# TIDAL STREAM

Tidal stream or tidal current energy harnesses the changes in sea levels due to gravitational interaction between the sun, Earth and moon.

It works by capturing kinetic energy from fast-flowing water driven by tidal currents. This is most effective in areas where tidal currents are intensified by topographical features including headlands, inlets and straits or other places where the shape of the seabed forces water through narrow channels

Tidal stream devices come in various designs but the industry has ***generally*** converged around concepts featuring turbines on a horizontal axis. These are similar to wind turbines but they tend to be smaller in size and capacity (around 1–2 MW as opposed to 8–12 MW for an offshore wind turbine)

Similar to wind farms, multiple tidal stream turbines can be deployed in the same location to form arrays. These can either be fixed on the seabed or have floating foundations.

The UK has around 10 MW of tidal stream generation capacity installed, which represents over half of the world's currently operational capacity.

As a sizeable domestic renewable resource with high predictability, tidal stream energy has the potential to contribute to sustainable economic growth in the UK, enhancing net zero efforts, improving energy security and generating jobs across the country.


Tidal Stream has the potential to lower UK energy system dispatch costs by £100-£600m annually by 2050, contingent on the trajectory of cost reduction achieved over the next decades.

Offshore Renewable Energy (ORE) Catapult is the UK's leading technology innovation and research centre for offshore renewable energy In March 2024, **ORE Catapult** launched its *Tidal Stream Technology Roadmap* which looks at various aspects of the technology demonstrating how cost reduction is crucial in enabling an accelerated growth trajectory for the sector.

The report discusses how cost reduction through technology innovation is essential for the tidal stream (TS) sector's growth, targeting around 1GW of installed capacity in the UK by 2035, as recommended by the Marine Energy Council (MEC).

There are two basic types- fixed and floating, each having distinct advantages. Fixed devices, being underwater, have minimal visual impact, aiding the consenting process.

With proper environmental planning and compact foundations, their impact on the marine environment can be minimised. Fixed systems are, however, challenging to retrieve, increasing operation and maintenance (O&M) costs for unplanned maintenance. Their proximity to the seabed limits them to specific site conditions, but tidal developers deliberately seek out highly energetic sites to maximise energy production.

| | MICROSCALE <100kW | SMALL SCALE 100kW - 1MW | UTILITY SCALE >1MW |
|---|---|---|---|
| **Fixed foundation Horizontal axis turbine** | **Guinard Energies**<br>**Nouvelles (FRA)**<br>P66, P154<br>**ORPC (USA)**<br>RivGen | **Nova Innovation (GBR)**<br>M100, M100D, M500D,<br>**QED Naval (GBR)**<br>Subhub Community Design<br>**Sabella (FRA)**<br>D08, D10, D12<br>**Proteus (GBR)** AR500<br>**Verdant Power (USA)**<br>TriFrame Gen5<br>**Hydrowing (GBR)**<br>HW500, HW1000 | **Andritz Hydro**<br>**Hammerfest (AUT)**<br>Mk1 1.5MW Turbine<br>**Proteus (GBR)**<br>AR1500, AR2000, AR3000<br>**Hydrowing (GBR)**<br>HW1500 |
| **Fixed foundation Vertical axis turbine** | **Instream Energy Systems (CAN)**<br>25kW Hydrokinetic<br>Turbine System | **Minesto (SWE)**<br>DG100, DG500<br>**Seaqurrent (NLD)**<br>TidalKite | **Hydroquest (FRA)**<br>Oceanquest 1,<br>Oceanquest 2 |
| **Fixed foundation Other** | **Minesto (SWE)**<br>Dragon 4 | | **Minesto (SWE)**<br>Dragon 12 |
| **Floating foundation Horizontal axis turbine** | | **Orbital Marine Power (GBR)**<br>SR250 (ScotRenewables)<br>**Sustainable Marine Energy (GBR)**<br>PLAT-I 4.63,<br>PLAT-I 6.40<br>**Aquantis (USA)**<br>Tidal Power Tug | **Magallanes (ESP)**<br>ATIR<br>**Orbital Marine Power (GBR)**<br>O2, SR2000<br>(ScotRenewables) |
| **Floating foundation Vertical axis turbine** | **Gkinetic (IRL)**<br>CEFA12 | **Aschelous Energy Ltd**<br>(GBR)<br>FITS Platform | |
| **Floating foundation Other** | | **BigMoon Power (USA)**<br>Kinetic Keel (prototype)<br>Kinetic Keel (~0.5MW) | |

Floating devices, positioned at the water's surface, offer significant O&M advantages since they avoid complex underwater operations. Their installation is simpler, relying on mooring and anchoring systems deployable during slack tides, reducing the need for dynamic positioning vessels. However, floating devices are more complex to engineer and are vulnerable to wave loading, which can affect power delivery quality and device longevity.

There are several other tidal stream (TS) devices being explored, such as oscillating hydrofoils, venturi turbines, Archimedes screws and kinetic keels. Among these, Minesto's "kite" design has shown significant promise. Resembling an underwater kite with a small rotor, it generates electricity by "flying" through the water column, similar to airborne wind technology.

## COST

The levelised cost of electricity (LCoE) varies between fixed and floating devices due to differences in scale, design and development stages.

Projects that secured funding through the UK Government energy generation subsidy scheme Contracts for Difference (CfD) for Allocation Round 4 (AR4) must reduce costs below £178.54/MWh by 2027 for commercial viability, a significant reduction from the 2018 weighted LCoE of around £300/MWh. This reduction seems achievable for certain devices like Orbital Marine Power's O2, which targeted an LCoE under £200/MWh for its first deployment at the European Marine Energy Centre (EMEC).

Continuous cost reduction is essential for making TS competitive with other renewable energy sources. Accelerated Reductions have already been achieved through economies of scale and increased turbine capacity. For example, Orbital Marine Power (OMP) scaled up from the 250kW SR250 turbine to the 2MW SR2000 and O2 turbines. Developers like Nova Innovation have also contributed to accelerated learning, deploying 100kW devices and scaling up to 500kW.

Their Shetland Tidal Array grew from three devices in 2016 to six by 2023, achieving cost reductions through increased reliability and reduced cable requirements via a subsea hub. Despite these advances, manufacturing volume barriers remain, such as inconsistent access to revenue support and long lead times in component manufacturing and procurement, which could cause bottlenecks.

Companies have sought to obviate blade failure by not underestimating mechanical loads during design. This has led to more cautious (and sometimes over-engineered) blade designs, increasing costs.

Standardisation of blades and advanced materials are critical for further cost reductions as rotor diameters increase with the advent of 3MW+ devices.

Long-term cost reductions will rely on continued learning by doing and innovation, as well as further reductions in capital cost. Overall, achieving commercial scale arrays by the late 2020s depends on overcoming manufacturing barriers and continued innovation to drive down costs and increase reliability.

ORE CATAPULT LOOKED AT TEN INNOVATION AREAS WITH A COST REDUCTION POTENTIAL.

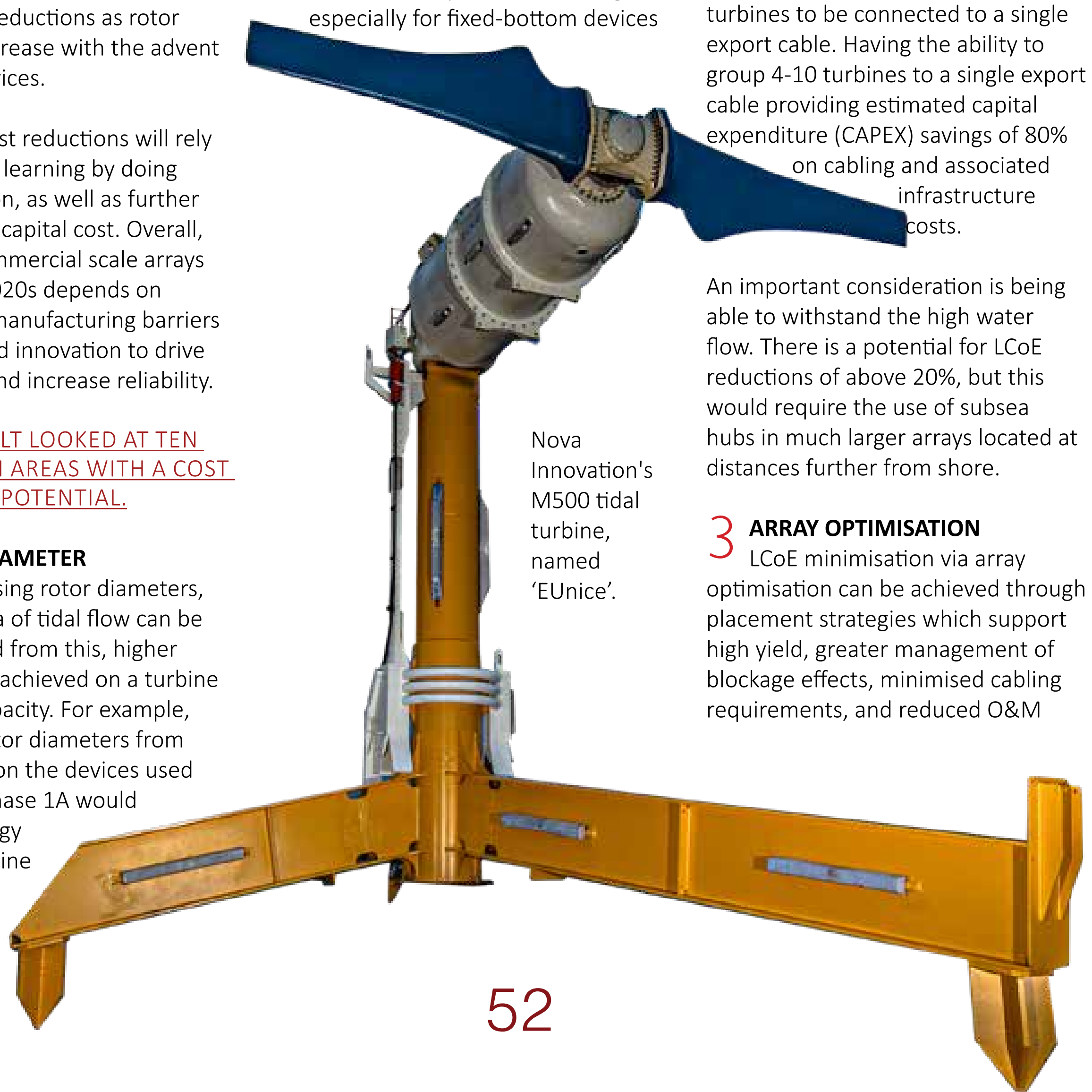
### 1 ROTOR DIAMETER

By increasing rotor diameters, a greater area of tidal flow can be captured, and from this, higher yields can be achieved on a turbine of a given capacity. For example, increasing rotor diameters from 18m to 24m on the devices used at Meygen phase 1A would improve energy yield per turbine by 34%.

> **INSURANCE**
>
> Insurance premiums are high, contributing significantly to the final project cost. A key factor driving high insurance premiums is the lack of performance data available to insurers, making it challenging to determine appropriate premiums for coverage.
>
> This creates a dilemma where developers hesitate to invest in technologies to increase operating hours due to the unavailability of suitable insurance.

Identifying suitable sites for larger rotor diameters presents challenges – especially for fixed-bottom devices – due to their proximity to the seabed. In many instances, this limits blade length. Floating devices face constraints related to sea surface conditions.

For both types, the costs associated with manufacturing, transporting, and installing larger blades, as well as any necessary design changes to accommodate greater mechanical loads, must be balanced against the potential site-specific increases in annual energy production.



Nova Innovation's M500 tidal turbine, named 'EUnice'.

### 2 SUBSEA HUBS

These enable multiple TS turbines to be connected to a single export cable. Having the ability to group 4-10 turbines to a single export cable providing estimated capital expenditure (CAPEX) savings of 80% on cabling and associated infrastructure costs.

An important consideration is being able to withstand the high water flow. There is a potential for LCoE reductions of above 20%, but this would require the use of subsea hubs in much larger arrays located at distances further from shore.

### 3 ARRAY OPTIMISATION

LCoE minimisation via array optimisation can be achieved through placement strategies which support high yield, greater management of blockage effects, minimised cabling requirements, and reduced O&M through improved load prediction and efficiency in marine operations.

Multiple models exist which can be used to calculate energy yield from arrays which employ both uniform and non-uniform spacing between turbines, with greater yields being possible when changing the locations of specific turbines. Modelling indicates that increases in yield of up to 30% can be achieved.

### 4 INNOVATIVE ANCHORS FOR FLOATING DEVICES

These solutions offer lower CAPEX, lower material usage, quicker installation time and lower OPEX throughout the lifetime of a floating TS project in comparison to gravity based and grouted anchors.

Significant CAPEX costs can be avoided through the use of rock bolt anchors due to the huge reduction in material required to support a given mooring load. A one tonne grout-free anchor can support a mooring load of around 200t while having far smaller mass and spatial requirements

Environmental impact is also reduced compared to grouted connections as these anchors are removable at the end of their life and leave no footprint after a TS project has been decommissioned.

### 5 STEP CHANGE IN RATED GENERATOR POWER

Increasing the rated power within a given rotor diameter increases the amount of energy that is produced at a particular rated flow speed regardless of increases in rotor diameter. This will lead to CAPEX increases due to the larger generator and higher rating of required power electronics.

Both cost and mass scaling, however, are non-linear so larger devices of the same asset class will be more material-efficient and will be favourable when looking at metrics like rated capacity per tonne.

### 6 CONTROLLERS

Controllers are comprised of electrical control strategy algorithms that bring about a desired performance profile for a given generation asset. They allow more efficient turbine and array operation, as well as the ability to operate in more extreme conditions.

The problem with many previous control strategies was that the load reduction implemented also significantly reduced turbine yield.

Looking to the present, the control strategies that are currently being developed in academia can reduce loading while minimising the bearing that this has on yield across the full range of flow speeds that a turbine may encounter.

### 7 OPTIMISED FOUNDATIONS FOR FIXED DEVICES

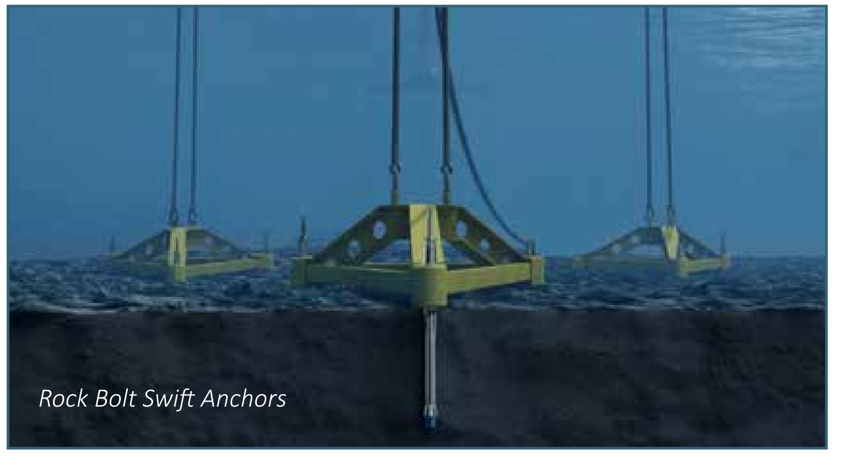
Gravity based foundations require significant amounts of concrete and steel and as a result, are sub-optimal in terms of their design and material efficiency. Due to the size and mass of gravity base foundations they are often transported to site on large, expensive installation vessels, thus increasing installation costs.

Monopile based foundations for fixed bottom devices are the most promising alternative solution to gravity bases at present, with such a solution requires far less material.

Beyond monopile foundations, a range of other concepts have been investigated for fixed bottom TS devices including streamlined twin turbine foundations which offer reduced hydrodynamic loading on turbines which minimised structural requirements while featuring fixation subsystems to maximise yields from oncoming tidal flows.

### 8 WET MATE CONNECTORS

Wet mates are used to enable subsea connection of individual turbines to wider turbine arrays and export cables. They offer several advantages against dry mate connectors which include removing the need to bring cables



*Rock Bolt Swift Anchors*

to the surface for connection or disconnection, thus reducing time and costs associated with installation and maintenance.

Because of quicker connection and disconnection, vessel hire periods can be reduced which allow larger weather windows in which it is safe to operate offshore. When considering wet mate installation versus that of dry mates, wet mate installation costs are estimated to be 65% lower.

At present many wet mates are highly bespoke and this results in far higher per unit costs, with designs often only being suitable for one turbine model.

Low order volume is another area which results in many TS developers having to settle for sub-optimal wet mate designs.

Wet mate suppliers are insistent on sticking to the "classic" voltage levels (eg, 6.6kV, 10kV). The cost of manufacture is reduced by sticking to standardised voltage levels

### 9 CABLE CONDITION MONITORING

As larger arrays come online in the later part of the 2020s, a better understanding of cable prognosis and failure modes to minimise downtime will be essential in reducing project OPEX while maximising generation hours for operators in the future.

While far less cable is used in TS projects due to the shorter distances to shore and smaller scale of projects compared to offshore wind, the site conditions are highly dynamic. They can potentially cause cable friction with the seabed and thus, wear.

### 10 PITCH CONTROL

Pitch control systems alter a turbine's blade angle in relation to the tidal flow. This can be executed to maximise power generation, minimise loading, and assisting turbine braking systems.

Pitch control systems bear some similarity to the electrical control strategies but instead of controlling interactions between generator electrical output and rotor torque; pitch control focuses on the angle at which each turbine blade operates.

The simplest method of pitch control is collective pitch control where all turbine blades collectively pitch together to the same angle, whereas individual pitch control (IPC) involves independently pitching each blade to its own angle.

When comparing fixed and floating devices, optimal IPC control strategies can vary. When successfully implemented on a TS turbine, optimised IPC hardware can play a role in maximising swept area for a given nacelle mass.

By increasing turbine yield, higher capacity factors are achieved, with each 1% increase in lifetime capacity factor resulting in a LCoE decrease of around 1% .

## NOVA INNOVATION

*Nova turbine*

Nova Innovation has developed that M100D and M500D models. Three M100D were installed in Shetland in 2020 and have been powering the grid.

The M500 tidal turbine, named 'EUnice' was also deployed in Shetland.

The company is currently involved in SeaStar, a 4 MW tidal energy farm that will be home to the largest number of tidal turbines in the world.

Nova will include sixteen M100D tidal stream turbines at the EMEC Fall of Warness test site, Orkney.

## ORBITAL

In 2021, Orbital Marine Power (Orbital) launched O2, perhaps the world's most powerful tidal turbine. The technology is based on a floating platform with twin turbines fixed to retractable legs. This means that the tidal turbine can be positioned in the most energetic parts of the water flow.

The company has been recently confirmed as the technology partner for Orcas Power & Light Cooperative (OPALCO)'s proposed site off Blakely Island in Rosario Strait, Washington State.

Building on a memorandum of understanding (MOU) signed between Orbital and OPALCO in 2021, this latest update follows the US Department of Energy (DOE) shortlisting two marine energy projects to receive $6 million for the development of a tidal energy research, development, and demonstration pilot site. At the end of the Phase 1 term, one of the two organisations will be funded to move forward with development of a full project.

If the chosen organisation at the end of the ten-month process, OPALCO proposes deployment of an Orbital O2 floating tidal energy turbine in Rosario Strait in the San Juan Islands to provide a local power supply and further assessment will be completed as part of Phase 1.

Orbital has also confirmed the building and launching of the next generation of Orbital floating tidal turbines in Nigg, Scotland. It has selected Global Energy Group as preferred supplier to lead the manufacture and assembly of turbines for the company's initial Orkney projects which have secured contracts under the UK Government's Contract for Difference auction rounds 4 and 5.

It is anticipated that turbine manufacture will start at Global Energy Group's Port of Nigg facility on the Cromarty Firth, later this year with first power expected from the Orkney connected projects in 2026.

In keeping with the company's vision of using a predominantly UK based supply chain for the manufacture and installation of its tidal projects, Orbital expects to demonstrate an unparalleled level of UK job creation on a per MW basis with the delivery of its CfD projects.

*Orbital Marine Power's O2*

## HYDROWING

HydroWing has designed an innovative new barge which will help drive down the cost of installation and maintenance for its tidal stream array technology.

HydroWing is designed to be a cost-effective and scalable solution to tidal stream energy generation. It was the largest tidal stream project in Wales to be successful in the UK government's latest Contracts for Difference round, having been awarded a 10MW project at the Morlais tidal energy site in Anglesey.

HydroWing technology offers a modular, reliable solution, based on its unique patented design. The wing system streamlines operations and maintenance by allowing for removal of sets of tidal energy turbines without the need to remove or work on the foundations.


*Quad hull barge*


*The HydroWing tidal energy device (Image: Inyanga Marine Energy Group)*

Commercialisation of the tidal energy sector has so far been held back by high operations and maintenance costs. HydroWing's next generation technology addresses that challenge head on. The new Quad Hull Barge is the latest innovation to the HydroWing system, which further increases productivity and drives down costs.

Richard Parkinson, MD of Inyanga Marine Energy Group, said "Offshore construction vessel availability is very weak with expensive day rates.

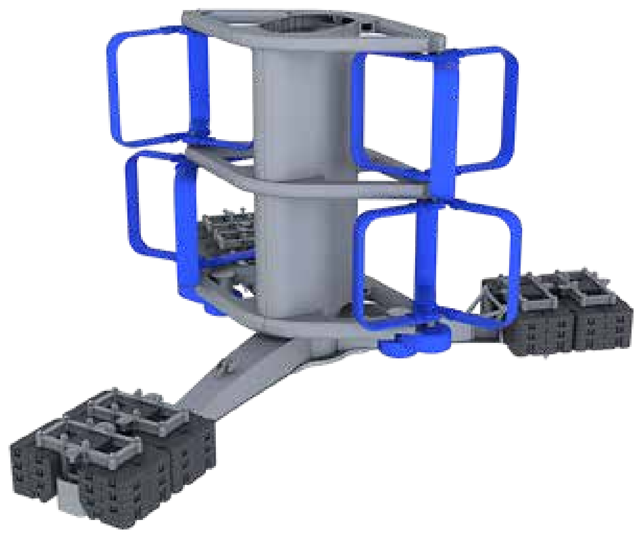
"By using four hulls connected by crossbeams and arch support beams, the limit to load width is dramatically increased. Where commercial vessels would typically need to place the load onto the deck with little to no overhang of the load, the Quad Hull Barge locks the load after lifting to the arch. This reduces offshore handling and makes the operation much safer."

## HYDROQUEST

French tidal stream company HydroQuest has developed the second generation of turbine, HQ 2.5, building on the reliability demonstrated by its prototype, while increasing the yield. Its weight is also reduced in order to facilitate its deployment and to lower operational expenditures.

Hydroquest will continue the demonstration and technological maturation of sub-sea tidal energy, maintaining the good positioning of French technologies on a growing international market.

*HydroQuest*



## MINESTO DRAGON 12


*Dragon 12*

Since Minesto installed the tidal kite Dragon 12 at the site in Vestmanna earlier this year, it has enjoyed a trouble-free three-month period of testing and electricity production, generating valuable results and data to underline commercial readiness of Dragon Class technology at commercial scale. Notably, real test data from the commercial scale D12 is now available to customers and is used to show autonomous functionality, product performance, and service interval analysis. The large Dragon 12 (1.2 MW) is accompanied by a smaller Dragon 4 (100kW) which means that two systems are installed and grid-connected in parallel.

## EMEC

EMEC is the world's first and leading wave and tidal energy testing facility and has hosted more ocean energy technologies than anywhere else in the world.

The UK Government has announced a new £4.6 million support package for the UK's islands, £3 million of which will be awarded to the Orkney-based European Marine Energy Centre (EMEC) over two years.

EMEC was set up as a not-for-profit test facility in 2003 following a recommendation by the House of Commons Science and Technology Committee to kick start a wave and tidal energy sector in the UK. An economic impact assessment spanning two decades of EMEC's operations values impact of the test centre to the UK economy at £370 million; £263 million of that was accrued in Scotland, and half of that, £130 million, in the Orkney Islands where EMEC is based.

## BLYTH RENEWABLE ENERGY CENTRE

ORE Catapult's National Renewable Energy Centre, Blyth is the UK's leading Technology Innovation and Research centre. Since 2013, it has been used for bringing 148 products and services to market and partnered over 650 research and development projects. The facility has supported over 1350 small to medium enterprises. Blyth was the testing site of Proteus' AR1000 and AR1500 fixed bottom turbine technology.

## PROTEUS

Proteus Marine Renewables was established in 2022, building on the foundations established by its predecessors Marine Current Turbines, and Atlantis. Its technologies have generated 22GWh which amounts to approximately one quarter of UK/EU's total output to date. Following successful testing and lessons learned, in 2017 one AR1500 was subsequently successfully deployed at the MeyGen site in the Pentland Firth, Scotland.


Proteus

The modular turbine system allowing broad flexibility in supply chain and assembly options, is customisable up to 3MW output with large rotor diameters, optimised to suit local environmental conditions, or to specific customer requirements, such as the AR500 system as Japan's first permitted tidal system, installed as a demonstration unit in January 2021.

The drive for a lower cost of energy has led to the design of the AR 3000, producing double the yield with increases in rotor swept area of 80%, with plans to deploy this in France, Scotland as soon as 2026. With a third party validated cost of energy reduction path and its own in-house expertise in marine construction, Proteus provides a holistic marine energy solution.

# RENEWABLES: TIDAL STREAM


# FALCON

Halifax, Nova Scotia-based Occurrent Power, formerly known as BigMoon Power, has appointed Jay McKenna as its new CEO. The company will manage BigMooon's original 500kW, patented surface-based device *Falcon* which commenced trails late 2022. It has enough to power for about 500 homes.

The Falcon has been described as a 21st-century adaptation of very old technology in the form of a Roman paddle wheel. Each unit consists of a large wheel suspended between the pontoons of a 30m barge anchored to the ocean floor. The barge can swivel to remain facing the current.

The system hopes to converts tidal energy into renewable electricity, with minimal impact on sea life and the ocean environment. A key design feature of Occurrent's tidal turbines are easy deployment and maintenance.

The equipment has to be robust to withstand the harsh conditions of a saltwater environment and in some of the highest tides in the world. It has to be protected from debris while minimising the impact on fish and marine mammals. BigMoon spent about $20 million on research and development over six years.

"Our ocean tides carry up to 800 terawatt-hours of energy per year, enough to power more than 50 million homes or 120 million electric vehicles," said McKenna. "We see real promise in converting this potential into cost competitive zero emission power for coastal communities."

Occurrent Power's first facility, under an existing power purchase agreement with Nova Scotia Power, will be at the Fundy Ocean Research Centre for Energy (FORCE) in the Minas Passage, Bay of Fundy. Occurrent Power plans to deploy additional facilities to meet the clean power needs of tens of thousands of households across Atlantic Canada and North America.

## WATTS OCCURRENT?

In 2019, Big Moon Power signed an agreement to participate in a tidal energy scheme in North Wales after signing an agreement with Morlais. Morlais is run by social enterprise company Menter Môn, It manages an area of 35Km² of the seabed near Ynys Cybi (Holy Island), Ynys Môn (Anglesey). The scheme has the potential to generate up to 240MW of low carbon clean electricity.

Earlier this year, Morlais, officially handed over the substation to site owner The move signals the successful delivery of the first phase of the project within the timeframe and to budget.

Construction of the substation is a key part of the infrastructure for the new development and Completion means the project can move to the next phase as it prepares for the deployment of turbines in the sea from 2026. Morlais will install the necessary infrastructure in the zone. It will then rent a berth to turbine development companies so they can use tidal energy to generate electricity.



BLUEVIEW BOSCH REXROTH BOWTECH BP BUCCANEER C-KORE CAMERON CASTROL
CHEVRON CODA OCTOPUS CONTINENTAL CYGNUS DAVID JONES/CHEVRON DEREGT
CABLES DIVEX DSPL DWT ECA ECOSUB EDGETECH EMGS EVOLOGICS EXAIL FISHER
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