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Offshore Wind Farm
Fundamentals

The Offshore Wind energy industry is set to boom over the next decades following the pushof several nations to lower their carbon emissions footprint via the use of renewable energy.

Along with the traditional front runners such as Great Britain, Germany and Scandinavian, many other countries like France, Japan and Taiwan have robust pipelines of project development for the years to come. The US alone has a target to deploy 30 GW of Offshore Wind energy by 2030.

Since early 2020, Bluestone Group has a desk dedicated to the wind energy sector, offering project management, client representation, design and manuals, and offshore teams for the

whole turnkey life cycle of offshore wind operations from planning to installation followed by operations and maintenance finishing with decommissioning.

This complimentary document covers the considerably basic technical principles of the typical Offshore Wind Farm development and aims to help those who are keen to understand more about this fascinating industry and possibly become part of it.

If you are a client, a contractor, an investor or a job seeker and you want to hear more about Offshore Wind energy and how Bluestone can support you don't hesitate to contact our team at your earliest convenience:

wind@bluestone-group.com

Bluestone Group, available where the wind blows!

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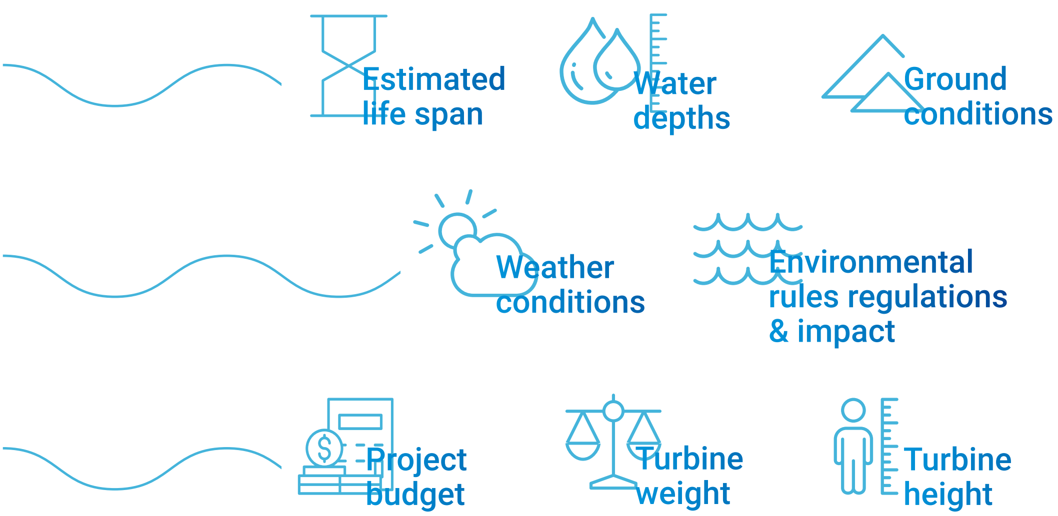
Offshore Foundations.

Offshore Foundations.

Offshore wind turbines have many different foundation types. This is necessary because of the different environments and locations in which they are installed.

The following aspects have to be taken into consideration before they are designed:

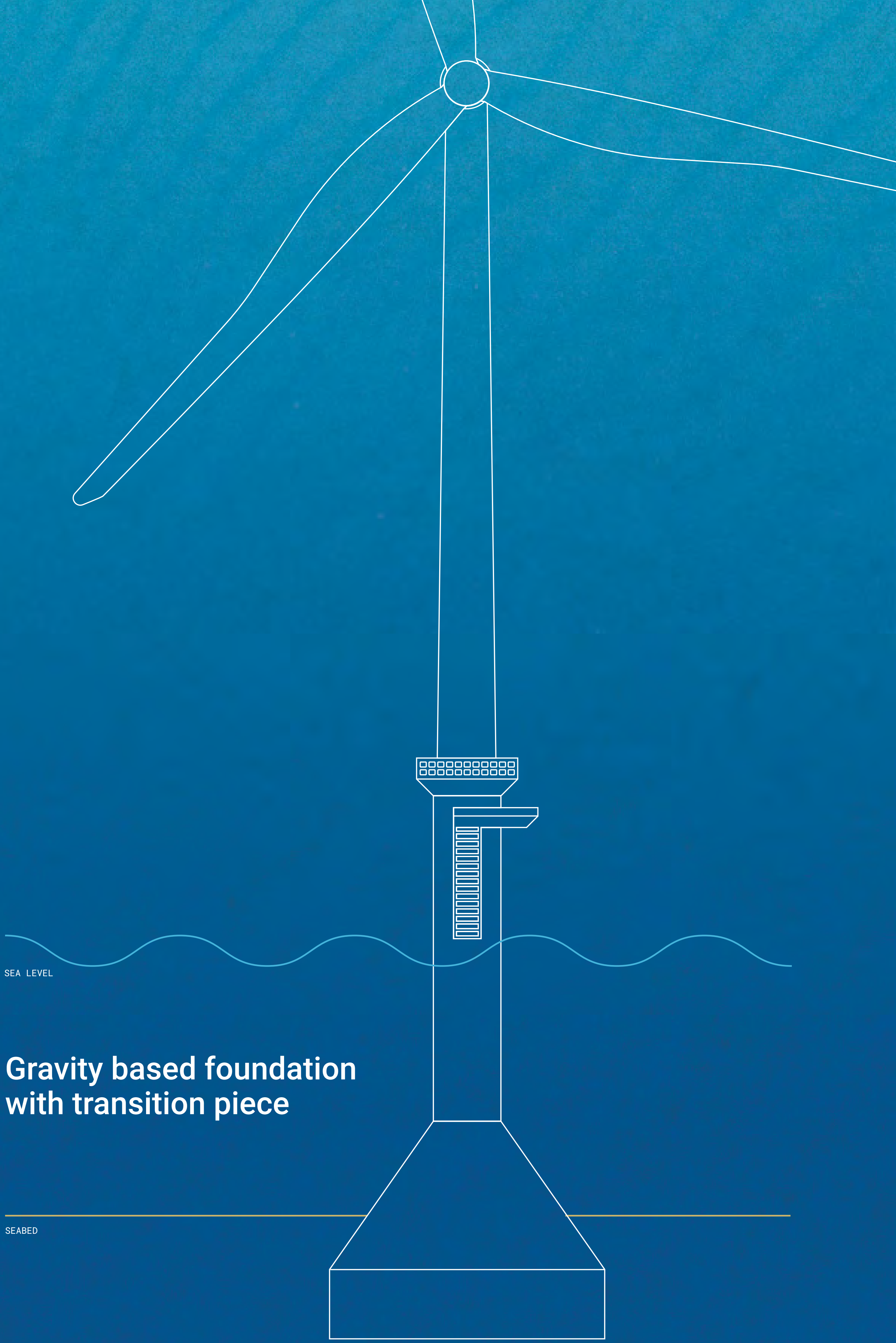


As at 2020, the five main foundation types listed below are in use:

01. Gravity based foundation with transition piece
02. Monopile with transition piece
03. Tripod with transition piece
04. Jacket with transition piece
05. Suction bucket with transition piece

The above list does not cover floating wind turbines because we are considering only the floating foundation part of the turbine and because it is not fixed to the seabed, but is moored and technically it is a floating structure.

Below we will go into more details of each foundation type, what they are used for and what the pros and cons of each foundation type are.



Gravity based foundation with transition piece

Depending on the environmental rules and regulations of the locations where monopiles are being installed, noise reduction aids and wildlife scaring devices are used. There are many methods for this, but the main ones used are:

- Pinger – seal scarer: a device designed to scare sea life away by giving off a high frequency noise, usually used for 30-60 minutes before starting installation.
- Bubble curtain: a tool deployed to make a curtain of air around the foundation during installation to help reduce the sound.
- NMS *(noise mitigation system)*: this is a system that goes around the pile. Similar to a bubble curtain, it uses compressed air, but this unit is designed to fit the design of the hammer and fits more tightly and closely to the monopile and is thus more effective.

01. Gravity-based foundation with transition piece

Gravity-based foundations are an old concept that is no longer in use much, and only 14 wind farm projects in the world have used them, three of which were met-masts gathering wind data.

They are made from steel and high-strength concrete and they are used for water depths greater than 20 m. The deepest gravity-based foundations deployed are at the Thornton Bank offshore wind farm located off the coast of Belgium, with water depths of 27 m.

The advantage of gravity-based foundations is that they have a minimal environmental impact during the installation process. Also, because they are not driven or drilled into the seabed, the decommissioning phase is more practical and less time-consuming.

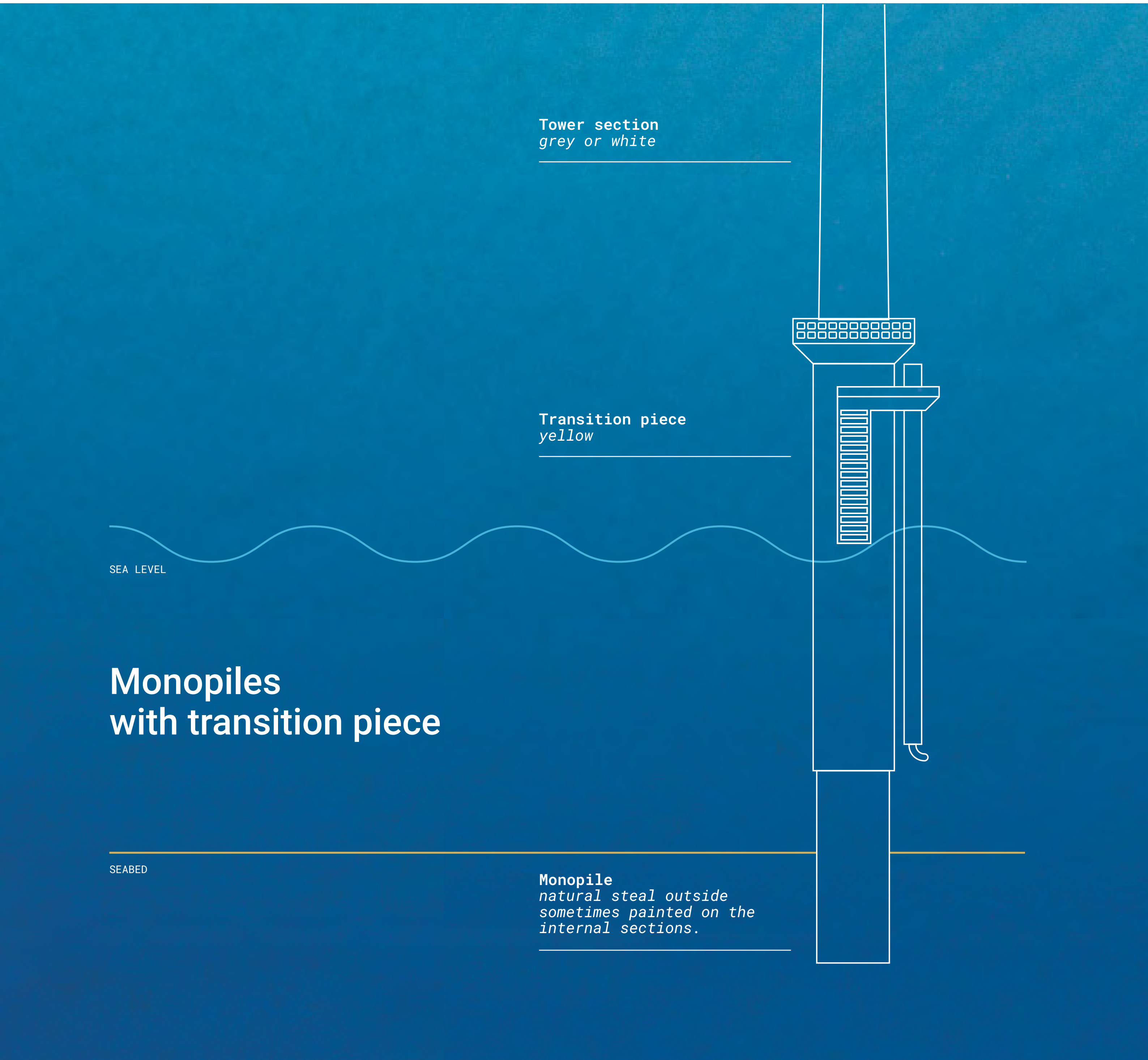
The asset is normally designed to float to make transportation and installation easier. Then, once it is in position, it is filled with water to deploy to the seabed and set on permanent foundations for turbines filled with cement.

02. Monopiles with transition piece.

A monopile is a single steel tube used as a foundation to support the weight of an offshore turbine once installed.

The weight, height and dimensions all vary depending on the water depths, the transition piece design and, most importantly, the ground conditions where the pile will be placed.

The transition piece is the designed intermediate section that connects the pile to the tower section of the WTG (wind turbine generator) and is also used for boat access to the turbine once it is operational.Methods of installing monopiles vary. The process is called pile driving or



foundation installation, using a hydraulic hammer, vibration tool or a drill.

In soft ground a vibration tool can be used, in medium strength ground a hydraulic hammer can be used, and in hard ground a drill and hammer need to be used.

Monopiles vary in design depending on the transition piece. There are the following types of transition piece that alter the design of the monopile:

01. Grouted flange
02. Bolted flange
03. Slip joint
04. Collared pile

Grouted flange

This is the oldest design and is the most commonly used throughout Europe. For this design the monopile will be tapered inwards at the top standing side so that the transition piece can be installed over the pile, with the pile making contact with the internal laydown guides.

To make an annular and connect the two structures together, the transition piece has a skirt that has a rubber seal. This is to make the annular, which is then grouted (filled with high-strength grout–cement).

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Before the grouting is started in between the transition piece laydown guides, the transition piece is jacked up and lowered down until it sits level.

Then the foundation is grouted and, depending on the product used, 3-28 days later the jacks are removed once the cement has set hard.

Bolted flange

This a fairly new method first used in the late 2000s. It is becoming more popular and is a great way to reduce the installation time and foundation size. Because the monopile has a flat flange on the top that connects to the bottom of the transition piece flange, there is no need to grout this. In the industry this is referred to as flange-to-flange connection.

Among the pros is that the annular skirt section of the transition piece can be dispensed with, saving money in steel.

Also, not waiting for the grout to set hard means that an installation vessel can follow and install the WTG while the weather is favourable, saving time and money. Among the cons, the bolts need to be checked annually and changed every few years depending on the design and stress.

Slip joint

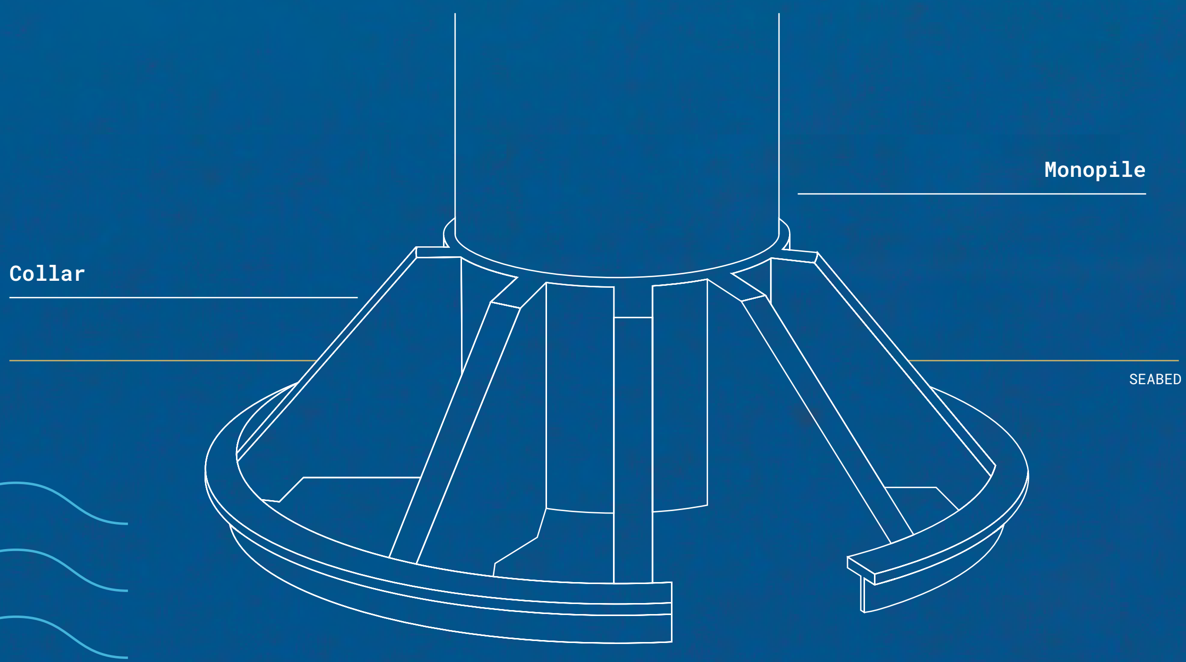
This is a new method of installation and only one has been installed as a prototype. This was installed in April 2020 by Van Oord on the Blauwind project also known as Borssele 3 offshore wind farm, located off the coast of the Netherlands for the clients Shell and Enerco. This structure works on friction and weight-to-gravity basis. The tapered pile and tapered transition piece are conical matching sections designed to fit tightly together, and the weight of the turbine allows the structure to stay stable, supporting the turbine as designed.

Because this is a prototype, it is difficult to comment on until more data has been realised in a few years.

Collared pile

The collared pile is also a new design that will be installed at seabed level, helping to minimise oscillations and improving the load-bearing capacity.

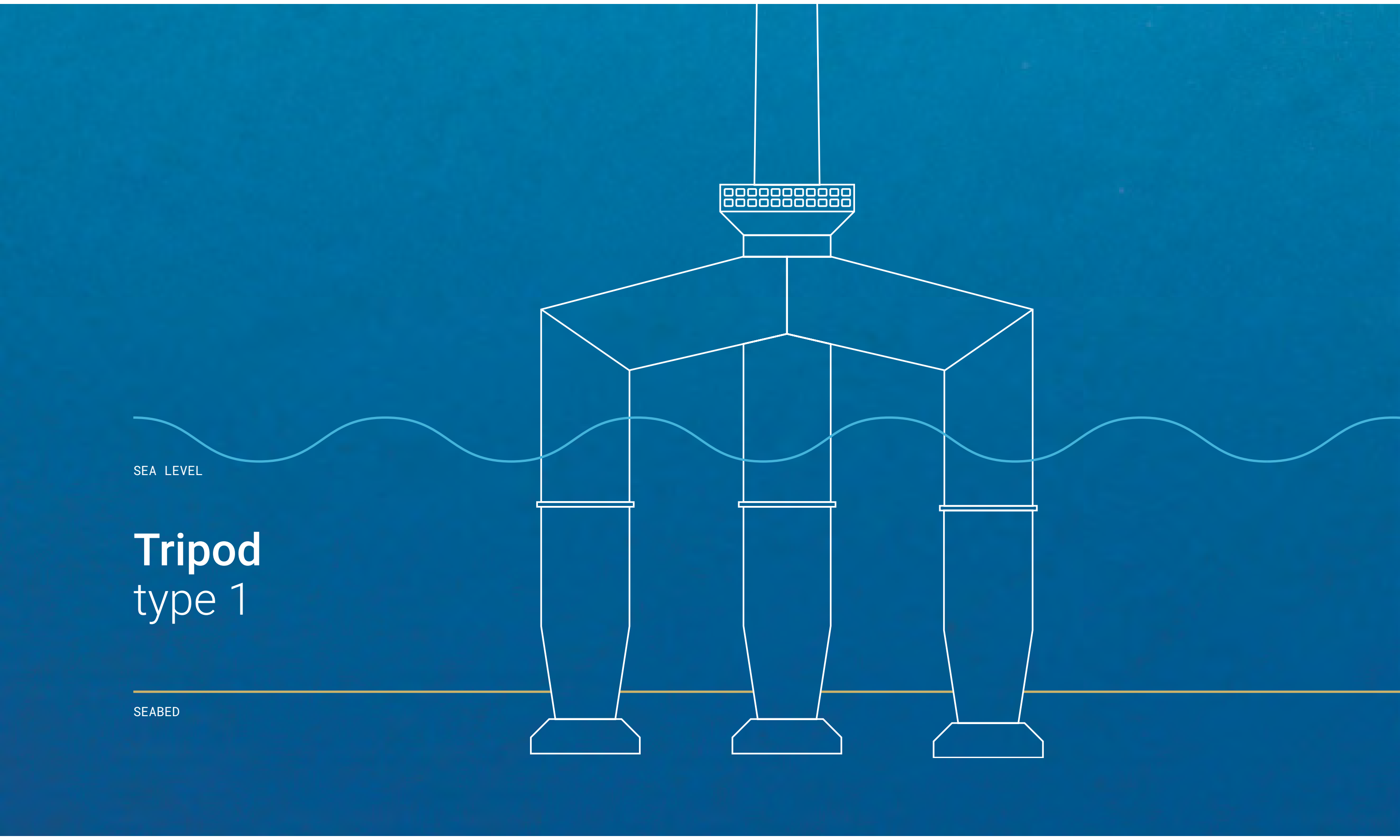
As per the picture below, it can use a bolted or grouted flange transition piece and the collars will be installed at the bottom of the pile, flush with the seabed.



⓪③. Tripod
with transition piece.

The tripod foundation is designed for deep water with harsh conditions and shallow water with strong currents and tidally impacted areas.

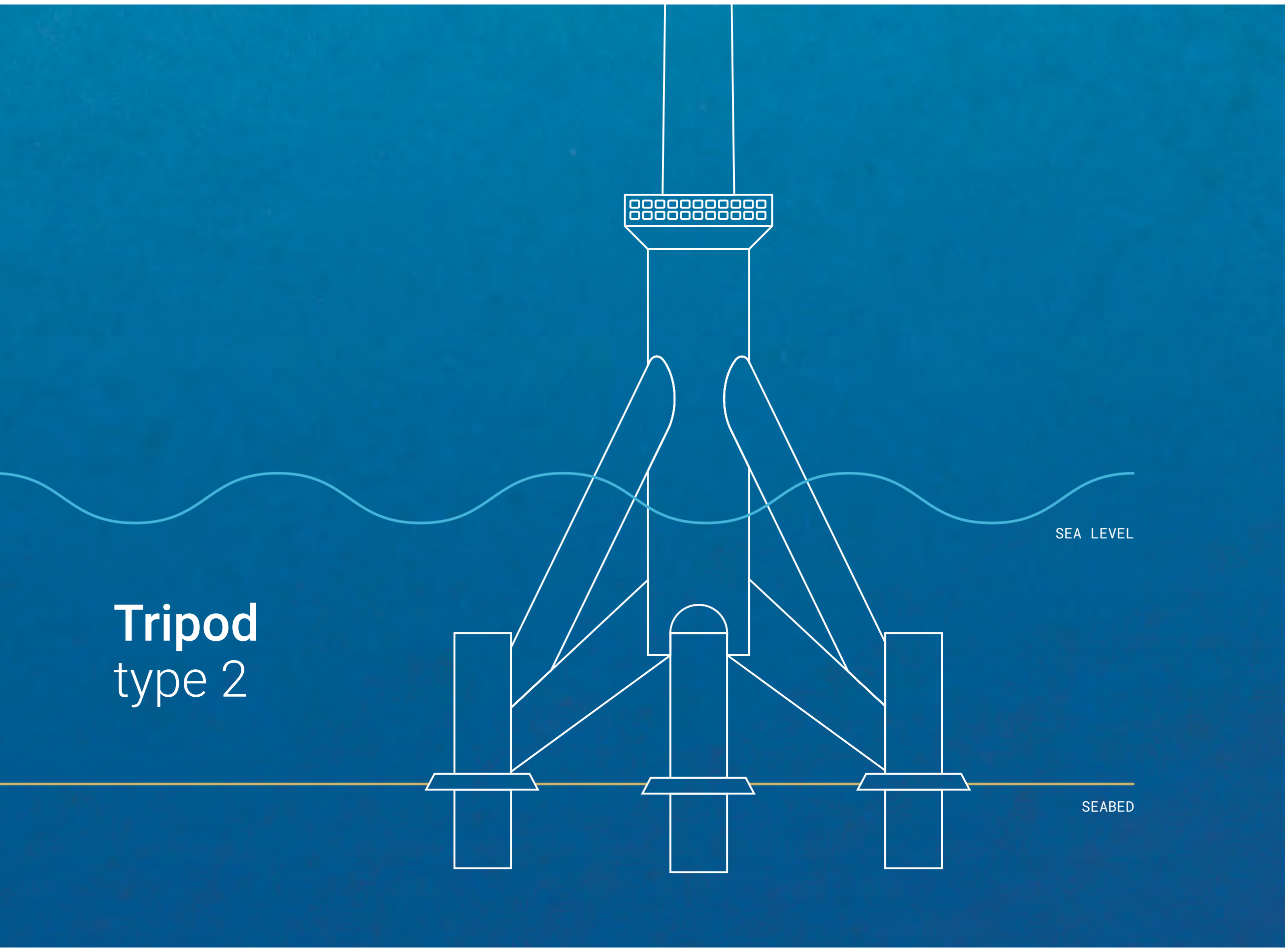
There are two types of tripod foundations in use. They have the same name but are designed and installed differently, so we will refer to them as type 1 and type 2. Please see the pictures and further information below.



Tripod foundation type 1

Tripod foundation type 1 is designed for average coastal water depths of 15-25 m that have strong sea conditions. To install this type of tripod first three piles are installed (driven with a hydraulic hammer) subsea. To ensure the positions of the piles match the legs of the tripod, a piling template is used as per the picture below.

Once the three piles have been installed, the template is removed and the piles are dredged to remove all debris inside from the seabed - sand, silt, clay, shells, etc.
Then the tripod is lowered subsea and the tapered legs fit inside the dredged piles and stop at the designed area by shim plates welded onto the legs that sit on the pile. This area has pre-installed jacks attached to the shim plates, so if the level of the tripod needs to be altered it can.Finally, the legs are filled with grout which overflows into the piles once set, making a sturdy strong foundation.



Tripod foundation type 2

Different to the type 1 and monopile transition piece installation, this tripod is pinned to the seabed with three piles but also the installation is in reverse.

The tripod is lowered to the seabed then, with support from a ROV (remotely operated vehicle) for vision, one at a time the slightly tapered piles are driven into the seabed to pin the tripod into position. Some type 2 tripods have a grout inlet on each leg and they are grouted to stabilise the foundation further; other tripods have grout seals called packers on each of the fixing rings so they can cement the connection of the tripod to the pile, making it more stable in later years and minimising movements.

03. Jacket with transition piece.

Jackets are installed in the same way as type 1 and type 2 tripods. They are a strong structure that is preferred for heavy loads such as substations and are also good for medium strength grounds to evenly distribute the load they are bearing, whether that is a turbine, met-mast, converter or substation.

Three leg jacket

Designed to have the strength and stability of the 4-leg jacket, but with one less leg, saving time on installation and fabrication and saving overall cost.

Like the type 1 tripod, the three piles are first installed and the jacket sits on the pile and is grouted.

Four leg jacket

The traditional design first used in oil and gas and used by the wind industry due to its effectiveness.

Like the type 1 tripod, the four piles are first installed and the jacket sits on the pile and is grouted.

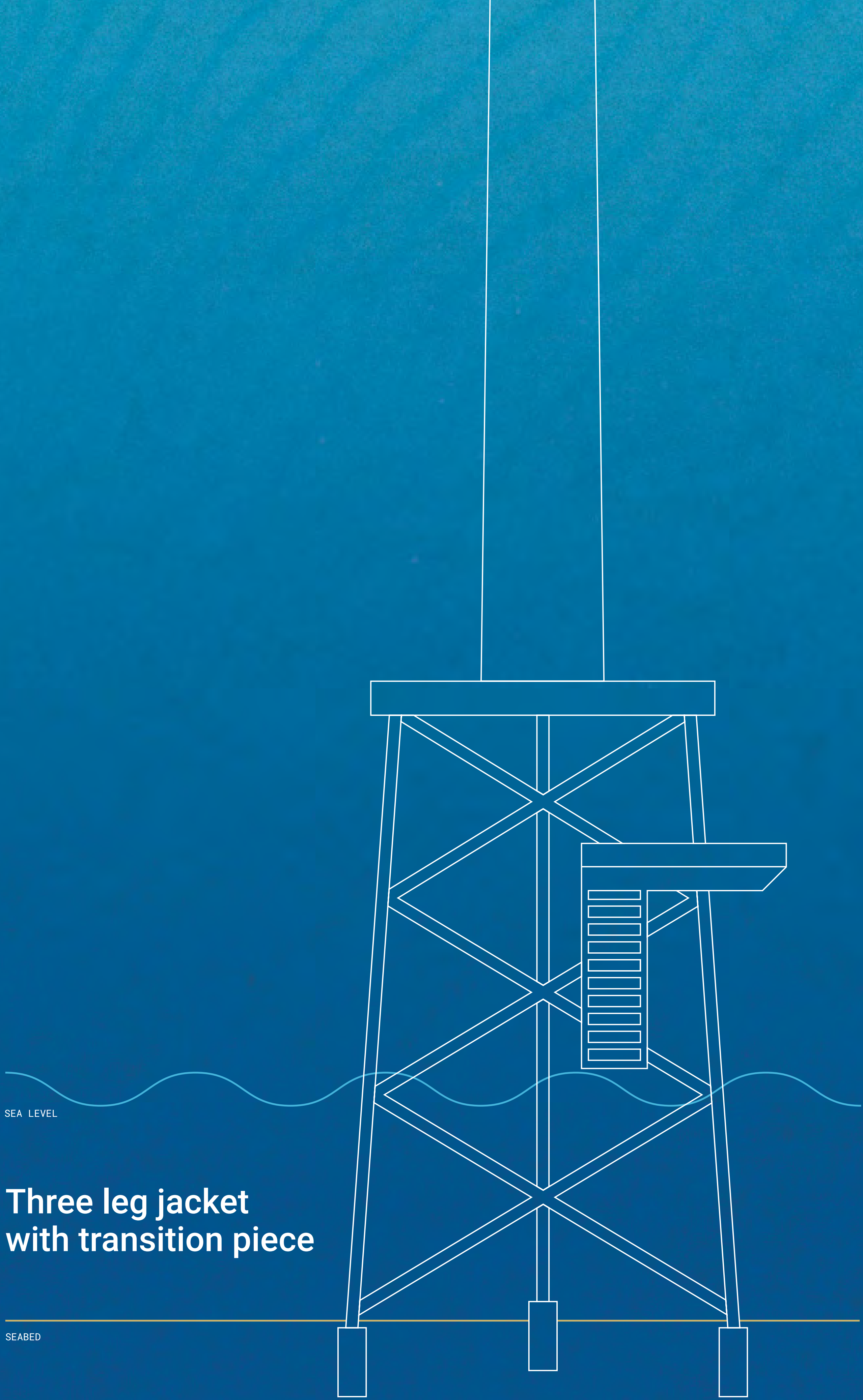
Twisted jacket

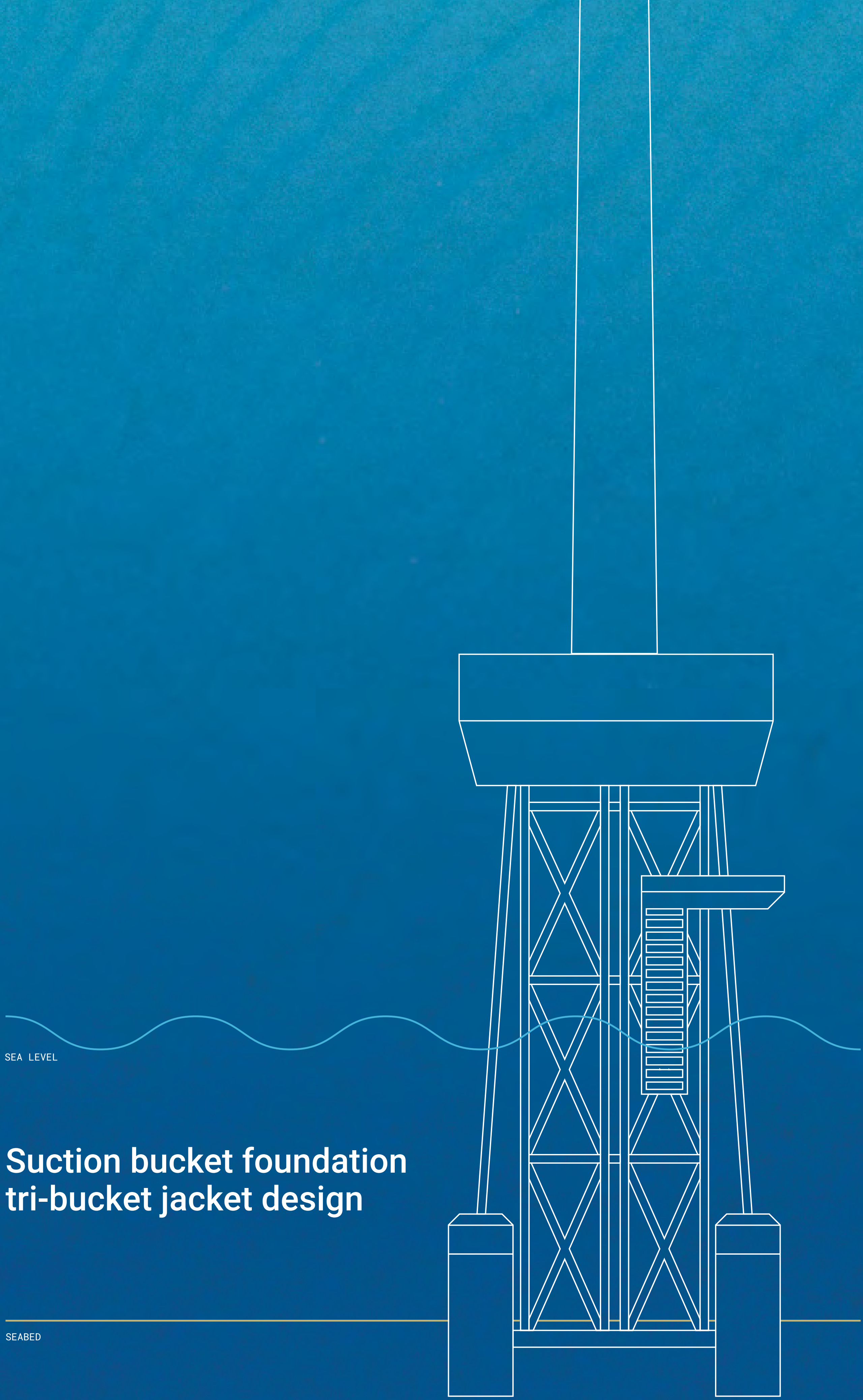
This jacket is pinned to the seabed and grouted in the same way as type 2 tripods.

The structure is twisted, and the piles go into the seabed at different angles.

This foundation is great for supporting uneven loads such substations and met-masts.

Three leg jacket with transition piece





Suction bucket foundation tri-bucket jacket design

05. Suction bucket with transition piece.

The suction bucket with a transition piece is where it can get confusing. To explain it without going into too many irrelevant details, the foundation is a metal pile driven into the seabed in the same way as for monopile, tripod and jacket installation.

This design works very well on clay and sand locations, but is not suitable for hard ground or rocky locations.

The foundation is installed and fixed to the seabed via suction anchor piles. Depending on the design, there can be 1, 3, or 4 etc. of these.

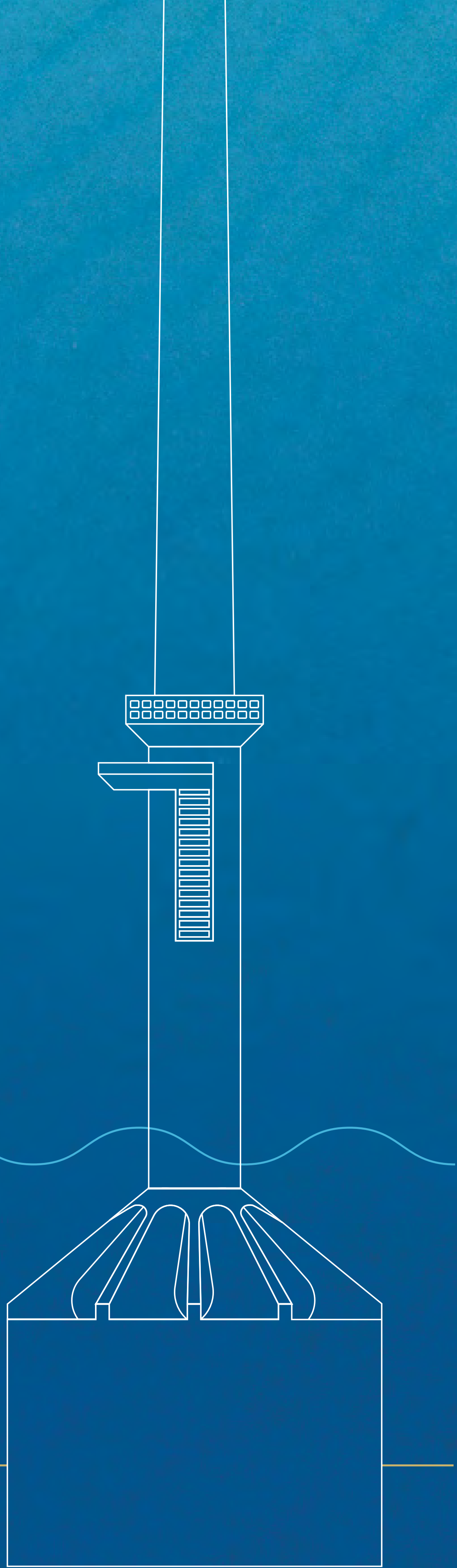
The piles are not driven into the seabed with a hammer, drill or vibration tool. They are a semi-enclosed structure with only an opening at the bottom and suction pump mounting holes at the top.

Once the pile is lowered to the seabed and self-penetrated as far as possible, the pump sucks the water and air out of the pile until the pile is driven into the seabed to the target penetration. Then the pump is disconnected and the pump holes are covered with a hatch with help from an ROV.

- Suction bucket foundation tri-bucket jacket design

- Suction bucket foundation single bucket transition piece design

Both designs have been used in Oil&Gas in the same way as the jacket foundation before use in wind energy. They are a great method used for fixed moorings of vessels, but some problems with installation and stability on wind farms have occurred. The soil survey and calculations need to be checked and reviewed closely before choosing this foundation type.



Suction bucket foundation single bucket transition piece design

Industry terminology used for foundation installation

BC
Bubble curtain

BBC
Big bubble curtain

SS
Seal scarer

TP
Transition piece

MP
Mono pile

SB
Suction bucket

ROV
Remotely operated vehicle

WOW
Waiting on weather

NMS
Noise mitigation system

PT
Pile template

MOM
Minutes of meeting

DPR
Daily progress report

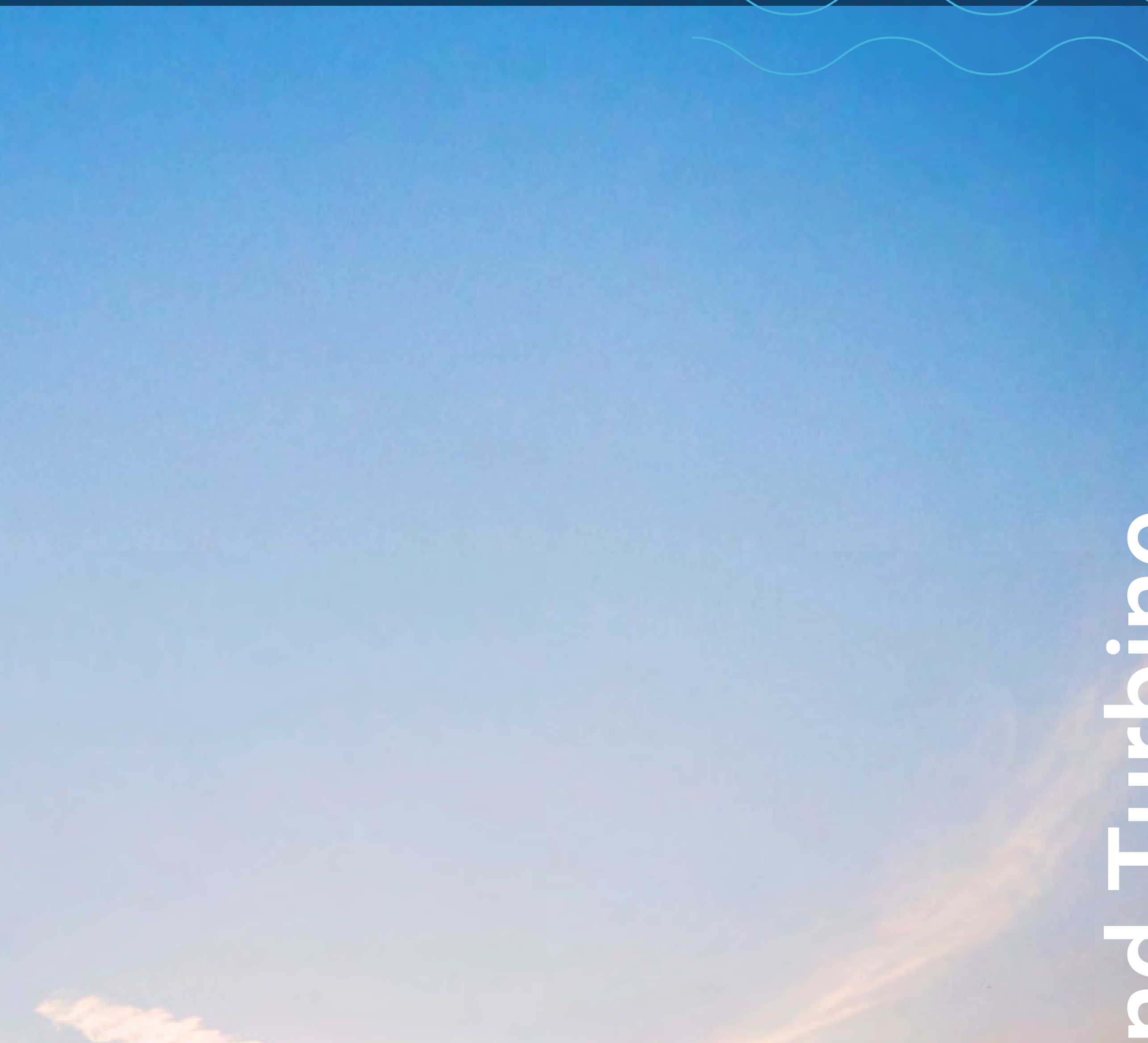
TBT
Tool-box talk

LP
Lift plan

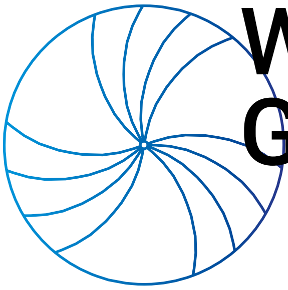
PTW
Permit to work

RAMS
Risk assessments & method statement

module - 02



Wind Turbine Generators.



Wind turbine Generators.

01. WTG introduction information

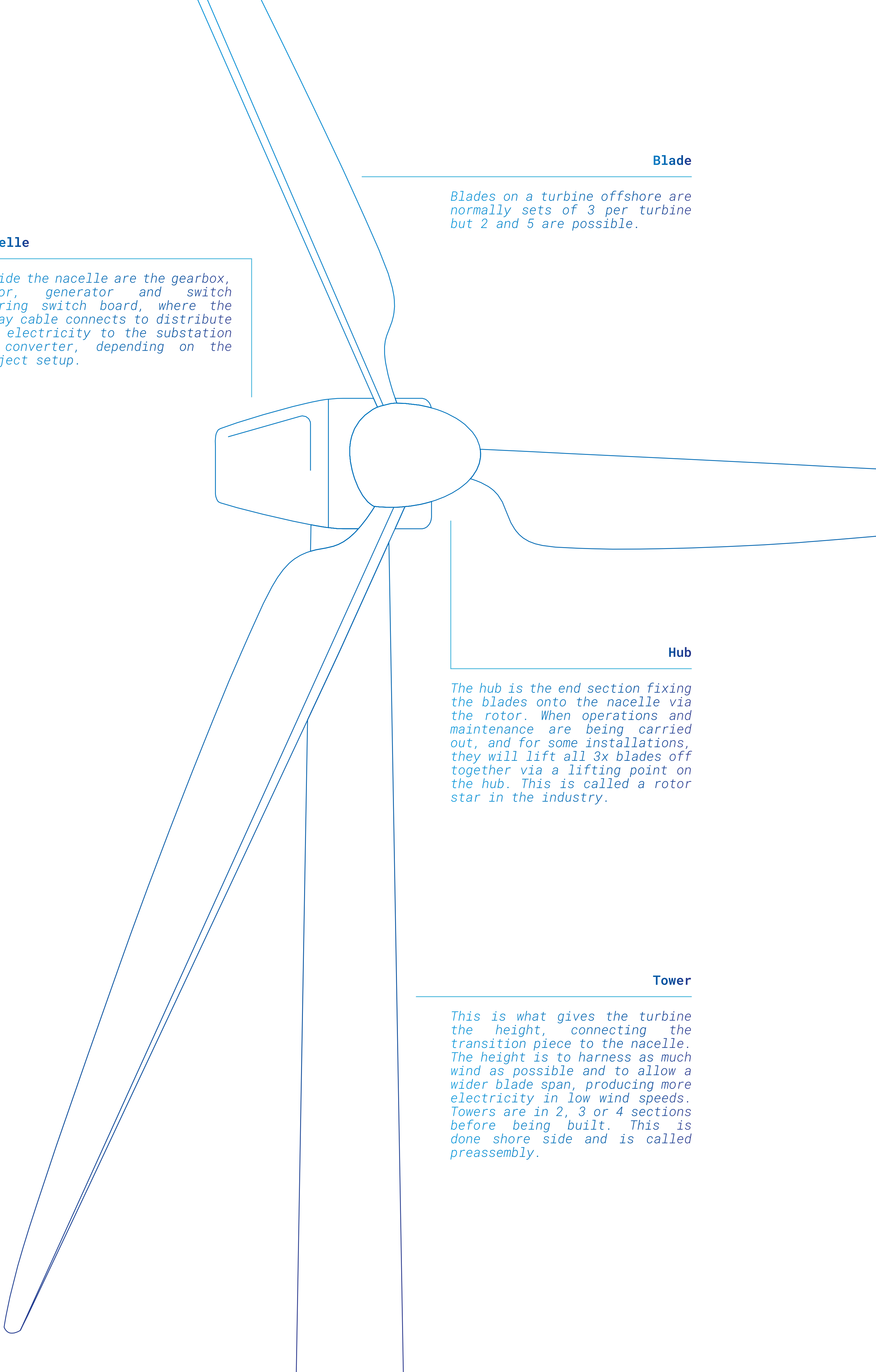
A wind turbine converts the kinetic energy of the wind to a useful mechanical energy. This energy is used in mechanical form to turn the generator and provide electricity. The turbine is turned when the wind contacts the blades, causing them to turn the rotor linked to the turbine.

The wind speed determines what gear the turbine will be in and the amount of electricity that will be produced. Most turbines operate at between 4 metres per second as a minimum and 40 metres per second as a maximum.

In low wind speeds the turbine will be turned on with its stored electricity and then the wind will continue to turn the blades and rotor, producing electricity. This is done remotely via the wind farm optimisation team known in the industry as the SCADA team because the remote access software used is called SCADA.

In high wind speeds the turbine will produce more electricity because the higher kinetic energy makes the blades rotate faster, making higher mechanical energy that is converted to electricity.

Wind turbine generators are known in the industry as WTGs. The package and installation cover not only the turbine but also the tower section and blades.



Nacelle

Inside the nacelle are the gearbox, rotor, generator and switch gearing switch board, where the array cable connects to distribute the electricity to the substation or converter, depending on the project setup.

Blade

Blades on a turbine offshore are normally sets of 3 per turbine but 2 and 5 are possible.

Hub

The hub is the end section fixing the blades onto the nacelle via the rotor. When operations and maintenance are being carried out, and for some installations, they will lift all 3x blades off together via a lifting point on the hub. This is called a rotor star in the industry.

Tower

This is what gives the turbine the height, connecting the transition piece to the nacelle. The height is to harness as much wind as possible and to allow a wider blade span, producing more electricity in low wind speeds. Towers are in 2, 3 or 4 sections before being built. This is done shore side and is called preassembly.

02. WTG manufactures

There are many turbine manufacturers in the industry, but the two main companies are Siemens® and Vestas®.

Other companies trying to compete and making good progress are:

- GE- General Electric®
- GW - Gold Wind®

SGRE

SIEMENS Gamesa RENEWABLE ENERGY

Siemens Gamesa Renewable Energy® is the biggest turbine manufacturing company in the world after Siemens bought out Repower, Senvion, Arriva, Ad-win and Gamesa. They have been in the business since the early 1980s with their first name of Bonus.

MVOW

MHI VESTAS OFFSHORE WIND

Mitsubishi Vestas Offshore Wind® is a big player in the industry. Vestas is a company that was formed in 1945 as an engineering and blacksmith shop, first involved in the wind business in the 1980s called NEG-Micon. They entered a partnership for offshore wind with Mitsubishi Heavy Industries in 2013 and became independent again in 2020 when they bought the 50% share back from Mitsubishi.

03. WTG pre-assembly.

WTG components are manufactured in different locations and transported to a port for pre-assembly. They are moved and shipped by SPMTs, HGVs and vessels, all depending on the locations and project.

The pre-assembly consists of:

- Cold commissioning of the nacelles, where they are tested and programmed for their project location. This is known in the industry as CC M&E, standing for cold commissioning mechanical & electrical.
- Hub installation: the hub is attached and connected to the nacelle and guide pins are installed on the hub for the offshore installation of the blades.
- Tower erection of the tower parts: the towers mainly come in two, though sometimes three, sections to save time with tight installation weather windows. They are built into one section at site.
- Blade sets: the blades all have a slightly different weight, so they are put into sets of the same weight for installation. This is to ensure that the turbines do not wear the gearbox or rotor due to oscillations because the balance and weight of the blades is out.

04. WTG transportation.

WTG transportation is split into three areas. Please see below further information and pictures of the equipment vessels and vehicles used:

- Transportation from manufacturer's yard to pre-assembly site
  Depending on the project location and the pre-installation pre-assembly port used, they are transported by sea and road using HGVs & SPMTs.
- Transportation at pre-assembly site (port)
  Moving the components is done using SPMTs' mobile cranes and crawler cranes.
- Transportation from pre-assembly site to offshore wind farm
  Transporting the WTGs to the offshore field for installation is done using the installation vessel. This is different to foundations because sometimes foundations are floated out or transited via a barge.

05. WTG installation Vessels.

Offshore wind farm WTG installation needs to be done at present using self- elevating barges. However, as the technology improves it might be possible to do this with dynamic positioning heavy lift vessels in the future, as foundations are installed in the present day, to save time and minimise seabed footprints.

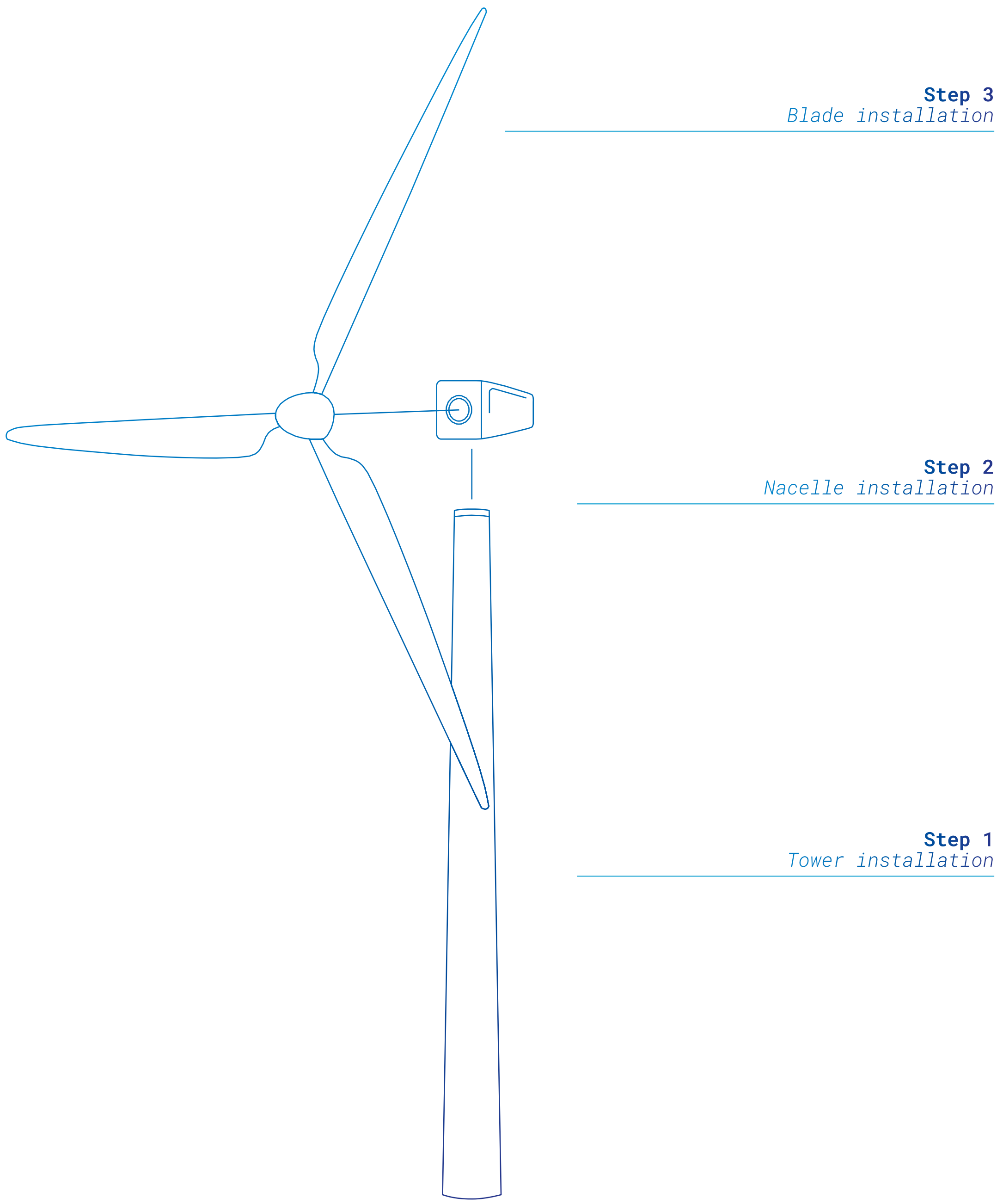
In the early days with smaller turbine heights and weights, jackups that were purpose-built for marine construction and oil and gas were used for WTG transportation and installation.

In the modern day, because the wind energy industry has expanded and because the weights and heights of WTGs are getting bigger, purpose-built vessels are now made. These are called WFIVs, which stands for wind farm installation vessels. Unlike the old jackups, they don't need a tug boat to run anchors or tow them because they are self-propelled and have a DP system (dynamic positioning), a computer system using GPS and lasers called fan beams to keep the vessel in the correct heading and position.

06. WTG installation.

First the installation vessel needs to take up position and jack to height at the installation location where the pre-installed foundation is positioned.

Then the WTG installation offshore goes through the following steps:



There is talk of using a big DP-HLV in the future for single-lift installation of WTGs, but the technology is not mature and trials have not yet been done for fixed foundation wind farms. However, for floating wind, this has been successfully done.

Step 1 | **Tower installation**

The tower is sea fastened to the deck of the vessel, the vessel crane connects the tower lifting tool (rigging) to the tower, then the seafastening is removed and the tower is landed on the foundation flange to the bottom tower flange. This is done with the use of guide pins and the TGS (tower guidance system), a posh word for cameras. Once the tower is landed, the tower is bolted to a high torque and the rigging is removed. Along with the tower cover, this is a small lid used to minimise the elements while the tower is stored at site and onboard the vessel. Lifting operations are normally limited to 20 metres per second for this lift.

Step 2 | **Nacelle installation**

The nacelle is loaded on the deck in a square frame and the frame is seafastened to the vessel deck. For installation of the nacelle, it must be unbolted from the frame and all testing completed so that the nacelle is part- functional for the installation process.

Once the nacelle is cold (ready for installation), the crane will connect the rigging to the nacelle for the lift. This is via nylon lifting slings and a spreader frame known in the industry as a nacelle lifting yoke. The reason the spreader bar is necessary is because the weight of the nacelle is uneven until the blades are attached.

Step 3 | **Blade installation**

Blade installation is done using different methods and different tools, depending on the manufacturer. Single blade installation is the most common with modern large diameter blades, but sometimes all three 3 blades can be installed at once.

WTG installation | additional information

When the blades are all attached to the turbine, a final torque of the bolts is made. This is known in the industry as stretching the blades.

When the turbine is left for the commissioning team with one blade at 2 o'clock, one at 6 o'clock and one at 10 o'clock, this is known as 'bunny ears' as per the picture above.
The nacelle is tested by the factory before its transported. Then, when the turbine is at the pre assembly site, it's set up and tested along with the ROC (remote operations control) being added when the turbine is programmed and set up at this site. This is called cold commissioning.
Final completion tasks to the turbine are known as completion works. These are done by M&E staff from the turbine manufacturer or designated 3rd party competent company, ensuring bolts tightening ,fluids check, post installation electrical test and they also try to make the lift operative, so that when the commissioning team arrive they don't need to climb the turbine. When the turbine is connected to the array cables and has passed all required testing the hot commissioning can be considered completed.

When the turbine power is cut off for repair work or testing, this is known as LOTO, which stands for Lock Off Tag Off.

Industry terminology used for WTG installation.

WTG
Wind turbine generator

TLT
Tower lifting tool

LY
Lifting yoke

LOTO
Lock off tag off

TGS
Tower guidance system

BIT
Blade installation tool

HT
High torque

WOW
Waiting on weather

Blade stretching
Final torque of bolts fixing the blades

WFIV
Wind farm installation vessel

MOM
Minutes of meeting

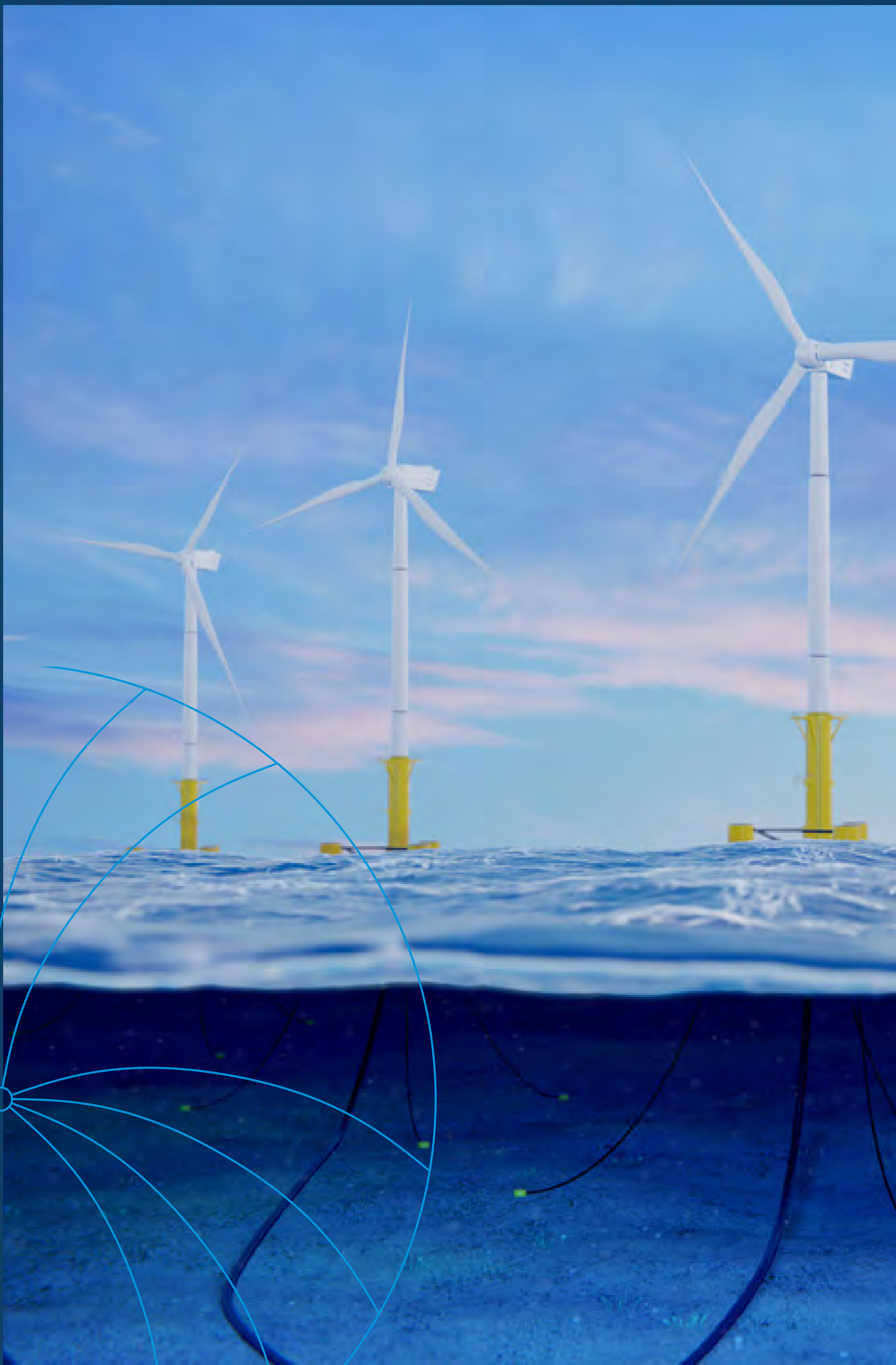
DPR
Daily progress report

TBT
Tool-box talk

LP
Lift plan

PTW
Permit to work

RAMS
Risk assessments & method statement



Cable Installation.

module - 03

Cable installation.

Offshore wind is split into packages that are tendered, managed, and executed by different staff, companies and vessel types that specialise in the specific operation.

The cable package consists of the following operations:

- ◎ Survey (UXO'S & MB)
- ◎ Corridor clearance
- ◎ Trenching
- ◎ Burials
- ◎ Cable protection systems (CPS)
- ◎ Scour protection
- ◎ Cable lay
- ◎ Cable pull
- ◎ Testing and termination

This module will cover: cable types, cable laying, cable pulls, cable protection,messenger wire, vessels used, and industry terminology.

The other operations will be covered in future modules.

01. Cable types.

The main cable types include but are not limited to:

- Array *(inter-array cables)*
- Export *(export cables)*
- Continental *(intercontinental cables)*

We have not included communications cables above because most wind energy projects have the fibre-optics (comms cable) built into the export, array, and continental cable, so they don't lay separate cables for this in the way that oil and gas still do for platforms and pipelines.

Array cables

Array cables are the string of cables forming the circuit from each individual turbine to the substation. They are installed in single lengths in series from one turbine to its neighbouring turbine. They are usually 36 kV for modern projects but at earlier wind farms they range from 28 kV to 36 kV.

All array cables in use are 3-core. Most modern cable also has fibre-optic wire built in. This is used for the telecommunications (mainly SCADA), for the remote operations of the turbines, turning them into the direction of the wind to harness as much energy as possible, and turning them on and off.

Export cables

Export cables transfer the power produced at the wind farm to the land-based grid connection. On most projects, this is two 220 kV cables. The length varies depending on the distance between the wind farm and the chosen grid connection.
All offshore wind farm projects are different. Exports cables may go from the offshore substation to the high-voltage direct current platform or to the offshore converter unit. The length, voltage and number of export cables are all dependent on the project.

Some single substation wind farm projects install three export cables, using two and having the third as a spare.

Some projects have more than one substation, so more export cables are needed, with two as a minimum per substation.

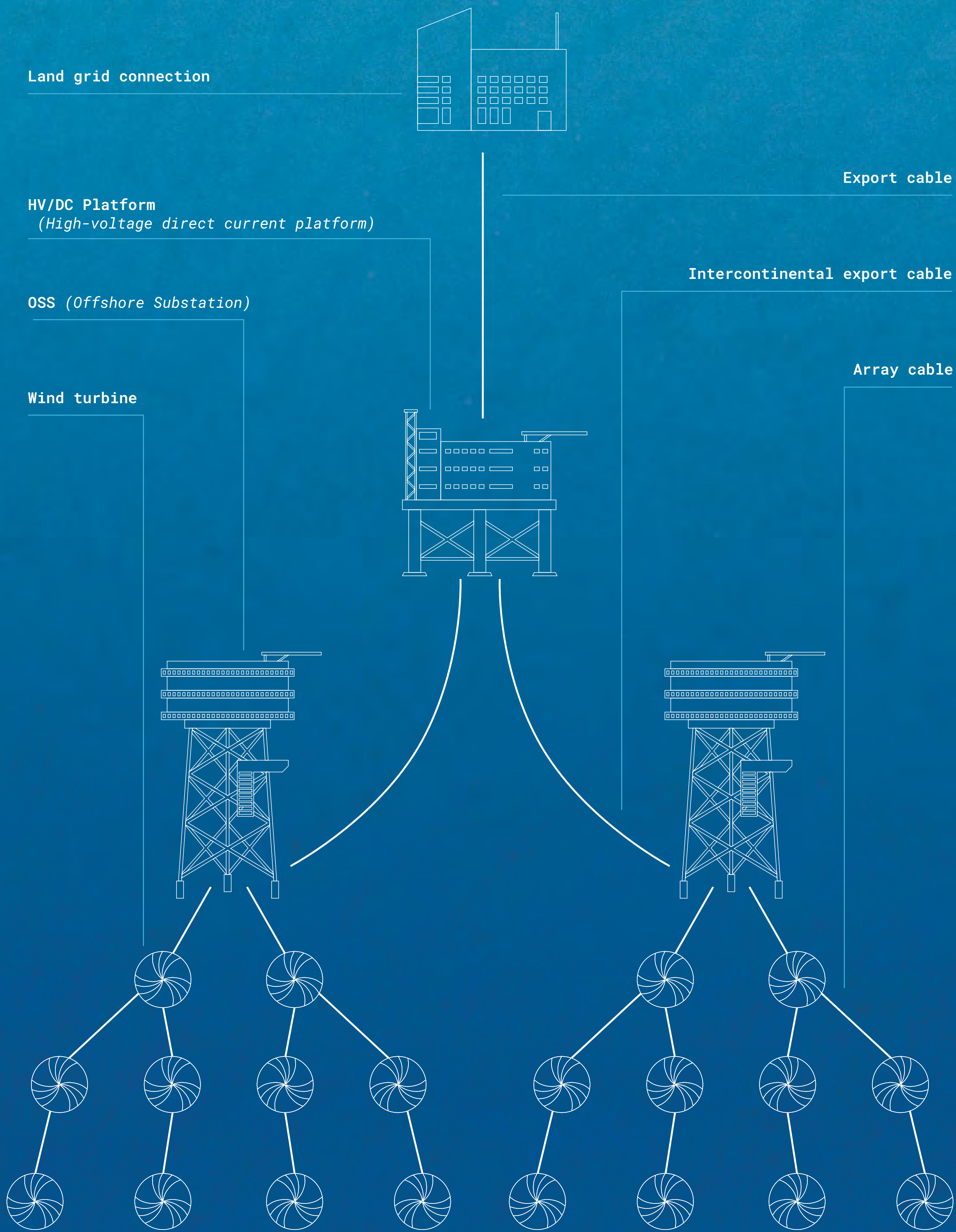
Some projects have continental cables that join the wind farm to a high-voltage direct current platform. Some projects export the electricity to more than one grid connection. This will alter even more in the future as battery land storage technologies and techniques start to improve.

Inter-continental cables

Continental cables can mean two things in the wind farm industry:

- Firstly, they can be an export cable that travels to a different country than where the wind farm is located.
- Secondly, they can be a cable that travels and distributes the electricity from a windfarm to a converter or high-voltage direct current platform before the export cables send the power to the land-based grid.

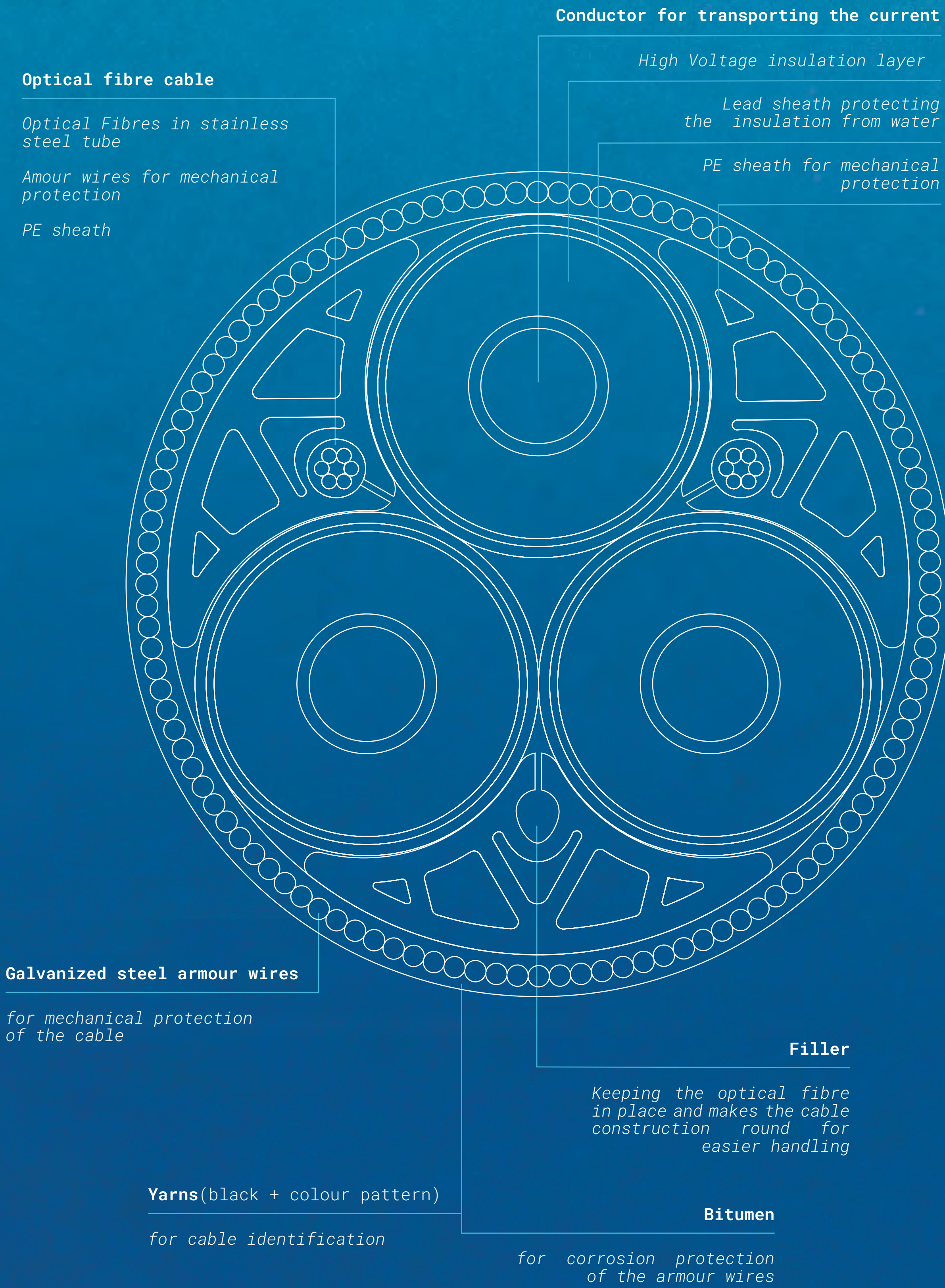
In summary, intercontinental cables are the same design and voltage (typically 220 kV) as export cables, but they just travel to more than one place or country before the land-based grid.



Land grid connection
Export cable
HV/DC Platform
(High-voltage direct current platform)
Intercontinental export cable
OSS (Offshore Substation)
Array cable
Wind turbine

02. Typical Cable diagram.

Please see below a diagram of typical cable design showing the fibre-optics, the three cores and the protective layers. Array and export cables look the same and only the size varies: the higher the voltage, the bigger the cable.



03. Cable installation. Vessel used

CLV'S

Cable laying offshore can be done with more than one vessel type, but the modern day purpose-built vessels are registered and called CLVs. Cable laying vessels have dynamic positioning so they can stay in position for cable pulls, cable jointing and cable cuts, along with having a minimum of:

- 1x Cable Carousel
- 1x Cable tensioner
- 1x Cable chute
- 1x Small crane
- 1x ROV work class

In the past, dynamic position vessels (DPVs) and barges were hired and the above equipment was added to the vessel for the project during the mobilization.

The top of the range modern CVLs have two carousels below deck level, saving deck space for equipment and the working area.

Having two carousels on a vessel is preferred because it saves time, money, and port-calls in the good weather months, but the higher daily rate of the vessels can make them undesirable for small jobs in the winter months.

CTV'S

Crew transfer vessels are used in the wind farm industry to get teams of crew for the cable installation onto the required assets.

The CTVs push against the purpose-built boat landing of the vessel, turbine or substation, and the crew climb the ladder wearing a harness to gain access.

CTVs are also used for shift changes on non-manned assets and crew changes on nearshore projects.

This method can only be used once the foundation is installed and weather is feasible, with maximum 2 m waves, etc.

In locations where the sea state is more adverse all year round, they use a walk-to- work system on an MPV (multipurpose vessel) or WFSV – WFSB, the name depending on the size.

The industry leader for the walk-to-work system is Ampelmann. If you're interested in walk-to-work systems there are lots of videos available online.

04. Cable loading.

Cable is manufactured in specialist facilities and is mainly transported on temporary cable drums, usually made of steel, to the loading site.

Once the cable laying vessel is ready to load the cable onto the carousels, this is a slow process, normally taking 10-20 m per minute.

Sometimes export cable or specially made cable is loaded to carousels directly at the cable manufacturer's site.

05. Cable installation.

Cable installation consists of the following operations:

- Cable pulling
- Cable pulling
- Cable laying
- Testing and terminations

Sometimes the cable is laid first and recovered at a later date for the cable pulls, followed by testing and terminations. This is called (pre-lay) wet storage. The cable is pulled via a messenger wire and a winch system to its desired location, sometimes a beach pull, sometimes through a j-tube on a wind turbine, or sometimes on a substation, depending on what cable type it is.

Cable pulling

The messenger line is recovered with an ROV offshore or by hand for a beach pull and is connected to the cable end using a Chinese finger.

Once the messenger wire is connected to the cable, a winch is operated and the carousel turns to offload the cable and the cable is pulled to its required location.

During this operation, a cable tensioner is used to ensure that the cable is not too slack or tight, which could damage the cable or cause the messenger line to fail.

Cable laying

Cable laying is a slow and straightforward operation during good weather conditions, but the cost and risks can be massive if the cable is damaged.

For this reason, the cable is constantly watched and tensioned. There are cameras on deck and on the carousel, and ROVs are deployed subsea to monitor the cable and connect the cable to the messenger wire if required, along with 24-hour installation teams.

The carousel turns to offload the cable,

the vessel moves, and the cable is laid off the vessel from the chute to ensure that the MBR (minimum bend ratio) is not exceeded. The MBR varies for all different cable designs, but is usually 6-8 times the diameter. The usual speed for laying cable is 15-25 metres per minute, but each job and vessel varies.

Cable protection systems

There are many types of cable protection systems. Some are added to the cable ends before it is laid, while some are attached to the j-tubes of the turbine, platform, and substation foundations for connection to the cable during the cable pull operations. The usual design is with sleeves that are attached to the cable, made of high- strength plastic.

Cable protection systems (CPS) and cable protection are different. A cable can also be covered with concrete mattresses known as scouring mats and the installation mattressing and rocks can be dumped under and over the cables to protect them. This is known as rock dumping. Both the mattressing and rock dumping will be covered in the scour protection module.

Industry terminology used for cable package.

CLV
Cable lay vessel

MPV
Multi-purpose vessel

CPS
Cable protection system

SS
Sub station

OSS
Offshore sub station

HVDCP
High voltage direct current platform

WFSV
Wind farm support vessel

WFSB
Wind farm support boat

WOW
Waiting on weather

MBR
Minimum bend radius

Arrays
Inter-array cables

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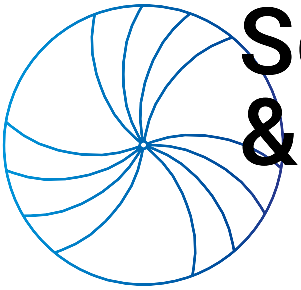
module - 04

Scour & Scouring.



Scour & scouring.

When an offshore wind farm is built there is a subsea package that is linked to the cable package on almost every project I have worked on, called scour / anti- scouring.

Scour

Scour is an occurrence that happens with most installed offshore structures. It's a process where the seas, current and tide move the seabed away from the structure, leaving a hole around the structure.

Scouring

Scouring is an occurrence that happens when the seabed debris, mainly but not limited to sand, is carried in the current, tide and seas causing abrasion to anything it makes contact with.

01. Scour / scouring protection

Scour and scouring protection can be completed in several different ways depending on the environment and studies of the area where the wind farm is being installed.

To protect cables the main methods are:

- Cable burial / trenching
- Rock dumping
- Cable protection system installation
- Concrete mattress installation

To protect platform and turbine foundation structures the main methods are:

- Rock dumping
- Concrete mattress installation

In this module we will cover mattress installation and rock dumping, the two main methods that are used for both cable and foundation scour / anti-scouring protection. Also I will include the rock types, industry terminology and vessel types used.

Cable protection systems and cable burial will be covered in separate modules.

02. Rock dumping.

Rock dumping is a straightforward process that has been used successfully for a long time now. However, as the industry has evolved, the methods for loading, transportation and installation have improved.

03. Rock loading.

For loading of rock to the vessel, conveyor belts and 360 excavators are used both at the quarry or rock storage site and onboard the vessel.

04. Rock transportation.

Transportation of rock is the same as always. The installation vessel loads the rock from the storage site or quarry and transports it to the installation site (wind farm)

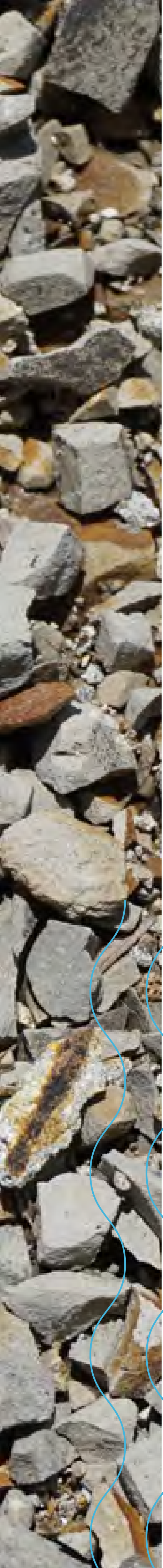
The only thing that has altered is the vessel capabilities. Modern vessels can travel carrying up to 30,000 tons of rock at an economical speed of 18 knots.

In the past RIVs (rock installation vessels) could only carry 10,000 tons travelling at 12 knots.

05. Rock installation.

Vessels used for rock dumping have several names depending on the equipment onboard, the company of classification and country they are registered in. Please see below the most common classes used:

- RIV *(Rock installation vessel)*
- SRIV *(subsea rock installation vessel)*
- FPV *(fall pipe vessel)*
- RDV *(rock dumping vessel)*
- SSDV *(side stone dumping vessel)*



06. Rock types.

For rock dumping, different rock density and different rock sizes are used. Please see below the most common types used for wind farm scour and scouring protection:

- Scatter layer

  (1-3 inch small stones, 2000 KG/M³)
  a ground layer used on very soft ground before a filter layer is installed to make the ground denser. This is a cheap grade stone that can be installed in large amounts fast. It is very rarely used for offshore projects but used more for nearshore export cables.

- Filter layer

  (1-6 inch stones, 2630 KG/M³)
  an under layer used to minimise the amount of armour layer used and installed to make a more natural formation known in the industry as a berm.

- Armour layer

  (12-18 inch rocks, 6150 KG/M³)
  a top layer of big strong rock stabilising the installed filter layer and stopping the risk of any damage to the asset that the rock is protecting.

07. Rock installation.

For rock installation the four methods are:

- String of buckets
- Fixed fall pipe
- Side stone dump
- Side chute dump

String of bucket for rock installation

The bottomless buckets are joined together with rigging, mainly chain, and secured to the monopile.

With the use of the vessel's conveyer belt and the 360 excavator for loading the belt, the rock is dumped down the buckets, and with the help of gravity the rocks drop to the target location with the use of the vessel's GPS and the ROV for visual confirmation.

This is commonly used for the armour layer because it rarely blocks and is a fast method.

Fixed fall pipe for rock installation

This is the most popular and most accurate way to dump rock. Like the string of buckets, the fall pipe is lowered from the monopile subsea. The conveyor belt loads the rock into the fall pipe. Most modern vessels use this method and are registered as an FPV (fall pipe vessel). Lowering the fall pipe can be time-consuming but, once installed, it is fixed and accurate compared to the string of buckets, which can move off course with strong current or sea states.

Side stone dumping for rock installation

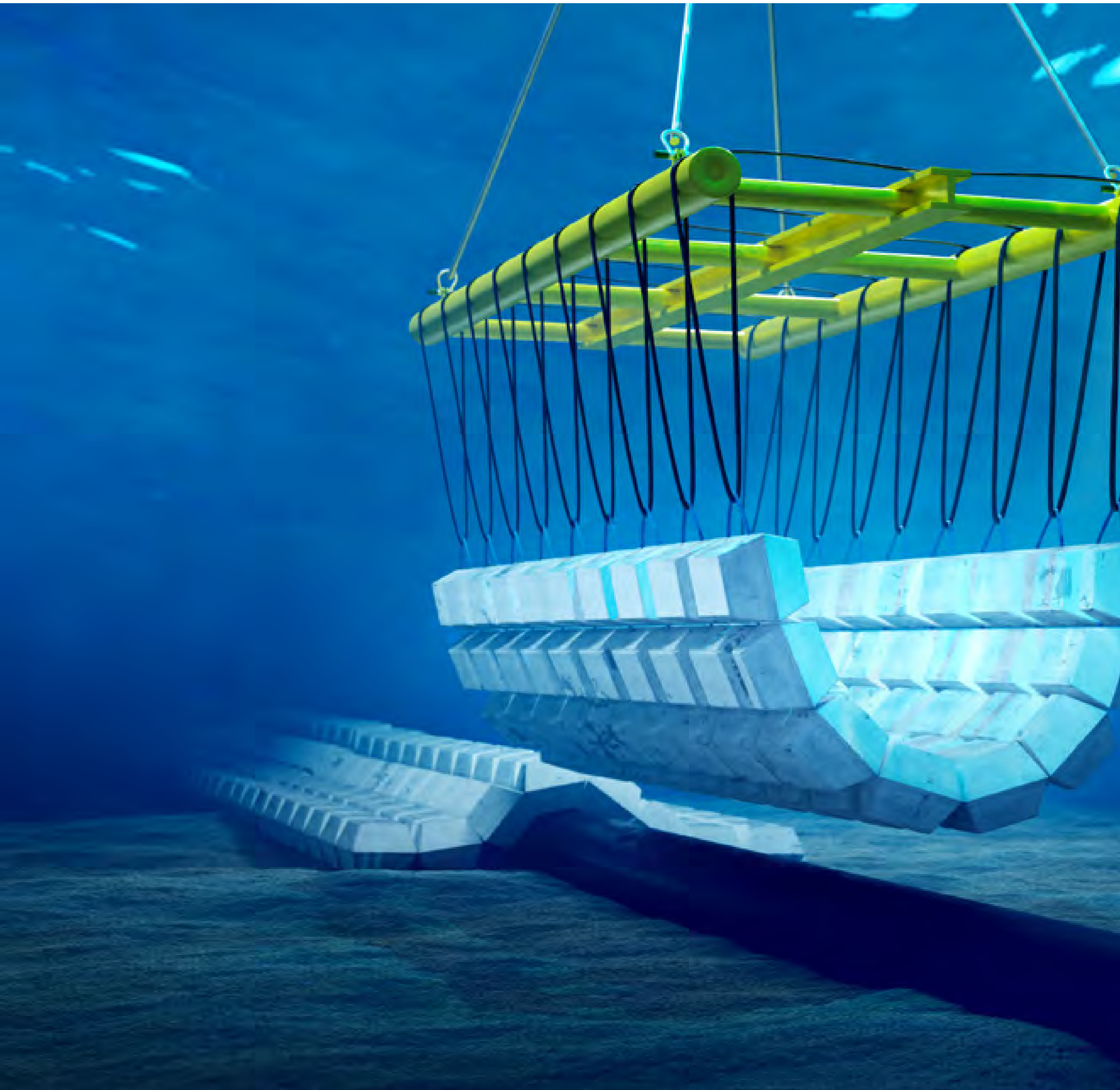
Side stone dumping is a method that is fast and can be used for any rock size. It was the first method of rock dumping developed and works very well in shallow waters, but only puts the rock in one area. So, unlike the fall pipe, buckets and side chute, it's not practical for covering cable or pipes and is mainly used to cover piles at offshore fixed structures.

Side chute dumping for rock installation

Side chute dumping is a slow process used on vessels close to assets for the first few metres until they can reach the target with the monopile for dumping with a fall pipe or string of buckets. The chute is a rockslide that hangs over the vessel and is loaded usually with a single 360 excavator, one excavator bucketful at a time. But on specialised projects a conveyor belt can be used to save time.

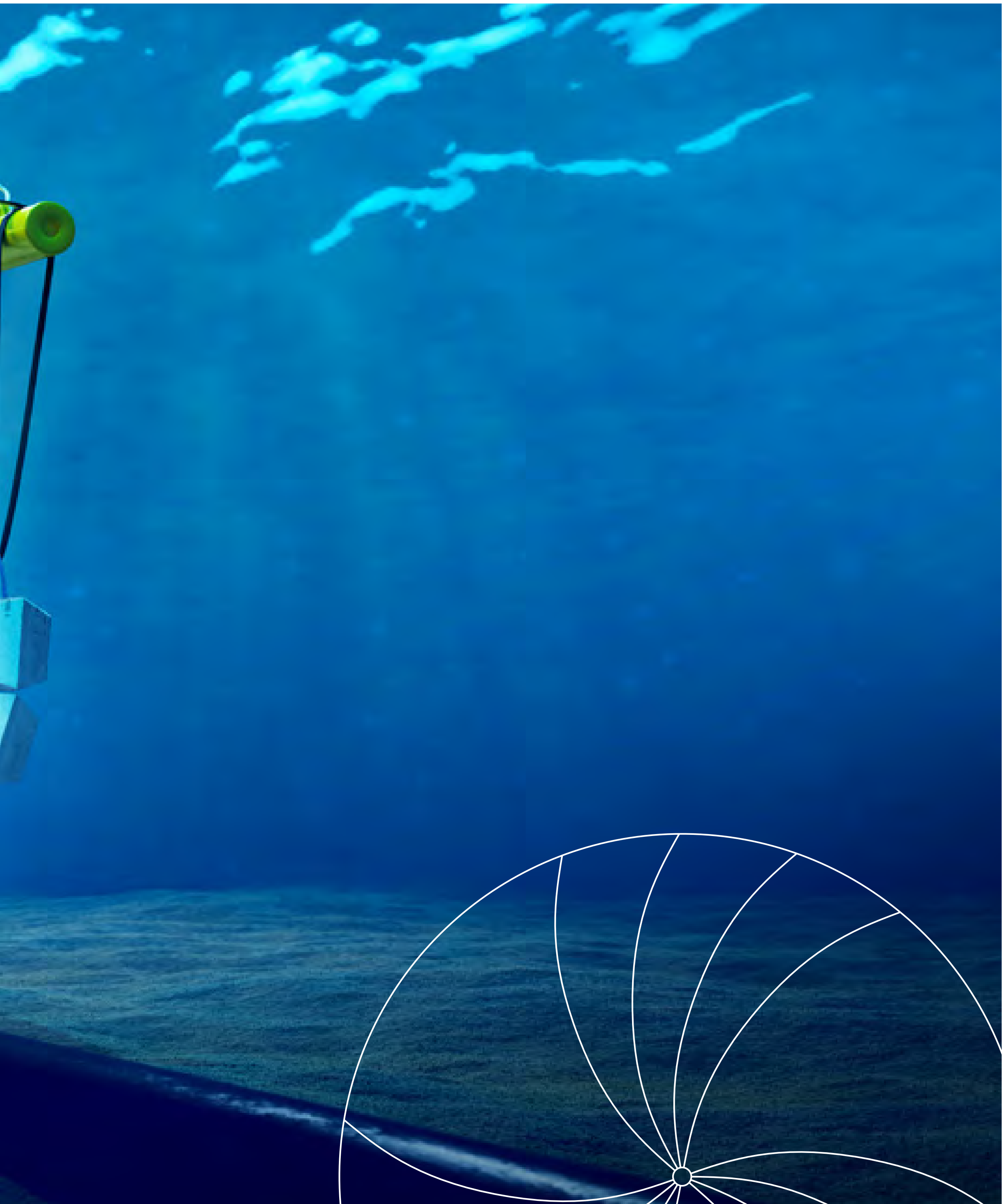
08. Mattress transportation & installation

Scouring mats are commonly used around piles to protect from scour but are not used much for scouring protection as rocks are preferred. In some areas that have low currents and are not tidally affected, concrete mattresses will be laid as a stabiliser for the cable because they are cheaper than rock and can be installed fast using cheap vessels that only require a subsea crane, an ROV and a hydraulic cutting tool for the installation slings built into the mattresses.



Unlike rock dumping, there are not many methods for installation, but only one set of steps as follows:

- Load the mattresses on to the selected and hired installation vessel.
- Transport the mattresses on the vessel to the deployment site.
- Connect the mattresses to the crane.
- Install the mattresses subsea to the cable or structure foundation location.
- Disconnect the mattresses from the crane using an ROV or specialist tool.



BLUE STONE GROUP

Industry terminology used for rock dumping.

RIV
Rock installation vessel

MPV
Multi-purpose vessel

SRIV
Subsea rock installation vessel

FPV
Fall pipe vessel

RDV
Rock dumping vessel

SSDV
Side stone dumping vessel

FP
Fall pipe

FFP
Fixed fall pipe

RI
Rock installation

Pre-lay
Survey before rock or mats are installed

Post-lay
Survey after rock or mats are installed

SOB
String of buckets

SC
Side chute

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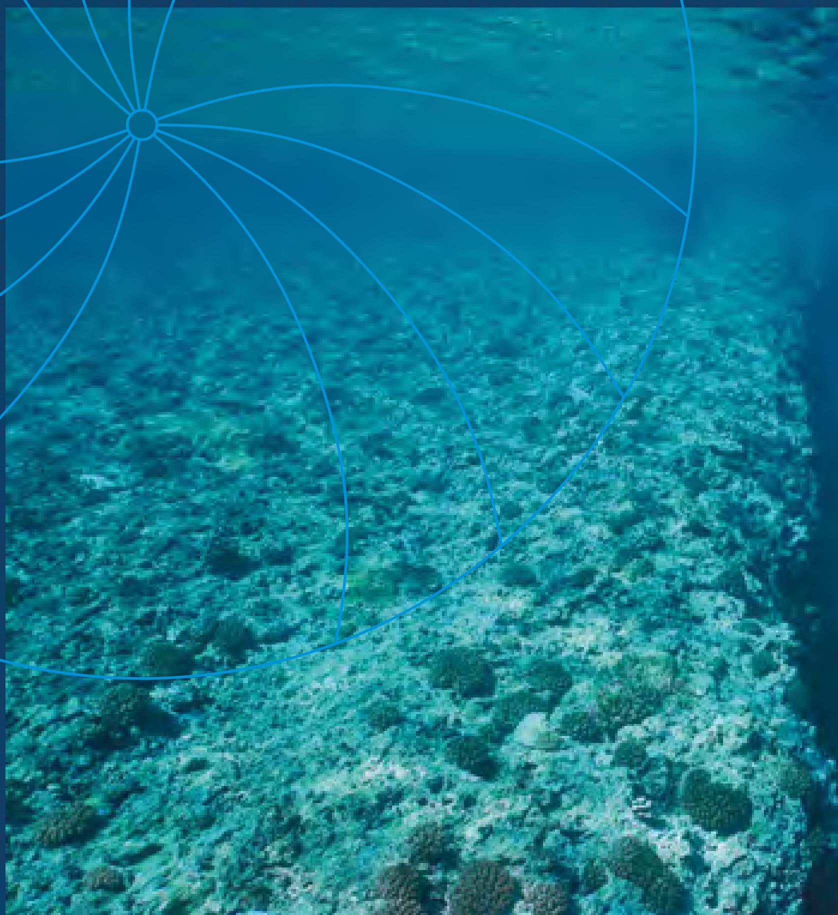


module - 05

Trenching & Burials.

Trenching & burials.

A trench is a type of excavation that is usually deeper than it is wide, and narrower compared to its length.

In geology, natural trenches are created as a result of erosion by rivers, scouring by currents and tides, or movement of the tectonic plates.

In the wind farm industry and cable industry for telecommunications and oil and gas, trenches are man-made using several methods and tools. The main ones are:

- Plow
- Trencher

For trenching, the old and still most commonly used method for soft grounds, sand, clay and silt is to deploy a plow, which is dragged across the seabed-corridor by a vessel at sea. This makes the cable corridor (trench), then the cable is laid into the trench using a cable sledge. The backfill can be done with a water-jetting tool or, if the area is subject to high scouring, rocks are dumped over the cable.

01. Plow.

This is a traditional shape, but its modern hydraulic arm makes it possible to alter the depth fast.

02. Plow system.

This is a similar design to a normal plow, but it is deployed offshore and pulled to the shore using a winch. This is only used for export cables and still needs a vessel on standby monitoring the tool and available to assist if the tool gets stuck.

03. Cable sledge system.

This is a modern method used to stop the cable from bending when it's being laid and to make laying the cable faster, without needing to worry about the vessel heading as much during rough seas.

04. Trencher.

This is a modern tool and method used for trenching, cable burials and cable recovery.

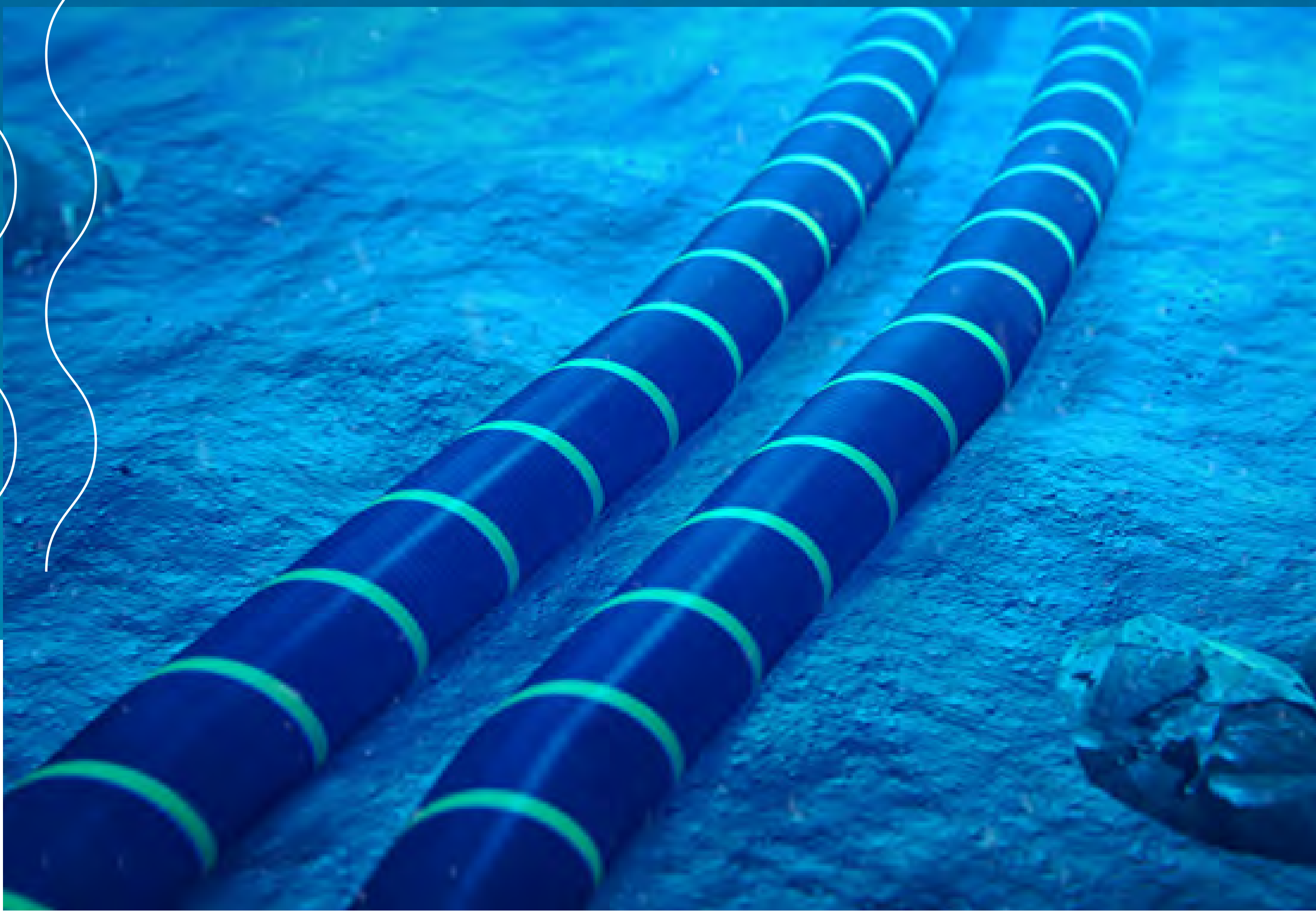
The tool has tracks so it can walk along the seabed by itself. The method for moving the seabed is high-pressure water jetting, known in the industry as mass flow.

04. Cable burials.

Some modern tools known as plow burial tools or lay and burial sledges are deployed during the cable laying process and bury the cable as it is laid.

Older methods are rock dumping, which is expensive, so it is only used if the cable requires stabilisation from strong seas or protection from scouring.

Please see the picture below of export cable being buried by a trenching tool.



The cable industry is massive. It covers and connects the world for electricity, internet and communications.

- Land based.
- Wireless.
- Offshore.
- Overhead.

Additional information about cable trenching and burials can be found on the internet.

Industry terminology used for trenching & burials.

CSS
Cable sledge system

MPV
Multi-purpose vessel

SRIV
Subsea rock installation vessel

FPV
Fall pipe vessel

RDV
Rock dumping vessel

SSDV
Side stone dumping vessel

Pre-lay
Survey before rock or mats are installed

Post-lay
Survey after rock or mats are installed

SOB
String of buckets

SC
Side chute

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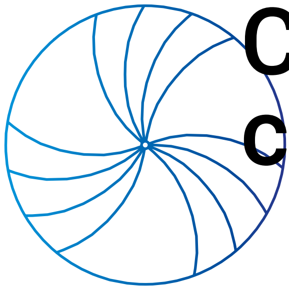
Corridor Clearance.

module - 06



Corridor clearance.

Before an offshore wind farm is built, the location is checked for a couple of years to check the habitat for nature and marine life.

If there are no environmental restrictions, a met-mast and wave buoy are then installed in an approved checked safe location and these will monitor and record the wind speeds and sea states

This data from the met-mast (meteorology mast) and wave buoy is recorded and, if it is cost-effective with a good amount of winds, then a government submission for consent (construction permit) is applied for. This takes some time, and in some countries more than others.

If the wind farm is approved for pre-construction, a UXO (unexploded ordnance) survey will first be carried out to clear any UXOs. Some bombs from past wars may be found, but some objects are large rocks and boulders that are recorded and left.

Then a soil investigation survey is completed, sometimes by drilling core samples and at other times using acoustic and multibeam surveys to see what possibilities are available.

All this survey and meteorological data is given to the engineering and project planners, who choose the foundation type, location of turbines, substation, and cable corridors, depending on the best available ground in the windy areas.

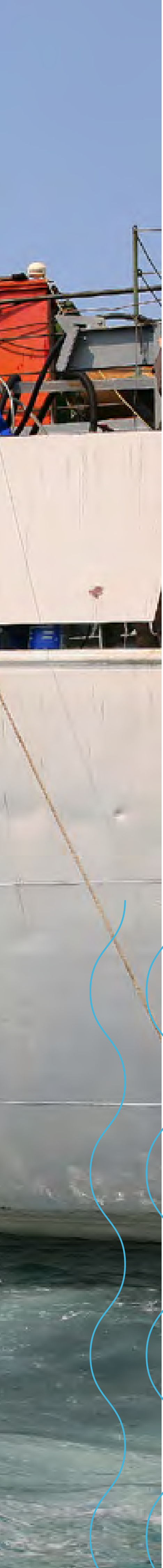
Once the agreed locations of the turbines and cables are approved by the government, grid, and stakeholders, a pre-lay survey will be completed for the array and export cable corridors.

If, during the cable corridor survey, debris and boulders are found, they must be removed. This is called corridor clearance.

Corridor clearance is done in two main methods:

- Boulder removal and relocation
- PLGR


COMANCHE



01. PLGR

PLGR (the pre-lay grapnel run) is where a grapnel is deployed subsea and the hooks on the grapnel, when dragged across and over the cable corridor (seabed), remove non-organic debris such as old cables, ropes, fishing nets, etc.

This is a straightforward operation that has been used by fishermen for years, such as when they lose a fishing net and need to recover it.

02. Boulder removal & relocation

Boulder removal and relocation is used for large boulders only. Small stones and rocks will be moved with the plow or massflow water-jetting excavator during the trenching operation where the cable corridor is made. This will be covered in another training module.

Boulder removal is done using a grab system, which is is a hydraulic claw and a separate ROV, or sometimes a tool with both combined.

The reason it is called removal and relocation is because most of the time the boulders are relocated. They are moved to a location on the boundary of the wind farm. This creates a man-made reef for marine life and helps reduce scouring.

Industry terminology used for corridor clearance.

BRT
Boulder removal tool

Met-Mast
meteorology mast

UXO
Un-Exploded Ordnance

PL
Pre lay

PLR
Pre lay run

PLGR
Pre lay graplin run

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module - 07

Meteorology Masts.

Meteorology Masts.

Meteorology masts, known in the industry as met-masts, are free-standing towers that hold weather measurement tools and equipment. Their job is to record the weather in several forms, such as air density, air static formations, air temperature, wind speeds and sea wave heights.

This data, known as data analysis (D-A), is crucial to the planning stages warranting the feasibility of the wind farm and indicating the best locations to put the turbines. It also gives the most productive turbine size in megawatts for output, and finally the tower height based on the recorded wind speeds at different heights.

The time spent monitoring and reviewing this data in the industry is known as wind resource assessment (WRA), which is carried out by special wind optimisation professionals who also use data from the met-masts and turbines, when operational, to turn the turbines into the wind (direction), harnessing as much electricity as possible.

01. Met-masts.

The following equipment is installed on both shore-based and offshore met-masts:

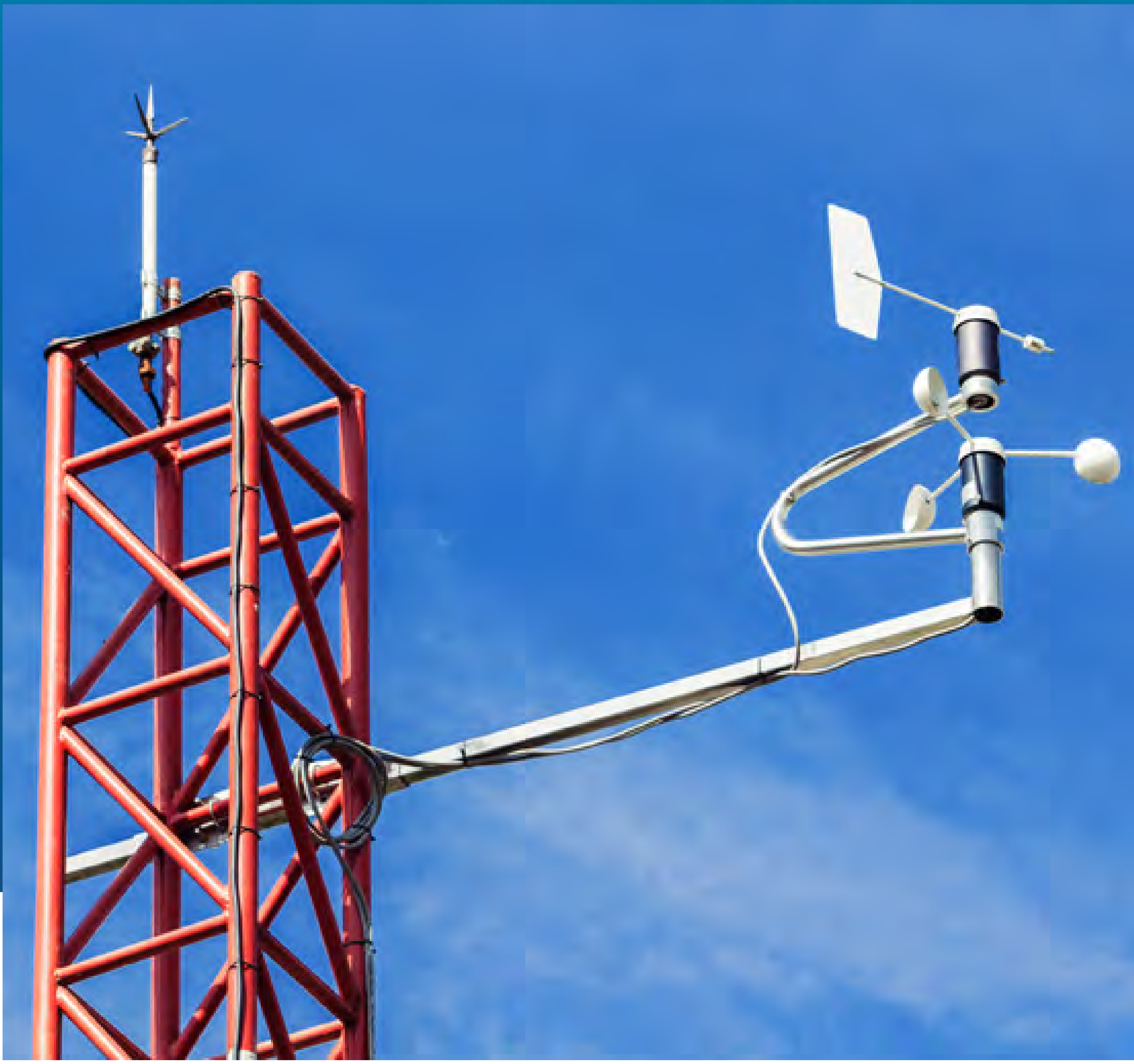
Lightning rod

This is used to measure static formations (lightning). If an area has frequent thunder and lightning, a windfarm will not be installed there because of the high risk of asset damage, human damage, and also because insurance on the turbine would not be cost-effective.

Weather-vane

This is used to record the wind direction. This is more important for the foundation installation for the position of boat landing for vessel CTV transfers and scouring risks.

Met-masts are used by weather forecasters for predicting the weather after monitoring the trends of the actual weather, but also for wind analysis and optimisation before and after wind farm installation.



Cup anemometer

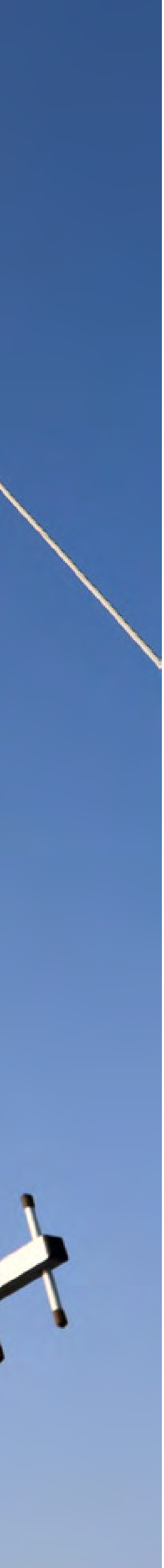
This is used to measure the wind speed and duration. Annual hours are forecasted in 1000s. This is because most wind turbines are serviced every thousand hours once operational.

Thermometer

This is used to measure temperatures. This is important in the design of turbines for correct coatings and pricing operations, as well as maintenance mainly for antifreezing of blades in colder locations such as the Baltic Sea and the Americas.

Pycnometer

This is used to measure the air density. Dense air will create resistance with the turning blades, affecting the amount of electricity produced.



02. Shore based met-masts.

Aside shows a picture of the standard shore based met-mast.

03. Offshore met-masts.

Before an offshore wind farm is approved and given construction authorisation, a met-mast is first installed.

The met-mast should be the same height or higher than the proposed turbines that will be installed in that location.

On average, the met-mast will be installed 10 years prior to the application for consent with governments for the wind farm project. For this reason, sometimes one met-mast will be installed by a client and the data will be sold to other clients, speeding the process up and saving time and money for companies fortunate enough to buy the data.

Offshore met-masts have many different foundation types and sometimes prototypes. This is a great way for clients to test designs, but the most common foundation used is the transition piece with a grouted flange standing on a single monopile.

04. Modern offshore met-masts.

Modern offshore met-masts have solar panels onboard, used for powering the equipment.

The above is the DB-MME met-mast for the Dogger Bank offshore wind farm. It was installed by Four Winds in 2012. A lot of equipment is on the met-mast as a backup because the project involves 1000 turbines, and the data needs to be as precise as possible to ensure a return for the investors once the wind farm is operational.

05. Wave rider buoy.

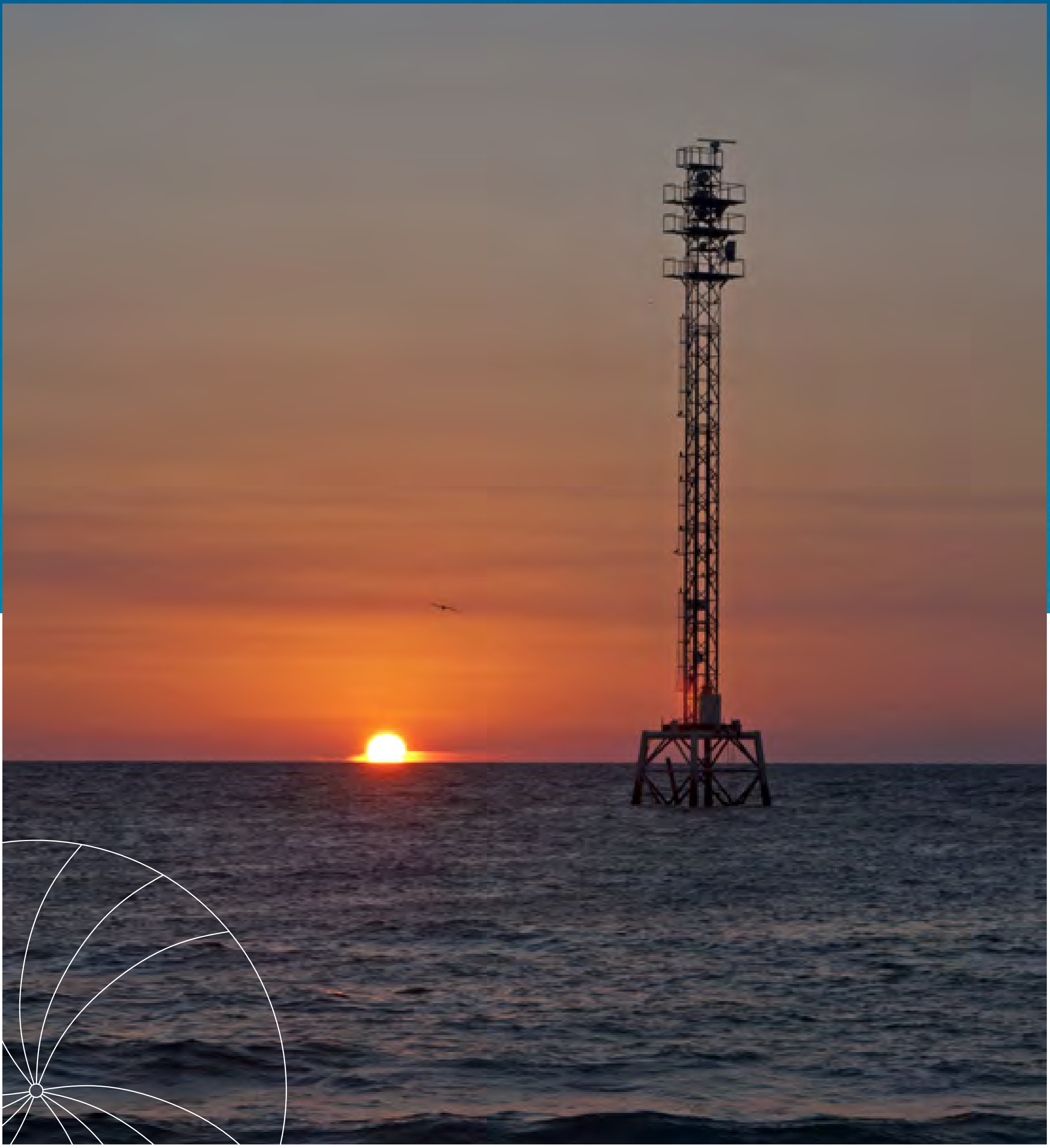
Offshore met-masts usually have a wave rider buoy (wave rider) anchored to the surrounding seabed or the met-mast foundation.

Data from the wave rider buoy is important for the foundation selection and installation. In rough seas, stronger foundation types are used. Also the most frequent sea directions will decide the location and heading of the boat landing for crew transfers to the turbine, and also the cable array position to minimise scouring of the foundation and j-tubes.

06. Decommissioning.

Some met-masts are decommissioned once the wind farm project is completed and operational. Sometimes they are sold to private companies or used for wind optimisation companies and weather forecasting companies.

Their removal depends on their age, height, the feed of data and the regulations of the country where the mast is located.



Industry terminology used for meteorology mast's.

D-A
Data analysis

WRA
Wind resource assessment

MME
Mast meteorology

Met-Mast
Meteorology mast

Waverider
Wave rider buoy

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module - 08

Floating Wind

Floating wind.

1888 | The world's first wind turbine was built in the USA in 1888, made of wood, iron and copper by Mr Charles Brush.

1980 | The world's first wind farm was built in 1980 in New Hampshire, USA, consisting of 20 turbines at 30 kW and a total capacity of 0.6 MW, called the UMass Windfarm and built by college graduates via the government-funded UMass program.

1991 | The world's first offshore wind farm was Vindeby Offshore Wind Farm located off the coast of Denmark, built in 1991 by Dong Energy, now known as Orsted.

EARLY
2000 | In the early 2000s a European offshore windfarm boom started, and countries globally were building large numbers of land-based wind farms.

2007 | In 2007 the world's first floating wind turbine was developed by Statoil and Siemens. The single floating turbine was deployed in 2009 off the coast of Norway. The project is called the Hywind Demo offshore wind farm.

2021 | At present, in 2021, many floating wind farms are being installed on an international scale and the floating wind industry is considered as a separate segment, known as floating offshore wind (FOW).

Why was floating wind developed?

To make wind energy cost-effective and profitable for investors, it's important that wind farms are installed in locations that have lots of wind all year round.

Offshore wind is the prime location because, unlike shore-based locations, there are no hills or mountains sheltering the turbines from the wind.

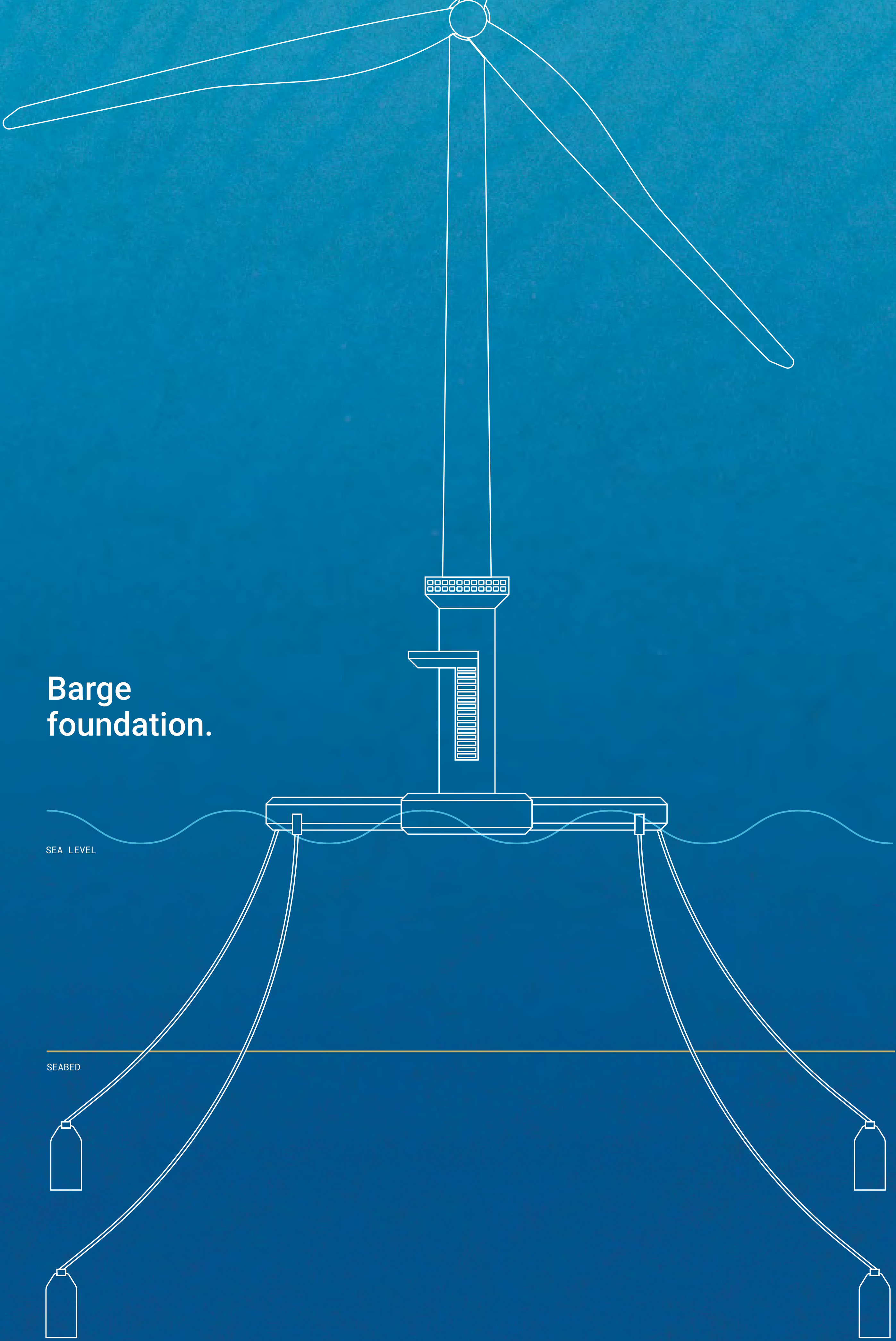
Some offshore windy locations have ground that is too soft for a fixed foundation and turbine to freely stand on.

Some offshore windy locations have ground that is too strong to be cost-effectively drilled and the foundations and turbines installed.

For the below reasons, the floating turbine found a gap in the offshore wind market:

- Ground too soft
- Ground too strong
- Water depths too deep

Barge foundation.



Floating wind foundation types.

There are several prototypes being developed for the floating wind industry, but there are only four floating supporting structures (foundations) in use, as follows:

01. Barge foundation.
02. Semi-sub foundation.
03. Spar floating foundation.
04. Tension floating platform foundation.

01. Barge foundation.

Unlike a normal barge used in the maritime industry, this foundation has a large monopile. This is to reduce the amount of metal used, saving money on materials and anodes for the anti-corrosion.

The turbine is offset, not in the centre of the floating foundation. The load is compensated with ballast water as per the design of the barge, which can be altered by pumping water in and out of the structure when required.

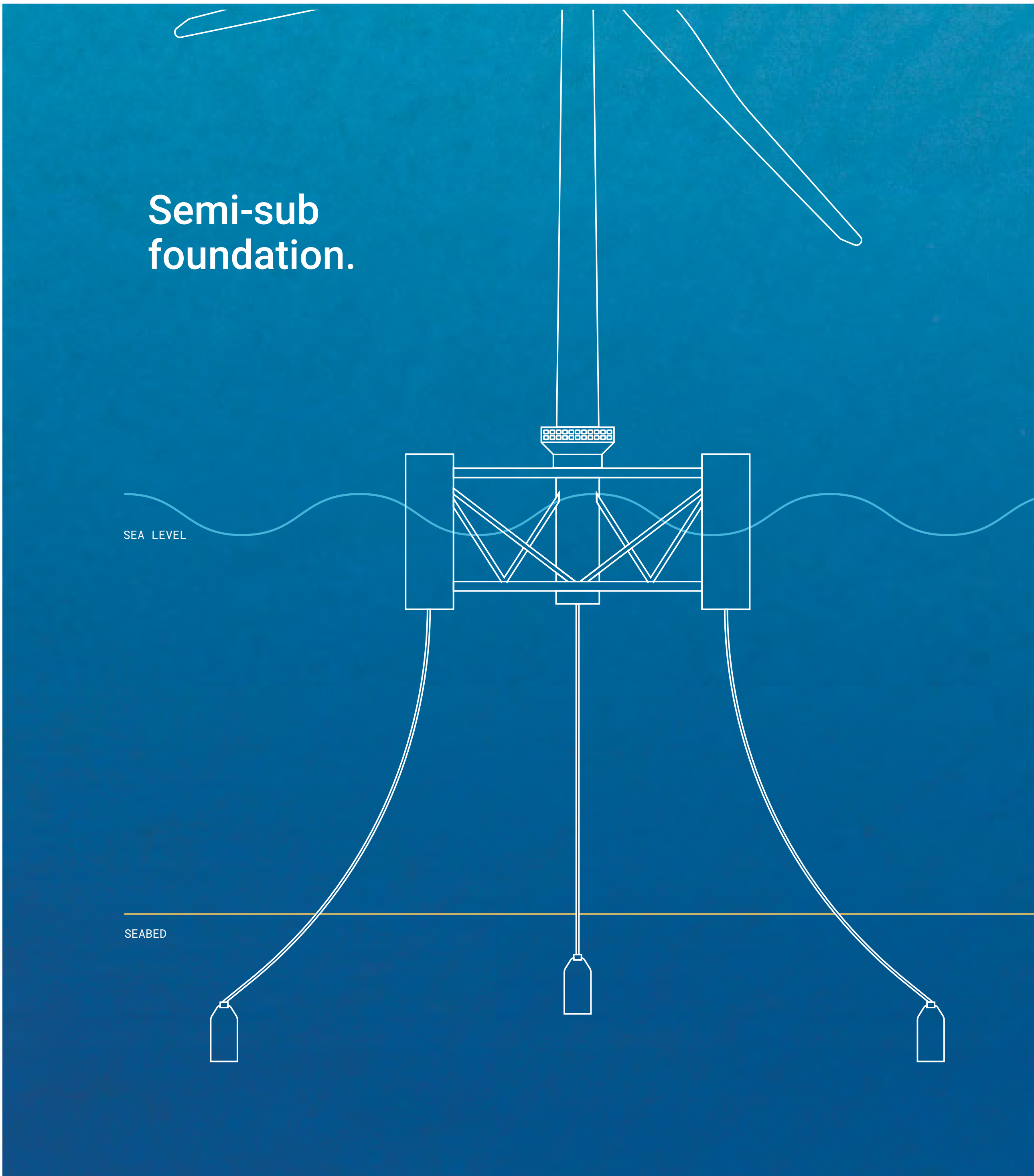
It is called a barge foundation because the square structure floats on top of the water, moored via anchors, and only a small section (draft) is under the water.

02. Semi-sub foundation.

Below is an example of a semi-sub foundation type. This foundation type is the most commonly used.

This foundation gets its name because the structure supporting the weight of the turbine is partly submersed under the sea and part floating.

Like all floating structures, this is moored in location using anchors.

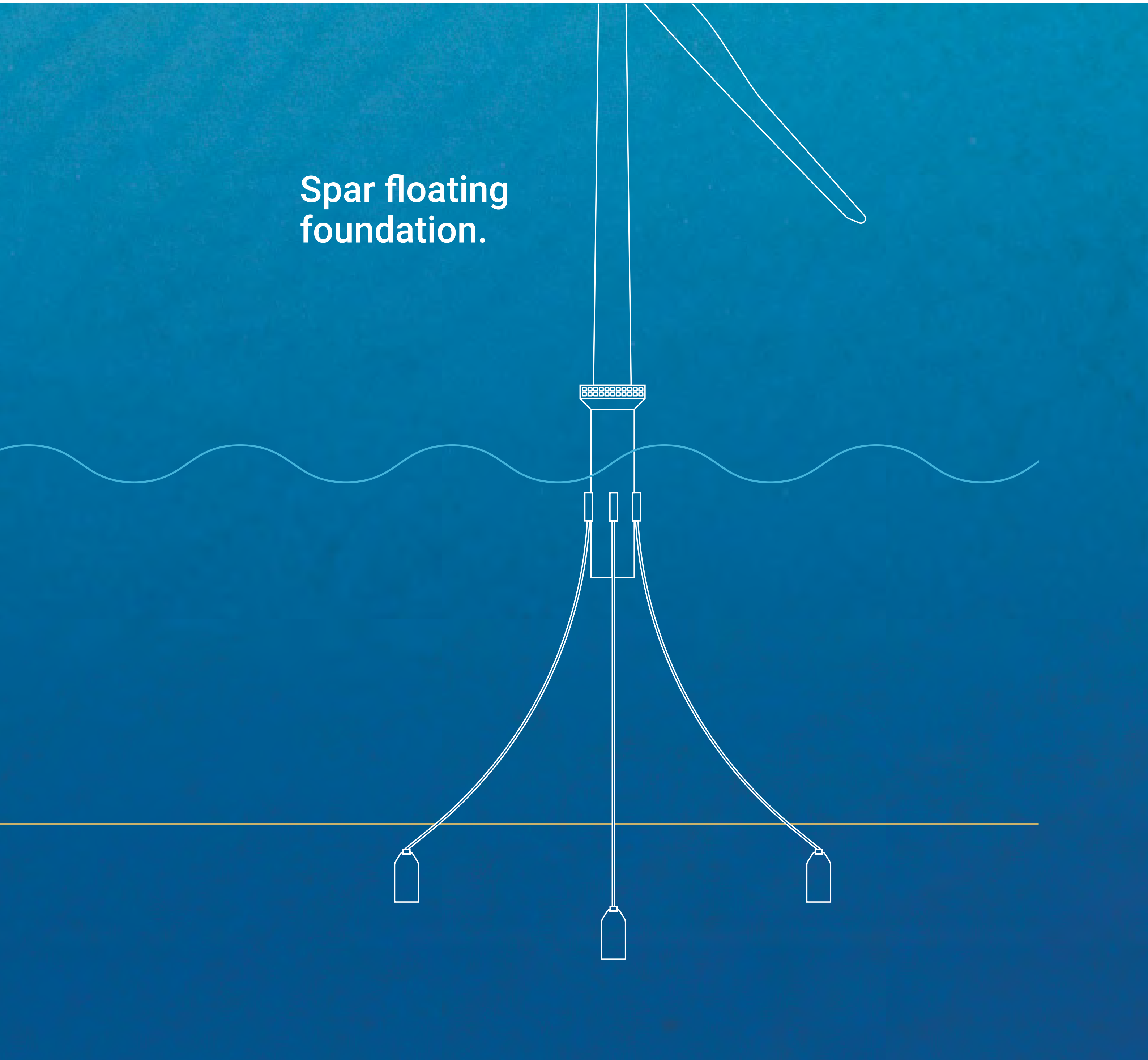


03. Spar floating foundation.

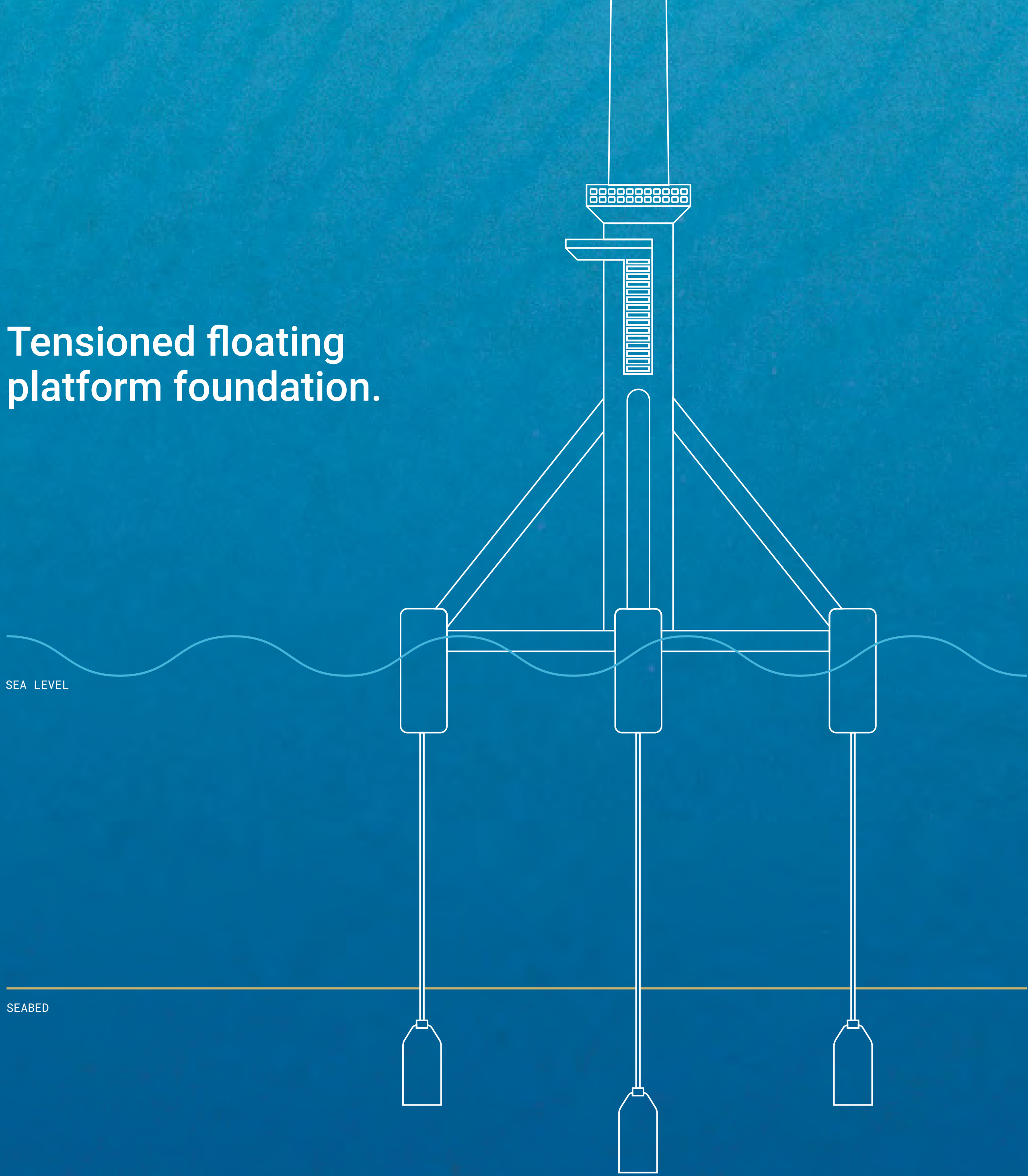
Below is a picture of a floating turbine off-shore operational using the spar foundation type.

This was the first ever floating foundation, used on the Hywind Demo offshore wind farm in 2009.

For installation, the foundation is floated out horizontally, then water is added into the structure, which completes the upending process, making it upright and vertical using the laws of gravity. Then the foundation is moored and the pre-assembled complete turbine tower, nacelle, bulb, and blades are installed and bolted on.



Tensioned floating platform foundation.



04. Tensioned floating platform foundation.

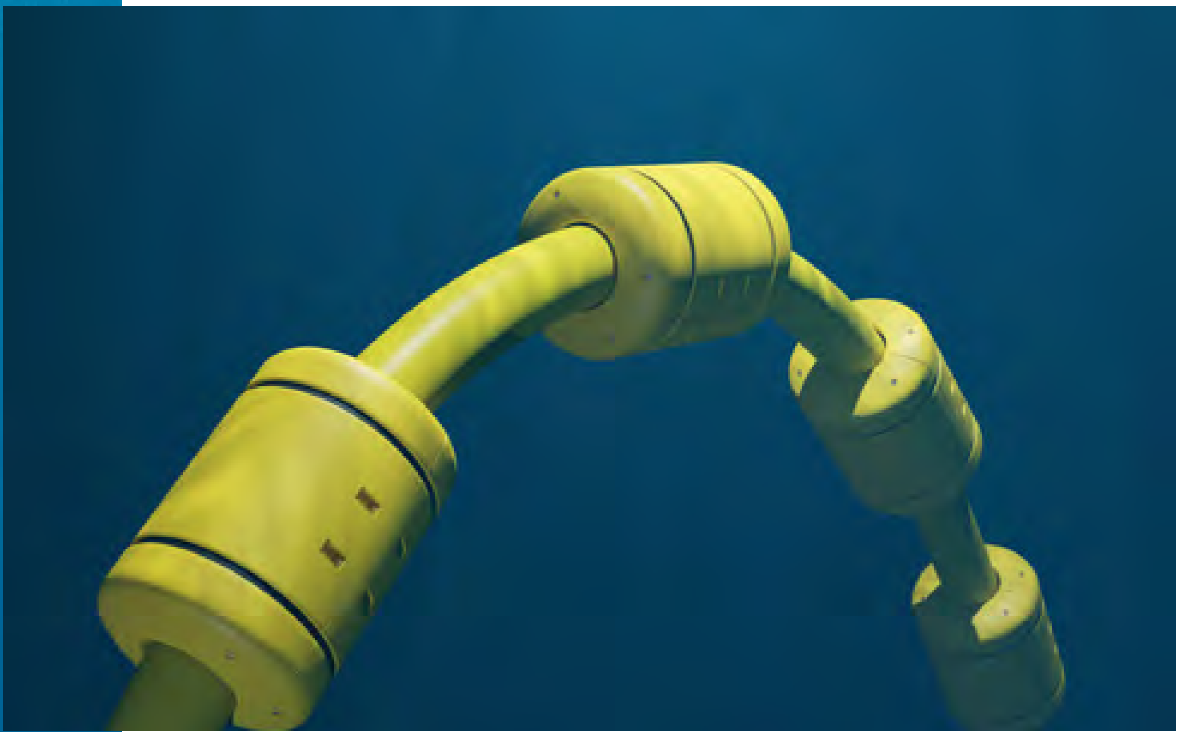
Above is a picture of a floating turbine offshore operational using the tensioned floating platform foundation type.

This is the same as a semi-sub foundation, except that the amount of metal used is reduced and is compensated by using a mooring system that keeps the turbine more static.

Instead of chains, it will be moored under tension using anchor wire or specialist Dyneema® rope.

06. Floating turbines pre-assembly

Floating turbines are pre-assembled in port in a cost-effective sheltered location and towed out to sea for deployment (mooring) at their arranged location, excluding the spar floating foundation, which needs to be done in two stages.



06. Floating wind transmission.

Floating wind, like fixed static wind turbines, needs array cables and export cables. Every project varies depending on the water depths and the distance to the shore.

If it's a deep water location, the cables are semi-submersible, designed to be lighter, and floats are attached to them as per the picture above.

The substations for floating wind nearshore on prototypes are land-based, but floating substations are being designed and under construction for some of the bigger floating wind projects scheduled to start this year.

Industry terminology used for floating wind.

FOSS
Floating offshore sub station

FOWF
Floating offshore wind farm

FOW
Floating offshore wind

MOM
Minutes of meeting

DPR
Daily progress report

TBT
Tool-box talk

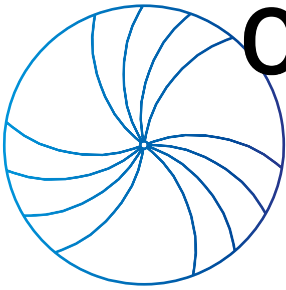
PTW
Permit to work

RAMS
Risk assessments & method statement

ROV's
Remotely operated vehicles

O&M.

module - 09



O&M.

Operations and maintenance of a wind farm starts as soon as the project is fully commissioned. It ends when the project is no longer operational and is being decommissioned.

The concepts and methods of the day-to-day operations and maintenance are changing on an annual basis. All the different turbine designs and types require different maintenance. Information on most of the tasks for offshore projects is given below.

01. Operations.

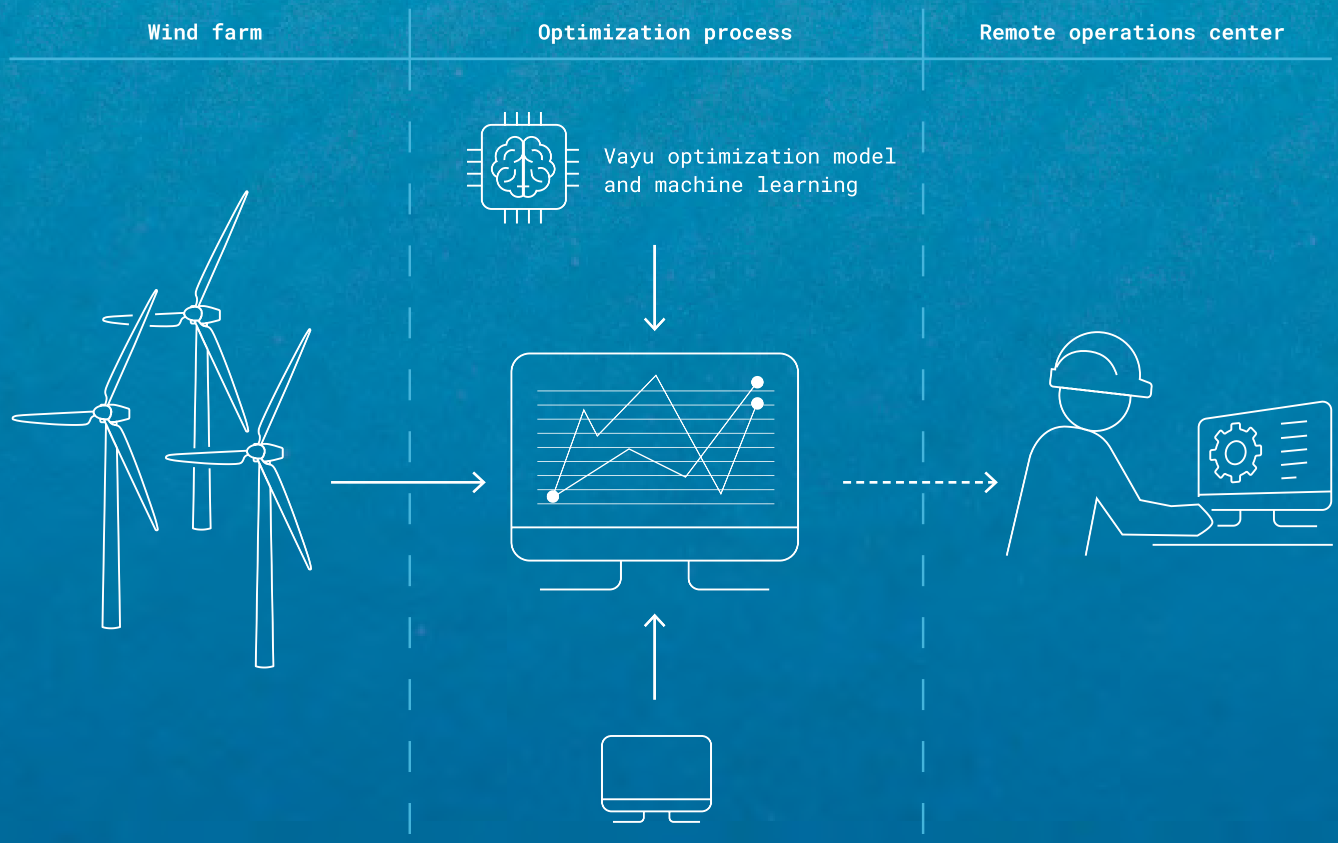
Operations are split into the following divisions:

- Management and support
- Optimisation & analysis via SCADA
- Marine coordination
- Safety & security

(02). Management and support.

Onshore there will be an operations and maintenance base. This is always by the chosen port of call used for the crew transfer, so remote sites will have a helicopter landing pad, and most used is a site located by a seaport where crew boats and project vessels will dock. Some large projects have more than one base and some projects use both helicopters and crew transfer vessels.

Support for the project will be by the operation and maintenance manager, logistics manager, buyer, supervisors, and general staff, such as the site coordinator and technicians.



03. Optimisation & analysis via SCADA.

The day-to-day operational goals of the wind farm optimisations team are to harness as much electricity as possible. The turbines are remotely operated using SCADA software and technology turned into the wind and, when required, turned off or out of the wind.

If the turbine is faulty, too hot, too cold, frozen, or requires maintenance, an inspection or lubrication, the SCADA technology can turn the turbine off. As a contingency and safety barrier, the turbines are manually locked off internally before any work is started by the offshore technicians. This is known as LOTO (lock off tag off) and is done both shore-based and in the turbine, making the O&M activities much safer.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04. Marine coordination.

The logistics manager, harbour manager, safety manager and weather forecast provider all work with the marine coordination centre, known as the MCC.

They give its staff (marine coordinators) information on safety, weather, and tides.

There is lots of marine software available, but most projects use Sea-planner, a system that uses GPS, sonar, radar and SCADA and has access to the project and can see all vessel and crew movements.

All vessel movements need to be authorised by the duty on shift marine coordinator over the Tetra or UHF radio. They will check the weather forecast, project traffic, if all people onboard the vessel have up to date certification and inductions and also, most importantly, if the permit to work is authorised by safety and permit control.

05. Safety and security.

Safety and security are important. They vary on every site and offshore project. Large projects have guard vessels offshore and security for the site and shore-based buildings. All the equipment and supplies used for wind energy are expensive and need to be secure and safe.

Operations and maintenance sites will have a minimum of one safety manager and one safety coordinator / advisor making sure all local and company project rules and regulations are followed, including but not limited to correct use of PPE equipment.

06. Maintenance.

Maintenance is split into the following divisions:

- Foundation maintenance
- Array maintenance
- Turbine maintenance
- Export & grid connection maintenance
- On shore logistics
- Offshore logistics

Foundation maintenance.

Foundation maintenance is a bigger task than people expect, requiring annual inspections of the welding, paint, marine growth, and anodes.

Also, if it's a bolted flange foundation, tightening of the nuts and bolts that are securing the turbine in place is needed, and if it's a grouted flange foundation checking that the grout has no cracks or has corroded away is required.

General tasks are also bird mess removal, marine growth and salt removal and tightening of platform bolts, which loosen with the wear and tear caused by oscillations and vibrations.

Array maintenance

Array maintenance is carried out frequently. Array cable testing from shore and substation to ensure that cables are not damaged, and array cable protection inspection via ROV is carried out, checking that CPS, rocks, and mattresses are in place protecting the cable. When cables are damaged, cable repair work is carried out.

If the CPS is damaged or the rocks used as scour protection have moved, a cable campaign will be considered and, if it's within budget and considered necessary, carried out.

Unlike turbine and foundation maintenance, rock dumping and mattress installation can be completed all year round without having to turn the turbines off.

Turbine maintenance

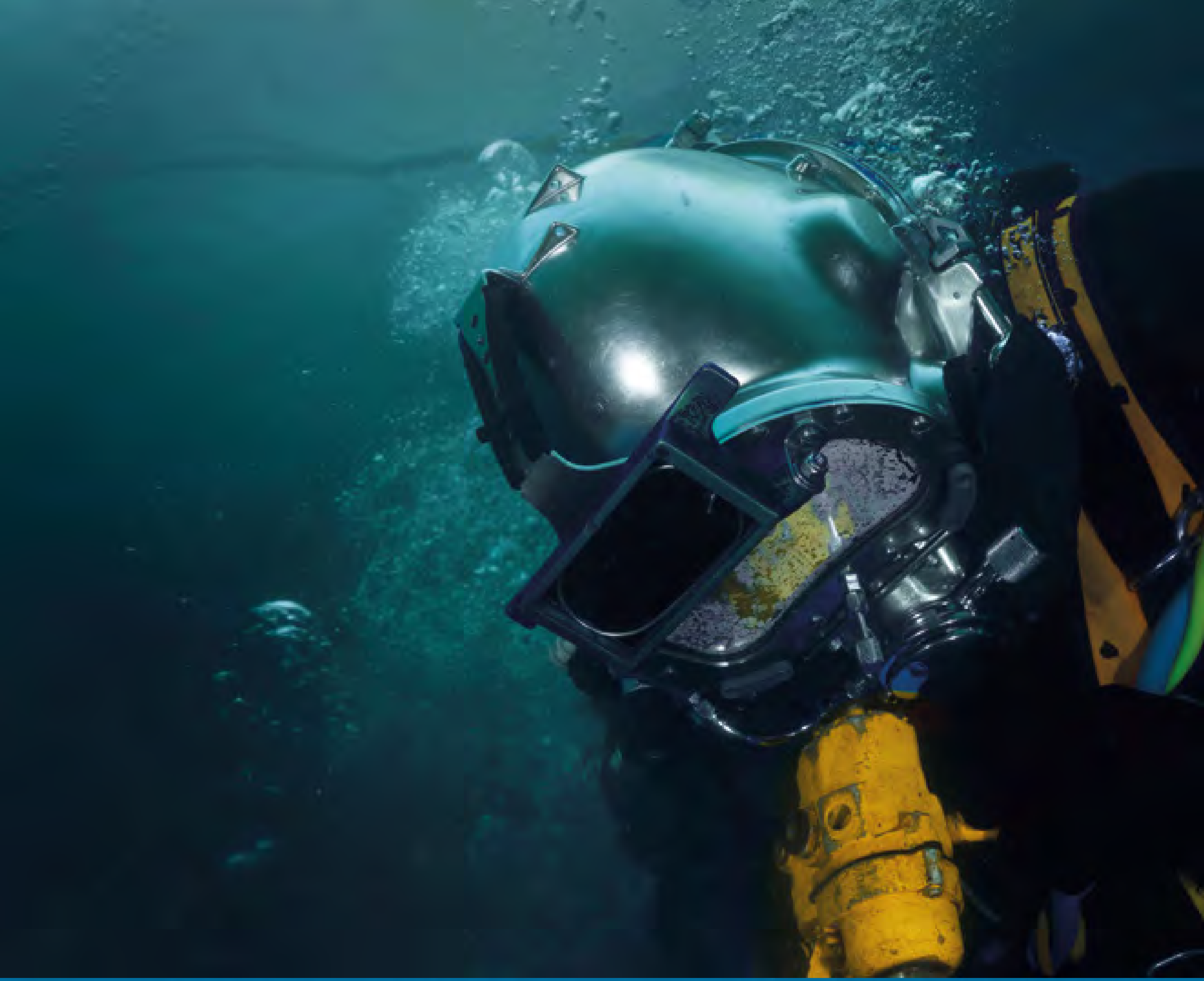
Turbine maintenance is the biggest and broadest maintenance task for any wind farm project. Below are the areas and general maintenance duties:

- Towers: starting at the bottom, the towers are cleaned for anti-corrosion, checked for moisture, and paint and structural inspection and repairs when required. A bolting inspection and campaign are carried out when required.

- Nacelles: the nacelle section requires several operations, but the most frequent is lubrication and changing of the oils. There may be 10-80 gallons of gearbox oils depending on the turbine size and design, with an average of 65 gallons. Also hydraulic oils and different types of grease are used for many different components.

- Blades: the blades must be inspected, the bolts checked and tightened and cleaned, and also, in cold temperatures, frequently de-iced. If the blades are damaged they need to be repaired and in some cases replaced. Work on the blades is normally carried out during the summer months when it is less windy, so minimal money is lost having the turbines turned off.

If the components are damaged and it's not cost-effective to fix them, which is known in the industry as BER (beyond economical repair), then a component exchange will be carried out by a third-party contractor using a fit for purpose vessel.



Export & grid connection maintenance

The export cable, like the array cables, requires visual inspections and physical testing.

The substation on site sending the electricity to the grid, and the offshore substation storing and sending electricity from the string of arrayed turbines to the shore all require maintenance

The platform and foundation of the offshore substation require anti-corrosion work and component exchange of the breakers and converters when they are faulty or past their usage date.

On shore logistics

Depending on the project size and location, the logistics can vary, but below are some of the plant equipment and machinery needed.

- Forklifts: these are used for getting parts and supplies from HGVs to the storage locations, mainly warehouses, and to port for them to be lifted to vessels for offshore deployment.
- Vans and jeeps: vehicles are given to staff if the operations and maintenance centre is in a remote location, but can also be used for shift changes of site staff, such as marine coordination, O&M supervisors, O&M managers, and general operatives.
- SPMT: these are used for moving heavy or large equipment such as blades, nacelles, and gearboxes to the warehouse and to the port or jetty for loading to vessels for component exchange.
- Tractors: if the location has a jetty or pontoon that is tidal, sometimes small vessels are brought in on trailers for maintenance. This is carried out using tractors.
- Cranes: on some sites there will be a mobile crane used for loading vessels and for moving heavy wind turbine components around the operations and maintenance site.

Offshore logistics

Depending on the project location, tidal impacts and security risk, there are many different vessels used for the project operations and maintenance offshore logistics. The most commonly used are crew transfer vessels because they are fast, and if they are already taking technicians to the offshore wind farm they can take parts and supplies with minimal extra costs.

Several other vessels are used. Please see below the main vessels for day-to-day operations and maintenance:

Guard vessel (PGV) project guard vessel:

This is a vessel that will circle the wind farm, monitoring the area and making sure no turbines are visibly damaged, no fishing boats are in the restricted areas, no criminals are using the turbine for drug smuggling, no thieves of the water (pirates) are stealing parts from the turbines, no immigrants are on the turbines for temporary shelter, etc.

Crew transfer vessel (CTV):

This is a vessel that gets the technicians from shore to the turbines and substation for general routine maintenance, and will also provide consumables and crew changes for other vessels and temporarily manned platforms. This vessel can also bring parts and supplies out on request.

Wind farm service vessel (WFSV):

This is a larger vessel that is stationed to a wind farm offshore if there is a large volume of maintenance such as a bolting campaign, painting campaign or, if the project has tidal restrictions, as a place that the technicians will sleep on and, with the support of a hydraulic gangway or CTV, join the turbines daily. This vessel can also bring parts and supplies out on request.

Emergency response vessel (ERV):

this a vessel that has a team onboard that are medically trained. This ERT (emergency response team) can be deployed to site if there is a risky operation being performed, such as people working over the water, or if there is no helicopter access to the project, or if there is a large number of people working on the project and the closest hospital is a significant distance away.

07. Miscellaneous.

There are many different maintenance tasks to be carried out on any wind farm, whether shore-based or offshore. Below is a list of operations carried out during the life cycle of most offshore wind farms:

- Statutory inspections *(annual inspections of lifting equipment)*
- Cleaning of bird mess, salt residue and marine growth
- Lubrication and oil change of turbines
- Bolting campaigns
- Blade repair campaigns
- Painting campaigns
- Paint inspection
- Cable inspection
- Cable replacement
- Cable repairs
- Blade replacement
- Anti-freezing of blades *(via drones or rope access crew)*
- Gear box change or upgrade *(retro fit)*
- Anode inspection of foundation of turbine or OSS
- Anode replacement
- Anode cleaning

Industry terminology used for O&M.

OWF
Offshore wind farm

O&M
Operations and maintenance

PGV
Project guard vessel

OMS
Operations and maintenance site

H&S
Health and safety

MCC
Marine coordination centre

PTW
Permit to work

CTV
Crew transfer vessel

WSFV
Wind farm service vessel

ERV
Emergency response vessel

ERT
Emergency response team

OSS
Offshore substation

AP
Appointed person

BLUESTONE GROUP

Bluestone Group has an office dedicated to the wind energy sector, offering blue & white collar workers for the whole turnkey life cycle of shore-based and offshore wind farms.

Our skilled, industry GWO certified workforce has been involved in the wind industry for over 15 years and can supply its services to both project clients and contractors on short notice.

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