Report prepared on behalf of

Department for Energy Security & Net Zero

UK renewables deployment supply chain readiness study

Appendix

April 2024

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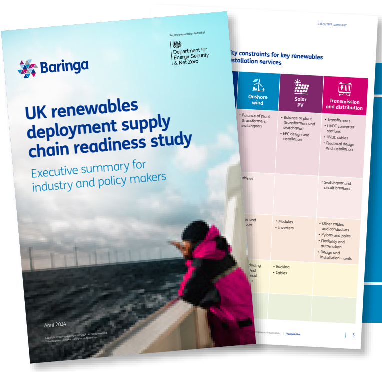

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9. Appendix: Renewable energy supply chains explained

This appendix provides an overview of components and installation services involved in each supply chain discussed in this report.

9.1 Offshore wind

Turbines

Offshore turbines are significantly larger but otherwise similar to their onshore counterparts. They consist of composite blades, a steel tower, a composite nacelle housing bearings, a drive shaft, gearbox (except for direct-drive models), generator, and other subcomponents. Turbines have increased from 3 MW to 15 MW over the last decade – with speculation about even larger turbines of 20 MW or more in the future.

Although the same suppliers operate in both the offshore and onshore markets, the supply chains and factories are largely separate.

Example suppliers

- **Turbines:** Siemens Games, Vestas, and GE dominate the European and US markets and focus on blade manufacturing and nacelle assembly. Several large Chinese turbine OEMs have yet to have an impact on Europe and the US. Additional blades are manufactured by LM Wind.
- **Towers:** Outsourced to CS Wind, GRI Renewable Industries, GSG Towers, Haizea Wind Group, Titan Wind Energy, and Welcon.

Fixed foundations

Cylindrical steel monopiles are the dominant fixed-bottom foundation. These are piledriven into the seabed and suitable for water depths of up to 60 metres, provided the seabed is not rocky or silty. To avoid damage from the piledriver, a separate transition piece (TP) is added after monopile installation; this provides an access and mounting point for the turbine.

Jackets are three- or four-legged lattice structures fabricated from welded sections of steel pipework. They can be used in deeper water and on rocky or silty seabeds. A TP is not required because they are lowered into place.

Example suppliers

- **Monopiles:** Bladt (now owned by CS Wind), EEW, Haizea, Navantia Windar, Sif, Steelwind Nordenham, and Titan (Ambau).
- **Transition pieces:** Bladt, EEW, Smulders, ST3 Offshore (now owned by Vestas), and Wilton.
- **Jackets:** Aker, Harland and Wolff, Lamprell, Navantia Windar, Smulders, and ST3 Offshore.

Floating foundations

Although floating foundations are established in the oil and gas sector, they are a very new technology for offshore wind. The majority of floating wind projects have been small pilots. The world's largest floating wind farm has an installed capacity of only 88 MW and was completed in 2023 (Hywind Tampen in Norway).

There are over 50 competing floating foundation designs of four main types: spars, semi-submersibles, barges, and tension leg platforms (TLPs). Semi-submersibles and barges are likely to dominate the market, and can be manufactured from steel or concrete.

Example suppliers

- As this is an emerging technology, there is not yet a well-established supply chain for floating foundations.
- **Recent/potential suppliers:** Aker, Navantia Windar, Smulders/Eiffage Métal, and Welcon.
- In some cases, there are partnerships with designers like Stiesdal, Principle Power, and BW Ideol.

Array cables

Array cables are typically three-core submarine medium- or high-voltage AC cables. They connect multiple turbines in loops or strings to the offshore substation or converter station. A typical design consists of stranded copper or aluminium conductor cores (with their own screening, insulation, and protective sheath). These are bundled with an optical fibre and surrounded by fillers, armouring, and an outer polymer sheath.

Array cables are typically 33 kV or 66 kV and may rise to 132 kV as turbine sizes increase.

Example suppliers

- JDR Cable Systems, Prysmian, Hellenic Cable, Nexans, NKT, and TKF.

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Export cables

Export cables can be either high-voltage direct current (HVDC) or high-voltage alternating current (HVAC). HVDC is typically used for longer cable lengths (>80 km), where their lower power losses improve efficiency. HVDC cables are single core and laid either as single 'monopole' connections or as double 'bipole' connections to increase capacity and provide redundancy in case of failure. Some HVDC designs are suitable for both onshore and offshore.

Offshore HVAC cables have a similar triple-core construction to array cables, while onshore HVAC cables are typically laid as sets of three single-core cables.

Example suppliers

- Hellenic Cables, LS Cable, Nexans, NKT, Prysmian, and Sumitomo.
- There is substantial overlap between HVAC and HVDC cable manufacturers, with the majority manufacturing both, although often in different factories.
- Different AC subsea cable types and sizes can be made in the same facility, so many HVAC cable suppliers also manufacture array cables.

Substations and converter stations

HVAC substations and HVDC converter stations consist of gas- or air-insulated switchgear, transformers, reactive power management, a supervisory control and data acquisition (SCADA) system, controls, and earthing systems. HVDC converter stations also use converter valves comprising insulated-gate bipolar transistors (IGBTs), which convert the incoming AC supply from turbines to DC for transmission at the offshore station (and then back to AC for grid connection at the onshore station).

Offshore stations are housed in topsides on platforms supported by jacket foundations – HVDC topsides are significantly larger than HVAC topsides. Topsides also incorporate many auxiliary systems such as power supplies, fire suppression, and helipads. Onshore stations are housed in much simpler industrial buildings.

Example suppliers

- **HVAC and HVDC electrical systems:** GE, Hitachi Energy and Siemens (Schneider Electric also provides HVAC systems).
- **Offshore platforms and foundations:** Aker, Bladt, Harland and Wolff, Heerema, McDermott, McNulty Offshore, and Sembcorp.
- **Onshore buildings:** Outsourced to construction contractors.

Foundation and turbine installation vessels

Typically, these are jack-up or heavy-lift vessels equipped with large cranes, specialist mission equipment, and sea fastenings for storing and handling components. For example, monopile installations require specialist upending tools and grippers with either anvils and hammers or vibrotools.

Jack-up vessels can operate in higher wind speeds but are limited to shallower sites. Heavy-lift vessels allow faster installation because they can move between turbine locations more quickly.

There is considerable overlap between turbine and foundation vessels, although the challenges of larger turbines and foundations are leading to more differentiation (which is reflected in crane hook height and load rating).

Example suppliers

- **Vessel operators:** Boskalis, Cadeler, DEME Group, Fred Olsen, Hafvram, Heerema, Jan de Nul, Saipem, Scaldis, Seajacks, Seaway 7, and Van Oord.
- **Shipyards:** Generally in China and Korea.

Cable installation vessels

Most vessels can lay both array and export cables. They are equipped with cable storage carousels, specialist cable tensioning and handling equipment, ploughs or injectors for laying and burial, and remote operating vehicles (ROVs).

Historically, smaller, more manoeuvrable vessels have been favoured for array cables, with vessels with larger carousels favoured for export cables (because they are longer). Export cable vessels may also need a shallower draught as they come closer to shore to terminate the cable. However, this distinction is less pronounced as turbine size and spacing increase, and large vessels may be preferred for their greater operational efficiency.

Example suppliers

- **Operators:** Asso, Boskalis, DEME, Global Marine, Jan de Nul, Subsea 7, and Van Oord.
- **Cable manufacturers with their own fleet:** Nexans, NKT, and Prysmian.

Ports

Marshalling or staging ports are used for receiving, storing, and marshalling turbine components such as blades, nacelles, and towers (towers are typically received in sections and therefore require preassembly). Foundations can also use marshalling ports, but can often be stored and delivered directly from supplier yards.

Ports also act as focal points for manufacturing clusters, as many offshore wind components are too large for road transport and so must be manufactured near the quayside. Many nacelle, blade, tower, foundation, and cable factories are located in port clusters – which will also be critical for floating foundation manufacturing.

Example suppliers

- **UK:** Able Seaton, Cromarty Firth, Belfast, Dundee, Great Yarmouth, Hull, and Nigg.
- **North Sea projects can also be served from European ports:** Cuxhaven (Germany), Esbjerg (Demark), Ostende (Belgium), and Eemshaven, Ijmuiden, and Vlissingen (Netherlands).

9.2 Onshore wind

Turbines

Onshore wind turbines are similar to their offshore counterparts and are comprised of blades, nacelles, and towers. The main differences are:

- the smaller size of onshore turbines (typically 3 MW to 5 MW, with new models reaching 6 MW to 7 MW)
- improved noise performance
- less frequent use of direct-drive technology.

Onshore wind turbines are offered in a range of IEC wind classes. The majority of wind turbines installed in the UK are in Scotland and are built to meet the highest 1A classification due to the extreme wind conditions.

Example suppliers

- **Turbines:** Enercon, GE, Nordex, Siemens Gamesa, and Vestas, with some blade manufacturing outsourced to LM Wind.
- **Towers:** Outsourced to CS Wind, GRI Renewable Industries, GSG Towers, Haizea Wind Group, Titan Wind Energy, and CS Wind.

Foundations and civil works

There are several types of onshore foundations based on soil conditions:

- gravity foundations: are commonly used and consist of steel-reinforced concrete poured on site, with larger shallow mat foundations for sites with weaker soil conditions
- rock foundations: use anchors at rocky sites where conventional concrete foundations are unsuitable
- underneath piled foundations: consist of an array of piles in softer mud and marsh conditions.

Foundations are usually part of the civil contract, which includes other elements like access roads, drainage, crane pads, laydown areas, fencing, and landscaping. The civil contractor is also often the prime contractor for electrical works.

Example suppliers

- RJ McLeod, Howard Civil Engineering, and MMK Civil Engineers.

Transport and installation

Turbine transport and installation form part of the turbine supply agreement (TSA), and as such are organised by the OEM.

Road transport involves specialised vehicles and equipment, for example:

- for towers and nacelles: heavy haul trucks with semi-low loaders and extendible flatbed semi-trailers
- for blades: blade trailers and wing carriers.

Once components are on site, self-propelled modular transporters and mobile cranes are used for moving and installing components. Telescopic cranes have a capacity of up to 1,200 tonnes, and lattice boom cranes have a capacity up to 3,500 tonnes.

In Scotland, most wind turbine components are treated as abnormal loads and can only be moved outside peak traffic hours with a police escort.

Example suppliers

- Mammoet, McFayden, DSV, Chris Bennett (Heavy Haulage), Weldex, Konecranes, Ainscough Crane Hire, and Collett.

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Balance of plant

Balance of plant for onshore wind consists of transformers, switchgear, and SCADA systems.

Transformers step up the voltage to reduce distribution and transmission line losses. They consist of a steel core with primary (input) and secondary (output) copper windings on each side, immersed in a tank of oil-based or synthetic coolant. Distribution transformers range from 11 kV to 132 kV, while transmission transformer voltages include 132 kV to 400 kV, depending on whether they are in Scotland or the rest of the UK. Transformer MVA depends on the wind farm's size and complexity, and ranges from 50 to 100.

Onshore switchgear allows electricity generation to be disconnected and reconnected to the grid so as to manage maintenance and outages and prevent overloads. The most common switchgear variant is SF6-gas-insulated, and developers have highlighted their intention to phase out SF6 switchgear.

SCADA is a control system that enables users to monitor and control remote operations of wind turbines and other associated systems in real time. Specifically, SCADAs display data like wind speed, wind direction, power blade position, temperature, and blade vibration.

Example suppliers

- **Transformers:** Efacec, Fuji Electric, GE Grid, Hitachi Energy, Hyosung, Hyundai, Kyte Powertech, Ormazabal Cotradis, Schneider Electric, Siemens Energy, and Toshiba.
- **Switchgear:** ABB, Anchor Electrical, Eaton, Havells India, Lucy Electric, Orecco Electric, Schneider Electric, Siemens Energy, and SwitchGear Company.

Array and export cables

Array and export cables are medium- to high-voltage AC cables that are either triple-cored, trefoiled single-core, or single-cored cables laid separately. As with offshore cables, both copper and aluminium cores are available.

Array cables are typically 30 kV to 36 kV, and export cables are typically 132 kV to 400 kV. Onshore cables tend to be more commoditised and less specialist than offshore ones.

Example suppliers

- Nexans, NKT, Prysmian, and many smaller suppliers.

9.3 Solar PV

PV modules

Crystalline silicon accounts for 95% of global PV production capacity and is the focus of our analysis. Cadmium telluride thin-film PV makes up the remaining five percent, with perovskites emerging as an alternative module material.

Silicon modules are divided into monocrystalline and polycrystalline modules; monocrystalline has superior efficiency of over 20%. Modules are manufactured from metallurgical-grade silicon derived by using carbon electrodes to reduce mined quartz in high-temperature electric furnaces. The quartz is further purified, cast, or crystallised into silicon ingots and doped with boron or phosphorus.

The ingots are then sliced into thin wafers, which are transformed into solar cells. The cells are interconnected, encapsulated in ethylene vinyl acetate (EVA), and sandwiched between glass and a back sheet on an aluminium frame. They can also be sandwiched between two sheets of glass and a second, reverse-facing sheet of PV cells on bifacial panels. Modules produce DC and require inverters to convert the electricity to AC for export.

Example suppliers

- Canadian Solar, JA Solar, Jinko Solar, LG Solar, LONGi, Hannah QCells, REC Group, Risen Energy, Sunpower Maxeon, and Trina Solar.

Balance of plant

Balance of plant for solar PV consists of transformers and switchgear (as with onshore wind), and inverters to convert DC output to AC for export.

There are several types of inverters:

- central inverters: which connect centrally to all module arrays
- string inverters: which connect to a string of modules
- micro inverters: which are typically limited to rooftop solar and fitted to individual panels.

Commercial-grade central solar inverters range from 30 kW to 500 kW, depending on the solar installation size. They use high-powered semiconductors like insulated-gate bipolar transistors (IGBTs), similar to those used in HVDC converter stations.

For solar PV, the primary transformer type is oil-immersed or auxiliary – with voltages of 11 kV, 33 kV, 66 kV, 132 kV, or 400 kV, depending on whether they are connecting to the distribution or transmission network. Inverters and transformers can be combined into a single component.

Gas-insulated switchgear is commonly used for solar PV because it provides a highly electrically insulated atmosphere that prevents arcing between components that would otherwise need to be spaced much further apart. Developers are phasing out SF6 (which is commonly used for gas-insulated switchgear) in favour of alternatives with a lower global warming impact.

Example suppliers

- **Inverters:** FIMER, Ginlong, Growatt, Huawei, Power Electronics, Sineg Electric, Sungrow, SMA Solar, Solaredge, and TIMEIC.
- **Transformers:** Efacec, Fuji Electric, GE Grid, Hitachi Energy, Hyosung, Hyundai, Kyte Powertech, Ormazabal Cotradis, Schneider Electric, Siemens Energy, and Toshiba.
- **Switchgear:** ABB, Anchor Electrical, Eaton, Havells India, Lucy Electric, Orecco Electric, Schneider Electric, Siemens Energy, and SwitchGear Company.

Array and export cables

DC array cables connect solar panels in series or parallel configurations and transport generated electricity to inverters. They are typically 4 to 6 mm double-core copper cables with a positive and negative conductor and polymer insulation. Voltages range from 600 V to 1500 V depending on the system design, the number of panels in the series, and inverter requirements.

AC cables carry the converted AC power from the inverters to the distribution or transmission substation. They can be rated at 11 kV, 33 kV, 66 kV, 132 kV, or 400 kV depending on the solar installation size and whether they are connecting to the distribution or transmission network.

Example suppliers

- Nexans, NKT, Prysmian, and many smaller suppliers.

Racking

Racking systems attach solar modules to surfaces like roofs, walls, and the ground – and angle them to capture maximum solar energy. Ground-mounted racking consists of a tilted metal frame constructed from >3 mm thick organically coated, galvanised steel or aluminium. This is mounted on a concrete slab or metal piles.

For warehouse roofs, racking is made from similar materials and consists of a frame fastened to the beams and rafters. If a roof-penetrating system is inappropriate – such as for metal roofs or clay tile roofs – rooftop racking systems can be free-standing and ballasted. Some racking includes sun-tracking devices that use sensors and motors, but these are not yet widely used in the UK.

Example suppliers

- Genesis Solar, K2 Systems, Mounting Systems GmbH, Project Solar UK, REDtip Solar Mounting Systems, SOLFIT, Solion, Renusol, Schletter Group, Solarport Systems, Sunfixings, Tata Steel, Van der Valk Solar Systems, and Zimmerman.

Engineering, procurement, and construction

Engineering, procurement, and construction (EPC) companies provide end-to-end solar services including:

- designing the system
- procuring equipment
- managing the project
- installing solar modules, racks, and electricals
- maintaining the solar farm.

EPCs often specialise in residential, commercial rooftop, or commercial ground-mounted solar. Commercial solar developers contract EPCs to procure components and construct farms. Many developers retain procurement of modules, which are then free-issued to the EPC.

Example suppliers

- ABO Wind UK, Absolute Solar and Wind, Anesco, Angle Renewables, BayWa r.e., Baba Energy UK, Beletric Solar, British Solar Renewables, Equans, Ethical Power Connections, Locogen Energy Services, and YLEM Energy.

9.4 Transmission and distribution

Transformers

Typical transformer voltage levels include:

- 400/132 kV or 275/132 kV supergrid transformers at grid supply points
- 132/11 kV and 132/33 kV grid transformers at bulk supply points
- 66/11 kV and 33/11 kV at primary transformers at substations
- 11/400 V distribution transformers at secondary substations.

Transformers also vary in terms of their power ratings (measured in kVA or MVA). While most are ground-mounted, smaller units can be pole-mounted.

Example suppliers

- ABB, Brush, Efacec, GE Grid, Hitachi Energy, Kolector Etra, Kyte Powertech, Ormazabal Cotradis, Schneider Electric, Siemens Energy, Tironi, and Toshiba.

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Overhead conductors

Overhead lines are typically bare, uninsulated, stranded conductors. Depending on the strength, sag, conductivity, and anti-corrosion requirements, they can be pure aluminium, aluminium alloy, or steel-reinforced aluminium. Each conductor carries a single phase of power. Pylon or pole crossarms physically space out conductors.

Conductors are available with cross-sectional areas to cater for different voltage levels from 11kV to 400 kV.

Example suppliers

- 3M, Cabelte, Coreal, ECN Cunext, FBE, Garrite, Lamfil, Lumpi Berndorf, Prakab Prazska Kabelova, Quintas and Quintas, Tratos, TFK, and WDI.

Underground cables

Underground cables are more costly, and are favoured in urban and sensitive areas to avoid the visual impact of overhead lines. Distribution networks typically use 11 kV, 33 kV, 66 kV, and 132 kV AC underground cables, with 275 kV and 400 kV in transmission. They use either aluminium or copper cores with increasing cross-sectional areas as loads increase. From 33 kV and above, these tend to be single-core cables, but both single-core and triplex are used at 11 kV.

Example suppliers

- Brugg Kabel, Cabelte, Demirer Kablo, Estralin HVC, Hellenic, Nexans, NKT, Prysmian, Solidal, Sudkabel, and Tratos.

Submarine cables

Submarine cables are rarely used in distribution networks except for water crossings to islands.

In transmission networks, they are used for international interconnectors and increasingly for ‘offshore bootstraps’, which offer an accelerated way to link two parts of the onshore network with fewer planning consent, land negotiation, and construction challenges.

Submarine transmission cables are identical to those used for offshore wind export cables. They are triple-core HVAC cables or single-core HVDC cables laid either as single ‘monopole’ or double ‘bipole’ connections.

Example suppliers

- Hellenic Cables, LS Cable, Nexans, NKT, Prysmian, and Sumitomo.

HVDC converter stations

As with offshore wind, HVDC converter stations consist of gas- or air-insulated switchgear, transformers, reactive power management, converter valves, SCADA systems, controls, and earthing systems. In the short- to medium-term, all HVDC converters are anticipated to be located onshore, so they can be housed in conventional industrial buildings rather than on offshore platforms.

Example suppliers

- GE, Hitachi Energy, and Siemens.

Switchgear and circuit breakers

Switchgear and circuit breakers are used to disconnect circuits in response to faults – or to isolate and earth them for maintenance.

For transmission networks at 132 kV and above, they are often integrated into modular gas- or air-insulated systems (the former having a more compact footprint). For distribution networks, they are integrated into gas- or air-insulated 11 kV ring main units, where they also enable switching between circuits.

Example suppliers

- **Gas-insulated switchgear:** GE, Hitachi, and Siemens.
- **Ring main units:** Lucy Electric, and Schneider.

Other electrical equipment

Networks use a wide range of additional equipment – such as shunt reactors, synchronous condensers, and static VAR compensators – to manage reactive power. They use voltage control, capacitors, and filters to improve power quality and harmonics.

Example suppliers

- GE, Hitachi, and Siemens.

Pylons and poles

Transmission networks use latticework steel pylons for 275 kV and 400 kV overhead lines; distribution networks use them for 132 kV. Wooden poles are used for lower voltages. The T-Pylon, manufactured in China, is an alternative transmission pylon design with lower visual impact.

Example suppliers

- **Pylons:** Had Fab and Painter Brothers.
- **Poles:** Calders and Grandidge, Power Pole, and Scanpole.

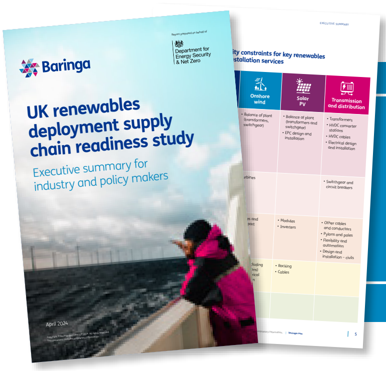
Installation

Both transmission and distribution networks rely heavily on third-party civil and electrical contractors because their own workforces are primarily focused on maintenance and emergency response.

Example suppliers

- Babcock, Balfour Beatty, Burns and McDonnell, Linxon, Morrisons, Murphys, and Volker Infra.

This publication is available from https://www.gov.uk/government/publications/uk-renewables-deployment-supply-chain-readiness.



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UK renewables deployment supply chain readiness study

Appendix

Prepared on behalf of

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