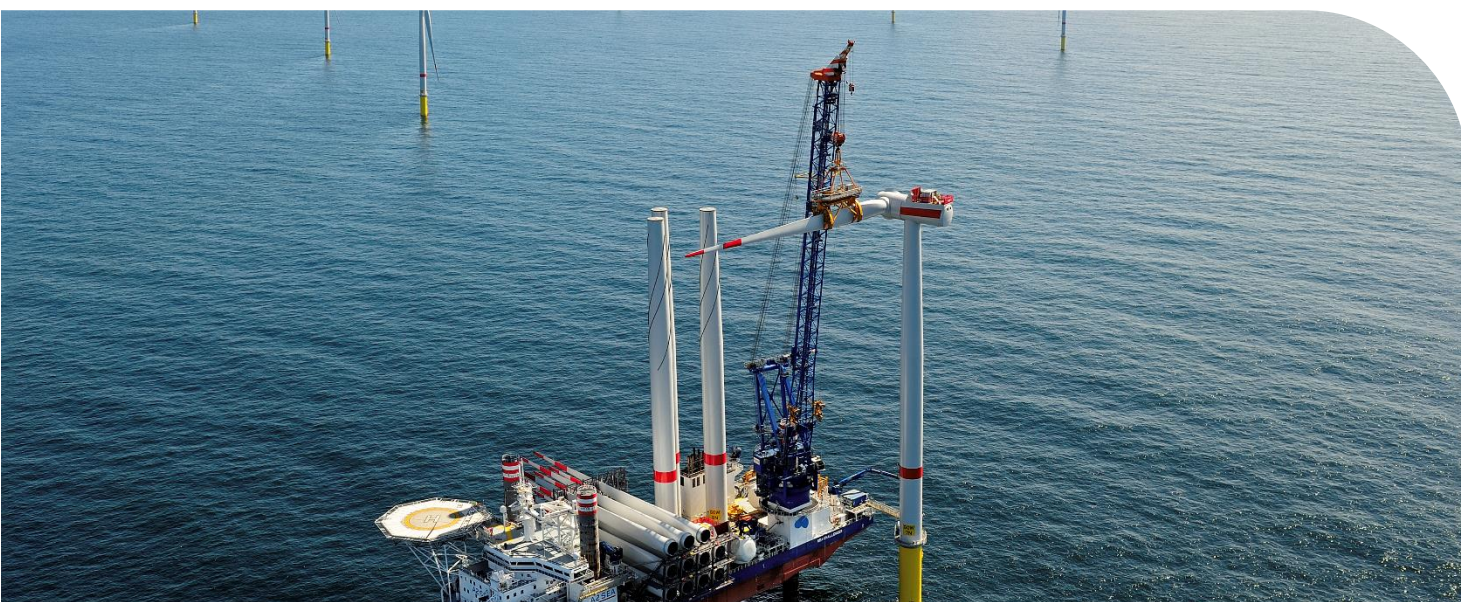




Baltic  
InteGrid

Integrated Baltic Offshore  
Wind Electricity Grid Development



# Supply Chain Analysis of the Offshore Wind Energy Transmission Industry

Overview for the Baltic Sea Region

October 2018

# Supply Chain Analysis of the Offshore Wind Energy Transmission Industry Overview for the Baltic Sea Region

By Gert Proba (Gesellschaft für Wirtschafts- und Technologieförderung Rostock GmbH), Julia Sandén (IKEM), Nils Heine (INWL), Jan Brauer (Deutsche WindGuard GmbH)

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## List of Abbreviations

Abbreviation	Explanation
AC	Alternating current
BSR	Baltic Sea Region
CCV	Catenary continuous vulcanization
DC	Direct current
HVAC	High-voltage alternating current
HVDC	High-voltage direct current
MMC	Modular multilevel converter
MVA	Megavolt-ampere
OWE	Offshore wind energy
PLB	Post-lay burial
ROV	Remotely operated vehicle
SLB	Simultaneous lay and burial
SME	Small and medium-sized enterprises
TSO	Transmission system operator
VCV	Vertical continuous vulcanization
VSC	Voltage source converters
WTG	Wind turbine generator

## Abstract

A supply chain analysis is an essential tool in increasing the efficiency and speed of product and service delivery. An up-to-date analysis of the offshore wind supply chain is vital to the success of the Baltic InteGrid project, an interdisciplinary and transnational research initiative to optimize offshore wind development in the Baltic Sea Region. The following report provides project stakeholders with an overview of the current supply chain for key components of the offshore wind transmission system, including subsea cables, converters, transformers, substation foundations, and protective equipment for offshore wind service and maintenance activities. The report forecasts supply capacities for 2020, 2025, and 2030 to identify possible bottlenecks and market potentials for component supply, maintenance, and services, with a particular focus on small and medium-sized enterprises.

The information in this report was collected from interviews with current EU market leaders, as well as from publicly available profiles that identify companies' targeted market segments. The data reveal that, in the EU and Baltic Sea offshore wind market, equipment production takes place under significant cost pressure and highly competitive conditions. Companies seeking to enter the offshore wind market face significant entry barriers, which are especially formidable for SMEs. This environment creates openings for larger companies (e.g., suppliers from Asia) to enter the European market.

## Introduction

A supply chain analysis is an essential tool in increasing the efficiency and speed of product and service delivery. An analysis of the offshore wind supply chain is vital to the success of the Baltic InteGrid project, an interdisciplinary and transnational research initiative designed to optimize offshore wind development in the Baltic Sea Region (BSR). The following report provides project stakeholders with an overview of the current supply chain for key components of the offshore wind transmission system, including subsea cables, converters, transformers, substation foundations, and protective equipment for service and maintenance of offshore wind energy (OWE) infrastructure.

This deliverable provides stakeholders with up-to-date information on relevant conditions for the development of a regional meshed grid by providing insight into the fields of policy and regulation, market and supply chain, technology and grid design, environment and society, and spatial planning. The analysis also assesses related costs and benefits.

Information in this report was collected from interviews with current EU market leaders, as well as from publicly available profiles (including business and production site locations, key economic figures, OWE experience, competitive advantages, and current market share) and portfolios that identify the companies' targeted market segments. Relevant components, materials, and services are identified, as are groups of suppliers and maintenance and service providers.

The first section of this report outlines the specific components necessary for the construction of OWE transmission systems. It also provides an overview of the construction timeline and related requirements, including those for basic studies, grid connection, and transmission components. Relevant tasks for development and implementation are specified, as well as the components, materials, and services required in these stages.

The second section provides information on component suppliers and on maintenance and service providers. In addition, it forecasts their projected capacities for 2020, 2025, and 2030 to identify possible bottlenecks and market potentials for component supply, maintenance, and services, with a particular focus on small and medium-sized enterprises (SMEs). The data indicate that companies—especially SMEs—intending to enter the OWE market for export cables face significant barriers, primarily because the production of offshore export cables is a cost-intensive process that requires highly specialized manufacturing facilities. New market entrants face extremely high costs (e.g., to build a manufacturing plant, hire skilled workers, purchase specialized cable-laying vessels, and develop subsea cable expertise). As is the case in the subsea cable market, in the long run, these conditions create openings for larger companies (e.g., suppliers from Asia) to enter the European market. Long-term experience and multinational working structures are

required to ensure sufficient quality.

Technology for offshore substation foundations, also addressed in section 2, is less complex. New market entrants require large production facilities for manufacturing large and heavy components, as well as direct water access for product transport. SMEs are unlikely to enter this market because of the cost-intensity of the production process. Larger companies may consider entering the market by creating subsidiaries and drawing on preexisting expertise in the field.

The third section addresses maintenance and repair services related to offshore wind energy transmission systems. These include all technical and administrative measures (including management approaches) that can be implemented during the lifetime of a unit to maintain safe and adequate functioning. Because machines and equipment must be operational under extremely challenging environmental conditions, quality requirements are high. Most manufacturing companies offer maintenance and servicing solutions and, in some cases, full life-cycle management; however, subcontractors are often hired to carry out some of these tasks.

The report concludes by projecting future market development. In the coming years, maintenance and repair services are forecast to be the most promising fields for new entrants, including SMEs.



## Offshore Wind Energy Transmission Systems: General Information and Construction Timeline

This supply chain analysis addresses offshore wind energy (OWE) transmission systems. It therefore covers export cables, offshore converters, foundations and protection equipment, offshore transformers, and maintenance and services.

The overall duration of the offshore transmission system installation process greatly depends on the converters and transformer installation. When certain components (e.g., converters) are not installed on time, the start of the installation process for the onshore converter and export cable is postponed until installation of the offshore transformer begins. The process can be delayed significantly as a result.

Figure 1 shows an example of a grid connection timeline for an 80 km export cable. The duration of the different tasks includes the design, production, transportation, and installation.

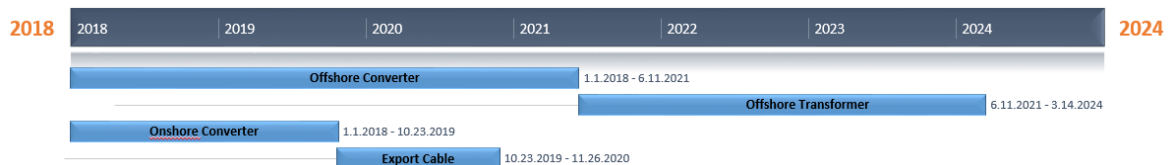


Figure 1: Overview of the construction timeline for an offshore transmission system.<sup>1</sup>

### 1.1 Basic Studies

Basic studies are mandatory prior to the construction of any offshore wind grid and are typically based on environmental surveys. Ornithological and mammal surveys evaluate the impact of the offshore wind farm (OWF) on marine birds and species using survey vessels and aircraft. Soil conditions are examined by special geophysical survey vessels.

### 1.2 Grid connection

The grid connection allows the offshore wind infrastructure to transfer electricity to the onshore grid of the target country. The process thus requires onshore subgrade and onshore converters, as well as offshore subgrade and offshore converters. The transmission system operator (TSO) is responsible for the grid connection, while the OWF operator bears responsibility for the substation.

<sup>1</sup> Source: own figure

## 1.3 Grid Connection Components

### 1.3.1 Export cables

In OWFs, the connections (export cables) from the transformer stations to the converter stations or to the onshore grid are served by high-voltage cables transmitting alternating current (AC) or direct current (DC). AC cables have been the preferred export cable because the technology is mature and thus cost-efficient. DC, however, is becoming more popular as OWFs are built farther from shore because energy transmission loss is much lower than that of AC cables.<sup>2</sup>

The market for subsea cables is dominated by a few multinational corporations. Manufacturing subsea cables requires highly specialized facilities. For example, export cables must be very long to minimize the number of required joints. The production of such long cables requires special production technology, such as vertical continuous vulcanization (VCV) and catenary continuous vulcanization (CCV) lines. These permit a continuous vulcanization process that helps to properly insulate the core of the subsea cables.<sup>3</sup>



Figure 2: A cable-laying vessel.<sup>4</sup>

There are two methods of laying cables: post-lay burial (PLB) or simultaneous lay and burial (SLB). In the PLB method, the cable is laid on the ground and a remotely operated vehicle (ROV) is used to bury it using water jets. In the SLB method, a jet sledge pulls the export cable over the seabed. The ground is trenched by a device at the front of the unit while the cable is placed in the ditch from the back of the unit. In both variations, vessels must include a large spindle with a cable wound around the shaft (see fig. 2). The average speed for cable laying is 200 m/s.<sup>5</sup>

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<sup>2</sup> Claus Gorgs, "Deutschlands schwimmende Steckdose" [in German], *Manager Magazin*, 20 July 2017, <http://www.manager-magazin.de/unternehmen/energie/general-electric-jagt-siemens-bei-offshoe-windkraft-a-1158523-3.html>.

<sup>3</sup> See "Media Center," ABB, 8.8.2017, <http://new.abb.com/media>.

<sup>4</sup> Image source: "Olympic Taurus," Van Aalst Group B.V., accessed 7 June 2018, <http://www.vanaalstmarine.com/references/573>.

<sup>5</sup> Angel G. Gonzalez-Rodriguez, "Review of Offshore Wind Farm Cost Components," *Energy for Sustainable Development* 37 (April 2017): 16, <http://dx.doi.org/10.1016/j.esd.2016.12.001>.

### 1.3.2 Foundations

Various foundations can be used for OWFs. The most common types are monopiles, jackets, and tripods. The choice of foundation design for offshore wind substations depends on the water depth and the load carried. Jacket foundations are generally favored because transformers and converters carry extremely heavy loads (see fig. 3).



Figure 3: A jack-up barge installing jackets.<sup>6</sup>

Vessels are needed to transport substructure components from the harbor to the OWF location. There, a crane is used to lift the foundation into the correct position and push it into the ground. Depending on the fixation method, a drilling rig may also be required.

### 1.3.3 Offshore and onshore converter

The converter station converts the electricity generated by OWFs from AC to high-voltage direct current (HVDC). The electricity is then transmitted to a land-based converter station, where it is converted back to AC and fed into the grid. Seven converter stations have been built to date and two are under construction.



Figure 4: A floating crane lifting a converter.<sup>7</sup>

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<sup>6</sup> Image source: Katharina Garus, "Foundations for Offshore Wind Farm Nordsee Ost Are Installed," Offshore Wind Industry, published 26 March 2014, <http://www.offshorewindindustry.com/node/22999>.

The offshore converter needs a transportation vessel to transport it to its destination. An additional floating crane is necessary to lift it up to the previously installed foundation (see fig. 4). The duration of the installation process is roughly 30 months for offshore and 22 months for onshore converters.<sup>8</sup>

### 1.3.4 Transformer

At the transformer station, the power from the individual wind farms is collected and upscaled for further transmission (see fig. 5).



Figure 5. A floating crane lifting a transformer.<sup>9</sup>

The installation process for the transformer is the same as that for the offshore converter. Offshore transformers are installed within 24 months, although the process takes 18 months for onshore transformers.

## 2. Main Component Suppliers

The main components of an OWF are the wind turbines (to generate the electricity), the transformer (to upscale the voltage), the converter (to convert AC to DC), and the subsea cables connecting the various components.

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<sup>7</sup> Image source: Detlef Koenemann, "Europe's Powerhouse," Offshore Wind Industry, published 23 April 2015, <http://www.offshorewindindustry.com/news/europes-powerhouse>.

<sup>8</sup> See, among others, "Beschleunigungs- und Kostensenkungspotentiale bei HGÜ-Offshore-Netzanbindungen" [in German], Fichtner Group, June 2016, 13, [https://www.offshore-stiftung.de/sites/offshorelink.de/files/documents/Studie\\_Beschleunigungs-%20und%20Kostensenkungspotenziale%20bei%20HG%C3%9C-Offshore-Netzanbindungsprojekten\\_Kurzfassung\\_0.pdf](https://www.offshore-stiftung.de/sites/offshorelink.de/files/documents/Studie_Beschleunigungs-%20und%20Kostensenkungspotenziale%20bei%20HG%C3%9C-Offshore-Netzanbindungsprojekten_Kurzfassung_0.pdf).

<sup>9</sup> Image source: "RWE Installs Nordsee Ost Platform," reNEWS, 21 July 2014, <http://renews.biz/70725/rwe-installs-nordsee-ost-platform/>.

## 2.1 Cables

The following cable companies produced all of the inter-array and export cables for the European offshore wind market in 2016.<sup>10</sup>

### 2.1.1 Prysmian Group

<i>Key economic figures:</i>	Revenue: €7.6 billion (2016) Employees: 21,000 (2016) Headquarters: Milan, Italy Founded: 2011 Website: <a href="http://www.prysmiangroup.com">www.prysmiangroup.com</a> <sup>11</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Medium voltage inter-array cables</li> <li>• High-voltage alternating current (HVAC) export cables up to 400kV</li> <li>• High-voltage direct current (HVDC) export cables up to 600kV<sup>12</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• BorWin2 (125km HVDC 300kV + 75km HVAC 155kV)</li> <li>• HelWin1 (85km HVDC 250kV + 45km HVAC 155kV)</li> <li>• HelWin2 (85km HVDC 320kV + 45km HVAC 155kV)</li> <li>• SylWin1 (159km + 45km HVDC 320kV)</li> <li>• West of Adlergrund (HVAC 220kV)<sup>13</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	N/A
<i>Market share specifics for the OSW industry:</i>	Inter-array: 9% (European market, 2016) Export cables: 52.2% (European market, 2016) <sup>14</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	Prysmian is the world leader in submarine connections for offshore wind farms. It has installed over 800km of inter-array cables and over 500km of inter-array cables to date. <sup>15</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Arco Felice Plant, Italy             <ul style="list-style-type: none"> <li>○ MV, HVAC up to 400kV and HVDC up to 600kV</li> <li>○ 2 CCV (catenary continuous vulcanization) lines</li> <li>○ 2 lapping lines</li> <li>○ Located directly at the Mediterranean Sea</li> </ul> </li> <li>• Pikkala plant, Finland             <ul style="list-style-type: none"> <li>○ MV, HVAC up to 400kV and HVDC up to 525kV</li> <li>○ 1 CCV (catenary continuous vulcanization) lines</li> <li>○ 2 VCV (vertical continuous vulcanization) lines</li> <li>○ Located at the Baltic Sea</li> </ul> </li> <li>• Drammen Plant, Norway             <ul style="list-style-type: none"> <li>○ Array cables up to 66kV</li> <li>○ Located directly on the Baltic Sea<sup>16</sup></li> </ul> </li> </ul>

<sup>10</sup> *The European Offshore Wind Industry: Key Trends and Statistics 2016*, Wind Europe, 2016, 14, <https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Offshore-Statistics-2016.pdf>.

<sup>11</sup> "About Us," Prysmian Group, last updated 18 May 2018, <https://www.prysmiangroup.com/en/about-us>.

<sup>12</sup> "Products and Solutions," Prysmian Group, last updated 30 November 2017, <https://www.prysmiangroup.com/en/products-and-solutions>.

<sup>13</sup> "Offshore Wind Farms," Prysmian Group, accessed 7 June 2018, <https://www.prysmiangroup.com/en/products-and-solutions/power-grids/offshore-wind-farms>.

<sup>14</sup> Wind Europe, *Key Trends and Statistics 2016*, 14.

<sup>15</sup> "Inter-array Cable Systems," Prysmian Group, accessed 7 June 2018, <https://www.prysmiangroup.com/en/products-and-solutions/power-grids/offshore-wind-farm/inter-array-cable-systems>.

*Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):*

The order book stood at €2.0B as of year-end 2016, with a positive outlook for 2017, both for interconnections and for offshore wind farm connections. The group reached full production capacity in every factory in the first half of 2016.<sup>17</sup>

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<sup>16</sup> “Production Facilities,” Prysmian Group, accessed 7 June 2018, <https://www.prysmiangroup.com/en/products-and-solutions/power-grids/production-facilities>.

<sup>17</sup> *2016 Yearly Overview*, Prysmian Group, 2017, 14, 49, [https://www.prysmiangroup.com/sites/default/files/atoms/files/20170505Prysmian\\_Report\\_singole\\_lowFINAL.pdf](https://www.prysmiangroup.com/sites/default/files/atoms/files/20170505Prysmian_Report_singole_lowFINAL.pdf).

## 2.1.2 Norddeutsche Seekabelwerke GmbH (NSW)

<i>Key economic figures:</i>	Part of General Cable Corporation Revenue: €3.9 billion (2016) Employees: 11,700 (General Cable); 500 (NSW only) Headquarters: Nordenham, Germany Founded: 1899 Website: <a href="http://www.nsw.com">www.nsw.com</a> <sup>18</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Medium-voltage inter-array cables</li> <li>• HVAC export cables up to 150kV</li> <li>• HVDC export cables up to 250kV<sup>19</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• Offshore wind farm Rødsand II (80km inter-array)</li> <li>• Offshore wind farm Alpha Ventus (16km inter-array)</li> <li>• Borkum Riffgrund 1 (2x13km 155kV AC export cable)<sup>20</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	2008 <sup>21</sup>
<i>Market share specifics for the OSW industry:</i>	Inter-array cables: 43.6% (European market, 2016) Export cables: 17.4% (European market, 2016) <sup>22</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	General Cable NSW benefits from a global reach and worldwide expertise. NSW was one of the forerunners in the subsea cable industry laying their first subsea communications cable with a length of over 7,000km in 1904. <sup>23</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Nordenham, Germany <ul style="list-style-type: none"> <li>○ NSW headquarters. The facility is located next to the Weser River. A deep-water pier ensures access for cable vessels. The cables can be directly transferred from storage to the vessels.</li> </ul> </li> <li>• Aberdeen, UK <ul style="list-style-type: none"> <li>○ NSW technology<sup>24</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	N/A

## 2.1.3 NKT Group GmbH

<i>Key economic figures:</i>	Revenue: €1.0 billion (2017) Employees: 3,400 Headquarters: Cologne, Germany Founded: 1891
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<sup>18</sup> "Facts and Figures," Norddeutsche Seekabelwerke GmbH, accessed 7 June 2018, <http://www.nsw.de/en/about-us/corporate-profile>; General Cable, *Annual Report 2016*, accessed 19 June 2018, 36, <http://investor.generalcable.com/phoenix.zhtml?c=81254&p=irol-reportsannual>.

<sup>19</sup> "Products and Services," Norddeutsche Seekabelwerke GmbH (on 27.6.2018 available at [http://nsw.de/Portals/0/Blobs/1221/NSW\\_Power-Broschu%CC%88re\\_11\\_2017\\_Screen.pdf?ver=2017-11-23-122105-890](http://nsw.de/Portals/0/Blobs/1221/NSW_Power-Broschu%CC%88re_11_2017_Screen.pdf?ver=2017-11-23-122105-890)).

<sup>20</sup> "References," Norddeutsche Seekabelwerke GmbH, accessed 7 June 2018, <http://www.nsw.de/en/References/Cable#>.

<sup>21</sup> Ibid.

<sup>22</sup> Wind Europe, *Key Trends and Statistics 2016*, 14.

<sup>23</sup> "Company Profile," Norddeutsche Seekabelwerke GmbH (on 2.6.2018 available at: <http://www.nsw.de/de/%C3%9Cber-uns/Unternehmensprofil>)

<sup>24</sup> "Locations," Norddeutsche Seekabelwerke GmbH (on 27.6.2018 provided at: <http://www.nsw.de/de/%C3%9Cber-uns/Unternehmensprofil>)

	Website: <a href="http://www.nkt.com">www.nkt.com</a> <sup>25</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Medium voltage inter-array cables</li> <li>• HVAC export cables</li> <li>• HVDC export cables (added to the portfolio through the ABB merger)<sup>26</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• 2010 Walney I offshore wind farm (33kV inter-array)</li> <li>• 2011 Baltic 1 offshore wind farm: first commercial offshore wind farm in the Baltic Sea (150kV export cable and 33kV inter-array)</li> <li>• 2011 Cork Harbour II interconnector (220kV cable)</li> <li>• 2012 Anholt Offshore wind farm (245kV export cable)</li> <li>• 2012 Gwynt y Môr Offshore wind farm (132kV export cable)</li> <li>• 2012 Riffgat offshore wind farm (150kV export cable)</li> <li>• 2013 Baltic 2 offshore wind farm (150kV export cable)</li> <li>• 2013 West of Duddon Sands offshore wind farm (150kV export cable)</li> <li>• 2014 Amrumbank West offshore wind farm (33kV inter-array)</li> <li>• 2014 Q10 offshore wind farm (33kV inter-array)</li> <li>• 2014 Solent Crossing, Isle of Wight (132kV cable)</li> <li>• 2015 Gemini offshore wind farm (220kV export cable)<sup>27</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	N/A
<i>Market share specific to the OSW industry:</i>	Export cables: 13% (NKT) 17.4% (ABB cables purchased by NKT in 2016); combined total of 30.4% (European market, 2016) <sup>28</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	A pioneer in the cable industry. NKT has great expertise in the fields of energy transportation and cost-efficient manufacturing. The acquisition of ABB's cable business provides the company with new extensive experience and expertise, particularly in the DC high-voltage market. NKT installed more than 3,000km of cable in offshore projects. <sup>29</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Cologne, Germany <ul style="list-style-type: none"> <li>○ Product range: Medium voltage cables, high-voltage cables, high-voltage accessories, fiber-optic products, superconducting cables, submarine cables, and VALCAP® grid monitoring systems</li> <li>○ Including CCV (catenary continuous vulcanization) lines and VCV (vertical continuous vulcanization) lines</li> <li>○ Access to the Rhine River</li> </ul> </li> <li>• Karlskrona, Sweden <ul style="list-style-type: none"> <li>○ Production, installation, and service of high-voltage cables in both AC and DC for submarine and underground applications</li> <li>○ Production lines for paper-insulated and XLPE (cross-linked polyethylene) cables exist</li> <li>○ 1 CCV (catenary continuous vulcanization) line and 1 VCV (vertical continuous vulcanization) lines</li> <li>○ Cables can be loaded onto ships directly from the factory</li> <li>○ Access to the Baltic Sea<sup>30</sup></li> </ul> </li> </ul>

<sup>25</sup> "Profile and Key Figures," NKT, accessed 7 June 2018, <http://www.nkt.com/about-us/profile-key-figures.html>.

<sup>26</sup> "Products," NKT, accessed 7 June 2018, <http://www.nkt.com/products.html>.

<sup>27</sup> "Wir Verbinden Erneuerbare Energie: Onshore, Offshore und Photovoltaik [in German]," NKT, n.d., 11, [http://www.nkt.de/fileadmin/user\\_upload/nkt\\_com/Catalogs\\_brochures/Onshore\\_Offshore.pdf](http://www.nkt.de/fileadmin/user_upload/nkt_com/Catalogs_brochures/Onshore_Offshore.pdf).

<sup>28</sup> Wind Europe, *Key Trends and Statistics 2016*, 14.

<sup>29</sup> "About Us: History," NKT, accessed 14 June 2018, <http://www.nkt.de/ueber-uns/geschichte.html>.

<sup>30</sup> "About Us: Locations," NKT, accessed 14 June 2018, <http://www.nkt.com/about-us/locations.html>.



*Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):*

Orders on hand for 2017: €189 million; 2018: €113 million (on and offshore high-voltage orders)<sup>31</sup>  
The acquisition of ABB's cable business provides NKT with increased production capacity and new expertise, particularly in DC technology.<sup>32</sup>

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<sup>31</sup> *Annual Report 2016*, NKT, 2017, 16, <http://www.nkt.dk/media/99429/NKT-2016-Annual-Report.pdf>.

<sup>32</sup> "NKT Cables' Acquisition of ABB HV Cables Completed," NKT, published 1 March 2017, <http://www.nkt.com/about-us/news-events/news/news-report/news/nkt-cables-acquisition-of-abb-hv-cables-completed.html>.

## 2.1.4 Nexans S.A.

<i>Key economic figures:</i>	Revenue: €5.8 billion Employees: 26,000 Headquarters: Paris, France Founded: 1897 Website: <a href="http://www.nexans.com">www.nexans.com</a> <sup>33</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Medium-voltage inter-array cables</li> <li>• HVAC export cables of 60kV–500kV</li> <li>• HVDC export cables up to 525kV<sup>34</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• West of Duddon Sands (123km of 34kV inter-array cables)</li> <li>• Westernmost Rough (53km of 34kV inter-array)</li> <li>• Hywind (12km of 24kV XLPE HVAC export cables)</li> <li>• Belwind (165MW, 52km of 152kV XLPE HVAC export cables)</li> <li>• Northwind (57km of 229kV XLPE HVAC export cables)</li> <li>• Gode Wind 1 and 2 (134km of 34kV inter-array cables)</li> <li>• Anholt (160km of 34kV inter-array cables)</li> <li>• Borkum Riffgrund 1 and 2 (81km + 105km of 34kV inter-array cables)</li> <li>• Riffgat (24km of 33kV XLPE HVAC export cables)<sup>35</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	2010 (Walney)
<i>Market share specific to the OSW industry:</i>	Inter-array: 30.2% (European market, 2016) <sup>36</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	Nexans provides cable solutions for approximately 50% of European wind farms and plays a leading role in the development of wind farm technology. It also oversees the full installation of wind farms and the communications infrastructure. <sup>37</sup>
<i>Location of the production centers for the products delivered to the OSW market and for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Halden, Norway <ul style="list-style-type: none"> <li>○ High-voltage laboratory</li> <li>○ Two vertical lay-up machines</li> <li>○ Continuous cables of up to 145km can be manufactured and transferred</li> <li>○ 100 m high vertical production line for XLPE cables (VCV)</li> <li>○ Located directly at the Baltic Sea<sup>38</sup></li> </ul> </li> <li>• Hanover, Germany <ul style="list-style-type: none"> <li>○ Low-, medium-, and high-voltage cables</li> <li>○ Design of cable systems</li> <li>○ Located at the Mittelland Canal<sup>39</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to</i>	Backlog orders of €1.7 billion as of the end of 2016 <sup>40</sup>

<sup>33</sup> “Overview,” Nexans, accessed 14 June 2018, [https://www.nexans.com/eservice/Corporate-en/navigate\\_208174/Overview.html](https://www.nexans.com/eservice/Corporate-en/navigate_208174/Overview.html).

<sup>34</sup> “Integrated Cable Solutions for Offshore Wind Development,” Nexans, 2016, 6–11,

[https://www.nexans.com/eservice/...en/.../Broch\\_Offshore\\_Windfarms\\_2015.pdf](https://www.nexans.com/eservice/...en/.../Broch_Offshore_Windfarms_2015.pdf).

<sup>35</sup> Ibid.

<sup>36</sup> Wind Europe, *Key Trends and Statistics 2016*, 14.

<sup>37</sup> “Nexans at Offshore Wind Energy 2017,” Nexans, accessed 15 June 2018, [https://www.nexans.com/eservice/Corporate-en/navigatepub\\_142484\\_-35800/Nexans\\_at\\_Offshore\\_Wind\\_Energy\\_2017.html](https://www.nexans.com/eservice/Corporate-en/navigatepub_142484_-35800/Nexans_at_Offshore_Wind_Energy_2017.html).

<sup>38</sup> “Nexans Norway: Complete Subsea Cable Systems,” Offshore Technology, accessed 15 June 2018, <http://www.offshore-technology.com/contractors/cables/nexans/>.

<sup>39</sup> “Kabel für Offshore Windparks” [in German], Nexans, August 2003, 3, [http://www.nexans.de/Germany/2008/nexans\\_Kabel\\_fuer\\_windparks\\_0805.pdf](http://www.nexans.de/Germany/2008/nexans_Kabel_fuer_windparks_0805.pdf).

<sup>40</sup> *2016 Full-Year Results*, Nexans, 9 February 2017, 3, [https://www.nexans.com/Corporate/2017/1702\\_PR\\_FY\\_2016\\_GB.pdf](https://www.nexans.com/Corporate/2017/1702_PR_FY_2016_GB.pdf).

## Supply Chain Analysis of the Offshore Wind Energy Transmission Industry

*the OSW market (as of 2020, 2025,  
2030):*

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## 2.1.5 JDR Cable Systems Ltd.

<i>Key economic figures:</i>	Revenue: ~€100 million (2013) Employees: more than 500 Headquarters: Littleport, UK Founded: 1990 Website: <a href="http://www.jdrcables.com">www.jdrcables.com</a> <sup>41</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• 1kV–72kV medium-voltage inter-array cables<sup>42</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• Dudgeon wind farm, UK (95km inter-array cables)</li> <li>• Nordsee One (70km inter-array cables)</li> <li>• Sandbank (105km inter-array cables)</li> <li>• Great Gabbard (200km inter-array cable)</li> <li>• London Array (200km inter-array cable)<sup>43</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	N/A
<i>Market share specific to the OSW industry:</i>	Inter-array: 17.2% (European market, 2016) <sup>44</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	JDR offers key services at each stage of a project and verify outcomes with extensive testing techniques. The company was acquired by Polish cable company TFKable in August 2017. <sup>45</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Hartlepool, UK <ul style="list-style-type: none"> <li>○ Quayside manufacturing site strategically located alongside a North Sea port</li> <li>○ Highly flexible production setup with capability in ultra-long cables and umbilicals</li> <li>○ The factory can deliver cables of up to 4000 tons</li> </ul> </li> <li>• Littleport, UK <ul style="list-style-type: none"> <li>○ Engineering</li> <li>○ Design</li> <li>○ Project management</li> <li>○ Research and development<sup>46</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	N/A

<sup>41</sup> “Working at JDR,” JDR Cables, accessed 14 June 2018, <http://www.jdrcables.com/careers/working-at-jdr/#sthash.fGLIshbl.VWsOvHiC.dpbs>; JDR Cables, “History,” accessed 14 June 2018, <http://www.jdrcables.com/about/history/#sthash.1vEXs0WN.A5yTbyZm.dpbs>.

<sup>42</sup> “Subsea Power Cables,” JDR Cables, accessed 14 June 2018, <http://www.jdrcables.com/oil-gas/subsea-power-cables/#sthash.pcYyEf9O.dpbs>.

<sup>43</sup> “Example Project Experience: Renewables Projects,” JDR Cables, accessed 14 June 2018, <http://www.jdrcables.com/renewables/example-project-experience/#sthash.ErLFIRGO.Zy3LJlaq.dpbs>.

<sup>44</sup> *Key Trends and Statistics 2016*, Wind Europe, 14.

<sup>45</sup> “Our Capabilities,” JDR Cables, accessed 14 June 2018, <http://www.jdrcables.com/about/our-capabilities/>

<sup>46</sup> “Global Manufacturing and Service,” JDR Cables, accessed 14 June 2018, <http://www.jdrcables.com/about/global-manufacturing/#sthash.NqHTMIR.9dKSbHEE.dpbs>.

## 2.1.6 TELE-FONIKA Kable (TFKable)

<i>Key economic figures:</i>	Revenue: N/A Employees: 4,000 Headquarters: Mylenice, Poland Founded: 1992 Website: <a href="https://www.tfkable.com">https://www.tfkable.com</a> <sup>47</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Medium-voltage inter-array cables</li> <li>• High-voltage cables up to 240kV<sup>48</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	N/A
<i>Date of entry into the OSW industry:</i>	N/A
<i>Market share specific to the OSW industry:</i>	No cable deliveries to offshore wind energy projects in Europe in 2016 <sup>49</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry</i>	Reliable cable provider and market leader in Poland. In August 2017, it was announced that TFKable would acquire the British cable manufacturer JDF Cable and thus strengthen their expertise, product portfolio, and competencies. <sup>50</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Wielicka plant (Krakow, Poland)<sup>51</sup> <ul style="list-style-type: none"> <li>◦ Medium voltage with XLPE insulation</li> </ul> </li> <li>• Bydgoszcz plant (Poland) <ul style="list-style-type: none"> <li>◦ Medium- and high-voltage up to 500kV<sup>52</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	Will increase production capacity through the acquisition of JDR Cables Ltd. <sup>53</sup>

<sup>47</sup> "Group Information," TELE-FONIKA Kable, accessed 14 June 2018, [https://www.tfkable.com/en\\_pl/about-us/group-information.html](https://www.tfkable.com/en_pl/about-us/group-information.html).

<sup>48</sup> "A New Beginning in Oil and Gas: Offshore Cable Range," Offshore Cables, TELE-FONIKA Kable, accessed 15 June 2018, retrieved from [https://www.tfkable.com/en\\_pl/catalogs-and-brochures/brochures.html?limit=8&page=2](https://www.tfkable.com/en_pl/catalogs-and-brochures/brochures.html?limit=8&page=2).

<sup>49</sup> *Key Trends and Statistics 2016*, Wind Europe, 14.

<sup>50</sup> "Group Information," TELE-FONIKA Kable,.

<sup>51</sup> "Plant Locations: Factory Krakow-Wielicka," TELE-FONIKA Kable, accessed 14 June 2018, [https://www.tfkable.com/en\\_pl/about-us/group-information.html](https://www.tfkable.com/en_pl/about-us/group-information.html).

<sup>52</sup> "Plant Locations: Factory Bydgoszcz," TELE-FONIKA Kable, accessed 14 June 2018, [https://www.tfkable.com/en\\_pl/about-us/group-information.html](https://www.tfkable.com/en_pl/about-us/group-information.html).

<sup>53</sup> Plamena Tisheva, "TFKable Receives Regulatory Approval for JDR Buy," *Renewables Now*, published 28 August 2017, <https://renewablesnow.com/news/tfkable-recvies-regulatory-approval-for-jdr-buy-581291/>.

## 2.2 Converters

The following three companies build offshore converters.

### 2.2.1 ABB Ltd.

<i>Key economic figures:</i>	Revenue: €33.4 billion Employees: 132,000 Headquarters: Zurich, Switzerland Founded: 1988 Website: <a href="http://www.abb.com">www.abb.com</a> <sup>54</sup>
<i>Product portfolio – Converters:</i>	<ul style="list-style-type: none"> <li>• Complete AC and DC converter stations</li> <li>• DC transmission link solution</li> <li>• Voltage source converter system HVDC Light®</li> <li>• HVDC transmission</li> <li>• Offshore and onshore DC stations, including buildings, platforms, and grid code compliance<sup>55</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• BorWin 1 <ul style="list-style-type: none"> <li>○ Converter type: VSC HVDC Light®</li> <li>○ Power: 400MW</li> <li>○ Voltage: DC voltage level 150kV; AC voltage level 156kV</li> </ul> </li> <li>• DolWin 1 <ul style="list-style-type: none"> <li>○ Converter type: VSC (HVDC Light)</li> <li>○ Power: 800MW</li> <li>○ Voltage: DC voltage level 320kV; AC voltage level 155kV</li> </ul> </li> <li>• DolWin 2 <ul style="list-style-type: none"> <li>○ Converter type: VSC (HVDC Light)</li> <li>○ Power: 916MW</li> <li>○ Voltage: DC voltage level 320kV; AC voltage level 155kV<sup>56</sup></li> </ul> </li> </ul>
<i>Date of entry into the OSW industry:</i>	The BorWin 1 converter was commissioned in 2009–10. The offshore wind farm Walney was commissioned in 2012. ABB had previously been active in the subsea cable business but sold that business segment to NKT in 2016. <sup>57</sup>
<i>Market share specifics for the OSW industry:</i>	Converters The company installed three of seven active converters (in the North and Baltic seas). <sup>58</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	ABB is the world’s largest power transformer manufacturer, delivering 1,000+ units annually from 13 factories worldwide. <sup>59</sup>

<sup>54</sup> “Facts and Figures,” ABB, accessed 14 June 2018, <http://new.abb.com/investorrelations/company-profile/facts-figures>.

<sup>55</sup> “HVDC,” ABB, accessed 14 June 2018, <http://new.abb.com/systems/hvdc>.

<sup>56</sup> “BorWin 1,” ABB, accessed 14 June 2018, <http://new.abb.com/systems/hvdc/references/borwin1>; ABB, “DolWin 1,” accessed 14 June 2018, <http://new.abb.com/systems/hvdc/references/dolwin1>; ABB, “DolWin 2,” accessed 14 June 2018, <http://new.abb.com/systems/hvdc/references/dolwin2>.

<sup>57</sup> “Organisations Working on Walney Phase 1,” 4C Offshore, accessed 14 June 2018, <http://www.4coffshore.com/windfarms/contracts-on-walney-phase-1-uk31.html>.

<sup>58</sup> “Highlights 2016,” *ABB Annual Report 2016*, ABB, accessed 14 June 2018, <http://annualreport2016.e.abb.com/introduction/highlights-2016.html> plus calculations based on [https://en.wikipedia.org/wiki/List\\_of\\_HVDC\\_projects#Europe](https://en.wikipedia.org/wiki/List_of_HVDC_projects#Europe) (available on 27.6.2018)

<sup>59</sup> “Power Transformers,” ABB, accessed 14 June 2018, <http://new.abb.com/docs/default-source/ewea-doc/built-for-reliability-and-efficiencyfe8e4be2c1f463c09537ff0000433538.pdf?sfvrsn=2>.

<p><i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i></p>	<ul style="list-style-type: none"> <li>• Hanau, Germany             <ul style="list-style-type: none"> <li>○ Production site high-voltage products</li> <li>○ Main River access</li> </ul> </li> <li>• Vaasa, Finland             <ul style="list-style-type: none"> <li>○ Motors and generators</li> <li>○ Baltic Sea access</li> </ul> </li> <li>• Ludvika, Sweden             <ul style="list-style-type: none"> <li>○ High-voltage products</li> </ul> </li> <li>• Drammen, Sweden             <ul style="list-style-type: none"> <li>○ Transformers/high-voltage products</li> <li>○ Located at the Drammensfjord, which leads into the Baltic Sea<sup>60</sup></li> </ul> </li> </ul>
<p><i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i></p>	<p>N/A</p>

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<sup>60</sup> Ibid.

## 2.2.2 Siemens AG

<i>Key economic figures:</i>	<p>Revenue: €79.6 billion          Employees: 351,000 (total); 52,000 (Energy Division)          Headquarters: Berlin and Munich, Germany          Founded: 1847          Website: <a href="http://www.siemens.com">www.siemens.com</a><sup>61</sup></p>
<i>Product portfolio - Converters:</i>	<ul style="list-style-type: none"> <li>• Compact HVDC Solutions             <ul style="list-style-type: none"> <li>○ Power rating: up to 1,200 MW @ 320kV DC</li> <li>○ Converter technology: voltage-source converters (VSC) or diode rectifiers</li> <li>○ Optional features: accommodation; direct 66kV connection with wind turbine generator (WTG)<sup>62</sup></li> </ul> </li> </ul>
<i>Previous relevant OSW activities:</i>	<p>Converter</p> <ul style="list-style-type: none"> <li>• BorWin 2<sup>63</sup> <ul style="list-style-type: none"> <li>○ Converter type: VSC HVDC Plus (modular multilevel converter, MMC)</li> <li>○ Power: 800MW</li> <li>○ Voltage: DC voltage level 300kV; AC voltage level 155/300kV</li> </ul> </li> <li>• BorWin 3 (under construction)</li> <li>• HelWin 1<sup>64</sup> <ul style="list-style-type: none"> <li>○ Converter type: VSC HVDC Plus (MMC)</li> <li>○ Power: 576MW</li> <li>○ Voltage: DC voltage level 250kV; AC voltage level 155/250kV</li> </ul> </li> <li>• HelWin 2<sup>65</sup> <ul style="list-style-type: none"> <li>○ Converter type: VSC HVDC Plus (MMC)</li> <li>○ Power: 690MW</li> <li>○ Voltage: DC voltage level 320kV; AC voltage level 155/300/380kV</li> </ul> </li> <li>• SylWin 1<sup>66</sup> <ul style="list-style-type: none"> <li>○ Converter type: VSC (HVDC Plus)</li> <li>○ Power: 864MW</li> <li>○ Voltage: DC voltage level 320kV; AC voltage level 155/300/380kV</li> </ul> </li> </ul>
<i>Date of entry into the OSW industry:</i>	<p>One of the first companies within the offshore industry, part of the first offshore project in 1991<sup>67</sup></p>
<i>Market share specifics for the OSW industry:</i>	<p>Converters          The company installed four of seven active converters (in the North and Baltic seas).<sup>68</sup></p>

<sup>61</sup> "Siemens at a Glance," Siemens, accessed 14 June 2018, [https://www.siemens.com/investor/en/company\\_overview.htm](https://www.siemens.com/investor/en/company_overview.htm).

<sup>62</sup> "Grid Access Solutions Built on Experience," Siemens, accessed 14 June 2018, <https://www.siemens.com/global/en/home/products/energy/high-voltage/grid-access-solutions.html>.

<sup>63</sup> "BorWin 2 Converter: Information," 4C Offshore, accessed 14 June 2018, <http://www.4coffshore.com/windfarms/hvdc-converter-borwin2-converter-cid3.html>.

<sup>64</sup> "HelWin 1 Converter: Information," 4C Offshore, accessed 14 June 2018, <http://www.4coffshore.com/windfarms/hvdc-converter-helwin1-converter-cid5.html>.

<sup>65</sup> "HelWin 2 Converter: Information," 4C Offshore, accessed 14 June 2018, <http://www.4coffshore.com/windfarms/hvdc-converter-helwin2-converter-cid8.html>.

<sup>66</sup> "SylWin 1 Converter: Information," 4C Offshore, accessed 14 June 2018, <http://www.4coffshore.com/windfarms/hvdc-converter-sylwin1-converter-cid12.html>.

<sup>67</sup> "Wind Power," Siemens, accessed 14 June 2018, <https://www.siemens.com/global/en/home/company/about/businesses/wind-power.html>.



<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	Siemens is one of the most experienced companies in the offshore business. It was a pioneer in the industry, developing the first wind park in 1991. <sup>69</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Berlin, Germany <ul style="list-style-type: none"> <li>○ Switchgear and components</li> </ul> </li> <li>• Nuremberg, Germany <ul style="list-style-type: none"> <li>○ Converters, transformers and components<sup>70</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030)</i>	Currently constructing BorWin 3; recently won a contract for DolWin 6 <sup>71</sup>

<sup>68</sup> “Evaluation of active converters based on [https://en.wikipedia.org/wiki/List\\_of\\_HVDC\\_projects#Europe](https://en.wikipedia.org/wiki/List_of_HVDC_projects#Europe) (as available on 27.6.2018)

<sup>69</sup> “Wind Power,” Siemens, accessed 15 June 2018, <https://www.siemens.com/global/en/home/company/about/businesses/wind-power.html>.

<sup>70</sup> “Siemens Erhält Großauftrag für Offshore-Netzanbindung DolWin6 von TenneT” [in German], Siemens, 17 July 2017, [https://www.siemens.com/press/de/pressemitteilungen/?press=/de/pressemitteilungen/2017/energymanagement/pr2017070370emde.htm&content\[\]=EM](https://www.siemens.com/press/de/pressemitteilungen/?press=/de/pressemitteilungen/2017/energymanagement/pr2017070370emde.htm&content[]=EM).

<sup>71</sup> Ibid.

## 2.2.3 General Electric Company

<i>Key economic figures:</i>	Revenue: €123.7 billion Employees: 295,000 Headquarters: Boston, U.S.A. (GE Headquarters) Founded: 1892 Website: <a href="http://www.gegridsolutions.com">www.gegridsolutions.com</a> <sup>72</sup>
<i>Product portfolio – Converters:</i>	<ul style="list-style-type: none"> <li>• HVDC systems</li> <li>• Flexible AC transmission systems</li> <li>• Industrial DC substations<sup>73</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	Converters <ul style="list-style-type: none"> <li>• DoIWin 3 converter (under construction)<sup>74</sup> <ul style="list-style-type: none"> <li>○ Converter type: VSC HVDC Plus (MMC)</li> <li>Power: 900MW</li> <li>Voltage: DC voltage level 320kV; AC voltage level 155kV</li> </ul> </li> </ul>
<i>Date of entry into the OSW industry:</i>	The planned commission date for the DoIWin3 converter is 2017. Horns Rev 2 was commissioned in 2009.
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	GE Grid Solutions is a joint venture of Alstom and General Electric. Both companies have extensive experience in the power industry. The joint venture equips more than 90% of power utilities worldwide. <sup>75</sup> GE has developed a standardized process for the development and production of converters which will ultimately lead to great reductions in cost. <sup>76</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	The converters and transformers are produced in Mönchengladbach, Germany. The factory is one of the most modern in the world, and the company is constantly investing in modernization solutions to keep the factory up to date. <sup>77</sup>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	N/A

<sup>72</sup> *Forward Looking Statements*, GE, 2016, 18, 28, 35, [http://www.ge.com/ar2016/assets/pdf/GE\\_2016\\_Form\\_10K.pdf](http://www.ge.com/ar2016/assets/pdf/GE_2016_Form_10K.pdf).

<sup>73</sup> "Systems and Services: HVDC Systems," GE Grid Solutions, GE, accessed 14 June 2018, <https://www.gegridsolutions.com/PowerD/catalog/hvdc.htm>.

<sup>74</sup> "DoIWin3 Converter: Information," 4C Offshore, accessed 14 June 2018, <http://www.4coffshore.com/windfarms/hvdc-converter-dolwin3-converter-cid14.html>.

<sup>75</sup> "GE Digital Energy and Alstom Grid Combine to Form GE's Grid Solutions, Addressing Global Power Needs," GE Grid Solutions, GE, 9 November 2015, [https://www.gegridsolutions.com/press/gepress/GridSolutionsPressRelease\\_Website.pdf](https://www.gegridsolutions.com/press/gepress/GridSolutionsPressRelease_Website.pdf).

<sup>76</sup> Claus Gorgs, "Deutschlands schwimmende Steckdose" [in German], *Manager Magazin*, 20 July 2017, <http://www.manager-magazin.de/unternehmen/energie/general-electric-jagt-siemens-bei-offshore-windkraft-a-1158523-3.html>.

<sup>77</sup> Jan Schnettler, "Alstom Grid in Mönchengladbach: Transformatoren zu Land, zu Wasser und zur Schiene" [in German], *RP Online*, 3 December 2013, <http://www.rp-online.de/nrw/staedte/moenchengladbach/transformatoren-zu-land-zu-wasser-und-zur-schiene-aid-1.3859870>.

## 2.3 Transformers

The following five companies manufacture transformers.

### 2.3.1 ABB Ltd.

<i>Product portfolio – Transformers:</i>	<ul style="list-style-type: none"> <li>• Generator step-up transformers</li> <li>• System intertie transformers               <ul style="list-style-type: none"> <li>○ Ratings up to 1,300 megavolt-amperes (MVA)</li> <li>○ Primary voltage of 765kV and higher</li> <li>○ Secondary voltage 230kV</li> </ul> </li> <li>• HVDC converter transformers<sup>78</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	Transformers provided for the following wind farms: <ul style="list-style-type: none"> <li>• Walney Phase 1 and 2<sup>79</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	The offshore wind farm Walney was commissioned in 2012. ABB had previously been active in the subsea cable business but sold that business segment to NKT in 2016. <sup>80</sup>
<i>Market share specifics for the OSW industry:</i>	Transformers The company supplied one of 21 active wind farms with a transformer.
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Hanau, Germany               <ul style="list-style-type: none"> <li>○ Production site high-voltage products</li> <li>○ Main River access</li> </ul> </li> <li>• Vaasa, Finland               <ul style="list-style-type: none"> <li>○ Motors and generators</li> <li>○ Baltic Sea access</li> </ul> </li> <li>• Ludvika, Sweden               <ul style="list-style-type: none"> <li>○ High-voltage products</li> </ul> </li> <li>• Drammen, Sweden               <ul style="list-style-type: none"> <li>○ Transformers/high-voltage products</li> <li>○ Located at the Drammensfjord, which leads into the Baltic Sea<sup>81</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	N/A

<sup>78</sup> “AC Solutions for Offshore Wind Connections,” ABB, accessed 14 June 2018, <http://new.abb.com/systems/offshore-wind-connections/ac-solutions>.

<sup>79</sup> “Organisations Working on Walney Phase 1,” 4C Offshore, accessed 14 June 2018, <http://www.4coffshore.com/windfarms/contracts-on-walney-phase-1-uk31.html>.

<sup>80</sup> Veronica Ek, Corinne Gretler and Sheenagh Matthews, “ABB to Sell Cables Business to Danish NKT for \$934 Million,” *Bloomberg*, 21 September 2016, <https://www.bloomberg.com/news/articles/2016-09-21/abb-to-sell-cable-business-to-nkt-cables-for-934-million>.

<sup>81</sup> ABB, “Power Transformers.”

## 2.3.2 Siemens AG

<i>Product portfolio - Transformers:</i>	<ul style="list-style-type: none"> <li>• HVAC solutions, single-transformer platform <ul style="list-style-type: none"> <li>○ Single-transformer platform: offshore transformer module (OTM®)</li> <li>○ Power rating: up to ~400 MW</li> <li>○ Voltages: 132–230kV</li> <li>○ Versions: Stand-alone or integrated with turbine</li> </ul> </li> <li>• HVAC solutions, multi-transformer platforms <ul style="list-style-type: none"> <li>○ Multi-transformer platforms</li> <li>○ Power rating: over 400MW</li> <li>○ Voltages: 132–230kV<sup>82</sup></li> </ul> </li> </ul>
<i>Previous relevant OSW activities:</i>	<p>Transformers provided for the following wind farms:</p> <ul style="list-style-type: none"> <li>• Anholt</li> <li>• BARD Offshore 1</li> <li>• Greater Gabbard</li> <li>• Gwynt y Môr</li> <li>• Lincs</li> <li>• London Array</li> <li>• Nordsee Ost</li> <li>• Rodsand 2</li> <li>• Thanet<sup>83</sup></li> </ul>
<i>Date of entry in the OSW industry:</i>	One of the pioneer companies within the offshore industry; part of the first offshore project in 1991
<i>Market share specifics for the OSW industry:</i>	<p>Transformers</p> <p>21 active wind farms were taken into account, of which the company supplied nine with transformers</p>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Berlin, Germany <ul style="list-style-type: none"> <li>○ Switchgear and components</li> </ul> </li> <li>• Nuremberg, Germany <ul style="list-style-type: none"> <li>○ Converters, transformers and components<sup>84</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (time frame 2020, 2025,2030):</i>	N/A

<sup>82</sup> “Shaping the Future of Transformers,” Siemens, accessed 14 June 2018, <https://www.siemens.com/global/en/home/products/energy/high-voltage/transformers.html>.

<sup>83</sup> “References,” Siemens, accessed 14 June 2018, <https://www.energy.siemens.com/nl/en/power-transmission/facts/static-var-compensator-plus/references.htm>; “Offshore Substations Database,” 4C Offshore, accessed 14 June 2018, <http://www.4coffshore.com/windfarms/substations.aspx>.

<sup>84</sup> Siemens, “Siemens Erhält Großauftrag.”

### 2.3.3 General Electric Company

<i>Product portfolio –Transformers:</i>	<ul style="list-style-type: none"> <li>• Power transformers                             <ul style="list-style-type: none"> <li>○ Large power transformers up to 1200kV AC and power ratings up to 1000MVA</li> <li>○ Small and medium power transformers up to 245kV and 120MVA</li> </ul> </li> <li>• Conventional power transformers</li> <li>• Special transmission</li> <li>• HVDC converter transformers<sup>85</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	Transformers provided for the following wind farms: <ul style="list-style-type: none"> <li>• Borkum Riffgrund 1</li> <li>• EnBW Baltic 2</li> <li>• Global Tech 1</li> <li>• Horns Rev 2</li> <li>• Meerwind South/Ost</li> <li>• Sheringham Shoal<sup>86</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	Horns Rev 2 was commissioned in 2009.
<i>Market share specifics for the OSW industry:</i>	Transformers The company supplied transformers for six of 21 active wind farms.
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Germany</li> </ul> The converters and transformers are produced in Mönchengladbach. The factory is one of the most modern in the world and the company is constantly investing in modernization solutions to keep the factory up to date. <sup>87</sup>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	N/A

<sup>85</sup> “Power Transformers,” GE Grid Solutions, GE, accessed 14 June 2018, [https://www.gegridsolutions.com/HVMV\\_Equipment/power-transformers.htm](https://www.gegridsolutions.com/HVMV_Equipment/power-transformers.htm).

<sup>86</sup> “Offshore Substations Database,” 4C Offshore, accessed 14 June 2018, <http://www.4coffshore.com/windfarms/substations.aspx>.

<sup>87</sup> Jan Schnettler, “Alstom Grid in Mönchengladbach.”

### 2.3.4 CG Power Systems

<i>Key economic figures:</i>	<p>Part of the Avantha Group  Revenue: N/A  Employees: ~15,000 (total)  Headquarters: Mumbai, India (parent company: Crompton Greaves)  Mechelen, Belgium  Founded: 1937  Website: <a href="http://www.cgglobal.com/be/">www.cgglobal.com/be/</a><sup>88</sup></p>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Power transformers <ul style="list-style-type: none"> <li>○ 25kVA–1500MVA</li> </ul> </li> <li>• Distribution transformers</li> <li>• Special transformers<sup>89</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<p>Transformers provided for the following wind farms:</p> <ul style="list-style-type: none"> <li>• Amrumbank West</li> <li>• Butendiek</li> <li>• Humber Gateway</li> <li>• Northwind</li> <li>• West of Duddon Sands<sup>90</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	Northwind and West of Duddon Sands have been active since 2014.
<i>Market share specifics for the OSW industry:</i>	<p>Transformers  The company supplied transformers to 5 of 21 active wind farms.</p>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	CG is one of very few companies worldwide that designs and manufactures a wide and diverse range of power and distribution transformers, as well as reactors from 160kVA–600MVA. <sup>91</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Mechelen, Belgium <ul style="list-style-type: none"> <li>○ Headquarters</li> <li>○ Design, testing, and production of transformers</li> </ul> </li> <li>• Tapiosele, Hungary <ul style="list-style-type: none"> <li>○ One and three phases, mineral-oil-immersed transformers for outdoor or indoor operation</li> <li>○ Power range up to 600MVA and voltage range up to 750kV.<sup>92</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	N/A

<sup>88</sup> *Strengthening the Core: 79<sup>th</sup> Annual Report 2015–2016*, CGGlobal, 2016, 231, <http://www.cgglobal.com/pdfs/annual-report/ar15-16/AR1516.pdf>.

<sup>89</sup> Ibid.

<sup>90</sup> “Corporate Structure,” CGGlobal, accessed 14 June 2018, <http://www.cgglobal.com/others/joint-ventures/CG-Holdings-Belgium-NV.html>.

<sup>91</sup> “Strategic Business Areas,” CGGlobal, accessed 14 June 2018, <http://www.cgglobal.com/frontend/Crompton.aspx?cnl2=LX5/16gdGRw=>.

<sup>92</sup> “Industrial Systems,” CGGlobal, accessed 14 June 2018, <http://www.cgglobal.com/frontend/Crompton.aspx?cnl2=k0Pk0x/pup4=>.

## 2.3.5 Schneider Electric

<i>Key economic figures:</i>	Revenue: €24.7 billion Employees: 144,000 Headquarters: Rueil-Malmaison, France Founded: 1836 Website: <a href="http://www.schneider-electric.com/ww/en/">http://www.schneider-electric.com/ww/en/</a> <sup>93</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Power transformers</li> <li>• Special transformers</li> <li>• Distribution transformers<sup>94</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	Schneider Electric provides the full electrical package for Arkona wind farm. <sup>95</sup>
<i>Date of entry in the OSW industry:</i>	N/A
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	Schneider Electric has transformer manufacturing plants worldwide, which provides the company with a high level of local and global expertise in that field. <sup>96</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Metz, France <ul style="list-style-type: none"> <li>○ Oil- and dry-type transformers</li> <li>○ Dry type up to 15MVA, 36kV</li> <li>○ Liquid filled up to 60MVA, 110kV</li> </ul> </li> <li>• Warsaw, Poland <ul style="list-style-type: none"> <li>○ Oil-immersed and cast-resin transformers</li> <li>○ Dry-type up to 4MVA, 36kV</li> <li>○ Liquid-filled up to 2.5MVA, 36kV</li> </ul> </li> <li>• Kocaeli, Turkey <ul style="list-style-type: none"> <li>○ Oil distribution transformers, medium power transformers, cast-resin transformers, and special transformers</li> <li>○ Dry-type up to 25MVA, 52kV</li> <li>○ Liquid-filled up to 80MVA, 170kV<sup>97</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	AREVA's preferred supplier for transformers and circuit breakers. <sup>98</sup>

<sup>93</sup> "Company Profile," Schneider Electric, accessed 15 June 2018, <http://www.schneider-electric.com/en/about-us/company-profile.jsp>.

<sup>94</sup> "All Products," Schneider Electric, <http://www.schneider-electric.com/en/all-products>.

<sup>95</sup> Schneider Electric, "Company Profile."

<sup>96</sup> "Local Operations," Schneider Electric, accessed 15 June 2018, <https://www.schneider-electric.co.in/india/en/support/operations/local-operations/local-operations.page?>

<sup>97</sup> "Organisations Working on Arkona," 4C Offshore, accessed 15 June 2018, <http://www.4coffshore.com/windfarms/contracts-on-arkona-de46.html>.

<sup>98</sup> "Areva and Schneider Electric Join Forces to Develop Offshore Wind Power in France," AREVA, 12 March 2014, <http://www.sa.areva.com/EN/news-10160/areva-and-schneider-electric-join-forces-to-develop-offshore-wind-power-in-france.html>.

## 2.4 Protection Equipment

The following companies produce protection equipment components for offshore wind farms.

### 2.4.1 ABB Ltd.

*Product portfolio:*

- Air-insulated switchgear
- Hybrid switchgear
- Gas-insulated switchgear
- Generator circuit breakers
- Disconnectors
- Surge arrester
- Monitoring and controlled switching
- Substation automation protection and control
- Fault current limiting
  - Fault current limiters up to 40.5kV, 5000A and a switching capability of 210kArms breaking capacity<sup>99</sup>

### 2.4.2 Siemens AG

*Product portfolio:*

- High-voltage switchgear and devices
- Circuit breakers
  - Circuit breakers for air- (AIS) and gas-insulated (GIS) switchgear for rated voltages from 72.5kV to 800kV
- Disconnectors and earthing switches
  - High-voltage disconnectors and earthing switches for applications from 72.5kV to 800kV
- Surge arresters
  - High-voltage and medium-voltage surge arresters with system voltages from 3kV to 1,200kV
- Gas-insulated switchgear
  - Gas-insulated switchgear for rated voltages from 72.5kV to 550kV
- Medium-voltage switchgear
- Air-insulated switchgear
- Gas-insulated switchgear
- Grid power conversion systems<sup>100</sup>

<sup>99</sup> “Low Voltage Products for Wind Power,” ABB, accessed 15 June 2018, <http://new.abb.com/low-voltage/industries/wind-power>; “Fault Current Limiting,” ABB, accessed 15 June 2018, <http://new.abb.com/medium-voltage/apparatus/fault-current-limiting>.

<sup>100</sup> “Energy,” Siemens, accessed 15 June 2018, <https://www.siemens.com/global/en/home/products/energy.html>.



### 2.4.3 General Electric Company

<p>Product portfolio:</p>	<ul style="list-style-type: none"> <li>• Circuit breakers                             <ul style="list-style-type: none"> <li>○ Circuit breaker enclosures</li> <li>○ DC high-speed circuit breakers</li> <li>○ Insulated case circuit breakers</li> <li>○ Low-voltage power circuit breakers</li> <li>○ Medium-voltage power circuit breakers</li> <li>○ Mini circuit breakers and supplementary protectors</li> <li>○ Molded case circuit breakers</li> <li>○ Previous-generation circuit breakers</li> <li>○ Remote racking devices</li> <li>○ Residential circuit breakers</li> </ul> </li> <li>• Switchgear                             <ul style="list-style-type: none"> <li>○ Load interrupter switches</li> <li>○ Low-voltage switchgear</li> <li>○ Medium-voltage switchgear</li> <li>○ Previous-generation switchgear<sup>101</sup></li> </ul> </li> </ul>
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### 2.4.4 CG Power Systems

<p>Product portfolio:</p>	<ul style="list-style-type: none"> <li>• Switchgear products                             <ul style="list-style-type: none"> <li>○ Vacuum circuit breakers</li> <li>○ Vacuum interrupters</li> <li>○ Vacuum contactors</li> <li>○ Gas circuit breakers</li> <li>○ Ring main units</li> <li>○ Disconnectors</li> <li>○ Surge arresters</li> <li>○ Gas-insulated switchgear</li> </ul> </li> <li>• Protection, control, and automation                             <ul style="list-style-type: none"> <li>○ Total substation automation solutions</li> <li>○ Protection relays and IED</li> <li>○ Products for automation and controls</li> <li>○ Services for automation and controls</li> <li>○ Distribution automation</li> <li>○ Protection and control panels<sup>102</sup></li> </ul> </li> </ul>
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<sup>101</sup> “Electrical Distribution,” GE, accessed 15 June 2018, <http://www.geindustrial.com/products/electrical-distribution>.

<sup>102</sup> “Switchgear Products: MV/HV/EHV/UHV,” CG Global, accessed 15 June 2018, <http://www.cgglobal.com/frontend/Category.aspx?cnl2=u5n211FvXc=>.

## 2.4.5 Schneider Electric

<p><i>Product portfolio:</i></p>	<ul style="list-style-type: none"> <li>● Low-voltage products and systems               <ul style="list-style-type: none"> <li>○ Busway and cable management</li> <li>○ Circuit breakers and switches</li> </ul> </li> <li>● Medium-voltage distribution and grid automation               <ul style="list-style-type: none"> <li>○ Medium-voltage switchgear</li> <li>○ Medium-voltage transformers</li> <li>○ Medium-voltage/low-voltage</li> <li>○ Switchgear components<sup>103</sup></li> </ul> </li> </ul>
<p><i>Previous relevant OSW activities:</i></p>	<p>Provided products for the following projects:</p> <ul style="list-style-type: none"> <li>● Veja Mate</li> <li>● Rödsand</li> <li>● Baltic 2</li> <li>● Alpha Ventus</li> <li>● Riffgat</li> <li>● Global Tech</li> <li>● Thornton Banks</li> <li>● Gunfleet Sands</li> <li>● Walney 1 and 2<sup>104</sup></li> </ul>
<p><i>Key strengths/competitive advantages of the company within the OSW industry:</i></p>	<p>Schneider Electric offers a large variety of protection equipment for wind farm applications. It also supplies wind farm substation control systems, wind farm weather and power management, and wind farm management systems.</p>

<sup>103</sup> Schneider Electric, "All Products."

<sup>104</sup> "Medium Voltage Switchgear for Offshore," Schneider Electric, accessed 15 June 2018, <https://de.scribd.com/document/165113246/Offshore-Switchgear>.

## 2.4.6 Hyosung Corporation

<i>Key economic figures:</i>	Revenue: \$17 billion (~\$14 billion) Employees: 25,000 Headquarters: Seoul Founded: 1966 Website: <a href="http://www.hyosung.com/en/index.do">http://www.hyosung.com/en/index.do</a> <sup>105</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Power transformers</li> <li>• Oil-immersed transformers</li> <li>• Cast-resin transformers</li> <li>• High-voltage switchgears</li> <li>• Control and protection panels</li> <li>• Intelligent electronic devices</li> <li>• Preventive diagnostic system</li> <li>• Engineering and solutions<sup>106</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	Hyosung developed Korea's first geared-type wind turbine and a 2MW wind turbine system. <sup>107</sup>
<i>Date of entry into the OSW industry:</i>	The company has been developing wind turbines since the mid 1990's. <sup>108</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	Hyosung provides total energy solutions. It markets their products worldwide and offers a complete spectrum of energy solutions.
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	Changwon plant, South-Korea Sejong plant, South-Korea <sup>109</sup>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	N/A

<sup>105</sup> "Hyosung Corporation Is New Owner of Lloyd Dynamowerke," Wire Düsseldorf, Messe Düsseldorf GmbH, accessed 14 June 2018, [https://www.wire-tradefair.com/cgi-bin/md\\_wiretube/lib/pub/tt.cgi/Hyosung\\_Corporation\\_is\\_new\\_owner\\_of\\_Lloyd\\_Dynamowerke.html?oid=2361978&lang=2&ticket=g\\_u\\_e\\_s\\_t](https://www.wire-tradefair.com/cgi-bin/md_wiretube/lib/pub/tt.cgi/Hyosung_Corporation_is_new_owner_of_Lloyd_Dynamowerke.html?oid=2361978&lang=2&ticket=g_u_e_s_t).

<sup>106</sup> "Power Systems PU," Hyosung, accessed 14 June 2018, [http://www.hyosung.com/en/biz/power\\_industrial\\_systems/power\\_systems.do](http://www.hyosung.com/en/biz/power_industrial_systems/power_systems.do).

<sup>107</sup> Ibid.

<sup>108</sup> "Wind Turbine Systems," Hyosung, accessed 14 June 2018, <http://www.hyosungpni.com/eng/product/GreenEnergy/WindTurbineSystem.jsp>.

<sup>109</sup> "Global Network," Hyosung, accessed 14 June 2018, <http://www.hyosungpni.com/eng/customer/globalNetwork.jsp>.

## 2.5 Offshore Substation Foundations

The following five companies supply offshore substation foundations.

### 2.5.1 Sif Group B.V.

<i>Key economic figures:</i>	Revenue: €400.3 million Employees: 620 Headquarters: Roermond, The Netherlands Founded: 1948 Website: <a href="https://sif-group.com/en/">https://sif-group.com/en/</a> <sup>110</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Monopiles</li> <li>• XL monopiles</li> <li>• Piles for jackets</li> <li>• Tubulars for gravity-based structures</li> <li>• Suction-based foundations</li> <li>• Jack-up legs</li> <li>• Anchor/mooring piles</li> <li>• Cladded structures</li> <li>• Jacket tubulars: jacket legs, launch legs, cones, bracings, pile sleeves, pin piles, internal ring stiffeners<sup>111</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• Amrum Bank (80 monopiles and 80 transition piles)</li> <li>• Meerwind (30 monopiles)</li> <li>• Sheringham Shoal (90 monopiles and 88 transition pieces)</li> <li>• Gunfleet Sands 1 (30 monopiles and 30 transition pieces)</li> <li>• Gunfleet Sands 2 (18 monopiles and 18 transition pieces)<sup>112</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	N/A
<i>Market share specifics for the OSW industry:</i>	32.5% in substructures (European market, 2016) <sup>113</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	Sif is the leading supplier of offshore foundations for wind projects. Its experience in building oil and gas platforms and its existing production lines make it an important market player within the offshore platform market.
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<p>The Sif headquarters and main production site is situated along the river Maas, near the city of Roermond in the Netherlands. This allows for Sif's transport of the oversized piles and foundations, using its own river barges, to a site in the Port of Rotterdam at Maasvlakte 2.</p> <p>The Sif assembly and coating hall is located there, including 42 ha storage area and a state-of-the-art terminal with a 400-meter-deep quay section on-site.<sup>114</sup></p>
<i>Current and projected production</i>	The order book is largely filled for 2017. 2018 and 2019 may be

<sup>110</sup> *Annual Report 2016*, Sif, 2017, <http://sif-group-annualreport.com/>.

<sup>111</sup> "Foundations for Oil and Gas Platforms," Sif, accessed 14 June 2018, <https://sif-group.com/en/oil-gas/foundations>.

<sup>112</sup> "Projects," Sif, accessed 18 June 2018, <https://sif-group.com/en/oil-gas/projects#list>.

<sup>113</sup> *Key Trends and Statistics 2016*, Wind Europe, 13–14..

<sup>114</sup> *Leading in Offshore Foundations: Offshore Foundations: Offshore Foundations for Wind Turbines and Oil and Gas Platforms*, Company Profile Sif, Sif, June 2016, <https://sif-group.com/en/about-us/media-kit/375-documentation>.

<i>capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	slower due to low gas and oil prices. In 2017, production exceeded 200,000 tons for the first time. <sup>115</sup>
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<sup>115</sup> *Annual Report 2016*, Sif Holding N.V.

## 2.5.2 EEW Group

<i>Key economic figures:</i>	Revenue: ~€480 million (2014) Employees: 2,100 Headquarters: Erndtebrück, Germany Founded: 1936 Website: <a href="http://www.eew-group.com">http://www.eew-group.com</a> <sup>116</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Monopiles</li> <li>• XL monopiles</li> <li>• Transition pieces</li> <li>• Jack components</li> <li>• Pin piles/suction piles</li> <li>• Cones</li> <li>• Jack-up legs</li> <li>• Jacket components</li> <li>• Topsides/decks</li> <li>• Tension legs<sup>117</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• Sandbank (72 monopiles)</li> <li>• Gwynt y Môr (160 monopiles)</li> <li>• Beatrice (84 jackets)</li> <li>• Walney 1-5 (189 monopiles)</li> <li>• Veja Mate (67 monopiles)</li> <li>• Baltic I and II (183 monopiles and jackets)<sup>118</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	N/A
<i>Market share specifics for the OSW industry:</i>	28.2% in substructures (European market, 2016) <sup>119</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry</i>	Very experienced company, ready to install pipe components. Three specialized construction plants for offshore wind components.
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Erndtebrück, Germany</li> <li>• Rostock, Germany <ul style="list-style-type: none"> <li>○ Direct access to the Baltic Sea</li> </ul> </li> <li>• Siegen, Germany</li> <li>• Billingham, UK<sup>120</sup></li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	Rostock: 200,000 MTA production capacity Erndtebrück: 108,000 MTA production capacity Siegen: 40,000 MTA production capacity + 30,000 MTA Billingham: 35,000 MTA production capacity <sup>121</sup>

<sup>116</sup> “EEW Group” [in German], Deutschlands Top-Familienunternehmen, accessed 15 June 2018, <http://www.top-familienunternehmen.de/companies/Oo7z4FZ/erndtebr%C3%BCcker-eisenwerk-gmbh-%26-co.-kg/umsatz/mitarbeiterzahl>.

<sup>117</sup> “Offshore Oil and Gas,” EEW, accessed 15 June 2018, <http://www.eew-group.com/industries/offshore-oil-gas/>.

<sup>118</sup> “Portfolio,” as available on 27.6.2018 at <https://eew-group.com/index.php?id=55&L=1%22#c313>

<sup>119</sup> *Key Trends and Statistics 2016*, Wind Europe, 13–14.

<sup>120</sup> “Locations,” EEW, accessed 15 June 2018, <http://www.eew-group.com/locations/>.

<sup>121</sup> *Ibid.*

## 2.5.3 Steelwind Nordenham

<i>Key economic figures:</i>	Part of the Dillinger Group Revenue: N/A Employees: ~300 Headquarters: Nordenham, Germany Founded: 1685 (Dillinger), 2014 (Steelwind) Website: <a href="http://www.steelwind-nordenham.de/steelwind/index.shtml.en">http://www.steelwind-nordenham.de/steelwind/index.shtml.en</a> <sup>122</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• XL monopiles</li> <li>• Transition pieces</li> <li>• Conical</li> <li>• Tubular piles<sup>123</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	Race Bank offshore wind farm (91 XL monopiles) <sup>124</sup>
<i>Date of entry into the OSW industry:</i>	2014 <sup>125</sup>
<i>Market share specifics for the OSW industry:</i>	14.8% in substructures (European market, 2016) <sup>126</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	Part of Dillinger Group. Dillinger is Europe's leading producer of heavy plate. <sup>127</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Nordenham (Blexen), Germany <ul style="list-style-type: none"> <li>○ Direct North Sea access</li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	DONG Energy contracted Steelwind to supply monopiles for Borkum Riffgrund 2. Steelwind plans to produce 100–120 monopiles per year. <sup>128</sup>

<sup>122</sup> "About Us," Steelwind Nordenham, accessed 14 June 2018, <http://www.steelwind-nordenham.de/steelwind/unternehmen/wersindwir/index.shtml.en>.

<sup>123</sup> Steelwind Nordenham, "Products," accessed 14 June 2018, <http://www.steelwind-nordenham.de/steelwind/produkte>.

<sup>124</sup> "Organisations Working on Race Bank," 4C Offshore, accessed 14 June 2018, <http://www.4coffshore.com/windfarms/contracts-on-race-bank-uk18.html>.

<sup>125</sup> Steelwind Nordenham, "About Us."

<sup>126</sup> Wind Europe, *Key Trends and Statistics 2016*, 13–14.

<sup>127</sup> Dillinger, "Rollout Pünktlich zur Eröffnung: Steelwind Nordenham Produziert Mega-Monopile mit Weltweit Größtem Durchmesser" [in German], 18 September 2014, <https://www.dillinger.de/d/de/aktuelles/news/rollout-puenktlich-zur-eroeffnung-steelwind-nordenham-produziert-mega-monopile-mit-weltweit-groesstem-durchmesser-68279.shtml>.

<sup>128</sup> Ibid.

## 2.5.4 Ambau GmbH

<i>Key economic figures:</i>	<p>Revenue: unavailable          Employees: 750          Headquarters: Am Mellensee, Germany          Founded: 1993          Website: <a href="http://ambau.com/">http://ambau.com/</a><sup>129 130</sup></p>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Monopiles</li> <li>• Transition pieces</li> <li>• Large-diameter pipe components</li> <li>• Components</li> <li>• Jacket piles<sup>131</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• Windpark Nordergründe (monopiles und transition pieces)</li> <li>• Nordsee One (monopiles und transition pieces)</li> <li>• Wehlens (offshore tower for Siemens Wind Power GmbH)</li> <li>• SeaAngel (offshore tower for Mitsubishi Heavy Industries)</li> <li>• Meerwind South and East (monopile and transition pieces)</li> <li>• Global Tech 1 (offshore tower (for Adwen GmbH)</li> <li>• Thornton Bank 1–3 (offshore tower for Senvion GmbH)</li> <li>• BARD Offshore 1 (offshore tower (or BARD Holding)</li> <li>• Alpha Ventus (offshore tower)<sup>132</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	Alpha Ventus, the first project, was started in 2009. <sup>133</sup>
<i>Market share specifics for the OSW industry:</i>	12.5% in substructures (European market, 2016) <sup>134</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	Ambau is an experienced company in the offshore industry and has worked on many offshore projects. <sup>135</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Am Mellensee, Germany             <ul style="list-style-type: none"> <li>○ Headquarters</li> </ul> </li> <li>• Gräfenheinrich, Germany             <ul style="list-style-type: none"> <li>○ River Sea shipping access (Binnenhafen Aken/Elbe)</li> </ul> </li> <li>• Cuxhaven, Germany             <ul style="list-style-type: none"> <li>○ Direct North Sea access (deep water terminal)</li> </ul> </li> <li>• Dessau-Roßlau, Germany             <ul style="list-style-type: none"> <li>○ River Sea shipping access (Binnenhafen Dessau)<sup>136</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	N/A

<sup>129</sup> Ambau GmbH, “Historie,” on 27.6.2018 available at <http://ambau.com/home/>

<sup>130</sup> Statista, “AMBAU GmbH: Umsatz und Mitarbeiter 2016” [in German], accessed 15 June 2018, <https://de.statista.com/unternehmen/118100/ambau-gmbh>.

<sup>131</sup> Ambau GmbH, “Gründungsstrukturen” [in German], accessed 15 June 2018, <http://ambau.com/produkte/gruendungsstrukturen/>.

<sup>132</sup> Information on individual projects [in German] retrieved on 15 June 2018 from Ambau GmbH, “Referenzen” accessed 18 June 2018, <http://ambau.com/referenzen/nordergruende/>.

<sup>133</sup> Ambau GmbH, “Offshore-Testfeld Alpha Ventus” [in German], accessed 15 June 2018, <http://ambau.com/referenzen/alpha-ventus/>.

<sup>134</sup> Wind Europe, *Key Trends and Statistics 2016*, 13–14.

<sup>135</sup> Ambau GmbH, “Growth with Energy,” accessed 15 June 2018, <http://ambau.com/en/home/>.

<sup>136</sup> Ambau GmbH, “Standorte” [in German], accessed 15 June 2018, <http://ambau.com/unternehmen/standorte/>.



## 2.5.5 Bladt Industries

<i>Key economic figures:</i>	<p>Revenue: DKK 3,484 million (€468 million)                  Employees: ~826                  Headquarters: Alborg, Denmark                  Founded: 1965                  Website: <a href="https://www.bladt.dk">https://www.bladt.dk</a><sup>137</sup></p>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Monopiles</li> <li>• Transition pieces</li> <li>• Jackets</li> <li>• Offshore wind substations</li> <li>• Infrastructure and oil and gas platforms<sup>138</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• Veja Mate (67 transition pieces)</li> <li>• Burbo Bank Extension (31 transition pieces)</li> <li>• Wikinger (41 jacket foundations)</li> <li>• Sandbank (72 transition pieces)</li> <li>• Gode Wind 1 and 2 (total: 97 transition pieces + 97 monopiles)</li> <li>• Butendiek (80 transition pieces)</li> <li>• Baltic 2 (41 jacket foundations + 39 transition pieces)</li> <li>• Westernmost Rough (35 transition pieces + 35 monopiles)</li> <li>• Borkum Riffgrund 1 (77 transition pieces + 77 monopiles)</li> <li>• Meerwind (24 transition pieces)</li> <li>• Horns Rev 2 (91 transition pieces + 91 monopiles)</li> <li>• Hornsea Project One (fabrication of three offshore substations)</li> <li>• Bligh Bank (fabrication of offshore substation)</li> <li>• Nordsee One (fabrication of offshore substation and jacket structure, including piles)</li> <li>• Sandbank (fabrication of offshore substation and jacket structure, including piles)</li> <li>• Walney 1 and 2 (fabrication of offshore substation and jacket structure)</li> <li>• Gunfleet Sands (fabrication of offshore substation)<sup>139</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	First foundation delivered 2002 (Samsø, Denmark) <sup>140</sup>
<i>Market share specifics for the OSW industry:</i>	7% in substructures (European market, 2016) <sup>141</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	<p>Bladt Industries was the first company ever to produce a substation. It has extensive experience, with 40 years of offshore know-how.</p>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Aalborg, Denmark                         <ul style="list-style-type: none"> <li>○ Production and development</li> </ul> </li> <li>• Lindø, Denmark                         <ul style="list-style-type: none"> <li>○ Workshops</li> <li>○ Manufacturing large steel structures.</li> <li>○ Movable roof and back</li> <li>○ 1,000-ton gantry crane</li> <li>○ Painting and blasting facilities</li> </ul> </li> </ul>

<sup>137</sup> Bladt Industries, *Annual Report 2016*, 2017, 6-7, 8-9, [http://www.epaper.dk/bladtas/annualreport2016/annualreport2016\\_low/](http://www.epaper.dk/bladtas/annualreport2016/annualreport2016_low/).

<sup>138</sup> Ibid.

<sup>139</sup> Ibid.

<sup>140</sup> Bladt Industries, "List of References: Foundations and Substations Offshore," June 2018, [https://www.epaper.dk/bladtas/referencebrochures/2018\\_06\\_offshorewind\\_ref\\_final/](https://www.epaper.dk/bladtas/referencebrochures/2018_06_offshorewind_ref_final/).

<sup>141</sup> Wind Europe, *Key Trends and Statistics 2016*, 13–14.

	<ul style="list-style-type: none"> <li>• Teesside, UK <ul style="list-style-type: none"> <li>○ Steel manufacturing facilities</li> <li>○ Blasting and painting facilities<sup>142</sup></li> </ul> </li> </ul>
<p><i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i></p>	<p>Currently working on:</p> <ul style="list-style-type: none"> <li>• Hornsea Project 1<sup>143</sup> <ul style="list-style-type: none"> <li>○ 56 transition pieces for this project will be manufactured in Teesside</li> <li>○ 40 transition pieces will be manufactured in Aalborg</li> </ul> </li> <li>• Beatrice<sup>144</sup> <ul style="list-style-type: none"> <li>○ 30 jacket foundations will be manufactured in Lindø</li> </ul> </li> <li>• Arkona<sup>145</sup> <ul style="list-style-type: none"> <li>○ 60 monopiles (subcontracted to EEW)</li> </ul> </li> <li>• Walney Extension<sup>146</sup> <ul style="list-style-type: none"> <li>○ Production of 47 transition pieces<sup>147</sup></li> </ul> </li> </ul>

<sup>142</sup> Bladt Industries, “Facilities,” [https://www.bladt.dk/teesside-uk-\(1\).aspx](https://www.bladt.dk/teesside-uk-(1).aspx). [I got an error message for this page. But I found a new source w/ the info: reNEWS Ltd., “Bladt, EEW Set Up Shop in UK,” 21 November 2014, <http://renews.biz/79560/bladt-eew-set-up-shop-in-uk/>.

<sup>143</sup> 4C Offshore, “Hornsea Project One Offshore Wind Farm,” last updated 3 June 2018, <http://www.4coffshore.com/windfarms/hornsea-project-one-united-kingdom-uk81.html>.

<sup>144</sup> 4C Offshore, “Beatrice Offshore Wind Farm,” last updated 8 June 2018, <http://www.4coffshore.com/windfarms/beatrice-united-kingdom-uk53.html>.

<sup>145</sup> 4C Offshore, “Organisations Working on Arkona Offshore Wind Farm.”

<sup>146</sup> 4C Offshore, “Organisations Working on Walney Extension,” accessed 14 June 2018, <http://www.4coffshore.com/windfarms/contracts-on-walney-extension-uk63.html>.

<sup>147</sup> Bladt Industries, reNEWS Ltd., “Bladt, EEW Set Up Shop in UK (on 29.6.2018 available at: <http://renews.biz/79560/bladt-eew-set-up-shop-in-uk/>)

## 2.5.6 St3 Offshore

<i>Key economic figures:</i>	Revenue: N/A Employees: <1,000 Headquarters: Szczecin, Poland Founded: 2013 Website: <a href="https://st3-offshore.com">https://st3-offshore.com</a> <sup>148</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Transition pieces</li> <li>• Jacket foundations</li> <li>• Monopiles<sup>149</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• Race Bank (91 transition pieces)<sup>150</sup></li> <li>• Borkum Riffgrund 2 (20 bucket jacket foundations)<sup>151</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	2015 (first contract: Race Bank) <sup>152</sup> Factory building started in 2013 <sup>153</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	St3 Offshore has a state-of-the-art facility with the highest gantry crane in Europe: 120m high, with 1,400 tons of lifting capacity. <sup>154</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Szczecin, Poland <ul style="list-style-type: none"> <li>○ Engineering and design department</li> <li>○ Highest gantry crane in Europe</li> <li>○ Direct Baltic Sea access<sup>155</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	Transition pieces capacity: 150 pcs/year <sup>156</sup>

<sup>148</sup> "About Us," ST3 Offshore, accessed 15 June 2018, <https://st3-offshore.com/about-us/>.

<sup>149</sup> "Products," ST3 Offshore, accessed 15 June 2018, <https://st3-offshore.com/production/products/>.

<sup>150</sup> "Organisations Working on Race Bank," 4C Offshore.

<sup>151</sup> "Organisations Working on Borkum Riffgrund 2," 4C Offshore, accessed 15 June 2018, <http://www.4coffshore.com/windfarms/contracts-on-borkum-riffgrund-2-de30.html>.

<sup>152</sup> "Organisations Working on Race Bank," 4C Offshore.

<sup>153</sup> "Factory in Szczecin," ST3 Offshore, accessed 15 June 2018, <https://st3-offshore.com/production/factory-in-szczecin/>.

<sup>154</sup> "About Us," ST3 Offshore.

<sup>155</sup> "Factory in Szczecin," ST3 Offshore.

<sup>156</sup> "Products," ST3 Offshore.

## 2.5.7 GSG Towers

<i>Key economic figures:</i>	Revenue: N/A Employees: N/A Headquarters: Gdańsk, Poland Founded: 2010 Website: <a href="http://www.gdanskshipyard.pl/en">http://www.gdanskshipyard.pl/en</a> <sup>157</sup>
<i>Product portfolio:</i>	<ul style="list-style-type: none"> <li>• Offshore structures (including foundations)</li> <li>• Wind towers<sup>158</sup></li> </ul>
<i>Previous relevant OSW activities:</i>	<ul style="list-style-type: none"> <li>• Birkum Riffgrund (transformer foundation; subcontracted by Bladt Industries)<sup>159</sup></li> <li>• Hornsea (three parts of the transformer Foundation; subcontracted by Bladt Industries)<sup>160</sup></li> </ul>
<i>Date of entry into the OSW industry:</i>	The wind power production line was opened in November 2010. <sup>161</sup>
<i>Key strengths/competitive advantages of the company within the OSW industry:</i>	GSG Towers, part of Stocznia Gdańsk, is a modern manufacturing facility with significant expertise in steel structures. It is strategically located at the Baltic Sea. <sup>162</sup>
<i>Location of the production centers for the products delivered to the OSW market and reasons for choosing these locations:</i>	<ul style="list-style-type: none"> <li>• Gdańsk, Poland <ul style="list-style-type: none"> <li>○ Two outfitting berths</li> <li>○ Modern cleaning and painting line</li> <li>○ Specialized cranes</li> <li>○ Seven-acre production hall</li> <li>○ Direct Baltic Sea access<sup>163</sup></li> </ul> </li> </ul>
<i>Current and projected production capacity for the products delivered to the OSW market (as of 2020, 2025, 2030):</i>	Production capacity of 150 thousand tons per year and 28 wind towers per month. <sup>164</sup>

<sup>157</sup> “About the Group,” Stocznia Gdańsk, accessed 15 June 2018, <http://www.gdanskshipyard.pl/en/about-us/about-the-group>.

<sup>158</sup> Aldona Dybuk, “Ships, Towers, and Constructions: Made by Stocznia Gdańsk,” Manufacturing Journal (website), last updated 15 June 2018, <http://www.manufacturing-journal.net/company-profiles-home/56-construction/1925-ships-towers-and-constructions-made-by-stocznia-gdask>.

<sup>159</sup> “GSG Towers to Build a Huge Transformer Station,” Stocznia Gdańsk, 12 August 2016,

<http://www.gdanskshipyard.pl/en/contact-media-tenders/news/gsg-towers-to-build-a-huge-transformer-station>.

<sup>160</sup> “Automated Prefabrication,” Stocznia Gdańsk, accessed 15 June 2018, <http://www.gdanskshipyard.pl/en/automated-prefabrication/our-offer-prefabrication>.

<sup>161</sup> Manufacturing Journal, “Ships, Towers, and Constructions.”

<sup>162</sup> Ibid.

<sup>163</sup> Ibid.

<sup>164</sup> “Production Assets,” Stocznia Gdańsk, accessed 15 June 2018, <http://www.gdanskshipyard.pl/en/about-us/production-assets/wind-tower-line>.

## 2.6 Barriers to Entry into the EU and Baltic Sea Offshore Wind Market

Companies seeking to enter the offshore wind market face significant entry barriers, which are particularly formidable for SMEs. Each of the main components of the supply chain discussed above is associated with specific entry barriers.

### 2.6.1 Cables

The production of offshore cables is very cost-intensive and requires highly specialized manufacturing facilities. All companies that produced inter-array and export cables for the European market in 2016 had been in business for many years, and most were large and well-established multinational corporations.

For new market players, the extremely high costs of market entry include investments to build a manufacturing plant, hire skilled workers, buy specialized cable-laying vessels, and develop expertise in subsea cabling. The cables must be extremely durable to withstand underwater conditions. Subsea cables are made to cover extremely large distances, thus minimizing the number of joints required; as a result, the subsea cable production process differs greatly from that for onshore cables. Only specialized manufacturing plants can perform the necessary production steps. The production of HVDC cables is associated with greater risks than is that of HVAC cables. HVDC technology is less established, and it would be more difficult for SMEs to absorb potential setbacks and associated financial losses.

Entry into the European offshore wind market is very challenging for small and medium-sized cable manufacturers. Larger, more established cable manufacturers (such as suppliers from Asia), with greater financial resources and expertise, are more likely to enter the European market.<sup>165</sup>

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<sup>165</sup>*Submarine Telecoms: Industry Report 3*, TeraBit Consulting, 2014 (on 27.6.2018 available at <http://www.sata-sec.net/downloads/bsn/2014-submarine-cable-market-industry-report.pdf>); Matthew Hirsch, "HVDC on the Rise: EPRI Helps Industry Navigate New Opportunities with High-voltage Direct Current Transmission," EPRI Journal (website), published 18 January 2018, <http://eprijournal.com/hvdc-on-the-rise/>.

## 2.6.2 Converters, transformers, and protection equipment

Competitive pressure and production costs for converters, transformers, and protection equipment are very high for existing players and would be even higher for new market entrants, due to their relative lack of experience.

The research and development of converters, transformers, and protection equipment is extremely cost-intensive and must include additional elements, such as employee training and education. Like the subsea cable market, component development and manufacturing requires specialized facilities, a wide international network of experts, and relevant know-how.

The market for converters is very new; only seven substations have been built to date. The costs associated with the technology are high. In general, only large corporations can absorb the associated risks.<sup>166</sup>

Offshore challenges like extremely deep water, hostile weather conditions, and lack of shore-side infrastructure pose additional entry barriers. The components must survive for many years in an aggressive marine environment. Not only must market players deal with considerable cost pressures; they must also produce extremely durable and high-quality products.<sup>167</sup>

Small and medium-sized manufacturers are unlikely to enter the market. As with subsea cables, larger companies (e.g., suppliers from Asia) would be far better equipped to enter the European market. Established corporations are expected to dominate the market in the long run.<sup>168</sup>

## 2.6.3 Offshore substation foundations

The barriers for new market entrants offshore substation foundations are different from those for the products described above. The technology for foundations is less complex than is that for cables, converters, and transformers. There are some similarities, however; for example, new market entrants must have facilities suitable for manufacturing large and heavy products. They also need direct water access to transport products in order to avoid the higher costs of road transport.<sup>169</sup>

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<sup>166</sup> Claus Gorgs, "Deutschlands schwimmende Steckdose" [in German], *Manager Magazin*, 20 July 2017, <http://www.manager-magazin.de/unternehmen/energie/general-electric-jagt-siemens-bei-offshoe-windkraft-a-1158523-3.html>.

<sup>167</sup> Ole Jacob Wang Nielsen, "Reducing Weather Downtime in Offshore Wind Turbine Installation," *High Wind Challenge*, published 13 June 2016, <https://highwind.editionmanager.com/2016/06/13/reducing-weather-downtime-in-offshore-wind-turbine-installation/>.

<sup>168</sup> Claus Gorgs, "Deutschlands schwimmende Steckdose" [in German], *Manager Magazin*, 20 July 2017, <http://www.manager-magazin.de/unternehmen/energie/general-electric-jagt-siemens-bei-offshoe-windkraft-a-1158523-3.html>.

<sup>169</sup> Norbert Hartfil, "Nordenham: Steelwind-Ansiedlung versetzt Blexer in Hochstimmung" [in German], *NWZ Online*, 24 September 2011, [https://mobil.nwzonline.de/wesermarsch/wirtschaft/nordenham-steelwind-ansiedlung-versetzt-blexer-in-hochstimmung\\_a\\_1,0,583171070.html](https://mobil.nwzonline.de/wesermarsch/wirtschaft/nordenham-steelwind-ansiedlung-versetzt-blexer-in-hochstimmung_a_1,0,583171070.html).

Here, too, high capital intensity poses a significant obstacle for SMEs seeking to enter the market. Larger companies may consider entering the market by creating subsidiaries and drawing on preexisting expertise in the field. One example is Steelwind Nordenham, which is part of the Dillinger Group, an established steel producer.<sup>170</sup>

### 3. Maintenance and Service

Maintenance and repair service refers to the combination of all technical and administrative measures (including management approaches) performed over the lifetime of a unit to maintain safe and proper functioning. Especially in offshore wind projects, the machines and equipment are exposed to potentially hostile environmental conditions. It is in the manufacturers' interest to have to perform as little maintenance and repair work as possible—particularly in the early years of the project—because the unique challenges of the offshore environment make activities more expensive and therefore have a greater impact on overall profitability.

Many companies provide asset and condition monitoring, a system in which components are constantly monitored to detect wear or corrosion in a timely manner. It extends service life and helps avoid costly productivity losses. Companies may also include end-of-service-life support, a service in which the manufacturer provides solutions for or takes over the decommissioning process and product teardown.<sup>171</sup>

Most of the manufacturing companies offer maintenance and servicing solutions. Often the large companies hire subcontractors for some of the maintenance and service tasks.

First, an overview about the services offered by the component manufacturers will be given. Additionally, other companies from the maintenance and service industry will be described.

#### 3.1 Cables

All the component manufacturers offer maintenance services. Additionally, some offer full life cycle management.

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<sup>170</sup> Steelwind Nordenham, "About Us."

<sup>171</sup> "Condition Monitoring Systeme" [in German], wind-turbine.com, 27 June 2015, <https://wind-turbine.com/magazin/ratgeber/betriebsfuehrung/40196/condition-monitoring-systeme.html>.

### 3.1.1 Prysmian Group

<p><i>Company offers:</i></p>	<p>The Prysmian Group provides monitoring and maintenance, as well as complete assets management.</p> <ul style="list-style-type: none"> <li>• Diagnostics for predictive maintenance</li> <li>• Maintenance decision support</li> <li>• Spare parts management</li> <li>• Fast intervention in case of fault</li> <li>• Corrective maintenance</li> <li>• Global presence</li> </ul> <p>The Prysmian Group Asset Monitoring System offers in-depth, accurate, real-time information on the status of the project. Prysmian’s technological platforms, PRY-CAM and Multipurpose Monitoring System, have service capabilities for components including cables, terminations, and joints.<sup>172</sup></p>
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### 3.1.2 Norddeutsche Seekabelwerke GmbH (NSW)

<p><i>Company offers:</i></p>	<p>SW offers repair and maintenance service.</p> <ul style="list-style-type: none"> <li>• On-site analyses</li> <li>• Selection of the cable route/protective measures</li> <li>• Development of cables and technology</li> <li>• Product selection</li> <li>• Project management (documentation, training, permits, etc.)</li> <li>• Proactive repair and maintenance strategy<sup>173</sup></li> </ul>
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### 3.1.3 NKT Group GmbH

<p><i>Company offers:</i></p>	<p>NKT Asset Management Services were established to manage existing cable systems and include:</p> <ul style="list-style-type: none"> <li>• Experienced, highly-skilled field engineers that are ready to be deployed quickly</li> <li>• A selection of partner service providers, enabling NKT to offer a comprehensive set of services</li> <li>• A single point of contact for all services</li> <li>• 24/7/365 asset management</li> </ul>
<p><i>Additional company specifics:</i></p>	<p>NKT has a recycling program. The NKT plant recycles 97% percent of the cable scrap that it processes. The cables are broken down into their components (plastic, insulation, and metals), which are then</p>

<sup>172</sup> “Smart Monitoring and Maintenance,” Prysmian Group, accessed 15 June 2018, <https://www.prysmiangroup.com/en/products-and-solutions/power-grids/smart-monitoring-and-maintenance>; “Partial Discharge Measurement with PRY-CAM,” Prysmian Group, accessed 15 June 2018, <https://www.prysmiangroup.com/en/products-and-solutions/services/partial-discharge-measurements-with-pry-cam>.

<sup>173</sup> “Services,” NSW, accessed 15 June 2018, <http://www.nsw.de/en/Cable/Services>.



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sorted, processed, and rebuilt into new products for the cabling industry.<sup>174</sup>

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<sup>174</sup> “Asset Management,” NKT, accessed 15 June 2018, <http://www.nkt.com/services/asset-management-services.html>.

### 3.1.4 Nexans S.A.

<i>Company offers:</i>	Nexans provides a variety of different services and solutions for its customers including: <ul style="list-style-type: none"><li>• 24-hour hotline for high-voltage troubleshooting</li><li>• Recycling for cable drums</li><li>• Cable management</li></ul>
<i>Additional company specifics:</i>	Nexans offers a recycling solution for production waste and end-of-life cables. <sup>175</sup>

### 3.1.5 JDR Cable Systems Ltd.

<i>Company offers:</i>	JDR services offer full life-cycle support, including repair and maintenance. <ul style="list-style-type: none"><li>• Installation, repair (including emergency response)</li><li>• Equipment and product maintenance (onshore and offshore)</li><li>• Asset healthcare and assurance</li><li>• Equipment and product upgrades</li><li>• Cable installation support and consultancy</li><li>• Assistance during laying operations</li><li>• Offshore pull-ins and temporary hang-offs</li><li>• Cable terminations</li><li>• Electrical and fiber-optic testing</li><li>• Full repair service, including field splice repairs<sup>176</sup></li></ul>
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## 3.2 Converters, Transformers, and Protection Equipment

All manufacturers offer maintenance services. Some also provide full life-cycle management.

### 3.2.1 ABB Ltd.

<i>Company offers:</i>	ABB provides services throughout the life cycle of the transformer and the converters, from commissioning to recycling. <ul style="list-style-type: none"><li>• Advanced services (e.g., monitoring)</li><li>• Maintenance and repairs</li><li>• Installation and commissioning</li><li>• Spares and consumables</li><li>• Engineering and consulting</li><li>• Training<sup>177</sup></li></ul>
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<sup>175</sup> “Nexans Recycling Solutions: Your Cable Waste Has Never Been More Valuable!,” Nexans, accessed 15 June 2018, [http://www.nexans.com/eservice/Corporate-en/navigate\\_245577/Recycling.html](http://www.nexans.com/eservice/Corporate-en/navigate_245577/Recycling.html).

<sup>176</sup> “Renewables Product and Installation Services,” JDR Cables, accessed 19 June 2018, <http://www.jdr cables.com/product-and-installation-services-4/renewables-field-services/#sthash.vqLOYqGE.mwa47nCr.dpbs>.

<sup>177</sup> ABB, “Transformer Service,” accessed 15 June 2018, <http://new.abb.com/products/transformers/service>.

<i>Additional company specifics:</i>	ABB offers life-cycle assessments that help develop long-term maintenance and improvement plans. End-of-life services (decommissioning, resale, disposal, and recycling): ABB offers a life-cycle management service to provide effective maintenance, migration, and obsolescence planning. <sup>178</sup>
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### 3.2.2 Siemens AG

<i>Company offers:</i>	Siemens offers service solutions across the whole value chain. <ul style="list-style-type: none"> <li>• Remote diagnostics center</li> <li>• Flexible service solutions</li> <li>• Scheduled services</li> <li>• Troubleshooting</li> <li>• Standard corrective work</li> <li>• Major corrective work</li> <li>• On-site technical support</li> </ul>
<i>Additional company specifics:</i>	Siemens life-cycle stages include materials, manufacturing, installations, operation and maintenance, and dismantling and recycling. <sup>179</sup> At the end of the product life cycle, Siemens disassembles the components. Material transportation and disposal is carried out in accordance with environmental regulations. <sup>180</sup>

### 3.2.3 General Electric Company

<i>Company offers:</i>	GE Grid Solutions offers several additional services, including: <ul style="list-style-type: none"> <li>• Asset Performance Management (APM) software suite</li> <li>• Consulting</li> <li>• Support and services</li> <li>• Technical training</li> <li>• Custom expert services provided as part of a multi-year partnership</li> <li>• Comprehensive services to ensure full equipment availability and performance</li> <li>• Proximity to the manufacturer’s local service personnel and remote operations support</li> <li>• Prompt response time with 24/7 emergency support</li> <li>• Reliable asset management and life extension of equipment</li> </ul>
<i>Additional company specifics:</i>	GE offers Asset Performance Management (APM), with “value-added

<sup>178</sup> “Service for ABB Power Converters and Inverters,” ABB, accessed 15 June 2018, <http://new.abb.com/power-converters-inverters/service>; “End of Life Services: Life-cycle Management,” ABB, accessed 18 June 2018, <http://new.abb.com/products/measurement-products/service/end-of-life-services>.

<sup>179</sup> “Wind Turbines and Service Solutions” – See: Siemens <https://www.siemens.com/content/dam/webassetpool/mam/tag-siemens-com/smdb/wind-power-and-renewables/corporate-campaigns/environmental-product-declarations/epd-swt-7.0-154.pdf>, page 6 (as available on 27.6.2018)

<sup>180</sup> “A Clean Energy Solution: From Cradle to Grave,” Siemens, accessed 18 June 2018, <https://www.siemens.com/content/dam/internet/siemens-com/global/market-specific-solutions/wind/brochures/epd-swt-6-0-154.pdf>; “Uniting Environment and Technology”, See: <https://www.siemens.com/content/dam/webassetpool/mam/tag-siemens-com/smdb/wind-power-and-renewables/corporate-campaigns/environmental-product-declarations/epd-swt-7.0-154.pdf>, page 7 (as available on 27.6.2018)

solutions” to optimize asset operation and decisions on maintenance and replacements. APM accounts for “asset condition, criticality, and performance objectives.”<sup>181</sup>

### 3.2.4 CG Power Systems

*Company offers:*

CG Global provides services including installation, maintenance, servicing, refurbishment, and repairs.

- Installation and relocation
- Repairs and refurbishment
- Transformer enhancement and improvement
- Spares and equipment
- Testing and advice
- Life extension programs supported by condition-based monitoring systems<sup>182</sup>

### 3.2.5 Schneider Electric

*Company offers:*

Schneider Electric offers comprehensive maintenance services, from preventive to corrective measures, including:

- On-site diagnostic and condition-based maintenance
- Wind farm substation control systems
- Wind farm weather and power management
- Wind farm management system

## 3.3 Other Companies Offering Maintenance and Service Solutions

The following companies offer maintenance and service solutions.

### 3.3.1 Briggs Marine and Environmental Services

<i>Location:</i>	Burntisland, UK Aberdeen, UK Direct water access <sup>183</sup>
<i>Company offers:</i>	Vessel charter Marine salvage Diving services Environmental services <sup>184</sup>
<i>Previous OSW activity:</i>	The Briggs Group has a long-time maintenance contract with Ørsted. It is responsible for the maintenance and repair of export and inter-array cabling for several offshore wind farms, including Anholt. <sup>185</sup>

<sup>181</sup> “Services,” GE Grid Solutions, GE, accessed 19 June 2018, <https://www.gegridsolutions.com/services.htm>; “Services: Asset Performance Management,” GE Grid Solutions, GE, accessed 15 June 2018, <http://www.gegridsolutions.com/services/apm.htm>.

<sup>182</sup> See: <http://www.cgglobal.com/others/joint-ventures/CG-Holdings-Belgium-NV.html> (as available on 27.6.2018)

<sup>183</sup> “Where We Work,” Briggs Marine and Environmental Services, accessed 15 June 2018, <http://www.briggsmarine.com/about-us/where-we-work/>.

<sup>184</sup> “Marine Services,” Briggs Marine and Environmental Services, see: <http://www.briggsmarine.com/services/> (as available on 27.6.2018)

### 3.3.2 ElecTech Solutions

<i>Location:</i>	Great Yarmouth, UK Near the shore <sup>186</sup>
<i>Company offers:</i>	Marine electronics Communications Environmental and remote monitoring <sup>187</sup>
<i>Previous OSW activity:</i>	Amrumbank West Maintenance and repair services for buoys Real-time website data <sup>188</sup>

### 3.3.3 NDE Offshore

<i>Location:</i>	Sollentuna, Sweden <sup>189</sup>
<i>Company offers:</i>	<p><b>ROV</b></p> <ul style="list-style-type: none"> <li>• Inspection</li> <li>• Pipeline survey</li> <li>• Cable tracking</li> <li>• NDT work</li> <li>• Trenching operations</li> <li>• Mechanical work</li> <li>• Dive support</li> </ul> <p><b>Rope</b></p> <ul style="list-style-type: none"> <li>• NDT</li> <li>• General construction</li> <li>• Inspection</li> <li>• Repair</li> <li>• Maintenance</li> </ul> <p><b>Diving</b></p> <ul style="list-style-type: none"> <li>• UW welding</li> <li>• HP waterjet cleaning</li> <li>• Dredging</li> <li>• Welding</li> <li>• NDT: MPI/eddy current/ACFM</li> <li>• Inspection</li> </ul> <p>Corrosion protection:</p> <ul style="list-style-type: none"> <li>• Underwater painting, anode replacement, etc.<sup>190</sup></li> </ul>
<i>Previous OSW activity:</i>	Worked for and with Siemens and ABB on wind farms including Global Tech 1 and BARD 1. Tasks included inspecting the foundations and performing maintenance and installation. <sup>191</sup>

<sup>185</sup> “Organisations Working on Anholt Wind Farm,” 4C Offshore, accessed 15 June 2018, <http://www.4coffshore.com/windfarms/contracts-on-anholt-dk13.html>.

<sup>186</sup> “Contact,” ElecTech Solutions, accessed 15 June 2018, <http://electechsolutions.co.uk/pages/contact/contact.asp>.

<sup>187</sup> “About Us,” ElecTech Solutions, accessed 15 June 2018, <http://electechsolutions.co.uk/pages/about/about.asp>.

<sup>188</sup> “Organisations Working on Amrumbank West,” 4C Offshore, accessed 15 June 2018,

<http://www.4coffshore.com/windfarms/contracts-on-amrumbank-west-de05.html>.

<sup>189</sup> “Contact,” NDE Offshore, accessed 15 June 2018, <https://www.ndeoffshore.com/contact/>.

<sup>190</sup> “Services,” NDE Offshore, accessed 15 June 2018, <https://www.ndeoffshore.com/services/>.

<sup>191</sup> “References,” NDE Offshore, accessed 15 June 2018, <https://www.ndeoffshore.com/References/>.

### 3.3.4 HBC Group

<i>Location:</i>	Gilleleje, Denmark Cheshire, UK <sup>192</sup>
<i>Company offers:</i>	<p><b>UK branch</b></p> <ul style="list-style-type: none"> <li>• Rigging</li> <li>• Construction</li> <li>• Cable testing</li> <li>• Cable termination</li> <li>• Confined space work</li> <li>• Generator management</li> </ul> <p><b>Denmark branch</b></p> <ul style="list-style-type: none"> <li>• Diving</li> <li>• Subsea inspections</li> <li>• Subsea construction</li> <li>• Subsea installation</li> <li>• Subsea maintenance</li> <li>• Confined space diving</li> <li>• Survey</li> <li>• ROV work</li> <li>• O&amp;M<sup>193</sup></li> </ul>
<i>Previous OSW activity:</i>	<p>Borkum Riffgrund 1: subsea structural inspections (ongoing)</p> <p>Borkum Riffgrund 2: subsea structural inspections (ongoing)</p> <p>Gode Wind 1 and 2: subsea structural inspections; (ongoing)</p> <p>Horns Rev 2: subsea structural inspections (ongoing)<sup>194</sup></p>

### 3.3.5 Pharos Offshore Group

<i>Location:</i>	Cheltenham, UK <sup>195</sup>
<i>Company offers:</i>	<ul style="list-style-type: none"> <li>• Subsea trenching Vehicle</li> <li>• Subsea cable plough</li> <li>• Subsea cable recovery</li> <li>• Subsea excavation</li> <li>• Concrete mattress installation</li> <li>• Route clearance</li> <li>• Subsea cable recovery package</li> <li>• Subsea boulder and debris removal</li> <li>• Consultancy, design, and build<sup>196</sup></li> </ul>
<i>Previous OSW activity:</i>	<p>Walney: boulder clearance</p> <p>London Array: export cable repair<sup>197</sup></p>

<sup>192</sup> "Contact," HBC Group, accessed 15 June 2018, <http://hbc-tec.co.uk/contact/>.

<sup>193</sup> "Services," HBC Group, accessed 15 June 2018, <http://hbc-tec.co.uk/services/>.

<sup>194</sup> "Wind Farm Experience," HBC Group, accessed 15 June 2018, <http://hbc-tec.co.uk/about/wind-farm-experience/>.

<sup>195</sup> "Pharos Offshore Group," Pharos Offshore Group, accessed 15 June 2018, <http://www.pharosoffshoregroup.com/>.

<sup>196</sup> "Services," Pharos Offshore Group, accessed 15 June 2018, <http://www.pharosoffshoregroup.com/services/>.

<sup>197</sup> "Projects," Pharos Offshore Group, accessed 15 June 2018, <http://www.pharosoffshoregroup.com/projects/>.

## 4. Outlook

The data collected for this report indicate that market entrants with limited experience face sizable barriers and formidable economic risks. These conditions create openings for larger companies (e.g., suppliers from Asia) to enter the European market.

As shown in section 3, the European market is dominated by a few well-established suppliers of OWE transmission components, especially in the case of export cables. An increasing demand for export cables is forecast for the coming years. The interviews indicate that, in Europe, the supply is limited, though currently sufficient. If demand increases suddenly, a rapid adjustment on the supply side will be required in order to avoid potential bottlenecks.

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