Baltic InteGrid

Integrated Baltic Offshore Wind Electricity Grid Development

RECOMMENDATIONS

TO THE ENTSO-E'S TEN YEAR NETWORK DEVELOPMENT PLAN

Interreg Baltic Sea Region

EUROPEAN UNION EUROPEAN REGIONAL DEVELOPMENT FUND

EU STRATEGY FOR THE BALTIC SEA REGION FLAGSHIP

Recommendations
to the ENTSO-E's Ten Year Network Development Plan

Baltic InteGrid project team under the direction of Mariusz Wójcik

Published by: Baltic InteGrid, 21.09.2018

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1. Purpose of the document

The purpose of this document is to provide recommendation as part of the official consultation of the Ten Year Network Development Plan 2018 (TYNDP 2018) held in the period 03.08 and 21.09.2018. The recommendations were developed under the Baltic InteGrid project, co-financed from EU funds under the INTERREG Baltic Sea Region 2014–2020 program, whose goal is to explore the potential of an electricity grid in the Baltic Sea integrated with offshore wind farms. It aims at contributing to a sustainable electricity generation, the further integration of regional electricity markets, and to enhance the security of supply around the Baltic Sea.

This document is based on the findings from the Baltic InteGrid project. It condenses in one place the full knowledge and analytical results developed within the project and in particular:

- The report "Towards a Baltic Offshore Grid: connecting electricity markets through offshore wind farms" - PreFeasibility Studies report for Polish-Swedish-Lithuanian and German-Swedish-Danish interconnectors integrated with offshore wind farms,
- Findings from the conference "Offshore Grid and Offshore Wind Energy in the Baltic Sea – Opportunity for Integrating Energy Markets" which was held in Warsaw on the 7th of June 2018.

The report and the summary of the conference will be attached to recommendations on submission.

2. Challenges and drivers for the Baltic Sea Region

The recommendations are addressing challenges and drivers specific for the Baltic Sea Region. TYNDP 2018 report "Focus on the Nordic and Baltic Sea" recognizes the following challenges and drivers for grid development in the region:

- Renewable resources are located far from the consumption centres,
- Nuclear and other thermal generation are decommissioned and being replaced by renewable generation,
- The need for flexibility, also between synchronous areas, is increasing,
- Consumption is being established in new places because of the electrification of new sectors in society.
- A special challenge in this region is the ongoing process of integrating the Baltic States in the EU electricity system. This is both a national and an EU strategic priority.

In addition to the above, based on the analyses performed within the Baltic InteGrid project, the following challenges/drivers can be added:

- Offshore wind energy is expected to develop very rapidly and on a large scale in the Baltic Sea Region (especially in the South Baltic). The economic potential of offshore wind power in the Baltic Sea by is estimated for 9 GW by 2030 and 35 GW by 2050.
- Should this potential be realized without coordination among developers, investors and the TSOs it would mean dozens of radial connection cables and cable corridors which may cause significant spatial conflicts with other sea and seaside users/uses: military areas, environmental protection, tourism, fisheries, navigation etc.
- EU CO_2 targets and corresponding increasing costs of CO_2 emission allowances, new Renewable Energy Sources (RES) goals, high industrial potential related to offshore wind energy and falling prices of this technology only support rapid deployment of wind farms at sea – in consequence offshore wind energy could have a major role in shaping not only the energy sector but also the maritime industry in the region.

- Offshore wind farms, in particular in the South Baltic, are planned in locations such as South Middle Bank and Arkona Basin where it is possible to connect them to offshore hubs being part offshore grid connecting countries in the region.
- Currently approx. 1,8 GW in OWFs is installed in the Baltic Sea, however numerous projects are being under development. Failing to take coordinative actions may lead to lock-in to a radial connection topology and inefficient wind farm cluster designs, resulting in higher costs for the end-consumer and potential spatial conflicts.
- Development of a Baltic offshore grid would facilitate balancing of the variable energy from wind at sea through stable hydropower from the Scandinavian countries.

3. Recommendations

Recommendation 1 – Transmission projects with status "under consideration" should be analysed in view of potential integration with OWFs

- The following projects should be considered and further investigated in view of potential integration with planned offshore wind farms:
  - Project no. 179: "DKE-DE (Kontek2)" connecting Denmark East and Germany,
  - Project no. 234: "DKE-PL1" connecting Poland and Denmark East,
  - Project no. 239: "Fenno-Skan1 renewal" connecting Sweden and Finland,
  - Project no. 267: "Hansa PowerBridge II" connecting Germany and Sweden (recommendation for this particular project is included further in the document).
- An example of such approach is included in the TYDNP 2018 for Project 260: "New Great Britain - Netherlands interconnection", which states "This project considers the possibility of a second 1-2GW interconnector between GB and the Netherlands. The project will also consider UK / NL offshore wind connection optionality". Similar approach could be applied the listed projects.
- Offshore wind energy (OWE) may develop very rapidly and on a large scale in the Baltic Sea Region (especially in the South Baltic) making it the next offshore wind energy region after the North Sea. Within the next decade it is estimated that additional 7,2 GW in offshore wind farms will be built in the BSR, totalling to 9 GW in 2030[1].
- This creates an immense potential for building an offshore grid integrated with offshore wind farms (OWF). Studies performed within the Baltic InteGrid project show that with high level of OWE deployment, integration of OWFs with interconnectors can bring additional benefits: cost-sharing opportunities, reducing overall system costs, increasing system flexibility, increasing Cross-Border Energy Trade (CBET), increasing RES deployment in line EU climate strategy, reduce spatial conflicts etc.
- It has to be kept in mind that the Cost-Benefit Analysis (CBA) for an integrated solution has to be performed on a case-by-case basis and is very much dependent on the level of offshore wind deployment in the analysed area and the level of integration. This applies especially to complex setups where protection systems, such as HVDC breakers, are required.
- Building on the assumption stated in the TYNDP 2018 Executive Report that "*The costs of analysing potential future projects is small compared to the costs of building them, justifying to some extent the analysis of diverse solutions for uncertain needs.*" – the aforementioned projects should be further investigated including the following elements:

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[1] Estimates given by WindEurope and confirmed by offshore wind potential analyses performed within Baltic InteGrid.

- Potential OWFs that could be connected to the interconnection given their status of development, planned commissioning year, capacity etc.,
- Costs and benefits of such solution,
- Purpose of the interconnector (e.g. security of supply, cost convergence between markets etc.) and whether integration with OWFs meets or hinders that purpose.

- Failing to conduct such analysis can result in: locking-in to solutions that rule out integration of OWFs in the future, miss out on the cost reduction opportunities and/or reduce the potential of OWE in the region.

Recommendation 2 - Include a Polish-Swedish-Lithuanian interconnection integrated with planned OWFs as a project candidate to the next TYNDP 2020.

- Results of the report "Towards a Baltic Offshore Grid: connecting electricity markets through offshore wind farms"[2] show a high potential for introducing a grid solution integrated with OWFs for Poland, Sweden and Lithuania, both for High and Low Offshore Wind Power (High/ Low OWP) scenarios.

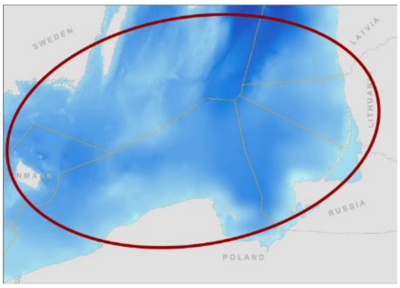

Figure 1 Case Study 1 Area

- The cost-benefit analysis performed within the study show that regardless of the level of OWE deployment in the study area (see Figure 1) benefits from connecting OWFs to an offshore grid outweigh the costs.
  - For the High OWP build-out (assuming 11,2 GW for the whole study area in years 2025-2045) the partial integration scenario (Scenario 2a) is the most favourable.

    The scenario presents the possibility of a partially integrated system, incorporating both radial and integrated OWF connections. The design logic of this scenario is to connect OWFs close to shore (Slupsk Bank, Lithuanian and Swedish projects near the coast) radially with AC technology, and the wind farms far offshore (South Middle Bank on the Polish and Swedish side) would be integrated with new HVDC interconnectors (currently existing HVDC lines: NordBalt, SwePol Link are not considered for integration with OWFs).

    This type of design would need a fair level of cooperation for all projects and stakeholders using the VSC-HVDC system. In return, the solution could provide higher flexibility, utilisation rates and cost sharing opportunities between interconnector and OWF connection.

    The grid costs are lowest for the partial integration scenario – 2.96 billion EUR. The costs for the zero integration and the maximum integration scenarios are: 3.27 billion EUR and 3.50 billion EUR respectively. Based on CBA analysis, compared to the base-case scenario (zero integration), the partial integration brings additional benefits of 0,36 billion EUR.

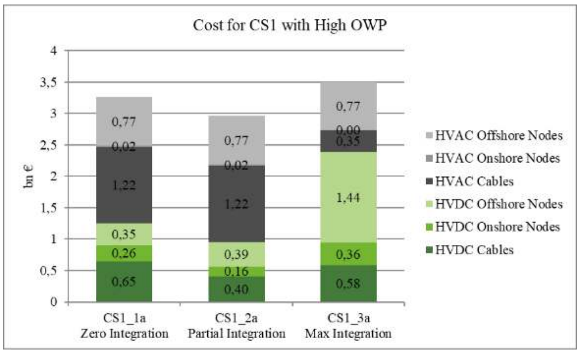

Figure 2 Cost structure for the Case Study 1 (CS1) scenarios / High OWP

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[2] Wójcik et al. "Towards a Baltic Offshore Grid: connecting electricity markets through offshore wind farms". Baltic InteGrid (2018)

The partial integration scenario could depict the development of OWE in Poland and Sweden, with the most developed projects in Poland being planned to be connected radially. However, projects farther from shore, at Southern Middle Bank (both in Swedish and Polish waters), will be developed most likely after 2030 and could be connected in a more coordinated approach.

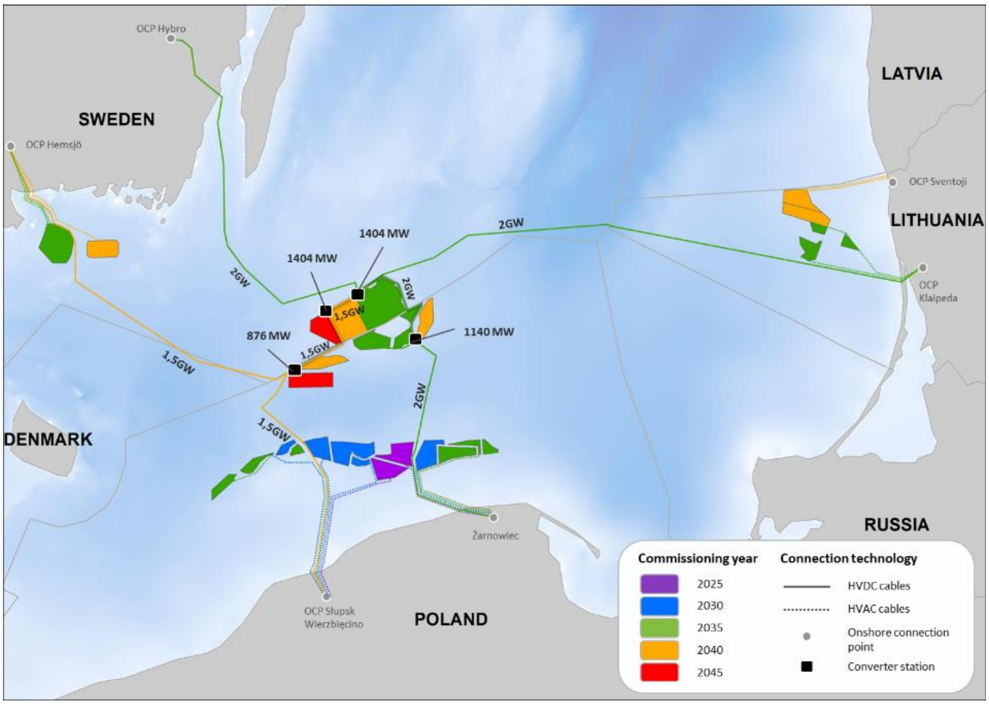

Figure 3 Case Study 1 - Scenario of High OWP/partial integration - schematic build-out

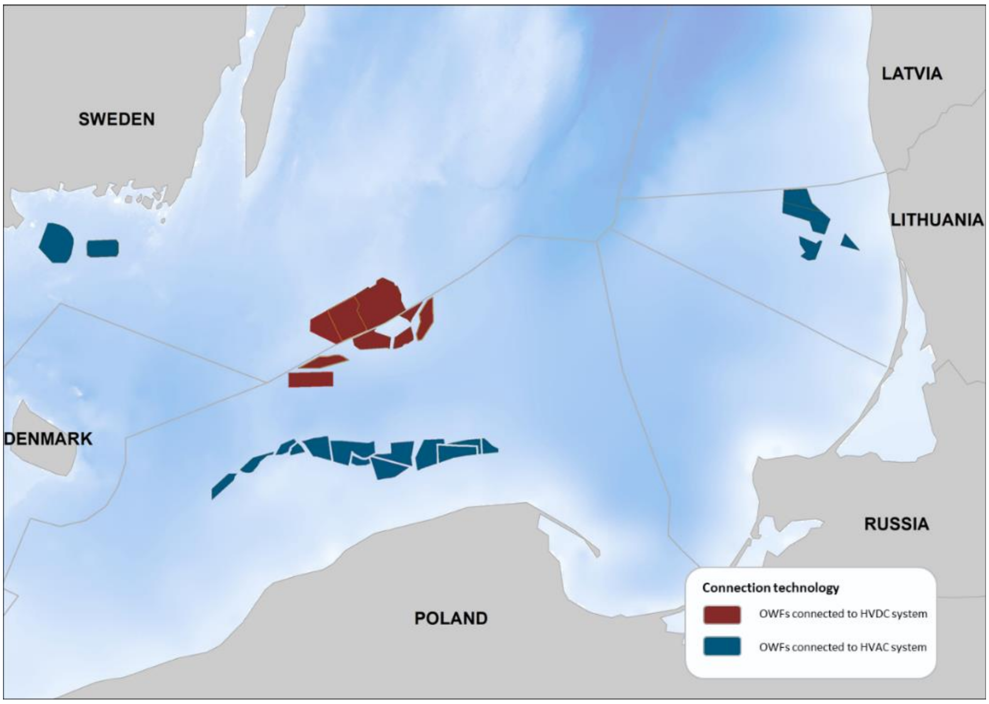

Figure 4 Case Study 1 - Scenario of High OWP/partial integration – connection technology

- For the **Low OWP build-out** (assuming 5,7 GW in the whole study area in years 2025 - 2045) the maximum integration scenario (Scenario 3b) is the most favourable.

  This introduces the concept of full integration of OWP into the border-crossing VSC-HVDC system. All OWFs are connected to the offshore DC grid. The key characteristic of this scenario can be summarised as high cooperation and planning requirement, technically challenging, flexible power flow routing, the possibility for high utilisation rates, shorter total cable lengths and the possibility to share costs between interconnector and OWF connection infrastructure.

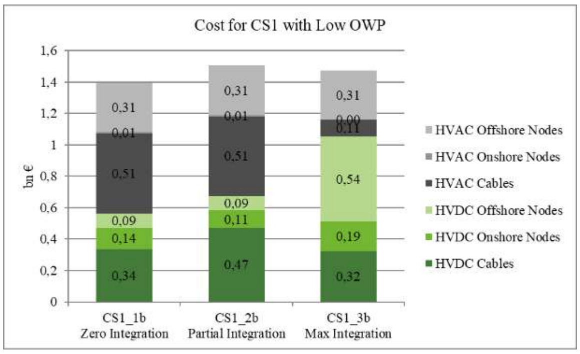

Figure 5 Cost structure for the Case Study 1 (CS1) scenarios / Low OWP

  The grid costs are lowest for zero integration scenario – 1.40 billion EUR. The costs for the partial integration and the maximum integration scenarios are: 1.50 billion EUR and 1.47 billion EUR respectively.

  Even though the costs for the maximum integration scenario are higher, the benefits surpass the costs and compared to the base-case scenario (zero integration), the additional benefits amount to 0.91 billion EUR.

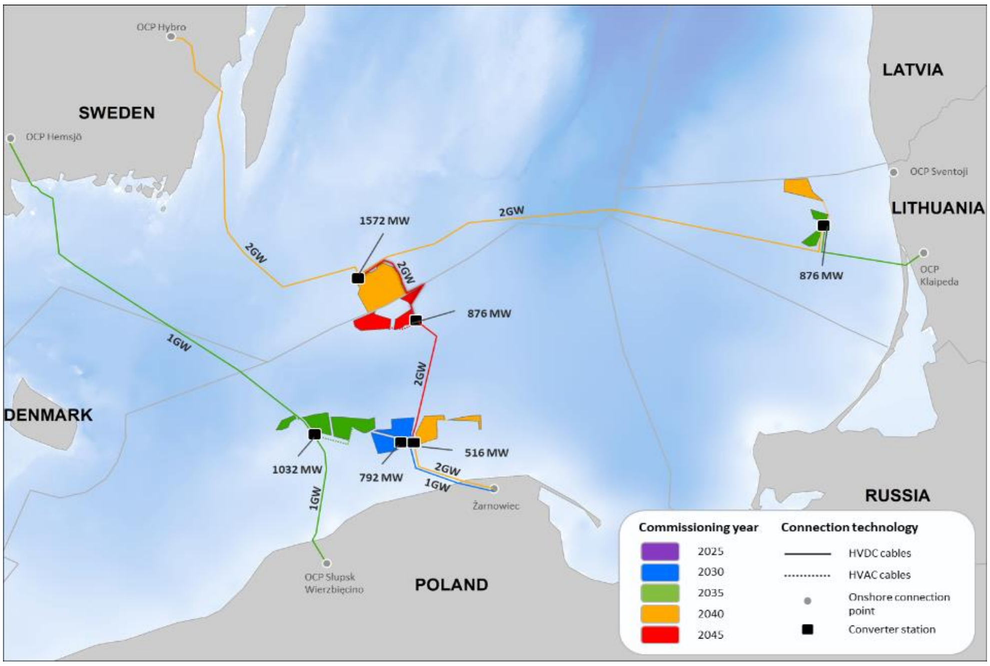

Figure 6 Case Study 1 - Scenario of Low OWP/maximum integration - schematic build-out

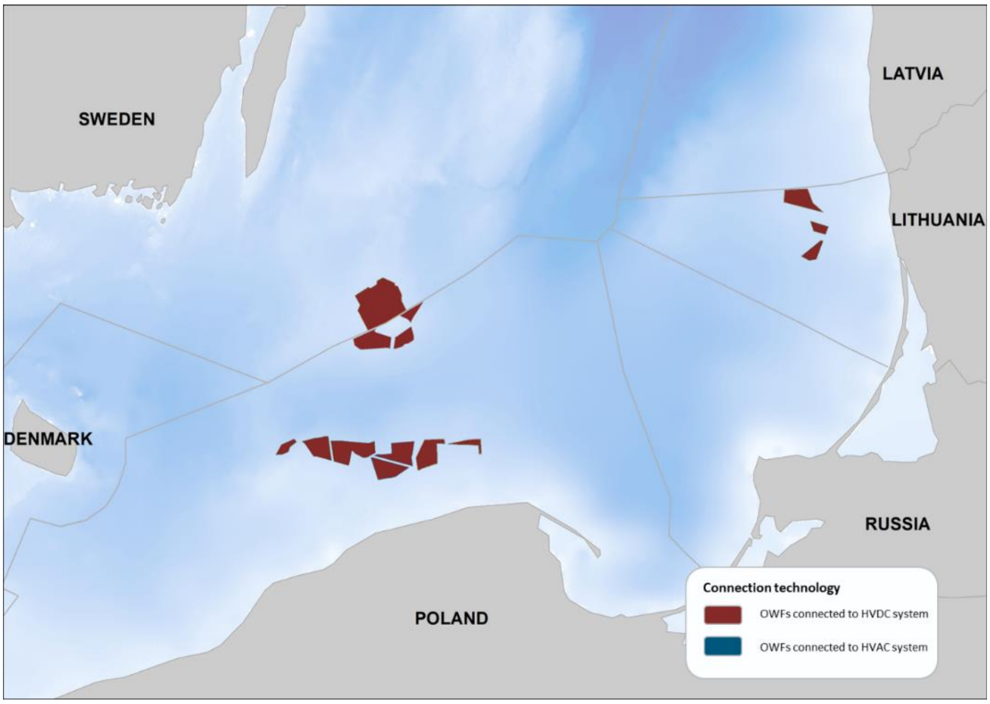

Figure 7 Case Study 1 - Scenario of Low OWP/maximum integr. – connection technology

- The adequacy analysis proved that in all proposed scenarios the system has enough capacity available, but higher integration provides the system with more flexibility with regard to the adequacy rate.

Table 1 Summary of Cost-Benefit Analysis – Case Study 1

CS1 (PL/SE/LT)					
High Offshore Wind Power			Low Offshore Wind Power		
Zero integration	**Partial Integration**	Max Integration	Zero integration	Partial Integration	**Max Integration**
Benefits minus costs relative to base case (higher is better)					
base case	**0.36 bn€**	-0.15 bn€	base case	0.81 bn€	**0.91 bn€**

Table 2 Summary showing the most economic scenarios

	Case Study 1 (PL/SE/LT)
High OWP	Partial Integration
Low OWP	Maximum Integration

- Benefits of PL-SE-LT interconnection integrated with offshore wind farms:
  - Further support for the process of synchronisation of the Baltic States, by strengthening security of supply through a HVDC connection. Current TYNDP 2018 assumes a Project **170 "Baltics synchro with CE"** which includes a submarine, asynchronous HVDC connection between Poland and Lithuania by 2025. The proposed PL-SE-LT project candidate assumes that first element of this connection would be built in the period 2030 – 2035, therefore it would mean an additional interconnection increasing the trading capacity and supporting the security of supply for the Baltic States.
  - Furthermore, Project 170 can pave the way for a following Polish-Swedish-Lithuanian connection, if not from technical point of view, then at least from a spatial perspective. Currently the Project 170 is considered as a straight line between Poland and Lithuania, which assumes crossing through Russian Exclusive Economic Zone (EEZ). From a permitting point of view and given that the waters around Kaliningrad region are used in majority as military exercise area, such route might prove to be challenging. Therefore a potential route through Swedish EEZ might be considered more favourable. Such route is proposed in the case study presented in Figure 3 which was based on a detailed analysis of other sea uses.
  - Reduction of price differences between continental and Nordic markets. It is worth noting, that based on the "European maps of average hourly price differences between market areas"3 in all envisaged 2030 scenarios, the price differences between Poland and Sweden (SE4) are at least 10-15 EUR and in one scenario even above 15 EUR. Taking into account the recent increase in energy prices in Poland this can become an important factor for the development of new North/South connection.
  - Higher utilisation rates, since the capacity of the cable not used for exporting electricity from wind farms can be used for CBET. However, the situation of near-maximum infrastructure utilisation rate would require that one of the interconnected countries would always have a sufficiently high power demand and electricity price in relation to the other interconnected country(s).
  - Lower risk of social conflicts. Public acceptance and spatial conflicts are becoming more and more important in planning of infrastructure projects. They can cause delays or even cancellation of investments. It has to be emphasised that according to the analysis perfomerd within Baltic InteGrid, the proposed project candidate would result in significant reduction of number of cables and landfalls (up to 3 times less in maximum integration scenario) compared to radial connection of all OWFs projects.
- It is worth noting, that a second Polish-Swedish connection was considered for the TYNDP 2016, as it showed potential benefits related to price differences. Eventually, the decision by the TSOs (Svenska Kraftnät and PSE S.A.) was not to nominate it as a new project candidate for inclusion in the TYNDP 2016 due to various reasons. Perhaps, integration with OWFs can constitute a missing link that would improve the feasibility of such approach.
- Viability of a new Polish-Swedish interconnection (with potential connection to Lithuania) integrated with OWFs was confirmed by the Polish Institute of Power Engineering[4] in an expert opinion. According to experts, such connection would increase the cross-border trade capacity and will contribute to meeting the export/import capacity targets set by EU for 2030.

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[3] TYNDP 2018 Executive Report Appendix

[4] Institute of Power Engineering in Gdańsk. „*Opinia ekspercka w zakresie budowy połączenia Polska – Szwecja – Litwa zintegrowanego z morskimi farmami Wiatrowymi z uwzględnieniem uwarunkowań Krajowego Systemu Elektroenergetycznego*". Gdańsk, 2018. http://www.fnez.pl/upload/File/Opinia%20PL-SE-LT.pdf

- In order to introduce the project further actions will be required, to name a few:
  - Detailed and in-depth feasibility study for the PL-SE-LT connection. Inclusion of the project in TYNDP 2020 would enable the way for obtaining the Project of Common Interest status and unlock financing from the EU.
  - Discussions among the TSOs in the respective countries and investors including establishment of a working group.
  - Strategic declarations, included in official policy document in the involved countries that will support OWE and offshore grid development.
  - Review and of the legislative framework that will allow for connecting OWFs to cross-border connections.

Recommendation 3 - Hansa PowerBridge II should be considered in terms of integrating offshore wind farms in the German, Swedish and Danish waters

- The results of the study "Towards a Baltic Offshore Grid: connecting electricity markets through offshore wind farms" [5] show that an interconnector with the integration of offshore wind energy between Germany and Sweden has economic benefits[6]. Therefore, it is recommended that the Hansa PowerBridge II project will also consider the DE / SE / DK offshore wind connection optionality - similar to the Project 260: "New Great Britain - Netherlands interconnection".
- The results of the aforementioned study for a potential German-Swedish interconnection integrated with OWFs proved that - provided critical mass of OWE - in the study area, an integrated solution is more favourable than radial connection of OWFs.
  - For the High OWP build-out (assuming 3.7 GW for the whole study area[7] in the years 2025 - 2045) the maximum integration scenario is the most favourable due to reduced costs. This scenario assumes that all OWFs are connected to an HVDC offshore grid. This leads to an offshore system with two offshore HVDC converter stations.

    Such approach however, requires large efforts to coordinate international energy infrastructure and sea use planning, extensive technological know-how regarding multi-terminal systems.

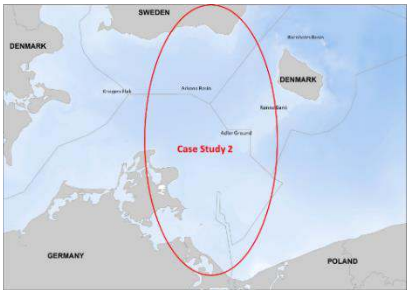

Figure 8 Case Study 2 Area

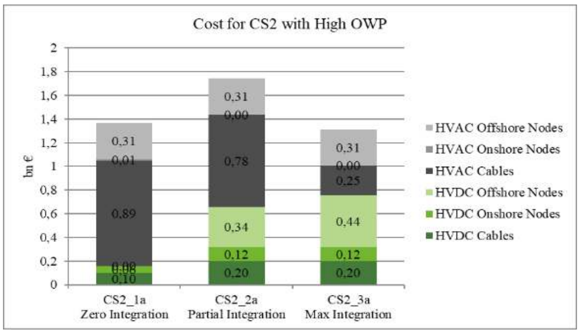

Figure 9 Cost structure for the Case Study 2 (CS2) scenarios / High OWP

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5 Wójcik et al. "Towards a Baltic Offshore Grid: connecting electricity markets through offshore wind farms". Baltic InteGrid (2018)

6 The analysis performed within the Baltic InteGrid project was done independently from the assessment performed by: 50Hertz, Svenska Kraftnät and Energinet. Furthermore, the underlying assumptions differ in some respects to Hansa PowerBridge II project, e.g. different connection point in Germany.

7 The build-out in this study was assumed prior to the announcement of Germany's last offshore tender. The exact results of the tender were not expectable: three projects within the Baltic Sea were awarded – two in the EEZ and one in the territorial waters with in the state of Mecklenburg-Vorpommern. Therefore, the case study does not depict the actual build-out within the German waters. However, the results of the case study (e.g. the cost-benefit analysis) would most likely only change slightly, if the case study were adjusted to the actual situation.

The benefits of such a system could be high infrastructure utilisation rates and cost sharing opportunities between interconnectors and OWF connection infrastructure.

The grid costs are lowest for the maximum integration scenario – 1.32 billion EUR. The costs for the zero integration and the maximum integration scenarios are: 1.37 billion EUR and 1.75 billion EUR respectively. Based on the CBA analysis, compared to the base-case scenario (zero integration), the additional benefits of the maximum integration amount to 1.81 billion EUR.

In addition, grid integration brings additional benefits of reducing the number of subsea cables and landfalls 6-fold. This is critical in terms of impact on other sea users, public acceptance in the touristic areas and environmental protection.

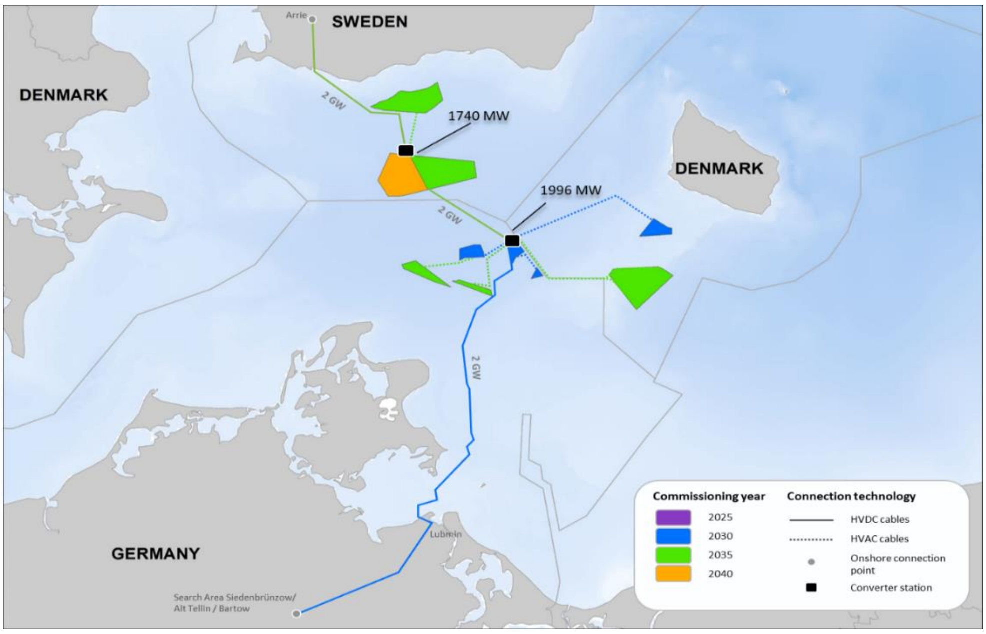

Figure 10 Case Study 2 - Scenario of High OWP/max. integration - schematic build-out

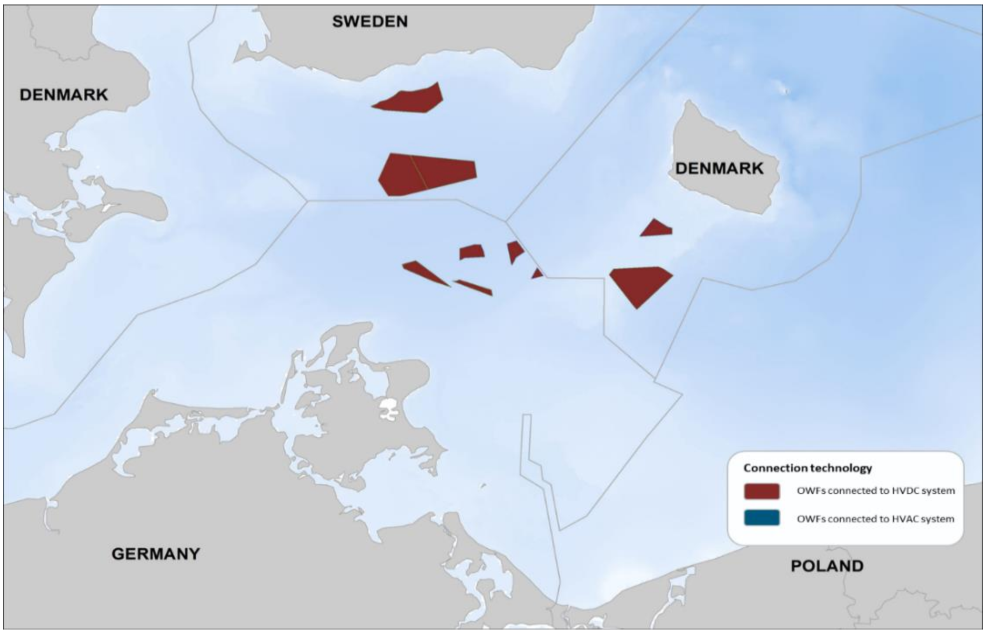

Figure 11 Case Study 2 - Scenario of High OWP/max. integration – connection technology

- If a critical mass is not met however, like in the Low OWP build-out (assuming 1.9 GW in the years 2025 - 2045) no extra benefit and no cost reduction can be observed for wind farm integration. Here, the zero integration scenario should be favoured. This means that all projects are connected radially to shore.

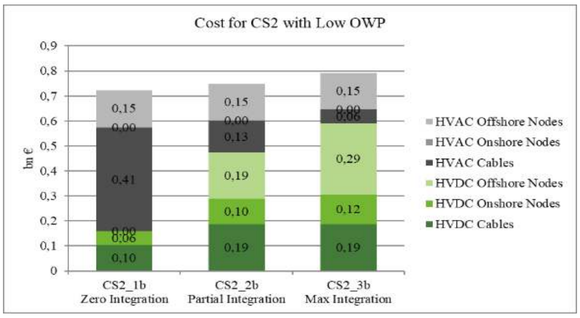

Figure 12 Cost structure for the Case Study 1 (CS1) scenarios / High OWP

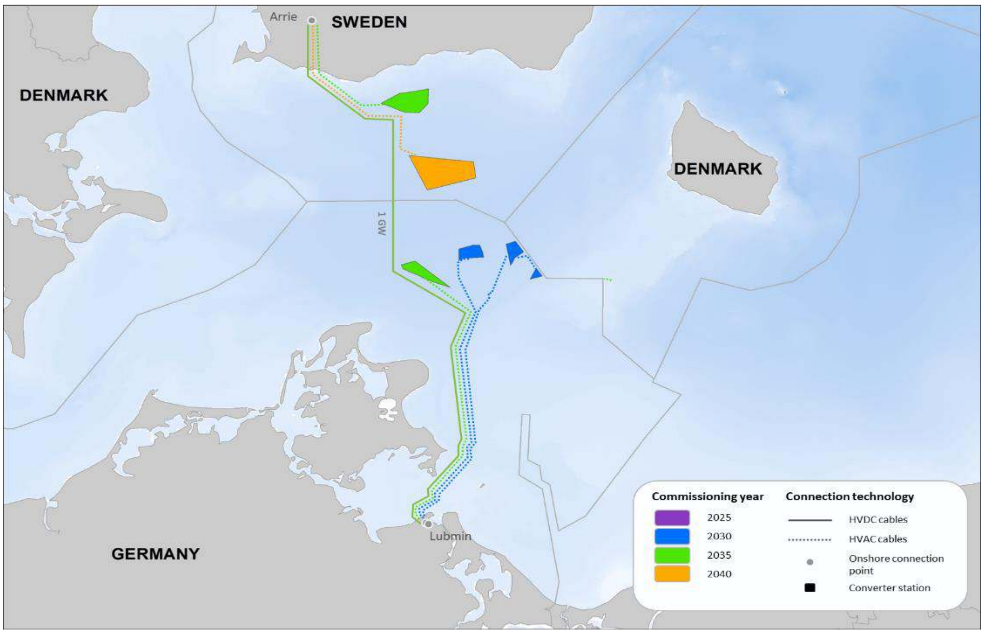

Figure 13 Case Study 2 - Scenario of Low OWP/zero integration - schematic build-out

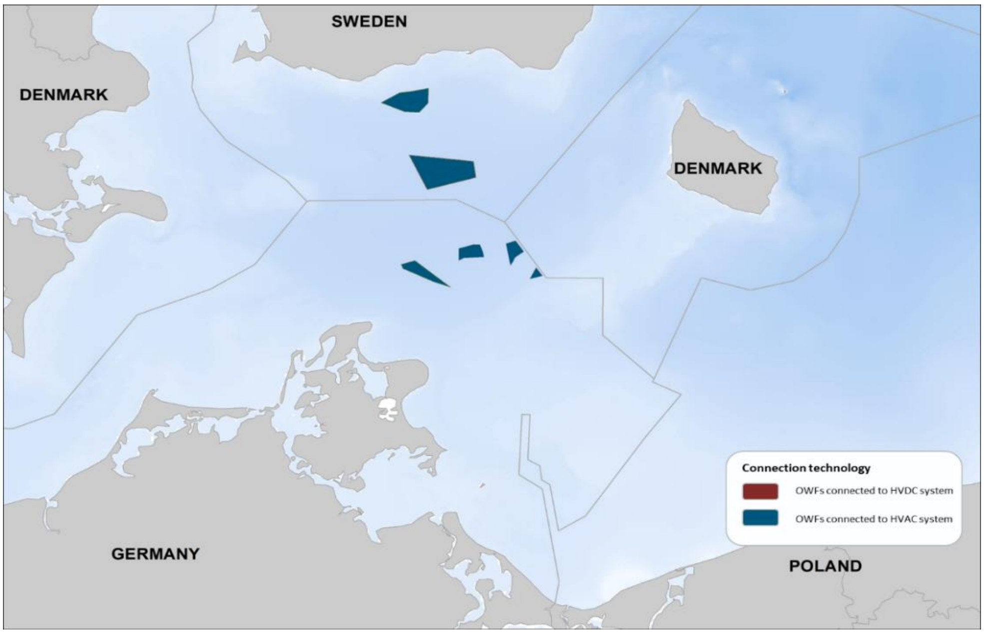

Figure 14 Case Study 2 - Scenario of Low OWP/zero integration – connection technology

- The adequacy analysis proved that in all proposed scenarios the system has enough capacity available, but higher integration provides the system with more flexibility with regard to the adequacy rate.
- Apart from the benefits related to lower system costs, the project can contribute to higher flexibility of the system and reducing electricity prices through providing cheap renewal energy and - in times of no wind – cross-border energy trade.

Table 3 Summary of Cost-Benefit Analysis – Case Study 2 (relative values)

CS2 (DE/SE/DK)					
High Offshore Wind Power			Low Offshore Wind Power		
Zero integration	Partial Integration	**Max Integration**	**Zero integration**	Partial Integration	Max Integration
Benefits minus costs relative to base case (higher is better)					
base case	1.45 bn€	**1.81 bn€**	**base case**	-0.06 bn€	-0.08 bn€

* figures above are presented as relative values to the base case scenario which is zero integration.

Table 4 Summary showing the most economic scenarios

	Case Study 2 (DE/SE/DK)
High OWP	Maximum Integration
Low OWP	Zero Integration

Recommendation 4 – Scenario assumptions in terms of OWE development in the Baltic Sea should be revised following the market trends and opening of new markets

- Current scenario assumptions do not provide the full view of expected development of offshore wind energy in the Baltic Sea. For example the capacity in OWFs in Germany is given collectively for whole country including the North Sea which makes it impossible to identify capacities for the Baltic Sea.
- According to Baltic InteGrid calculations which are consistent with WindEurope's estimates, 9 GW in OWFs can be operating until 2030 in the Baltic Sea Region.
- It has to be emphasised that none of the scenarios assumed for TYNDP 2018 is even close to 9 GW by 2030 (estimations used for TYNDP range from 4,5 – 6 GW until 2030[8]). The consequence of such conservative approach is the possibility to overlook potential benefits such as integration of offshore wind with an offshore grid.
- The estimations are based on economic feasibility of OWE projects and are backed by the market information:
    - German TSO together the Regulator BnetzA have assumed 3 GW until 2030 in the Offshore Grid Development Plan (currently approx. 0,7 GW operating and 0,4 GW under construction).

[8] Since the OWE capacities for Germany where not divided by sea basin it was assumed that the 3 GW in 2030 was reached in every scenario and that the remaining OWE capacity was related to the North Sea.

  - During the conference held in on the June 7th, 2018 in Warsaw "Offshore Grid and Offshore Wind Energy in the Baltic Sea – Opportunity for Integrating Energy Markets" representative of the EU Commission, DG Energy confirmed that with its high potential and its mature maritime industry environment, Poland may lead in development of offshore wind farms and grids.
  - The results of a survey performed by the Polish TSO (PSE S.A.) show that investors are ready to develop up to 16,7 GW in offshore wind in Polish marine areas.
  - The Polish Government Plenipotentiary for Strategic Energy Infrastructure declared that even 10 GW could be built in Poland until 2030. This comes along with the declaration that PSE S.A. is willing to build an offshore grid that could accommodate such capacity.
  - Although such declarations should be assessed against the real development of OWE projects and building of legal and operational framework for OWE development in Poland, it is clear that the industry players and investors are ready to develop offshore wind in a rapid manner.
- Given the above, it is recommended to revise the scenarios during next TYNDP development period and incorporate less conservative assumptions for OWE in the Baltic Sea Region (at least in one of the scenarios) to cover full range of possible future outcomes.

Recommendation 5 – Communication between stakeholders should be facilitated, active role of ENTSO-E and TSOs is crucial.

- Within the Baltic InteGrid project a Baltic Offshore Grid Forum (BOGF) was established which is an umbrella platform for conferences and workshops held within and after the project's end. BOGF builds upon the project's existing region-wide network of relevant experts and contacts related to offshore wind, sustainable energy and grid development, actively pursuing the participation of more stakeholders.
- One of the key conclusions from the conference held under BOGF umbrella on June 7th, 2018 in Warsaw was that development and implementation of an offshore grid integrated with offshore wind farms requires close cooperation between all stakeholders (investors, developers, administration and transmission system operators). This communication requires active participation of ENTSO-E and TSOs in the industrial discussion.
- BOGF can serve as a tool for facilitating communication between stakeholders and we encourage ENTSO-E and TSOs in the Baltic Sea Region countries to actively participate in the discussions to ensure proper communication among stakeholders.

Recommendation 6 – Include "Project 170 - Baltics synchro with CE" in the Regional Insight Report "Focus on the Nordic and Baltic Sea"

- The new subsea HVDC connection between Poland and Lithuania accompanied by reinforcement of national grids in those countries is included in the TYNDP list of projects, it is not, however, referred to in the Regional Insight Report. The importance of this connection in relation to synchronisation of the Baltic States requires that it is directly referred to in the document.