ScottishPower Renewables

STILLSTROM by Maersk

OPERATION ZERO

Electrification of Service Operation Vessels.

Offshore charging solutions for Service Operation Vessels:
A cost competitive enabler to decarbonise marine operations
in offshore wind farms and de-risk future fuel-costs.

A white paper made by ScottishPower Renewables and Stillstrom by Maersk

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Executive Summary

ScottishPower Renewables (SPR), part of the Iberdrola Group, is a leading developer of renewable energy solutions, driving the transition to a cleaner, greener and more sustainable future. The company has established ambitious Greenhouse Gas (GHG) emission reduction targets and is exploring technologies which can contribute to decarbonising its marine operations. SPR in collaboration with Stillstrom conducted a feasibility study to assess the viability of integrating and operating offshore charging infrastructure in their windfarms. This White Paper presents the main conclusions from that feasibility study and is shared with the wider industry via the Operation Zero initiative, in the hope that improved understanding of the technology will accelerate adoption of zero emission vessels.

During the operation and maintenance (O&M) phase, an offshore wind farm (OWF) needs to be supported by a range of vessels, among these, Service Operation Vessels (SOVs), which can operate for several weeks in the OWF before being required to return to port for refuelling or other needs. SOVs are today almost entirely fuelled by fossil fuels like marine gas oil (MGO), with the GHG emissions from SOVs typically representing 15-20% of total emissions across the lifecycle of an OWF.

Electrification of marine vessels is in general advancing following the continued development of better and cheaper battery technologies enabling decarbonised vessel operations as well as emission free propulsion and lower frequency servicing requirements.

Fully electric ferries have begun servicing shorter distances creating knowledge and improved technology on how vessel electrification can be operated. Next step on the vessel electrification journey is to operate in more open waters without frequent port calls. Battery-powered Service Operation Vessels (E-SOV) in OWFs could be the technology that showcases operations in open waters. E-SOVs can thereby both reduce GHG emissions in OWFs and act as inspiration for coming steps like hybrid battery-powered container vessels, which are likely to be an economically attractive decarbonised option within a regional route going forward. [1]

A key challenge in marine electrification is the lack of access to grid and charging infrastructure for vessels, but OWFs bring the grid infrastructure to the open waters, thereby creating opportunities to charge vessels offshore using energy derived directly from wind turbines.

The study showed that the inclusion of offshore charging and E-SOVs in an OWF is fully feasible from a technological, operational and economic perspective. An OWF operator can install a charging system in-situ, which can be used to recharge E-SOVs on-site, with the power generated from the OWF itself. This can contribute significantly to the decarbonisation of O&M tasks at sea.

The OWF owner benefits from being able to provide electricity from the OWF, thereby securing greater control over fuel costs for the SOV. The SOV operator benefits from this security of supply and can de-risk future fuel costs, mitigate against potential geopolitical risks, and against increasing regulatory costs of GHG emissions.

An OWF of around 1 GW would typically be serviced by an E-SOV with a battery capacity of around 25 MWh. The service vessel in such a set-up can operate under battery power in a zero-emission mode for up to 18-19 hours a day and charge during the night or when the operational schedule allows.

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[1] Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. (2024, September 4). Understanding the potential of battery-electric propulsion for cargo vessels: A pre-feasibility study. https://www.zerocarbonshipping.com/publications/understanding-the-potential-of-battery-powered-vessels-for-deep-sea-shipping/

A transition to battery electric operations using power generated in an OWF for fuelling would cut O&M related CO_2-emissions by approximately 4,700 tons CO_2 per year compared with using marine gas oil as fuel for a service operation vessel.

This study shows that already today the business case for a combination of electrical charging infrastructure and E-SOVs for new OWFs is a cheaper option than other decarbonised solutions such as e-methanol fuelled SOVs. Moreover, it is within competitive range of the business case for MGO based SOVs, when all costs and benefits for the OWF-owner are considered for SOV operations.

Charging infrastructure located on an offshore substation (OSS) or wind turbine generator (WTG) will require structural modifications to accommodate the weight and loads imparted by the equipment. Therefore, it will be cheaper and easier to design for a charging solution in the design phase of a new OWF compared to the case of retrofit. Retrofitting is possible but it will be more challenging as the new load on the structure will have to be re-calculated and approved. Engineering-wise this is possible, but it will come with additional costs to handle warranties and liabilities.

Depending on the operational requirements for the site and its geographic size and layout, an OWF of around 1 GW will typically require one or two offshore charging stations. Therefore, only one or two structures in the OWF will require adaptions to host the offshore charger.

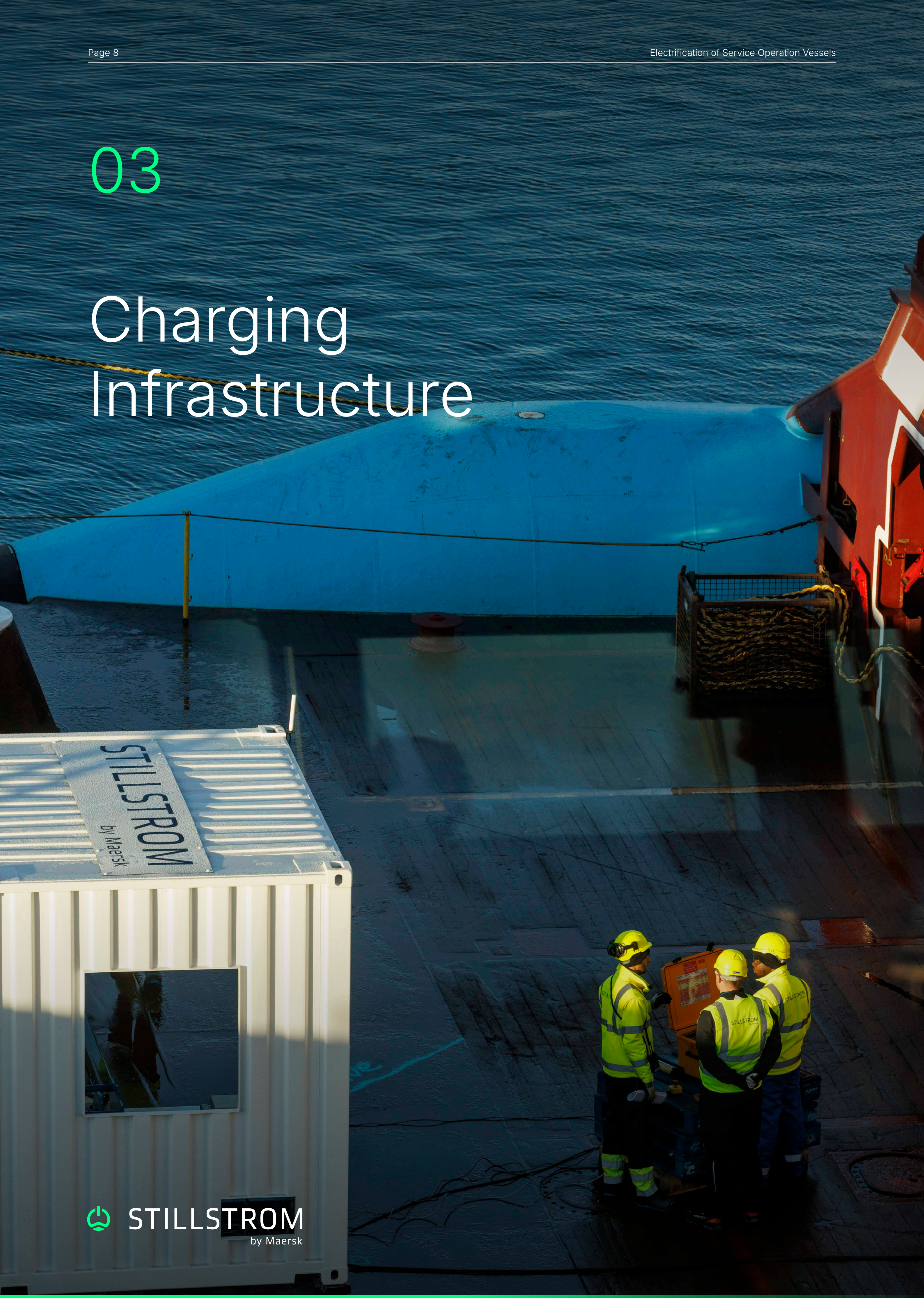
02

Offshore Charging

In recent years, OWF owners have faced increasing pressure to decarbonise their assets and reduce emissions. O&M activities represent a significant emission source which, to date, have been largely unaddressed. Electrifying SOV operations is a commercially viable and highly energy efficient solution that can contribute to addressing O&M emissions. Using an E-SOV can replace fossil fuels and thereby avoid GHG emissions, remove particle emissions like NOx and SOx, and reduce noise due to electric propulsion being a quieter option in comparison to a standard combustion marine engine.

To support the daily O&M schedule in an OWF a standard E-SOV will use approximately 1-1.2 MWh/h, from a combination of transit, idling on dynamic positioning (DP) and transferring personnel. After 18 hours of daily operation, a 6-hour window remains for connecting and recharging the batteries before the daily cycle repeats. Consequently, to replenish the depleted battery while simultaneously providing power to the E-SOV's hotel load and DP systems, a power transfer to the vessel of around 6 MW is needed.

Stillstrom provides technology with 6 MW of charging capacity, and the ability to increase this up to 8 MW on request. From the outset it has been paramount to keep the system safe and robust while balancing the trade-off between using the lowest possible standard voltage and avoiding high current capacity. This ensures compliance with the IEC 80005 standard for shore power and providing a voltage of 11 kV to run this power capacity in just one cable from the fixed charging point to the vessel.



03

Charging Infrastructure

The concept is to charge in the OWF, where the E-SOV operates. The OWF offers dense electrical infrastructure in a defined operational area with the possibility to connect to ample power. The E-SOV connects directly to a WTG or an OSS via a Stillstrom Offshore electrical Charger (SOeC), see figure 1 below.

Figure 1: The concept of offshore charging

3.1. Stillstrom Offshore electrical Charger

The SOeC is based on a modularised system, which provides an end-to-end solution for facilitating the power transfer from the OWF to the E-SOV. The modularised approach ensures that regardless of the chosen charging solution (hang-off or buoy – see overview below) the technology itself is the same across the SOeC solutions. The SOeC technology solution connected to the WTG or OSS consists of:

- Boom crane
- Cable reel and winch
- Umbilical cable
- Local equipment room
- 66/11 kV transformer with neutral earthing resitor

The location of the charger and the concept for connection can be adapted to the specific layout and requirements of the OWF. The standard solution is to use existing structures as described above and locate the hang-off and the charger either on a WTG or the OSS. In some cases, it may not be possible to place the charger on a WTG or OSS. In those instances the charger may be located on a stand-alone structure such as a buoy or dedicated foundation using a separate subsea cable to connect to the overall OWF infrastructure.

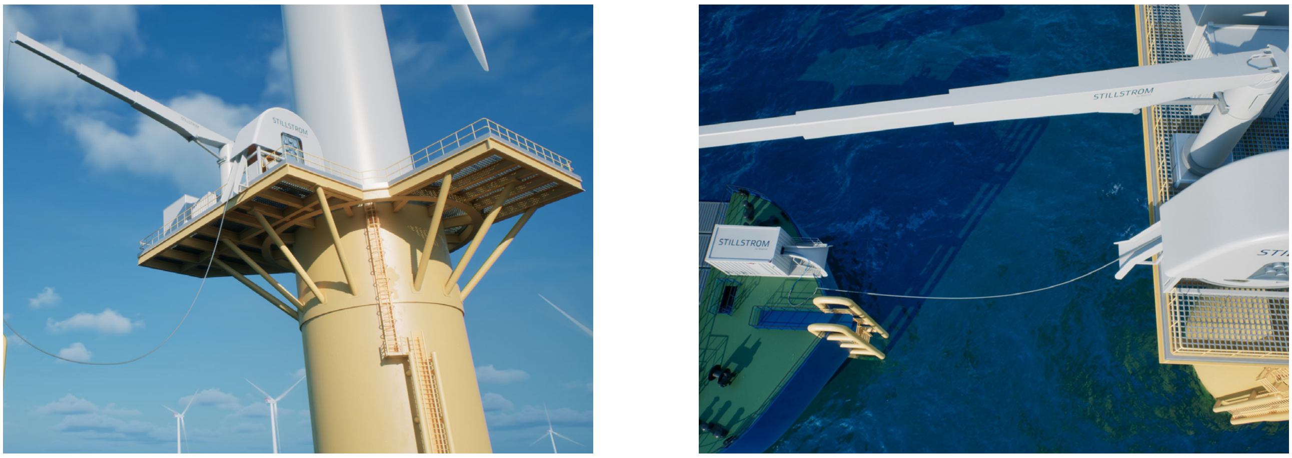
Stillstrom will also provide a vessel connection unit (VCU), which will be installed on the E-SOV to ensure an optimal interface to the vessel and the vessel's battery system.

The VCU will consist of:

- Containerised housing of the vessel equipment and cable chute
- Pull-in winch
- Connector
- Latching mechanism
- Electrical components

The location of the VCU is flexible. Figure 2 below illustrates an aft deck arrangement.

Figure 2: SOeC solutions and vessel connection unit



Hang-off from WTG

Hang-off from OSS

Separate charger, buoy/foundation

Vessel connection unit

3.2. Technical feasibility

Battery powered vessels are available and are already proven across different vessel segments. The SOeC solution is based on existing technologies and adapted to operations in the harsh offshore environment.

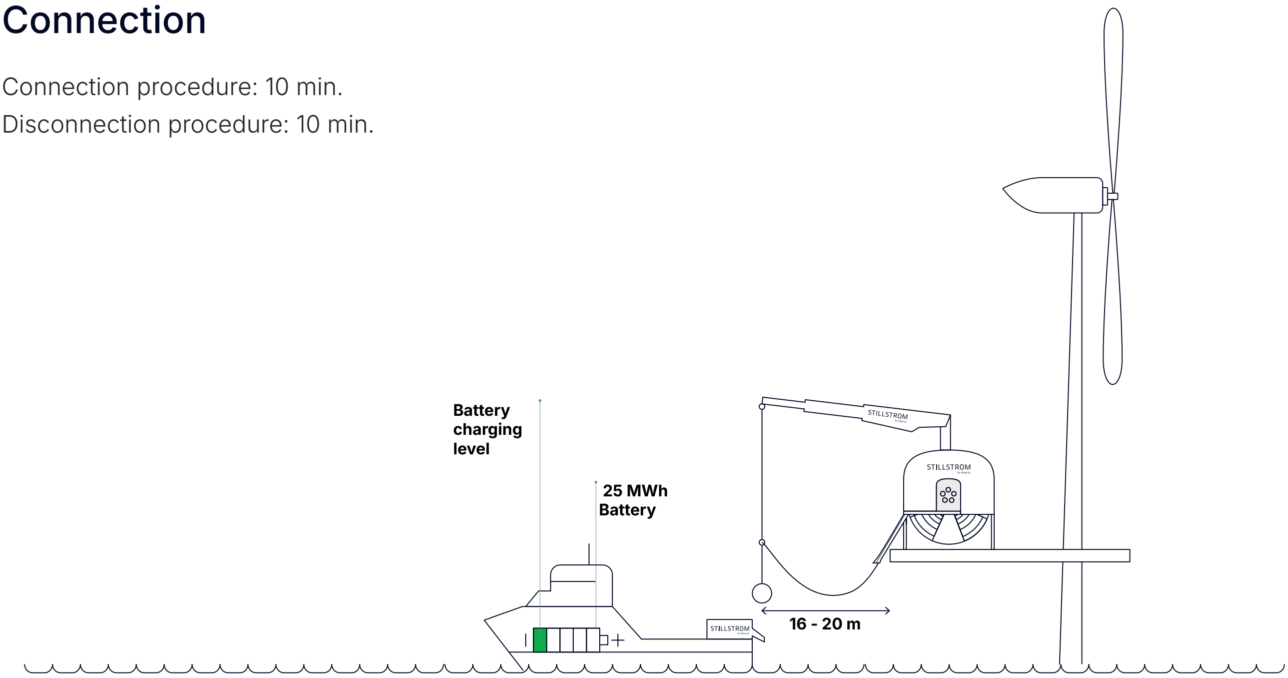
The charger will have an interface at the OWF as the power supplier and an interface to the E-SOV as the power consumer. The SOeC-solution will also include a SCADA and vessel connected solution to ensure data communication between the OWF, the SOeC and the E-SOV. The solution will be automated to a broad extent to allow safe and efficient handling of the charging process with no manual handling for establishing the connection.

Table 1: Main specifications of the SOeC solution

Parameter	**Value**
Input voltage to charger from WTG or OSS	33, 66 or 132 kV
Output voltage from charger to vessel battery	11 kV
Frequency	50 Hz or 60 Hz
Charging power – effective	6-8 MW
Recommended metocean conditions while connecting/disconnecting	Wave height up to 2.5 m Hs, wind gust up to 18 m/s. Metocean limits depend on E-SOVs DP capabilities and risk profile
Recommended metocean conditions while charging	Wave height up to 4.5 m Hs, Metocean limits depend on E-SOVs DP capabilities and risk profile
Design lifetime	25 – 35 years
Emergency disconnect	Yes

Connection

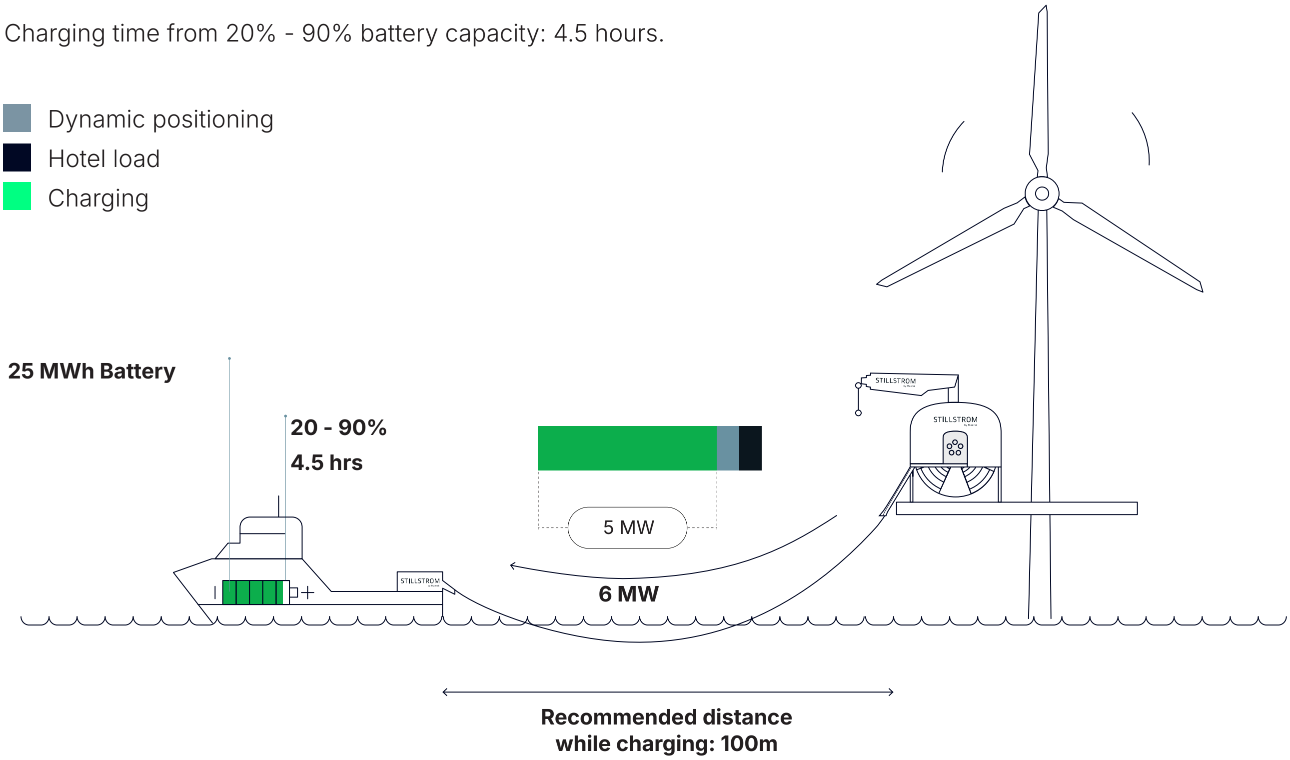
Connection procedure: 10 min.
Disconnection procedure: 10 min.



Charging

Charging time from 20% - 90% battery capacity: 4.5 hours.

▨ Dynamic positioning
■ Hotel load
🟩 Charging



3.2.1. The offshore wind farm

In the OWF the SOeC will be connected to the inter array cable distribution network, either at an individual WTG or at the OSS.

3.2.2. The E-SOV

E-SOVs are available for order from leading vessel designers and yards with battery units of 20-30 MWh allowing full daily operations only using electrical power. To charge the E-SOV, a VCU will be installed on the vessel. The VCU will be the interface point to the electrical system onboard the vessel from where the battery can be charged. The VCU can be placed at the aft deck or another location on the vessel depending on vessel design and operational requirements.

The E-SOV will typically be equipped with a hybrid engine system. However, an internal combustion engine will be available in addition to the battery-powered system to ensure safe operation regardless of the charging level of the battery, harsh weather, emergencies etc. The internal combustion engine can be designed to run on green fuels like e-methanol allowing the E-SOV to operate fully decarbonised no matter the situation or task.

3.2.3. The SOeC

The SOeC consists of building blocks including flexible cables, cable reel, crane, transformer and other electrical equipment. The figure below shows the entire SOeC solution installed on a WTG transition piece. From left to right this includes the step-down transformer and electrical control unit, the crane and the cable reel system.

Figure 3: SOeC solution mounted on a WTG structure

3.2.4. Installation

Ideally the SOeC is installed on the WTG or the OSS as an integrated part of the onshore assembly of those structures. In this case it will also be possible to test and validate the system onshore before the structures are shipped out to the OWF for installation. Retrofit is also possible, but this will in most cases require offshore reinforcement of the structure.

The buoy or a separate foundation with the charging equipment are more flexible solutions when it comes to location in the OWF. The buoy or the separate foundation will be connected either to a WTG or an OSS via a subsea cable. This will require the WTG or OSS to be fitted with an additional J-tube to facilitate the connection. This is fully technically feasible.

Similar to the hang-off solution, it is easier and more cost-efficient to integrate the buoy or separate foundation during the design phase of the OWF compared to the case of retrofitting a buoy or dedicated foundation.

3.2.5. Standards

As offshore vessel charging is a relatively new industry, it is important to develop standardisation of charging systems and their associated interfaces to ensure interoperability between different OWFs, E-SOVs and chargers. This will allow for quicker adoption of the technologies, lower costs (due to scale advantages) and improved roll-out of safety features across the market.

Standards should, to the extent possible, be aligned with existing standards in adjacent areas like onshore power supply and charging standards for vessels in ports. Stillstrom is currently working closely with other industry partners, including other charging system vendors and standardisation bodies, to produce a white paper which takes a first step to align and detail new areas of standardisation relevant to offshore charging as compared to existing shore power standards.
In addition, a proposal has been accepted within the relevant Technical Committee of the International Electrotechnical Commission to include standardisation of off-/onshore power transfer within their Strategic Business Plan.

04

Operational Feasibility

In planning and execution of the offshore charging operation, operational procedures have been developed based on regulations, codes and industry best practices which are used in the offshore wind industry today. This is to ensure a safe, efficient and standardised operation.

The operational offshore charging procedures describe how to:

- Approach the offshore charging structure,
- Remotely operate the boom crane, so no personal transfer is needed for starting charging session,
- Receive the charging cable by a messenger line at a safe hook-up distance of approximately 15 m steel-to-steel,
- Automatically connect the charging equipment to the vessel,
- Position the vessel while charging in a safe drift-off position in predefined operational zones 60-100 m away from the connection structure allowing for an optimal heading while keeping energy consumption at a minimum,
- Disconnect and return the charging equipment

Operational procedures have been created defining under what circumstances an emergency disconnection will occur and how it will be executed. Redundant systems are part of the solution meaning that there are different ways of disconnecting, both manually and automatically, in case of an emergency.

The charging operation is designed to require minimal manual handling from the vessel crew. The only current manual handling needed is when the deck crew will receive a low-weight messenger line from the crane of the offshore charging structure's rigging arrangement and connect the line to the connection unit. The operation is similar to the well-known offshore lifting operations happening today on a daily basis, however, there is next to no weight involved when doing the manual handling in this operation.

The charging procedure can be viewed at stillstrom.com/offshore-wind.

05

Business Case

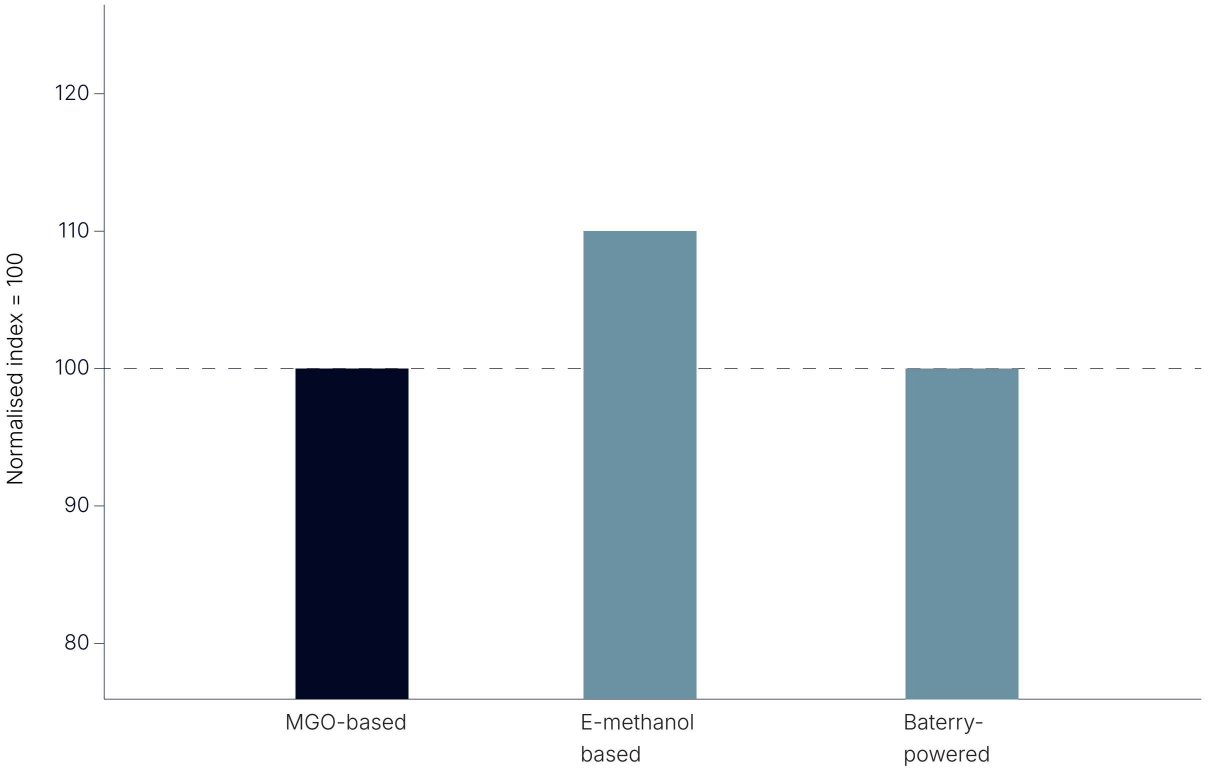
The business case which is the basis for this study on electrification of service vessel operations in offshore wind farms includes all costs and benefits such as:

- CAPEX and OPEX for the charger
- The CAPEX and OPEX of an E-SOV relative to an MGO or alternative fuel equivalent and the subsequent impact on the charter rate of the vessel
- The fuel costs for the MGO or e-methanol vessel
- The price of electricity used to charge the E-SOV batteries in the OWF
- The anticipated impact of future carbon taxation for carbon emitting SOVs

The overall cost comparison, shows that even at this early stage for battery powered E-SOVs it has the same cost level as a standard MGO-based SOV solution and it is approximately 10% cheaper than using other decarbonised solutions like e-methanol, as shown in Graph 1 below.

Graph 1: Cost differences between fuel-based SOVs and E-SOV.

SOV-costs relative to MGO-based SOV incl. CAPEX and OPEX



The conclusions illustrated in the above graph are based on the current price of MGO, e-methanol, electricity, charter rates, inflation and EU ETS. The cost for the E-SOV also includes the CAPEX and OPEX for installing and operating a SOeC charging system.

The assumptions do not consider, for example, the risk of future price volatility on MGO-fuels, see Graph 2 below, nor the potential additional income stream due to the potential sale of carbon credits. Together with the potential for cheaper and improved batteries in the future, the business case presented below could be considered as conservative. An E-SOV and SOeC solution might therefore perform even better than reflected in the graph above.

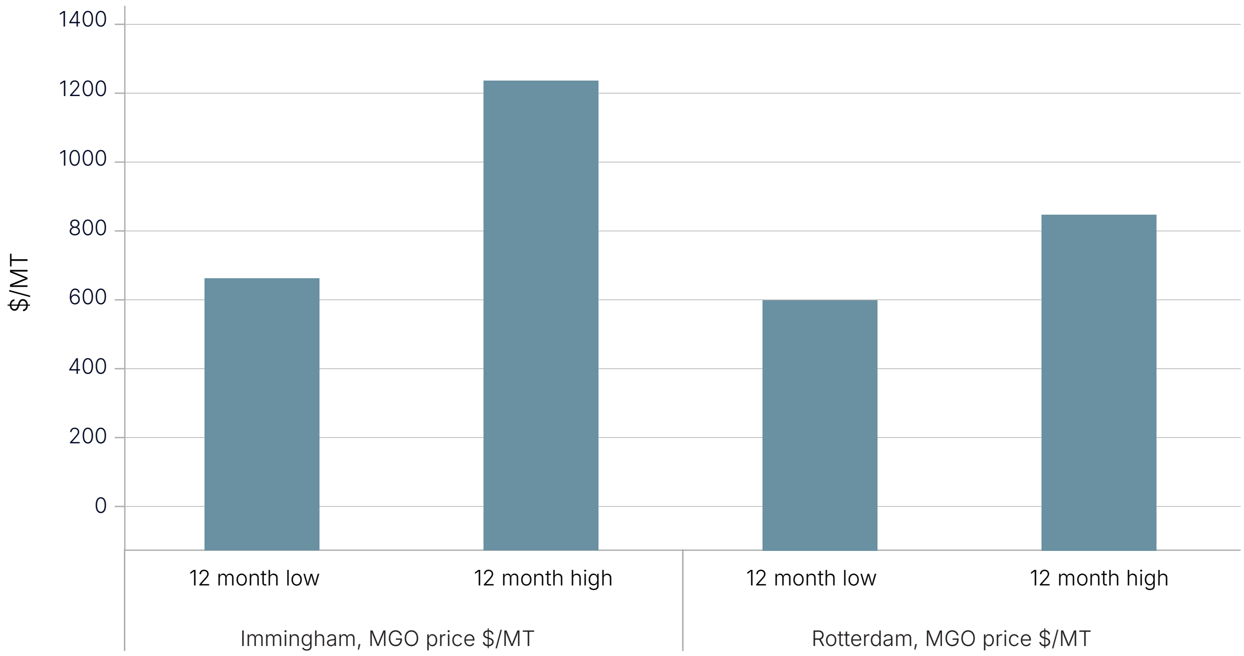
5.1. MGO price volatility

Fuelling an MGO-based SOV means exposure to the volatile MGO-price in nearby ports where the vessel is fuelled. As an example, the MGO price at Immingham on the UK's east coast the price varied from circa $600/MT to $1,200/MT between Nov. 2023 – Nov. 2024 - see Graph 2 below.

In Rotterdam the variation has been a bit more moderate, with a 12-month low of $600/MT and a high of more than $850/MT. In Immingham, the price varied up to around 100% from low to high, while in Rotterdam the high price was approximately 40% higher than the lowest price over the 12-month period.

Graph 2: MGO prices, max/min over 12 months

MGO price Nov. 23 - Nov. 24



5.2. SOeC CAPEX comparison

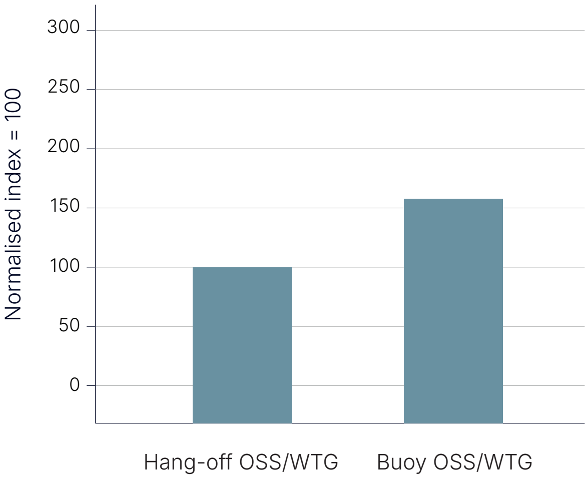
The hang-off solution placed on an OSS has the lowest CAPEX costs of the four set-ups, see Graph 3 below. This is due to more space and proximity to other transformation equipment, which makes it easier to install and optimise the system CAPEX. A hang-off from a WTG is roughly 20% more expensive compared to the hang-off at the OSS. A buoy solution more than doubles CAPEX compared to the respective hang-off solutions. This is due to the buoy structure itself, the subsea cable and the anchor system, compared with a hang-off system.

Graph 3: CAPEX comparison

5.3. SOeC OPEX comparison

OPEX for the SOeC is similarly cheaper when having a hang-off solution compared to a buoy solution. Access to the buoy is more complicated than accessing a WTG or OSS. The available space at the buoy for maintenance work is similarly more challenging. The buoy will moreover require additional regular underwater inspection which is not needed if the SOeC is installed on a WTG or OSS-structure. In total it is estimated that OPEX increases with approximately 60% if a buoy is chosen compared to a hang-off solution.

Graph 4: OPEX comparison



5.4. SOeC related costs

To sum up, the most cost-efficient charger solution is using the OSS as the location for the SOeC-solution, with slightly higher costs when it comes to using a WTG structure. OPEX in the two cases are assessed to be roughly at the same level and complexity. Buoy solutions offer more flexibility on where in the OWF the charging infrastructure can be located, but this comes with a price mark-up compared to the hang-off solution. Buoy solutions can also be preferred in the case of retrofitting, if it is too costly to reinforce the needed structures for the SOeC in the OWF.

06

Regulatory Framework

The regulatory framework in each individual market impacts OWF owner's opportunities and abilities to optimise the business case when considering an offshore charging solution.

In the United Kingdom, the OWF owner has the responsibility to design and construct the OSS and then divest it to an Offshore Transmission Owner (OFTO), who would then own and operate the asset throughout the lifetime of the asset. This system gives the advantage to the OWF-owners, that they can design for chargers to be located on the OSS and include it in the OFTO contract including responsibilities, access to the OSS, liabilities etc.

Markets like the German[3] and Dutch market are on the other hand characterised by having the transmission system operator (TSO) as responsible for design, construction and ownership of the OSS as well as the export cable to shore. This creates some challenges in terms of using the OSS as there will be a need for a specific contract between the TSO and the OWF. It can as well be more difficult to get space and structural integrity into the design of the OSS as this structure may have been designed before the winner of a given OWF-auction is known.

In markets like the Danish market, where the OSS and export cables to the onshore connection point is designed, constructed and owned by the OWF owner, it is relatively straightforward to integrate space and design for a SOeC at the OSS. The OWF owner can also explore opportunities to overplant the generation capacity and thereby optimise the production potential for the OWF also reflecting the own-consumption of electricity to charge E-SOVs in the OWF.

Besides markets like the Danish, where the OWF owner has full ownership and control of the OSS, it might be attractive to locate SOeCs on WTGs as this will reduce transactional costs compared to developing a contractual set-up with the OFTO owner or in the more complex case the TSO.

6.1 Electricity price for charging E-SOV in the offshore wind farm

Table 3 below gives an overview of the price of electricity while charging depending on the level of production and export cable capacity and the wholesale market electricity price onshore covering both buying to or selling electricity from the OWF.

Supply of electricity	**Electricity price while charging**	
Own electricity production up to export cable capacity	Reflects the lost income. MWh used for charging instead of selling to the market	In case of a Contract for Difference (CFD) or other regulated price, the CFD/regulated fixed price will be equal to the charging price per MWh. This will be valid for the duration of the CFD or other contract, e.g. the first 15 years in the UK CFD scheme. A fixed price such as Corporate Power Purchasing Agreement cPPA would have the same impact as a CFD.
		In case of full electricity market exposure, the charging price will reflect market price at every half hour/hourly price depending on the market set-up.
Own electricity production exceeding the export cable capacity	As the excess production in principle is lost production, the charging price will be like the marginal cost of having the WTGs delivering the excess production. The marginal cost for offshore wind energy is close to zero.	
Onshore supply of electricity for charging purpose	The price depends on the agreement with onshore and offshore grid operator for the use of the export cable and OSS as well as onshore grid cost and the onshore electricity including potential taxes. In case that the OWF-owner also owns the transmission asset to shore, then the costs will be the marginal cost for using the transmission asset to the SOeC, the onshore grid costs and the electricity price incl. potential taxes.	

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[3] In Germany some OWF owners have the ownership of a smaller OSS, which is connected to the TSO's OSS where power from multiple OWFs can be collected and send to shore. The OWF owner's own OSS can be used to host a SOeC solution and thereby reduce contractual complexity as all assets are owned by the same entity.

In most cases the OWF will be able to export the electricity to shore as the production is typically smaller or equal to the export cable capacity. In these cases, as mentioned above, the cost for electricity in the wind farm is equal to the lost income by not sending a part of the production to shore and the electricity market but instead used in the OWF for charging of the E-SOV. All excess production above export cable capacity is in principle without additional costs as the marginal cost of wind power is close to zero. In contrary to excess production buying electricity in power market and getting the electricity through the grid to charge the E-SOVs can potentially cover grid tariffs, potential taxes and the electricity price itself.

For the OWF owner the use of the asset's electricity production for charging an E-SOV will almost fully de-risk future energy costs for SOV operations. The electricity price can be fixed for a number of years as in the case of a 15-year CFD contract in the UK. In other markets like The Netherlands, Germany and Denmark the OWF-owner will be exposed to the volatile wholesale market price of electricity, which also opens for additional levers to plan the charging schedule of the vessel when the electricity prices are low under the constraints of operational needs.

6.2 Cost of charging

The cost for supplying an E-SOV from the OWF is the lost income of approximately 22 MWh electricity per day of operation. The 22 MWh is used to re-charge the battery in the E-SOV from 20% to 90% as well as servicing the dynamic positioning system and auxiliary system on the vessel. The value of the electricity will depend on factors mentioned in Table 3 above.

6.3 Regulatory Focus Areas

Before integrating a SOeC-solution in a specific OWF, the asset owner will have to check the regulatory framework and grid connection agreements clarifying if any challenges integrating a SOeC-solution exists. The following issues are neither an exhaustive list nor necessarily an actual issue due to market variations. The list is created to ensure awareness around potential regulatory issues, such as:

- Potential limitations on the access to "own consumption" in the OWF.
- Potential limitations on the access to power generation from shore if there is not sufficient production in the OWF to supply the charging of an E-SOV.
- The cost of being supplied with electricity from the onshore grid – taxes, tariffs and electricity prices.
- Retro-fitted SOeC-solutions might need new approvals to cover for the potential structural changes. It cannot be ruled out that some regulators will require additional environmental impact assessments/studies before approving the installation of a SOeC-solution.
- To what extent can the new consumption point in an OWF participate in e.g. balancing and other ancillary electricity markets.
- Impacts due to regulatory framework aiming at decarbonising the shipping industry such as e.g. FuelEU, Alternative Fuel Infrastructure Regulation, EU ETS, IMO-regulation etc.
- Safety requirements for handling the charging processes and the equipment.
- Ownership of OSS and the impact this could have to access an SOeC solution located on this structure.

Each of the regulatory issues can be managed either by pricing them into the business case in case of no or very low likelihood of changing the regulation. In case of an opportunity to change a given regulatory issue, then dialogue with relevant regulatory authorities can change the regulation into a better solution for society as well as the OWF owner.

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[4] Own calculations based on charging 70% of the 25MWh battery = 17.5MWh and consumption due to dynamic positioning and auxiliary service on the E-SOV 2x500kWh during the 4.5 hour charging session, in total 4.5MWh consumption. The total electricity consumption during a full charging is 17.5MWh + 4.5MWh = 22 MWh.

07

Broader Trends for Electrification of Vessels

During the last couple of years, the interest in electrification of larger vessels has been growing due to the continuous cost reduction of battery technologies, which has significantly improved the business case for battery-powered vessels. E-SOVs are an obvious next step in this development, taking advantage of readily available electricity supply and infrastructure at an OWF. This comes in addition to the development of more short-route ferries that are becoming electrified and charged in ports.

In September 2024 the Maersk Mc-Kinney Møller Center for Zero Carbon Shipping published a report on the potential for battery-powered feeder vessels with relatively short operational distances. The report concludes that there is likely to be a larger uptake of battery powered container and tanker vessels within the coming years among shipowners with decarbonising targets as hybrid battery powered feeder vessels are cheaper options than e-methanol fuelled vessels in most scenarios. This white paper also indicates that the business case for decarbonising vessels will be improved along with electrification opportunities as the e-fuel prices are assessed to be relatively high compared to electrification solutions for vessels.

Electrification of vessels will support higher energy efficiency as an E-SOV will have an efficiency of 80 – 90% efficiency from well-to-propeller, while e-fuels have an energy efficiency around 10 – 20% due to energy losses in the production of the e-fuels based on electricity and the loses while using the fuels for propulsion of the vessel. A battery-powered vessel is therefore 4 – 10 times more energy efficient than the decarbonised alternative of e-fuels.

08

Conclusion

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It is fully technically and operationally feasible to use a SOeC system in an OWF, enabling fully battery powered E-SOV operations. This will benefit the OWF owner in the following ways:

- Utilising an E-SOV in combination with a charging solution is at the same total cost level as an MGO-based SOV-solution if either the WTG or OSS can be used as structure for the installation of a SOeC-solution.
- The fully decarbonised business case comparing the costs of using E-SOVs to the use of e-methanol fuelled SOVs shows that the E-SOV-solution is significantly cheaper than a fully e-methanol fuelled SOV. It gives a clear indication that OWF-owners with ambitions to decarbonise their SOV operations should electrify to the greatest possible extent by operating an E-SOV in combination with offshore charging.
- Significant decarbonisation potential, as MGO-fuelled SOVs account for 15 – 20% of the total CO_2-emissions from cradle to grave in an OWF. An E-SOV will reduce the CO_2-emission by approximately 4,700 ton per year and more than 115,000 tons over the 25-years lifespan of an offshore windfarm. The switch to E-SOV operations will moreover eliminate almost all NOx, SOx and other particle pollutions from the vessel.
- E-SOVs will increase energy efficiency compared with standard marine engine solutions regardless of the fuel type.
- De-risking the business case by removing the exposure to volatile fuel prices as well as geopolitical risks impacting both fuel prices and supply.
- De-risking price increases associated with charges for Carbon rich fuels from the EU and IMO. Both bodies have established Net Zero emission targets for the maritime industry by 2050 and it is expected charges for GHG emissions will increase as this date approaches.
- Gaining a potential additional revenue stream by selling surplus carbon credits.
- The crew comfort level will increase onboard the E-SOV as the electric propulsion will limit noise, particles and vibrations compared to a standard MGO-based marine engine. The batteries will supply all energy needs covering propulsion of the E-SOV, auxiliary systems and the vessels DP- system.

In an OWF, the cheapest O&M costs are realised by locating a charging system on either an OSS or a WTG. The CAPEX for the OSS solution is slightly cheaper than the WTG-solution, but in some markets the OWF-owner is not responsible for the OSS, which makes the WTG-solution a simpler choice and lowering the transaction costs compared to an OSS-solution.

The regulatory set-up and ownership structure of the OSS will influence opportunities to exploit the full cost optimisation potential when using an E-SOV for the daily O&M vessel operations as well as e.g. the opportunities to retrofit a charging solution into an existing OWF. An example of the regulatory framework's impact on the cost optimisation could be, that in markets where the OWF-owner receives the wholesale market price as remuneration, there the cost optimisation will besides the O&M schedule also consist of the electricity wholesale market price. The lower wholesale market price the lower lost income due to the charging of the E-SOV. Exploiting the cheapest possible hours for charging simply creates the opportunity to realise energy cost savings under consideration of O&M needs.

Electrification of vessels is ramping further up and E-SOVs are one of the most obvious next steps and the needed technologies – chargers and battery powered vessels will only be more rapidly improved with more and more battery powered vessels being introduced in this and the coming decade.

09

Abbreviations

CAPEX	Capital expenditures
DP	Dynamic position
E-SOV	Battery-powered/electrified service operation vessel
GHG	Greenhouse gas emissions
MGO	Marine gas oil
O&M	Operation and maintenance
OFTO	Offshore transmission asset owner (United Kingdom)
OPEX	Operational expenditures
OSS	Offshore substation
OWF	Offshore wind farm
SOeC	Stillstrom Offshore electrical Charger
SOV	Service operation vessel
TSO	Transmission system operator
VCU	Vessel connection unit
WTG	Wind turbine generator

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