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MARINE LIMITED

Wavemaster Zero-C Project

— White paper

CONTENTS

Problem Statement

In 2018, the shipping industry was responsible for 1.08 gigatonnes of greenhouse gas emissions, of which 1.06 gigatonnes was CO2. Shipping emissions account for 2.89%[1] of global anthropogenic emissions, greater than the 6th most polluting country in the world[2].

There is thus a clear impetus for shipping to transition to lower carbon options. The offshore wind industry has the potential to act as a 'springboard' industry, providing early adoption of technologies and market models that can assist a broader maritime decarbonisation.

Bibby Marine Services is an operator of Service Operation Vessels (SOV). SOVs are medium sized ships that provide operation and maintenance to offshore wind farms which are too far for daily vessel visits from shore. SOVs can stay out in the field for 28 days, returning to one single port to refuel and restock. Based on current licence applications it is expected that 25 SOVs will be in operation worldwide, with 7 vessels operating in UK waters alone by 2025. As a market, SOVs make up roughly 0.02% of global maritime CO2 emissions. SOVs typically burn low polluting fuels such as Marine Gas Oil (MGO), as such their emissions won't have a big contribution compared to heavy fuel oil burning vessels such as tankers and cargo carriers. However, since SOVs are a medium to large sized vessel (70-120m typically), scaling up technology for this fleet can enable a zero emission pathway for large ships.

There remains large uncertainty about which technologies and fuels present the best solution for SOVs in the near term. The Bibby Wavemaster Zero-C project has therefore assessed available fuels for near term feasibility. This study considered fuel sourcing, energy density, storage, and cost to define a route forward.

This paper details the outcomes of the Bibby Wavemaster Zero-C project and necessary support required moving forwards to enable the vision of zero-carbon SOVs in service by 2025.

1 International Maritime Organization, "Fourth IMO GHG Study 2020 -Final Report," 2020.
2 Union of Concerned Scientists, "Each Country's Share of CO2 Emissions," Union of Concerned Scientists, 12 08 2020. [Online]. Available: https://www.ucsusa.org/resources/each-countrys-share-co2-emissions. [Accessed 11 12 2020].

Project Findings

Using Maritime 2050 and the Clean Maritime Plan as a basis, Bibby identified 5 fuels which have strong potential to fuel SOVs and larger vessels. While all of these fuels have the potential to be zero carbon fuels for shipping, each have different advantages and challenges attributed to them.

The shortlist of fuels were biodiesel, hydrogen, ammonia, methanol and batteries.

The Wavemaster Zero C project conducted a comprehensive assessment of these fuels, taking into consideration vessel, port and decarbonisation requirements. This assessment was based on the Bibby Service Operation Vessel 7071 Configuration, Figure 1. This vessel has installed engine power of 3600 ekW, distributed over 3 diesel generators and a diesel fuel oil capacity of 260 m3; sufficient for 1 month of operation.

The summary of the fuel assessment for this vessel can be seen in Figure 2. This aims to take account of all major drivers for fuel selection, including not only technology performance but also technology readiness, commercial viability and environmental impact.

It is recognised that this assessment has been made based on today's technology availability and pricing. Therefore, fuels which have a longer lead time to market, such as hydrogen, may in the future present a more attractive offering than they do today. However, this approach is accepted as offshore wind is a new and rapidly growing market, up to 100 new SOVs, are expected to be built between now and 2030 to serve European farms, Figure 8. Delaying the utilisation of new fuels which are available today will allow this fleet to come to market with today's technology and miss the potential decarbonisation benefit between now and 2030. This could result in an increase in Offshore Wind O&M emissions as more farms become operational. Although in the longer term green hydrogen may be a credible solution, near term technology demonstrations will instead be focused on fuels which have the potential to reach market by 2025.

When considering operation of a single ship, bio-diesel scored highly. This can be considered a "drop-in" fuel, meaning vessel and fuel bunkering change required would be minimised and existing infrastructure could be used. However, when considering a future fleet, the availability of the crop and fuel will be a significant challenge. There will also be competition for these fuels with other industries, such as aviation, meaning sourcing this fuel for marine use may be problematic. These fuels are also, at best, net-zero carbon as opposed to true-zero; carbon is removed from the atmosphere in the production of this hydrocarbon fuel which is then burned by the vessel, releasing the CO2. For these reasons, although a high scoring fuel, it is considered that biodiesel should NOT be pursued for further product development.

Figure 1 - Baseline vessel

Fuel	Biodiesel	Hydrogen		Ammonia	Methane	Batteries
		LH2/GH2	LOHC			
Energy Density						
Energy Source Availability						
Commercial availability						
Production Technology Readiness						
Transport, Supply & Storage Technology Readiness						
Bunkering Technology Readiness						
Infrastructure						
Cost						
Environmental impact						
Total	26.3	10.3	10	13.7	18.3	18.7

Figure 2 - Technology assessment scoring

The fuels selected for potential for near term technology demonstration are therefore methanol and batteries.

Methanol

Methanol has the potential to offer significant emissions savings, however as with bio-diesel it is a net zero, rather than true zero option. Synthetic methanol (a.k.a. Green-methanol or e-Methanol) will be required in order for operations to be carbon neutral. As with bio-diesel, there will be challenges around the supply of this, but over the longer term it is expected to become commercially available to maritime users. Methanol which is not carbon neutral could play a part in the "transition phase". Methanol offers a number of advantages as a fuel, including its low cost, ease of production and handling, and compatibility with existing engine technologies. The use of fuel cells in combination with methanol is an area of interest over the medium to longer term and could also be of interest as part of a longer term transition to hydrogen.

Batteries

Batteries are the only near term true zero carbon option. The have operational range limitations compared to traditional fuels, however, the technology would still be capable of supporting offshore wind operations if there was locally available recharging facilities at wind farms. Several projects have been funded under CMDC Round 1 to deliver such technologies and first of kind products can be expected to reach market around 2025. Although battery OPEX costs are likely to be acceptable, the capex costs of the battery remains high; it is likely an incentive will be required to promote the accelerated transition to battery technologies. Additionally, battery life limitations are still significant, development is needed to ensure robust batteries which can maintain performance over the life of the vessel.

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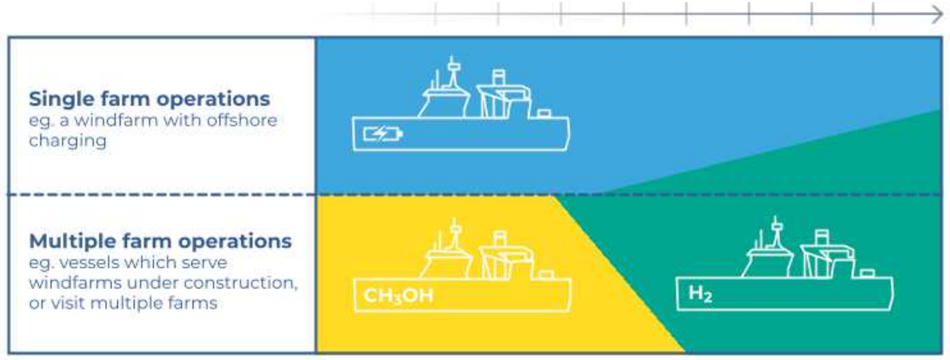

Figure 3 - Technology Priorities

Technology priorities

Both battery and methanol options score similarly, but have different strengths and limitations vs. the baseline of marine gas oil (MGO). As there is no 'silver bullet' technology which can be selected, when considering a new-build SOV model we have to consider the specific use of the vessel.

Batteries, as the only true zero option, offer potentially the largest near term carbon reduction. They are however, limited in terms of available range and time at sea without a recharge. During the operations and maintenance phase of a wind farm, which is the majority of it's lifecycle, it is possible for offshore infrastructure to be put in place to accommodate at wind farm recharging. This infrastructure will not be possible however, for offshore wind farms which are in the construction phase, and battery recharge time may also limit operations where a single SOV is used to visit multiple wind farms or sites. It is therefore expected that methanol vessels will be the primary fuel of choice for this market segment in the short to medium term.

Over the longer term, and in particular if we see uptake in other industry sectors, it's anticipated that hydrogen will have a role to play and could potentially serve both segments of this market. Hydrogen technology development will therefore remain an area of interest, although technology demonstrations in the near term will focus on closer to market technologies.

Supporting infrastructure development

The Wavemaster Zero-C project also looked at the supporting port and offshore infrastructure required to refuel green vessels. Eventually, this infrastructure will be required at ports across the UK. However, at this early stage, when new fuels and infrastructure are expensive, when utilisation of these fuels is low, and when future fuel pathways are not yet clear, it is a commercial challenge for ports who wish to implement this infrastructure.

The offshore wind industry has the potential to accelerate this, by providing firm and long term utilisation. Operations and maintenance ports are chosen ahead of the construction phase of a windfarm and both CTV and SOV utilisation of the selected port is therefore typically secured for the life of the farm; 20 years +. In particular, SOVs, which have long tender times and typically serve a single wind farm, can provide a significant and repeated utilisation forecast for the ports they frequent. As part of the next step technology demonstration, finding a partner port to deliver this infrastructure will be crucial, this project has identified strong potential UK candidates.

Battery charging upgrades required

Fuel handing of batteries or shore charging is inherently different to traditional fuels as there is no liquid or gas to transport. Electrification does negate the risk of fuel spillage but introduces new safety concerns regarding high voltages at the quayside. Charging cables can be isolated during the hook up to the vessel to help reduce this risk and safety and handling procedures would need to be considered.

The size of the batteries on the vessel and charging time requirements would drive the size of the cable and voltages, and rapid charging technologies could reduce the vessel downtime but could require higher infrastructure investment. Electric charging bunkering follows two main methodologies: direct charging with a loading arm, or wireless induction charging. Although wireless charging is still in development, shoreside power supply via loading arm is currently in use in various ports around the world.

Additionally, a shore charging system supplemented with smart grid connected batteries could offer benefits. It could reduce cost by scheduling battery charging when there is excess supply to the grid, for example, at off-peak hours overnight. It could also be connected directly into local renewable energy generation (wind, solar, etc.), reducing the carbon footprint of the charging scheme further.

Methanol upgrades required

Due to the similarity to MGO, infrastructure changes required for methanol would be minimal. However, methanol has a lower volumetric energy density than MGO, therefore around 2.3 times more storage space is required to maintain the same overall energy capacity.

Fuel handing requirements for methanol are broadly similar to that of MGO, however the toxicity and fire hazards of the fuel may require additional precautions, including alcohol-resistant foams, to be implemented during handling. Methanol must be stored in metal or glass containers and supply systems must include stainless steel pipe work and have solvent resistant coating on the inside of all supply hoses. Double walled piping may also be used as a precaution.

Bunkering for methanol would follow a similar series of operations to MGO, and has been implemented at over 100 ports worldwide, including for the Stena Germanica RoPax ferry operating between Kiel and Gothenburg.

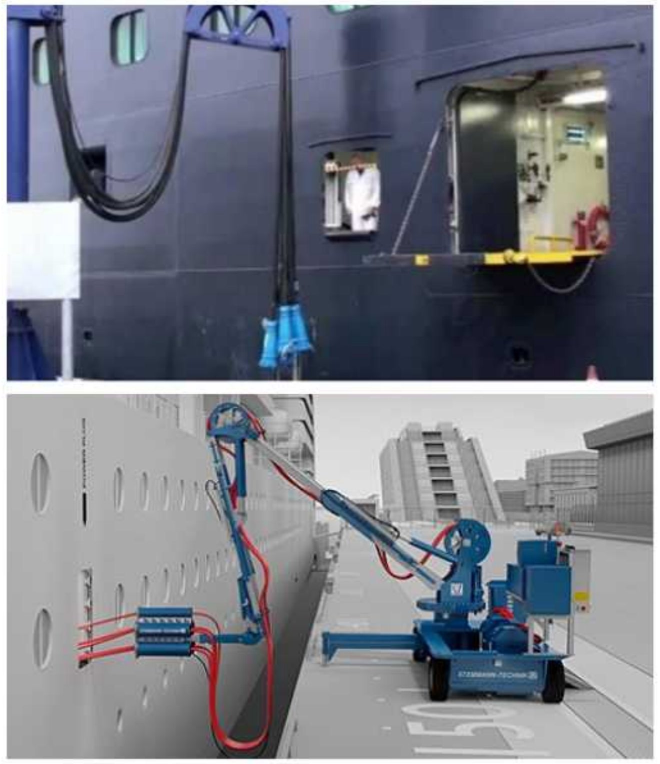

Figure 4 - Shore Power Loading Arms[3]

Figure 5 - Stena Germanica Methanol Refuelling Infrastructure

3 https://electrotechnical-officer.com/shore-supply-connection-on-ship-electrical-system, https://www.stemmann.com/en/products/onshore_power_supply/shore_connect_for_cruise_line_ships

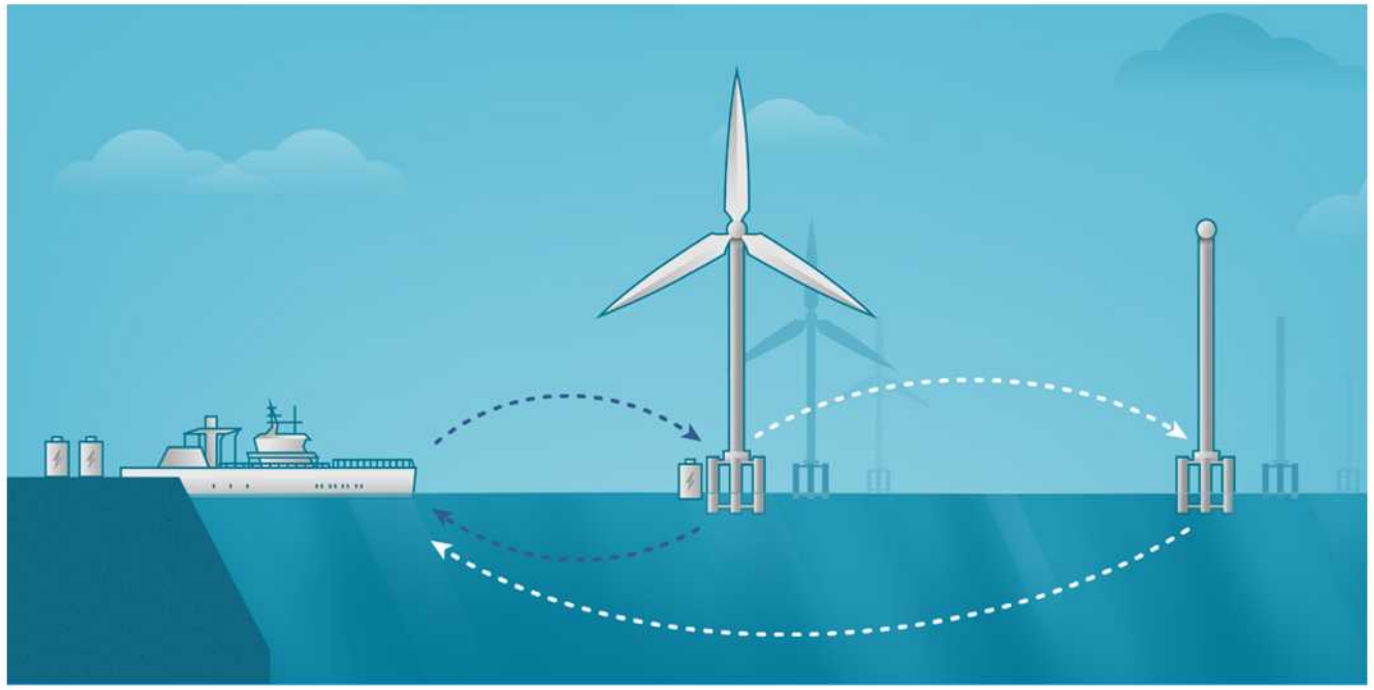

Figure 6 - Future infrastructure and Fuel mix

Offshore Recharging

In addition to the infrastructure needed by ports, a move to offshore charging infrastructure could also potentially revolutionise offshore vessel operation. Recharging at a wind farm would allow SOVs to operate with reduced range, opening up the opportunity for battery powered vessels. These systems would allow e-CTVs and e-SOVs to plug directly into the wind turbine for recharging at sea. There are various developments in progress to develop this infrastructure, including CMDC projects by MJR, and a collaboration between Verlume and Oasis Marine. Maersk are also developing an offshore recharging solution. It is expected that the optimum recharging solution in the future will incorporate both onshore and offshore recharging, and we may start to see this infrastructure around offshore wind ports by 2025.

Next Steps

Battery Powered Vessel Technology Demonstration

The Bibby Wavemaster SOV typically supports a single wind farm from a single port of operation. The first priority for demonstration will therefore be a battery powered vessel.

This will be:

- Suitable for routes which Bibby's vessels operate today.
- Capable of delivering a route to true zero operation.
- Potentially backed up by smaller methanol engine if required.
- Cheaper to operate than a similar methanol vessel over time (excluding the high initial capex cost).
- Capable of delivering a reduction in other emissions (e.g. NOx) compared to combustion alternatives.

It is expected this technology demonstration will be supported as part of the Clean Maritime Demonstration Competition, and will be completed by Q1 2025.

Delivery of this technology demonstration project will showcase UK leadership in the design and manufacture of industry leading, battery powered vessels. This SOV, as medium to large sized vessel, can also demonstrate how these technologies can scale up to enable a zero emission pathway for other maritime applications.

UK Build Study

Although this study has not looked in detail at the UK design and manufacture supply chain for these vessels, the National Shipbuilding Strategy Refresh[4] identified vessels supporting offshore wind as a potential route to growing UK content and supporting UK shipbuilding. Currently, none of the SOVs operating in UK waters were built in the UK. Following this project, and in collaboration with the National Shipbuilding Office, it will be a priority to engage with UK shipyards with the potential to manufacture these vessels, to ensure they are well placed to support demonstration and first-of-kind vessels in the next 1-5 years. Building these early vessels could position UK shipbuilding to be at the forefront of a market delivering between 129-309 new build SOVs by 2050, Figure 8, as well as developing technologies and skills which could be applied to the wider maritime sector.

Remaining barriers to adoption for this vessel

To deliver this battery vessel demonstration to market, with maximum UK content, there are still significant barriers to overcome by 2025:

- High initial CAPEX costs of batteries.
- Securing demonstration funding for 2 year technology development project.
- Ensuring UK Supply chain readiness for the manufacture of future vessels.
- Ensuring port shore power and offshore infrastructure readiness, availability and regulation.

Figure 7 - Battery vessel configuration

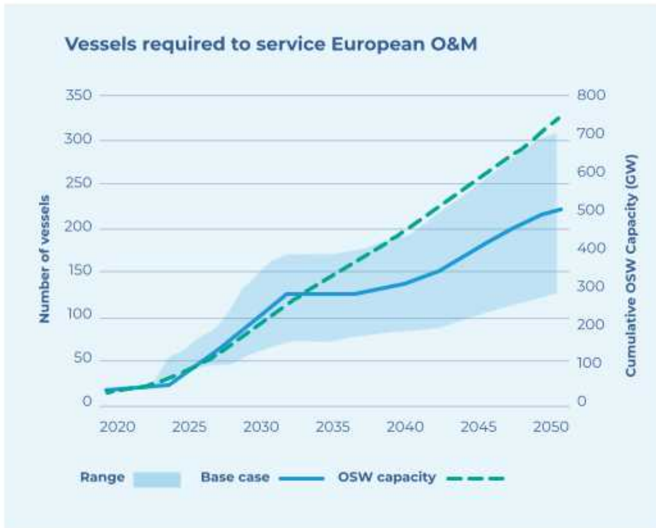

Figure 8 - Pipeline of SOVs serving European O&M

4 Refresh to the National Shipbuilding Strategy - GOV.UK (www.gov.uk)

What action is needed?

Having identified a significant market opportunity for these vessels, a credible technology pathway and tangible next steps, this paper seeks to identify key priority actions which would support successful vessel delivery to market. This will require collaborative action from Governments and Industry, including collaboration between offshore wind developers and the maritime supply chain.

In the next 12 months, priority actions are:

- Sourcing demonstration funding for a 2 year demonstration project. To enable a 2 year demonstration project, this funding will ideally be available at the beginning of 2023/24 tax year. The Clean Maritime Competition is a potential route to support this action, but a significant increase in project duration in comparison to CMDC rounds 1 and 2 will be required to enable surety of funding for this 2 year technology demonstration.

- A study of UK supply chain readiness and, pending study results, support to ensure readiness. None of the SOVs currently serving UK offshore wind farms were built in the UK. To improve this position moving forward, an understanding of the ability of UK yards to build these vessels to a competitive time and cost needs to be better understood. It is possible that technology implementation could enable UK build.

In the next 2 years, priority actions are:

- Implementing policy incentives requiring vessels to be "clean". In the next 5-10 years, it is unlikely that any novel fuel will be cost competitive with the current baseline. This is due to either high initial CAPEX for technologies such as batteries, or expensive fuel production pathways for fuels such as e-Methanol. Incentivising a clean fleet via policy and regulation would enable the context for transition. This could be done via inclusion of offshore wind vessels in the UK ETS, or potentially by including clean vessels in future CfD allocations.

- Ensuring demonstration infrastructure availability in same timeframe as vessel demonstration. To support this demonstration a lead port will be required to implement shore power, and, preferably, an offshore recharging demonstration for this vessel could also be conducted. As this infrastructure will, in the first instance, only support a single vessel, it is likely to also require demonstration funding until increased utilisation is possible.

In the next 3 years, priority actions are:

- Support for high initial CAPEX for cleaner vessels. CAPEX costs for the first generation of clean vessels could be 20-50% more expensive than baseline. This will be partly offset by potentially reduced OPEX costs, but support for high initial costs for first movers is still expected to be required. The business model for battery operated fleets are yet to be fully understood. Potentially, battery "leasing" schemes, where the cost of the battery and energy is spread over the life of the vessel, could reduce the impact of this high initial CAPEX. However, annual tax incentives, akin to reduced road tax for electric cars, could still be utilised to ensure there is minimal additional cost for operators who choose a clean vessel.

Conclusion

The rapid growth of the offshore wind sector ensures the opportunity in the design, manufacture and operation of these vessels is significant. Early support for design and manufacture demonstrations, coupled with underpinning policy actions outlined above will allow the UK to be at the forefront of this opportunity.

Bibby Marine Services are well placed to deliver technology demonstrations, building on already strong sector understanding and support. The Wavemaster Zero-C project has identified optimum technology pathways, enabling a transition to vessel demonstration to be carried out within a 2 year timeframe. To support near time operationalisation and maximise emissions savings, battery electric technology will be the focus of this demonstration. The actions outlined in this report will enable this technology demonstration to transition to operational carbon savings by 2025, as well as creating meaningful jobs, increasing GVA and learning in the UK.

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MARINE LIMITED

Bibby Marine Limited
3rd Floor, Walker House, Exchange Flags,
Liverpool L2 3YL
Phone: (0151) 708 8000
www.bibbymarine.com