Supply chain challenges for the Supergrid development and employment opportunities

Final Report

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<tr>
<td>AC</td>
<td>Alternating Current</td>
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<td>DC</td>
<td>Direct Current</td>
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<tr>
<td>CLV</td>
<td>Cable Lay Vessel</td>
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<tr>
<td>ENTSO-E</td>
<td>European Network of Transmission System Operators for Electricity</td>
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<td>EU</td>
<td>European Union</td>
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<td>EWEA</td>
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<td>GW</td>
<td>GigaWatt = 1.000MW</td>
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<td>HV</td>
<td>High Voltage</td>
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<td>HVAC</td>
<td>High Voltage Alternating Current</td>
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<td>HVDC</td>
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<td>Hz</td>
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<td>km</td>
<td>Kilometre = 1,000 metres</td>
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<td>kV</td>
<td>Kilovolt = 1,000 Volts</td>
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<td>kW</td>
<td>Kilowatt = 1,000 Watts</td>
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<td>LCC</td>
<td>Line Commutated Converters</td>
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<td>LDPE</td>
<td>Low Density Polyethylene</td>
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<td>m</td>
<td>metre</td>
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<td>MI</td>
<td>Mass Impregnated Paper Insulation</td>
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<td>MV</td>
<td>Megavolts = 1,000 kilovolts</td>
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<td>MVA</td>
<td>Mega Volt Ampere</td>
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<td>MW</td>
<td>Megawatt = 1,000 kilowatts</td>
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<td>MWh</td>
<td>Megawatt Hour</td>
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<td>NSCOGI</td>
<td>North Seas Offshore Grid Initiative</td>
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<td>OHL</td>
<td>Over Head Line</td>
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<td>OG-report</td>
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<td>OSS</td>
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<td>PPL</td>
<td>Polypropylene Paper Laminate</td>
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<td>P&amp;L</td>
<td>Permits and Licenses</td>
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<td>PR</td>
<td>Primary Reserve</td>
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<td>RES</td>
<td>Renewable Energy Source</td>
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<td>SCFF</td>
<td>Self-Contained Fluid Filled</td>
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<td>SSCV</td>
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<td>T&amp;D</td>
<td>Transmission &amp; Distribution</td>
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<td>TSV</td>
<td>Trench Support Vessel</td>
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<td>TYNDP</td>
<td>ENTSO-E Ten Year Network Development Plan</td>
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<td>VSC</td>
<td>Voltage Source Converter</td>
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<tr>
<td>WTG</td>
<td>Wind Turbine Generator</td>
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<td>XLPE</td>
<td>Cross Linked Polyethylene</td>
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3.0. Introduction

The aim of this report prepared by FOSG Working Group 3 is to assess possible supply chain constraints including education, training and employment opportunities, which will be a result of the development and construction of Supergrid. So far, the analysis only relates to the North Sea region and therefore to the North Sea offshore grid as part of the future European Supergrid.

The supply chain constraints included in this document are very much influenced on issues covered by other FOSG documents such as for example the implementation of a European regulatory framework which should be the basis of large scale development projects such as Supergrid. Until such a framework is established, the development of some initial parts of a Supergrid may be temporarily hampered as recently demonstrated in Germany whereby TenneT has postponed the development of new grid connection projects pending the outcome of the German Grid Crisis discussions.

The main supply chain questions to be answered in this document in order to arrive at conclusions and/or recommendations are as follows:

1. What do we consider to be first phase of Supergrid? What would be the pace of development of such a Supergrid?
2. An estimated overall circuit length of approximately 30,000 km¹ (about 1/3 HVAC and 2/3 HVDC) may be needed for offshore grid in Northern Europe by 2030. Do we have the capacity to deliver these submarine power cables?
3. Subsequently is there sufficient installation capacity in the present and future market available to install these subsea power cables systems?
4. There is an estimated requirement of 228 no’s of DC converters² (offshore and onshore) to be installed up to 2030. Do we have the capacity to deliver all electrical and structural components? Is there sufficient design and construction capacity to build these offshore DC converter platforms?
5. Subsequently is there sufficient installation capacity available to transport, install and commission all these DC converter platforms in a given time frame?
6. What are the potential social and economical effects of Renewable Energy (Offshore Wind Farms in particular) including Supergrid?

Remark: Throughout this report various numbers of installed offshore wind and wave and tidal capacity GW expectations by 2030 are shown varying between 125 GW and 143GW. These numbers are used in various reports which were studied by FOSG. We have not concluded on a final number as the final number of GW’s developed by 2030 are still subject to discussion at various national levels within EU.

¹ OG-report
² OG-report
3.1. Supergrid First Phase

3.1.1. The OffshoreGrid project
The OG-report used as the basis for this report is a techno-economic study funded by EU's Intelligent Energy Europe (IEE) program. The report summarizes the key assumptions, the methodology and the results, draws conclusions from the works and provides recommendations.

Figure 1: FOSG - Phase 0 and Phase 1

3.1.2. The benefits of an offshore grid
The exploitation of Europe's offshore wind potential brings new challenges and opportunities for power transmission in Europe. Offshore wind capacity in Europe is expected to reach approximately 143GW\(^3\) in 2030. The majority of the sites currently being considered for offshore wind projects are situated close to the European coast, not further than 100 km from shore. This is in part due to the high cost of grid connection, limited grid availability and the absence of a proper regulatory framework for wind farms that could feed several countries at once. Looking at the North Sea alone, with its potential for several hundreds of GW’s of wind power (outlook 2050), an offshore grid connecting different Member States would enable this wind power to be transported to the load centers and at the same time facilitate competition and electricity trade between countries.

As described in more detail in FOSG report on technology developments the following conclusions can be defined as a result of a Supergrid being developed and built:

\(^3\) EWEA
a. Security of supply
   - Improve the connection between big load centers around the North Sea.
   - Reduce dependency on gas and oil from unstable regions.
   - Transmit indigenous offshore renewable electricity to where it can be used onshore.
   - Bypass onshore electricity Transmission bottlenecks.

b. Competition and market
   - Development of more interconnection between countries and power systems enhances trade and improves competition on the European energy market.
   - Increased possibilities for arbitrage and limitation of price spikes.

c. Integration of renewable energy
   - Facilitation of large scale offshore wind power plants and other marine technologies.
   - Enabling the spatial smoothing effects of wind and other renewable power, thus reducing variability and the resulting need for flexibility.
   - Connection to large hydropower capacity in Scandinavia, introducing flexibility into the power system to compensate for variability from wind and other renewable energy sources.
   - Contribution to Europe’s 2020 targets for renewables and CO2 emission reductions.

3.1.3. OG-report: Main results in a nutshell

The first step of the OG-report was to study the connection of the offshore wind farms to shore, without looking into the details of an interconnected solution yet. In this regard the report comes to the conclusion that using “hub–connections” for offshore wind farms – that is, connecting up wind farms that are close to one another, forming only one transmission line to shore – is often highly beneficial.

Second step, based on this hub-connection scenario two highly cost efficient interconnected grid designs were then drawn up - the “Direct Design” and “Split Design”.
Direct Design:
In the Direct Design, interconnectors are built to promote unconstrained trade between countries and electricity markets as average price difference levels are high. Once additional direct interconnectors become non-beneficial, tee-in, hub-to-hub and meshed grid concepts are added to arrive at an “overall grid design”.

@ OG-report  Figure 2: Direct Design
@OG-report   Figure 3: Split Design

**Split Design:**
The Split Design is essentially designing an offshore grid around the planned offshore wind farms. Thus, as a starting point not only direct interconnectors are investigated but also interconnections are built by splitting the connection of some of the larger offshore wind farms between countries. These “split wind farm connections” establish a path for (constrained) trade. These offshore wind farm nodes are then - as in the Direct Design - further interconnected to establish an overall 'meshed' design where beneficial.

**Total Investment Costs:**
Based on the conclusions of the OG-report the total investment costs (see figure 1.1 OG report and figure 4 below) are €86 bn for the Direct Design and €84 bn for the Split Design. This includes €69 bn of investment costs for the most efficient connection (hub-connections where beneficial as in the hub base case scenario) of the ~130GW of offshore wind farms to shore, as well as about €9 bn for interconnectors planned within the Ten Year Network Development Plan (TYNDP) of the European transmission system operator association (ENTSO-E). The rest of the investments that make up the €84 bn or €86 bn for this further interconnected grid are €7.4 bn for the Direct Design and €5.4 bn for the Split Design. These relatively
small additional investments generate system benefits of €21 bn (Direct Design) and €16 bn. (Split Design) over a lifetime of 25 years – benefits of about three times the investment.

In addition to connecting 143 GW of offshore wind power to the grid, the offshore interconnection capacity in northern Europe can, as a result, be boosted from 8 GW today to more than 30 GW, see also Entso-E figure 5 below!
Both designs are thus highly beneficial, from a socio-economic perspective. When comparing in relative terms by looking at the benefit-to-CAPEX (Capital Expenditure) ratio, the Split Design is slightly more cost-effective than Direct Design and yield a higher benefit return on investment.

There are many other benefits from the investments in an offshore grid, including connecting generation in Europe (in particular wind energy) to the large hydro power “storage” capacities in northern Europe, which can lower the need for balancing energy within the different European regions. Offshore hubs also mitigate the environmental and social impact of laying multiple cables through sensitive coastal areas and allow for more efficient logistics during installations. Furthermore a meshed offshore grid based on the tee-in concept and hub-to-hub interconnections (see figure 6 below) makes the offshore wind farm connection more reliable and can significantly increase security of supply within Europe.

Figure 6: Tee-in concept and Hub - Hub

Remark: Redundancy measures in Supergrid concept need to be included as increased dependency on such a large scale grid system make the system also vulnerable to connection failures and subsequently restoration capacities need to be included in the concept design (same as in telecom).

Figure 7 below extracted from the OG-report, indicates in different scenarios the HVAC and HVDC cable circuit lengths to be installed by 2030 for the regions around the Baltic and North Sea, the English Channel and the Irish Sea.
In the “Radial case”, in which all offshore wind farms are connected individually to the on shore grid, around 42,000 km high voltage submarine circuit should be installed by 2030. (Remark: the added cost for radial case is: ~€14bn)

In the “Hub case”, in which different offshore wind farms can be connected to one offshore substation (hub) before the power is exported to the shore, the circuit length can be dramatically reduced to 28,000 km (=Base case for WG3)

The “hub base case” scenario served as the starting point for the overall northern Europe offshore grid design development. The additional circuit length to develop this grid is estimated to 3,000 km for the “Split design” and 3,800 km for the “Direct design”. The overall circuit length needed is about 31,000 km for the Split design and 32,000 km for the Direct design. For both 10,000 km are AC cables.

If this were done, the report has calculated that €14 bn could be saved up to 2030 compared to connecting each of the 321 wind farms individually to shore – that is, investments would be €69 bn as opposed to €83 bn.
The report assessed 321 offshore wind farm projects, and recommends that 114 of these 321 be clustered in hubs. (Approx. 228 onshore and offshore DC converters).

3.1.4. Key notes

- A final view on the 1st leg of Supergrid seems still premature, the planning and construction of offshore wind farms in the North Sea (in particular UK and Germany) which are considered to be a backbone of wind farms to be included in Supergrid is still in planning phase with various options under consideration, until there is more clarity about final planning and realization we trust to define the 1st leg of the Supergrid.

- Supergrid proposes the Split Design Concept as suggested in the OG-report.

- North – South grid connections compare with East – West grid connections seems more adequate in terms of power distributions.

- Potential timescales:
  - 2012-2020: Develop the appropriate regulatory, technical, and supply chain frameworks for the delivery of the Supergrid. Development and planning of first projects (phase one) within Supergrid concept. Remark: For more details concerning development of Supergrid from a technical perspective reference is made to table 3.4 – “development of Supergrid in 3 phases”, in FOSG report ‘Roadmap to the Supergrid Technologies’ page 59!
• 2020-2030: Construct the first phase of the Supergrid, connecting ~130 GW of Offshore Wind Capacity in Europe to the Member states load centers, with a total circuit length of ~30,000 km thus enabling a Single European Electricity Market,
• 2030-2050: deliver a complete Supergrid connecting a Single European Electricity market with neighboring markets.

3.2. Submarine Power Cable: Demand & Supply

Remark: Cable Technologies including High Voltage AC and DC submarine power cables are described in chapter 2.5, page 47-52, of the Work Group 2 report.

3.2.1. Future Demand for HV cable supply
The potential demand for HV submarine power cables is estimated on the basis of the Offshore Grid report presented in the previous chapter. Depending on the design of the grid (hub, direct or split), the overall route or circuit length needed is estimated at 28,000 km with an additional 3,000km or 3,600km for split design or direct design. (See also figure 7 – AC and DC circuit lengths, above).

Considering that AC circuits use 3-core HVAC cables and DC circuits use two single core HVDC cables (bi-polar system), high voltage submarine cable needs up to 2030 in northern Europe would be, under this OG-report assumptions, about 10,000 km HVAC 3-core cable (thus 30,000 km AC 1-core cable) plus 2*20,000 km HVDC 1-core cable (40,000 km DC 1-core cable). See Nexans images, (photo 1 & 2) for 3-core XLPE AC and MI DC cables below.

Photo 1: AC – 245kV 3-core XLPE: @ Nexans

Photo 2: DC 450kV MI (NorNed) @ Nexans
HVAC and HVDC submarine power cable systems are part of the long distance transmission systems to transport offshore generated wind power (AC) via HVDC technology to the onshore AC grid system as shown in the figure 9 below.

To assess orders of magnitude of the annual needs for HV cable, we need to use rough proxies such as the following:

- offshore wind would develop according to EWEA trajectory up to 2020 and with a constantly growing pace between 2020 and 2030, respecting interim target of 43 GW by 2020 and final target of ~143 GW by 2030; (see figure 10 below)
- high voltage cable demand proportional to offshore wind installed capacity. (Figure 11)
Figure 10: Offshore wind development in northern Europe: ~130 GW 2030 (EWEA)

Figure 11: Corresponding annual HV cable demand under these assumptions
Under these assumptions:
- Before 2015, maximum annual HV (AC or DC) submarine cable demand could be about 1,900 km 1-core length;
- In 2020, annual pace could be about 4,200 km 1-core length per year;
- Between 2020 and 2030, annual cable demand could reach up to about 5,500 km of HV (AC or DC) 1-core cable per year.

Those approximations have to be considered as estimated ceilings as:
- This is skewed upwards for the first phase (before 2020) as offshore wind should develop at growing distance from shore, thus with increasing high voltage cable demand for wind farms to be built after 2020 and, consequently, inferior export cable length for wind farms to be built before 2020;
- Regarding AC/DC breakdown, those results presume a constant share of AC/DC. Though, the share of DC should increase as UK round 3 projects will materialize. Nevertheless, as a DC circuit requires 2 single-core cables and an AC cable requires 3-core, when counting 1-core length the results are not that different.

On top of this estimated demand for Northern Europe, further market demands should be noted for other projects including offshore wind farms outside Europe, interconnection projects outside Northern Europe, such as Islands Connections and HV cable demands for offshore O&G industry.

3.2.2. Manufacturing capacity versus demand:

Respecting EU competition requirements, FOSG couldn’t organise exchange of information relative to individual manufacturing capacities between cable suppliers. Thus, FOSG relies on published information to assess the overall manufacturing capacity of cable suppliers in Europe.

According to Bloomberg New Energy Finance:\n
« [Before 2011 supply of high voltage export cables] has been dominated by three established players: ABB, Prysmian and Nexans. At current capacity this trio can produce 800 km of HVAC cables per year, or 2,400 km of cable core, but this may be increased to 1,400 km per year with minimal investment required to install new extrusion lines at existing plants. […] This capacity will be supplemented by two market new comers NKT and NSW (a subsidiary of General Cable) which have already secured contracts – and JDR Cables from 2014. […] By 2015, we expect cable production from the six market participants to reach 1,300 km per year, or potentially up to 2,000 km with capacity increases from the established players.”

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2,000 km capacity of cable is around 5,000 km of 1-core (depending on the breakdown between AC and DC) which is above the need seen on the market for offshore wind farms (4,200km/y) by 2020 with a high hypothesis.

Thus, European high voltage submarine cable capacity should broadly exceed by 2015 the high estimation of needs for northern Europe offshore wind farms and offshore grid, leaving capacity available (between 2,000 and 4,100 km / yr cable core) for projects elsewhere in Europe and rest of the world. Moreover, cable manufacturers also have capacities in the Far East Region.

**Beyond 2015, as cable demand would continue to grow, European cable manufacturers would progressively adapt their capacity as the forecasted demand become reality.**

Indeed, the European cable industry\(^5\) is willing to continue investing in production facilities in Europe to meet the growing demand for submarine cables as it did for underground cables in 2011, the European cable and wire manufacturing industry has increased its annual production capacity to around 3,500 km of extra high voltage cables\(^6\). With this 40% increase since 2008, industry responds to the increased demand for partial undergrounding of transmission lines.

This statement is confirmed notably by the recent (8 December 2011) announcement from ABB of a major investment to double the capacity of its high-voltage cables manufacturing facility in Karlskrona, Sweden, to meet growing demand for subsea power cables.

**Lead Times for New Production Capacity:**
The lead time needed to bring new subsea cable capacity on line should not be a barrier to meet the growing demand. Indeed, if building a new cable factory from green-field could take 3 years, expansion is most likely to come from existing submarine cable HV or even MV cable suppliers setting up new HV production facilities around existing plants.

Moreover, those lead times are compatible with offshore wind or interconnection projects lifetime which is rather in the range from 5 to 8 years, exceeding by far the lead time to bring new cable manufacturing capacity on line.

Finally, the earlier the cables are ordered, the better can be the manufacturing planning and thus the higher will be the capacities.

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\(^5\) Cf. Europacable press release: « European cable manufacturers commit to support large scale renewable deployment” 29 November 2011.

\(^6\) Cf. Europacable press release 13 July 2011
ENTSO-E shares this view in its report issued in November 2011; “A stronger relationship between offshore project owners and cable suppliers will assist in ensuring that manufacturing capacity can meet the growing demand for offshore grid connections. Forward ordering quantities of cable to secure capacity and de-risk investment by cable suppliers would benefit this.”

Nevertheless, beside the development of XLPE HVDC cable (max. rating assumed today: 320kV, see also table 2 in this chapter), European cable manufacturers have capacity to produce paper insulated (MI) cables which allow higher voltage (in service today: 500kV, awarded 600kV (MI-PPL)), require significantly less factory joints and have a long proven track record, thus being a technical option to be considered in particular offshore where cost are expected to be similar to XLPE (which is different from land where XLPE can be significantly less expensive because lead sheath used in submarine cable as water barrier can be replace by aluminium).

It is clear that the prediction and planning of future projects is complex and the possible demand for various HV power cable types may be uncertain. Indeed, the numerous studies about the development of offshore wind and the supply chain requirements conclude on various forecasts. Indeed, OffshoreGrid study’s hypothesis related to offshore wind development is ambitious for 2020 (43 GW in Northern Europe which is more than EWEA’s estimation of 40 GW in 2020 for all European countries, this EWEA target being considered as ambitious). Whether the prognosis of 43GW can be accomplished by

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7 Entso-E report ITTc.l.1.3.3.
2020 need to be seen and confirmed in the very near future as this may be influenced by the developments in UK (round 3) and with German grid connection projects being delayed. Moreover, it is worthwhile to flashback to the past history whereby over the last two decades a number of very large interconnector projects were announced which indicated a rather stable production process for cable suppliers to keep up sufficient levels of production and storage facilities and staff. In reality several of these large projects did not materialise (yet) and subsequently “overcapacity” in the market was closed at that time.

It is fair to say that today 2011/2012 the market seems to be in an upswing strategy based the fact that offshore wind will develop as planned by governments, capital investments can be attracted and finance and economical crisis are not lasting too long.

In recent years, we have already seen that existing cable production capacities have been extended with more production lines and that the commitment of the European cable manufacturers to adapt their capacity to meet the demand is materializing.

At last, the sector should wonder about relationship between stakeholders including the risk sharing between suppliers and customers to find the most efficient balance allowing long term confident relationship in the whole supply chain.

With early clear and firm commitments and firm planning of projects there’s no doubt that the cable industry will adapt its capacity to meet the increasing demands.

3.2.3. Key notes:

- a growing annual demand for submarine HV cable up to 2030 induced by Northern Europe development of offshore wind, but still uncertainty on the pace;
- on the basis of the OG-report and the ENTSO-E Offshore Transmission Technology report dated 24-11-2011, there is no evidence that there would be a supply bottleneck in the short term (< 2015);
- the cable manufacturing industry commitment to invest to meet the effective growing demand has demonstrated its credibility. In case further investments are needed the lead time to built and test new capacities will be 3-4 years.;
- with clear and phased commitments for all stakeholders (especially on regulatory framework and subsequently financing issues) to develop the offshore grid in northern Europe, cable supply shouldn’t be a bottleneck in the medium to long term.
3.3. Cable installations

In Work Group 2 report, Appendix II, some of the installation principles associated with submarine power cable installation activities are described and should be read in conjunction with this chapter 3.3.

3.3.1. HV power cable installations:

The installation of any submarine power cables is a challenging operation requiring specific equipment and expertise and should be given careful planning of available resources and preparation before commencing any project.

Submarine power cables are typical installed from a dedicated cable laying vessel (CLV) which is either a dedicated vessel or a barge or other vessel modified to install power cables. These CLV’s need to be equipped with one or more large turntables (large rotating platform) for storing the power cables to be installed (static-baskets are unsuitable for larger submarine cables due to the torsional forces involved when coiling a cable relative to winding onto a turntable). For the installation of HVDC a dual turntable system is needed when there is a requirement to bundle the cables. For non-bundled cables single turntable systems can be used by installing cables with a pre-determined separation at the seabed.

The two of the largest CLV’s, Giulio Verne and Skagerrak, today can install approximately 7,000 ton of power cable in a single installation campaign. The maximum length of cable a single CLV can install in a single campaign is subject to cable design, cable handling, cable configurations (single AC cable or bundled DC or non-bundled DC cables) and cable weights.

HV Cable laying activities can be divided in several types of operations:

- Shore landing activities, at deepwater and shallow water:
  - Deepwater shore landings can usually be executed by main cable lay vessel as there are no draft restrictions for the cable lay vessels.
  - Shallow water shore landing usually requires shallow water barges or vessels which can be beached if required and possible. Draft restrictions caused by long shorelines with water depth less than 10m eliminate the potential use of large power cable ships in these areas.

- Deepwater cable laying activities:
  - Most sea areas with more than 10m water depth can be considered as deepwater cable laying operations which can in general and in particular for most North Sea areas be executed by either large power CLV’s and smaller CLV or barges. Deeper water areas assume more > 100m and subject to cable weight require additional cable equipment to ensure sufficient tension capacity to control cable laying.
Cable Protection i.e. Burials:
In order to protect the HV cables from damage from marine activities such as fishing gear, etc., the cable needs to be buried. Subject to the soil conditions along the cable route, this can be accomplished either by using mechanical trenchers such as ploughs or wheel chain cutters which cut a trench for the cable to fall into. When the soil is jettable cables can be protected by water jetting whereby high pressure water jets fluidise a tranche of the seabed which the cable sinks into and is then covered.

Ploughing (See photo 4) or cutting is a more complex operation and is generally carried out by the main CLV in a simultaneous lay and burial operation. The burial speed for this type of operation is generally very low and determines the lay speed. Post lay, burial by water jetting is more flexible and usually faster as lay and burial are separated and therefore the laying speed (CLV) cannot be hampered by burial operations. Post lay burial is usually conducted by a separate trenching support vessel (TSV) following the CLV to minimise the time that the main CLV is required at sea.

![Photo 4: Simultaneous lay & burial concept by using plough at shore landing in UK](image)

Summarizing cable installation requirements:
The following considerations and remarks should be made before making any final conclusions about annual lengths of cables to be installed by available cable lay vessels:

- Cable production schedules and storage facilities determine installation schedules.
- Installation requirements (Surface lay or Simultaneous lay & burial)
- Sailing distance between factory and installation site
Jointing operations (timing and skills)
Weather windows (summer & winter seasons)
Environmental restrictions
Permits and Licenses
Marine Warranty Requirements
etc

Remark: Sailing distance from factory to installation site has major impact on annual installation capacities. The majority of CLV's are slow speed vessels due to their length/width ratio. Subsequently if a non-European power cable project needs to be executed for example in Arabian Gulf in Asia, sailing times are heavily influencing project schedules.

**Considerations for Project Planning:**
The methodologies for cable protections determine to a large extend the engagement of the CLV in the cable installation process. The speed of cable lay between surface lay and simultaneous plough operations can differentiate by a factor 5 – 10 in some cases. It is obvious that the utilisation factor of a CLV on an annual basis will be significant influenced. **Smart Resource Project Planning is needed!**

### 3.3.2. Installation capacity requirements:
An estimated overall route or circuit length of approximately 30,000 km \(^8\) (about 1/3 HVAC and 2/3 HVDC) may be needed for offshore grid in Northern Europe by 2030.

The development of projects requiring CLV's to be utilised are the main drivers for cable installers to invest in cable installation capacities. Noting there is a correlation between projects, the cable supply planning and the installation planning, cable installers will try to align themselves with the production planning and resources available to meet cable installation demands.

Project planning and long term planning of projects will be ultimately important for the supply chain to make an optimal use of the available capacities. Instead of projects competing with each other which we have often seen (for example in Offshore wind projects) planning between Grid connection projects should be overall coordinated to make optimum use of existing capacities, **in other words we need an “Overall Planning Authority” engaged in Smart Resource Project Planning for large scale developments such as rolling out Supergrid concept!**

Remark: Planning of installation activities during winter seasons in North Sea should be re-considered as they introduce large planning constraints and last but least they are risky and costly.

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\(^8\) OG-report
Supply chain challenges for cable installations:
Submarine power cable installation is a highly specialised industry, requiring dedicated power cable CLV’s to be manned by highly specialised crews.

In the recent years some new CLV’s with up to 4.600 ton capacity have been delivered in the market which was notably a result of the UK round 1 and round 2 offshore wind farm developments and considering next generation wind farms planned. Recently a new installation vessel AMC Connector (see photo 5) with 6.000 ton +3.000 ton cable storage capacity was introduced to participate in power cable market. Another CLV with 5.000 ton capacity will be delivered in 2012. (See table below). No real shortage of CLV’s has been encountered sofar.

Photo 5: AMC Connector, chartered by ABB

Capacity available till 2030:
Today (1Q2012) there is still new tonnage under construction as well as some conversions planned (see table). It should be noted that CLV’s also find themselves in demand in the oil & gas sectors, which may introduce some further increasing competition for their services.

The need of long distance power transmissions such as Supergrid and point to point interconnectors introduce large scale HVDC projects (2 parallel HVDC cables) with relative long single power cable lengths (>100km) and subsequently large loading capacities. This demands opens the introduction of larger CLV’s with more capacities in different cable lay configurations.

Some large conversions of existing tonnage are being considered in near future with dual turntable systems (2 x 5.000 ton and 2 x 8.000 ton). This additional tonnage potentially support future demands (up to 2030), however as those vessels are also aged conversions, their lifetime may be restricted and new tonnage may be needed in future.

To release these new tonnages different contracting strategies will be required by project initiators to enable “independent” cable installation contractors and cable manufacturers to invest in these new vessels. By this change in contracting strategy the supply chain will be able to offer more flexible installation solutions.
**Capacity demand up to 2015:**
As concluded in chapter 3.2 Submarine Power Cable: Demand & Supply, the existing HV cable supply industry will be able to deliver ~2,000 km of cable length (HVAC and/or HVDC) by 2015. So the question is whether we have sufficient installation capacity available up to 2015 and beyond compared to the forecast needs of submarine cables after 2015?

Analysing the potential (theoretical) installation capabilities of the known 7 no’s of CLV’s ~ 40,000 tons of total turntable(s) capacity is available today, we conclude that there is no immediate bottleneck to install 1,300 km today or potentially 2,000 km of HV cables per annum for projects up to 2015. A total of 2,000 km of HV power cable is equal to ~130,000 – 200,000 ton of power cable/annum.

In average each of the CLV’s should be able to execute 4-5 single power cable lay campaigns per annum. This can be accomplished but require optimal planning of resources, including cable manufacturing.

**Table 3: Potential Cable Lay Vessels, including converted MPV’s:**

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Contractor</th>
<th>Type/name of CLV</th>
<th>Built</th>
<th>Turntable Capacity</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Prysmian*</td>
<td>Giulio Verne</td>
<td>1984</td>
<td>7.000 ton</td>
<td>1 turntable.</td>
</tr>
<tr>
<td>2.</td>
<td>Nexans*</td>
<td>Skagerrak Several conversions</td>
<td>1976</td>
<td>7.000 ton</td>
<td>1 turntable.</td>
</tr>
<tr>
<td>3.</td>
<td>AMC/Ezra</td>
<td>AMC Connector</td>
<td>2011</td>
<td>6.000 ton + 3.000 ton</td>
<td>MPV, contract arrangement with ABB*.</td>
</tr>
<tr>
<td>4.</td>
<td>VSMC</td>
<td>Stemat Spirit</td>
<td>2010</td>
<td>4.600 ton</td>
<td>1 turntable.</td>
</tr>
<tr>
<td>5.</td>
<td>Topaz</td>
<td>Team Oman</td>
<td>1999</td>
<td>3.300 ton</td>
<td>1 turntable. Long term charter to ABB*</td>
</tr>
<tr>
<td>6.</td>
<td>Smit Marine Contractors</td>
<td>Ndurance</td>
<td>2012</td>
<td>5.000 ton</td>
<td>New Built 2012. 1 turntable</td>
</tr>
<tr>
<td>8.</td>
<td>Smit Marine Contractors</td>
<td>Ndeavor</td>
<td>2013</td>
<td>5.000 (option) ton</td>
<td>Multi purpose vessel, New Built 2013</td>
</tr>
<tr>
<td>9.</td>
<td>DEME/Tideway</td>
<td>Rolling Stone</td>
<td>2013</td>
<td>2 x 5.000 ton</td>
<td>Conversion planned 2013</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>10.</td>
<td>Deeprock</td>
<td>Seahorse</td>
<td>2014-2015</td>
<td>2 x 8.000 ton</td>
<td>Conversion planned</td>
</tr>
</tbody>
</table>

*) Company also supplies HV power cables

Remarks:
- This table only contain CLV’s, however there are several anchor type barges equipped with turntables available in the power cable installation market, which are primarily specialized for landfall and very shallow water operations. Some of these barges can release some of potential demand in the installation market when this occurs.
- It should be noted that cable lay vessels engaged in the submarine telecom industry are in generally not suitable for the installation of submarine power cables due to the size and handling criteria differences between power cables and telecom cables.

Capacity demand 2015-2030 period
In theory the tonnage available today and in next 5 years ahead of us would be capable of installing 30,000 km power cable in the coming years to 2030.
Remark: This picture may change in case other projects elsewhere in the world are being awarded calling on same installation capacity in same time sequence.

The CLV’s planned (total capacity ~ 36,000 ton) is almost same as the existing capacity today again if this new capacity does not materialize there is a potential bottleneck in the installation market.

Capacity demand: > 2030:
For the long term development (> 2030 outlook) of large scale offshore grid systems such as Supergrid additional large scale tonnage (CLV’s) will be required in order to optimise the installation process and to reduce installation costs. CLV with large cable storage capacities (turntables) have a rather high productivity as the installation allow longer cable sections to be installed with less time consuming cable jointing operations where needed. Construction of these new CLV’s requires a high upfront investment and so ways of de-risking this investment should be considered through improved CLV owner relations and forwardly securing their services.

3.3.3. Key notes
- Assuming up to 2030 approx. 30,000km of HVAC&DC power cable routes need to be installed it seems that the existing and planned capacities can cope with the demand to install this capacity.
• Future projects and demands elsewhere in the world and in other energy fields such as O&G industry should be monitored carefully as this influence the installation market significant and therefore it should not be underestimated.
• Careful planning of supply and installation demand has significant influence concerning yearly production and installation levels. A call for an overall planning and resource authority should be considered by all stakeholders. Where new installation capacity is required (stakeholder conclusions) upfront investments need to be made by supply chain. Upfront planning and early commitment by stakeholders is needed to avoid future bottlenecks.
• The skills gap in combination with new CLV’s should not be ignored; cable jointers and specialist offshore cable installation knowledge is in short supply. Steps could be taken by the industry to close this skill gap.

Photo 6: @VSMC: Stemat Spirit beached at landfall UK

Photo 7: @VSMC: Shore landing Maasvlakte
Team Oman + shallow water barge

Photo 8: @ABB Team Oman – HVDC semi coilable.
3.4. Network Technologies for Supergrid

3.4.1. Introduction
A broad variety of technical solutions is available today for connecting RES as well as strengthening or expanding existing transmission networks. The 2 basic principles of electric power transmission are AC and DC. Both principles are used today. High power converters provide the necessary conversion of voltage and currents to exchange power between AC and DC networks.

AC Transmission Systems:
By far the most common electric power transmission technology used today is AC transmission. FOSG report ‘Roadmap to the Supergrid Technologies’ describe AC transmission systems in chapter 2.2.

Photo 9: @ Nexans: Skagerrak in Oslo Fjord:
Balance of plant suppliers for AC Transmissions systems:
- ABB
- Alstom Grid
- Siemens T&D
- CG
- Others …..

DC Transmission Systems:
The use of HVDC for power transmission is now a mature technology. From the first experimental schemes in Germany in the 1940’s to the first commercial schemes in Sweden in early 1950’s, HVDC has found a wide acceptance for many projects throughout the world. FOSG report ‘Roadmap to the Supergrid Technologies’ describe DC transmission systems in chapter 2.3

Balance of plant suppliers for DC Transmissions systems:
- ABB
- Alstom Grid
- Siemens T&D
- Others ….. ?

Supernode Concept
HVDC transmission can be operated in parallel with an integrated HVAC system creating a hybrid transmission system. Beside the increase of transmission capacity the HVDC can provide additional benefits to the AC system. Here a new type of combination of HVAC and HVDC systems is described called the “Supernode”
No show-stoppers:
FOSG report ‘Roadmap to the Supergrid Technologies’ has not identified any “show-stoppers” to the development of a European Supergrid. The VSC Transmission technology has already matured significantly during the last 15 years. For visionary long term planning of Transmission or Independent System Operators, the availability of key VSC-Grid technologies such as control and protection methods, main circuit design, grid master control, offshore operation experience and selective fault clearance techniques such as, DC breakers, can be assumed. This should give confidence to specify grid-enabled point-to-point connections that could be expanded to multi-terminals building blocks for a larger overlaid grid. The critical time-line for introduction of new technology lies primarily in solution of non-technical issues that will create a strong market growth and technology push. An early solution of these hurdles will influence the future roadmap to a greater extent than may be foreseen, due to the extended time constants in planning and construction of new transmission capacity.

Further details covering network technology for Supergrid can be found in chapter 2 of FOSG report ‘Roadmap to the Supergrid Technologies’.
3.5. Offshore Converter Platform installations

History:
So far generally Offshore Sub-Stations (OSS) have been built as HVAC platforms whereas the high voltage switch gear platforms, which connect a couple of OSS to the HVDC export cable are built as HVDC platforms (See figure 12: Supernode). In the German North Sea around twenty HVAC platforms are already in operation, under construction or planned. Another nine DC converter platforms are planned and/or under construction.

Remark: Borwin A converter platform is only one installed and operational today!

Both platform types need different installation methods because of the overall size and weight of the electrical equipped topside. Subsequently the industry can be divided in HVAC and HVDC platform concepts and installation methodologies.

Figure 13: Grid Access Projects in German North Sea
(dark blue: in operation or construction; light blue or green: planned)
3.5.1. Installation methodologies of HVAC substations

With a typical platform weight between 1.500 ton and 2.000 ton and physical dimension around 30 * 30 m with another increase in future up to 3.000 – 4.000 ton the methodology to install HVAC substations structures are very much similar to the capacity being used in O&G industry. Heavy lifting contractors can transport and install these offshore platforms without any major technical issues. Track records over the last 40 years have proven this. See photo below.

Photo 11: OG-report: courtesy of SLP Engineering

The first generation HVAC platforms (monopile concepts – see Belwind photo 10, chapter 3.4.1) in the North Sea and Irish Sea have been installed using sheer legs and floating cranes such as "Rambiz" which are more suited to operate in shallow waters and near shores with protected waters. The further use of this type of installation equipment in more remote offshore areas in North Sea is very unlikely due their operational limitations.

For the next generation of AC substations which are being built further O&G related heavy lifting capacities will be required, see photo SHL below Sheringham Shoal AC platform. Several heavy lifting contractors, such as Heerema, Seaway Heavy Lift and Saipem with large offshore crane vessels are operational in the North Sea and will be able to support the installation activities for large scale and large size AC platforms. As for all offshore projects the commitment to use this type of crane vessels should be made early in the development process in order to secure the vessels and also cover some of the structural design issues which effect offshore installation works.
Photo 12: @ Seaway Heavy Lifting – Sheringham Shoal AC platform.

**Self Installing AC platforms:**
Alternatively and as platforms grow in size and weight new platform concepts are being developed in order the industry to be less independent of the O&G heavy lift contractors. New installation technologies using self installing concepts for AC platforms will also be introduced, example of this development is the Alstom concept shown in figure 14 below:

![Figure 14: HVAC self-floating and self-installing 33/155kV offshore substation for offshore wind farm MEG 1 (Alstom Grid / SIAG)](image-url)
The marine technology and experience needed to install this type of platforms is readily available in market as in O&G similar type of projects has executed throughout the years. (see also HVDC self installing platform concepts).

**Conclusion AC platforms:**
In conclusion AC platform constructions, based on monopile and jacket constructions have not been hampered by any supply chain constraints as there are sufficient equipment suppliers, fabrication yards and heavy lift contractors available in the market. For new self installing AC platform concepts similar situation exist.

### 3.5.2. Construction & Installation methodologies of HVDC converter platforms

Offshore platforms are required to house offshore HVDC converters and associated switchgear and equipment. As converter power ratings increase so does their size and weight. As such this will have an impact on the size and construction of this type of platforms that will house these large DC converter systems. Present AC offshore platforms can weigh up to 3,000 - 4,000 tonnes. It is clear that this size and weight will further increase with larger DC converter platforms such as shown at Borwin A DC converter platform.

There is substantial worldwide knowledge in offshore platform construction from the O&G industry where platforms of a weight in excess of 10,000 tonnes are constructed routinely.

Until now offshore DC converter platforms have largely been bespoke solutions, though a level of standardisation can be seen to be developing among design and manufacturers. This is expected to continue with the expansion of offshore networks...
where both manufacturers and the asset owners will be looking for increased standardisation in order to ease construction, transportation, installation as well as maintenance and operation of the assets.

Due to the size and platform weights of the new generation DC converter platforms new installation concepts are under development and under construction at present. The size and weight of the so called jacket design structures are exceeding traditional lifting capabilities in the O&G market; subsequently this has led to first innovations by the suppliers and installers.

Innovations like this try to reduce the requirement for expensive offshore HLV’s such as HLV Thialf and the likes and thus ease some of the supply chain constraints for platform installations. Beside the high costs, the availability of this type of HLV capacity is also critical as they serve a worldwide market. These innovations should facilitate a faster rollout of offshore transmission technology.

**In conclusion:** As such there is no perceived technical barrier to constructing, transport and install offshore platforms capable of accommodating a 2GW HVDC converter.

**Remarks:**
1.) *Much of the integrated design calls for the installation of two no’s of 1GW converter platforms in order to reduce the risk of stranded assets and also to introduce better redundancy in the system.*
2.) *Design and installation engineering of new and sometimes innovative platform concepts always seems to be underestimated and subsequently cause delay in overall delivery times. This is likely to improve after 1st generation platforms have been delivered.*

**Construction sites:**
In principle all reputable and sufficient large offshore construction yards are able to build large and complex HVDC platforms (construction time, excluding design, approx. 2-3 years) like Hyundai, Samsung, Daewoo, McDermott, Cosco, Dubai Drydocks. In Europe the offshore constructions yards of Heerema and Aker can be considered. At present the majority of construction projects are driven by O&G and this will not change in the coming decades. At present it seems that available construction yards are able to meet the future demand for construction of DC converter platforms. However some of this construction capacity may be engaged in the fabrication of large scale turbine steel foundation constructions, which may effect total construction capacities including DC converter platforms.

**Floating and Semi-Floating concepts**
With weights for floating platforms exceeding a critical mass additional installation equipment will be needed such as large submersible barges to assist during offshore installations.
The marine activities associated with this type of installation activities (see photo’s 15 & 16) are relative short in time but need a suitable weather window for sail out and installation. The installation conditions are usual rather critical as most of these concepts are designed to make a one lifetime trip, large investments in improving transport and installation criteria are usually not justified. To achieve full benefit of floating platform concepts the final hook-up and pre-commissioning activities should be carried out as close as possible near the installation site, for example for Germany between Eemshaven and Cuxhaven and for UK at East coast UK ports or ports in Holland. Offshore hook-up and commissioning is significant ore expensive as onshore is one of the lessons we have learned from O&G!

Installation planning:
Since the transportation and offshore installation are critical for weather (waves and swell) it is rather difficult to predict the ultimate installation window. This implies that most of the works should be carried out in summer period or at least in periods which show statistical favourable conditions.

Port facilities:
Ports are not considered to be very critical for HVDC platforms; however we should be aware that there might be competition with Offshore Wind as they run large scale projects with huge demands on port logistics which may influence our HVDC activities. Very early commitments will be needed to secure quayside access for HVDC platform preparations.

Marine Installation resources:
The dedicated resources available to execute these marine installation activities are somewhat limited to the extend that only a few real specialist companies in this field of operation are available. The use of general marine support facilities is not very critical as a large fleet of this type of equipment is available in the area. However, project planning and engineering for this type of operations should not be underestimated as lessons have learned in the past.
Examples of these floating and self installing innovations are:
- ABB “self installing concept based on Gravity Based Structure “concept.
- Siemens “self lifting solution” called Wipos
- Alstom > assume AC concept to allow DC converter capacity.
Innovative and reliable self-installing design
Gravity Based Structure

- 700 – 1100 MW HVDC
- "Self-installed" Gravity Based Structure
- Steel structure
- Rest on seabed after installation
- Water depth 15 – 45 m
- Topside length 70 – 90 m
- Topside with 40 – 45 m (excl legs)
- Design base NORSOK, SOLAS, DNV
- Power cables and cassions collosion protected in legs
- Normally unmanned - remote operation
- Design life 30 years

Figure 15: Self-installing design with gravity based structure by ABB
Estimated Yearly Requirements (average):
Based on a number of 228 no’s of DC converter platforms⁹ are needed till 2030 and following estimation 50% offshore and 50% onshore converter and a power capacity of 1 GW per platform an estimated number of 114 offshore DC converter platforms are needed till 2030. The total number may be influenced by the future capacities of these converter platforms. Assume we can increase capacity from 1 GW to 2GW the numbers may change accordingly.

Based on these estimations the supply chain has to deliver an average of 6-7 HVDC converter platforms per year. Like the offshore construction yards and marine contractors had done in the O&G business in history they have the challenge to organize themselves to meet this demand.

3.5.3. Key notes:
- The installation of Offshore substations/platforms for AC systems is not critical as there is sufficient transportation and lifting capacity available in the North Sea.

⁹ OG-report
• The European T&D industry has adopted the challenge to provide suitable offshore HVAC and HVDC platforms under the utilization of the known fabrication and construction industry (including steel and concrete gravity based structures) as well as the O&G and marine contracting industry (installation methods).
• Since there is strong correlation between marine installation operations and design of offshore platforms as proven in O&G industry. An early engagement of design, supply, fabrication, construction, marine transportation and installation is of crucial importance!
• The supply chain has to deliver an average of 6-7 HVDC converter platforms per year. Like the offshore construction yards and marine contractors had done in the O&G business in history they have the challenge to organize themselves to meet this demand.

3.6. Employment and Educations

3.6.1. Employment

Since the development of RES over the last decade there are job opportunities in this relative new industry at various levels in the supply chain.

The development of RES throughout Europe has according to recent publications by EWEA created already more then 200,000 direct and indirect jobs at various levels of expertise. FOSG do not intend to give opinion about how subsidies can be used to create jobs either in RES or in other parts of the economy such as for example in the agricultural sector. Some of these jobs are considered as new jobs for example in the offshore construction industry where we see new marine resources including equipment and crews entering the market. It can be expected that the number jobs in the RES industry will continue to increase in the years ahead of us. The shift of RES to the offshore environment will also be reflected in the workforce as more and more of these future jobs will be needed offshore, for example for construction of a Supergrid but also for maintenance.

A relative small portion of this workforce will be engaged in the development and roll-out of the Supergrid concept. It is important to understand that the workforce engaged in this concept is a rather crucial part as Supergrid is supportive to the distribution and transmission of our energy from power generation areas (offshore) to the consumer areas throughout Europe (onshore) and also contributes to trade and the fulfilment of the European Internal Electricity Market.
This report is not meant to provide an analyse of detailed effect of job creation, but as the Supergrid has a positive socio-economic value compared to the alternatives it is important to underline that it will contribute to the development of EU's economy

3.6.2. Educations:
Throughout NW Europe we noticed many initiatives by universities, technical institutions etc. that new training schemes are being developed to meet our present and future demands. Leading countries are Denmark, Germany and UK, with other countries following.
An important factor covering education will be that certificates being awarded to students will be recognized in other European countries as our industry is engaged in cross border projects.

3.6.2. Key notes
- The stakeholders engaged in the realisation of Supergrid will be challenged by an increase demand on staff and personnel to run future projects. Although the numbers may be insignificant compare with RES the importance of these jobs are unquestionable.
- Following in the wake of substantial success in the onshore wind industry, by acting as a first-mover, Europe could exploit future export opportunities to the American and Asian markets.
- The renewable industry generally has a higher proportion of jobs classified as “high-skilled” than the economy at large. There is current evidence that companies are finding these positions difficult to fill, highlighting the importance of a focus on training and education measures to prevent future shortage in this often neglected component of the supply chain.
- A strong relationship between the Industry and its Customers will encourage new skills to enter our industry. Long term commitments will attract these skills to come forward.

3.7. Conclusions:
Offshore wind energy is considered a cornerstone of European energy policy; however it still needs development and experience in order to reduce risk estimations for investments. The envisaged ~143 GW of installed wind capacity and the necessary transmission capacity needed to realise the proposed offshore grid design in 2030 is enormous, and the demand for equipment and trained personnel along the supply chain will be huge.

For the development of offshore wind, even though there is strong political driver in North European countries, some uncertainties remain on the actual pace of development.
For the development of a Pan-European offshore Supergrid, at this early stage, characterized by an uncertainty of the principle to be confirmed by the setting of a regulatory framework particular, and thus a higher level of uncertainty about the pace of development of this European Supergrid.

There are still relatively few manufacturers of some of the key elements that will be required to create an offshore grid. An expected increase in demand for these technologies both in Northern Europe and globally means that, as soon as the political commitments to develop such an offshore grid will be reliable enough, the European industry is expected to continue to invest to expand their manufacturing base at a pace corresponding to the progressively growing demand, allowing reasonable delivery times to projects and thus a continuous development of the offshore grid needed to deal with the development of offshore wind.

**Key findings synthesis**

<table>
<thead>
<tr>
<th>Position</th>
<th>Key message</th>
</tr>
</thead>
</table>
| **Stable and Regulatory Pan-European framework to be established to justify Supply Chain to make the appropriate investments needed to participate in the development of a European (offshore) Supergrid** | The Supply Chain is in full preparation to meet the future demands foreseen as a result of RES and Supergrid developments. The implementation of a Regulatory Framework will further support the Supply Chain in their developments. It is of importance to obtain clarity about some of the main issues as this will assist the Supply Chain in the execution of their investments:  
- What is the timeframe for implementation of New Pan-European Regulatory Framework.  
- Do we meet the RES targets in the given timeframes?  
- Offshore Grid Systems rely on Onshore Grid Systems, as a consequence the onshore grid enforcements and where needed new North-South onshore HV grid systems will be required. How do we accelerate onshore grid developments?  
- How do we manage the Not In My Back Yard effect at public level (Supermarket approach) |
| **Permits & Licenses: History has learned that development of Offshore Grid connections is a time consuming exercise with significant impact on “The WHEN” and “WHAT”. History has shown grid** | The Supply Chain in support of their investment plans are calling for the following improvements to avoid further delays in projects:  
- A more transparent and time limited P&L process.  
- A better involvement from Supply Chain in the P&L process enabling long term contractors experience to be engaged. |
### What are the main challenges for the Supply Chain for Phase 0 and Phase 1 development of the Supergrid.

A minimum capacity of clustered power (several GW’s) need to be operational before we can distribute excessive wind energy across the North Sea.

Based on a firm and long term and adequate planning of projects (Call it: Smart Resource Project Planning), additional production and fabrication facilities will be required to meet future demands. Subsequently additional investments by Supply Chain will be required and shall be made accordingly as history has shown.

To support the Supply Chain any obstructions or barriers affecting their investment plans should be avoided or when they occur clearly communicated with the Supply Chain in order to avoid stranded assets.

### Supergrid Phase 0 – What do we develop first?

There are two main options which depend on progress of Offshore Wind projects:
- North – South grid connections or
- West – East grid connections

The OG-report concludes that North-South connections have a better wind correlation then some of the East – West connections. Subsequently this implies that connection of Norwegian hydro power should be the first leg of Supergrid.

### Stronger relationship between Developers and Supply Chain is crucial.

The Supply Chain is fully aware of the expectations in the Grid market and is in full preparation to meet this demand. A strong and long term relationship including risk sharing schemes between Developers and Supply Chain will support that manufacturing and installation capacity can meet the growing demand.

**“Smart Resource Project Planning “should be One of the backbones for all future projects!”**

### Supply of Submarine Power Cables. The offshore market believes the cable supply market is under pressure to meet the demand. Reality or not?

With their existing capacity and the numerous announcements of capacity increases, the European cable suppliers will be able to meet the HV subsea cable demand up to 2015-2020 with significant margins to serve also demand outside northern Europe. Indeed, independent market analysis show that the European HV subsea cable
capacity is increasing from previously 800 km of AC cable to about 2.000 km in the few years to come with investments from the 3 incumbent suppliers (Nexans, ABB and Prysmian) and from 3 new European players in HV submarine cables (NKT, NSW and JDR).

To meet the long term demand (>2020) for supply of HV submarine power cables further investments in large scale cable storage and production facilities may be needed. Recently over the last few years, we have seen investments following up the market growth, in particular Nexans, ABB and Prysmian increasing significantly their production capacity for both HVAC and HVDC subsea cables, and new players such as NKT and NSW entering the HVAC market.

For HV underground and MV subsea cables, the competition has also invested in additional capacities which demonstrate investment preparedness of cable suppliers.

| **Installation capacity of Submarine Power Cables.** | The installation capacities for HV power cables available today (Cable Route Length) seems sufficient to follow the market and subsequently the cable supply demand in NW Europe up to 2015 -2020. |
| **Installation capacity needs to be in balance with cable supply, storage and long term planning of projects.** | To meet market developments beyond 2020, new Cable Lay Vessels (CLV) with a typical turnaround time for construction of 2-3 years may be required. Some of these CLV’s may need to replace some of the “aged” existing vessels. Plans for new tonnage including conversions of existing construction vessels are already tabled and will be available in due time. |
| **Supply and installation of offshore AC substations** | As for the cable supply and with currently 2 new vessels under construction, the industry is investing in the necessary equipments to cope with the growing demand. |

The recent years have shown that the fabrication and installation of AC substations up to max. 500MW are not hampered by supply chain issues. The supply chain is confident that this part of the market can meet the future demand without real constraints. Technology wise there are no barriers affecting this part of the Supply Chain.
### Supply of new self installing offshore DC converter platforms.

Is technology available to design, construct and install these DC converter platforms in an offshore environment and within a realistic timeframe.

DC converters operate in a harsh offshore environment. The design of large offshore structures including DC converter platforms is usually driven by the offshore conditions including transportation and installation activities.

With introduction of larger power ratings and higher transmission voltages increase size and weights of platforms are moving away from Heavy Lifting solutions towards self-installing concepts either semi-floating or full floating.

In recognition thereof and as a first step, the first generation of design for new generation DC converter platforms are developed and under construction by the market. From Lessons Learned in this process 2nd and 3rd generation platforms will be developed by the Supply Chain.

The development of 1st generation DC converter platforms called for significant investments by the T&D contractors which demonstrate their willingness to commit to major investment schemes. Obviously as part of the development process further investments may be needed and will be made as history showed.

To avoid bottlenecks in the supply of DC converter platforms the turnaround time from Design to final installation and commissioning need to be improved.

### Marine Installation activities of large sized offshore convert platforms exceeding heavy lifting capacities

The 1st DC converter platform installed by ABB was Borwin “A” (400MW, 150kV), this relative small platform was installed using Heavy Lift by an unique HLV Thialf.

One of the Lessons Learned from this project was to move towards new installation technology based on self installing concepts.

This “new technology” is not new as it has been used in the O&G industry on many occasions as well as in the Marine Construction Industry.

One important Lessons Learned from the marine industry is that an early involvement of the marine installation contractors is crucial for a successful project.

The resources are readily available in the market!
### Logistics: Port and Yard facilities; Do we foresee similar constraints as in the Offshore wind?

The demand on ports and yard facilities is relative small compare to Offshore wind. Competition with Offshore Wind projects should be avoided. Cables are produced at existing facilities with their own port facilities. CLV’s only use ports incidental for mobilisation and demobilisations or shelter. Offshore platforms such AC substation and DC converters are built at dedicated construction yards with their own port facilities. For final hook-up and commissioning near the offshore installation sites quay side facilities. Including sufficient crainage may be required. However the majority of these structures are no longer then 100mtr and is not considered being critical. For some marine operations deepwater may be required >15m however this in NW Europe not considered to be a bottleneck.

### Employment and education opportunities

**Employment:**

The development of Pan European Supergrid in combination with RES opens large scale employment opportunities in Europe. The total number of employment which is directly related to Supergrid is difficult to quantify and also rather low (assume less 5%) of total demand due to a rather high level of automation in activities. R&D activities are taking an important part of this demand. Design, fabrication, construction, hook-up and commissioning of grid systems including offshore platforms call for significant numbers of staff and workers; this can lead to several thousands of employees.

**Educations:**

In the slipstream of RES there is a strong recognition in the market that Renewables is a new industry which also requires its own R&D, education requirements including a significant amount of HSE training of all labour in order to work under harsh offshore environments. Especially countries around the North Sea are introducing R&D centers as well as education at university levels and technical colleges covering technique but also logistics which is the prime for offshore wind developments. The FOSG is actively involved in supporting these institutions by exchanging knowledge and information.
**Concluding FOSG vision:**

- The Supply Chain engaged in FOSG is already engaged making necessary investments and will continue to do so for the future.

- Smart Resource Project Planning should be adopted by the market!

- A strong and long term relationship including risk sharing schemes between Developers and Supply Chain will support that manufacturing and installation capacity can continue to meet the growing demand.