Pioneering spirit

ESNA's incorporation of surface effect ship design into offshore operations has found form in *Sea Puffin 1* and the hybrid-powered *CWind Pioneer* – and future moves into hydrogen power are planned, reports Alan Bliault, FRINA


CWind Pioneer has been hailed as the world's first hybrid surface effect ship

ESNA is a relatively new naval architecture practice located in Kristiansand, Southern Norway. The founders of the company, who have backgrounds in surface effect ship (SES) design, set out to utilise special characteristics of the SES concept for improved logistical operations at offshore wind farms and oil and gas installations.

They started with the design of *Sea Puffin 1*, an in-field shuttle craft launched in 2018 for offshore wind farms, acting as a daughter to construction vessels. Presently, ESNA's design of a hybrid-powered SES for UK-based CWind – a provider of CTVs, project services and training to the offshore wind sector – is due to start operations in the Netherlands. Named *CWind Pioneer*, the vessel is contracted on a long-term basis to Ørsted's Borssele 1 and 2 offshore wind farms. And, as this project moves to completion, ESNA is now studying the feasibility of a zero-emission SES using a combination of batteries and fuel cells.

Sea Puffin 1

The *Sea Puffin 1* SES daughter craft is where it all started. ESNA found that, with active damping of the air cushion system, the boat could achieve superior comfort for those on board – and, when 'docking' at a structure (for example, a wind turbine), could keep the motion at the docking point almost still, even in significant sea states up to 1.8m.

This provides an increased operational weather window, and could reduce the amount of time that technicians may require to overcome seasickness – which, in turn, brings significant benefits in increased productivity.

Sea Puffin 1 is a 15m loa catamaran, designed to be launched and deployed by a standard davit from a mothership. She uses an air cushion to offer operational wave height similar to larger catamaran CTVs, burning significantly less fuel oil during all operational phases.

Realisation and development of the vessel was supported by The Carbon Trust's Offshore Wind Accelerator (OWA) programme, Enova, Innovation Norway, RFF Agder and SkatteFUNN in Norway. Vessel operator WindPartner contracted Denmark's Esbjerg Shipyard to construct *Sea Puffin 1* in 2017.

Sea Puffin 1 has an aluminium hull and conventional diesel-driven waterjets. The air cushion is supplied by a diesel engine-powered centrifugal fan, mounted in a volute forward of the wheelhouse. The SES configuration also follows well-established design practice in Norway, with simple deep segments at the bow and a multiple-lobe bag skirt at the stern.

The key innovation for this vessel is the cushion damping control system, whose active instrumentation and electrical activated flow control was developed in-house by ESNA. The control system responds to cushion pressure pulsations and

ESNA's first SES for the offshore wind sector was the daughter craft *Sea Puffin 1*

TECHNICAL PARTICULARS	
Sea Puffin 1	
Length	15m
Breadth	5.6m
Draught	1.4m (off cushion) / 0.5m (on cushion)
Deadweight	2tonnes
Forward cargo deck capacity	>15m²
Main engines	2 x 260kW diesels
Propulsion	2 x waterjets
Cruising speed	>25 knots
Fuel consumption:	150litres/hour at 100% engine power
Offshore technicians	9-12
Operational wave height for safe turbine access	>1.8m Hs, head sea / 1.5m Hs for all sea directions
Classification society	Bureau Veritas
Notations	✠ HULL ● MACH, Light Ship - Fast passenger vessel, Sea Area 2

vessel motions to minimise accelerations and damp the motions themselves.

Sea Puffin 1 conducted successful transit and push-on trials at Vattenfall's Horns Rev 1 and Ørsted's Horns Rev 2 wind farms, off Denmark, between June and August 2018, and in significant wave heights of 1.75m. The performance was verified with in-situ wave buoy measurements.

The trials, which were supported by the OWA, demonstrated record low fuel consumption at less than 100litres per hour. Dan Kyle Spearman, manager of offshore wind access systems at The Carbon Trust, commented: "I was on board the vessel during testing and was impressed with the step up in performance for a daughter craft."

Subsequently, *Sea Puffin 1* has also undertaken successful operations at Equinor's Hywind floating turbine wind farm. The COVID pandemic has made spot charter operations difficult since March 2020, but WindPartner is actively marketing the vessel towards projects such as Dogger Bank, in the North Sea, and investigating a Mark 2 version of the concept.

CWind Pioneer

Building on the experience and learnings gained from *Sea Puffin 1*, the larger SES CTV, *CWind Pioneer*, was developed in partnership with operator CWind. *CWind Pioneer* is a game-changer for the industry because of its ability to handle a significant wave height of 2m during technician transfers. At the same time, it will decrease fuel consumption and CO_2 emissions.

This design has a hybrid diesel-electric arrangement: transits between port and the wind farm/worksite are conducted under diesel power, while in-harbour manoeuvres and loitering on stand-by at the wind farm are powered by batteries alone. This facilitates a reduction in diesel engine hours and optimises diesel engine efficiency when the engines are required, which helps to minimise CO_2 emissions during the working day. The main engines can also be declutched from the waterjets and used to charge the batteries, should this be required whilst the vessel is stationary.

The twin catamaran hulls are built in marine-grade aluminium, and the superstructure is manufactured in composite materials. The cushion is bounded by deep segments at the bow and a multi-lobe bag skirt at the stern. Forward-mounted centrifugal fans feed the air cushion, supporting approximately 80% of the vessel weight. The remaining 20% is supported by hull buoyancy. As with *Sea Puffin 1*, a cushion air control system has been installed to minimise motions and accelerations for both transits and turbine-boarding operations.

The design and build, with 24-passenger capacity, pays particular attention to technician and crew health, safety and comfort, to deliver the workforce in the best possible work-ready condition. As this project was carried out during 2020's pandemic, special attention was paid to personal safety for the passengers, and Plexiglas divisions have been incorporated all around the seats.

Both passengers and crew have access to fully air-conditioned, personalised seating, and the galley area features a microwave, a fridge, hot water and a separate seating area. An area with lockers and shelving can be used as a changing space and to store the technicians' luggage.

ESNA carried out a Monte Carlo simulation of voyages, calibrated to actual trials data for *Sea Puffin 1*, and adjusted *CWind Pioneer*'s design to assist in predicting the performance envelope and optimising the onboard software. This should assist operations planning in service. Wight Shipyard Co. (WSC) was selected to manage the build project, from its development stage through to delivery.

The hybrid SES' twin 809kW diesel engines will deliver sprint speed and high bollard push, while the batteries power the SES lift fan systems and hotel load. The vessel can also operate in diesel-electric mode, where the diesel engines power the waterjets and the in-line shaft generators provide electric power for driving the SES

CWind Pioneer can undertake transits at between 27-38knots, with a sprint speed in excess of 43knots

A cushion air control system was installed on *CWind Pioneer* to minimise motions and accelerations for both transits and turbine-boarding operations

lift fan, meeting hotel load requirements and charging the batteries. In stand-by mode, the batteries can supply the propulsion while the auxiliary generators provide electrical power for the lift fan and vessel services.

Significant fuel savings could be achieved through minimising inefficient low engine power running hours, with battery drive modes including wind farm stand-by and low-speed/harbour operations. This will lead to an engine operating hour reduction of 50% during wind farm battery stand-by.

The vessel completed trials in the Solent area during February 2021, during which it achieved speeds up to 43.5knots, and was blessed at WSC's facility on the Isle of Wight on 23 February, before delivery into service for Ørsted.

Zero-emissions goal

The zero-emissions goal is shared by many companies in the offshore wind industry. In recognition of this development of a low-emissions vessel, CWind was awarded funding and support through the OWA's Low Emission Vessels competition, which helped CWind and ESNA to develop *CWind Pioneer*'s hybrid SES CTV design.

For the hybrid SES project, this meant supporting the development of reduced emissions, fuel consumption and maintenance costs; understanding and evaluating the cost-benefit of existing and future powering and storage technologies from other industries; and assessing infrastructure required for offshore operations.

The project modelled drivetrain power capabilities to provide data to enable operators to make informed decisions about which system will be best suited to them. It also used data modelling to enable faster improvements than would normally be expected through conventional prototyping.

A simulation tool was developed to model the driveline, the SES components and operational calculations, and to produce comparative data for conventional vessels. It was also used to test the hybrid drive, to provide insights into possible efficiencies by comparing simulation tool data sets with full-scale trials. The simulation tool will be further used to address new hybrid/battery technology for development and optimisation.

CWind Pioneer has been designed to make use of digital technology in a way not previously attempted. CWind is actively researching the viability of significantly increasing the sensing and data-gathering systems on board, to deliver a system that uses big data to help continuous operational improvements.

In October 2019, CWind announced a long-term charter contract agreement with Ørsted, starting in early 2021. *CWind Pioneer* will operate between the Dutch port of Vlissingen and the Borssele 1 and 2 farms, located 23km from the Dutch coast in the North Sea.

CWind Pioneer will not only enable Ørsted to deliver and service wind farms efficiently through reduced transit times, but will help it to meet its target of achieving a carbon-neutral footprint by 2040.

ZES SES: the next step

A possible next step forward from the hybrid SES CTV concept is to move to all-electric power – either through pure battery power or a combination of batteries and fuel cells.

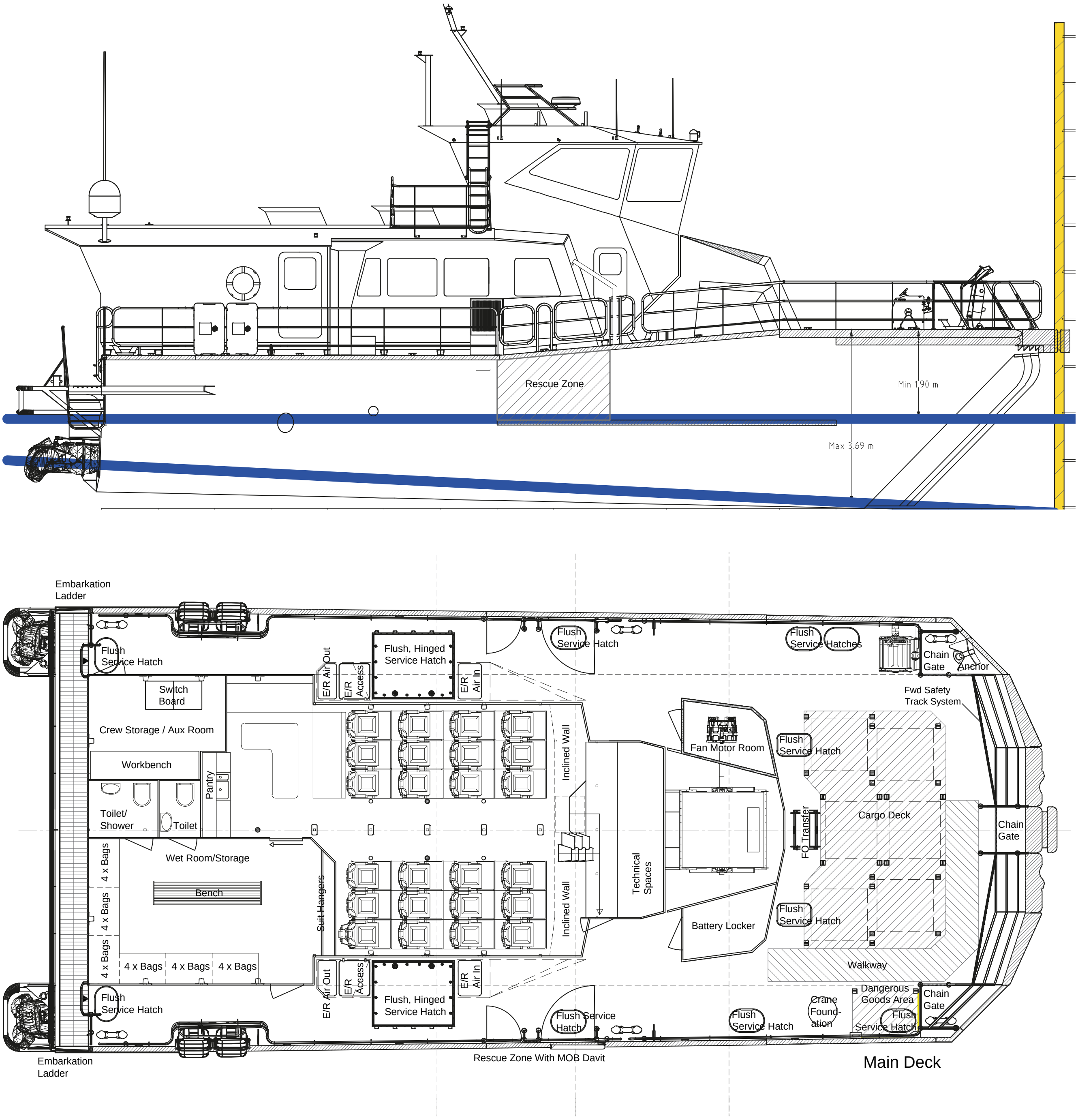
TECHNICAL PARTICULARS

CWind Pioneer

Length, oa	22m
Breadth	8.9m
Draught	1.9m (off cushion) / 0.5m (on cushion)
Forward deck space	30m² (max)
Cargo deck strength	1.5tonnes/m²
Max deck cargo	7tonnes
Tank capacities	
Fuel	14,000litres
Fresh water	400litres
Black water	400litres
Fuel transfer	>12m³
Main engines	2 × Scania DI 16 076M
Output of each	809kW
Waterjets	2 × RR Kamewa S50-3/CA
Gearbox	ZF
Electric motors	2 × 130kW
Electrical power bank	87kWh usable energy
Centrifugal lift fan	1 × 240kW
Service speed	27-38knots (dependent on sea state)
Max speed	43knots+ (up to 30min with battery power to lift/services)
Fuel consumption (per hour)	404litres@full speed (approx.) / 350litres@service speed (approx.)
Navcomms	2 × high-speed radars: one X-Band, 9GHz; 1 × broadband 4G radar Class A AIS 1 × type-approved magnetic compass 1 × gyro compass Depth sounder (integrated with navigation system) Rhotheta RT-202 CrewFinder 2 × VHF radiotelephones, fixed with DSC and DSC Watch Receiver
Crew	3
Offshore technicians	24
Classification society	Bureau Veritas
Notations	✠ HULL ● MACH Wind Farms Service Ship - S0, Sea Area 2 (2.5m Hs) Electric Hybrid (PM, ZE) MCA HS-OSC, Cat 1

The latter approach could effectively replace the diesel engines, generators and fuel with fuel cells and a power control system, allowing the batteries to be used for low-demand on-site loitering, and the fuel cells to be used for recharging the batteries when needed.

The general arrangement of the hybrid SES CTV *CWind Pioneer*



The challenge with this approach is primarily the storage of hydrogen as liquid H_2 instead of as compressed gas. At present, regulations do not allow H_2 storage within a hull, and so the right storage place must be found above deck.

Then, one is left with the challenges associated with heavy high-pressure vessels or insulated tanks. H_2 is rather light, even in liquid form, so the mass of the tank located above deck is the main design issue.

Having a solution for the vessel is only part of the solution, since hydrogen is normally produced close to its usage point, rather than being transported over long distances. Additionally, to be truly 'zero-emission', one really needs H_2 produced by electrolysis for vessels such as ESNA's proposed ZES SES CTV. Some wind farm operators, including Ørsted and Equinor, are now working on this aspect with pilot projects for H_2 production.

"Fuel cells are costly power units, but excellent for providing a steady state power demand," says Morten Kostøl, electrical engineer at ESNA. "Batteries are costly and heavy energy units, but excellent at handling rapid changes in power demand."

Considering the daily load profile and combined use of hydrogen and batteries, ESNA has found an economically and technically feasible solution for offshore wind CTVs. The key is to minimise power and energy requirements.

ESNA has developed a simulation tool which can simulate thousands of wind farm operational day trips (1). This is used to optimise vessel size vs. battery; fuel storage; and fuel cell capacity.

Plexiglas divisions were installed around *CWind Pioneer*'s passenger seats in response to the COVID-19 pandemic

Parameters such as speed loss, transit speeds, transfer time, transfer push force, stand-by time and weather conditions are represented by statistical distributions, and randomly chosen for each operation. The programme is an in-house software tool utilising Monte Carlo simulation, which can easily be adapted to various vessel sizes, types and operational profiles.

"Such a tool is necessary to select optimum main dimensions, speed and resistance performance, as well as the maximum power need and total voyage energy consumption," explains Nere Skomedal, ESNA co-founder. "We cannot oversize anything, since it would not only affect the price; it would also affect the lightship weight and performance.

"But we cannot undersize either. Our simulation tool and experience have helped us achieve the perfect size."

In early 2020, ESNA started work on the hydrogen-fuelled Zero Emission Small Ships (ZES Ships) concept, based on available and tested systems. With a length of 18m, the ZES SES CTV is planned to carry 12 offshore technicians, reach a top transit speed of 30knots and access wind turbines in significant wave heights up to 1.8m. The vessel is well suited to all-day operations, serving wind farms or other installations situated 5-20nm offshore.

ESNA's proposed ZES SES CTV will run either on pure-battery power or a combination of batteries and fuel cells

The concept is based on a power system with fuel cells keeping the batteries charged, while the batteries power the main engine and lift fan operation. A control system will balance fuel cell and battery operation throughout the working day. The simulation programme has been used to fine-tune the overall electrical power system, since this is critical to first cost, operating cost and reliability.

While an initial design has been developed, turning the ZES SES CTV concept into reality will be a significant challenge, and so ESNA has applied for R&D funds from the Norwegian government, with the aim of completing development of the vessel by 2023. This should fit with the current ongoing development of H_2 production and marine fuel stations. Funding was approved in February 2021.

Meanwhile CWind aims to follow ESNA's ZES SES CTV work closely, while gaining its own experience with *CWind Pioneer*: the operator's ambitions with regard to the use of instrumentation and optimisation will have equally important input to the ZES variant. ***SBI***

References

1. *Power and Energy Solutions*, Issue 1, 2020, pp.22-24: "Developing zero emission small ships".