Baltic InteGrid

Integrated Baltic Offshore Wind Electricity Grid Development

Assessment of Baltic hubs for offshore grid development

A report for the Baltic InteGrid project

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Interreg Baltic Sea Region

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List of Abbreviations

BSR	Baltic Sea region
HVAC	High voltage alternating current
HVDC	High voltage direct current
OMS	Operation, maintenance and service
OWE	Offshore wind energy
SME	Small and medium-sized enterprise

Summary

The Baltic InteGrid project is exploring the potential of a meshed offshore electricity transmission grid for the Baltic Sea region (BSR). The offshore wind market in the region could increase from 1.8GW installed at the end of 2017 up to 9.5GW at the end of 2030. This increase in capacity offers opportunities for port hubs in the BSR looking to contribute to the future development of the offshore transmission grid through supporting supply chains across the lifecycle of transmission assets.

This study was tasked with identifying potential hubs for the manufacture, installation and maintenance of the offshore wind transmission grid. The study describes 14 opportunity ports with the potential to contribute to the future development of the offshore grid in the BSR.

This study identified the following main conclusions:

- The BSR is well placed to deliver export cable manufacturing and installation, based on a strong existing supply chain including port infrastructure at the point of supply.
- The BSR has sufficient port infrastructure in place to meet demand for substation structure and electrical supply and installation.
- There will be more opportunities for BSR hubs in the transmission maintenance supply chains than in manufacture and installation.
- BSR ports can take advantage of their expertise to improve transmission manufacture, installation and maintenance.
- Barriers to developing the optimal port infrastructure in the BSR are competition from outside the region and the relatively low level of demand.
- German ports are the most likely to develop into and remain as hubs for the offshore transmission sector.

1. Introduction

Offshore wind energy (OWE) plays an increasingly important role in a diversified and sustainable future energy mix. Offshore wind capacity in Europe totals 15.8GW (2017), the vast majority of which is located in the North Sea.[1] The Baltic Sea region (BSR) offers good conditions for offshore wind development: compared with the North Sea, waters are relatively shallow, wave height is lower, tides are less pronounced and potential sites are close to shore, resulting in lower manufacturing, installation and grid infrastructure costs. By 2030, the BSR could have 9.5GW in offshore wind capacity[2], of which only about 1.8GW has been installed by the end of 2017.[3]

The Baltic InteGrid project is exploring the potential of a meshed offshore electricity transmission grid for the BSR. It aims to contribute to sustainable electricity generation, to integrate the regional electricity markets further, and to enhance the security of supply around the BSR. The Baltic InteGrid project supports research efforts to equip its stakeholders with insights on the development of a regional meshed grid across a range of fields, including market and supply chain analysis.

The purpose of this study is to identify potential hubs for the manufacture, installation and maintenance of components involved in offshore wind transmission grid development. The study describes the port infrastructure requirements for the defined elements of the offshore wind transmission grid, identifies Baltic port hubs with the capability to contribute to the future development of the offshore grid in the BSR, and provides conclusions about sites identified as suitable for supporting this market.

This study is not meant to advocate for specific port improvements or for realignment for any particular use of the opportunity ports.

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[1] WindEurope, *Offshore Wind in Europe - Key trends and statistics 2017* (online, 2018), 17-20. https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Offshore-Statistics-2017.pdf

[2] Baltic InteGrid, *Internal document* (2018).

[3] WindEurope, *Offshore Wind in Europe*, 20.

2. The offshore wind energy grid

2.1 Supply chain

The offshore wind transmission supply chain can be categorised into three areas: export cables, substation structure and substation electrical. This includes both HVAC and HVDC substation technology. Work packages in each of these areas may be further divided into three lifecycle stages of manufacture, installation and maintenance. The classification of these supply chains is described in

Table 1,

Table 2 and

Table 3.

	Manufacture	Installation	Maintenance
Export cables	Cable core	Installation engineering	Asset management
	Insulation and armouring	Route engineering	Cable surveys
	Cable assembly	Route clearance	Fault identification
	Testing	Vessel mobilisation and port services	Cable joint manufacture
	Transport	Installation equipment manufacture	Replacement cable manufacture
	Storage	Installation equipment services	Cable jointing
		Cable vessel manufacture	Cable repair vessel manufacture
		Cable vessel operation	Cable repair vessel mobilisation
		Vessel services	Cable repair vessel operation
		Crew services	Weather forecasting
		Cable lay	Marine warranty surveying
		Cable pull-in	
		Cable burial and trenching	
		Cable survey	
		Cable termination	
		Cable commissioning	
		Weather forecasting	
		Marine warranty surveying	

Table 1 Classification of the offshore transmission export cable supply chain.

	Manufacture	Installation	Maintenance
Substation structure	Structural design	Installation engineering	Asset management
	Platform structure fabrication	Substation load-out	Above water surveys of coatings and steelwork
	Platform structural steel	Barge manufacture	Below water surveys of coatings and steelwork
	Platform secondary steel	Barge operation	Surveys of grout integrity
	Platform architectural steel	Heavy lift vessel manufacture	Replacement component manufacture
	Helicopter deck	Heavy lift vessel operation	Repair work
	Accommodation and safety	Crew services	Weather forecasting
	Foundation structure fabrication	Vessel mobilisation and port services	Marine warranty surveying
	Foundation structural steel	Weather forecasting	
	Foundation secondary steel	Marine warranty surveying	
	Coatings		
	Cathodic protection		
	Blast protection		

Table 2 Classification of the offshore transmission substation structure supply chain.

	Manufacture	Installation	Maintenance
Substation electrical	Electrical design	High voltage and medium voltage installation	Asset management
	High voltage transformers	High voltage and medium voltage commissioning	Maintenance
	High voltage direct current power electronics	Low voltage installation	Replacement component manufacture
	High voltage reactive compensation systems	Low voltage commissioning	Crew vessels
	High and medium voltage switchgear		Crew services

	High voltage control and protection system		
	Medium voltage control system		
	Low voltage distribution, control and monitoring systems		

Table 3 Classification of the offshore transmission substation electrical supply chain.

2.2 Coastal infrastructure requirements

2.2.1 Export cables

Manufacture

The size and mass of export cables requires manufacturing at quayside or in close proximity where cables can be loaded directly onto the cable installation or transport vessels. The production line is typically laid out in long horizontal bays with gantry cranes to move finished components. Due to bend radius restrictions and water depth restrictions, many cable facilities use spool tracking on the quayside which can extend via a gantry out into the sea.

Cable cores may be manufactured inland but future manufacturing is ideally only at sites with suitable waterfront, ideally coastal, infrastructure. Materials for cable production can be transported by standard truck, rail or sea-borne containers. Finished components are stored on large-capacity carousels or reels inside or outside the factory. These carousels measure around 30m in diameter and have a bearing pressure of 10t/m2 at capacity and so the storage area may need to be reinforced, although this does not need to be at quayside if there is a path for feeding the cable to an installation vessel.

Installation

Ideally subsea cables are loaded onto an installation vessel at the manufacturing facility, but onshore or offshore storage may be necessary depending on the installation timetable. If the manufacturing facility is a long way from the wind farm site, the cable may be transported as freight on carousels or reels.

Cable installation vessels do not require a high specification port as cable lay vessels have generally shallow draft and are usually self-loading. Vessels are between 75-145m in length, 18-32m in beam, have a draft of 6-9m and require under 25m of air draft.

Maintenance

Subsea cable maintenance is carried out over the lifetime of the asset. It is vital to keep the transmission system running reliably and efficiently, and to correct faults quickly to maximise the export of power generated. Operation, maintenance and service (OMS) facilities are typically in operation for 25 years or more. Ideally, they are located close the transmission system to minimize distance and travel time. Service is conducted on a regular annual schedule and repairs must be completed quickly to minimize the time the

transmission system is off-line. Storage facilities for spare cable require quayside infrastructure for hosting up to 10,000t of cable as well as specialist equipment for cable storage, loading and unloading.
Vessels for cable survey and repair are typically smaller (about 90m long) than those used in cable installation and the choice can depend on cost and availability. Numerous BSR ports are physically suited for maintenance and service.

Indicative port requirements for cable manufacture, installation and maintenance are given in
Table 4.

Category	Port characteristic	Manufacture	Installation	Maintenance
Water access	Horizontal clearance	28m	28m	28m
	Air draft	30m	30m	30m
	Vessel draft	6m	6m	6m
Waterfront site	Total area	90,000m^2	-	-
	Round-the-clock operation	No	No	Yes
Quay	Length	125m	125m	90m
	Ground strength (crane footprint and lay-down areas)	2t/m^2	2t/m^2	2t/m^2
Fabrication and storage	Workshop space	>100m x 10m	-	-
	Storage space - open air	2,000m^2	-	-
	Storage space - enclosed	-	100m x 25m[4]	-
Land access	Standard truck	Yes	Yes	Yes
	Oversize truck	No	No	No
	Rail access	Yes	No	No

Table 4 Indicative export cable supply chain port parameters.[5]

2.2.2 Substation structure

Manufacture
The substation platform is similar in construction to an offshore oil or gas platform. Offshore wind substations are generally custom-built for a specific project and, unlike foundation production, do not require investment in serial manufacturing capability. Manufacturers can supply both the offshore wind and oil and gas sectors.
The manufacturing process involves the fabrication of large steel modules with the integration of complex systems including electrical, piping, climate control, fire

[4] A storage facility is likely to be able to accommodate cables for a range of customers.
[5] BVG Associates, *Report 1: An evaluation of 10 Virginia ports*, (online: Virginia Department of Mines, Minerals and Energy, 2015), 36-39. https://www.dmme.virginia.gov/DE/LinkDocuments/OffshoreWind/PortsStudy-Report1.pdf .

suppression, personnel safety and overnight personnel accommodation. Components such as steel plate, other raw materials, and secondary and architectural steel structures usually manufactured by a third party, can arrive by a range of transportation methods. Final assembly requires large cranes for sizeable components. For an HVAC substation, the finished units can have dimensions upwards of 30m by 50m and weigh 800-2,500t. HVDC substations are typically larger with dimensions around 80m by 50m and weighing upwards of 10,000t. These manufacturing sites typically require a covered fabrication hall, and heavy lift and ground bearing capacity. Heavy-lift vessels or barges are required to transport the substation from the manufacturing site to the installation site.

Installation

There is generally no requirement to store substations prior to installation as load-out is done from the manufacturing facility. Installation is carried out either by heavy-lift sheerleg crane vessel accompanied by feeder vessel carrying additional components (for a conventional substation), a heavy lift vessel or by barge (for a self- installing substation). Some sheerleg vessels can only operate in relatively calm sea conditions and this may necessitate short-term storage space. A sheltered harbour close to development site would then be required.

Heavy lift and sheerleg crane vessels are between 85-185m in length, 40-50m in beam, have a draft of 4-13m and may require up to 50m of air draft. An ocean service barge is between 60-110m in length, 20-30m in beam and has a draft of 3-6m.

Maintenance

As with cable OMS, substation service is conducted on a regular annual schedule over the asset lifetime and repairs must be completed quickly to minimize the time the transmission system is off-line. OMS facilities for the wind farm will provide wharf and docking space for crew transfer vessels and the ability to transport smaller components for service and repairs. Typical vessels are twin hulled for maximum stability, comfort, and speed. These vessels typically are up to 30m in length, have a shallow draft of 2m, and provide room for passengers and crew of 15, a small cargo space, and a crane.

An OMS port for a wind farm needs to be available 24 hours a day (although this will be driven by the need to access the wind turbines rather than the substation) and an operator will therefore avoid tidal or lock-bound ports, those with competing access from other users or where activity is prohibited at night.

Indicative port requirements for substation manufacture, installation and maintenance is given in Table 5.

Category	Port characteristic	Manufacture	Installation	Maintenance
Water access	Horizontal clearance	50m	50m	5m
	Air draft	Unrestricted	Unrestricted	5m
	Vessel draft	8m	8m	2m
Waterfront site	Total area	200,000m^2	200,000m^2	-
	Round-the-clock operation	No	No	Yes
Quay	Length	120m	120m	30m
	Ground strength (crane	20t/m^2	20t/m^2	-

	footprint and lay-down areas)			
Fabrication and storage	Workshop space	100m x 35m x 30m	-	-
	Storage space - open air	-	-	-
	Storage space - enclosed	-	-	-
Land access	Standard truck	Yes	Yes	Yes
	Oversize truck	Yes	No	No
	Rail access	Yes	No	No

Table 5 Indicative substation structure supply chain port parameters.[6]

2.2.3 Substation electrical

Substation electrical components such as switchgear, reactive compensation systems, transformers and low-voltage systems can be manufactured inland and transported to the substation structure manufacturing site by multiple transportation methods. There are no specific port requirements for the manufacture of substation electricals.

The physical installation of the electrical systems takes place at the site of substation manufacture prior to load-out to the installation site, where commissioning of high voltage systems takes place. Once the electrical systems are integrated with the substation structure during manufacture, the installation and service port requirements for substation electricals are the same as described for the substation structure above. There are no specific port requirements for the installation and maintenance of substation electricals.

[6] BVG Associates, *Report 1: An evaluation of 10 Virginia ports*, 36-39

3. Baltic ports

3.1 Existing Baltic capability

3.1.1 Export cables

Manufacture

Several of the market leaders in export cable supply operate facilities in the BSR due to the high demand for subsea interconnector cables. NKT (Sweden)[7], Nexans (Norway and Germany), TF Kabel (Poland) and Prysmian (Finland and Norway) supply subsea cables to projects across Europe. These companies take on most of the work packages in the area of cable supply but transport and storage may be subcontracted.

Current port infrastructure to meet cable supply demand in the BSR is adequate.

Installation

Bohlen & Doyen (Germany), Nexans, ABB (Denmark) and Siem Offshore Contractors (Germany) are large cable installation organisations with offices in the BSR and are capable of fulfilling many of the installation work packages with their own fleet. Some activities such as route clearance, trenching, cable lay and cable burial are subcontracted to regional small and medium-sized enterprises (SMEs). In the BSR companies such as Peter Madsen Rederi (Denmark), JD-Contractor (Denmark), Blue Star Line (Denmark), Baltic Offshore (Sweden) and Boskalis Sweden (Sweden) have performed these activities.

Baltic demand for cable installation is small and this will be met by cable installers from inside and outside the BSR. The primary opportunities for Baltic hubs will be in short-term storage of cable prior to installation and accommodation of vessels, where current port infrastructure is likely to be adequate.

Maintenance

Several cable suppliers and installers in the BSR such as NKT, Nexans, and ABB can also take on cable service work packages. Some activities such as weather forecasting and fault identification have been contracted by an operator to BSR SMEs such as DHI Group (Denmark) and JD-Contractor.

The primary opportunity for Baltic hubs will likely be in long-term storage of spare cable and accommodation of vessels for cable survey and repair.

3.1.2 Substation structure

Manufacture

The MV Werften shipyards in Rostock-Warnemünde, Wismar and Stralsund (Germany) have produced several substation structures for German North Sea projects. Bladt Industries (Denmark) and EEW Special Pipe Constructions (Germany) have produced structures and component pieces for substation foundations and EPG (Poland) has manufactured a substation topside. Companies in the BSR that have track record in

[7] First instances of companies mentioned are provided with the country they are located. Country location is omitted for subsequent mentions of a company.

substation structural design include Overdick (Germany), Ramboll (Denmark) and ISC Consulting Engineers (Denmark).
Baltic market demand for substation structure supply is small and current port infrastructure for this is likely to be adequate. Substation structure demand in the BSR will probably be also met by suppliers from outside the region.

Installation
SeaRenergy (Germany) and A2Sea (Denmark) have track record in substation foundation installation. ITW Densit (Denmark) have performed substation foundation grouting.
Baltic market demand for substation installation supply is small and current port infrastructure for this is likely adequate. Substation installation demand in the BSR will also be met by suppliers from outside the region.

Maintenance
The BSR will require some infrastructure to accommodate large vessels used in major substation component replacement and repair, but there is little demand for this activity as there is a low major component failure rate. Crew vessels are required to access the substation for structural maintenance and service. There is a moderate demand for this activity but it does not require a high specification port. Companies in the BSR with the capability to perform substation structure service include NDE Offshore (Sweden), Offshore Industrie Service (Germany) and Baltic Diver (Germany).

3.1.3 Substation electrical

Manufacture
Owner-furnished equipment, primarily power electronics equipment, can arrive by truck, rail, barge, or ship to the substation structure fabrication yard from outside the BSR. Supply of this equipment does not require high specification port or dedicated infrastructure as most general cargo vessels, if required, can self-load and unload using onboard cranes. Electricals may be exported through Baltic ports, however in small quantities. The current port infrastructure for is adequate for substation electrical supply. Companies in the BSR performing substation electrical design and supply include Semco Maritime (Denmark) and ABB.

Installation
Crew vessels are required to access the substation for electrical installation but demand is low and this does not require highly specialised infrastructure. Specialist work packages such as commissioning and testing can be performed by BSR companies including Delpro wind (Poland), Semco Maritime and ABB.

Maintenance
Same requirements as substation structure service. Companies such as Offshore Industrie Service are capable of performing substation electrical service.

3.2 Availability of additional infrastructure

3.2.1 Methodology

A list of 306 Baltic ports from an online database was considered and filtered initially on water depth and ability to accommodate required vessels. From the remainder of the list, opportunity ports were identified based on their proximity to current and future offshore wind transmission projects, accessibility, availability and synergies with the existing supply chain. A large number of ports were found to accommodate crew vessels for substation servicing. The study identified 14 opportunity ports for further assessment.

For each opportunity port the port characteristics were assessed against the indicative requirements for export cables and substation at each supply chain lifecycle stage: manufacture, installation and maintenance. Assessments were made using publically available information and supported by engagement with the port authority where necessary. The characteristics were scored on a colour scale of green, amber or red based on their suitability for each activity:

Green signifies that the port characteristic meets most of the indicative port requirements for supply chain work packages in that area.
Amber signifies that the port characteristic meets some of the indicative requirements for supply chain work packages in that area.
Red signifies that the port characteristic meets few or none of the indicative requirements for supply chain work packages in that area.

As the opportunity ports identified for further assessment were all currently functioning ports it was assumed additional characteristics such as office space, car parking, internet, heating, water, electrical supply, security, and radar and communications all meet optimal requirements.

3.3 Opportunity ports

The 14 opportunity ports identified for further assessment are listed in alphabetical order in Table 6 and their location in the BSR shown in Figure 1. Assessments for the port are made considering the port authority area as a whole rather than specific facilities or locations within them.

	Port	Country
1	Gdynia	Poland
2	Karlskrona	Sweden
3	Klaipėda	Lithuania
4	Koverhar	Finland
5	Liepāja	Latvia
6	Lübeck	Germany
7	Muuga	Estonia
8	Norrköping	Sweden

9	Rønne	Denmark
10	Rostock	Germany
11	Sassnitz-Mukran	Germany
12	Stralsund	Germany
13	Świnoujście	Poland
14	Wismar	Germany

Table 6 List of Baltic Sea opportunity ports included in the study.

Figure 1 Location of opportunity ports in the Baltic Sea region.

3.4 Port of Gdynia

3.4.1 Port overview

The Port of Gdynia[8] is a large multipurpose port on the west coast of the Gulf of Gdańsk. The port has year-round natural protection from the open sea by the Hel Peninsula, offering ice-free and tideless waters. It operates 24 hours a day.

The total port land area is over 620ha with over 11km of quayside for handling operations. Berths at the port handle bulk cargo, heavy goods and container shipments as well as ferry and cruise vessels.

OWE activity relevant to the transmission supply chain at the Port of Gdynia has included secondary steel fabrication by EPG for the 385MW Arkona project in the Baltic Sea and modification works of a wind turbine foundation installation vessel at the Nauta Shipyard.

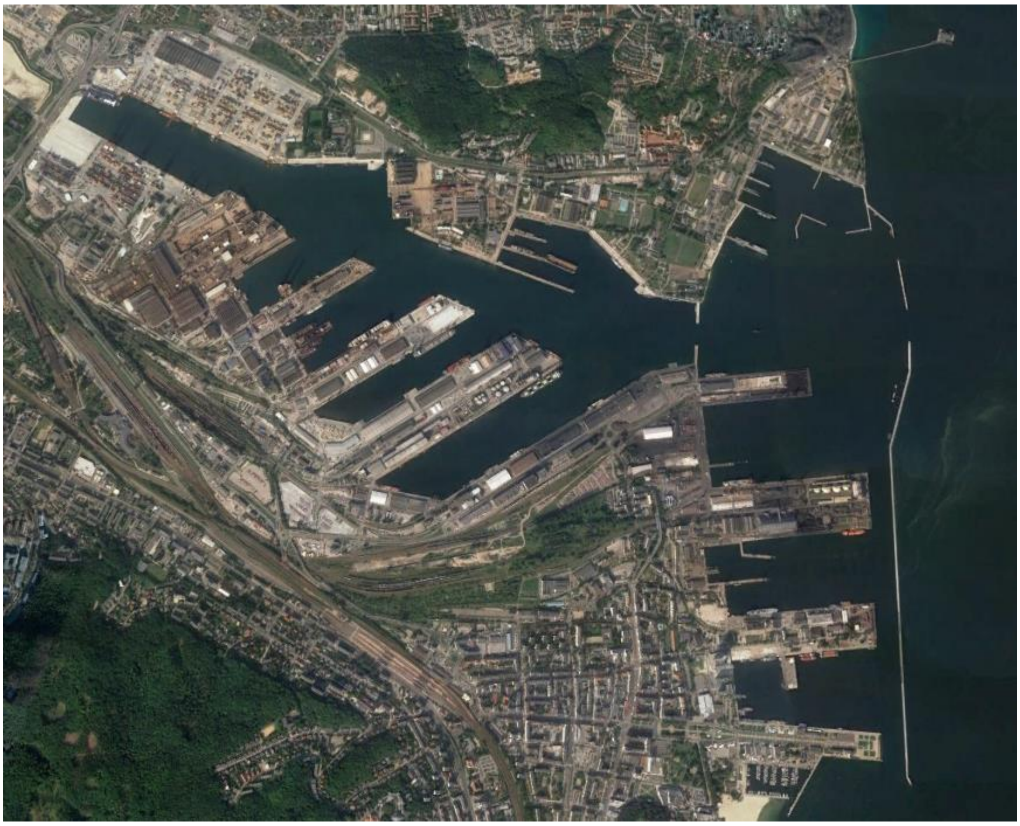

Figure 2 Aerial view of the Port of Gdynia.

Port characteristic	Value
Total port area	620ha
Max. vessel draft	13m
Max. vessel length	380m
Max. air draft	Unrestricted
Horizontal clearance	100m

Table 7 Port of Gdynia characteristics.

[8] https://www.port.gdynia.pl/en/

3.4.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 8 Assessment of Port of Gdynia for export cables.

3.4.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 9 Assessment of Port of Gdynia for substation.

3.4.4 Conclusions

The Port of Gdynia offers expertise and port infrastructure to serve a range of maritime industries. However, most of the port area is currently well utilised with many of the terminals at the port specialised to serve these areas. It would therefore be unlikely that facilities for export cable or substation manufacture would be developed at the port. However, some aspects of the substation manufacturing or installation supply chain, such as secondary and architectural steel fabrication and vessel mobilisation, can be carried out at Gdynia. The port is close to several offshore wind projects in development and so could be used as a base for operations and maintenance of future transmission assets.

3.5 Port of Karlskrona

3.5.1 Port overview

The Port of Karlskrona[9] is a multipurpose terminal in the Blekinge archipelago in the south of Sweden. The port is well sheltered by the number of islands in the surrounding area and currently hosts both cargo and passenger traffic. The port area has recently undergone development and has over 10ha of prepared surfaces with a further 10ha in planning.

The Port of Karlskrona is the location of an NKT high voltage cable facility (previously owned by ABB) that has manufactured cables for several offshore wind projects, including 60km of 150kV export cable for the Baltic 1 project.

Figure 3 Aerial view of the Port of Karlskrona.

Port characteristic	Value
Total port area	40ha
Max. vessel draft	9m
Max. vessel length	70m
Max. air draft	Unrestricted
Horizontal clearance	Unrestricted

Table 10 Port of Karlskrona characteristics.

[9] https://www.karlskrona.se/hamn

3.5.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 11 Assessment of Port of Karlskrona for export cables.

3.5.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 12 Assessment of Port of Karlskrona for substation.

3.5.4 Conclusions

The Port of Karlskrona plans to be a base for expanding companies in the area but has space to also establish new enterprises, such as a potential hub for offshore transmission maintenance. While a successful cable manufacturing, installation and maintenance facility already operates at Karlskrona serving the BSR as well as exporting across Europe, there is a permit to construct a further quay and local plans for creating several surfaces for further logistics and port purposes.

3.6 Port of Klaipėda

3.6.1 Port overview

The Port of Klaipėda[10] is a multipurpose deep-water port and Lithuania's biggest transport hub. Klaipėda is on a natural river harbour and is the northernmost ice-free port on the eastern coast of the Baltic Sea. The port area has over 24km of quayside, nearly 10ha of covered warehouse facilities and over 100ha of open storage sites.

The waters to the east of the Port of Klaipėda have been identified as potential areas for offshore wind development and several projects located there have submitted applications for consent. The NordBalt interconnector cable to Sweden also connects to Klaipėda.

Figure 4 Aerial view of the Port of Klaipėda.

[10] https://www.portofklaipeda.lt/en?page=en

Port characteristic	Value
Total port area	550ha
Max. vessel draft	13.8m
Max. vessel length	350m
Max. air draft	Unrestricted
Horizontal clearance	130m

Table 13 Port of Klaipėda characteristics.

3.6.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 14 Assessment of Port of Klaipėda for export cables.

3.6.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 15 Assessment of Port of Klaipėda for substation.

3.6.4 Conclusions

The Port of Klaipėda would be well suited to many aspects of offshore transmission grid development. With offshore wind projects under consideration in nearby waters it is likely that this port will be utilised for OWE activities in the future. There is no cable production facility at Klaipėda and, although the location and port characteristics could accommodate this in the future, current cable supply in the BSR is already adequate. There are several large shipbuilding and fabrication yards at Klaipėda that could perform substation structure fabrication. However, with no experience in substation manufacture and adequate capacity elsewhere it is likely supply will come from other locations both within and outside the BSR.

3.7 Port of Koverhar

3.7.1 Port overview

Koverhar Harbour[11] is one of several ports run by the nearby Port of Hanko. The port is in the southernmost tip of Finland and experiences mild winters that allow the waters to remain mostly free of ice year round. The port is under continuing development and has the objective of developing into a modern logistics centre, in collaboration with local supply chains. Currently the port has 100ha of prepared surface and is seeking to expand this further over the 600ha of available land area.

Figure 5 Aerial view of the Port of Koverhar.

Port characteristic	Value
Total port area	100ha
Max. vessel draft	6m
Max. vessel length	190m
Max. air draft	Unrestricted
Horizontal clearance	40m

Table 16 Port of Koverhar characteristics.

[11] http://www.koverhar.fi/

3.7.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 17 Assessment of Port of Koverhar for export cables.

3.7.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 18 Assessment of Port of Koverhar for substation.

3.7.4 Conclusions

The Port of Koverhar is not yet able to accommodate services for an OWE transmission grid. However, the nascent offshore wind sector in the Gulf of Finland and Gulf of Bothnia is anticipated to see growth that may require future port infrastructure for cable and substation maintenance. Koverhar is one of several ports in the region that may be able to accommodate this in the future should current development ambitions be realised.

3.8 Port of Liepāja

3.8.1 Port overview

The Port of Liepāja[12] is a multipurpose ice-free port in Latvia's south-west, on the western coast of the Baltic Sea. It is Latvia's third largest port. Over the past ten years the port has been redeveloped with a focus on improved cargo handling and storage. Alongside specialist berths for dry and general cargo there are berths for fishing vessels, liquid cargo and ship building and repair. The port area has over 10km of quayside, 10ha of covered warehouse space and 44ha of open storage sites.

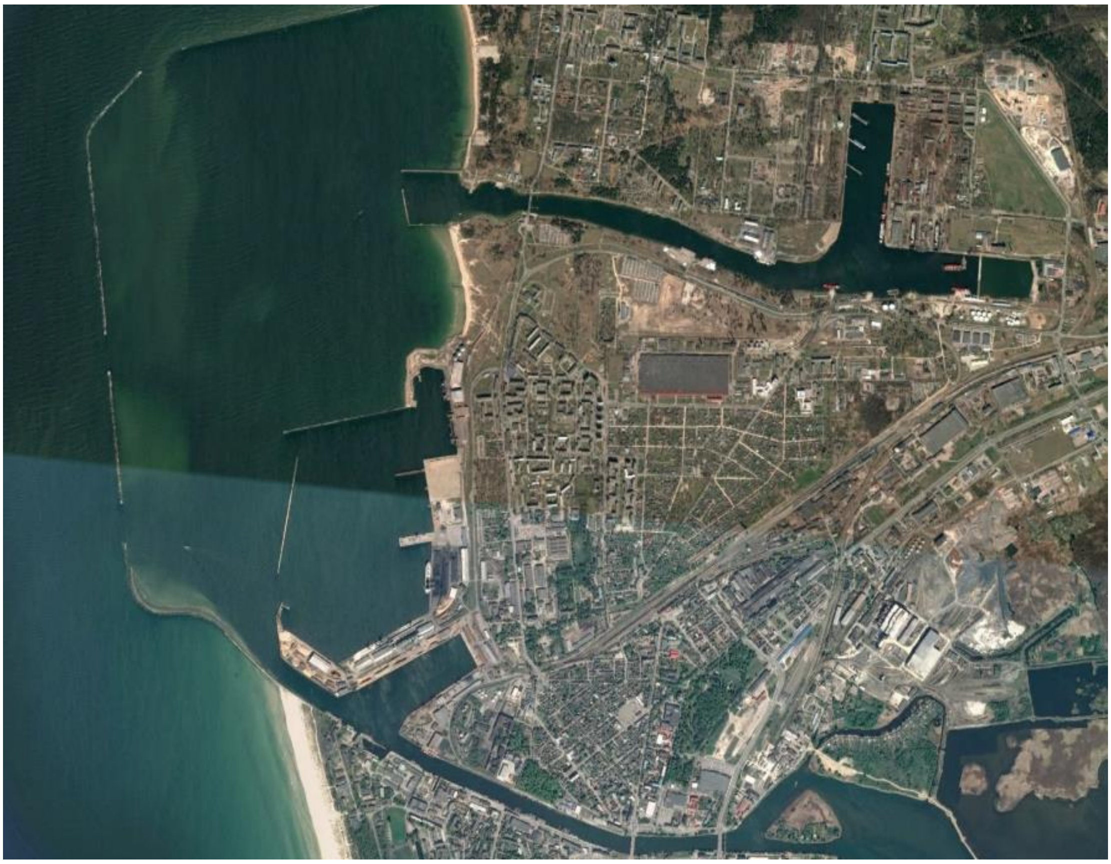

Figure 6 Aerial view of the Port of Liepāja.

Port characteristic	Value
Total port area	370ha
Max. vessel draft	10.8m
Max. vessel length	240m
Max. air draft	Unrestricted
Horizontal clearance	50m

Table 19 Port of Liepāja characteristics.

[12] http://www.liepaja-sez.lv/en

3.8.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 20 Assessment of Port of Liepāja for export cables.

3.8.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 21 Assessment of Port of Liepāja for substation.

3.8.4 Conclusions

The Port of Liepāja currently lacks the infrastructure for export cable or substation manufacturing but could support cable and substation maintenance. While Liepāja is in a region of the Baltic Sea with good wind resource, offshore wind projects in the area are still only at an early development stage. With no transmission assets likely to be required in the region before 2030 it is unlikely the Port of Liepāja will be developed as a hub for offshore transmission activities, despite its capability to do so.

3.9 Port of Lübeck

3.9.1 Port overview

The Port of Lübeck[13] in Germany is in the south-west of the Baltic Sea and has four port terminals along the River Trave. The natural river harbour provides good shelter for vessels and the port operates around the clock. The port has over 4km of quays and over 20ha of covered storage across the four sites. Most of the quays at each of the terminals are highly specialised and each serve a diverse range of customers including ro-ro ferry traffic, automobile export, paper manufacturing and forestry products.

The Baltic Cable interconnector connecting the electric power grids of Germany and Sweden joins an onshore converter station at Lübeck-Herrenwyk.

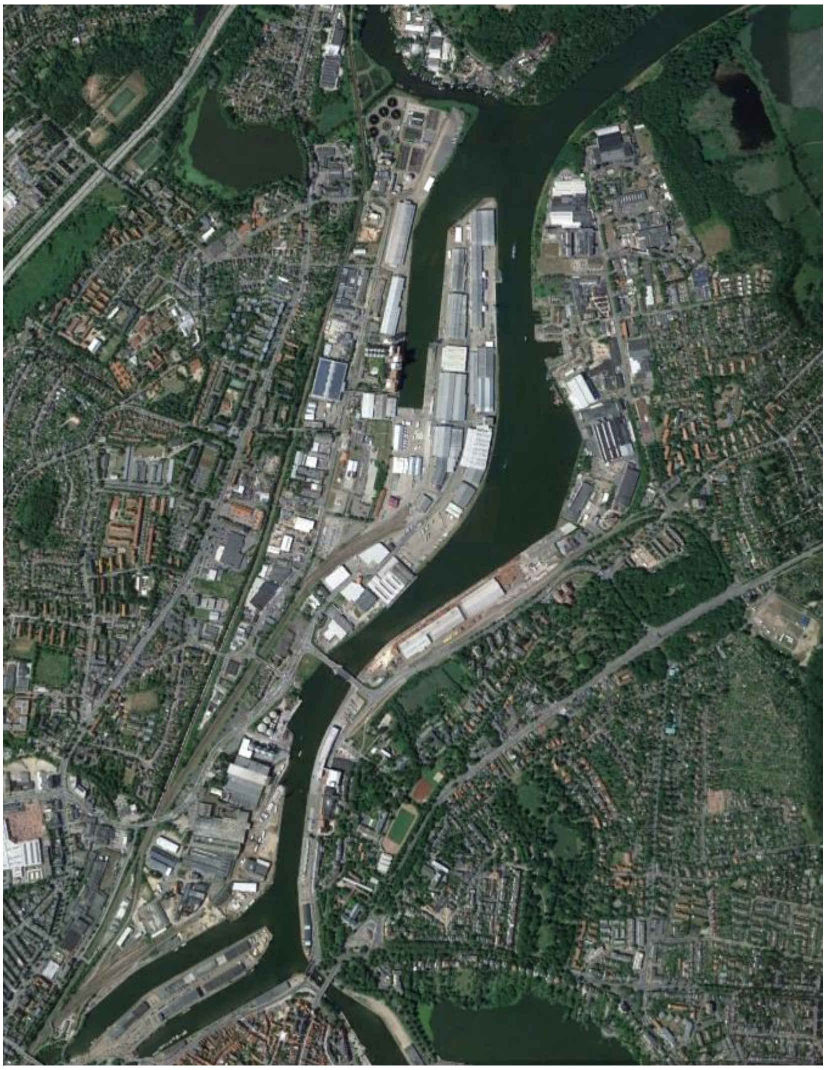

Figure 7 Aerial view of the Nordlandkai terminal at the Port of Lübeck.

[13] https://www.lhg.com/index.php?id=4&L=1

Port characteristic	Value
Total port area	156ha
Max. vessel draft	9.5m
Max. vessel length	200m
Max. air draft	Unrestricted
Horizontal clearance	50m

Table 22 Port of Lübeck characteristics.

3.9.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 23 Assessment of Port of Lübeck for export cables.

3.9.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 24 Assessment of Port of Lübeck for substation.

3.9.4 Conclusions

The Port of Lübeck is currently well utilised with many of the terminals at the port serving specialised maritime industries. It would be unlikely that facilities for export cable or substation manufacture would be developed at the port. However, some aspects of the substation manufacturing or installation supply chain, such as secondary and architectural steel fabrication and vessel mobilisation, could be carried out at Lübeck. The port is close to a several offshore wind projects currently in development and offers expertise and port infrastructure in serving maritime industries and so could be utilised as a base for operations and maintenance of transmission assets.

3.10 Port of Muuga

3.10.1 Port overview

The Port of Muuga[14] is one of five harbours that comprise the Port of Tallinn, Estonia. Muuga is of the few ice-free deepwater ports in the northern BSR and is the biggest cargo harbour in Estonia. Several of the constituent ports are undergoing continued development to handle an increase in demand for cargo handling. The Muuga harbour development is based on zoning of the harbour area by the different commodity groups it currently serves.

Figure 8 Aerial view of the Port of Muuga.

Port characteristic	Value
Total port area	520ha
Max. vessel draft	15m
Max. vessel length	300m
Max. air draft	Unrestricted
Horizontal clearance	Unrestricted

Table 25 Port of Muuga characteristics.

[14] http://www.portoftallinn.com/muuga-harbour

3.10.2 Export cables

	Meets requirement		
	Manufacture	**Installation**	**Maintenance**
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 26 Assessment of Port of Muuga for export cables.

3.10.3 Substation

	Meets requirement		
	Manufacture	**Installation**	**Maintenance**
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 27 Assessment of Port of Muuga for substation.

3.10.4 Conclusions

The Port of Muuga and other constituent harbours of the Port of Tallinn are not yet able to accommodate services for an OWE transmission grid. Offshore wind deployment in Estonia is in its infancy with no projects currently installed. However, around 900MW of capacity could be built by 2030 (Baltic InteGrid, 2018). This growth may require future port infrastructure for cable and substation maintenance where ports developments provide an opportunity to create maintenance hubs. A port such as Muuga may undergo further development to serve this future Estonian and north Baltic market.

3.11 Port of Norrköping

3.11.1 Port overview

The Port of Norrköping[15] is a logistics port on the east coast of Sweden, 130km south of Stockholm. Norrköping sits at the end of the Bråviken bay and provides good shelter on a 24-hour basis without restrictions for bad weather. The port area is around 45ha of which over 20ha is prepared surface and 6.5ha is covered warehouse.

Norrköping is close to a Swedish national interest area for wind farm development where projects are currently in an early planning stage. The port gained experience as a central supply base for the pipe laying of the Nord Stream offshore pipeline project. Norrköping was chosen because it is a modern full-service port with good infrastructure for all modes of transport and a wide range of companies specialising in logistics and supply chain services.

Figure 9 Aerial view of the Port of Norrköping.

[15] http://www.norrkopingshamn.se/en/

Port characteristic	Value
Total port area	114ha
Max. vessel draft	13.1m
Max. vessel length	240m
Max. air draft	Unrestricted
Horizontal clearance	60m

Table 28 Port of Norrköping characteristics.

3.11.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 29 Assessment of Port of Norrköping for export cables.

3.11.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 30 Assessment of Port of Norrköping for substation.

3.11.4 Conclusions

The Port of Norrköping is not suitable for cable manufacturing or the manufacture and installation of substations. However, the port has an ongoing mission to attract new business and new investors into Norrköping by creating an ideal environment for enabling growth in a range of industries. The port would be a good candidate to become a hub for offshore transmission maintenance should the proposed wind farm projects located close by be developed. Since having gained experience as an operations base for an offshore project, the Port of Norrköping has added further strength to its operations by investing in new facilities and infrastructure improvements.

3.12 Port of Rønne

3.12.1 Port overview

The Port of Rønne[16] is a traffic and commercial port on the Danish Island of Bornholm. The port has 32 quays and serves a range of customers including general and bulk cargo, liquid cargo and fishing.

The position of the island in the Baltic Sea puts the port in close location to current and future Danish, German and Polish offshore wind projects. The Port of Rønne was recently selected by VBMS as the service hub for the various vessels required during its cable-laying activities for the Arkona project in the Baltic Sea. Previously, route clearance works for the Arkona project were undertaken out of the Port of Rønne.

Figure 10 Aerial view of the Port of Rønne.

[16] http://www.roennehavn.dk/en

Port characteristic	Value
Total port area	40ha
Max. vessel draft	9m
Max. vessel length	240m
Max. air draft	Unrestricted
Horizontal clearance	100m

Table 31 Port of Rønne characteristics.

3.12.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 32 Assessment of Port of Rønne for export cables.

3.12.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 33 Assessment of Port of Rønne for substation.

3.12.4 Conclusions

The Port of Rønne has an ambition to take advantage of its location and the large number of vessels operating in the region to establish itself as a hub for maritime services including for the offshore wind industry. Rønne is currently disadvantaged in further positioning itself as a hub for the cable and substation maintenance supply chains due to its isolation from land access to mainland Europe for materials and replacement components. The port is also relatively small with little storage area, although there are plans to expand the port in the future.

3.13 Port of Rostock

3.13.1 Port overview

The Port of Rostock[17] is one of Germany's largest ports and is located in the south west of the Baltic Sea. The port has deep water, is tideless and is accessed via a canal free from locks. There are normally no restrictions for entering and exiting the port at night and the water is kept open to vessels as long as possible in winter as it only very seldom freezes over completely.

The port area is over 750ha and contains 47 berths along over 11km of quay. There are special berths reserved for ferry, coal, grain, heavy cargo, liquid cargo and chemical traffic with sufficient reserve area to allow for flexible reaction to shipping requirements.

The MV Werften (formerly Nordic Yards) facility at Rostock has been the location for manufacture of four offshore substations, with the most recent of these leaving the facility in June 2017. The port accommodates service vessels for the Baltic 1 and 2 offshore wind farms while the export cables for these projects, as well as the Kontek interconnector cable from Denmark, connect to the onshore substation at Bentwisch to the east of Rostock.

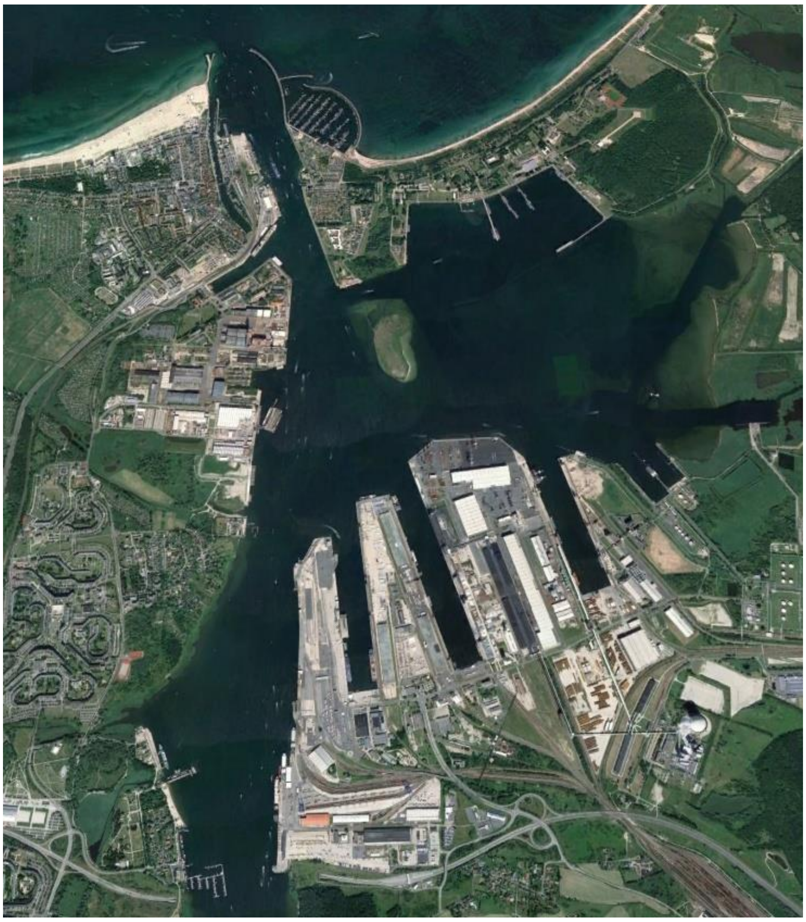

Figure 11 Aerial view of the Port of Rostock.

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[17] http://www.rostock-port.de/en/index.html

Port characteristic	Value
Total port area	750ha
Max. vessel draft	13m
Max. vessel length	300m
Max. air draft	Unrestricted
Horizontal clearance	50m

Table 34 Port of Rostock characteristics.

3.13.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 35 Assessment of Port of Rostock for export cables.

3.13.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 36 Assessment of Port of Rostock for substation.

3.13.4 Conclusions

The Port of Rostock is already well suited to the manufacture, installation and maintenance of offshore wind transmission assets. The port has an established track record supporting offshore wind activity as substation production and installation as well as both cable and substation servicing have been carried out at the port. There is no cable production facility at Rostock and with current port utilisation it is unlikely that facilities for this will be developed. Although the location and port characteristics could accommodate a cable manufacturing facility in the future, current cable supply in the BSR is already adequate.

3.14 Port of Sassnitz-Mukran

3.14.1 Port overview

The Port of Sassnitz-Mukran[18] is a multipurpose terminal on the island of Rügen and is Germany's easternmost deep-water port. The port area was further developed in 2015 to accommodate the installation of offshore wind projects and has since established facilities to enable it to be used as an operation and maintenance base. Berths at the port also handle ferry and cruise vessels as well as bulk cargo, heavy goods and container shipments.

The Port of Sassnitz-Mukran has been used as a staging area for the installation of several offshore wind farms, including floating storage of the Baltic 2 substation.

Figure 12 Aerial view of the Port of Sassnitz-Mukran.

Port characteristic	Value
Total port area	70ha
Max. vessel draft	9.5m
Max. vessel length	190m
Max. air draft	Unrestricted
Horizontal clearance	Unrestricted

[18] https://www.mukran-port.de/home.html

Table 37 Port of Sassnitz-Mukran characteristics.

3.14.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 38 Assessment of Port of Sassnitz-Mukran for export cables.

3.14.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 39 Assessment of Port of Sassnitz-Mukran for substation.

3.14.4 Conclusions

The Port of Sassnitz-Mukran is well suited to the supporting maintenance of offshore wind transmission assets and has the capability to accommodate export cable installation. The port does not currently have cable or substation manufacturing facilities or the space to accommodate these in the near future, although current port infrastructure in the BSR for the supply of these is already adequate.

3.15 Port of Stralsund

3.15.1 Port overview

The Port of Stralsund[19] is a multipurpose terminal on the south coast of the Strelasund, a sound of the Baltic Sea separating the island of Rügen from the mainland. The coastal breakwater harbour provides excellent shelter for vessels. The Port of Stralsund can be accessed from the north or south-east but vessels with an air draft above 40m need be aware of the Strelasund Crossing bridges that bisect the port area. The port has 2.7km of quays and 5ha of storage across its four harbours. Stralsund handles conventional cargo and bulk goods and serves steel and construction materials companies based at the port. The MV Werften (formerly Nordic Yards) facility at the Stralsund has been used for fabrication of foundation component structures.

Figure 13 Aerial view of the Port of Stralsund.

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[19] http://www.bpoports.com/stralsund.html

Port characteristic	Value
Total port area	26ha
Max. vessel draft	6.6m
Max. vessel length	240m
Max. air draft	(40m)
Horizontal clearance	Unrestricted

Table 40 Port of Stralsund characteristics.

3.15.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 41 Assessment of Port of Stralsund for export cables.

3.15.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 42 Assessment of Port of Stralsund for substation.

3.15.4 Conclusions

The Port of Stralsund is well suited to the maintenance of offshore wind transmission assets and has the capability to accommodate substation manufacture and installation, having undertaken foundation fabrication for a North Sea substation. The port does not currently have the space to develop cable manufacture facilities, although current port infrastructure in the BSR for the supply of these is already adequate.

3.16 Port of Świnoujście

3.16.1 Port overview

The Port of Świnoujście20 is the westernmost port in Poland on both the south of the Baltic Sea and the north of the Szczecin Lagoon. The natural river port is used for ferry and dry bulk cargo traffic as well as providing a gateway to Szczecin, 68km inland of Świnoujście. The port shares the canal with a naval base. It is also tideless and ice-free.
The Polish offshore wind project developer Polenergia, which plans to build the 600MW Baltic Środkowy III offshore wind farm in Baltic Sea, has stated the ports of Świnoujście and Szczecin could become bases for installation and maintenance companies working in the offshore wind sector.

Figure 14 Aerial view of the Port of Świnoujście.

[20] http://www.port.szczecin.pl/en

Port characteristic	Value
Total port area	350ha
Max. vessel draft	13.5m
Max. vessel length	270m
Max. air draft	Unrestricted
Horizontal clearance	Unrestricted

Table 43 Port of Świnoujście characteristics.

3.16.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 44 Assessment of Port of Świnoujście for export cables.

3.16.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 45 Assessment of Port of Świnoujście for substation.

3.16.4 Conclusions

Świnoujście doesn't have the facilities to manufacture substation components but its companion port of Szczecin has facilities owned by Finomar, Bladt Industries and ST3 Offshore that are capable of fabricating substation components. The opportunities for the Port of Świnoujście will likely be in the installation and maintenance supply chains, such as in providing vessel operations logistics and vessel services. The port location on the border between Poland and Germany may allow the port to serve both markets.

3.17 Port of Wismar

3.17.1 Port overview

The Port of Wismar[21] in Germany is in the western Baltic Sea on the southern shore of Wismar bay. The port has 2.5km of quays and 11.5ha of open storage across its 15 berths. The Port of Wismar is currently being extended with the addition of a further storage area, large quay facility and multi-functional areas for goods handling.
The MV Werften (formerly Nordic Yards) facility at Wismar has been used for fabrication of substation topside and foundation component structures.

Figure 15 Aerial view of the Port of Wismar.

[21] http://www.hafen-wismar.de/en/

Port characteristic	Value
Total port area	56ha
Max. vessel draft	8.5m
Max. vessel length	240m
Max. air draft	Unrestricted
Horizontal clearance	Unrestricted

Table 46 Port of Wismar characteristics.

3.17.2 Export cables

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 47 Assessment of Port of Wismar for export cables.

3.17.3 Substation

	Meets requirement		
	Manufacture	Installation	Maintenance
Water access			
Waterfront site			
Quay			
Fabrication and storage			
Land access			

Table 48 Assessment of Port of Wismar for substation.

3.17.4 Conclusions

The Port of Wismar has infrastructure for the manufacture, installation and maintenance of offshore wind substation structures. The port has the capability to stage cable installation and maintenance however there is no cable production facility at Wismar. The current port utilisation makes it unlikely that facilities for this will be developed. Although the location and port characteristics could accommodate a cable manufacturing facility in the future, current cable supply in the BSR is already adequate.

3.17.1 Other Baltic ports

This study identified 14 opportunity ports for further assessment. However, many ports in the BSR not classified as opportunity ports in the study may have an equal opportunity to those included.

Ports at Kiel (Germany), Gdańsk (Poland), Szczecin (Poland), Ventspils (Latvia), Trelleborg (Sweden), Oxelösund (Sweden), Kalmar (Sweden) and Vaasa (Finland) among others, could have justified further assessment.

4. Conclusions

The BSR is well placed to deliver export cable manufacturing and installation, based on a strong existing supply chain including port infrastructure at the point of supply.
There are a high number of cable manufacturing facilities in the BSR due the regional demand for interconnectors. These manufacturing facilities have since been utilised for the supply of high voltage export cables for offshore wind transmission, for both Baltic Sea projects and exported to projects outside the BSR. The strength of this supply means there is no clear demand for major new manufacturing and installation infrastructure in the BSR. Some ports will find opportunities to benefit from nearby manufacturing facilities or offshore wind farms such as in the provision of vessel services or short term cable storage.

The BSR has sufficient port infrastructure in place to meet demand for substation structure and electrical supply and installation.
The BSR has some capability to produce substations but the demand for these is low and supply will also come from outside the BSR. There is not a strong demand for new supporting infrastructure for substation structure and electrical manufacture and installation.

There will be more opportunities for BSR hubs in the transmission maintenance supply chains than in manufacture and installation.
The Baltic offshore grid it set to grow from 1.8GW of current installed capacity to up to 9.5GW in 2030. There are many ports in the BSR capable of establishing themselves as hubs for the maintenance supply chains of offshore transmission assets. These operations do not require specialist port infrastructure and so ports that are yet to develop experience in the OWE sector, such the eastern Baltic ports, may have an opportunity to support transmission maintenance. Offshore transmission maintenance supply chains are also more sensitive to distance from the installed transmission system. Manufacture and installation will more readily come from outside the BSR (such as the Baltic 2 export cable being manufactured by NSW General Cable in Nordenham) whereas maintenance is typically carried out from hubs close to where the transmission system is installed.

BSR ports can take advantage of their expertise to improve transmission manufacture, installation and maintenance.
There are several major ports in the BSR that can offer an advantage through the project lifecycle from their experience in areas such as cargo handling and logistics, and through close or even co-location of supply chain for export cables and substation manufacture, installation and maintenance. This then offers the opportunity to build hubs around these facilities to further drive economies of scale and co-location.

Barriers to developing the optimal port infrastructure in the BSR are competition from outside the region and the relatively low level of demand.
There is also competition for space and quays from within the port areas themselves. Publically owned ports are more likely to accept a new industry entering the port authority based on the economic benefit for a wider municipal area, whereas privately owned ports will assess a change to the utilisation of port infrastructure purely on

financial merit. There is also lack of certainty about the dates and total volumes of transmission grid that will be needed, which is a risk to ports considering investing in further infrastructure.

German ports are the most likely to develop into and remain as hubs for the offshore transmission sector.
The study identified more opportunity ports from Germany than any other country.

Current BSR transmission supply chains are predominantly located in Denmark and Germany. Although Denmark has the highest installed capacity within the BSR, Germany is anticipated to install a greater volume of capacity by 2030. German ports have the most infrastructure, due in part to the strength of the connection to central European industries. German ports and supply chains will likely continue to serve the offshore transmission sector in the BSR beyond projects installed in German waters. Ports in countries whose OWE sectors are in their infancy, such as Poland, Lithuania, Latvia and Estonia, will have to compete against the experience and track record of German hubs when their projects are ready to be developed.

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