2022.pdf