COST-EFFECTIVE

OFFSHORE WIND

MAMMOET

BRINGING IT TOGETHER

HARNESSING SEA WIND IS THE FASTEST ROUTE TO A SUSTAINABLE FUTURE - BUT ALSO THE MOST COMPLEX. MANAGING A GLOBAL SUPPLY CHAIN, EVER-EXPANDING TURBINES AND INFRASTRUCTURE DESIGNED FOR OTHER INDUSTRIES, DEVELOPERS MUST STILL DELIVER ENERGY AT A VIABLE COST PER MEGAWATT.

GOING GLOBAL

THE MASSIVE POTENTIAL OF OFFSHORE WIND IN HELPING TO ACHIEVE NET ZERO HAS MEANT THE SECTOR HAS SEEN EXCEPTIONAL GROWTH IN RECENT TIMES. ACCORDING TO THE IEA, THE GLOBAL MARKET GREW ANNUALLY BY NEARLY 30% BETWEEN 2010 AND 2018, AND CUMULATIVE OFFSHORE CAPACITY IS SET TO MORE THAN TRIPLE BY 2026, REACHING ALMOST **120GW.**

This growth is presenting new challenges that must be overcome to achieve the global output required. Entering new geographies is one of these – for example, in the US alone over **40 major projects** are planned, generating **40GW by 2040.** Alongside this, in seeking higher wind speeds for maximum efficiencies, turbines have grown in size and weight. 10MW turbines are now common, with the largest approaching 175m and a combined weight of over 5,000t including foundations.

The movement of such goliath items from fabrication to port facilities and readying them for assembly is a huge engineering endeavor. Not only in terms of the equipment needed – the hub height of modern turbines is beyond the reach of many cranes – but also the availability of port facilities that have suitable space and ground conditions to accommodate increased weights.

In many ways, the US embodies the growing pains faced globally as the sector continues to expand. More facilities and different types of equipment are now needed; a whole new skilled workforce must be found, and the geographic demands of an industry still largely centered in Europe must be overcome.

INFRASTRUCTURE CHALLENGES

First, ports must have the right infrastructure to handle the growing size of components. Nacelles are approaching 1000t; blades for 10MW turbines exceed 100m in length and tower sections are of a similar size.

The necessary deep-water ports are very hard to find, even in fully developed economies. In regions such as the Northeast US – perfectly familiar with seagoing cargo – offshore wind projects find themselves short of space. This can be compounded further by a lack of suitable ground strength - with 10t/m^2 typically available versus the 25t/m^2 needed for the movement of modern offshore wind components. Container terminals are increasingly being considered for use, but capacity is an issue as they will only offer part of the terminal and there is also risk as availability is contingent on fluctuating demand from their core businesses.
Unfortunately, given the pace of growth facilities are unlikely to have the luxury of time to make permanent

WHY MAMMOET?

- **50 years** of experience in complex offshore energy projects
- **More equipment** in more countries than any other supplier
- Familiar with **many scopes,** from fabrication yard to installation vessel
- We **manage complex global logistics** projects on a daily basis
- Large selection of **large ring cranes** capable of turbine pre-assembly and jacket load-outs
- **Expertise** in strengthening quays, building storage facilities and chartering vessels
- **Sustainability developments** including electric transportation, emissions-free cranes, alternate fuels
- Highest concentration of heavy lift engineering, with over **140 worldwide locations**
- **Global knowledge,** local experience: blending knowledge of local customs and legislation with the highest safety standards
- The only heavy lifting company with a **dedicated R&D department** working on offshore wind solutions
- **Single point of contact** – one face managing projects that cross continents
- **Early engagement** with local communities

changes to their infrastructure. This has meant increasing interest in how to put facilities in place on a temporary basis while infrastructure catches up.

THE RIGHT KNOWLEDGE AND SKILLS

At present, Europe remains the center of knowledge and expertise in offshore wind. But this will need to change as other regions ramp up activity. While in the short term this means there is a skills gap to bridge, different regions also present their own unique challenges in expertise that need to be overcome.

For example, depth of the seabed. Foundations on the US Eastern Seaboard will sit at around 15-65m, compared to 3-20m in the North Sea in Europe. This means bigger monopiles and a greater challenge to handle them. Also, differing soils. Off some coasts, the soil may only be stable after 30-40m of depth, which is driving the move towards XXL monopiles. Conversations are needed about which skills are required to best address these issues, in terms of lifting, transportation, storage and more.

To increase specialized knowledge alongside local labor laws and conventions, union apprenticeship programs and knowledge-sharing partnerships need to be set up to build a solid foundation for future projects.

BUILDING A GLOBAL FOOTPRINT

As with knowledge and skills, most fabricators and developers are in Europe, but the ambitious renewable energy targets set by governments mean production must rise exponentially; beyond the capacity of just one continent. By 2024, the US alone will need around 600 turbines to fulfil its planned projects; that's the entire 2021 world production capacity used by just one country. A similar situation is faced when it comes to equipment - in the short term, vessel costs will remain high, and as production volumes increase availability will become more limited.

Options are being evaluated to allow the industry to cope with this shortage - such as using onshore cranes to load turbines onto non-geared vessels, using ro-ro vessels, or converting vessels. For example, Siemens has built two ro-ro vessels that operate daily for Deugro, moving nacelles and towers continually, all over Europe. All options are expensive however, so there will be pressure to load these vessels as quickly and efficiently as possible – and not keep them waiting - to help drive down shipping costs - the largest outlay for any offshore wind project.

This means it's vital that a smooth global production line is put in place, managing complex projects across multiple continents – as has been the case for many years throughout heavy industry.

WORKING TOGETHER

With decades of proven expertise across the industry, collaboration between all players will be key to meeting the challenges posed by exponential growth. Organizations from across the supply chain with expertise in offshore wind and other energy industries, will have an important role in shaping the supply chains necessary to serve a market that is now truly global.

"Offshore wind provides the clearest path towards the carbon-neutral targets of 2030 and 2050. For countries without the shallow water areas and soil types to support fixed-bottom offshore wind, floating wind provides a route to more sustainable energy.

As more countries enter the offshore wind market, there needs to be a reliable pipeline of projects in place before ports will consider upgrades that are very specific to offshore wind to be worthwhile.

In the meantime, Mammoet can help by providing the temporary ground strengthening, lifting capacity and other infrastructure needed to get offshore wind projects off the ground."

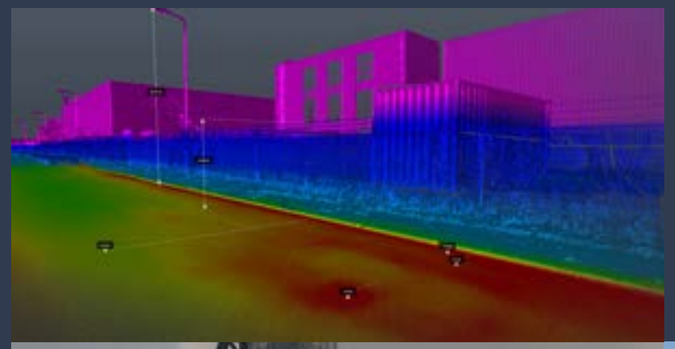
Francisco Rodrigues, Global Segment Lead for Offshore Wind, Mammoet

CAPABILITIES

- **Selection of vessels,** including stowage plans, strength analysis and sea fastening calculations
- **Development of new solutions** to handle transition pieces, pre-assemble turbines, strengthen the ground and more
- **Establishing the ideal transport route,** handling shipping agents, customs, inspections and other documentation
- **Marshaling of components at port,** including all storage, transportation and heavy lifting
- **Handling of foundation structure**s including jackets, monopiles and transition pieces, from fabrication to installation vessel
- **Handling of nacelles,** towers and blades, including road transportation from factory to quayside
- **Pre-assembly of turbines** at the quayside, using some of the world's largest land cranes
- **Maritime services,** including commissioning of auxiliary steelwork, ballasting, mooring and barging
- **Floating offshore wind services,** including transportation, load-out, launching and more

FRONT-END ENGINEERING & DESIGN (FEED)

THE PACE OF DEVELOPMENT IN OFFSHORE WIND MEANS COMPANIES MUST LOOK AHEAD OF THE MARKET TO ENSURE THE BEST SOLUTIONS ARE FOUND FOR CHANGING CUSTOMER REQUIREMENTS.



By using our global footprint, industry knowledge and Group R&D expertise, Mammoet works through complex technical and logistical solutions early in projects to ensure we assist our customers to optimize the final Megawatt price.

This begins at the FEED stage, where we work closely with developers, OEMs and other stakeholders to ensure the most effective heavy lifting and transport plan is in place. This allows us to provide practical, customized engineering advice that can lead to savings later in the schedule as issues are foreseen and dealt with during planning.

Such early involvement across projects around the world also means we can identify where innovation in equipment or services may better serve the market. This approach will be critical to meeting the growing challenges faced as the size and volume of offshore wind projects continues to grow.

CREATING MORE ROOM AT PORTS

As the need for port facilities capable of servicing large-scale offshore wind projects grows, many ports will need to explore how they can expand their limited storage space and enhance load bearing capacity to cater for the volume and weight of components involved.
In situations like this, Mammoet's innovative Enviro-Mat creates offshore wind ready ports from mere scrubland. It provides a more efficient, cost-effective and sustainable alternative to commonly-used materials such as gravel, mats or concrete slabs. Once mixed with cement, additives and local soil, it creates a hard surface with a load bearing capacity of up to 50 t/m^2. Best of all, once the job is complete the surface can either remain or be crumbled back into the ground soil with no adverse environmental effects. So, it can be used to provide both temporary and permanent pavement for storage areas and roads on site. This offers advantages on sites that were not originally designed to serve the offshore wind market, such as container ports, fishing ports and disused industrial facilities, such as power stations.

Some of our FEED services typically include, but are not limited to:

- FEED studies to evaluate project viability
- Full analysis of marshaling scenarios to support selection of installation strategies
- Assistance during the design of components to reduce logistical costs
- Planning simulations to assess different fabrication/ assembly methodologies
- Advice on local regulatory requirements
- Design of bespoke tools and equipment
- Ground conditions assessment
- Quay studies
- Design of temporary structures
- Swept path analysis
- Storage solutions design
- Lift studies for craneage activities
- Specialised lifting tools and methodologies
- Design of transport frames/ saddles
- Design of bespoke transportation solutions

FABRICATION

FABRICATION ALWAYS TAKES PLACE AGAINST THE CLOCK. EVERY DAY PILES SIT ON SUPPORTS IS A DAY SOMETHING ELSE CAN'T BE MADE; EVERY HOUR A VESSEL LIES IDLE COSTS DEMURRAGE; EVERY MINUTE THE FACTORY IS STILL GOES ON THE PAYROLL.

Success here is about how to transfer loads from production to storage, then from storage to vessel, as quickly as possible - using as little space as possible. Every second saved pays off hundreds of times over as successive batches go out.
We offer a one-stop shop of handling and marine services, from on-site transportation via SPMT, through a range of specialized equipment such as blade clamps and tailing systems, to complex load-outs including mooring and ballasting.

AN EFFICIENT PRODUCTION LINE

Our experts design smart, efficient load-out strategies, even as monopiles start to challenge the largest heavy lift vessels. We select from a wide range of equipment and, on occasion, design custom handling frames to transfer foundations and jackets without modification - speeding up schedules.
Dedicated teams offer a range of handling and marine services, from on-site transportation via SPMT, through specialized equipment such as blade clamps and tailing systems, to complex load-outs that include mooring and ballasting. We can even transport some components upright.

And as the offshore wind sector continues to develop, our experience of transferring some of the world's heaviest modules between vessel and land means projects can benefit from techniques that have been proven over decades throughout heavy industry.

Another important trend is the increasing height and weight of foundation components which have doubled in size over recent years. Monopiles of 2,500t with diameters of up to 12m are now commonplace. As the US market grows, differing seabed conditions will require XXL monopiles capable of reaching depths of 50 meters or more.
These specialist items need infrastructure and expertise to handle safely and efficiently. Mammoet has the technology and knowledge to ensure this, having worked closely with designers and fabricators to ensure logistics activity is aligned and suitable for the increasing size of components.

HANDLING OF JACKETS

Mammoet's work with the wider supply chain has allowed us to develop a full set of tools and methodologies for assisting the transportation and manufacturing processes of complex offshore wind structures like jackets.

Through jacking techniques, or our larger ring cranes, we can handle and rotate jackets, allowing them to be fabricated, extended or loaded-out. Our custom modular transport frames allow jackets to be transported on site without the need to fabricate custom steelwork for every project.

Once the time comes to load-out jacket structures, we can undertake complex ro-ro operations. To make sure components get to their destination safely, we design thorough sea fastening, grillage and support structures for onward marine transportation.

Some of our fabrication services typically include, but are not limited to:

- Providing and operating specialist equipment for transporting every component
- Co-ordination of crew members and stevedore management
- Creation of additional storage areas to suitable specifications
- Jacking, skidding and re-orientation of components
- Port-to-port transportation of tower sections, nacelles and blades
- Establishing the most suitable transport route in typically congested areas

MARINE TRANSPORT

Mammoet can provide a range of marine transport services. These include the supply and management of tugs and barges as well as the design and provision of sea fastening and grillage equipment. This allows us to offer a flexible approach – redesigning or modifying equipment to suit the demands of different projects.

"The United States is entering the offshore wind market in a big way. Under the current administration, it has rejoined the Paris Agreement and has a handful of projects already in the pipeline, totaling hundreds of units.

This is a significant development that will be felt strongly in the region, as facilities, vessels and workers must be found to meet demand. But the impact of this will also be felt globally; through higher-volume fabrication and more global project planning.

Mammoet's decades of experience in planning complex, modular projects across countries and continents will help to make this happen".

Robert Eykhout, Regional Commercial Lead for Offshore Wind, Mammoet

MARSHALING

The size of offshore wind components continues to grow: monopiles of 2,500t are now commonplace – even nacelles can now weigh over 1,000t. These are specialist pieces of equipment that require specific infrastructure to handle.
However, competition from more lucrative oil and gas projects means the offshore wind industry may need to consider less well-equipped locations that do not have the required ground strength, storage space or draft. This is a technical challenge and also puts pressure on schedules, as working envelopes tighten.

Even at ports used to serving offshore wind, with components this large the pressure to use space efficiently is always on. Vessels must be kept constantly working to maximize cost-effectiveness; documentation must be prepared promptly; components must arrive precisely on time at congested sites.
We act as a single point of contact from factory or storage to the installation vessel, re-ducing the number of interfaces experienced during each project, which in turn lowers the risk of delays. From interaction with shipping agents, through stevedore management, to lashing and sea fastening, we run a well-oiled machine.

Where infrastructure can be developed, we take a long-term approach, helping to create a lasting legacy to serve current and future wind projects. Where it can't, our engineers can temporarily strengthen the quay to support offshore wind marshaling using technologies such as Enviro-Mat.

HANDLING OF TRANSITION PIECES

Mammoet is experienced in the efficient movement and storage of transition pieces from the fabrication stage onwards – including movements in vertical and horizontal positions, the design of bespoke equipment and managing sea and river transport.

We have experience throughout the fabrication process, including offloading unprocessed tube sections and transporting transition pieces horizontally as they are produced. Once complete, our bespoke tailing frame allows these structures to be lifted into vertical orientation and stored over a much smaller physical area. This allows more ports to be used for offshore work and cuts down on handling time required for each piece.

This tailing frame can then be used to transport transition pieces out of storage again, meaning there is no need for auxiliary steel. Transition pieces can then be delivered directly under the hook of the installation vessel for easy load-out. Should load-out be taking place elsewhere, we can charter, sea fasten and deliver the pieces to any world location.

"In the short term, fabrication of monopiles, transition pieces and turbines will continue to take place around the North Sea in Europe. However, increased demand will result in more diversity.

Firstly, we will see additional fabrication taking place elsewhere in Europe. Later, facilities will be opened in North America. As the floating wind market matures, more fabrication will take place in Southeast Asia, as we have seen in other sectors.

Success will ultimately depend on managing this complex supply chain, with projects touching most continents in some way.

Mammoet's experience, gained from the world's largest modularized construction projects, will allow the offshore wind industry to simply re-deploy expertise that already exists and create value by developing new methods for handling, assembling and possibly launching components in the future".

Antoine Lefevre, Sales Manager for Offshore Wind, Mammoet

Some of our marshaling services typically include, but are not limited to:

- Efficient delivery of components through port customs
- Interaction with shipping agents
- Storage management of marshaling facilities
- Inspections, damage assessments and documentation
- Providing lashing and sea fastening
- Load-in and load-out of components from and to vessels

HANDLING OF MONOPILES

We understand the unique requirements involved in moving modern, large-scale monopiles and smaller diameter pin-piles – from barging, onsite transportation and storage to sea fastening, grillage support and load-out.

Our adjustable hydraulic saddles and new SPMT/jacking cradle solution allow monopiles to be stored lower to the ground, reducing the cost of supporting steel or create sand bunds. Our pin pile handlers allow these components to be stored at ground level, avoiding the risks involved with using reach stackers.

We provide adaptable sea fastening grillage, and are working on solutions to allow more piles to be transported safely for long-distance transport, enhancing the cost-effectiveness of offshore wind component transport to the US and Canada. Finally, our modular sheerlegs provide an alternative where ground bearing pressures are limited or SPMT load-in or load-out is not possible.

HANDLING OF NACELLES, TOWERS AND BLADES

Seeking stronger and more reliable winds, turbines and piles are increasing in size – and in doing so creating greater demands on logistics skills and equipment.

The advent of +10MW turbines such as Haliade-X has set a new bar for the scale of nacelle, tower and blade components and Mammoet collaborates closely with designers and OEMs to ensure that what is built can be transported in the best way. This has led to significant investment in our equipment to ensure efficiency, reduce risks and optimize execution at the terminal.

With the market's largest equipment fleet, Mammoet can mobilize a wide range of hydraulic saddles, blade clamps and transport frames to any worldwide location, allowing components to be stored compactly as manufactured, or closer to ground level. This quickens on-site transportations and ties up less space.

PRE-ASSEMBLY

The growing scale of turbines is having a huge impact on assembly requirements, with hub heights of up to 175m and nacelle weights pushing 1,000t. This is causing some projects using smaller or container ports to either reinforce the ground or avoid the quay edge entirely in order to perform pre-assembly work.

Keeping the installation vessel waiting is never an option. So, components must be stored for easy access and brought to the water's edge and as few time-consuming transfer or upending maneuvers as possible.
These demands have meant that fewer and fewer conventional cranes are up to the task, leaving only the world's largest cranes – such as Mammoet's PTC and SK models – suitable for the job.
The large radius of these cranes moves lifting away from the quay edge onto surer ground, while their giant hook heights allow turbine assembly to take place on or next to the quay, where it is most efficient. Their huge capacities allow loads up to 6,000t to be placed directly onto barges, which is a much more efficient alternative to SPMT jacket load-out.

Some of our pre-assembly services typically include, but are not limited to:

- Crane lifting and critical lift plans
- Lifting tools design
- Trained and experienced operators
- Co-ordination of lifting and assembly operations with bolting and electrical connections
- Full site and facilities management
- Assistance with loadout operations together with jack-up operator
- Co-operation with mechanical contractor

GREATER LIFTING POWER FOR BIGGER COMPONENTS

Demand for the world's largest cranes is growing and creating a potential bottleneck for offshore wind projects given their limited availability.

Recognizing the market needed greater lifting capacity, Mammoet has developed the **SK6,000.** Capable of lifting over **4,000t** to a height of **175m** and with a maximum reach of **144m**, it can turn the quayside into a highly efficient production line by lifting even the heaviest of components directly into assembly position or onto a vessel.
Designed to operate with maximum outreach and capacity in the minimum required footprint, the SK6,000 helps to free up valuable space on site whilst delivering a variety of lifts from just one position to execute projects as quickly and efficiently as possible.

What's more, the crane's propulsion systems can be electrically driven, meaning it can run from connection to mains electricity or hydrogen fuel systems, with no CO_2 emissions. The same is true for our SK190 and SK350 cranes.

SMART CABLE MANAGEMENT

Mammoet can provide a flexible, cost-effective alternative to fixed cable carousels.
A standard cable basket is placed on SPMTs, which are used in a carousel configuration to spool or unspool cable. This means cable winding can take place at the most convenient point on site and can be easily moved when needed. When finished, the basket can then be lifted by crane and stored out of the way.

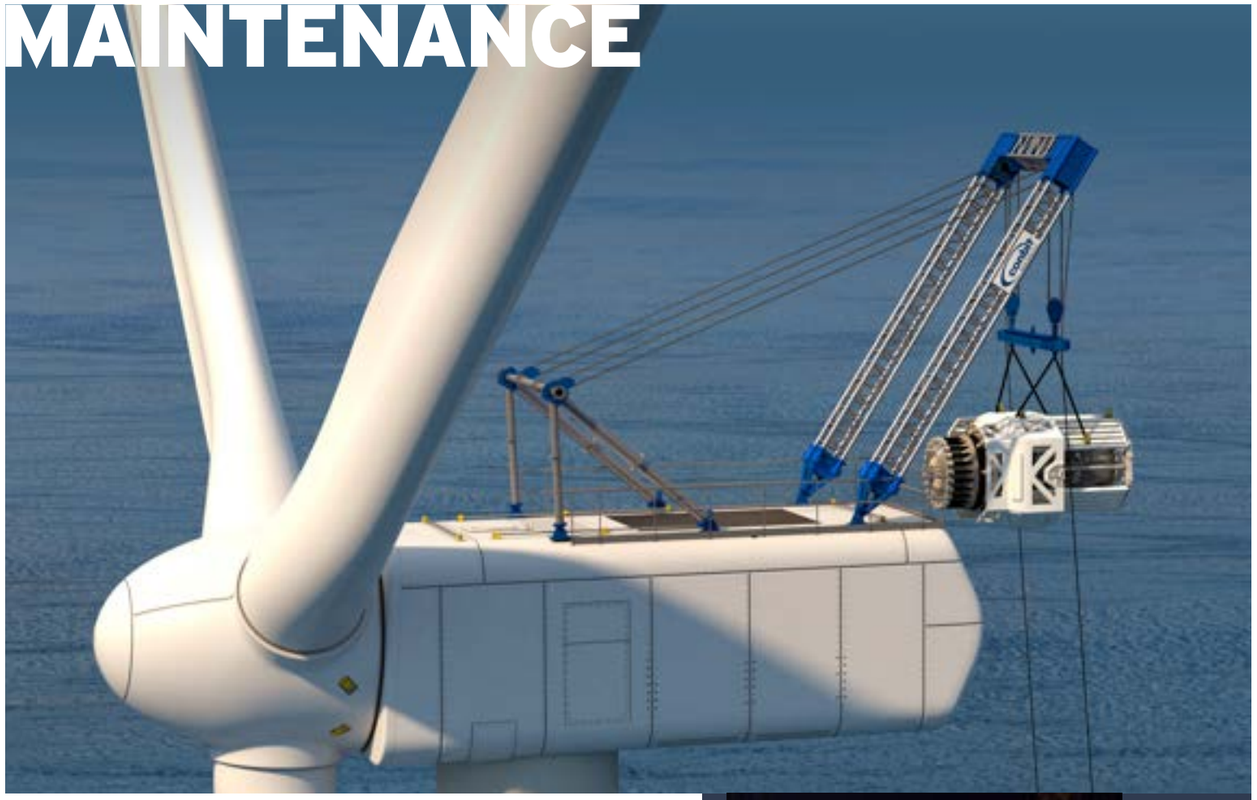
FAST MOBILIZATION AND DEMOBILIZATION

Installation vessels often need specialized assets to be moved on and off board in a short space of time to ensure work stays on schedule. Mammoet provides the expertise and equipment for this to be done as efficiently as possible; commonly including cranes, rigging and SPMTs – ensuring your vessels are correctly equipped to return to work as soon as possible. We can also help to maneuver components on deck; for example, by upending monopiles using a combination of SPMT, tailing frame and the crane's hook.

JACK-UP UPGRADES

Many installation vessels will need to be upgraded in the coming years in order to manage the larger size of components that are becoming standard. Downtime for these upgrades must be kept to a minimum, so specialist help can be required to replace equipment such as cranes as efficiently as possible. Mammoet can do this – removing and replacing legs and the crane itself where needed.

MAINTENANCE



Maintenance activities have been taking place at sea for many decades, across the energy sector. While many aspects of this are transferrable, one is not: where in other sectors there are hundreds of locations, in offshore wind there will be many thousands.

As offshore wind farms age, the likelihood of maintenance events will increase. Delivering the right equipment to the repair location will be a challenge in itself.
Intense competition will develop for the use of crane vessels; many of which will be too short to repair turbines at sea in any case. The significant technical challenge of performing repairs while floating is another issue.

Mammoet is innovating to develop solutions that will help maintenance to take place more easily. By utilizing gantry lifting systems attached to the turbine itself, items up to 200t can be lifted to and from the nacelle, facilitating repair of motors, gearboxes and generators at sea. Lifting systems using the turbine for support allow operators to respond more quickly to incidents, storing maintenance equipment locally for re-use. In this way, uptime is maximized, helping each offshore wind farm to deliver the greatest possible return on investment.

GETTING IT THERE

Offshore wind maintenance operations will require the transport of replacement turbine and substation equipment from the factory to the nearest suitable port. Mammoet has a wide selection of specialist low-bed trailers, blade clamps, tower clamps and other equipment to complete this job quickly and safely.

Using advanced techniques such as LIDAR scanning, we can find the fastest route between the point of manufacture and use. This can cut down on project cost significantly, as fewer modifications will be necessary to roads, bridges and tunnels along the route.

WHY USE A CRANE AT ALL?

Mammoet has used its experience honed throughout decades elsewhere in heavy industry to develop lifting systems that can reach locations that cranes cannot. The high cost and relatively short supply of crane vessels has meant that it is quicker and more cost-effective to design custom lifting systems. Conbit, part of Mammoet, specializes in just these scenarios.

By constructing modular lifting gantries, replacement parts of up to 200t can be lifted from a waiting vessel directly to the nacelle of the wind turbine. At offshore wind substations, we can take on any challenges beyond the reach of a deck crane. This makes it possible to complete certain types of maintenance and modification operations without the need for a heavy lift vessel, allowing transformers and other heavy equipment to be replaced without having to wait for transport availability.

Some of our maintenance services typically include, but are not limited to:

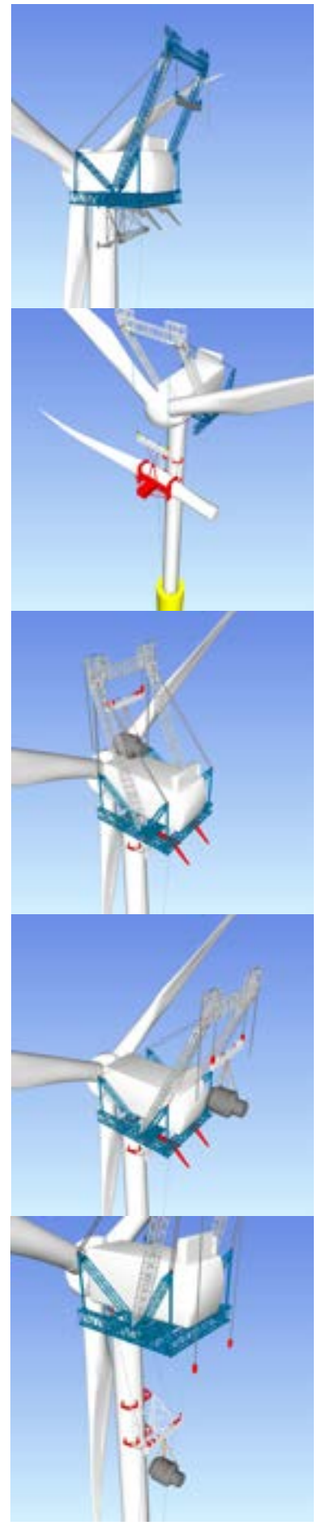
- Design of custom lifting systems for offshore maintenance
- Mobilization of equipment to and from port
- Quayside crane lifting of gearboxes, generators and motors
- Load-in and load-out of maintenance equipment
- Road transport of replacement parts from factory to port
- Storage of components at or near to port

"We estimate that 25% of offshore wind turbines will have a maintenance incident during their lifetime. Moreover, in floating wind, there is some uncertainty over how constant movement will affect the reliability of turbine components.

A large part of the operating expenditure of offshore wind farms will focus on repair of turbines. While it is inevitable that there is some randomness involved, innovative solutions can reduce the time taken to resolve incidents.

Custom lifting gantries are ideally suited to the offshore wind environment, where local port infrastructure may not be ideal, and maintenance events may be spread over a large geographical area".

Bram van Oirschot, Sales Manager for Conbit; part of Mammoet



FLOATING WIND

Floating wind offers the fastest route to 2030 emissions targets. As a maturing technology, there is not yet a standard implementation proven at commercial scale. Mammoet is committed to bringing a proven, flexible approach in helping this exciting field to realize its potential.

The sheer space required to build floating foundations will be a challenge for existing fabrication facilities – this will open the market to new entrants across the globe. Floating foundations are expected to grow to a **footprint of 10,000m² and 16,000t,** so need considerable infrastructure to handle them. As the sector matures, these modules will need to be fabricated, transported and launched in locations all over the world. This will require feats of engineering never before seen in the renewables sector – and further intensify pressures on time and space.

As turbines reach higher, innovations such as the SK6,000 will allow assembly to continue next to the quay, where it is most efficient. When maintenance events occur, our gantry solutions allow for fast repair at the turbine site, avoiding downtime while a suitable crane vessel is found.

Our offshore services team has transferred some of the world's largest structures between land and sea; constantly innovating to find a way into the water that is most efficient, safe and cost-effective.

ASSEMBLY

Modern 1,000t nacelles need to be installed 170m in the air; sometimes as far as 55m from the quay edge. This means that even when assembling from dry land, one of the world's largest crawler or super heavy lift cranes is required to complete the job.

Mammoet's largest cranes are the **perfect solution** to these challenges, able to take on heights of **175m** and with a maximum reach of **144m.** Using Mammoet's LR 13000, PTC or SK ranges of cranes allows ports and developers to shift spending on lift procedures into operational rather than capital expenditure, turning the smallest of ports into a functioning heavy lift terminal for the duration of each project.

FABRICATION

Fabrication facilities will face demand to increase production rates as the sector grows, whilst at the same time managing the increased storage and logistics demands of large-scale modules. There are limited dry docks of suitable size to get these structures in the water, neither is a slipway launch appropriate for such huge objects. So, fabrication sites will need a large draft, or the yard space needed to support crane launching.
Mammoet's extensive experience of huge load-outs elsewhere in heavy industry is a proven advantage for the fabrication of floating turbines; assisting clients to spread the risk and increase the cost-effectiveness of projects by providing load-outs worldwide.

AT THE PORT

Ports also face similar challenges around the size of components and both the scale and growing number of projects. Many will need to upgrade to deliver the required large areas of land, good maritime access and necessary ground capacity.
Project-based upgrades that can deliver the required capabilities using operational rather than capital expenditure will be the preferred option. We have helped major ports to develop their facilities with offshore wind in mind, providing additional space and ground reinforcement to marshal and store offshore wind components. Also, through innovations such as our SK6,000 crane, we provide temporary lift capacity, on-site only when it is needed.

Some of our floating wind services typically include, but are not limited to:

- Transportation of foundation sections during fabrication
- Storage and marshaling of foundations at port
- Load-out of floating foundations via SPMT
- Assembly of turbines at port using large crawler or ring cranes
- Ground strengthening, and the creation of additional storage space
- Transport and handling of turbine sections

LAUNCHING

With weights of anything between 3,000t and 16,000t, the launch of floating substructures is far from simple. The key challenge is to find a safe, cost-efficient and scalable method for placing large units in the water.

One common approach has been the use of semi-submersible vessels, with components rolled onto the vessel using SPMTs. However, the time needed to prepare floaters for launch is significant, so this approach may not be cost-effective at scale, due to the time the vessel would lie idle.

Using a heavy lift crane allows smaller foundations to be placed directly into the water, cutting down several shifts of work to a single day. This method mitigates the impact of swell on launching and requires a shallower draft than semi-submersible options, opening up more locations. It also reduces the requirement for specialized fastening and equipment when launching foundations.

OUR EXPERIENCE

A selection of Mammoet's global offshore wind projects

2013
SCOTLAND | Energy Park Fife
Transport and load-out of components, crane lifting and assembly of turbines near shore.

2018
UK | East Anglia ONE
Weighing, upending, transport and load-out of 60 jacket foundations at port.

2019
UK | Moray East Offshore Windfarm
Load-out, transportation and installation of pre-piling template.

2018
UK | Hornsea Projects One & Two
Load-out of over 100 transition pieces at fabricator; monopile and transition piece marshaling.

2022
UK | Seagreen Wind Farm
Load-out of jackets from fabricator quay to vessel using PTC 210-DS super heavy lift crane.

2016
UK | Dudgeon, Race Bank and Galloper Offshore Wind Farms
Over 4,000 separate operations to transport, load-in/out, marshal and assemble turbines and jackets.

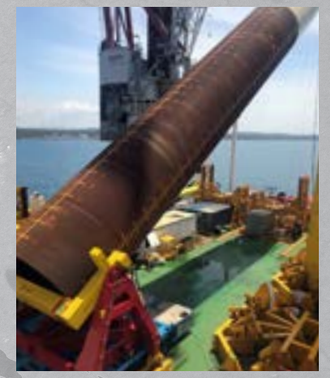
2019
FRANCE | Nacelle Unveiling
Fabrication site transportation of Haliade-X 12MW nacelle during its world premiere.

2019
DENMARK | Nissum Bredning Wind Farm
Installation of wind turbines over shallow water via crawler crane on a conventional barge.

2014
GERMANY | SylWin Alpha
Floatover installation of 14,000t substation at sea, over ten days.

2020
UAE | Hollandse Kust Zuid
Transport and load-out of substation, monopiles and jacket from fabrication yards.

2022
JAPAN | Akita Noshiro Offshore Wind Farm
Monopile upending operation on deck via SPMT and vessel crane.



2021
TAIWAN | Greater Changhua 1 and 2a Wind Farms
Marshaling of monopiles and transition pieces, port development, crane lifting for jacket assembly.

PROJECTS

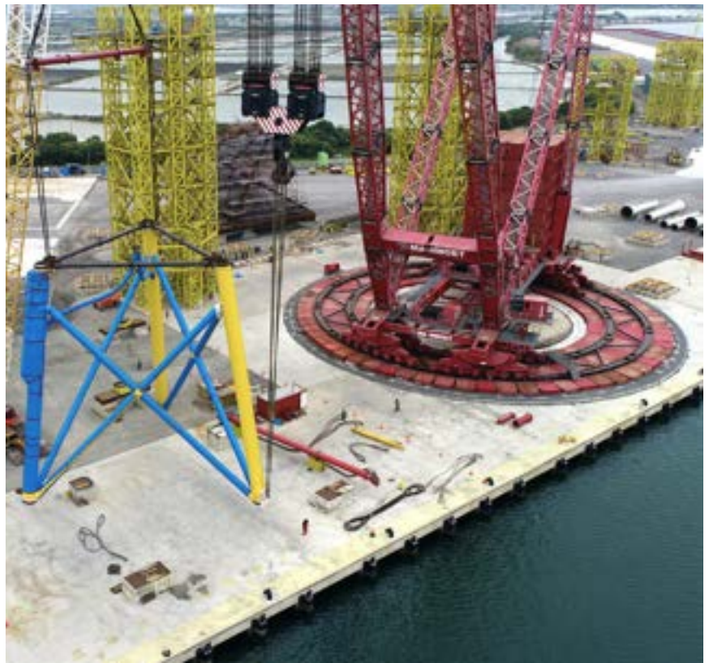
GREATER CHANGHUA 1 AND 2A
OFFSHORE WIND FARMS

DUDGEON, RACE BANK AND GALLOPER
OFFSHORE WIND FARMS

FORMOSA I
OFFSHORE WIND FARM

GREATER CHANGHUA 1 AND 2A OFFSHORE WIND FARMS

THE LIFTING CAPACITY OF THE **PTC210-DS RING CRANE** ALLOWED UP TO FOUR JACKETS TO BE ASSEMBLED AT ONCE AT THE SAME LOCATION.



The Greater Changhua 1 and 2a Offshore Wind Farms are located approximately 35km-60km off the coast of Taiwan's Changhua County. They are being constructed as part of Taiwan's transition towards renewable energy use.

Mammoet-Giant Taiwan joint venture has supported construction of these wind farms by providing a range of high-level engineering and design services, as well as assisting with the transport and integration of the jackets, ready for load-out.

Jacket foundations for the Greater Changhua 1 and 2a Offshore Wind Farms are comprised of upper and lower jackets. Mammoet designed temporary lifting lugs fitted to both the upper and lower jacket sections as they rolled off the production line.

These upper and lower jackets were sat on top of the custom support saddles – also designed by Mammoet-Giant engineers – which were used on the self-propelled modular transporters (SPMTs) to transport both upper and lower pieces between assembly stations. This method ensured a more efficient transportation process compared to other methods by reducing the time needed.

As part of this project, Mammoet's **PTC210-DS ring crane** was deployed for the **first time** to Taiwan.
The upper jackets – weighing 270t – were transported in turn around 100m from the storage area to the PTC crane, where they were erected so that the transition pieces could be fitted. A 750t crawler crane was used for the upending operation.
The lower jackets – weighing between 600t and 700t – were then also transported to the ring crane's location and erected in a similar fashion. Then the upper jackets, now fitted with transition pieces, were lifted by the PTC and mounted on the lower jackets.

The lifting capacity of the PTC210-DS ring crane allowed up to four jackets to be assembled at once at the same location, fast tracking the assembly work.
Finally, the completed jacket structures were lowered onto the SPMT/saddle combinations for transport to a storage area at the facility.

Transports of the jackets were conducted using 96 axle-lines of SPMT in two 4-file 24 configuration, with two transport beams. The beams – measuring up to 24m in length – were designed to bear the pile stoppers, allowing the transporters to lift the full jackets using the SPMTs' integral hydraulic suspension.
During the fabrication peak time, Mammoet tapped into its global network to make sure lifting equipment was available to meet short-term demands.

"Mammoet-Giant has provided strong support during the fabrication of the first Taiwan-made jacket foundations for the Greater Changhua 1 and 2a Offshore Wind Farms. The PTC 210-DS ring crane's high lifting capacity, together with the engineering expertise and solutions shown by the Mammoet-Giant team have provided both time and cost efficiency for the operations," commented Sing Da Marine Structure Corporation.

The Greater Changhua 1 and 2a Offshore Wind Farms will have an installed capacity of 900 MW once completed, enough to provide clean energy to one million households in Taiwan. They are also Taiwan's first large-scale, far shore wind farms.

FORMOSA 1 OFFSHORE WIND FARM

MAMMOET-GIANT DEVELOPED THE STORAGE YARD IN TAICHUNG FROM VACANT GRASSLAND INTO A MARSHALING AREA WITH **10T/M²** GROUND BEARING CAPACITY.

In order to move towards energy independence and to attract foreign investment, the Taiwanese Government has set a target of **5.5GW of clean energy generation capacity by 2025.** Despite its advanced infrastructure and industries, it is still facing major logistical, engineering and civil infrastructure challenges as it strives to meet this goal.

A key development in pursuit of this target is the Formosa 1 wind farm – the country's first commercial offshore wind project. To facilitate phase two of its construction, a partner was required with experience of managing complex heavy lifting projects across multiple sectors and continents. The joint venture between Mammoet and Giant Heavy Machinery Services was invited by offshore contractor Jan De Nul Group to meet this challenge.

Mammoet-Giant's scope was the onshore handling, transportation and storage of wind turbine foundations – consisting of 20 monopiles and transition pieces. This work began at the monopiles' fabrication facility in Rostock, Germany, and ended at the Port of Taichung, Taiwan. From there, Jan De Nul Group took over and installed the foundations at sea.

In Germany, Mammoet used a tandem-twin strand jack gantry system to lift the monopiles from the fabricator's trailers. SPMTs with pre-installed ocean transport cradles were then moved into position underneath the monopiles before load-out onto two flat deck carriers for ocean transportation.

While this was taking place, Mammoet-Giant was developing the storage yard in Taichung from vacant grassland into a marshaling area with the 10t/m^2 ground bearing capacity required to receive all foundation elements. The transition piece hardstand was constructed using reinforced concrete slabs, compliant with local regulations designed to mitigate against earthquakes and typhoons, which are common in the area.

Upon their arrival in Taiwan, load-in of the monopiles was carried out during a narrow tidal window, with two monopiles following one another off the flat deck carriers. Separately, the 465t transition pieces were discharged onto a custom-built transport frame designed by Mammoet's R&D department and fabricated by Giant's approved local supplier. These were then offloaded onto the storage yard by crawler cranes.

GLOBAL EXPERIENCE

During the offshore installation campaign, the monopiles and transition pieces were transported back to the quayside in batches of one and one for load-out by the Seaway Yudin for installation offshore in the Taiwan Strait.
Mammoet's vast global experience and Giant's unique local insight proved to be a winning combination. Having successfully undertaken a wide range of complex ports, civil and offshore projects spanning continents, Mammoet was well-positioned to deliver the optimal engineering and logistics required. Giant, a local expert with more than 20 years of experience in heavy lifting, was invaluable in liaising with local authorities and dealing with an array of complicated local regulations.

For the load-in in Taiwan, a maximum of **128 axle lines** of SPMT was used, in a tandem 4 file 16 configuration. For load-out, 96 axle lines in a 4 file 16 configuration was used, with two sets used for the monopiles and one set for the transition pieces. Crane lifting was performed with Demag CC6800 and CC8800 cranes.

The Mammoet-Giant joint venture allowed the customer to orchestrate a large and complex project through a single point of contact; one that encompassed heavy lifting, transportation, sea fastening, civil infrastructure, cargo handling and many other associated services. All equipment, as well as the required operating staff, logistics managers and HSE-Q staff were readily available, at capacity – and sometimes at short notice.

This work is now helping Taiwan to meet its ambitious renewable energy targets.

DUDGEON, RACE BANK AND GALLOPER OFFSHORE WIND FARMS

THROUGHOUT THESE PROJECTS, MAMMOET PERFORMED OVER **4,000 TRANSPORT OPERATIONS** AND EXECUTED OVER **3,300 LIFTS.**

Mammoet executed the handling and pre-assembly of offshore wind components, comprising of imported towers, nacelles, blades, a jacket and a topside to be used on the Dudgeon, Race Bank and Galloper offshore wind farms. The company provided a multi-service operation, involving the load-in and load-out, transportation and general handling of hundreds of offshore wind components.

With some rotor blades as long as 75m and nacelles as heavy as 360t, Mammoet adopted a ro-ro process (where possible) instead of lifting, to provide a safer and more cost-effective method. A range of equipment was used to carry out this complex scope of work, including SPMTs and specialist cranes: the LR1750/2 with 750t capacity, the LR1300 with 300t capacity and a telescopic crawler crane with 120t capacity. Meanwhile, Mammoet was given the scope of rolling-up, jacking-up, and loading-out a jacket and topside at the Dudgeon Offshore Wind Farm fabrication site in Lowestoft, Suffolk. These operations were part of the construction of an offshore facility, comprising of a topside and jacket structure.

Mammoet used its **award-winning Mega Jack 800 system** to jack-up a 954t jacket to 14m high. During the project Mammoet lifted hundreds of components using cranes, telehandlers and chain blocks. The site moves were also performed using 16 axle lines of SPMT in a configuration of 4 file 8.

One of the most critical scopes of the project involved the roll-up and jack-up of the jacket. Prior to the roll-up operation, four jacking towers were set-up with the first layer of bracing, which saved several days of set-up and installation time. The roll-up was carried out using Mammoet's AK912 and LR1600-2 cranes.

The jack-up operation took place one day after the roll-up. To perform the jack-up, suction buckets were positioned under each of the jacket legs and SPMT trailers were used to maneuver them into place. The Mega Jack 800 held the jacket in place whilst the suction buckets were welded to the jacket by the customer's operatives.
The success of the project depended upon the high-level engineering and design works carried out by SLP and Mammoet and close collaborative working with STDL to get the jacket ready for planned sail away on schedule.

Taken together, these three projects, Mammoet performed over 4,000 transport operations and executed over 3,300 lifts, with a combined handling weight of 58,000t. Combined, these three projects power over 1.2 million UK homes in total.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