FLOATING WIND

AN OVERVIEW OF CURRENT TECHNOLOGY

In recent years, fixed seabed-founded offshore turbines have become established as a valuable renewable energy resource.

Globally, the installed turbine base for captured offshore wind stands at 75 GW. By far, the majority of this is in China with Europe responsible for around 34GW.

Of all European offshore wind capture, 80% is enabled using monopiles (with the remainder coming from turbines mounted on jackets, gravity bases etc).

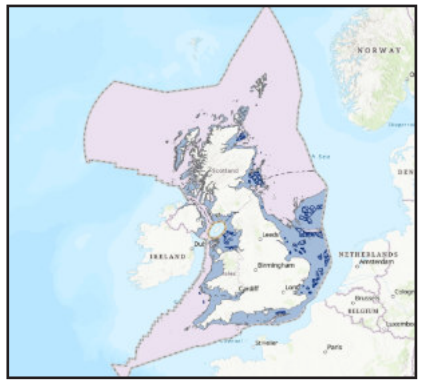
Monopiles are essentially, long cylindrical tubes that are installed by being hammered into the ground. The turbine is then mounted on this stable structure. These monopiles are fairly basic and relatively cheap tubular structures but only really suitable for 40m. Jackets can be used to extend the limits to 60m

Many companies are looking to harness the stronger winds further offshore using larger turbines, but these are beyond the economical limits of fixed-bottom foundations.as optimal locations are often in deep water.

Part of this report was written with reference to a webinar given to the SUT by Matthew Barnott, Engineer at Flotation Energy.

TYPES OF FOUNDATION

	Foundations
Monopiles	80%
Jacket	10%
Gravity Base	6%
Floating	0.4%



Map of UK EEZ limit showing depth less than 60m ☐ and greater than 60m ☐
Source: Flotation Energy

They require a different technology- Floating systems.

ADVANTAGES

Floating systems have a number of inherent advantages over fixed technology.

- Floating systems allow wind turbines to be placed in an optimum position for maximum energy capture. Further offshore, there is less interaction with the landmass and the result is a much smoother, less disturbed flow of air, which can lead to higher capacity factor.

(*The capacity is a term describing the proportion of energy the wind turbine can actually produce compared to the amount of energy it is theoretically possible to produce. Typically, fixed technology can harvest 30 - 40% of their potential but when placed further out into a better wind resource, this factor can increase upwards towards nearer 50% – 60%.*)

- Being much further away from land also reduces visibility from the coastline. This addresses concerns from some coastal communities.

- Offshore wind developers are conscious of ensuring that marine ecosystems and seabed habitats are disturbed to the bare minimum. Because floating offshore turbines are anchored to the seabed, the minimal piling of the mooring lines causes less vibration disturbance than those fixed directly to the sea floor.

- Installation of floating structures is more efficient because there is less requirement for large heavy lift vessels. They also do not require the same scale of seabed preparation and foundation work that fixed-bottom turbines demand.

- While at the end of the structural life, decommissioning is much easier as there is less infrastructure deeply embedded in the seabed. As more data is gathered subject to an end-of-life integrity assessment, it could be possible to relocate the turbine to another location. This is easier for floating systems.(This was done for the initial 2MW turbine that was installed at Kincardine. It was taken from one windfarm and placed at another site

- Floating platforms can be designed in a modular fashion, allowing for scalability. There is also greater potential for much higher local content as it is advantageous that the assembly of substructures and the turbines ideally are as close to the site as possible.

- Floating technology is well understood by decades of development by the oil and gas industry, however, serial production of these systems represents a challenge. At present, floating systems are relatively expensive because they are deployed on a small scale, but this could change as designs mature and become standardised.

COST

"Accessing deep waters has advantages, but this comes at a cost" said Matthew Barnott, Engineer at Flotation Energy. "A 2020 study suggested that the current economic cross-over between fixed and floating wind is around 90m, so that deploying either technology in these depths would cost about the same.

"It is important to highlight, however, that only 44 units have ever been installed globally, highlighting how new this technology is and the amount of learning still to do"

The relative cost difference is due to a number of factors. Floating systems are relatively more complex, requiring buoyancy chambers, a ballasting system, trusses etc. It also incorporates a large amount of steel, maybe 3000t for a semi submersible supporting a 15MW turbine.

When financing projects, the risk is largely unknown and, therefore, it costs more to borrow money.

"These projects need to be approached carefully," said Barnott. "At the start of any large projects, there will be a steep learning curve so companies need to reduce this by starting off small with demonstration projects. The results allows a learning curve without a high risk exposure. This also allows the company to slowly build a supply chain file attracting investment.

When the project finally expands, it can fully take advantage of these efficiencies with larger economies of scale. With the same people working on the projects, continually learning and as technology matures, costs will decrease.

TYPES OF FLOATING SUBSTRUCTURE

1 SPAR
SPARs are inherently stable and a relatively mature offshore technology. Examples include Hywind Tampen and Hywind Scotland

Hywind Tampen
Image: Aker Solutions

Of these spars, one is fabricated from steel and the other ,predominantly concrete.

Spars are very slender but needs a very great draught (Typically around 90m to stabilise a 6 MW turbine). All this makes manufacturing and transport & installation in particular very challenging. Deep draft structures require a deep water harbour to integrate the turbine.

While this is available in locations such as Norwegian fjords, it is not a feature of UK construction yards.

2 SEMISUBMERSIBLES
Semisubmersibles are relatively light and port-friendly and it is possible to adjust the design parameters to reduce the draft. They are, however, fairly complex and mass-production can be potentially challenging.

The semi-sub gains its stability from its outer dimensions activating the water plane area to compensate the overturning moment caused by the turbine thrust'.

To support a 6–10 MW turbine a semi-sub requires large outer dimension. This heavily decreases the number of possible manufacturing sites.

3 BARGES
Shallow draft Barges or a tested technology. These do, however, tend to be fairly large and as such the large water plane area is impacted by the waves and may lead to instability.

PIVOTBUOY PROJECT

The X1 Wind-led X30 1:3 scale prototype started April 2019 and was concluded last year as the world's first fully functional TLP floating wind platform to export power and Spain's first floating wind prototype to export electricity via a subsea cable.

The X30 floater was installed at PLOCAN, Canary Islands, with a Vestas V29 turbine adapted to downwind, under the scope of the PivotBuoy Project.

The Project demonstrated the PivotBuoy innovative mooring system configuration that combines the advantages of a SPM (single point mooring) with a small TLP (Tension-Leg Platform) mooring system, allowing the platform to reach deeper waters and minimizing the footprint and impact on the seabed.

Additional features of the platform include the light-weight and stable floater, which can be easily wet towed by local vessels thus simplifying and accelerating the installation process.

The X30 platform was towed to Arinaga Port for its full decommissioning, removing the key elements for further analysis. and offering some parts to the Instituto Técnológico de Canarias (ITC) for educational purposes at its facilities in Pozo Izquierdo.

SBM/TECHNIP

SBM Offshore and Technip Energies recently announced the formal implementation of Ekwil, a 50/50 Floating Offshore Wind (FOW) joint-venture.

Ekwil says it is a pure player delivery partner offering a diversified range of 'series production' Floating Offshore Wind solutions to meet the growing and demanding needs of energy customers around the world.

4 TLP
German wind structure design house GICON says that TLPs have significant advantages. They exhibit minimal dynamic response in restricted modes such as heave, roll and pitch.

The stability is ensured by taut mooring lines, causing the platform to behave similarly to a rigid structure in terms of motion amplitudes and resonance frequencies. The minimal pitching response is particularly advantageous for power production as it has a positive impact on the aerodynamic performance of wind turbines.

By tensioning the moorings, the entire structure becomes firmly braced, which resists even the strongest weather conditions with minimum accelerations and deflections.

Since Cigon proposed its first TLP design in 2009 , the design has undergone numerous evolutionary changes. The original design was based on a latticed structure. While this enjoyed several structural benefits, it was considered complicated and expensive to manufacture.

In 2015, the design incorporated a new gravity foundation that could be lowered to the seabed, greatly enabling one-step installation.

Since then, the company has looked at other technical innovations and computer simulations backed up by wave and wind tank tests to help to accelerate the progress It has also investigated numerous manufacturing strategies to help reduce costs.

GICON TLP

Shipyard and dry-dock rent can be minimised by prefabricating the components and transporting them to a harbour close to the commissioning site.

Most offshore structures are built using welded steel elements. This makes operations expensive and very time consuming. A single steel floating substructure for a 6 MW turbine takes at least four months. Taking into account man hours, rent for the dock and raw materials, the cost for the floating substructure comes in at € 2500-3000 per metric ton.

GICON is looking at prestressed ultra-high performance concrete (UHPC). This has a very high density and therefore high bearing capacities and means the units can be built more efficiently, leading to lighter designs.

SUBSTRUCTURE

When selecting a suitable substructure for a given project, there are a number of factors that should be taken into account, such as site conditions, water depth and especially the metocean regime.

"The turbines are not allowed to tilt or move around too much and there's also a question of where on sub structure to place the turbine," said Barnott. "In many designs, the tower is often positioned in a corner, but we have found that as turbines get bigger and heavier, placing it at the centre of the substructure makes it easier to level and add components.

"The types of construction material is also a important consideration. Steel is often considered the material of choice by shipyards. It is a lot denser than concrete but it requires a smaller mass to provide the same kind of mechanical properties. In this way, steel structures are lighter than concrete.

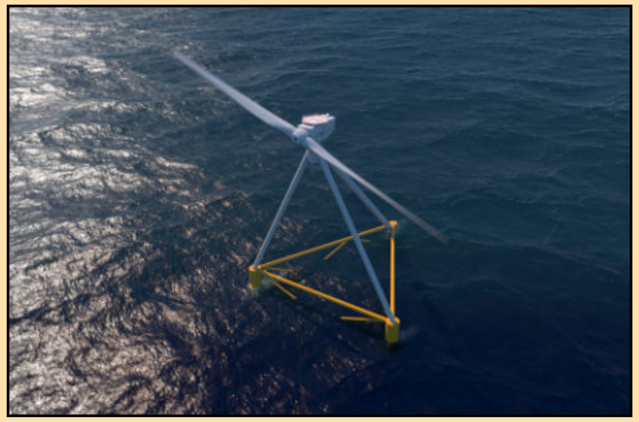
"Concrete substructures can be anywhere up to 15000t to support a 15 megawatt turbine, whereas, only 2500-5000t would be required for the same purpose. Ideally, we want to be able to manufacture components such as buoyancy chambers, trusses and the block components individually and then ship these to a nearby site for assembly.

"Welded connections can exhibit great strength, but research is showing that bolted connections are not only very strong, but can also accelerate the assembly time.

"Another focus is the delivery timeline. The turbine is the longest lead item and typically takes around about three weeks for each turbine to be integrated. In order to build structres at scale, we need to reduce this to nearer seven days.

"In order to achieve these times, we need to design the substructure around the port and not the port around the substructure. We can't be spending millions every time as the substructure of the turbine gets bigger. We need to be trying to design these things around what we've already got to bridge the gap between where we are now and where we need to be.

NEXFFLOAT



The NextFloat Project was launched in November 2022 by a consortium of thirteen partners with Technip Energies as the Project coordinator.

NextFloat's objective is to demonstrate at a full-scale the innovative floating platform design, while advancing in parallel on the industrialisation and scaling-up of the integrated solution up to 20MW+ scale, in preparation for commercial floating wind farms under development in Europe and other continents.

The 6MW pre-commercial prototype, called "X90", will demonstrate a cost-effective integrated system composed of a structurally efficient and lightweight floating platform.

MOORING

The types of mooring are often dictated by the design of the substructure. The most simple is the catenary mooring system - often used by barges and semi submersibles. This is. effectively a heavy length of chain that hangs down to the sea bed. As the structure moves off station, it lifts the chain upwards. Once the environmental force dissipates, the . weight of this chain pulls it back to its original location. These are typically only. , suitable for shallower sites. Lengths of heavy chain can be expensive, and there are a limited number of vessels that can install these.

It is also necessary to decide how many mooring lines will be required. It might be possible to reduce

WHEEL

Earlier this year, the WHEEL Consortium composed of 2-BENERGY, BOSKALIS, ROVER MARITIME, REPNAVAL, BRIDON-BEKAERT, VICINAY, PLOCAN, FIHAC, CEMEX, EnBW and ESTEYCO as the Coordinator and Technologist, gathered in Santander to witness first-hand the ambitious tank testing campaign of the WHEEL technology carried out in the facilities of FIHAC.

Further tests will be carried out soon -now in collaboration with the UPM (Polytechnic University of Madrid)- in order to also assess the external abrasion resistance of the suspension tendons around the connecting elements.

The next step is the construction of the WHEEL prototype in Q4 2025. It has been funded by the European Commission through the Horizon Europe programme.

The Wheel Image: Esteyco

HEXAFLOAT

Saipem has developed three novel designs for the offshore wind market. It has developed three novel designs for the offshore wind market.

It's STAR 1 one ithas developed three novel designs for the offshore wind market. It's star one it's a star shaped for column semisubmersible that can be fabricated from steel concrete or a hybrid. It uses a passive ballast system.

TheX:Base is a three column semisubmersible designed for 15 MW turbines

The Hexafloat is a novel pendulum structure featuring low steel mass for deep water sites. It is scalable to carry winter buying up to 15 MW.

Hexafloat

CULZEAN

France's TotalEnergies plans to launch a floating offshore wind pilot project to supply renewable energy to the Culzean offshore platform in the UK North Sea.

The 3 MW floating wind turbine will be located two kilometres west of the Culzean platform, 220km off the eastern coast of Scotland.

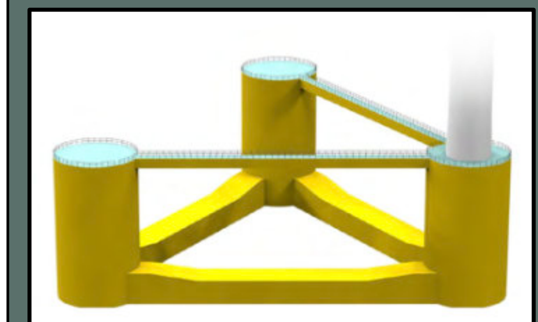
The wind turbine is planned to be installed on a modular, light semi-submersible floater hull designed by Ocergy, allowing for fast assembly and optimised costs, said TotalEnergies.

Expected to be fully operational by the end of next year, the turbine will supply around 20 per cent of Culzean's power requirement, thereby reducing its greenhouse gas (GHG) emissions, according to the company.

the chain size with the use of more lines but this means the total amount of chain is greater and it takes more hours installing it.

An alternative is a taut line, which is lightweight and has a smaller sea bed footprint. They may be challenging to install and subject to high loading. A combination of these is embodied in semi taut moorings. The footprint is small but the lines are lighter and better suited for deep water applications. It is, however, less field proven.

INO15



Technip Energy T.EN has developed the INO15 a cost-competitive 15 MW floater, standardised and easily scalable for mass production.

The INO15 is built on the IN012 concept (12MW), initially developed by subsidiary Inocean in 2021. The concept received Basic Design Approval from DNV and Approval in Principle from BV. The INO concept represents a three-column semi-submersible foundation designed to withstand diverse environmental conditions worldwide. This foundation embodies efficiency and resilience with its DNA rooted in lean design principles.

As part of the INO15 by T.EN programme, TEn leveraged in-house simulation tools to thoroughly analyse the dynamics between the floating platform and its integrated turbine. This comprehensive evaluation ensures optimal performance and seamless operation.

In the transition, weight was reduced by round 10% by mitigates risks and ensures fast implementation, engineered by T.EN teams as an assembly strategically eliminating diagonal bracings enabling businesses to embrace the ongoing
of several simple blocks, all sharing identical and an upper beam.

STANDARD FLOATING FOUNDATION

Image: BW Ideol / V. Joncheray

BW Ideol is one of the more established floating offshore wind developers. The company, however, recently announced that it was adopting a new market approach combining standardisation and mass production.

The universal floating foundation is based on BW Ideol's patented technology, the Damping Pool, characterised by a ring-shaped floating foundation which provides the stable base for the turbine. This can be optimised for all metocean conditions and compatible with all 15 MW+ wind turbines currently available.

"Our standard floating foundation design can be deployed in various site locations" said CEO, Paul de la Guérivière. "Previously, the normal practice in the floating wind industry is to re-engineer the floating foundation for each project. Because we have a standardised system, however, we can postpone the actual selection of the wind turbine size because our floating foundation will be the same.

"As such, it can be easily scalable to the next 20 MW+ wind turbines when available. This standard product, pre-certified in advance, unlocks mass-production by allowing multiple projects to be supplied from the same manufacturing line.

"This design retains the competitive advantages of the Damping Pool, particularly its compactness, with dimensions limited to 54m, and its shallow draft, below 12m in operation.

BW-Ideol's first use of the system was in 2018 on its Floatgen product, France's first offshore wind turbine at the SEM-REV test Site at Croisic where it was anchored in 33 m of water.Floatgen has already surpassed the 30 GWh electricity threshold, averaging 92.18%. In December 2023 it set a monthly production record of 922.026 MWh and a 61.96% capacity factor.

"Initially designed for a 5-year lifespan, the demonstrator observed results and the current condition of the floater and turbine allow for an additional 5-year extension without major maintenance. This extension will enable us to continue research and development projects.

We are testing new components on it, and we are so accumulating expertise . Over the time we have been able to. identify potential issues and components, and examine different behaviours and fatigue issues.

Floatgen with its 2 MW turbine was quickly followed by the Hibiki which was installed at the Kitakyushu Site in Water depths of 55m where it supported a 3Mw turbine.

The company is currently working on the precommercial development of the EOLMED PROJECT which will see three 10 MW (total of 30MW) Installed in Occitanie (France) by end of -2025 The turbines will be installed in 55m of water.

NEZZY^2

TWIN TURBINE OF A 15-MEGAWATT FULL-SCALE MODEL OFF THE COAST OF CHINA

EnBW is a major player in the offshore wind industry. This summer, it installed 64 foundations in the North Sea on He Dreiht, Germany's larger wind farm. The company has been particularly active in floating wind.

Its 2020 Nezzy² the double-rotor floating platform research project has become the OceanX structure that was fabricated at 1:1 scale in China by the company MingYang.

Earlier this year, MingYang successfully transported the turbine to its final location, 700km (much less, approx. 50nm) away off the southeast coast of China. It has been installed at the existing Qingzhou IV Offshore Wind Farm. The platform boasts a total capacity of 16.6 MW (2 x 8.3 MW),

NEZZY2 The Nezzy² design consists of two wind turbines supported by a partially submerged floating foundation. North German engineering company Aerodyn engineering tested the original 1:10-scale predecessor model based on a single turbine, in the sea off Japan in 2018. The 1:36 scale twin rotor successor was tested in an artificial wave channel in Cork, Ireland in 2017.

The two rotors double the output per floating foundation. Due to the two adjacent rotors, the point of attack for the wind is far lower than with a single large rotor. This gives the model greater stability in the water.

Nezzy², Hymendorf

A keynote of the design is that a platform operates downwind, with the wind impacting against the back of the nacelle rather than the side facing the hub. This allows the entire structure to rotate around its anchoring point, enabling it to passively align with the wind direction, like a vane.

The next stage was an 18m tall 1:10-scale prototype which was installed in a flooded gravel pit near Bremerhaven. There, the lack of waves and currents meant that wind tracking could be studied in isolation.

The water was about ten metres deep, which is equivalent to 100 metres water depth at full scale.

The next stage looked at its response to at wind and wave conditions. It was installed in the Baltic Sea, 650 metres off Vierow port in Greifswald Bay.

The18 metre tall model was tested in two different rotor configurations featuring two and three rotor blades respectively.

The body was composed of precast prestressed concrete elements, flooded so that only the three floats and the central tower protrude from the water.

The floating foundation self-aligns with the wind direction and is moored by six chains to anchors on the seabed. Two towers rising in V-formation from the centre of the foundation support the two wind turbines. Guy ropes link the towers together and to the foundation. –

With 180 sensors, it was tested how Nezzy² behaves when exposed to different wind directions and speeds, wave heights and directions. Nezzy² even withstood a storm tide.

Scaled up to the later true size of Nezzy², the wave and wind conditions were equivalent to a category four to five hurricane with waves reaching heights of up to 30m. Even under these extreme weather conditions, Nezzy² remained stable in the water.

The data produced went into the design of the 1:1 scale model used in China.

CENTEC TLP

A novel TLP has been designed by the Centre for Marine Technology and Ocean Engineering (CENTEC) of the University of Lisbon.

It is a self-stable platform carrying a 10Mw three-bladed turbine designed by DTU (Technical University of Denmark). The rotor diameter is 178.3m and the 673998kg Nacelle sits on top of a 628 422kg tower.

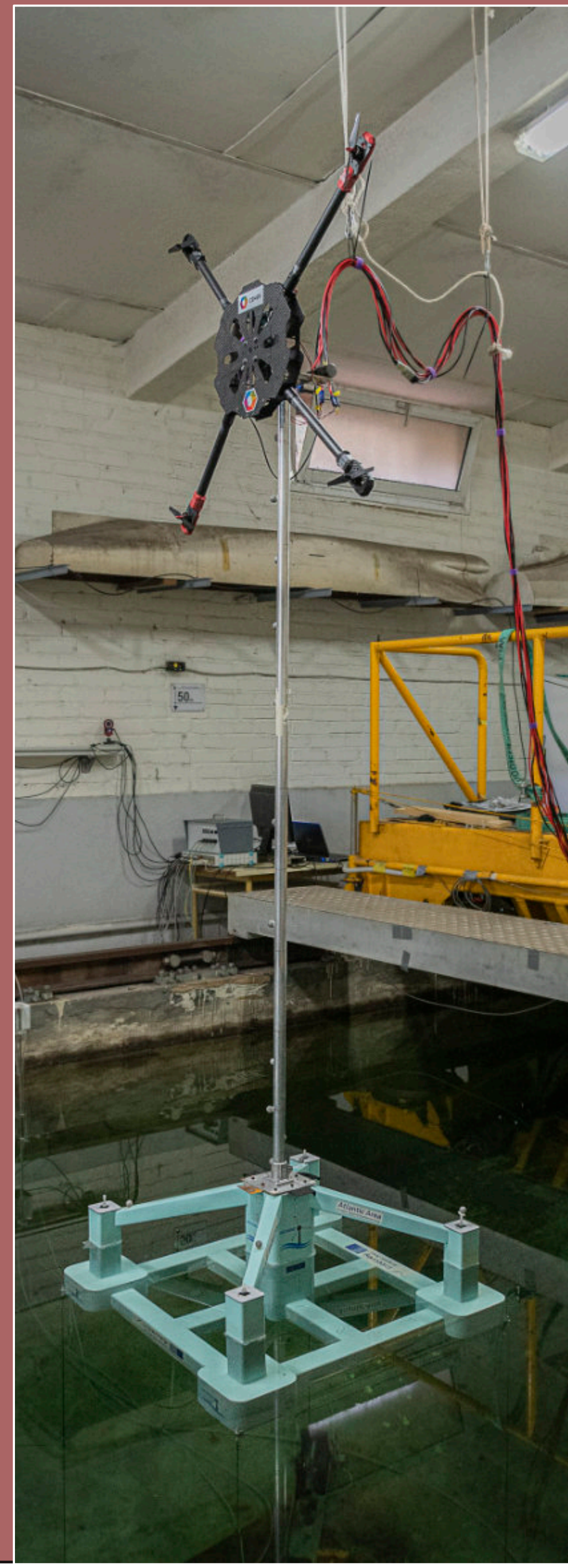
It has a total height (from keel to nacelle top) of 149.0 [m] and the Overall length beam is 49.0m. The Pontoon sides are 4.0m and the lower column is height is 7.5high by 10.5m in length.

The central column stands 10m above the waterline

During transport, the CENTEC-TLP is designed to float on its pontoons. The waterplane area stays constant as the structure heaves.It has a large moment of inertia to increase the metacentric radius , providinginherent stability. The prismatic lower and upper columns have rounded corners

When free-floating, it allows the platform to be towed irrespective of depth limits. The body needs to keep wave excitation ranges to below 5sec. A 3m significant wave height is an upper limit where towing operations can be safely undertaken.

The model has undergone considerable testing in various locations and in the wave tank at 1.60 scale is both regular and irregular waves approaching from the front and various diagonals.



DEMOSATH

Based in Leioa on the bay of Biscay, Spain, Saitec is the floating offshore wind company behind SATH technology.

For may years, it has been developing prototypes and testing progressively models reaching full-scale demonstration with the DemoSATH which was assembled in the port of Bilbao in northern Spain. Last September, the platform, with its 2MW turbine, was towed to the test site 2 miles offshore in a water depth of 85m. Hybrid mooring lines, composed of chains and fibre, anchored to the seabed hold the unit in position.

Saitec is also working closely on Geroa, a precommercial project planned for 2027. This will be followed by a second project in the Mediterranean Sea that is called Medfloat.

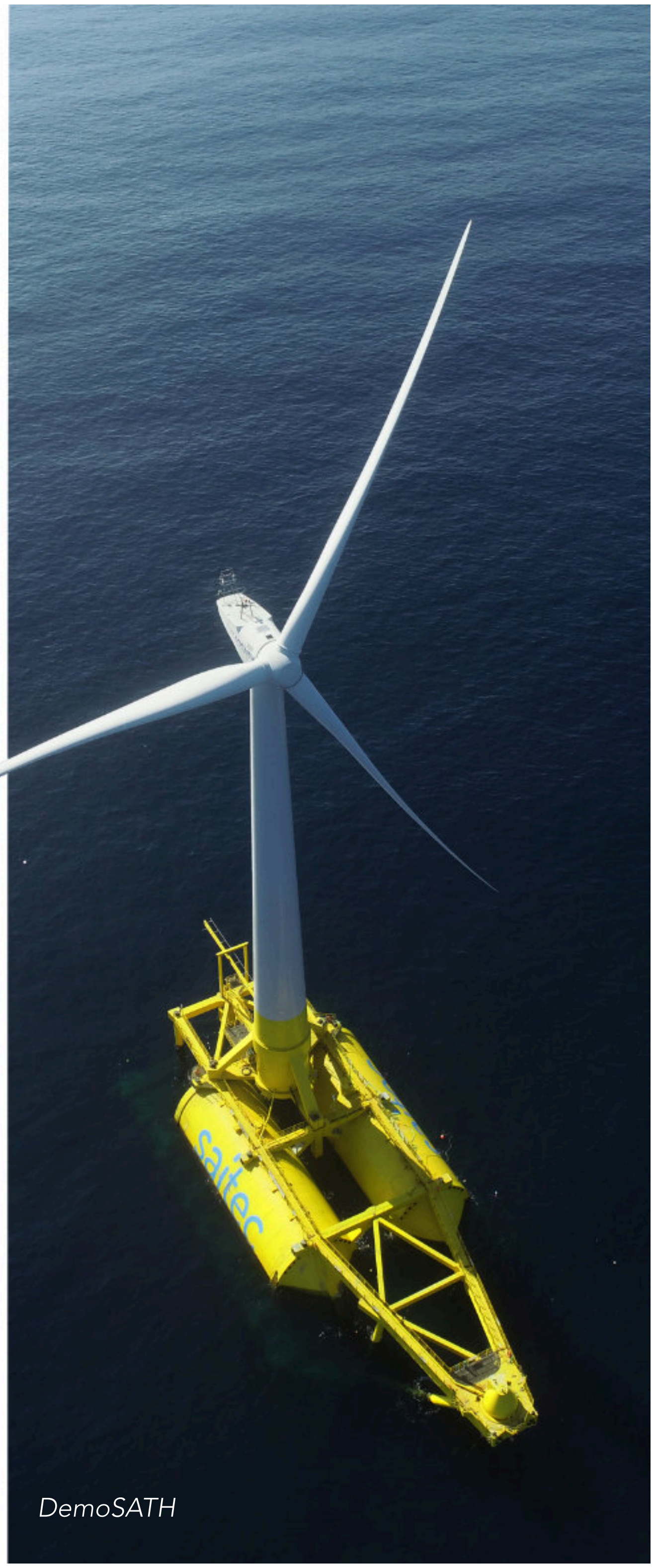
The basic concept is a floating body consisting of twin horizontal cylindrical hulls with conical ends, mounted on a heave plate. Above this is the frame structure that holds the transition piece on which the turbine sits. This frame structure extends to a single point morning of the type commonly used in FPSOs for the oil and gas industry.

This allows the platform to weathervane around the mooring, always assuring it is facing the wind. The mooring reduces environmental factors on the lines. The key feature of the design is that it is fabricated from reinforced concrete which provides an extended operational lifetime, reduced manufacturing and maintenance cost, has low emissions compared to steel, and often can be carried out provincially , maximising local content.

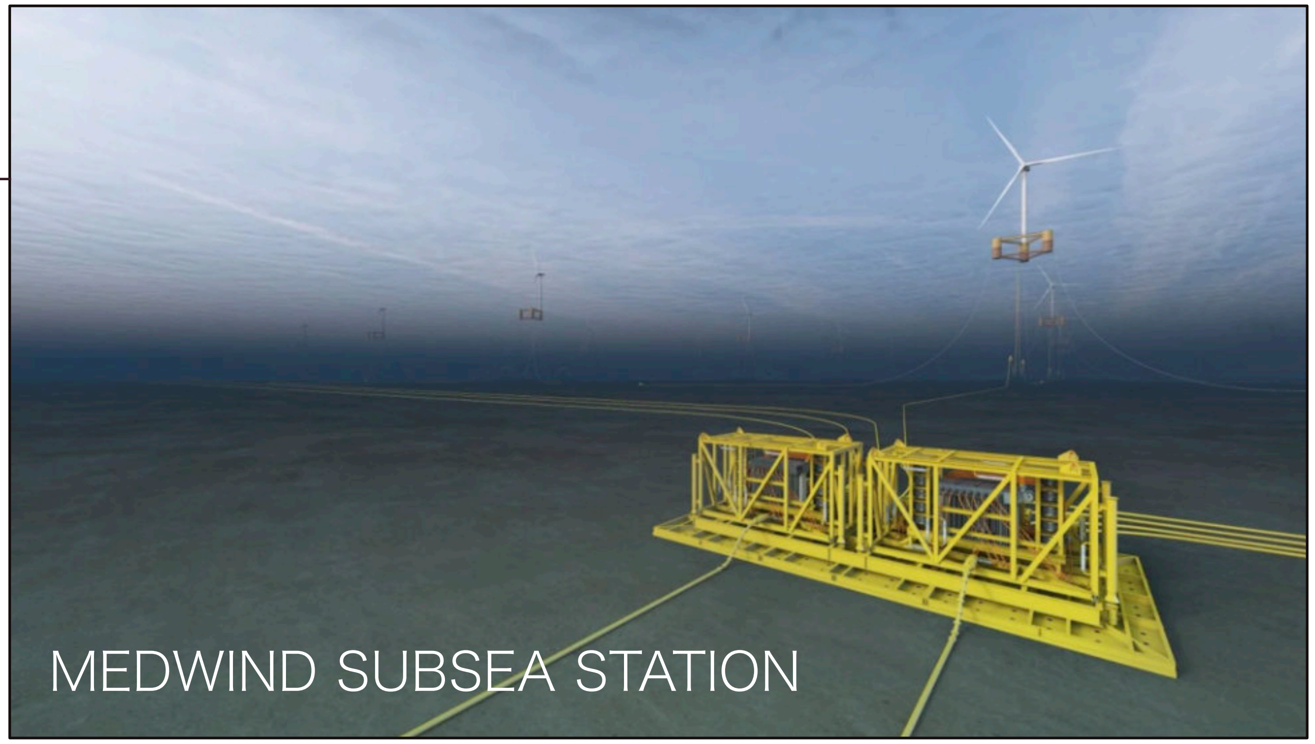
"We have designed the systems for very harsh conditions," said Melisa Aparicio, Marketing and Communications at Saitec," and have rigorously tested the structure at the Ifremer test tanks as well as those of the IHC in Santander and LIR in Cork, Ireland.

The design has demonstrated to be suitable for all the different locations where floating offshore wind is being planned. That includes extensive areas in both southern and northern Europe, west coast US and a great portion of the APAC region, among others.

"We are also planning to develop a construction hub to enable serial production of SATH floaters. Work is on going on in the region of Langosteira in Galicia."



DemoSATH



MEDWIND SUBSEA STATION

Renexia has signed a front-end engineering and design contract (FEED) with Aker Solutions to design the underwater substations for Med Wind. Aker Solutions will work in close cooperation with its subsea power alliance partner ABB ABB.

The agreement involves the design of eight modules, two for each section of the Med Wind park, to be laid on the seabed of the Strait of Sicily, at a depth of between 520 and 660 metres, into which the cables of the plant's floating turbines will be conveyed.

The energy produced by will then arrive on land at the Partanna and Partinico power stations, via a system of submarine and land-based cable ducts.

The start of the design phase was made possible by the results of oceanographic campaigns on the seabed where Med Wind will be built. The collected samples and analyses, along with studies of sea currents, helped identify the most suitable areas for the entire plant. These surveys also confirmed that the project meets all sustainability criteria and aligns well with the marine environment. Moreover, no sites of historical or archaeological significance were found anywhere near the area where the turbines will be moored.

Med Wind will be developed in several stages and, once fully operational, will be able to produce about 9 TWh per year of clean energy, equal to the energy needs of 3.4 million households and equivalent to 3% of the national energy demand, an important step for the energy transition path undertaken by Italy.

K-FLOATER

Last year, SK ecoplant and POSCO carried out model tests on their K-floater design. This secured basic design certification from DNV

The K-floating body is a 10 MW semi-submersible floating model which is capable of withstanding a typhoon of about 40 metres per second that occurs once every 50 years. It is understood to maintaining structural and functional stability even in extreme sea environments such as currents of 2m/s and 10m-high waves.

CONCRETE

Concrete floaters will play a key role in the future of offshore wind, and for good reason. So says Javier Berenguer, CEO of Madrid-based shore engineering company Beridi Maritime which specialises in the offshore wind sector.

Concrete has a number of inherent advantages.

"Concrete systems are built to endure," he said. "With minimal maintenance, these platforms help keep long-term costs in check. Moreover, concrete platform's robust nature means are less prone to fatigue, which translates to fewer maintenance."

Concrete floater

LOCAL ECONOMICS

Concrete's primary ingredients are locally abundant, meaning that every project has the potential to significantly boost the local economy.

ECO-FRIENDLY PRODUCTION

It is worth noting that concrete production generates fewer greenhouse gases than steel. This could make a big difference in reducing overall project costs, especially with the notable efforts of concrete producers to create more efficient and less polluting mixtures.

SIMPLIFIED LOGISTICS & ASSEMBLY

Many concrete platform designs, especially Triwind, is their compatibility with slipforming construction. This allows for the entire manufacturing and assembly process to take place on-site, eliminating the need for transporting massive components, which in turn slashes logistical costs and complexity.

LOWER AND PREDICTABLE UPFRONT COSTS

Compared to steel, concrete platforms generally come with a lower price tag and more stable pricing, allowing for more financial flexibility right from the start.

ACCESSIBLE EXPERTISE

With more specialists available in concrete construction, you're not just reducing costs; you're also opening the door to a broader range of expert services, ensuring your project is in the best hands.

SCALABILITY

As offshore wind turbines grow in size and capacity, concrete platforms are up to the challenge. They can easily scale to support larger turbines.

SECOND LIFE

What happens when a platform's job as a floater is done? Thanks to their similarities with port caissons, these structures can be repurposed for coastal defence or port expansion, extending their usefulness and value far beyond their initial purpose.