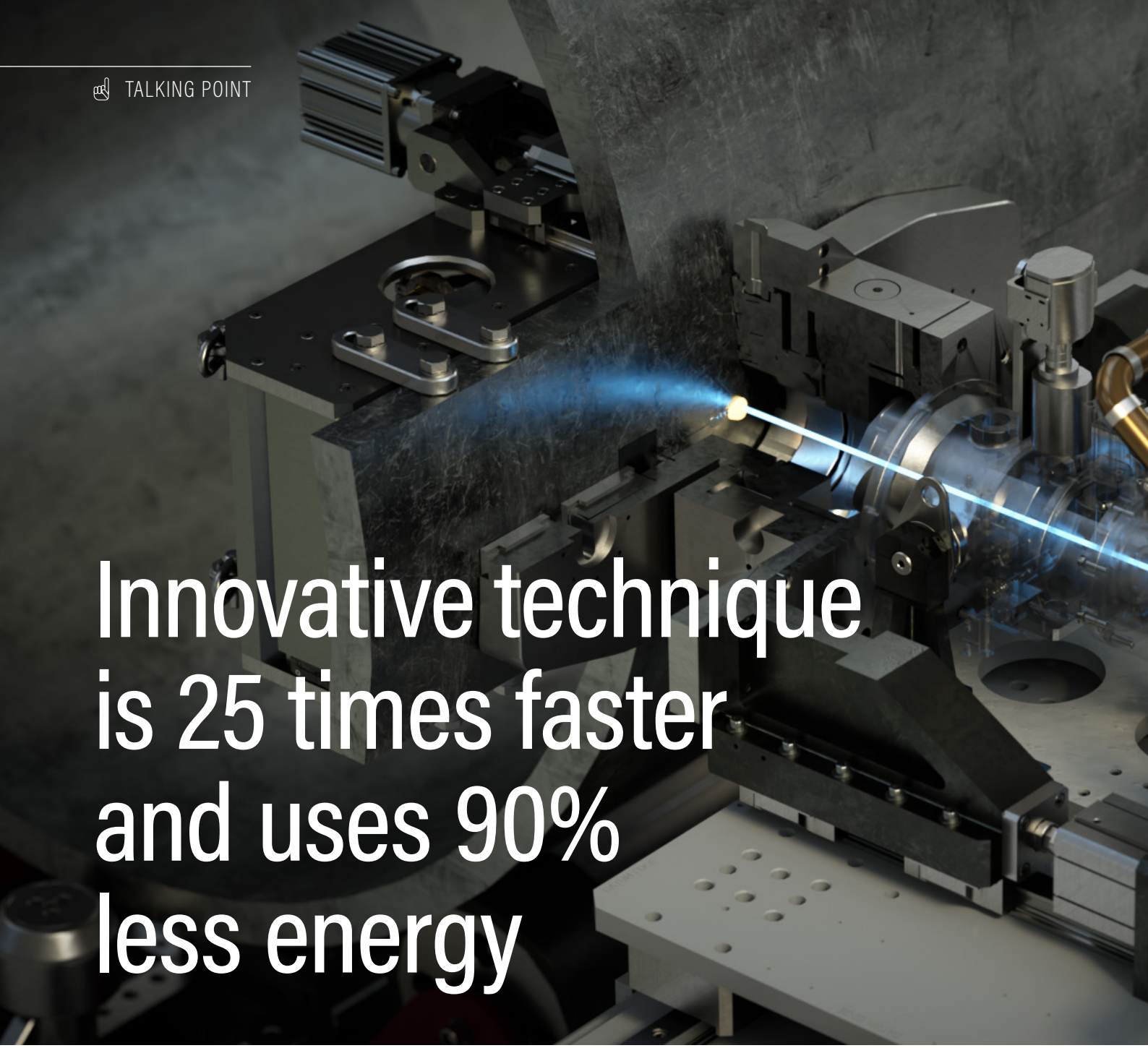


Innovative technique is 25 times faster and uses 90% less energy

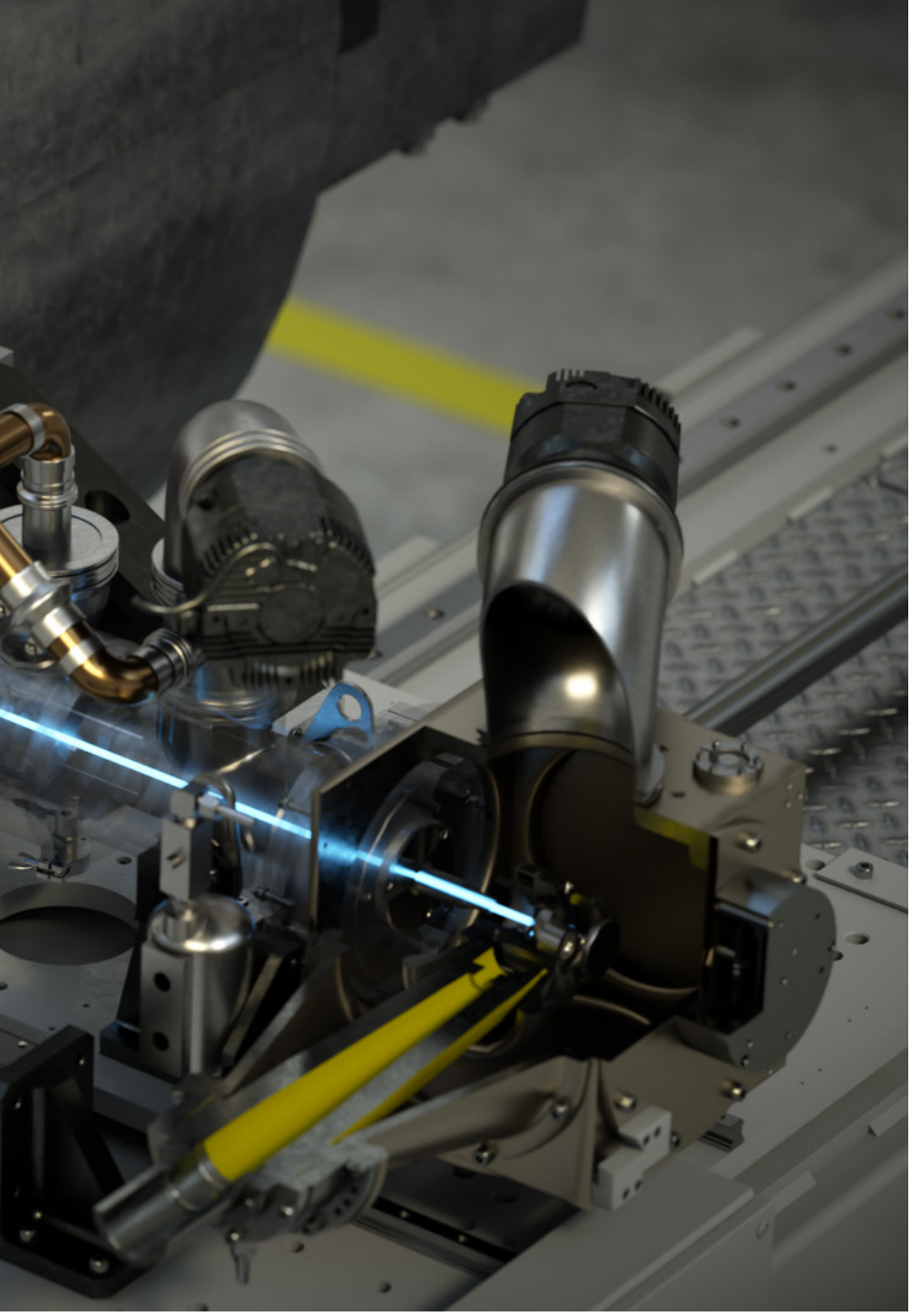
In December 2022, the UK Minister for Energy and Climate, Graham Stuart, signed a landmark agreement on renewable energy cooperation with the EU and North Seas countries. The agreement with the North Seas Energy Cooperation (NSEC) set out a framework for greater cooperation with the UK's North Seas neighbours, which will result in the development of an offshore renewable energy and grid infrastructure that is essential for meeting the UK's net zero commitment and bolstering European energy security[1].

This news was followed at the end of March 2023 by the launch of the UK Government's new energy strategy, Powering up Britain[2]. In this blueprint, the Government made clear its ambition to increase its offshore wind capacity, setting out the goal of delivering up to 50 gigawatts (GW) of offshore wind by 2030.

As the wind sector gears up to deliver on this target, turbine manufacturers are scaling up their search for innovative, transformational technologies that can help them accelerate the construction of offshore farms, both fixed or floating.

Ebflow™ from Cambridge Vacuum Engineering (CVE) is one such solution. In early May, it was announced that this innovative type of electron beam (EB) welding has been used to create the first-ever EB welded section to be incorporated in an offshore wind turbine monopile foundation transition piece.

Developed as part of a collaboration between CVE, SSE Renewables, Sif Group, and TWI, formerly The Welding Institute, the resulting



monopile is set for installation in the second phase of Dogger Bank Wind Farm, at present, the world's largest wind farm, which is located more than 130 km off the northeast coast of England.

Turbine monopiles are currently fabricated using conventional joining techniques, such as submerged arc welding (SAW). However, working together, the consortium has demonstrated that EB welding is significantly quicker, cheaper, cleaner, more energy efficient and produces high quality welds with excellent fatigue properties.

This is an innovative development that can weld monopiles at least 25 times faster than current SAW methods, cutting weld times down to 50 hours compared to 897 hours. It also uses 90% less energy, costs 88% less, and produces 97% less CO_2 emissions.

How EbflowTM works

Instead of welding inside a costly and size-limiting vacuum chamber, this solution uses a local vacuum system that creates and maintains a vacuum around only the seam that is being welded. This technique unleashes the potential to use EB welding on significantly larger components than in-chamber welding can accommodate, including the biggest monopiles. It also reduces costs and enhances productivity.

Employing sliding seals and precision handling, fast longitudinal welds can be created on large work pieces. It can also perform circumferential welds quickly and easily by changing the local head configuration. Data from CVE shows that Ebflow™ is 20 to 30 times faster than conventional submerged arc welding, with rates of 200 mm per minute achievable on 150 mm thick steel.

In addition, it is easy to transport and can be set-up and operated on-site, using readily available equipment. With on-site welding capabilities, there is the flexibility to weld objects of any size and to weld in a single pass. Transportation costs can also be reduced.

Crucially, Ebflow™ also doesn't require pre-heating. This is beneficial on several levels. With no pre-heating, energy costs are significantly lower, ~£6,323, compared to ~£57,480 for SAW. Post-weld inspections can also take place immediately, improving productivity.

Together, these factors add up to a greatly improved carbon footprint when you compare EB welding to SAW. CVE estimates that where SAW methods are used to create a turbine monopile, the amount of CO_2 produced would be in the region of 30,500 kg, that's the equivalent of 20 flights to New York and London. In contrast, this system only emits ~850kg of CO_2, the equivalent of half a flight from New York to London.

Aside from the obvious environmental and commercial benefits of using Ebflow™, the technology is also proven to deliver continuously repeatable and accurate high-quality welds, with localised residual stresses. The resulting weld is rendered metallurgically indistinguishable from the parent material, whilst also having minimal distortion.

Putting it into practice

The consortium involving CVE, SSE, Sif and TWI required the installation of an Ebflow™ system at Sif's Maasvlakte 2 facility in Rotterdam. On site, the technology was used to perform several longitudinal welds on 2750mm length seams on 8m diameter rolled cans with a wall thickness of between 67-85mm.

Qualification of the welding machine, weld procedures and operators was witnessed by third party inspectors and the regulatory body, DNV, which subsequently issued a technology qualification for EB welding and non-destructive testing (NDT) of the longitudinal seams produced with the process. This comprehensive testing programme proved that the system produces welds with fatigue strength that is at least as good, if not better, than observed in equivalent arc welded joints.

The resulting can was incorporated into a monopile transition piece in January 2023 and is scheduled to be installed offshore as part of a foundation in Dogger Bank Wind Farm in late 2023.

Olly Cass, SSE Renewables Project Director for Dogger Bank Wind Farm, said: 'This is a first-in-class project, establishing this UK innovation as a world-leading technology. With monopile type foundations accounting for over 90% of foundations used in UK projects, Ebflow™ RPEB could realise significant cost savings on future projects. These substantial savings will not only benefit the UK offshore engineering industry but could be passed on to UK energy consumers.'

'We're proud to be pioneering this innovative technique on Dogger Bank Wind Farm by demonstrating its capabilities on a critical offshore component and this would not have been possible without the great collaborative work with Cambridge Vacuum Engineering (CVE), Sif Group, and TWI. We're excited about what could be achieved by scaling up this method to pick up the pace as we work towards net zero targets.'

Chris Punshon, Head of New Energy Applications at CVE, said: 'The UK is already a leader in the world of offshore wind generation. The new targets set for the sector by UK Government mean a sustained period of further growth lays ahead. It's an exciting time for the industry and the pressure to deliver is now building. Turbine manufacturers must now ramp up their efforts, using proven technologies that can help them work more efficiently, without compromising quality or durability.

'Our work with our partners on the Dogger Bank monopile proves that the system will be a powerful asset in the toolkit of turbine manufacturers. We are excited to see the installation of the monopile we created together later this year and look forward to supporting the sector as it pushes ahead with the creation of more offshore wind farms.'

https://camvaceng.com/

Submerged Arc Welding		Ebflow
897 hours Pre-heat time: 1 hour Welding time: 896 hours (45 passes)	**TIME**	**50 hours** No pre-heat required Welding time: 50 hours (single pass)
65,982 kWh Pre-heat energy usage: 2,750 kWh Welding energy usage: 63,232 kWh	**ENERGY**	**1,860 kWh** No pre-heat required Welding energy usage: 1,860 kWh
£57,480 Cost of pre-heat: £1,100 Cost of consumables: £23,500 Cost of energy: £32,880	**COST**	**£6,323** No pre-heat required No consumables (filler wire or flux) Cost of energy : £6,323
30,484 kg Equivalent to 20 flights New York - London	**CO_2**	**859 kg** Equivalent to halfway of New York - London

Footnote:

1 https://www.gov.uk/government/news/uk-signs-agreement-on-offshore-renewable-energy-cooperation#:~:text=I'm%20pleased%20to%20agree,fivefold%20to%2050GW%20by%202030.

2 https://www.gov.uk/government/publications/powering-up-britain

Ebflow system highlights

A local vacuum is established and maintained only where it is needed

You can perform post-weld inspection immediately

Delivers increased weld quality and reliability, with low distortion

Minimal weld prep/bevel required – 'edge to edge' fit-up

Contributes towards significant improvements in carbon footprint, quality, economy, and productivity

The sliding seals and precision handling systems enable fast set-up and pre-welding operations for a variety of workpiece dimensions

Welding consumables are not required (no filler wire – autogenous)

Welding without pre-heating is possible