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The Offshore Renewables Issue

page 16

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Features

ON THE COVER

Alan O'Neill and his team at Charles Hodge Photography tracked progress on the 88-turbine, Sheringham Shoal Wind Farm offshore Norfolk, England, throughout its construction. The farm, jointly owned by Statoil, Statkraft and the Green Investment Bank, and operated through joint venture company Scira Offshore Energy, came on stream in 2012. *Image courtesy of Statoil.*

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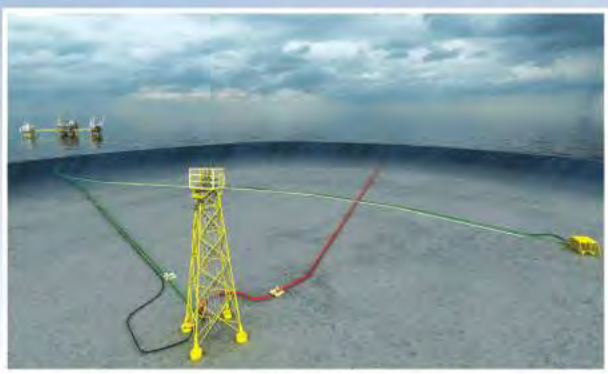

What's Trending

Just on the horizon

- BP sets 2018 target for Egypt's Atoll
- Statoil's Oseberg Vestflanken 2 approved
- Petrobras scores again at Libra

Activity

Britain to leave the EU

The British public has spoken. Late June, with a narrow margin, the leave campaign in the UK's referendum to stay in or leave the EU won by 52% to 48%, ending the UK's 43-year long membership in the EU. Follow more coverage of the "Brexit" decision and implications for oil and gas at **oedigital.com.**

Photo fromBP.

People

OneSubsea president jumps to Aibel

Mads Andersen will take over as the new president and CEO of Stavanger-based oil services firm Aibel, effective 1 January 2017. Jan Skogseth, Aibel's current president and CEO, since 2008, plans to retire. He will hold an advisory role in the company until spring 2017.

OE Expert Access Webinar with NOV

Using wired drill pipe to deliver project value

Despite the current low price environment, the interest and adoption of wired drill pipe technology continues to grow as a way to reduce well construction costs through elimination of rig time associated with data transmission and ROP limiters.

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Undercurrents

The human factor

As an industry, we have a tendency to forget, or simply overlook, the human endeavor that goes into the work behind the latest technology and engineering the industry produces.

This isn't just about long office hours. In the past year, two huge projects, major achievements in the world of subsea processing, started up. Both have their origins some 30 years ago. Both have had individuals involved right from the start through to final deployment.

The first is Kjell Olav Stinessen, now first chief engineer at Norway's Aker Solutions. He was at Kvaerner when he first sketched out an idea for subsea compression on the back of a napkin back in 1985. We featured Stinessen, shortly before the final realization of his vision at the Åsgard field, in our 2015 NCE Subsea supplement (*OE:* February 2015).

We must also recognize the business leaders who have had the courage to continue investing in these technologies.

The second is Bernt Helge Torkildsen. He is business and technology development manager, subsea compression system, emerging technologies, processing systems, OneSubsea. He was at the legendary Norwegian firm Framo Engineering when he first started thinking about multiphase compression, which last year bore fruit as the subsea multiphase compression project at the Gullfaks field.

The efforts of Torkildsen, alongside Simon Kallgraff, also from OneSubsea, and Jarle Ottar Hella and Caroline Bøe, from Statoil, were recognized by the Underwater Technology Foundation (UTF) in Norway (see page 64).

The UTF presented its second annual Subsea Award to all four for their work on the Gullfaks subsea multiphase compression project. Bøe, who initially worked on the cooler but went on to take a greater role, was lucky enough to be on the Gullfaks platform when the "start" button was pressed.

While the compressors have since been temporarily removed, due to a leak in a utility cable not related to the compressor station delivered, Statoil has confirmed that the units had been operating to its satisfaction.

As well as having their own vision and stamina to continue with these projects, when there have been detractors and disbelievers, they've also gone through changes in business ownership, management and economic climate. Technology development partners have come and go and other priorities have taken over. But, we must also recognize the business leaders who have had the courage to continue investing in these technologies.

We also hope that these examples give hope to those who, right now, might be thinking they might have the next new wave in technology in a market that isn't at all very encouraging.

It can be done. Those ideas that might seem farfetched right now could have a future. Engineering, manufacturing, materials science and design technologies have advanced at a terrific rate since the 1970s and 1980s. We can do more with less and with more exotic materials. The computation possible using today's machines and software is far beyond anything anyone might have dreamed, not least in the years when Stinessen and Torkildsen were first fleshing out their ideas, which should also make technology development faster.

The most exciting thing, for ***OE*** at least, is what new technologies the future might bring. But, let us not forget the minds, the humans, behind them.

BREXIT

As we went to press, the British public voted to leave the EU, which it helped create 43 years ago. Reaction from the oil industry has so far been muted, with Wood Mackenzie predicting little impact. To find out more, read our online coverage. See page 7 for details. **OE**

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The Barrel

The shape of things to come

Talking with the operator and service sector communities in recent weeks, in private and public forums, has underlined some key issues for the offshore industry.

As I said last month, the supply side is tightening and demand continues to grow – creating a positive outlook for the medium-term. That said, a short-term mind-set is a recurring weakness in the industry and so much of the current thinking is undeniably clouded by the misery of the past 24 months. We must not mistake the edge of the rut we are in for the horizon.

Will things recover to where they were in 2013-14? Probably not – the system was bloated and inefficient then. A correction had to come. For most service companies the focus is now on becoming as efficient as possible and keeping the bank happy.

For oil prices to continue to travel upwards, the speed with which North American shale producers ramp up activity will be critical.

A rapid return of a large number of land rigs boosting shale oil production could undermine the recovery and depress long-term prices.

The more likely outcome, however, is that only the very best shale producers (with the best balance sheets and the best acreage) will ramp up activity – the others will use cash flows from higher crude prices to pay down massive debt levels. That would result in continued production declines from US shale, which together with the impact of lack of investment across the remainder of the global oil complex, will ultimately lead to a much tighter market.

When will that take place? The consensus view is for that to happen in 2018, but that assumes the industry is not hit by a fast ball in the interim, like an implosion in Venezuela, an explosion of events in the Middle East/Nigeria or (perish the thought), another financial crisis.

However, the prognosis for the service sector in the shorter term is bleaker. Even a near-term recovery in crude prices will not spare it from the impending liquidity crisis, which is already visible and particularly so in the smaller company community. Things might get a little better in 1H 2017, but few see them getting much better until 2018. In the meantime, the banks are getting increasingly nervous and we are seeing more businesses going under.

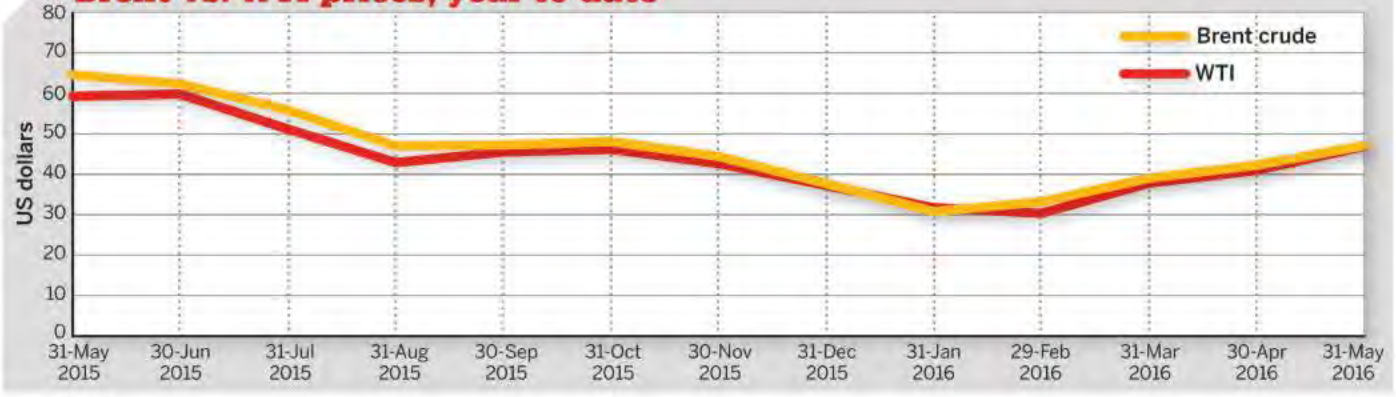
By the end of 2017, it is not unrealistic to anticipate that at least 20% of capacity will have been removed from the service sector through business failures. The percentage could be much higher. Operator failures could create a ripple effect, tipping other exploration and production, and service companies over the edge. Oil and gas is an industry of global strategic significance, but where is the government action to support it through the short-term?

Will things recover to where they were in 2013-2014? Probably not – the system was bloated and inefficient then. A correction had to come. For most service companies the focus is now on becoming as efficient as possible and keeping the bank happy.

The prize for surviving the downturn will be a wall of activity and opportunity – catching up on maintenance, repairs and modifications that have been put on hold, and at some point the exploration and production companies will all decide to push the go button at the same time. That can't come quickly enough. **OE**

***Colin Welsh** is head of international energy investment banking at Simmons & Company International, part of Piper Jaffray. He studied accountancy, economics and law at the University of Aberdeen and qualified as a Scottish Chartered Accountant with Ernst & Whinney (now EY).*

Brent vs. WTI prices, year to date



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Global E&P Briefs

A Statoil makes double discovery

Statoil has made oil discoveries at the Bay de Verde and Baccalieu prospects, in the Bay du Nord area offshore Newfoundland, Canada.

The discoveries are part of a 19-month exploration drilling program and helped reduce key reservoir uncertainties and confirm Statoil's original 300-600 MMbbl recoverable oil estimate, the firm said.

B Pemex offers Trion farm-out

Mexican state oil firm Pemex has offered its deepwater Trion field, near the US/Mexico maritime border, as its first farm-out.

Under Mexico's energy reform, farm-outs are an integral part of reforming Pemex and bringing in new investment.

Trion would likely be operated by a company other than Pemex, said Pemex CEO Jose Antonio Gonzalez Anaya. Possible partners will be announced after the deepwater bid round in December.

The Trion field, in the Perdido Fold area, contains about 480 MMbbl in 2500m (8202ft) water depth, and will require about US$11 billion worth of investment. More farm-outs are expected to follow.

C Another big Libra find

Petrobras made its seventh discovery inside the Libra block, in the pre-salt layer of the Santos basin.

Petrobras said the well encountered a 410m thick oil column and confirmed good-quality 27º API oil. The well, called 3-BRSA-1339A-RJS or, informally, NW2, is in the northeast section of the Libra block, 180km off Rio de Janeiro.

Drilling is underway at an eighth well, 3-RJS-743A, in the same area. The Libra Consortium comprises: Petrobras (40%), Shell (20%), Total (20%), CNPC (10%), and CNOOC (10%).

D Irish round awards 14 licenses

Fourteen new licensing options have been granted to 11 companies in Ireland's 2015 Atlantic Margin Licensing Round second phase. Of the 11 companies, there are nine operators: AzEire Petroleum (2 licenses); Capricorn Ireland (1); Europa Oil and Gas (4); Faroe Petroleum (1); Petrel Resources (2); Predator Oil and Gas (1); Providence Resources (1); Ratio Petroleum (1); and Scotia Oil and Gas (1). The two other companies are Theseus, partnering Predator; and Sosina Exploration, partnering Providence.

A total 28 licensing options have now been granted to companies in the 2015 round.

E Maria subsea templates installed

Wintershall's flagship development in Norway has reached a new milestone as the two giant subsea templates for the Maria field were installed.

The 285-tonne templates, each the size of a basketball court, sailed from Kristiansund in mid-Norway before being lowered onto the seabed on the Halten Terrace in the Norwegian Sea.

The templates were lifted onto Subsea 7's *Normand Oceanic* vessel, and traveled approximately 210km north, and installed on the Halten Terrace in the Norwegian Sea at 300m water depth. The planned production startup for Maria is in 2018.

The concept for the Maria field is to connect the reservoir to existing infrastructure via a subsea tieback – making the project smart and efficient in challenging times, according to Wintershall. Under the approved development solution, the tieback will involve connections to the Kristin, Heidrun and Åsgard B production platforms. Maria is German firm Wintershall's first development project on the Norwegian Continental Shelf.

F Oseberg Vestflanken 2 approved

Norway's Ministry of Petroleum and Energy has given Statoil's Norwegian North Sea Oseberg Vestflanken 2, or Westflank 2, the green light.

Using a remotely controlled 10-slot unmanned wellhead platform and two subsea wells, Statoil expects to tap some 110 MMboe.

The project is the first of three planned phases for developing the remaining reserves in the Oseberg area targeting the Alpha, Gamma, and Kappa oil and gas fields.

Oseberg Vestflanken 2 well stream will be routed to the Oseberg field via a new pipeline, with first production anticipated for Q2 2018. The wells will be drilled by the new category J jackup rig Askepott, which is currently under construction.

G COSL to survey Arctic

China's China Oilfield Services Ltd. (COSL) won a contract for 3D seismic acquisition covering over 4000sq km in Arctic waters. While the client and location

have not been made public, COSL said it plans to use its *Hai Yang Shi You 720* service vessel.

The up to 12-streamer configuration *Hai Yang Shi You 720* departed Kirkenes port, in the northeastern Norway, which leads out onto the Barents Sea, late April towing 4nm of seismic cable.

I Chariot expands in Morocco

UK-based Chariot Oil & Gas picked up 75% interest and operatorship in the Mohammedia Offshore Exploration Permits I-III, offshore Morocco in partnership with the Office National des Hydrocarbures et des Mines (25% interest).

The nearshore Mohammedia permits sit nearshore covers about 4600sq km in <500m water depth adjacent Chariot's Rabat Deep Offshore exploration permits.

Chariot said that the Mohammedia area, ober which it acquired 3D seismic data in 2014, contains a number of proven and potential play systems and various prospects with gross mean prospective resources for individual prospects ranging from 50-289 MMbbl, as audited by Netherland Sewell and Associates.

J Cooper exits Nabeul

Cooper Energy has exited the Nabeul Permit, offshore Tunisia, agreeing to pay along with its joint venture partners a compensation of US$3.2 million to fulfill its remaining permit obligations that previously included drilling a well.

Cooper Energy's share of the compenstaion amounts to $2.7 million.

The permit had been due to run through to 2021 and covered 3353sq km. Cooper still has stakes in the Hammamet (35% non-operated) and Bargou (30% operated) permits. The Hammamet permit is due to expire in September this year. Bargou runs through to 2021.

K MMIE open EG Ronda 2016

Equatorial Guinea's Ministry of Mines, Industry and Energy is offering 32 offshore blocks in the EG Ronda 2016 licensing round.

The acreage will include all remaining deepwater and ultra-deepwater blocks, including blocks A-12, which has hosted multiple oil discoveries, and the undrilled EG-05.

L Eni, BP hits big in Egypt

Italian explorer Eni and joint venture partner BP confirmed a new gas discovery in the Baltim South West exploration prospect in the East Nile Delta offshore Egypt.

The Baltim South West 1X well, about 10km north of the Nooros field in 25m water depth, encountered a ca. 120m of gross gas column, and 62m of net pay excellent quality sandstones.

Eni said it will also continue exploring the Great Nooros Area, which now

H Lukoil starts Caspian drilling

Lukoil began drilling operations at the Vladimir Filanovsky field in the Caspian Sea. The development well is being drilled from an ice-resistant fixed platform, LSP-1, with first production set for 2H 2016.

Filanovsky is 220km away from Astrakhan, Russia, in the northern part of the Caspian Sea, in water depths ranging from 7-11m. With recoverable reserves amount to 128 million ton of oil and over 41 Bcm of natural and associated gas, it is the largest of all fields discovered in Russia in the past 25 years.

Global E&P Briefs

holds an estimated 70-80 Bcm of gas in place, with the drilling of two additional wells.

Leviathan development plan approved

Noble Energy's development plan for the massive Leviathan field, offshore Israel, has been approved.

The development plan consists of a subsea system tied to a fixed offshore platform with tie-in onshore in northern Israel. The fixed platform's initial capacity is anticipated to start at 1.2 Bcf/d of natural gas and is expandable to 2.1 Bcf/d.

In addition to the approval, the Leviathan partners ahreed a US$2.5 billion gas sales and purchase agreement to supply up to 473 Bcf natural gas from Leviathan to IPM Beer Tuvia (IPM) for 18-years, or up to 72 MMcf/d. Leviathan is in the Levantine Basin, about 130km off Israel in 1600m water depth.

JV drills Sea of Okhotsk

A Rosneft and Statoil joint venture (JV) has begun drilling operations at the Ulberikanskaya-1 exploration well in the Sea of Okhotsk, using the *Nanhai-9* semisubmersible.

The well is about 420km from the port of Magadan in the Lisiansky license area. A second well will be also drilled this year within Magadan-1 section. Water depth at both drilling sites is less than 150m.

The JV also plans to acquire more than 26,000km of 2D seismic; more than 2000sq km of 3D seismic; 67,000sq km airborne geophysical surveys.

Inpex spuds Japanese well

Japan's Inpex is drilling an exploratory well in the Sea of Japan. The well is about 140km north of Yamaguchi Prefecture and about 130km northwest of Shimane Prefecture, in 210m water depth.

Last year, the firm said the objective of the project is to determine the presence of hydrocarbon deposits and conduct geological studies.

Santos plans sidetrack

Santos is drilling a sidetrack on the AAL-4X appraisal well offshore Indonesia after a mechanical obstruction in the wellbore halted proposed drill stem tests (DSTs) in the K-sand and G-sand reservoirs.

AAL-4X was drilled to a maximum total depth of 1246m in May, using PT Apexindo's Raniworo jackup. The well is in the Northwest Natuna permit area and includes the Ande Ande Lumut (AAL) oil project

Quadrant to spud Roc-2

Quadrant Energy due to start drilling the Roc-2 appraisal well on the Roc field early July usign Diamond Offshore's *Ocean Monarch* rig. The Roc-2 appraisal well is in the WA-437-P exploration permit in the North West Shelf of Australia.

It will be drilled to a depth of 5250m with capacity to extend to 5700m if justified. ■

Contracts

Siemens works UK windfarm

Siemens is to supply, install, and commission 102 type SWT-7.0-154, 7 MW wind turbines, for ScottishPower Renewables' 714 MW East Anglia ONE project.

Siemens will be responsible for servicing the wind farm for an initial period of five years, and has also been awarded a long-term service agreement which includes remote monitoring and diagnostics services.

The 300sq km East Anglia ONE wind park will be built 45km off East Anglia, England. The first wind turbines are due to be installed in the summer 2019, with startup scheduled for 2020.

Technip bags Libya work

Technip has been awarded contract to develop the Bahr Essalam, Phase II development in the central Mediterranean Sea, offshore Libya.

The natural gas field development will be tied back to the Sabratha platform, about 110km off Libya coast in about 190m water depth.

The scope of work will see Technip perform design, detailed engineering and deliver the project management, as well as procurement, installation, tie-ins, pre-commissioning and commissioning.

Technip will also deliver a gas gathering system, comprising production pipelines, subsea isolation valve, and umbilicals, and carry out diving and installation campaigns. The project also includes modifications to the Sabratha platform topsides.

Offshore installation is scheduled for 2H 2017 through to 2H 2018, and will involve several vessels, including *Deep Energy pipelay vessel, Deep Arctic* diving support vessel, and *G1200* S-lay vessel.

Aker gets Zohr gig

Aker Solutions will supply the umbilicals system for the Zohr gas field offshore northern Egypt.

The agreement with Petrobel, a joint venture between The Egyptian General Petroleum Corp. and Eni, is worth more than US$120 million (NOK 1 billion) and covers the delivery of 180km of steel tube umbilicals to connect the Zohr subsea development to an offshore control platform.

The work will be led by Aker Solutions' subsea division in Oslo and manufacturing will start immediately at the umbilicals plant in Moss, Norway. The umbilicals system will be delivered by mid-April 2017.

Boa bags GoM gig

Boa won a contract for light construction, heavy lift and possible umbilical lay operations and installations in the Gulf of Mexico for up to five months, including mobilization and options from Technip USA.

The project will utilize the offshore construction vessel *Boa Sub C*, including its 400-tonne active heave compensated main crane supported by the 30-tonne active heave compensated crane, both its OI Millennium work class ROVs and its 2500-tonne carousel. BOA will also provide project and construction crew.

Boa Sub C will start mobilization in direct continuation from completion of ongoing project in West Africa. ■

surgical precision

Allseas

Building blocks

Audrey Leon profiles Block Island Wind Farm, which is destined to be the US's first offshore wind project when it starts up later this year.

Block Island wasn't meant to be first. Once upon a time, a project called Cape Wind, offshore Massachusetts on the US east coast, was supposed to take that honor. But, as luck would have it, several issues would take the proverbial wind out of the Cape Wind project's sails, leaving Block Island the new frontrunner.

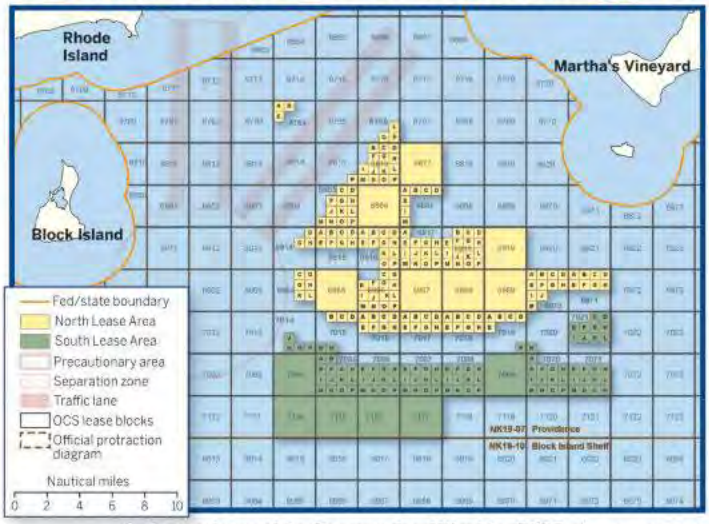
While Cape Wind's developers were securing a two-year suspension of operations for its works last July, Rhode Island-based developer Deepwater Wind was installing the first foundations for the Block Island Wind Farm, just months after securing financing for its US$290 million project.

Once complete, Block Island, 3nm offshore Rhode Island, will have 30MW capacity, made up of five Haliade 150 6MW offshore wind turbines. The turbines, which are twice the height of the Statue of Liberty with blade tips towering 600ft above the water, will be provided by Alstom, which was acquired by GE in late 2015.

For GE, the Block Island Wind Farm is an important test of its Alstom acquisition as GE attempts to move into the US wind power market, and pose a challenge to rival Siemens. "Today, offshore wind is a small market with big potential, and the Block Island project sits at the leading edge of innovation," said Anders Soe Jensen, CEO of GE's offshore wind unit, in November 2015. At the time, GE called the potential for US offshore wind energy "massive" – around over 4000 GW – which according to the US Department of Energy is more than four times the US' annual electricity production.

Jacket foundations, built by Gulf Island Fabrication, were installed in 2015.
Photo from Deepwater Wind.

North and South Lease Areas within the Rhode Island and Massachusetts Wind Energy Area



Acreage leased to Deepwater Wind in 2013. Map from BOEM.

The project has had the backing of the US Department of the Interior (DOI). On 27 July last year, when the *Weeks 533* crane barge lowered a 400-ton steel jacket foundation in 100ft of water, a "first steel in water" ceremony held. This event brought out US Secretary of the DOI Sally Jewell, Bureau of Ocean Energy Management Director Abigail Ross Hopper, Rhode Island Governor Gina M. Raimondo to support the project.

"Interior is proud to be a partner in this historic milestone for offshore renewable energy," Secretary Jewell said last July. "Deepwater Wind and Rhode Island officials have demonstrated what can be accomplished through a forward-looking vision and good working partnerships. Block Island Wind Farm will not only tap into the enormous power of the Atlantic's coastal winds to provide reliable, affordable and clean energy to Rhode Islanders, but will also serve as a beacon for America's sustainable energy future."

Indeed, the DOI continues to highlight renewable energy and sees Block Island as a model for future projects. According to agency's Economic Report for Fiscal Year 2015, released in June, the DOI blocked off $97.3 million for clean energy programs in 2015, with a slice of that for offshore wind. "Over

the summer of 2015, Interior's offshore wind energy leasing efforts led to beginning construction of the nation's first offshore wind farm. This first-of-its-kind project provides a model for the future development of offshore wind energy in America," the US agency said in June.

But, while Block Island is set to become the US' first operational offshore wind project, it's a global project with components from all over the world. The turbine blades were produced in Lunderskov, Denmark, then shipped to Aviles, Spain, where the tower sections were produced. The generator and nacelle were produced in St. Nazaire, France, and the bottom sections will be completed in Rhode Island. Houston-headquartered Gulf Island Fabrication carried out fabrication work on the project's five steel jacket foundations at the firm's Houma, Louisiana facility. Rhode Island's Specialty Diving Services conducted additional fabrication work on components for the foundation substructures at Quonset, Rhode Island.

Offshore installation progressed rapidly, with all five steel jacket foundations installed at the site by late November 2015. According to the developers, construction crews installed the last deck platform on 21 November. Deepwater Wind said about 200 workers and a dozen construction and transport barges, had taken part in the installation campaign over an 18-week period (July-November). Fred. Olsen's Windcarrier's *Bold Tern*, a self-propelled jackup, which was contracted by Deepwater Wind in 2014, assisted with installation activities.

Deepwater Wind began the work to install submarine cables in spring 2016. Spooling of the 20mi-long cable, which was made in South Korea, began in early April. The installation was expected to complete by July.

Also in April, Deepwater Wind helped christen the newbuild *Atlantic Pioneer*, which will be used to support construction and operation of the wind farm. In May, Deepwater Wind said the vessel helped transport workers, who are tasked with pulling-in the submarine cable, to the first foundation on the site.

The firm will also get some assistance from Louisiana-based Offshore Marine Contractor's two liftboats *Michael Eymard* and *Lacie Eymard*, both of which arrived on-scene in Rhode Island in late April.

Deepwater Wind expects installation of the five offshore wind turbines to begin in summer 2016. To complete this work, a temporary manufacturing facility was established at the Port of Providence (Rhode Island) for the assembly of turbine components. It is expected to take six months to complete the installation of critical electrical, mechanical and safety equipment within the bottom tower sections. Once assembled at the yard, the turbines will measure 270ft high and weigh approximately 440-ton.

Installed on their jacket foundations, and standing at 589ft above sea level, the turbines will be among the tallest in the world, the DOI has said. The project is expected to power about 17,000 homes. The facility will provide electricity directly from the wind farm to Block Island. Because the island uses only 1MW of power in the off-season and 4MW in the summer peak season, the remaining 90% of the energy produced during the off season will be sent to other state customers via a 25mi bi-directional submerged transmission cable between Block Island and the Rhode Island mainland.

The wind farm will produce more than 100 million kilowatt hours of clean energy annually, according to DOI.

GE and DOI aren't the only ones championing the Block Island project. National Ocean Industries Association (NOIA) President Randall Luthi praised the project, and its use of typical oil and gas service providers for offshore renewables work, last July.

"It is gratifying that Deepwater Wind chose NOIA member company Gulf Island Fabrication for the off-site construction of the foundations for this project," he said at the time. "It is also fitting that a company best known for fabricating offshore oil and gas structures played a role in constructing this historic project.

"NOIA has long supported an all-of-the-above offshore energy strategy, and we look forward to seeing more partnerships between offshore renewable companies and offshore oil and gas companies made possible by the success of the Department of the Interior's offshore wind leasing program." **OE**

Top – An offshore Haliade near Ostende, Belgium. Photo: A. Bocquel, GE Renewable Energy.

Center – The jacket foundations being installed at the Block Island Wind Farm site. Photo from Deepwater Wind.

Bottom – Nacelle bodies for the Block Island wind farm. Photo: A. Bocquel, GE Renewable Energy.

FURTHER **READING**

See more coverage of US wind projects on page 34.

In-Depth

Strong tailwinds

Offshore wind is headed toward new highs, with the North Sea region serving as the backbone of the global market, says Douglas-Westwood's Celia Hayes.

The offshore wind industry was initially disrupted by a range of technological and financial issues. However, in recent years, activity in the market has ramped up considerably.

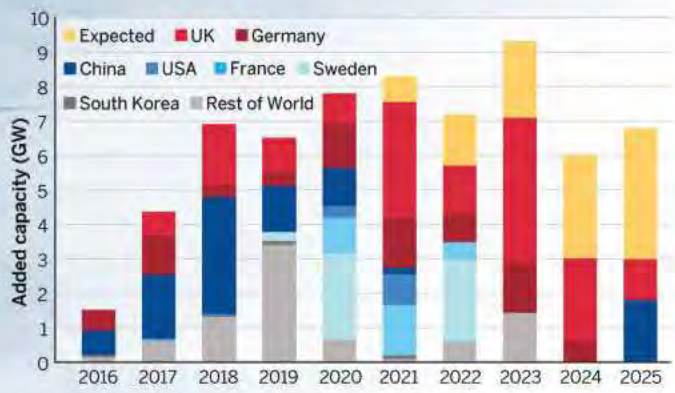
Renewables targets in Europe and factors such as energy supply security are driving further growth in renewables investment – realized in offshore wind projects throughout Western Europe.

Consequently, global capacity additions in 2015 doubled relative to 2014 – resulting in a record year for the offshore wind industry. In the past 12 months, the UK and Germany have added more than 3GW to the global market, which now stands at ~12GW of online capacity.

Although 2016 will be a quieter year in terms of additions, other facets of the market are developing this year: January saw the first instance of project decommissioning (Yttre-Stengrund, Sweden), onshore construction for the first commercial-scale floating windfarm (Hywind, Scotland) will begin and, towards the end of the year, the first commercial wind project will be commissioned in the US (Block Island, Rhode Island, see page 16).

The Block Island project will likely be closely watched as existing market players assess the potential of the US market. The prospective commissioning of Block Island has

Photo from iStock.



Global offshore wind capacity additions to 2025 ("Expected" additions represent a portion of currently conceptual projects to go ahead). Source: Douglas-Westwood, World Offshore Wind market Forecast 2016-2025.

re-invigorated interest in US offshore wind, previously dampened by attempts to develop the Cape Wind project.

There is a potential pipeline of over 17.5GW of additions planned for US waters, although the highly speculative nature of many of the proposed projects suggests that only a relatively small portion will likely be online by 2025. As a result, many of the existing offshore wind players will focus on growth in Asian markets and a strong European market – led by projects in the North Sea.

The North Sea is synonymous with the growth of the oil and gas industry in Western Europe. However, the region is rapidly developing a greener reputation as the backbone of the global offshore wind industry.

The majority of global activity over the next decade will take place in Western Europe, and in particular the North Sea region. The UK and Germany are expected to lead the charge, accounting for 46% of global additions to 2025 and contributing the majority towards 29GW expected to come online in the North Sea over the next decade – to which Belgium, the Netherlands, and Denmark will also contribute.

Meanwhile, the UK's round three megaprojects will begin

Quick stats

OE's at-a-glance guide to offshore hydrocarbon reserves and key offshore infrastructure globally is updated monthly using data from leading energy analysts Infield Systems (www.infield.com).

New discoveries announced

Depth range	2013	2014	2015	2016
Shallow (<500m)	73	72	55	5
Deep (500-1500m)	19	29	17	5
Ultradeep (>1500m)	34	13	12	4
Total	126	116	84	14
Start of 2016 date comparison	127	114	72	-
	-1	-	12	14

Note: Operators do not announce discovery dates at the time of discovery, so totals for previous years continue to change.

Reserves in the Golden Triangle

by water depth 2015-19

Water depth	Field numbers	Liquid reserves (mmbbl)	Gas reserves (bcf)
Brazil			
Shallow	9	34.50	333.28
Deep	13	1,316.00	1,695.00
Ultradeep	42	11,601.00	12,833.00
United States			
Shallow	9	66.60	152.00
Deep	20	918.36	1,231.57
Ultradeep	21	2,967.00	2,818.00
West Africa			
Shallow	114	3799.50	15,441.56
Deep	32	3457.50	5170.00
Ultradeep	10	1335.00	1000.00
Total	261	25,460.96	40,341.13
(last month)	(261)	(25,982.46)	(40,944.13)

Greenfield reserves

2015-19

Water depth	Field numbers	Liquid reserves (mmbbl)	Gas reserves (bcf)
Shallow	890	33,712.87	462,647.13
(last month)	(901)	(34,353.47)	(466,591.73)
Deep	132	7455.52	81,970.71
(last month)	(140)	(7871.52)	(89,755.71)
Ultradeep	79	16,191.40	41,748.00
(last month)	(84)	(16,448.90)	(42,190.00)
Total	1101	57,359.79	586,365.84

Pipelines

(operational and 2015 onwards)

	(km)	(last month)
<8in.		
Operational/ installed	41,457	(41,554)
Planned/ possible	24,400	(24,334)
	65,857	(65,888)
8-16in.		
Operational/ installed	82,961	(83,101)
Planned/ possible	48,031	(48,219)
	130,992	(131,320)
>16in.		
Operational/ installed	94,946	(95,079)
Planned/ possible	44,482	(44,423)
	139,428	(139,502)

Production systems worldwide

(operational and 2015 onwards)

Floaters		(last month)
Operational	270	(269)
Construction/ Conversion	49	(50)
Planned/possible	302	(299)
	621	(618)
Fixed platforms		
Operational	9155	(9189)
Construction/ Conversion	84	(75)
Planned/possible	1351	(1363)
	10,590	(10,627)
Subsea wells		
Operational	4863	(4888)
Develop	375	(382)
Planned/possible	6351	(6318)
	11,589	(11,588)

Global offshore reserves (mmboe) onstream by water depth

	2014	2015	2016	2017	2018	2019	2020
Shallow	14,559.00	20,490.00	37,492.63	16,056.29	15,154.32	22,229.82	24,438.65
(last month)	(14,559.00)	(20,484.04)	(37,569.64)	(15,791.01)	(15,666.57)	(22,746.47)	(24,934.07)
Deep	4474.00	955.55	5090.04	2685.57	3232.20	5783.88	5115.43
(last month)	(4474.00)	(955.55)	(5167.33)	(2685.57)	(3925.03)	(6173.22)	(5741.23)
Ultradeep	2343.00	1922.92	3141.08	3190.03	4437.08	4942.40	7841.37
(last month)	(2343.00)	(1922.92)	(3167.92)	(3190.03)	(4443.63)	(5440.92)	(7644.87)
Total	21,375.78	23,368.47	45,723.75	21,931.89	22,823.60	32,956.10	37,395.45

9 Jun 2016

Rig stats

Worldwide

Rig Type	Total Rigs	Contracted	Available	Utilization
Drillship	104	73	31	70%
Jackup	398	258	140	64%
Semisub	129	88	41	68%
Tenders	31	21	10	67%
Total	662	440	222	66%

North America

Rig Type	Total Rigs	Contracted	Available	Utilization
Drillship	31	27	4	87%
Jackup	23	6	17	26%
Semisub	14	10	4	71%
Tenders	N/A	N/A	N/A	N/A
Total	68	43	25	63%

Asia Pacific

Rig Type	Total Rigs	Contracted	Available	Utilization
Drillship	11	3	8	27%
Jackup	121	72	49	59%
Semisub	29	15	14	51%
Tenders	21	14	7	66%
Total	182	104	78	57%

Latin America

Rig Type	Total Rigs	Contracted	Available	Utilization
Drillship	29	22	7	75%
Jackup	52	36	16	69%
Semisub	26	22	4	84%
Tenders	2	2	0	100%
Total	109	82	27	75%

Northwest European Continental Shelf

Rig Type	Total Rigs	Contracted	Available	Utilization
Drillship	N/A	N/A	N/A	N/A
Jackup	47	38	9	80%
Semisub	40	32	8	80%
Tenders	N/A	N/A	N/A	N/A
Total	87	70	17	80%

Middle East & Caspian Sea

Rig Type	Total Rigs	Contracted	Available	Utilization
Drillship	1	0	1	0%
Jackup	111	86	25	77%
Semisub	4	3	1	75%
Tenders	N/A	N/A	N/A	N/A
Total	116	89	27	76%

Sub-Saharan Africa

Rig Type	Total Rigs	Contracted	Available	Utilization
Drillship	23	18	5	78%
Jackup	22	11	11	50%
Semisub	6	3	3	50%
Tenders	8	5	3	62%
Total	59	37	22	62%

Eastern Europe

Rig Type	Total Rigs	Contracted	Available	Utilization
Drillship	1	1	0	100%
Jackup	2	1	1	50%
Semisub	2	1	1	50%
Tenders	N/A	N/A	N/A	N/A
Total	5	3	2	60%

Source: InfieldRigs 13 June 2016

This data focuses on the marketed rig fleet and excludes assets that are under construction, retired, destroyed, deemed non-competitive or cold stacked.

construction in the next few years and are expected to contribute heavily to the UK's lead of the global offshore wind market over the next decade. Of the 11,700 turbines to be installed over the next 10 years (globally), 6800 will be installed in Europe – with the UK and Germany accounting for approximately 60% of installations.

It should be noted that these activity levels represent more for the industry than power to the grid, requiring a hike in local investment to reach full potential. The North Sea supply chain will need to develop quickly in order to cater for these projects – many manufacturers envision that without significant investment into new facilities, supply chain bottlenecks are likely.

Factors beyond supply chain development also threaten the strong global pipeline, including: installation challenges, health, safety and the environment, cost-overruns and policy changes, to name a few. Energy is always highly political and this is no different for offshore wind. Cooperative policy is not only key in ensuring a pipeline in established markets, but also the growth of offshore wind in emerging markets such as the US, France and Poland.

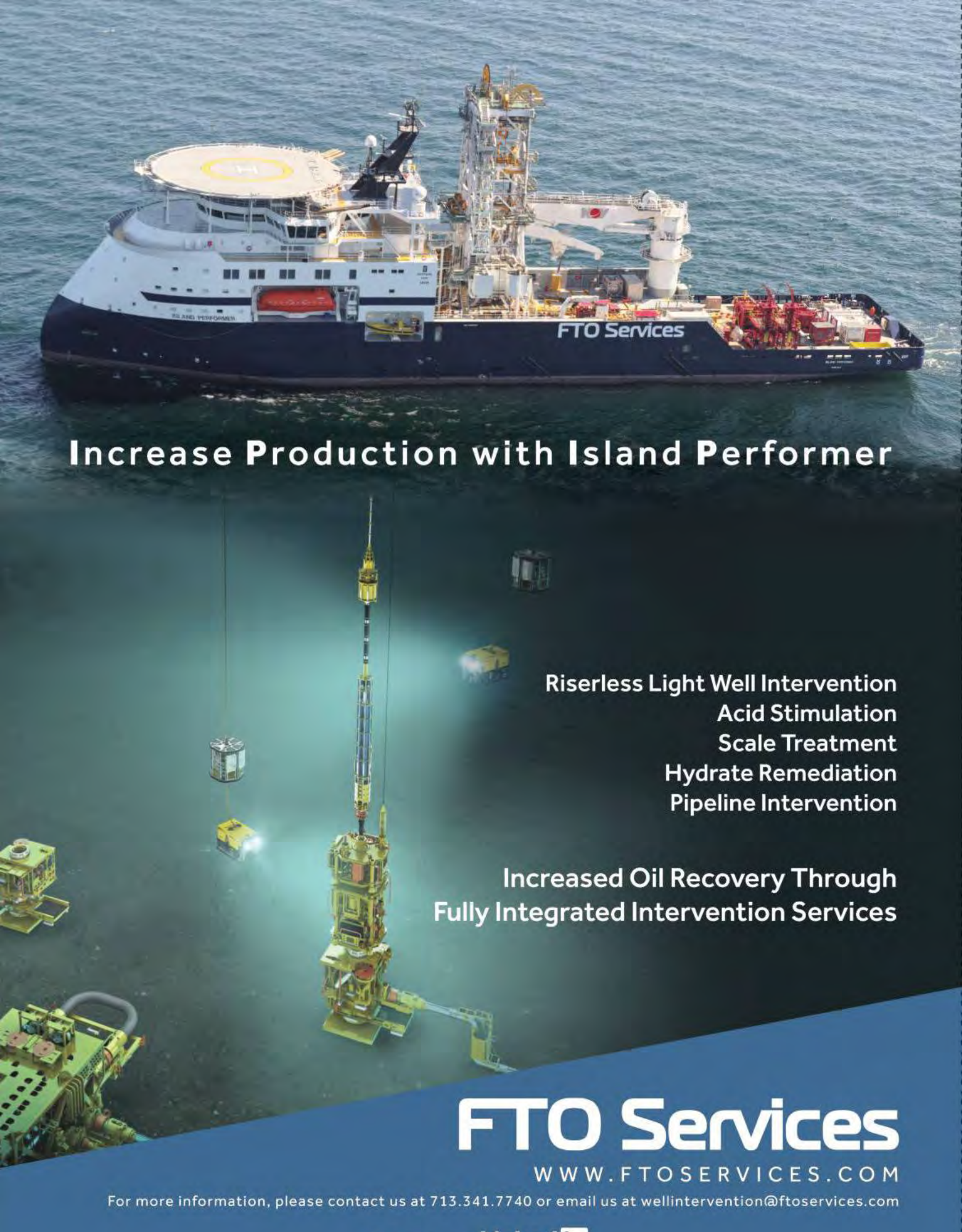
Notably, because of heavy political influence, the industry must eradicate a reliance on subsidy in order to ensure sustainability in the long-term. A prolonged period of cost reduction, innovation and investment will be required to maintain growth. Only with the above factors in mind (and amenable political conditions) will potentially strong markets like the US be better placed to develop on a scale equivalent to the North Sea.

Global activity to 2025 is forecast to reach new highs – capacity additions will peak at 9.3GW in 2023 and over US$222 billion (€200 billion) in capex will be spent over the next decade. The core of the global market will remain in the North Sea as UK and German activity levels are sustained – driving investment within the local supply chain.

To complement growth in Europe, the Asian market is also likely to develop quickly – chiefly through growth in the number of Chinese projects. Meanwhile, large potential markets will emerge, accounting for 14% of total capacity. Of these markets, the US holds large interest as Block Island is expected by many to kick-start development of a significant prospective pipeline. Nevertheless, Douglas-Westwood anticipates a moderate 1.4GW of capacity to come from the US by 2025.

The offshore wind industry faces many challenges, both local and global. However, through advancements in technology, ambitious renewables targets and ongoing cost-reduction, the industry will undoubtedly see significant growth over the next decade. **OE**

Celia Hayes *is a consultant in Douglas-Westwood's London office. Since joining DW, Celia has conducted high-level research on a variety of markets, with a focus on upstream oil and gas and renewables – aided by prior experience in extractive industries research for PwC. She is lead author of DW's recent Offshore Wind Market Forecast, covering market expectations and trends from 2016 to 2020. Hayes graduated from the Royal School of Mines, Imperial College London, with a Master's degree in Geology.*



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Tidal on the rise

Tidal energy is moving up a gear, with arrays becoming real and a supply chain being put to the test. But, there's still more to do. Elaine Maslin reports.

Tidal energy is making huge strides this year. The first commercial array is being built out in Scotland's Pentland Firth, between Orkney and the Scottish Mainland, by Atlantis Resources, meanwhile OpenHydro is building an array of its openhole devices off France.

Others are eyeing arrays, too, with floating devices starting to play a greater role, as well as concepts for platforms to house multiple original equipment manufacturer supplied turbines, showing the increasing confidence in turbine technology. Confidence in the technology is also helping to breed confidence in the supply chain, with various companies creating and designing bespoke vessels and tools to aid installation and maintenance.

But, for those not as commercially advanced as Atlantis (a stock market-listed outfit with backing from Morgan Stanley), creating a commercially attractive business is still tough, including for those looking to offer bespoke high-end vessels for the installation and maintenance market. Lessons are also being learned and cost savings sought as firms move into bigger projects.

And while the UK's Energy Technologies Institute predicts tidal energy could supply 20-100 TWh (terawatt hours) of the 350TWh of the UK's annual electricity demand, it says there's still some way to go before the technology could supply the 10-20GW it thinks the technology has the potential to supply.

An AR1500 being assembled at OREC. Photo from Atlantis Resources.

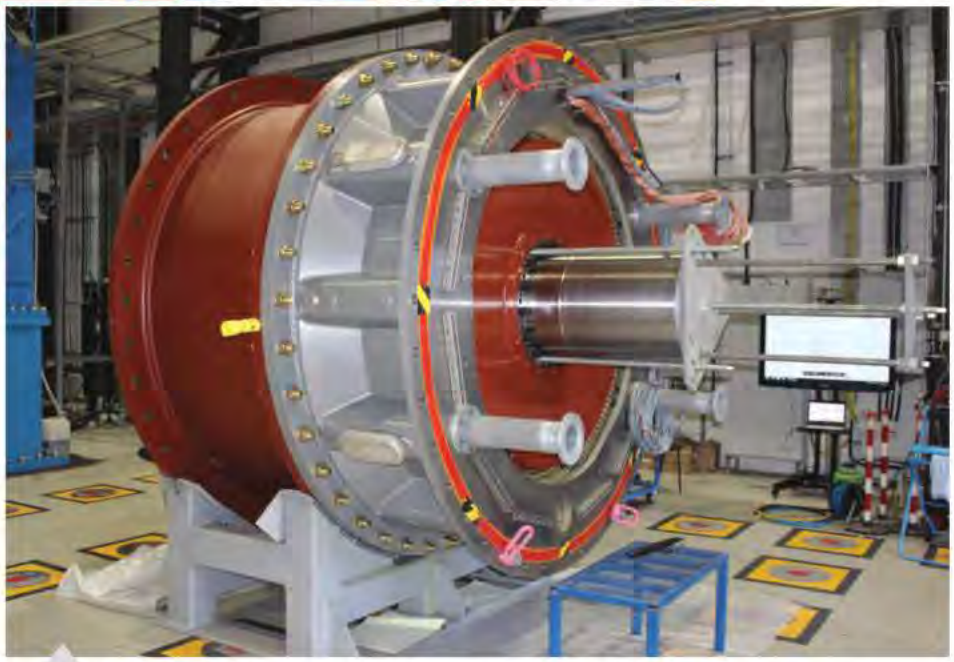
to be installed and grid connected by yearend. Lessons are being learned, the supply chain tested, and plans for the next phases of the project are being adjusted accordingly.

"The work we are now doing is around supply chain ability to deliver in time to correspond with financial close [on the next phase projects]," says Atlantis' CEO Tim Cornelius.

In Phase 1a, the four turbines, from two suppliers (1 x Atlantis AR1500 and three Andritz Hydro Hammerfest devices), each have their own gravity-based foundations. Some of the lessons learned on the project have been around the influence of turbulence on the design of the turbine support structure or foundation, which has driven a need for two different designs, says David Taaffe, project manager.

These structures are currently being built out at Nigg in Scotland. Some 16 of 24 ballast blocks had been manufactured by early May, each weighing 200-tonne, with six for each substructure. Installation is due in August, followed by turbine installation. The subsea power export cables are already laid.

To reduce costs, on the next phase, Phase 1b, Atlantis is looking at having two turbines per foundation, Taaffe told the All Energy conference and exhibition in Glasgow in May. Phase 1c could have up to 50 turbines installed. Other ways to reduce costs could be more standardization around the stabilization and yaw mechanisms, across the industry, Taaffe said.



An AR1500 generator and gearbox being assembled at OREC. Photo from Atlantis Resources.

Nothing is easy

Cardiff-based Tidal Energy Ltd has its eye on a 10MW array at St David's Head, in the Ramsay Sound, offshore Pembrokeshire, Wales, using its multiple turbine, gravity-based platform, called DeltaStream, which sway around to meet the tidal flow.

But first, the firm is testing a single device in the Ramsay Sound, a marine special area of conservation, to demonstrate the technology and assess its impact on the marine environment. One was finally installed in December last year, and is exporting power via a 1.2km subsea cable to shore, where it is conditioned before going into the grid.

"It's not been an easy path," says Martin Murphy, the firm's managing director, at All Energy. "One thing we have learned is that it is a long process. It needs stamina."

The fabrication contractor went into administration soon after fabrication started. Then, in 2015, a problem was found on the subsea cable, meaning that additional funding had to be found for repair work, which was carried out using the *Siem Daya I*, the same used by Atlantis on the MeyGen project.

The Ramsay Sound site has offered challenges around the nature of the tidal stream there, as well as installation processes and a tough business environment. One of the key issues in the Ramsay Sound is the difference in energy

This is because the levelized cost of energy (LCOE) for today's tidal energy converters is estimated to be in the range US$273-410 (£200-300)/ MWh compared to $176-226 (£129-166) for offshore wind projects. Which is why the focus has turned from proving the technology, to reducing the costs. The next hurdle will then be scaling up.

Leading the pack

The first 6MW phase (Phase 1a) of what will potentially be a 398MW array is being built out now, with four generators due

between the ebb and flow regimes. Due to the nature of the seabed, the north flowing flow creates intense turbulence in the environment.

To help understand more about how the device operates and interacts with the environment, an acoustic monitoring platform is being installed, with active sonar (acoustic Doppler current profiler) measuring current speed and data fed to the Delta stream, then via fiber optic cable to shore. There are also passive hydrophones on the device itself.

See if it floats

Smaller outfit Scotrenewables is making strides, too. Its 2MW, 550-tonne SR2000 device, which it describes as the world's largest tidal device, was launched in May at Harland & Wolff in Belfast, and is due to be taken to Orkney for a grid-connected test program.

The SR2000 is a floating structure, from which two 1MW turbines are suspended. This means it is nearer to the higher flowrates and away from turbulence on the seabed, says CEO Andrew Scott, as well as having reduced volumes of steel. It can be towed and installed on pre-installed seabed anchors and moorings using a 30-50-tonne bollard pull anchor handler without getting men in the water or on the device, he says. Maintenance is from a non-DP multicat vessel, like those used in the offshore wind industry, Scott says.

Delivery of the SR2000 may have taken slightly longer than planned, however. For Scotrenewables, lessons learned have been around resourcing, Scott told All Energy. "Hard lessons were learned around resourcing. While we have experience and knowledge, there was a shortfall around construction and execution skills and this is a common feature across marine renewables and is a vital learning curve."

More work also needs to be done around power take off optimization, Scott says. This is an area the wider industry is also focusing on (*see panel on page 30*). Scotrenewables is also looking to go to medium voltage systems to reduce the amount of onboard equipment, he says.

Pontoon platform

A floating, multi-turbine platform is also Cowes and Orkney based Sustainable Marine Energy's (SME) approach. The firm's Plat-O platform, comprising three connected semisubmersible "pontoons," is held beneath the sea surface. Turbines are mounted from the connections between the buoyant structures. The central pontoon contains the controls systems, etc., while the outer pontoons offer buoyancy.

The firm was recently awarded $6.15 million (£4.5 million) funding to help it start building out an array of Plat-O devices at EMEC, Orkney. A first device is due to be installed this summer, followed by a larger, 240kW, platform with Schottel Hydro Instream Turbines (SIT 250), production of which is due to start this summer, also in Scotland. Up to five will be installed. SME recently placed an order in for 16 Schottel tidal turbines, as part of its work.

Christoph Harwood, commercial director, SME, says that the design means vessels with lifting capability are not needed – multicat vessels can tow the devices out for installation

2 x Scotrenewables SR2000 being launched in May. Photos from Scotrenewables.

and a winch-based pull down systems moves the devices into their moored position.

After looking at gravity anchoring, SME developed a helical anchoring method, effectively creating rawl plugs in the rocky seabed at EMEC, deployed off a multicat vessel using an ROV. It was first trialed in Q1 2016 and results revealed at All Energy.

Openhole goal

One of the earliest tidal units in the water was OpenHydro's so-called openhole technology. The latest seafloor mounted (a gravity foundation made by pumping tubular steel frames full of concrete) 2MW, 16m-diameter unit weighs 300-tonne.

OpenHydro is working on the Cape Sharpe Tidal project, a joint venture with Emera Energy and OpenHydro in the Bay of Fundy, Nova Scotia, with two 16m diameter, 2MW machines being deployed this year. The export cables, connectors etc., were already installed. Another two machines are being built for the EDF Palpol Brehat project in France, which already has two installed. This 8MW project will help pave the way for the 14MW Normandie Hydro project, also off France, which will see seven tidal turbines in the Raz Blanchard by 2018. With these projects, as well as a plan for a 200MW project in the Pentland Firth and others, OpenHydro has some 900MW of projects in the pipeline, says James Ives the firm's CEO. Add other prospects the firm is looking at and the number increases to 2GW, he says.

OpenHydro developed its own deployment barge system for installation and maintenance. It takes just hours to deploy a machine, Ives says, with commissioning from the barge.

For OpenHydro, the latest testing has been less around the turbine and more about electronics testing, controls systems and optimizing power output from the turbines, Ives told the European Ocean Energy Conference in Edinburgh earlier this year.

OpenHydro's device being launched off France this year.
Photo from DCNS.

Reduce costs or scale up?

Despite the advances in the sector, arguments remain on the best way forward.

"Unless tidal energy can compete with offshore wind on profitability, it seems obvious they will fail to get interest in finance," says Peter Fraenkel, co-founder of Marine Current Turbines, a firm credited with helping get the tidal industry off the ground, and now a consultant.

"Wind turbines have grown [in size] because the only way to improve their performance is increasing the rotor swept area, which has grown by a factor of over 100. Costs are a quarter of what they were in 1980 in real terms.

"Today no one considers anything less than 5MW offshore," he says. "Tidal started scaling up but stopped in 2008. We cannot continue starting small and not scaling up or we will fail. The main message is that costs are not the biggest answer, low costs devices not much use if they are not profitable."

Fraenkel is involved in a new design, Super SeaGen, which is focused on having a large rotor space. It is a floating device with multiple turbines suspended off it, which can be lifted out of the water.

Jason Hayman, SME's CEO believes tidal needs has to go the way of fish farming, "using smaller vessels and local skills at a decent cost base."

"Sometimes we get caught up in the scale thing too much," Hayman adds. "We want to get the costs out, understand the mechanics and when we understand it, scale up.

"It's a common misconception we will drive the levelized cost of energy down with scale," he continues. "It contributes, but it's about how many times you do something. "They used to say we need DP. But, it is about process and learning and making things a lot cheaper."

However, Hayman says the problem is not related to the technology. "The problem," he says, "Is with the financial engineering and right level of government support to enable industry to stand on its own two feet."

Marine Current Turbines founder, Fraenkel, added a word of caution. "There is also a danger of over-egging the problems." **OE**

Harnessing heave

The wave energy sector has always provided something of a more mixed bag of concepts than the tidal sector. Elaine Maslin looks at some of them.

While there's been a lot of depression in the wave energy in the sector in the recent past, following two well-known players, Pelamis and Aquamarine Power, based in Scotland, falling into administration, the prospect of more arrays being built out, even at demonstrator level, is bringing some confidence back to the industry.

"It has been a difficult couple of years for wave energy, but to some extent I see a sense of confidence coming back," said Johnny Gowdy, who works for RegenSW, an independent market insight and advisory firm, at the All Energy conference in Glasgow in May. "Momentum is building back up with kit getting back in the water in the UK and around the world, and supply chain companies willing to invest."

Indeed, as he spoke, Seatricity was installing its latest Oceanus 2 device in the water at Wave Hub, off Cornwall, England. The firm is looking to build out a 10MW array there. Wello, a Finnish firm, was also working to get its Penguin device back in the water, at the Wave Hub test site off Cornwall, and it has started building a second unit, with a third planned. Across in Nova Scotia, Cape Sharp Tidal was due to install two, 2MW OpenHydro turbines at the Fundy Ocean Research Center for Energy in June. So-called second generation developers are also fast catching up with new ideas on ways to do things better.

Yet, there's still some way to go before the industry will reach a level of commerciality, said Adam Norris, founder and chairman of Wavepower, and chairman of a session at the European Ocean Energy Conference (EOEC) in Edinburgh earlier this year.

"The wind industry only really started in the 1980s and it took a while before it got commercial," he said. "Even though these are the early pioneers, they are giving us hope the industry can move at a pace. But it will be some time until it is fully commercial."

Carnegie Wave Energy

Carnegie Wave Energy has a number of projects planned, using its latest 1MW Ceto 6, sixth generation, 20m diameter unit, including integrated microgrids. The first Ceto 6 is due to be in construction this year, with commissioning due in 2017, for the fully funded Garden Island project offshore Australia. The next project is what could become a 10MW array offshore Cornwall. Carnegie's design is a point absorber.

A Ceto array. Image from Carnegie Wave Energy.

The Perth wave energy project. Photo from Carnegie Wave Energy.

using a submerged buoy, or actuator, 1-2m below the surface, which transfers ocean movement to a piston, fixed to the seafloor, to create hydraulic energy, which is converted into electricity, as well as desalinated water, using pressure to drive a desalination plant.

Its Ceto 5 unit, in a three, 240kW unit array off Perth, Australia, has seen 14,000 operating hours, with power generation onshore, plus water desalination. It was loaded up with some 400 sensors gathering more than 2.5 GB of data daily to aid optimization of the Ceto 6. On the Ceto 5, installation times were cut, from three days to 11 hours, port to port.

The Ceto 6 design moves the design on a step further with, unlike Ceto 5, more advanced controls and the power generation systems inside the buoy, for power generation offshore, reducing hydraulic line losses. Multiple devices are due to be installed at Garden Island, but it's not clear how many. Carnegie describes the Garden Island project as being the first renewable integrated microgrid, providing power and water needs. As part of its goals in this area, Carnegie recently acquired a 35% stake in Energy Made Clean, a Perth, Australia-based electric engineering firm.

Another Ceto 6 project is planned at the Wave Hub site offshore Cornwall, where Carnegie has permission to build an up to 10MW Ceto project. Finance is progressing on this project and the firm aims to start construction in 2017, with operations offshore in 2018. Further down the road, Carnegie is also looking at projects offshore Ireland, Chile, and Canada.

Tim Sawyer, CEO, Carnegie Wave Energy, says Ceto 6 is a larger unit. "The focus is on scale and also yield and getting costs down." Ongoing research is also being carried out at the University of Western Australia, looking at foundation design and loads and optimal number, size and arrangement of an array, and location of wave energy converters (WEC).

"It's a long process iterating and progressing the technology so it is survivable and affordable," Sawyer says. "But, the next deployment will be a step change."

CorPower

Swedish firm CorPower Ocean, one of the new generation of firms, also uses buoy technology, to absorb energy from the surge and heave of waves with its HiWave resonant WEC. But, it has sought to get out more with less using phase control, to enable it to oscillate in resonance with incoming waves. It does this using a pneumatic pre-tensioning system between the buoy and mooring system, to allow a higher rate of oscillation, as well as its WaveSpring technology, contained

My WEC for a PTO

Coming up with wave energy concepts has not been a problem in this nascent industry. Creating power take off (PTO) systems for wave energy appears to have been less easy.

As a result, the University of Edinburgh is leading a project to develop an all electrical drive train for marine energy converters, as part of a project dubbed Edrive-Mec.

Meanwhile, Wave Energy Scotland, set up in the wake of key Scottish wave energy developers Pelamis and Aquamarine Power going out of business, has also been seeking new PTO solutions.

Wave Energy Scotland's work saw it run two PTO programs last year, run in stages, from early stage feasibility to prototype demonstration. Ten feasibility studies were looked at, six concept developments and one prototype demonstration.

The early feasibility studies included hybrid electro-hydraulic power PTO systems, a power electronic controlled magnet gear, from Ecosse Subsea, a direct drive contra-rotating generator, and a direct contact dielectric elastomer PTO from the University of Bologna, Tim Hurst, CEO, Wave Energy Scotland, told All Energy in Glasgow.

Phase 2 projects include a hybrid digital displacement hydraulic PTO, using a digital displacement pump-motor and a reciprocating ball screw generator. Another concept, HiDrive, which is a direct drive PTO, is also being considered.

The difficulty around wave energy PTO is that generally a PTO and power conditioning system is needed to convert motion in multiple directions, as well as react to large forces or torques, while operating at low velocity, variable voltage and frequency, and with high reliability, availability and efficiency over a wide range of loads.

The two main options are hydraulics and direct drive and because of the difficulty outlined above, many have opted for hydraulics, either through high pressure oil or water, aided by the fact it's also available off the shelf, despite limitations around low efficiency at part load, ability to control it over a wide range of frequencies and possible displacement leading to end-stop problems.

The Edrive-Mec project was launched in April 2016 and is due to run through to March 2019. ▪

CorPower's cascade gear unit. Image from CorPower Ocean.

CorPower's WaveSpring invention.

A CorPower device.

The CorPower test rig.

within the buoy, which amplifies the motion created.

WaveSpring is a negative spring arrangement that widens the response bandwidth of point absorbers without needing real-time wave information or predication algorithms, avoiding losses associated with transmitting large reciprocating energy flows through the power take off system, the firm says.

This linear motion is then to be turned into high speed rotation energy using a compact cascade gear unit. The mechanical energy generated is transferred via flywheels to electricity using small generators. In a storm environment, the phase control can be detuned to make the device "transparent."

A full scale device, with a composite hull, is about 8m in diameter, and weighs about 60-70-tonne. While each would produces about 250-300kW, CorPower's concept is that the devices would be deployed in farms of 20-1000 units, to create 10-240MW farms, reducing costs through mass manufacturing and a maintenance scheme based on replacement of entire units.

"We think this is a good combination of robustness and simplicity," Patrik Moller, CEO, told the EOEC. The system has been built and modeled at scale and now the firm is working with partners, Iberdrola, EMEC, Norwegian University of Science and Technology at Trondheim, and others, to put a full scale device in the water at Scapa Flow at EMEC. It is under construction at the moment, with dry rig testing, using hardline in the loop, due in Stockholm, before deployment in February to mid-2017.

Albatern

Albatern is another second generation developer. The Scottish company has developed WaveNET, which uses an array of "Squid" generating devices, interconnected in a net type arrangement, which couples into a mooring system, to capture energy from the ocean surface.

The array comprises buoyancy Squid modules, each with three arms, which can link with other Squids. The Squid modules and their linking arms contain pumping modules, connected to a ballast riser, which is a node for a number of Squid units. Motion is converted to rotational movement by the pumping modules. Rotational movement is then converted to hydraulic energy through a geared hydraulic cylinder. A common hydrostatic transmission system collects the power from the pumping modules and feeds multiple power take off modules, converting the hydraulic power into electricity, which is combined before transmission to shore.

The net – which Albatern says is modular and so easy to transport and install – can be shaped to suit wave patterns, such as a wide net for low density sites, or deeper (longer) arrays for longer waves. David Campbell, commercial director, told EOEC that the notion is based on having a planar area with junctions so it is able to move.

In 2013, three 7.5kW WaveNET Series-6 Squid units were

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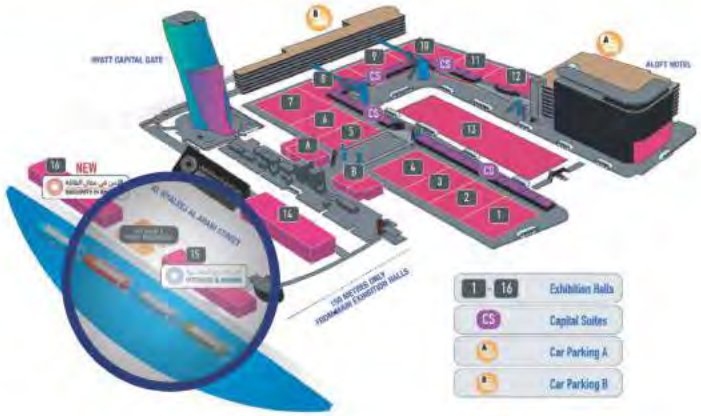

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deployed for testing at Kishorn, Scotland, to provide power for a Marine Harvest salmon farm off the Isle of Muck. A six-unit deployment was carried out from August to early November 2015.

Another project is planned for the deployment of a six-unit project, for 18 months, in up 20m water depth with 0.3-6m wave height off Ardnamurchan, Scotland, using Series-12 units, at 75kW. Power from the deployment is also due to be used to power a fish farm site. The next step will be grid-scale Series-24 WaveNet arrays, with 750kW units, which could be turned into 100MW arrays by 2024, Albatern says.

WaveRoller

Finnish firm AW Energy's WaveRoller is a nearshore, shallow water wave energy device, based on a composite panel, or flap, which is moved by the motion of the waves, driving hydraulic piston pumps in a closed hydraulic circuit, feeding a hydraulic motor unit.

Breaking waves

Danish firm Wavestar has a fixed installation wave energy concept, which could also incorporate wind turbines and even solar power, says CEO Laurent Marquis.

The core concept involves a row of half submerged buoys or floats, attached to a fixed platform. The floats rise and fall with the waves, producing energy via hydraulics into a generator. When the waves are too strong, the floats are lifted out of the water.

The Wavestar concept was invented by sailing enthusiasts Niels and Keld Hansen. In 2009, a half scale 600kW machine, using two 5m-diameter floats, was installed and then grid connected in 2010. Over four years, it produced 45.4 MW of energy, with 88% uptime, according to the firm.

The company has formed an industrial consortium for commercial testing of its first full scale 1MW Wavestar, including STX in France and JDN, to make the machine.

Marquis told the European Ocean Energy Conference in Edinburgh earlier this year that some €40 million (US$45 million) has been invested to get the company to where it is today. "We believe we need to invest the same amount again, if not more, to be commercial," he says.

The company has been through a learning curve. "[We] broke floats in the beginning," Marquis says. "There were failures due to failings in structure. Cracks in welding. The lifting system to take the system out of the water, a rolling screw, issues with that. [There was a] small fire in the machine because of electrics overheating. After all these failures, we found solutions to prevent it from happening again. Now we want to build bigger, with 20 floats," he says. "The complexity increases as it gets bigger. Twenty floats means more hydraulic oil, more control systems. There is a focus on improving performance and decreasing cost by optimizing the structure."

A new hydraulic power take off system has been developed by Wavestar and Aalborg University for this unit, using four generators at 160kW and two at 200kW, to support variable capacity, with an optimized control system. A jackup structure is also planned to be used for sites with high tidal range.

The company aims to produce a full scale, 1MW using a C6-1000 device, by 2019 at Belgian site owned by Parkwind, with commercial units by 2022. The family behind the Danfoss brand is a main shareholder in the company. ▪

The design, a 3x100kW demonstrator of which was installed off Portugal in 2012-14, comes from Finnish diver Rauno Kolvusaari, who saw a plate moving on a shipwreck and thought the movement could be harnessed. Earlier this year, the firm's latest power take off solution, for a 350kW commercial device, passed a six-month trial at WaveRoller's test center in Finland ahead of being shipped for trials offshore Portugal, where AW holds a 1MW lease site.

Tuula Maki, R&D manager, told EOEC the unit can be deployed using a barge, with seawater ballast to the take it to the sea floor. Scale testing has been carried out on the device and the latest is rated at 500-1000kW with 25-50% capacity. The firm has had performance validation by DNV GL and also has a technology certificate by Lloyd's Register.

Mermaid Power

Vancouver, Canada-based Mermaid Power also has a nearshore device, but in the form of a 100kW point absorber. Unlike others, however, the 3500kg point absorber, or motive float as Mermaid calls it, and power take off are housed in an accessible, 9m-wide, 7m-high, 12,000kg geodesic style dome supported on four semisubmersible buoys.

The dome constrains the point absorber to move vertically and supports the power take off equipment, described as a patented reciprocating to rotation motion converter, which delivers power to the electrical generator from up and down strokes, above the water.

The latest version of the device, the 25kW Neptune 3, was moored at Keats Island, Vancouver, in November last year. A Neptune 4 is being designed and Mermaid is looking for a site to test it.

China

These are just some examples of the many projects ongoing. And while much of the focus has been around Europe and Canada, Chinese firms have not been idle.

Dengwen Xia, vice director at China's National Ocean Technology Center, outlined at EOEC a host of technologies on which Chinese firms are working; although some may look similar to some European technologies. Since 2005, more than 20 small scale prototype WECs have been developed and completed, he says, including 50kW flap style devices, oscillating water columns and point absorbers, with offshore tests in Guangdong, Zejiang and Shangdong.

The Chinese are looking to build devices that suit wave regimes there, which, he says, is different from areas, such as Europe. "We developed the different technologies to try to solve these issues that only the China Sea area has," he says, highlighting the Guangzhou Institute of Energy Conversion's (GIEC) Sharp Eagle Wanshan, which launched in 2015.

Sharpe Eagle Wanshan is a 36m-long, 24m-wide semi-submersible structure containing a wave energy device. Currently, the power capacity is 120kW, but this will be expanded, says GIEC. In addition, solar panels, wind turbines and desalination units could be installed on top of the device.

"In the next five years we will continue to improve WEC technology. We are hoping to use it for inhabited islands and offshore facilities such as deep sea fish farming, etc.," Dengwen Xia told EOEC. OE

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Embracing wind

While the US is only on the verge of bringing its first wind farm online, Audrey Leon surveys some of the prospects slated for the country's federal waters.

Unlike Europe, the US has been a bit slower to adopt renewables as part of the energy mix. According to the US Energy Information Administration, in 2015, renewable energy sources accounted for about 10% of total energy consumption and about 13% of electricity generation in the country. Petroleum and natural gas make up approximately 63% of total energy consumption.

In May of this year, the US Department of Energy announced three offshore wind projects that would be eligible to receive up to US$40 million each in additional funding.

DOE chose the Atlantic City Wind Farm, developed by Fishermen's Energy, offshore New Jersey; Lake Erie Energy Development's (LEEDCo) Icebreaker project, near Cleveland, Ohio; and the University of Maine's New England Aqua Ventus I project.

The 24MW Atlantic City Wind Farm will feature six 4MW Siemens turbines, about 3mi offshore Atlantic City, New Jersey, in approximately 12m water depth. The project will utilize a fixed bottom, "twisted jacket" foundation, or Inward Batter Guide Structure, from Keystone Engineering, which DOE says is easier to manufacture and install than

Offshore wind rebounds

Cape Wind is a 130 x 3.6MW turbine offshore wind park planned for off Cape Cod, Massachusetts. But, it has been struggling to get off the ground for some 15 years, says Stephanie McClellan, director, special initiative on offshore wind, University of Delaware.

"People generally associated US offshore wind with that project," she says, "That it cannot get off the ground. However, it can and will and is. Block Island [a wind farm off Rhode Island (see page 16)] started construction last year and will become operational in 2016. This will move us past the perception you cannot build offshore wind in the States," McClellan told the All Energy conference and exhibition in Glasgow in May.

Most of the activity is in the Bos-Wash, or Boston-Washington, corridor, McClellan says, and, thanks to policies in those areas, a market comprising some 3-5GW potential is expected to become available in the next year or so.

There areas for offshore wind parks tend to be 10-15mi offshore, McClellan says, with 8.5-9m/sec wind speed in 30-40m water depth.

It isn't simple. Federal government is responsible for leasing site, while individual states approve power contracts. But it is happening.

New York state and Massachusetts in particular are taking the initiative in offshore wind. Massachusetts has set a policy goal of 50% renewables for the entire electricity load of the state by 2030, McClellan says. "They have acknowledged they cannot do this without offshore wind," she says. Indeed, the most prominent move towards offshore wind is being made in the Bay State, Massachusetts, McClellan says.

Last January, an leasing round was held with Denmark's DONG Energy and OffshoreMW (which is the US sister company of Germany's WindMW) – both of which have already built wind parks in Europe – as well as US firm Deepwater Wind taking leases.

Meanwhile, New York City's Mayor Bill de Blasio wants 100% of city government electricity from renewable electricity by 2050, and it has been accepted this will not be possible without offshore wind. To put the goal into perspective, New York City's government uses more electricity than the whole state of Delaware, McClellan says. ■

– By Elaine Maslin.

LEEDCo's mono bucket foundation. Photo from DOE.

Keystone Engineering's "twisted jacket" foundation to be used on the Atlantic City Wind Farm.

The twisted jacket foundation upright. Photos from Keystone Engineering.

traditional foundations.

"During operation, the Fishermen's project will act as an at-sea laboratory to further our knowledge about offshore wind, investigate the interactions between turbines, test new control systems, and provide information about potential environmental impacts of offshore wind while reducing the levelized cost of energy from offshore wind," says DOE.

The Lake Erie project, developed by LEEDCo, will see six 3.45MW direct-drive turbines installed on mono bucket foundations (a design which takes elements of gravity-based structures, monopiles and suction buckets) approximately 7mi off the coast of Cleveland, Ohio, in Lake Erie.

The mono bucket foundation was selected through significant engineering analysis, DOE says, and is expected to reduce installation time, costs, and environmental impacts compared to traditional foundations that require pile driving.

The third project championed by DOE is the University of Maine's. This involves a pilot floating offshore wind farm with two 6MW direct-drive turbines on semisubmersible foundations at a test site off of Monhegan Island, Maine. DOE says due to the project's deeper water depths traditional foundations are not practicable. The university will instead develop a new floating platform called VolturnUS.

According to the University of Maine, the VolturnUS design uses a concrete semisubmersible floating hull and a tower made from composite materials designed to reduce both capital, operation and maintenance costs, and to allow local manufacturing.

Denmark takes US interest

In February, Denmark's DONG Energy said it would take over an offshore New Jersey wind lease previously held by RES Americas Developments. The New Jersey lease encompasses 160,480 acres, approximately 10nm offshore in 80ft of water. DONG said the area could potentially accommodate more than 1000MW of offshore wind.

"The US is an interesting market for offshore wind with the potential to become a significant area for future development," says Samuel Leupold, executive vice president of wind power, DONG Energy.

The New Jersey lease is the second US lease area for DONG Energy. The first was acquired in June 2015, offshore Massachusetts. That project, Bay State Wind, calls for the construction and operation of a utility scale offshore wind farm off the southern coast of Cape Cod with an installed capacity of up to 1000MW. With water depths between 130-165ft, this site sits approximately 15nm from shore. **OE**

Indian summer wind

In India, there are two main regions, the states of Gujarat and Tamil Nadu, on the west coast, which are most likely to see activity, says Mark Leybourne, senior engineer at IT Power Consulting to the All Energy conference and exhibition in Glasgow in May.

A consortium, led by the Global Wind Energy Council, called Facilitating Offshore Wind in India, or Fowind, has been running a project over a couple of years to assess these areas, with involvement from Norway's DNV GL.

However, one of the big areas of uncertainty is offshore wind speeds in these areas, Leybourne says. A Lidar, a type of survey technology, was supposed to be put in offshore Gujarat in the summer but now likely October due to the monsoon season.

Estimates put Gujarat's offshore wind speed at about 7m/sec, Leybourne says. A series of zones have been set out and a process of zonal consenting has been started. Zone A, an area covering 1700sq km off Pipavav Port, is likely to be like first pilot project in coming years. There are established ports and existing offshore oil and gas capability, he says.

"The first project is likely to be around 300MW," he says, showing the scale of the ambition. "We have been working with the government on the supply chain and how to roll it out."

Tamil Nadu, meanwhile, has higher wind resources. Measurements have shown 8-9m/sec. But, the waters are a lot deeper and there is a lack of grid and port facilities, Leybourne says. "The local government is also a little less forthcoming towards offshore wind and spending money," Leybourne says. Nevertheless, a Lidar is also due to be positioned offshore at the end of this year or later next.

Charles Yates, managing director, CmY Consultants, says the attraction of these areas are that it's an open playing field for international players. For their first projects, the states are keen to get established technologies, so the barriers to entry are low, he says. Offshore wind, in fact, could see a 26% compound annual growth rate, between 2016 and 2025, he says.

"In 2-3 years' time there will be open international tenders for two projects in Gujurat and Tamil Nadu where the government wants established players, with financing and technology expertise, to get involved," he told All Energy. "There aren't barriers to import kit, transformers etc. The key thing is for the first projects to work." ▪

– By Elaine Maslin

Leader of the pack

Photo from iStock.

The UK oil and gas industry is eyeing opportunities in the offshore wind industry, says the EIC's Will Sharkey.

The UK has developed a project portfolio of unrivalled offshore wind capacity. With over 5GW already in operation and installed capacity expected to double by 2020, the UK is considered the global leader in offshore wind development. As a result, UK oil and gas companies are increasingly turning their attention to the cross-sector supply chain opportunities offered by this growing industry.

Many of the technologies for offshore wind development have already been proven in the oil and gas industry. UK expertise in offshore wind cable-laying, operations and maintenance and offshore platform construction, for example, is based on historical strengths in the oil and gas sector. Expertise, therefore, exists, but its availability to the offshore wind industry depends on a down cycle oil and gas industry that has traditionally operated with margins higher than offshore wind.

The UK government has pledged to support a further 4GW of offshore wind through future contracts for difference (CfD) auction rounds. This support will be capped initially at US$143 (£105)/MWh, before dropping to $116 (£85)/MWh for projects commissioned by 2026. Through technological innovation, competition and the deployment of larger, more efficient turbines, UK

UK offshore wind pipeline through to 2020

Project	Developer	Capacity (MW)	Project stage	Expected start-up year
Burbo Bank Extension	DONG Energy	258	Major contracts awarded (subcontracting opportunities)	2017
Blyth Offshore Wind Demonstration Site	EDF Energy Renewables	41.5	Major contracts awarded (subcontracting opportunities)	2017
Rampion	E.ON Climate & Renewables	400	Major contracts awarded (subcontracting opportunities)	2018
Race Bank	DONG Energy	580	Major contracts awarded (subcontracting opportunities)	2018
Walney Extension	DONG Energy	660	Major contracts awarded (subcontracting opportunities)	2019
East Anglia ONE	ScottishPower Renewables	714	Contracts being awarded	2019
Beatrice	Beatrice Offshore Wind Ltd (SSE, SDIC Power & Copenhagen Infrastructure Partners)	664	Contracts being awarded	2019
Neart na Gaoithe	Mainstream Renewable Power	450	CfD terminated	2020
Hornsea Project ONE	DONG Energy	1200	Contracts being awarded	2020
Triton Knoll	RWE Innogy & Statkraft	900	Early stage development – CfD bid accepted	2020

Data from EIC.

offshore wind costs are falling fast and the industry is confident that cost reduction targets will be met.

To bring about further cost reduction and minimize development processes, both government and industry are encouraging the engagement of the offshore oil and gas supply chain in upcoming offshore wind projects. As offshore wind farms grow in size and are further from shore in greater water depths, oil and gas companies are well placed to limit risk and drive innovation. By way of example, Statoil is currently developing the world's largest floating wind farm at Buchan Deep, off the coast of Scotland. Having been granted a seabed lease in May 2016, the Hywind pilot project will feature five 6MW turbines anchored to the seabed in waters up to 120m deep. The scheme will showcase the feasibility and cost efficiency of floating wind in deep sea areas.

The table demonstrates the high volume of offshore wind projects that are at different stages of development in the UK. Opportunities across the supply chain are available in the domestic market and, as the technology becomes industrialized across Europe, UK suppliers can profit from extensive export opportunities. By targeting governmental support, JDR Cables, for example, has successfully diversified from its core market of supplying umbilical cables to the oil and gas sector and achieved notable success in the UK offshore wind market. Having been awarded contracts for projects including Race Bank, Galloper and Rampion, JDR Cables has expanded to European markets and has secured orders to export to projects including Veja Mate, Sandbank and Nordsee One in the German North Sea.

Offshore wind project developers and tier one contractors recognize that innovation is key for driving cost reduction. Open to new market entrants, the offshore wind industry acknowledges that it can learn from oil and gas best practices. For oil and gas suppliers seeking to diversify, the sector presents significant opportunity. **OE**

Will Sharkey *is the sector analyst for renewables at the EIC. His remit covers the UK, Europe, the Indian Subcontinent and Sub-Saharan Africa. Will holds an MA in geography from the University of Edinburgh. Prior to joining the EIC, he worked for the tropical forest think tank Global Canopy Programme.*

Will it float?

Floating offshore wind projects are gaining momentum in Europe and elsewhere, including Japan. But, the concepts on offer still vary. Elaine Maslin reports.

The premise is that, as wind energy builds out in shallower waters, developers will look to deeper waters to build offshore wind farms.

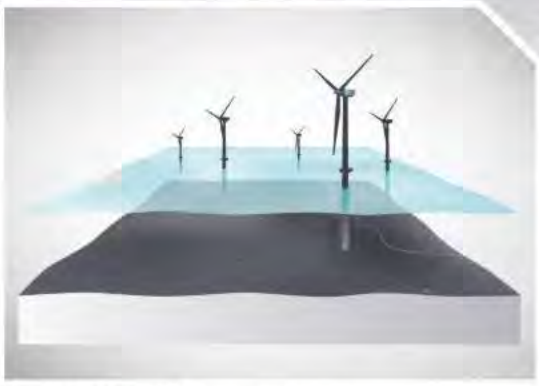
In some areas, such as Japan, where renewable energies are being sought following the Fukushima nuclear disaster, floating facilities are in fact the only option for offshore wind, as the continental shelf fast plummets into deepwater.

For the likes of Statoil, floating wind technologies offer the potential to provide power in remote areas or for oil and gas facilities.

But, floating wind could also be put into direct competition with fixed facilities, where opportunities to reduce costs, including around seabed preparation, could bottom out, or so the thinking goes.

"The potential for cost reduction on fixed structures is limited and where floating gets attractive," says Cian Conrow, sector lead, wind, at the Offshore Renewable Energy (ORE) Catapult, a UK-based technology and innovation research center, at the All Energy conference in Glasgow, Scotland, this May.

The ORE Catapult is partner in a collaboration project, LIFES50+, led by Norway's Marintek, involving 12 partners and US$8.25 million (€7.3 million) in European Union funding. It started in 2015 and will run for 40 months with a focus on proving technologies for floating substructures for 10MW wind turbines in >50m water depth. The partners included Spain's Iberdrola, DNV GL, and Danish engineers Ramboll.



Hywind schematic. Images from Statoil.

It could take time, however. A report written by DNV GL for Dutch innovation outfit TKI WindOp Zee in November 2015 said the then-current cost of floating wind solutions was estimated to be about 60% higher than bottom fixed solutions. "If floating is to become competitive it must demonstrate significant cost reduction, especially in the support structure, installation, moorings and anchors," the report says.

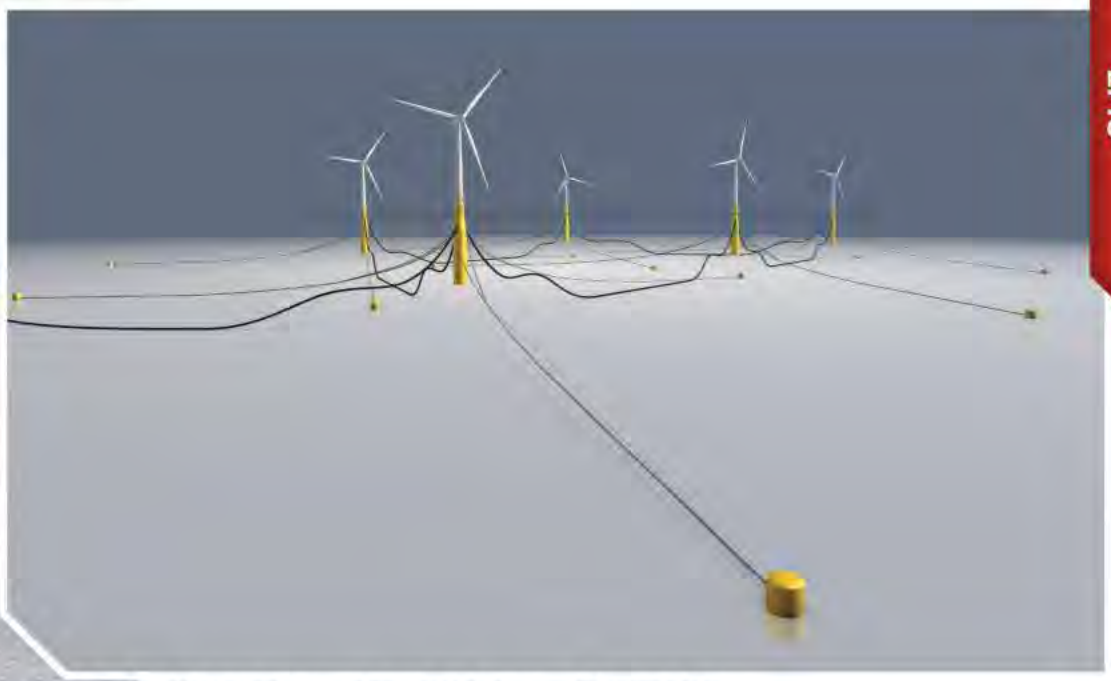
Yet, many think it's possible. According to the Energy Technologies Institute (ETI) in the UK, floating wind has the potential to have a levelized cost of energy (a metric on which the industry is measured) of less than $122 (£85)/MWh by the mid-2020s, in waters deeper than 50m (business consultancy EY recently said the same for offshore wind in general could read $101 (€90)/MWh by 2030). The ETI developed a floating design based on a tension leg platform.

Still, Una Brosnan, growth manager, offshore wind, at engineering firm Atkins, thinks there's an opportunity, not least thanks to the potential market, at some 4000GW floating wind potential in Europe, 2450GW in the US and 500GW in Japan, she told All Energy.

Leif Delp, project director for Statoil's Hywind floating wind park, told All Energy that the company's key markets are Japan, California, Norway, for powering oil and gas facilities, and also Scotland and France. Hywind, off Scotland, is set to lead the race to deploy floating offshore wind.

Hywind – in construction

The Hywind development is a 30MW park covering 4sq km and comprising five, 6MW floating wind turbines in up to 100m water depth. They will



Hywind, above and beneath the waves, 3D illustration.

Norman Pioneer **tows the first Hywind device.**

face relatively mild 1.8m mean wave heights, and 10.1m/sec average wind, off the coast of Aberdeenshire, Scotland. A 30km cable will connect the park to shore.

The project started as a concept in 2001, Delp says, during two engineers' lunch break at the Hydro offices in Oslo and went on to see a one-turbine pilot offshore Norway, operating since 2009.

It uses a standard Siemens offshore wind turbines supported on a customized steel ballasted spar structure, moored using three mooring lines, connected to suction anchors, and incorporating a patented active motion controller, to reduce fatigue, as well as a bridle system. Capacity on the first pilot has been 41%, Delp says. The structure is 14.4m in diameter and 280m-long in total, with 170m of it above sea level, resulting in 11,000-tonne total displacement. "It is like putting the London Eye on top of [the tower housing] Big Ben [the bell inside the tower]," Delp says.

Some 15 main contractors are on the project, from around Europe. These include Navantia, at Ferrol, Spain, which is fabricating the substructures. Vicinay, also in Spain, is producing the mooring chains. The nacelle towers are being fabricated in Bilbao, Spain. Saipem will carry out the mating of the towers and nacelles, in Norway, using its *S7000* heavy lift vessel. Isleburn is currently fabricating the suction anchors at Invergordon, Scotland. Balfour is responsible for electrical integration, Aluwind will do the tower internals, and Technip will do the marine operations, with Subsea 7 installing the electrical subsea cables from Nexans, which is due to start manufacturing the cables in Halden, Norway, early next year.

The project is on schedule for startup in Q4 2017, Delp says, following final commissioning in Q3-4 2017, offshore installation in Q2 2017, and offshore cable installation Q3 2017.

A future addition to the Hywind Scotland project is due to be Statoil's latest concept, Batwind – battery storage for offshore wind. Batwind is being developed in co-operation with Scottish universities and suppliers. A final investment decision on a 1MW Lithium battery is due to be made in Q2 2017, with installation potentially in 2018.

In another project involving Statoil, with partners including Nexen, ExxonMobil, Eni, and VNG Norge, DNV GL has been looking at how floating offshore turbines could help power subsea equipment, in particular water injection systems, including pumps and basic water treatment. The project recently completed a year-long Phase 1 feasibility study, which DNV GL said had positive results and could result in standalone systems. The next phase is to prove it and do a demonstration.

Approval in Principal

Engineers, who previously worked at oil majors Shell and ExxonMobil, are behind Principal Power's WindFloat, the project involving EDP, Spain's Repsol, and Portugal Ventures.

WindFloat, based in California, has two projects near-term on its radar, its 3-4, 6-8MW turbine 25MW Atlantic project, planned for installation in 2018 at a site in 100m water depth, 20km offshore Portugal. Following that, it is looking at a project, with 5-8 turbines totaling about 48MW, in Scottish waters. The Atlantic project is supported by Engie, Repsol, Chiyoda, Mitsubishi, and EDP Renewables. Japan, France, and the state of Oregon, on the US' west coast, are also in the firm's sights.

WindFloat's concept, the second generation of which recently gained approval in principal from classification firm Bureau Veritas, is a three-column semisubmersible structure, which heave plates on the bottom of each column for stability, alongside a hull-trim system, using active ballasting. It could take different standard offshore wind turbines.

It would be moored using drag embedded anchors – similar to drilling rig mooring – and could be installed using a tug and an anchor handler, said Joshua Weinstein, business development

Man with hi-vis gear.
Photo by Helge Hansen/Statoil.

and operations, Principle Power, at All Energy.

Since 2011, the firm has had a 2MW full scale pilot operating 5km offshore northern Portugal, which Weinstein says has exceeded expectations, producing 16GWh of energy. In the future, the firm wants to house 5-8MW turbines and future 10MW size turbines.

Multitasking

Danish firm Floating Power Plant has laid claim to having the world's only "proven combined floating wind and wave device," incorporating 5MW of wind and 2.6MW of wave power, using wave energy absorbers on a rocker arm.

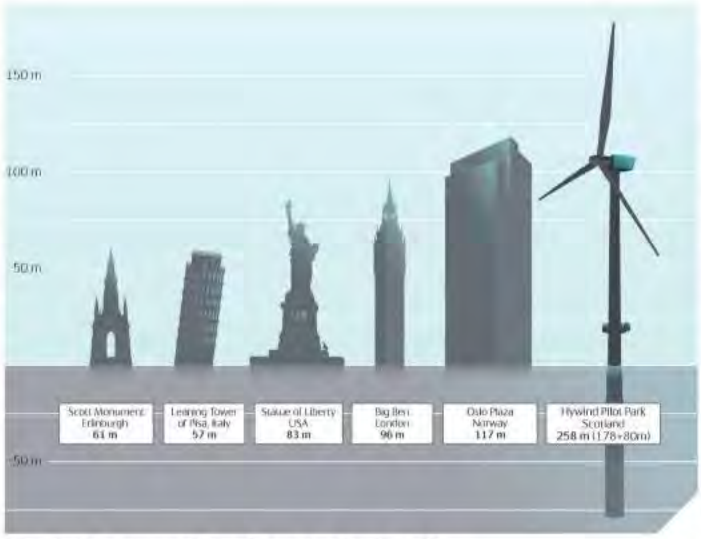
The firm's device sits on a semisubmersible cruciform shape structure, the stability of which it says is aided by the wave energy absorbers. The rocker arms sit in a channel, to enable control of the hydrodynamics, and they use double concave floats, instead of wedges. The wave energy absorbers also create a sheltered area for access to the platform.

A half scale prototype, the 37m-wide, 320-tonne P37, has spent around two years in testing offshore Denmark, including supplying compliant wave and wind powered electricity to the grid.

The firm's P80 commercial scale device, for sites above 45m water depth, will have a single turbine, up to 5MW, and up to 2.6km wave power, from four absorbers. It will be moored using disconnectable turret technology, to enable it to weather vane to the wind and allow a route for the export cable.

The firm is eyeing possible projects at Dounraey, in the north of Scotland, and off Pembrokeshire, Wales. Both are undergoing screening with an unnamed development partner. The firm wants to start with a P80 demonstrator, then built out a 7.8MW pilot park, then a 30MW array, and ultimately a 200MW park.

Floating Power Plant has also been picked as a preferred technology partners on an offshore wind park project being developed by THV Mermaid, a consortium, off Belgium, which was consented on the basis of including up to 20MW of wave power. This would be 50km from shore in 42m water depth and using a P60 unit, said Chris McConville, the firm's UK business developer, at All Energy.



Hywind in comparison to major landmarks.

Out of the box

Spain's Saitec Engineering, meanwhile, has developed something a bit different – the Sath (swinging around twin hull) concept. It has a substructure based on two large, horizontally orientated, side by side, concrete cylinders, which are ovoidal in cross section to reduce compression stresses, on a pitch and roll plate, to reduce pitch and roll. Luis Gonzalez-Pinto, Saitec's head of renewable energy, told All Energy that the Sath would be on a single point mooring system to enable it to weather vane into the wind, with an electrical swivel for the power export.

Saitec have trailed a scale model in a wave tank facility at the University of Cantabria, Spain. It had maximum oscillating angles of ±3 degrees, Gonzalez-Pinto says.

Earlier this year Marine Energy Engineering Solutions (MEES) and Doris Group's ODE subsidiary revealed a plan they had developed for a floating articulated wind column for deepwater areas for up to 8MW turbines. It is based on the concrete articulated column technology developed for the Maureen platform in the North Sea, which was decommissioning in 2001.

The pair think nearshore, floating solutions could reduce costs by eliminating the need for offshore transmission stations, reduce cable lengths and do away with a lot of seabed preparation work.

Meanwhile, China's Fujian Mindong Electric Power Corp is investing in the development of a 48MW floating wind farm in Fujian province. It would involve 24, 2MW turbines and could start construction in 2018.

These are just some of the projects in the market, with many more technology offerings in Europe and devices being trialed offshore Japan (*OE*: July 2014). While a clear winning design is not yet there, one thing is for sure, there're no end of ideas for one. **OE**

Going super critical

A $SCCO_2$ unit from Ocean Team.
Photo from Ocean Team.

Pipeline flushing is being given a breath of fresh supercritical CO_2, thanks to technology developed by Denmark's Ocean Team.

Pipeline operators have been suffering from a problem – how to flush and clean systems incorporating several kilometers of small inner diameter pipeline.

According to Noria, an American authority on machinery lubrication and oil analysis, 80% of breakdowns in fluid systems are caused by contamination problems.

It's a problem in subsea systems, which often contain umbilicals and controls lines up to 30km-long and with internal diameters less than 10mm and no efficient cleaning options currently exist, according to Denmark's Ocean Team.

A break down in a fluid system, which could be a hydraulic control line, could have serious impacts. Ocean Team highlights that of eight different safety systems that failed during the Gulf of Mexico Macondo incident, two were most likely due to system contamination, which could even have been introduced into the system prior to installation.

Espen Kähler Amundsen, head of engineering at Ocean Team, says contamination in hydraulic lines also results in hydraulic fluid leaking into the environment during venting due to excess pipeline pressure.

Flushing the lines using conventional method (laminar flow) does not prove efficient witnessing a too high-pressure loss. The turbulent flow required to flush material out just drops out, so the fluid is cleaned but not the pipe system, says Ocean Team. To be able to maintain the pressure needed to fully clean the pipeline would mean having to handle pressure losses above 30,000psi, the firm says.

After receiving a number of enquiries post-Macondo, Ocean Team set to work on a solution. The firm has developed cleaning method, using CO_2 in a liquid super critical state, which it thinks would also be useful for the nascent decommissioning industry.

The supercritical liquid state CO_2 ($SCCO_2$) is able to maintain a turbulent flow inside pipes as narrow as 1/4in in diameter and longer than 30km, says Ocean Team, degreasing and removing contaminated sludge as it goes. CO_2 in a liquid and supercritical state has a viscosity 10X lower than water and a carrying capacity similar to oil, says Ocean Team.

After proof of concept, Ocean Team ran two tests on a 6.5km-long dual 1/4in outer diameter control-line with several third party supervisors from a major North Sea operator present.

Flushing through a 13km, 1/4in outer diameter control-line shows a pressure drop of only 150 bar at a Reynolds no. of 19000. Together with the separation effect inside the Ocean Team's $SCCO_2$ unit, the method reached a cleanness of NAS1638 Grade 3/AS4059 Class 3 (Normally, a new oil has a standard purity of AS 4059 Class 8-12, yet, a purity

level of NAS 1638 Grade 6/AS4059 Class 6). The process removed all wax in the pipes, which had come from the manufacturing process, and it was performed in 24 hours.

In October last year, a Danish operator had Ocean Team work on a blocked wax inhibitor line, which was stopping a well producing on the Danish Continental Shelf. "Historically, the well would have to be changed," Amundsen says. "The well-owner desired to avoid including huge costs when the company had tried to unblock the pipes for three months. The $SCCO_2$ technology flushed a small hole in three days. The operator was saved a huge amount of money not changing the well."

"In the last 4-5 months we have also done a lot of flushing of coils, mostly for tests, where we are going to build some $SCCO_2$ plants for some costumers," Amundsen says. "These costumers are some of the biggest within tube/pipe manufacturing for the on and offshore industries, also the medical and aerospace industry."

Following the successful tests, a dedicated unit for commercial use is being built and the firm is in talks with an oil major about a subsea pilot project – sadly no names right now. This would be the first $SCCO_2$ subsea project in the North Sea. "That can change everything," Amundsen says. Ocean Team is also going to be carrying out tests at the facility of an umbilical tube manufacturer in August, Amundsen says. **OE**

The Bevel 360 tool in operation. Photos from OMS.

A 360° view

Blue laser beams are helping to make pipe fitting more accurate. Elaine Maslin reports.

In deepwater pipeline projects, welding fatigue-sensitive steel catenary risers (SCR), corrosion resistant alloy (CRA) pipes and flowline pipes to tight specifications is critical.

Counter-boring offers a way to control pipe geometry, but, due to cost considerations or pipe wall thickness limitations, is not always viable.

In order to minimize project risk, pipelay installation contractors and welders need to capture, record and analyze pipe end geometry quickly and accurately. Used correctly, this data can then help to ensure that pipes will fit together easily and within the welding specification requirements.

Red lasers are being used in engineering measurement, including for measuring the ends of oxidized steel pipes. However, they tend to create unwanted levels of distortion on highly reflective materials, making it hard to accurately measure profiles on certain metals.

UK-based Optical Metrology Services (OMS) has developed technology using blue lasers for pipe dimension and bevel analysis. Unlike red lasers, which operate at a wavelength of between 620-750 nanometers, blue lasers operate at a shorter wavelength of 405 nanometers, which makes it ideal when measuring hot or highly polished surfaces. OMS worked closely with Micro-Epsilon, a UK manufacturer, to find the right laser line scanners for its new tool, Bevel 360. Bevel 360 uses these lasers to perform a complete scan of the pipe end in about 25 seconds, producing a complete profile of the bevel face, enabling installation contractors to accurately check bevel geometry before the pipes are joined and welded. ▪

Flexibility

Olso, Norway-based SubseaDesign has developed a self-aligning subsea connector, a metal to metal seal for 3in to 40in pipes, called SeAlign.

And 72 are to be used on Statoil's Johan Sverdrup development offshore Norway on 8, 12, 14 and 18in pipes.

The flange connection tool allows for greater flexibility when joining pipes subsea, especially angled connections, instead of having tight tolerances and potentially having to force two ends together, which can create bending loads in the pipe system. This also avoids the potential for hydrogen induced stress cracking in duplex steels.

SeAlign, which uses a titanium seal due to its elasticity, although other metals could be used, self-adjusts to ± 3 degrees, finding the angle itself before it is fixed in place using a diver or Torocon ROV connection system. Using SeAlign can then mean the size of pipe spools can be reduced. SeAlign connectors can also be used again, says Bjorn Halvor Pettersen, one of the three co-founders of the company, set up in 2007.

Other owners include Hans Henrik Fjelldal, who was on the board of FMC Technologies up to 2007, working as senior engineering materials technology, and before that worked as senior engineer materials technology at Statoil. He was also a metallurgist at Norsk Hydro.

Among the company's other products are a wellhead load relief system, comprising a protection structure to which the BOP is connected to. It has already been used on a number of Statoil installations, reducing 60-80% in cyclic bending moments. ▪

SeAlign 18in diver assisted connector. Photo from SubseaDesign.

BP's Magnus platform. Photo from BP.

Boosting recovery

Former BP and Shell geologist Mike Shepherd says the North Sea demonstrates top in class oil recovery factors compared to the rest of the world, but could do better.

The quoted oil recovery factor from both the UK and Norwegian sectors is 46%, the highest of any petroleum province in the world.

This compares to a commonly-quoted average worldwide recovery factor of 30-35%, although this number is a guess rather than anything particularly evidence-based. The authors of a 2007 technical paper stated that the global recovery factor of oil fields could be as low as 22%.[1] The same paper quotes an average recovery factor of 39% for the US and 23% for Saudi Arabia.

Why would a high-cost offshore area, such as the North Sea, demonstrate top in class oil recoveries by comparison to onshore production? Because intuitively it's not expected. Favorable geology is one explanation; the reservoirs in the North Sea largely comprise sandstone rock and with only a small proportion of the complex and difficult carbonate reservoir intervals that are common in the Middle East for instance. The prevalence of light oil is another.

Nevertheless, a major factor is the implementation of reservoir management strategies by North Sea oil companies. Part of this is due to lucky timing. The start of oil production in the North Sea followed shortly after the oil price hike of 1973, when oil prices quadrupled. From the end of World War II, up until then, the oil price had been remarkably stable and low, at US$2-3/bbl (about $20-25 in today's money).

That had been enough to bring on stream the enormous oil fields of the Middle East and North Africa, many on primary production, and still make money. With the increase in the oil price, adding water injection wells became more attractive. Waterflooding was, therefore, implemented in most North Sea oil fields from the start of production and there is no doubt that this alone accounts for the much of the high recovery rates. The light oil in many of the reservoirs helps enormously, as waterflooding is more effective in pushing light oil into the production wells.

One other difference came into play in the North Sea. Whereas onshore fields are commonly drilled in spot patterns, with a high density of wells, this was not a feasible option offshore, where the drilling costs were up to 10x higher. Given the greater inter-well spacing forced on operators by the economics of offshore drilling, North Sea wells would have to be carefully placed to maximize their effectiveness. This meant making a big effort to understand reservoirs in detail, both in terms of reservoir continuity and complexity. In turn, there was a drive to improve seismic resolution, improve the geological description of reservoirs and to find cost-efficient means of drilling them. During the lifetime of the North Sea, our knowledge and technology has increased enormously and this has been a major driver for reserves increase in many North Sea fields.

Majestic Magnus

I used the Magnus field as an example of reserves growth in my recently published book on the history of North Sea oil – "Oil Strike North Sea" (Luath Press 2015). The field was expected to cease production in 1999, but it was still producing 12,000 b/d in 2015.

The field was discovered in 1974 in the northern North Sea. BP originally considered the discovery marginal. Although there were indications of a reasonable amount of oil there, about

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- ❑ 55 Consulting
- ❑ 56 HR, Staff Recruitment
- ❑ 99 Other *(please specify)* _____

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Magnus heavy oil. Staff photo.

450 MMbbl reserves were estimated at that time, the water depth of 186m was a critical factor and at the extreme limit of what could be done with 1970s North Sea technology.

The field is elongate in shape, extending north–south for 14km. If the water depth had been shallower, two fixed platforms would have sufficed to access the full length of the field. However, at 186m water depth, the cost of the two platforms was prohibitive. BP decided on one fixed steel platform in a central location on the field, developing the northern and southern ends of the field with subsea wells tied back to the platform.

The field came on production in 1983. It was initially thought that the reservoir sandstone had been deposited as a fairly simple connected body of sand and would need only a small number of wells to develop it. As a result, the platform was built with the capability of drilling only 20 wells, which turned out to not be enough.

Six appraisal wells showed that the field would produce more oil than initially thought; the reserves were now estimated as 450 MMbbl out of total oil in place of over 1 billion bbl. By 1987, the ultimate recoverable reserves had grown to 665 MMbbl, out of 1.665 billion bbl oil in place. We knew more about the geometry of the field by that time and the seismic resolution was improving.

As well as being bigger than originally thought, the Magnus reservoir is somewhat more difficult to manage than previously thought. Instead of behaving as one big connected volume, the geology is more complex, with faults and blanket mudstones dissecting the reservoir. As a result, the field could be shown to be divided up into a number of self-contained compartments, like the bulk-head of a ship.

As more and more data came in from the wells, the understanding behind the complexity of the reservoir increased. But, this intimate understanding of field performance has led to improved recovery of the remaining oil, and although the field team has had to do some juggling with the limited number of drilling slots on the platform, that hasn't impeded the reservoir management; new wells have successfully targeted undrained volumes of oil.

Today, BP is trying to push the ultimate recoverable reserves for the field towards a target of 1 billion bbl. BP has implemented enhanced oil recovery methods on the Magnus field using water alternating gas (WAG), which alternates six months of gas injection into the wells, followed by six months of water injection, repeated in yearly cycles. The gas mixes with the oil and makes it more fluid. When the water is subsequently injected into the reservoir, the cushion of water is able to push more oil out.

The Magnus field is just one of many large oil fields in the North Sea showing reserves growth thanks to the technological prowess demonstrated in the North Sea.

Could we do better?

Top in class, but could we do better? Yes in my opinion, and the regulatory authorities certainly think so, too. The new UK Oil and Gas Authority have been charged with the remit of working with government and industry to make sure that the UK gets the maximum economic benefit from its oil and gas reserves. A major part of this is concerned with increasing the reserves from existing fields.

Likewise the Norwegians share a similar focus and one industry group identified a target of 55% basin-wide oil recovery as a target to aim for. It's a stretch target but not unfeasible with improvements in drilling technology, particularly low-cost wells and the widespread implementation of IOR.

Norwegian oil company Statoil has published a mission statement on its website proclaiming that, "Statoil has set world-leading targets for recovery factor, with a goal of 65% as an average for platform operated fields and 55% from subsea-operated fields."[2]

An interesting area for speculation is to take the North Sea as an example for what could happen elsewhere in the world. If the global oil recovery is only 22%, then there is clearly an enormous resource available in the existing fields if we could somehow apply North Sea reservoir management practice worldwide.

Let's speculate further. If we assume that we have produced close to half the world's oil reserves, let's say 10% of the global oil in place, then an increase in the global recovery factor from 22-32% would produce all the world's oil all over again and that would still be a poorer recovery factor than what is anticipated for the North Sea.

Locating the remaining oil

Surprisingly, there is a technique with a long track record in improving oil recoveries in the North Sea that has not been universally implemented. This is the technique Shell calls "Locating the Remaining Oil," (LTRO) developed

in parallel in the 1980s by Shell and the Texas-based Bureau of Economic Geology. Shell were highly successful in implementing their LTRO techniques on their Brent fields in the 1980s and 1990s. Sometime after this, I worked with Caroline Gill of Shell to apply these techniques to the Shell-operated Nelson field and the paper we wrote together is still the most complete exposition of LTRO to date.[3]

The basic idea behind the technique is the observation that perhaps only six or seven geological or petrophysical features control connectivity and the location of reservoir dead ends in a typical oil field. These features are large-scale, yet they may not be immediately obvious unless you make a big effort to find out what they are, particularly because what matters varies considerably from reservoir to reservoir. The geologist is best-placed to carry out the analysis and it involves stepping beyond pure geology, as it is necessary to integrate the geological framework with production data to do the work. Once you have established the framework controlling flow behavior, then you have a much better chance of working out where the remaining oil is to be found. This reduces the risk on infill well targets.

The problem for modern geologists is that the technique involves stepping out of the standard computerized work flow for producing 3D reservoir models. I call LTRO the "missing workflow" because, as a procedure, it is not integrated within existing geological modeling software. It's not straight-forward to computerize LTRO practices as the process is data-intensive and involves analysis in two dimensions (graphical overlay of production data on geological data) rather than in the three dimensions, which modern geological software is accustomed to.

The problem is that if you don't explicitly model the features that control fluid flow in a reservoir it's a hit or miss issue whether the geologist's model will honor them or not. The features are subtle and often easy to overlook.

I reckon oil companies are becoming more and more aware of the problem of the "missing workflow" and are taking steps to rectify the issue. I certainly don't think it does any harm to actually get young geologists involved in understanding how a reservoir works rather than just modeling it. OE

Mike Shepherd *was born in Aberdeen and witnessed the arrival of the oil industry to the city in his teenage years. Later working for BP and Shell planning oil wells in the North Sea, his childhood dream of becoming a geologist was realized with over 30 years' experience in the oil industry. His previous work includes the textbook Oil Field Production Geology, used for postgraduate study both in the UK and abroad.*

Notes

1 I.Sandrea and R.Sandrea, 2007. Global oil reserves - Recovery factors leave vast target for EOR Technologies. Oil and Gas Journal. Part 1: November 5th, 2007. Part 2: November 12th, 2007.

2 www.statoil.com/en/TechnologyInnovation/OptimizingReservoirRecovery/RecoveryMethods/Pages/AboutRecoveryMethods.aspx

3 Gill, C.E. and M.Shepherd, 2010. Locating the Remaining Oil in the Nelson Field. In Vining, B.A. and S.C. Pickering (eds) Petroleum Geology: From Mature Basins to New Frontiers – Proceedings of the 7th Petroleum Geology Conference, P. 349-368. Geological Society, London.

Keep it clean

Halliburton's Alan Marr examines how fluid advances can enable more efficient well clean-outs.

Wellbore cleaning is crucial for maximizing the productivity and life of a well. Successful displacements should avoid non-productive time, minimize waste disposal, prevent formation damage due to residual solids, and allow completion equipment to be run safely. Residual oil and solids left behind by drilling operations can accumulate in drilling equipment, hindering completion operations and can also damage the producing formation. In the transition from drilling to completion operations, the wellbore is cleaned out and the drilling fluid is displaced with clean brine. A badly designed or poorly executed displacement can consume additional fluids, logistics and rig resources. Identifying the right technologies and processes can help complete wells effectively.

Recently, an operator achieved perfect displacement despite restricted pump rate. On an offshore platform well, pump rates were restricted during the cased-hole displacement due to the transfer restriction from rig to supply vessel. On a previous clean-out operation in which Halliburton was not involved, effective well clean-out was not achieved. The operator had to pull the completion and conduct a secondary cleanup. The end goal was to displace ENVIROMUL oil-based fluid to 10.0ppg sodium chloride brine with less than 0.05% solids and no visible oil.

As a result of lab testing, Halliburton Baroid's BaraKlean-648 surfactant-based casing cleaner was selected for the job due to its strong solvent action and high cleaning capacity at lower annular velocities. BaraKlean-648 casing cleaner is a blend of surfactants and solvents used in fluid displacement and cleanup operations. The casing cleaner has strong cleaning and wetting actions to break and disperse mud film and residue. It is soluble in all common brines and is designed for the removal of a range of water, oil and synthetic based fluids.

An example of a successful displacement is recognized by bright, clean pipes indicating clean casing and fluid. Photo from Halliburton.

The fluid cleaner was ideally suited to the technical constraints presented by this application. It also received the CHARM Gold rating, a widely accepted environmental classification and rating.

The displacement design was optimized using Baroid's Completion Fluids Graphic (CFG) proprietary software package, which simulates the effects of critical parameters such as pump rates, circulating pressures, and annular velocities. Displacement simulation had not been conducted in the initial cleanup operation.

The challenges presented by the low pump rates and restricted pit space were overcome by careful planning, preparation, and execution of the operation. The wellbore cleanup operation was executed as planned, and the target cleanliness standards were achieved after minimum over-displacement.

The drillpipe and all components of the string were found to be clean when the assembly was pulled to the surface. The design and execution of the displacement using BaraKlean-648 cleaner provided an efficient displacement and created clearly identifiable interfaces that maximized mud recovery and minimized over-displacement. Brine usage was reduced, while rig time and waste disposal were minimized. As a result, this equated to an estimated savings of three days of rig rate, as there was no requirement to conduct a secondary cleanup operation and to rerun the completion.

The design and execution of a successful wellbore cleanup depends on an effective combination of chemistry, engineering and field practice. Employing a customized design process for engineered displacements, powerful cleaning solutions and optimization using software modeling is critical to that success. **OE**

***Alan Marr** is currently global product manager for completion fluids with Halliburton's Baroid business line, based in Aberdeen, UK. Alan joined the oil industry over 10 years ago having previously worked for a pharmaceutical company. Alan's experience includes laboratory work, field operations and technical services. He is a member of the Society of Petroleum Engineers and NACE International. Alan holds degrees in chemistry and oil and gas engineering.*

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Staying ahead of downtime

Improved visibility and predictive maintenance can help keep operations running, says Rockwell Automation's Luis Gamboa.

Minimizing downtime is a goal for every offshore oil and gas operation. But, a number of modern challenges can make it especially difficult to achieve.

For starters, the advanced control systems used in offshore operations can require operators to interface with hundreds or thousands of data tags and resulting alarms. For many oil and gas producers, the approach used to deliver this data to operators involves populating as much of it as possible on a single HMI (human machine interface) screen. This can overwhelm operators and result in them missing important data or alarms before a downtime event occurs.

At the same time, oil and gas producers are experiencing challenges resulting from a generational turnover in their workforce. Their most experienced employees are moving toward retirement, and the pool of qualified workers to take their place is limited.

These skills challenges are being felt today in the industry. In its "Oil and Gas Global Salary Guide 2016," recruiting firm Hays surveyed oil and gas employers. It found that the two areas most affected by the skills gap are engineering and design (41%), and operations, maintenance and production (37%).

Lastly, many of the legacy systems in place today are unconnected. And, yet, it's this exact capability – connecting operations and capitalizing on previously inaccessible data – that can help offshore oil and gas operations reduce their downtime and overcome the many challenges they face.

Connecting offshore operations

By connecting people, processes and technology into a connected enterprise, offshore oil and gas producers can leverage the wealth of information existing in their equipment, processes and databases today to turn it into production intelligence, creating new opportunities for optimizing operations and improving the bottom line.

One of the key ways a connected enterprise can help offshore producers is in making equipment maintenance more predictive and proactive.

For instance, operations-management solutions can help streamline and simplify the information displayed for operators on HMI screens. Device and alarm data can be contextualized into information that is relevant to the individual operator, helping them be more successful in their role.

In place of displaying an overwhelming amount of data, operations-management solutions use multidimensional graphics, trends and gauges. These capabilities can show operational conditions in an easy to understand, contextualized way, to help operators more quickly spot issues before they evolve into downtime events.

Remote monitoring is another key capability in the connected enterprise. By leveraging hardware, software, sensors and wireless connectivity in real-time, subject matter experts working from a central, onshore location can access critical production intelligence from offshore production facilities that are hundreds or even thousands of miles away. This enables them to have full access to real-time operating conditions, predict changes, troubleshoot issues and determine process adjustments all from their workstations.

Remote monitoring can be especially valuable given today's skills-gap challenges. The ability to monitor systems and troubleshoot problems from a central location can help reduce the number of employees who need to be stationed on or dispatched to offshore production sites and more efficiently leverage the limited number of available experts in today's operations.

"By connecting people, processes and technology into a connected enterprise, offshore oil and gas producers can leverage the wealth of information."

Remote services

Oil and gas producers can also use remote-monitoring capabilities to better

utilize third-party support, such as virtual-support engineering services.

For example, a large privately-held oil and natural gas exploration and production company is taking advantage of such capabilities. The company has oil-drilling platforms and operations off Alaska's rugged Kenai Peninsula, where downtime can cost US$100,000 to $300,000 per day.

When the company upgraded its pumping equipment from gas-lift compressors to more efficient and reliable electrical submersible pumps, it used a third-party, virtual-support engineering service to monitor the pumps. The service uses cloud-computing technology to collect real-time data from the equipment and alert the third-party support engineers the moment an issue is detected.

It's these capabilities that make predictive analysis possible. Data is sent and stored with a local cloud agent that sends data directly to the company's central facility. Over time, the increased volume of data and system history collected allows for preventive maintenance and makes the pumping system more efficient and productive.

"The service gives my support staff comfort offshore. The last time we had one of our wells trip offline, within five minutes they had someone on the phone telling them what broke and what to test," said one of the company's facilities engineers. "The staff was able to verify the issue, replace the part and get it back online immediately. I am convinced it saved six or more hours of troubleshooting."

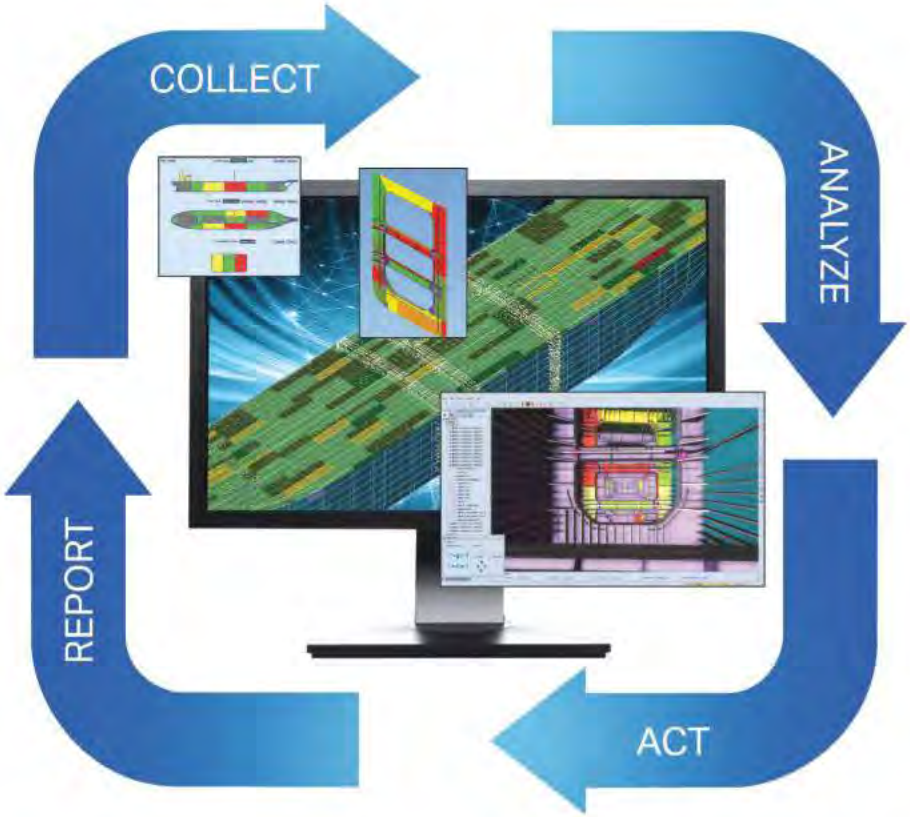
A business imperative

The wealth of production intelligence and unprecedented connectivity available in the connected enterprise are too valuable to ignore. By making these capabilities a business imperative, offshore oil and gas producers can convert their oilfield data into streams of actionable information, keep staff informed about critical predictive maintenance needs, and take action before production is disrupted. **OE**

Luis Gamboa *is the oil and gas market development lead of Rockwell Automation. Luis has more than 30 years of combined engineering, operations, and marketing experience in the oil and gas manufacturing and automation industry. He is currently responsible for the strategic and commercial development for Rockwell Automation's oil and gas development and growth initiatives, including digital oilfield technologies, operations and asset management, remote monitoring, subsea, process and motor control, hazardous location technology, marine solutions and integrated control, power and safety solutions.*

Lifecycle database improves SIM

Eeeteng Khoo and Christopher Serratella, of ABS, examine how lifecycle databases can improve structural integrity management.



ABS HM3D is a lifecycle tool that promotes streamlined structural integrity management. Image from ABS.

Challenging operating conditions, increased regulatory demands and the need to preserve asset condition and efficiency lead owners and operators of offshore assets to look for enhanced and cost-effective approaches to structural integrity management (SIM). The industry is shifting from calendar-based intervals toward more condition-based inspection or survey, where inspection, maintenance and repair (IMR) planning is being initiated in the design phase and is revisited and revised based on actual condition data obtained from the asset itself.

A key component of successful SIM is a well-maintained lifecycle database. Ideally, the database is set up with a record of baseline survey measurements and findings, providing the "starting" condition of the asset. Once the asset is in operation, the database is updated after each inspection, survey or repair to reflect the latest condition. This type of continuous condition tracking approach provides a comprehensive understanding of the asset's health and helps to define future IMR scope and engineering decision-making to prevent escalation in risk and cost.

Answering SIM challenges

Tracking and monitoring asset condition have always been a challenge due to the lack of common practice and experience in storing data and using that data for trending and predictive maintenance. ABS has created two SIM software tools to fill this void. Hull Manager (HM) and Hull Manager 3D (HM3D) are connected via a centralized database to enable fleet-wide trending via data gathered during inspections.

HM is a web-enabled 2D tool for planning, preparing, performing and reviewing inspections that uses a "traffic light" grading system to assess the asset condition and record, track and manage anomalies.

HM3D takes this functionality a step further, recording and displaying structural condition data in a virtual environment that provides the vessel management team with a "digital twin" of the asset that can be used to manage condition data. HM3D is a lifecycle database designed to record condition data from the design stage to the end of service life, using a 3D structural model. The tool allows users to access the history or present condition of a specific structure, compartment or even a complete asset with 3D visualization. It provides an overall view of

the structural health of an asset, with graphic filters to focus on condition and inspection findings such as fractures, corrosion levels, deformation and the condition of anodes.

The 3D tool also uses the traffic light grading system on steel structures to identify anomalous locations for IMR work so SIM activities like gauging and repair planning can be planned for optimal execution. For example, areas with substantial corrosion can be identified and assessed to determine if steel replacement is required. An optimal repair can be planned and the associated cost estimated using the software.

In addition, the tool has utility features to support engineering analysis tasks. Because corrosion is heavily dependent on the environment – and its pattern can change over time – a nominal corrosion rate may not be applicable for all the plates and stiffeners. The tool allows the corrosion rate of a specific plate or stiffener to be estimated using recorded gauging values, with options to apply a linear or non-linear trending to predict future wastage.

Geometry models with actual or predicted structural thickness can be extracted and imported into a finite element tool to generate a finite element model (FEM). The main function of this toolkit is to create an FEM with material and thickness properties from a geometry model based on specified requirements via an automated process, which can be used in strength and fatigue assessment and life extension evaluation. This functionality minimizes the FEM creation effort and cost.

Using this tool with the ABS Nautical Systems software enables seamless data-sharing among inspectors and operations and engineering teams, giving all parties real-time access to the latest asset condition, promoting better teamwork and communication, minimizing operation cost, and reducing asset downtime. Finally, lessons-learned can be documented and used as reference for future asset design and SIM programs. **OE**

***Chris Serratella**, director, data management and analytics in the ABS Corporate Technology group, is responsible for guiding ABS research, rule development and industry guidance, specializing in integrity management and methodology and software development related to integrity management. Serratella has worked in the marine and offshore industries for more than 28 years.*

*Based in Houston, **Eeteng Khoo** is senior engineer, structures and in-service technology in the ABS Corporate Technology group. Khoo has 10 years of experience in the marine and offshore industries and is responsible at ABS for research, rule development and industry guidance, specializing in structural integrity management and software development related to structural integrity management.*

West Africa

Tracking West Africa's deepwater development

Quest Offshore's Andrew Jackson discusses how the depressed global market dynamics are affecting one of the world's premier deepwater basins.

Oil from the Bonga North West underground reservoirs is produced through underwater facilities and transported by underwater pipelines to the existing Bonga floating, production, storage and offloading (FPSO) vessel. Photos from Shell.

Relatively speaking, greenfield, deepwater projects executed in West Africa, more than any offshore basin other than perhaps Brazil, are characterized by large standalone megaprojects. Super-majors have discovered vast resources in deepwater that have led to some of the largest, most complex, and most expensive field developments, which regularly include over 30 subsea trees, 50+ km of subsea production umbilical and infield flowline and high-capacity floating production assets.

Major operators such as Total, Shell, Chevron, ExxonMobil, BP and Eni have accounted for approximately 75% of all subsea equipment awards in the region since 2000. Given the swift and severe reductions to capital expenditures globally by these key players in the midst of a "lower for longer" oil price dynamic, it is no surprise that many large West African development projects have come under increased scrutiny in their path to final investment decision (FID) given their large scale and associated large development costs.

The allure of substantial deepwater reserves, however, and a mix of established and frontier acreage will ensure that West African opportunities will continue to hold significant potential within IOC's global upstream portfolio strategies. With this significant opportunity also comes significant risk as operators invested in the area have required contingency plans to handle local geopolitical issues, extreme project economic sensitivity and a relatively long development cycle typical to the region's large projects.

Subsea outlook

West Africa has long been a strong source for subsea equipment demand. Since 2000, the countries along West Africa have accounted for 23% of global subsea tree demand with over 75% of West African demand coming from supermajors. Angola and Nigeria have represented near 80% of the region's subsea demand since 2000. With an expected increase in regional diversity along the west coast of the continent, Angola and Nigeria's market share is anticipated to drop to below 70% of the region's subsea demand through the end of the decade.

Hundreds of pipelines are transferred by crane from a cargo barge to the vessel that lays them on the sea bed at Bonga North West offshore oil field.

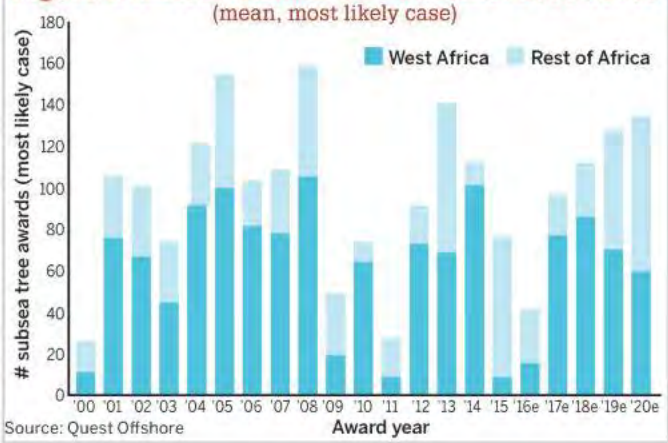
The high capital investment common to Angola and Nigeria is a predicted driver to this trend change as the industry moves through a period of low oil price and a serious focus on reducing the development cost of these projects. Smaller scope projects in other areas, namely the Transform Margin, are expected to see comparatively smaller project delays. Other areas around Africa are also expected to reduce West Africa's overall impact on the region's subsea demand as North and East Africa increase activity through the end of the decade.

While the previous decade was highly focused on greenfield project development, the early 2010's introduced an increase in brownfield subsea tree demand as a cost effective method of increasing oil production through floating production facilities with available production capacity. Projects such as Chevron's Agbami, Total's Girassol and Rosa and Shell's Bonga represent just a few of the major deepwater projects contributing regularly to the overall subsea demand via small-scale call-offs of additional subsea trees. Subsea tree awards for West Africa from 2000-2007 saw 14% for brownfield activity. The following eight years through 2015 saw that percentage grow to almost 25% of total subsea tree activity for the region as operators wished to maintain and extend production at large floating production units.

Construction activity underway

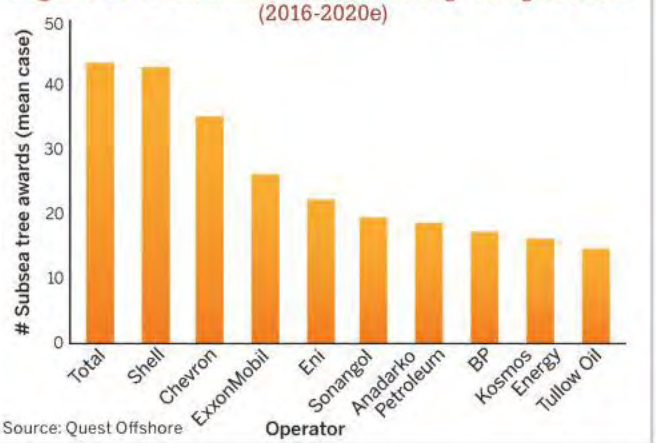
While the near-term outlook for greenfield, megaproject FID and associated equipment orders remains depressed, construction and pipeline installation activity in Africa is anticipated to rise in 2016 year over year buoyed by West African & Mediterranean installation projects. When compared to subsea equipment awards, installation activity occurs later in the

Figure 1: African subsea tree demand: 2000-2020e
(mean, most likely case)



Source: Quest Offshore

Figure 2: West Africa forecast top 10 operators
(2016-2020e)



Source: Quest Offshore

West Africa

The Saipem 3000 vessel installs umbilical cables at the Bonga North West offshore oil field.

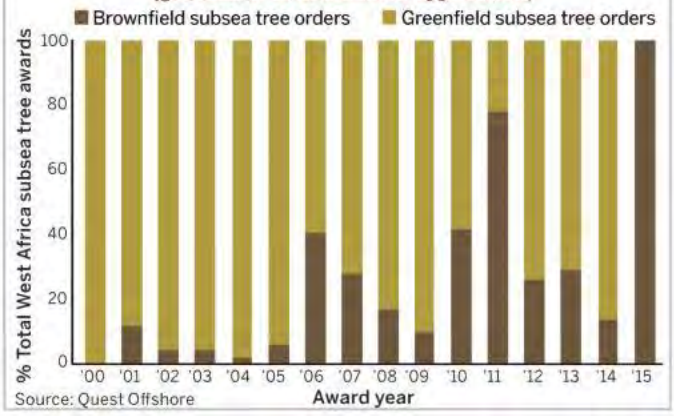
project development cycle and is less immediately affected by changing execution activity levels. For instance, marine installation activities at Total's Kaombo in Angola, Tullow's TEN Complex (Tweneboa, Enyenra, Ntomme) in Ghana, and Total's Egina in Nigeria contribute to West African pipeline installation activity in West Africa in 2016.

There are currently 14 high-end vessel assets operating in the West Africa region. Technip has three of these assets in the region including the *Deep Pioneer*, which is currently performing installation activities for Tullow's TEN Complex and the *G1200* and *Skandi Africa*, which are installing flowlines, umbilicals, subsea structures, rigid jumpers, manifolds and pumps on Total's Moho North field in Congo. Other vessels in the region include Oceaneering's *Ocean Intervention III* and Bourbon's *Bourbon Oceanteam 101*, which are currently working in BP's Block 31 field.

Total's Kaombo Phase 1 project will bring additional assets to the region in Q4 2016 to begin installation campaigns that will span throughout 2016 and 2017 for the project. The joint venture between Technip and Heerema Marine Contractors was awarded the engineering, procurement, construction, installation and pre-commissioning contract for the project's subsea umbilicals, risers and flowlines. Heerema's *Balder* vessel will install the risers and the pipe-in-pipe production pipelines and Technip's *Deep Blue* vessel will install all the remaining pipelines. Other vessels from Technip's fleet will install the flexibles and umbilicals and provide construction support work. The contract was awarded in April 2014 and is worth US$3.5 billion with Technip's share being 55% and Heerema's share 45%.

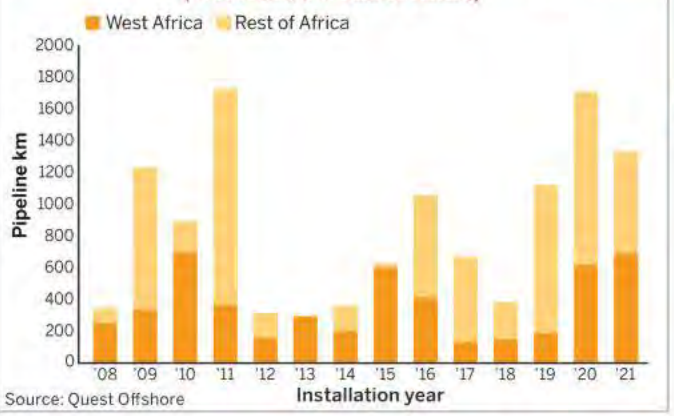
Although a great portion of demand is driven by new project development, there is also opportunity in inspection, maintenance, and repair (IMR) demand, which encompasses a large variety of work on existing fields, ranging from visual inspection, testing, and the repair or replacement of

Figure 3: West Africa subsea tree demand
(greenfield vs brownfield application)



Source: Quest Offshore

Figure 4: Deepwater pipeline installation forecast
(West Africa v. rest of Africa)



Source: Quest Offshore

components and pipeline infrastructure. *DeepOcean* was recently awarded a three-year contract to provide a light construction vessel to Tullow Ghana. The contractor has mobilized the *Dina Star* vessel, which commenced operations in March 2016 and will be performing IMR surveys and subsea construction on the Tullow Ghana-operated deepwater Jubilee and TEN Fields. *DeepOcean* also has the *REM Forza* mobilized in the region and is providing accommodation and construction support on the TEN project as well. The global subsea market has grown significantly over the past decade leading to a growing installed base of subsea wells with associated pipeline infrastructure providing opportunity in the IMR segment. **OE**

Andrew Jackson *serves as Quest Offshore's market research & database manager, where he works with the Quest research team to conduct research and analysis on offshore project development. Andrew graduated from Texas A&M University with a BBA in Information & Operations Management.*

West Africa

Petro-states in the making

Unlocking Senegal and Mauritania's major finds will be a huge hurdle, with a lack of infrastructure in both countries. But, it's also an opportunity for supply chain companies, says the EIC's Chad Barnes.

A worker onboard the *Ocean Rig Athena*. Photos from Cairn Energy.

West African oil producing nations, along with the rest of the world, are suffering the effects of the low oil prices. However, in the north of this region two countries are attracting interest as potential new energy nations.

Recent major discoveries in Senegal and Mauritania have the potential to transform both countries into net exporters within the next five years. Senegal persevered with over 140 exploration wells of limited success until Cairn Energy's FAN-1 and SNE-1 wells in the Sangomar Deep block in 2014 yielded major results. Both wells discovered significant hydrocarbon resources, with the SNE field having an estimated contingent resource of 561 MMbbl. Cairn is currently planning the SNE-4 appraisal well and could reach first oil as soon as 2021.

Cairn's success was shortly followed by Kosmos Energy in 2015, when the Tortue West structure was discovered straddling the Senegal/Mauritania border. Subsequent discoveries in both Mauritania and Senegal established the Greater Tortue Complex that has a P-mean gross resource estimate of 25 Tcf of gas. A development concept will be selected in mid-2016, with a floating LNG facility looking the most likely option.

Although yet to produce any hydrocarbons, Senegal has great potential to become a petro-state due to its political stability and positive investor climate. Both Senegal and

The ultra-deepwater drillship *Ocean Rig Athena* was previously chartered for drilling operations offshore Senegal, most recently on Cairn's SNE-4 appraisal well.

Mauritania were quick to enter into a memorandum of understanding with Kosmos Energy, which sets out the principles for an intergovernmental cooperation agreement for the development of the cross-border Greater Tortue resource. Kosmos Energy believes that gas demand will have risen by the time the field becomes operational and is looking to capitalize on the current low contractor costs.

Senegal and the SNE discovery has much in common with petro-state Ghana and the Jubilee discovery of 2007. Ghana boasts political stability, like Senegal, and had no significant oil activity until the Jubilee field started production in 2010.

Initially, Ghana seemed set to thrive from new oil and gas revenues and had promised to learn the lessons from nearby African nations to avoid the "oil curse." However, six years after first oil, Ghana's economy is declining and the government was forced to take a near US$1 billion emergency loan from the IMF in 2015.

Senegal's President Macky Sall, a geologist and former director general of Senegal's national oil company Petrosen, has insisted they will not suffer the same fate and stressed that Senegal will take "every measure" to ensure the projects are carried out in the "best interests of all current and future generations."

Kosmos Energy, which is a partner in the Jubilee field, has claimed an excellent working relationship with both Senegal and Mauritania, and is confident that Senegal will benefit from their 10% stake in the Greater Tortue Complex project.

Following the two major discoveries, neighboring countries have now also received attention as new frontier regions. A new 3D seismic survey was completed offshore Gambia last September by Erin Energy. The area has massive potential as it lies in the block directly south and on the same trend as the FAN-1 and SNE-1 hydrocarbon discoveries. Likewise, Woodside Energy has recently taken ownership of the AGC Profound block in Guinea-Bissau, as the discoveries have significantly de-risked the area.

Huge challenges will need to be overcome to develop the SNE and Tortue fields as Senegal and Mauritania lack the infrastructure and capabilities required for the billion dollar projects. This provides opportunities for supply chain companies with extensive offshore experience to offer their services to meet the future demand. **OE**

***Chad Barnes** is the sector analyst at the EIC for the upstream sector, and covers this remit globally. He has a degree in geology from the University of Leeds, UK, and a master's degree in integrated petroleum geoscience from the University of Aberdeen. Prior to the EIC, Chad worked with North Sea operator, Ithaca Energy.*

Solutions

Siemens unveils subsea comms solution

Siemens introduced its Advanced Converter & Switch (ACS) for subsea Ethernet communication at higher data rates and over longer lengths. This communication solution can be used for connecting to existing subsea fields, for field extensions, or for new developments.

The ACS links existing copper cables with fiber technology for longer lengths. It can combine and convert various types of communication up to 84km at 3000m below sea level. This includes communication between sensors and control systems subsea, as well as subsea to topside communication.

The basic design of the ACS comprises one-atmospheric chamber housing, a glass-to-metal penetrator on the copper side and glass-to-glass on the fiber side, and a printed circuit board (PCB) card. The modular PCB is designed for installation in existing subsea technology, which solves challenges in power consumption, EMC, signal monitoring, and conversions. Its modular design may be configured in various ways, providing the possibility to combine several fiber optic and/or electrical Ethernet interfaces integrated to a flying lead, sensor harness, umbilical termination, or even a subsea Ethernet switch.

www.siemens.com

Peak extends SIMULTRA range

Peak Well Systems extends the SIMULTRA range of retrievable bridge plugs with the successful completion of ISO-14310 V0 gas testing of a 5.5in retrievable bridge plug in 20lb API casing.

The results of the testing showed repeatable zero bubble gas performance over a single test sequence that ranged from 25-175°C and from 7500psi above and below the seal.

"Proving V0 performance across such a wide operating range in a single test run without the need to break testing into smaller temperature increments is a huge achievement and demonstrates not only the seal's robustness but also the technology's unique capability relative to traditional seals," says Robin McGowan, Chief Technology Officer at Peak Well Systems.

Peak has now successfully achieved V0 certification for its 4.5in plug in 11.6-15.1lb casing as well as for its 5.5in plug in 20lb which is also suitable for 23lb casing.

Peak aims to have the complete SIMULTRA range, which will include a 7in plug, available for sale or rental by Q3 2016.

www.peakwellsystems.com

iXblue offers AUV INS

The iXblue's Phins Compact line offers AUV users the ability to choose an inertial navigation system (INS) adapted to their vehicle. Based on iXblue's fiber-optic gyroscope technology, Phins C3, C5, and C7 are fully scalable systems with a similar architecture and interface.

The Phins C5 (ex Rovins 154, IMU 90-based) has been on the market, but the Phins C3, based on iXblue's IMU 50, is a new inertial system designed for man portable AUVs, with a small and light structure, mostly for shallow water applications. Also, the Phins C7 (IMU 120) is now smaller for a better AUV integration.

The Phins Compact line benefits from the performance of the fiber-optic gyroscope technology: the low consumption, solid-state, and strap-down inertial systems enable stealth autonomous navigation, designed to provide accurate heading, roll, pitch, speed and position. With a mean time between failures up to 100,000 hours and with no need for preventive maintenance, the systems is designed for high levels of reliability and robustness. Phins C3, C5, and C7 are ITAR-free, dual-use systems and are all compatible with DELPH INS post-processing software.

www.ixblue.com

Now an INS for all AUV types

iXblue

MacGregor launches fiber-rope retrofit option

MacGregor's fiber-rope retrofit option for its subsea cranes replaces the original steel wire rope with high-performance synthetic fiber rope.

The retrofit system is designed in modules for rapid installation. It includes a deepwater capstan traction device, delivered in partnership with Parkburn Precision Handling Systems,

which replaces the crane's original main winch and overcomes the problems traditionally associated with handling fiber rope. The system also includes a low tension fiber-rope storage drum.

Fiber rope's advantage when used in this context is that it weighs virtually nothing in water, regardless of the length of rope paid out; it does not add anything to the load experienced by the crane. Effectively, a 100-tonne fiber-rope crane has the same lifting capacity as a 250-tonne crane with steel wire rope, lifting at a depth of 3500m.
www.macgregor.com

Materia develops subsea resin

Materia has introduced its Proxima thermoset resins for subsea and downhole tools applications.

Proxima HTI resins for high temperature subsea thermal insulation provides a thermal barrier between high-temperature flowlines and seawater, and can maintain structural integrity in operating environments at water depths greater than 10,000ft. Earlier this year, Materia was selected to supply pipeline insulation materials for Shell's Appomattox development in the deepwater Gulf of Mexico.

Proxima STR thermosets, lightweight and capable of withstanding the hydrostatic pressures of deep- and ultra-deepwater environments, are designed for use in syntactic foams for subsea buoyancy applications.

For downhole tools, Proxima HPR casting resins are designed for thermal stability and toughness when drilling with polycrystalline diamond compact (PDC) or tricone bits. When long fiber composite performance is required, Proxima ACR infusion resins incorporate fiberglass and carbon fiber to improve thermal stability, corrosion resistance, and reliability.
www.materia-inc.com

GE releases new subsea connector

GE Oil & Gas's has released its MECON WM 36/500 wet mate connector, which has been certified for operation up to 36 kV and 500 amperes in water depths down to 10,000ft (3000m).

"Unlike conventional stab-type connectors, we deploy a unique connection process that ensures that we are in full control of the electrical environment inside the connector before completing the electrical connection," said Alisdair McDonald, subsea power and processing leader at GE Oil & Gas.

An in-situ flushing process is performed after the connector halves are brought together and before the electrical connections are completed to enable the verification of a benign electrical environment. To remove any contaminants the connector is flushed with seawater first, fresh water second, alcohol third, and dielectric fluid last. Then the dielectric fluid is analyzed to verify a benign electrical environment before the electrical and mechanical connection is completed. The process is enabled by a closed-loop flushing tool mounted on a conventional ROV, and takes less than 20 minutes in total to complete. **www.geoilandgas.com**

FEI upgrades 3D software

FEI has upgraded its Auto Slice & View three-dimensional (3D) reconstruction software to improve 3D imaging speed, accuracy, use, and cost effectiveness.

To affect productivity, the new Slice & View software 4.0 can combined imaging with analytical capabilities to prevent information loss when sectioning a sample, modify automated procedures on-the-fly, and add analytical signals if an unexpected feature is revealed. To save time, specific areas or slices can be selected for imaging and analysis. Slice & View analyses can also be performed at multiple sites to allow long, unattended runs over night or weekends.

For precision and accuracy, new algorithms help to ensure uniform thickness of the slices and precise and reproducible placement of each cut.

The interface has also been redesigned to optimize user guidance, streamline the setup of automated procedures, and enable procedures to be tagged as templates. **www.fei.com**

New Wärtsilä analysis launched

Wärtsilä has launched Wärtsilä Offline vibration analysis service, which monitors the health of propulsion and other rotating equipment, to detect and remedy component defects, alignment issues and balance problems.

In addition, Wärtsilä Engine efficiency monitoring service is now available for dual-fuel engines. With this service, customers can optimize their fuel consumption by adjusting their operations according to real-time data.

Wärtsilä Condition based maintenance service has been updated to allow daily follow-up of equipment condition, enabling Wärtsilä to take a more proactive role in supporting the customers' business.
www.wartsila.com

DIF Preview

A new way to P&A

In advance of the Deepwater Intervention Forum this 9-11 August 2016, Jerry Lee reports on a new approach to riserless plug and abandonment carried out by Wild Well Control in the US Gulf of Mexico.

With plugging and abandonment (P&A) projects on the rise and regulations expanding, companies are looking to optimize expenditures whenever possible.

New regulations require companies to isolate and test outer annuli of wells because the annuli between the casings may become leak paths after the well has been abandoned.

To address this issue, Wild Well Control, with support from Marubeni, developed a new riserless P&A approach that is currently being utilized in P&A operations in the Gulf of Mexico on a nine-well campaign. This new approach can be used on either a multiservice vessel or a rig.

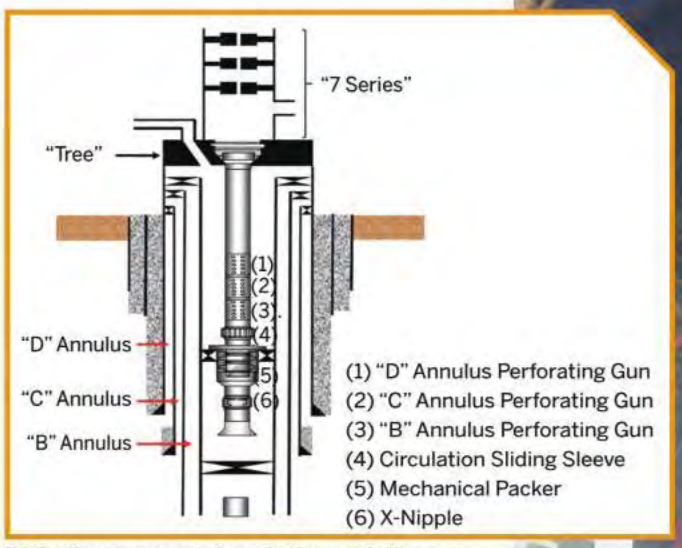
"Normally, it's done by cutting and removing the casings; I don't have an inner annulus if I remove the cut casings," says Martial Burguieres, vice president subsea well services, Wild Well Control. "We do just the opposite. We actually leave the casing in place and place competent, tested cement plugs in those outer annuli."

Prep to splash 7Series from *Ensco 8505*.
Photos from Marubeni and Wild Well Control.

The approach utilizes multiple Wild Well Control technologies and techniques. The 7Series is a 7 3/8in nominal light well riserless intervention system that is placed on the subsea tree (vertical or horizontal). With a pressure control head and lubricator assembly attached to the system, riserless intervention is enabled. DeepRange, a fully BSEE APM approved riserless P&A tool, is run in conjunction with the 7Series and allows perforating and circulating plugging material through an outer annulus, rather than perforating and squeezing. The concentric circulating system (CCS) is a pipe-in-pipe system that utilizes a 6 5/8in drill pipe and a 2 7/8in internal tubing to circulate material to and from the surface through flexible hoses between the CCS and the 7Series and the wellhead. The 6 5/8in drill pipe is also used as a landing string for the 7Series and the DeepRange (PA) tool. The well intervention control system was developed in conjunction with input from Oceaneering and provides subsea electro/hydraulic controls.

To perform the P&A operation, the crew first performs a temporary well abandonment, cutting and pulling tubing. The crew then sets a cast-iron bridge plug (CIBP) in the production casing, via e-line, and sets a packer assembly several hundred feet above the plug. The 7Series intervention system then connects to the wellhead and the DeepRange tool is run through the 7Series. After the PA seal assembly is stung into the packer, creating the "A" annulus between the tool and the production casing, the upper isolation assembly is locked and the crew retrieves the DeepRange running tool.

The casing is perforated below the packer using e-line carried charges specifically developed to penetrate the casing size(s) in the well. The casing above the packer is then perforated using charges carried on the PA tool tubing string. Using the CCS, circulation is



PA Tool component description and diagram.
Image from Marubeni and Wild Well Control.

established through the DeepRange tool and below the packer through the "B" annulus, and the returns are taken back to the vessel/rig. With circulation established, cement (and/or resin) is pumped into the "B" annulus. After it hardens, the well is pressure tested as required by applicable BSEE regulations. Unlike the perforating and squeezing method, where the cement can go up or down the annulus, successful circulation tests allow the location of the cement to be known and multiple annuli can be perforated and isolated. To date, as many as three annuli have been perforated, cemented, and tested.

With the first cementing job done, e-line perforation into the "C" annulus below the packer is performed. Testing through the "B" annulus upper perforations then confirms isolation of the lower perforations into the "C" annulus, and the second set of charges on the DeepRange tool are activated to penetrate into the "C" annulus above the packer. Circulation is then established through the "C" annulus. The circulation process is repeated, the cement (and/or resin) is pumped and set, and the cement is pressure tested.

"We leave the uppermost annular plug in what we call a balance condition, which is essentially a solid cement column across the well," Burguieres says. "This fully meets BSEE regulations for a plugged and abandoned well."

To complete the well abandonment, the DeepRange system is retrieved, another CIBP is set above the upper perforations, and cement is dump-bailed or spotted on top as another mechanical seal.

The systems are currently being used on the eighth well of a nine-well campaign. In the first seven successfully abandoned wells, anywhere from 1-3 annuli were required to be plugged and tested. The last two wells each have two annuli to be plugged and tested.

The Wild Well Control, Marubeni, and *Ensco 8505* rig operations teams overcame several new challenges on the first two wells: deploying the DeepRange tool, deploying the well control package below 7000ft, and using a new control system. **OE**

Running DeepRange assembly from *Ensco 8505*.

Wild Well Control will present on this topic at the 2016 Deepwater Intervention Forum this 9-11 August 2016, presented by ***OE****. To view the full agenda and/or register, visit:* **www.deepwaterintervention.com.**

Activity

NEL completes test facility upgrade

NEL has completed the latest upgrade phase of its wet gas test facility, in response to increasing industry demand. The upgraded facility has been designed to more accurately simulate the increased flowrates experienced during production and processing.

The UK facility can now achieve dry gas flowrates exceeding 2000cu m/hour, with simultaneous water and oil injection rates each of 90cu m/hour. These flowrates in pressures up to 63 bar mean that the facility can better simulate the conditions experienced in the field. "This upgrade enables us to meet our customers' growing demand to test meters in high pressure gas flows, and with water and oil liquid loading simultaneously," said Phil Mark, group manager for testing services at NEL. "The increased flow rates mean that wet gas flow meter manufacturers will be able to test larger meters than they have in the past. The facility will also be of interest to operators that are looking for independent validation and calibration of flow meters before they are installed in the field."

UTF Subsea award for Gullfaks Multiphase Compressor

This year's Underwater Technology Foundation (UTF) Subsea Award has been presented to Bernt Helge Torkildsen and Simon Kallgraff, from OneSubsea, and Jarle Ottar Hella and Caroline Bøe, from Statoil, for their significant contributions to OneSubsea's Multiphase compressor technology and its successful first installation at the Gullfaks field, offshore Norway.

The four individuals were nominated for the "stamina and visionary mindset" displayed as part of the work on this project over several years, which was instrumental in enabling this game-changing technology to be brought to market for use on subsea gas fields.

The winners received the award at a banquet dinner during the Underwater Technology Conference, held in Bergen, in June, at which ***OE*** is principal media partner.

Gullfaks subsea multiphase compression, using two OneSubsea multiphase compressors, came on stream on 17 September last year in Block 34/10 in the northern part of the Norwegian North Sea.

While they have since been temporarily removed, due to a leak in a utility cable not related to the compressor station delivered, Statoil has confirmed that the units had been operating to its satisfaction and are set to increase recovery rates on the field from 62% to 74% for the Gullfaks field.

Forum unveils test tank and accreditation

Forum Energy Technologies, a subsea technology provider, has unveiled a deepwater test facility and received industry accreditation for the calibration laboratory at its new European Operational Centre in Aberdeen.

The primary purpose of the test tank and laboratory is to provide full control, certification and faster turnaround in preparing Forum's rental inventory for hire. In addition, the firm will also offer a full test and calibration service to customers.

The indoor test tank is dedicated to testing subsea tooling and survey sensors as well as work-class remotely operated vehicles. It measures 5m x 6m x 4.5m, is fitted with overhead 10T crane, lighting, cameras, and a viewing platform.

The calibration laboratory has been accredited by Valeport and conforms to traceable procedures for the recalibration of Valeport CTDs (conductivity, temperature and density) and Sound Velocity sensors and parameters fitted on current meters, tide gauges, wave recorders and loggers.

Mokveld commissions test bunkers

Dutch firm Mokveld Valves has commissioned two new test bunkers for testing critical, high-quality valve systems.

Developed internally by Mokveld, the bunkers allow pressure testing with nitrogen and helium up to 1200 bar, and temperature testing within a range of -196-200°C. The bunkers are fully automatically controlled and meet the latest safety requirements.

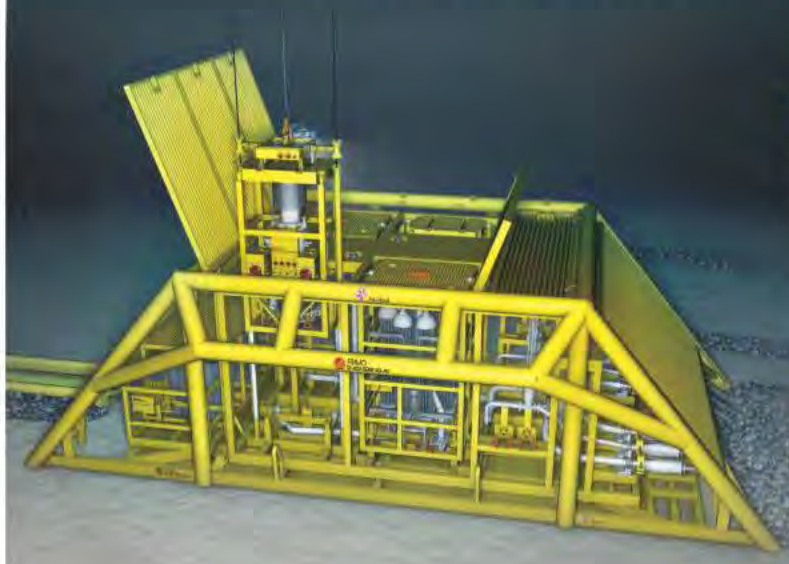
The bunkers were built to address the increasingly stringent demands of the industry in terms of quality and safety, such as fugitive emissions, PR2, or type approval testing.

After the completion of these bunkers Mokveld will continue to expands its testing facilities by constructing two other test bunkers which are expected be completed in 2016.

Editorial Index

What's next

Coming up in OE August



The Subsea Factory issue

OE shines a spotlight on the subsea factory with profiles of prominent projects and an examination of the market outlook.

Plus

- EPIC – Marginal Fields
- Subsea – Well Intervention
- Production – Inspection, Repair, Maintenance
- Drilling – Efficiency
- Automation – Networking
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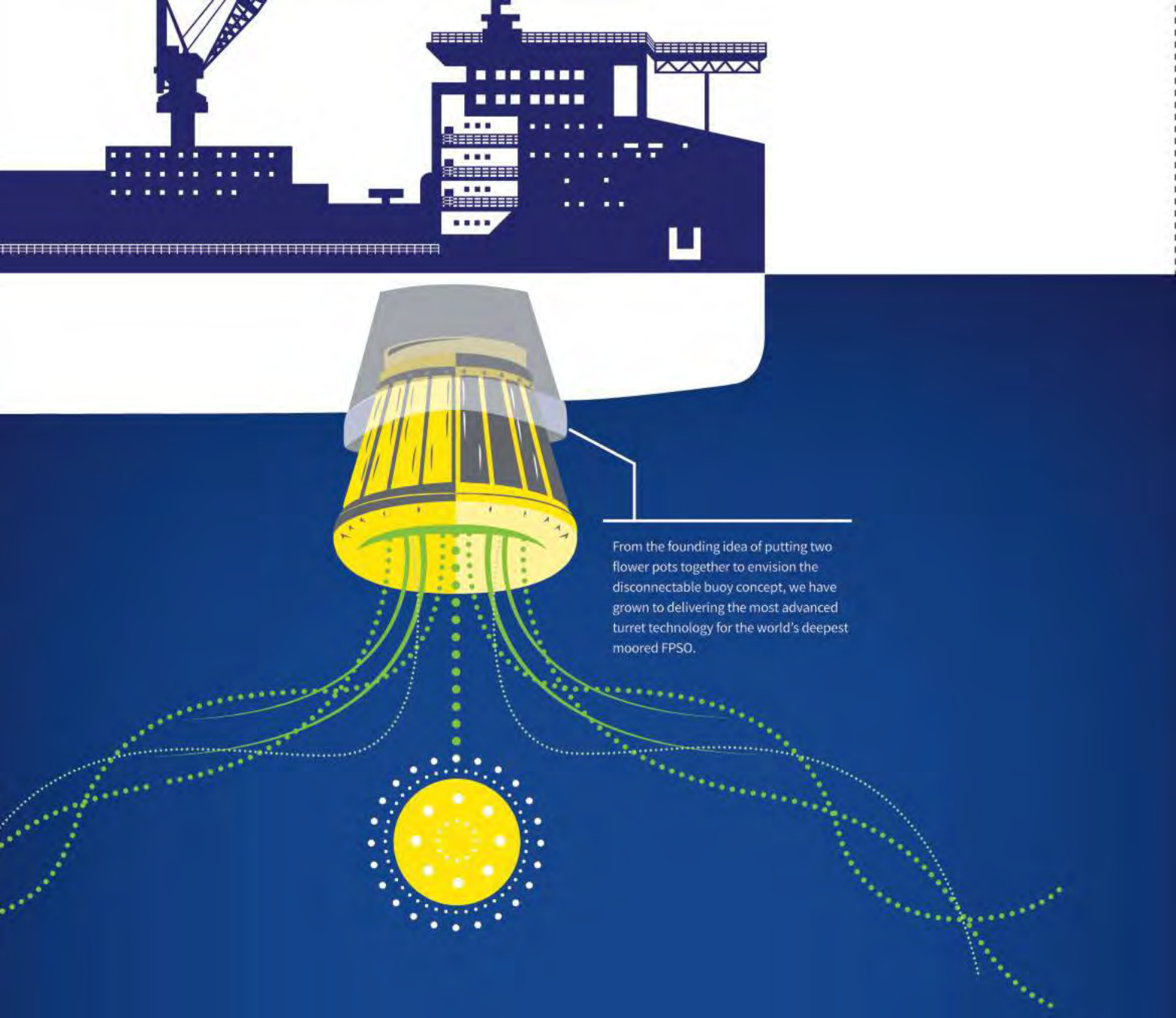

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