Fisheries Innovation & Sustainability

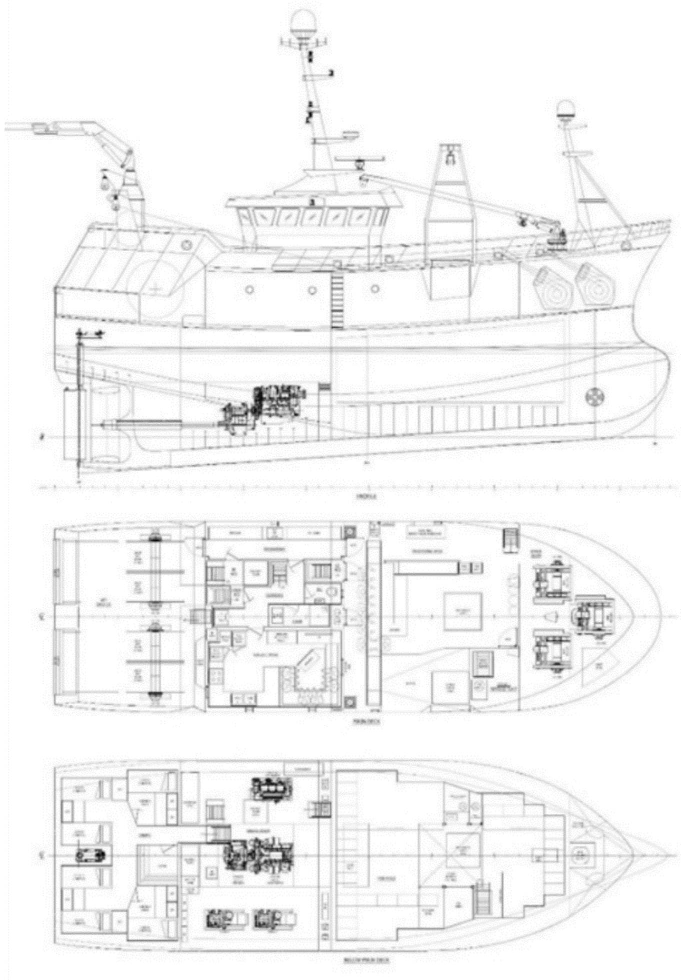
Net Zero Vessels Concept Design Project

Stage 2

A REPORT COMMISSIONED BY FIS AND PREPARED BY:
Macduff Ship Design Ltd.

Fisheries Innovation & Sustainability

Net Zero Vessels Concept Design Project



August 2023

MACDUFF SHIP DESIGN

University of Exeter | Centre for Future Clean Mobility

Scottish Government
Riaghaltas na h-Alba

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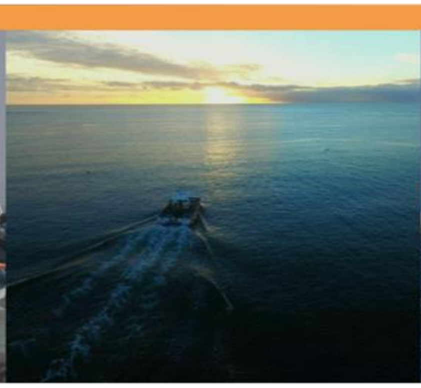


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FISHERIES INNOVATION & SUSTAINABILITY

NET ZERO FISHING VESSEL CONCEPT DESIGN PROJECT

STAGE 2

BY	D BOAG
DATE	13/07/23
VERSION	Final 1

RINA CORPORATE PARTNER

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ISO 9001:2015 REVISION PAGE

VERSION	DATE	COMMENTS
Draft 1	29/3/23	Initial draft sent to FIS for comment and stakeholder feedback gathered at the Scottish Skipper Expo, 13-14 May 2023
Draft 2	21/06/23	Draft sent to FIS, University of Exeter Centre for Future Clean Mobility, Macduff Shipyards for comment
Final 1	13/07/23	Draft sent to FIS & University of Exeter Centre for Future Clean Mobility for final comments

Contents

OVERVIEW

In April 2022, Fisheries Innovation Scotland, now Fisheries Innovation & Sustainability, organised the 'Vessels of the Future' workshop in Glasgow, which was attended by stakeholders and industry leaders across the fishing industry. This workshop[1] identified the need for the 'creation of a roadmap' towards a net-zero future for the Scottish fishing sector, highlighting the need for a business case for change and existing regulatory barriers as the key potential obstacles to this transition.

Stage one of FIS and Macduff Ship Design's 'Concept Design Project' was completed in January 2023. The report analysed three different UK fishing vessel types and highlighted a range of technical, financial, and regulatory barriers associated with a move to net zero vessels for the fishing sector.

Despite these barriers, the report emphasised a number of important reasons underpinning the need for the fishing industry to investigate and invest in its transition to net zero operations. These included the significant risk associated with a collective failure across the industry to invest and develop solutions whilst time is available, ultimately resulting in the prevention of vessel operation due to a lack of compliance and readiness by the net zero deadline. Additionally, it was noted that, should other industries push technology and infrastructure that are unsuitable, or which do not represent the best solutions for UK fishing vessels, vessel owners may become constrained by these options, resulting in the need to make more compromises on design and operation. Furthermore, the first report highlighted that it is difficult to predict what will happen with diesel price as demand from other industries – especially automobiles – reduces in the coming year. It is very possible that an increase in diesel cost could make much of the current fleet uneconomically viable from an operational perspective, effectively making vessels stranded assets.

This report focuses on stage two of the project. This project, made possible by the Marine Fund Scotland, takes forward the stage one outline analysis to produce the first detailed concept designs for net zero vessels of these types. The report also analyses the technical, financial, and regulatory issues related to making these concept designs a reality.

Both stages of the project have been assisted by the University of Exeter's Centre for Future Clean Mobility (CFCM) who have extensive expertise in clean power train design and power cycle data.

The two most plausible net zero options, as identified in the stage one report, were selected for development into concept designs for each of the three vessel types. These options are:

Less than 10m Creel -	Battery Electric Methanol
About 15m Nephrops -	Methanol LNG (Liquified Natural Gas)

[1] Report_Vessels-of-the-Future-Workshop_Final.pdf (fiscot.org)

Less than 24m Whitefish -	Methanol LNG

EXECUTIVE SUMMARY

Following a wide-ranging analysis of a range of alternative fuel options considered in stage one of the net zero fishing vessel Concept Design Project, stage two developed two concept designs for each vessel type – less than 10m creel boat, 15m Nephrops trawler, and a less than 24m registered whitefish trawler – utilising the most plausible fuel options highlighted in the stage one report. The resultant six concept designs produced have been subject to a proof-of-concept procedure to verify their feasibility in terms of their potential to be built and to achieve the same operation as the parent vessels. The report firstly sets out the details of the parent vessels, then provides the modified specification of each vessel, identifying for each the major challenges relating to the modifications.

The following summary sets out the key adjustments from the parent vessel and the associated challenges with each modification.

- Battery electric creel vessel: This vessel can utilise a similar GRP hull to the diesel parent vessel. In comparison to the parent vessel, whilst it does have a reduced range, it does have sufficient capacity to undertake the assumed four-hour operation cycle twice. Key challenges associated with this transition are the capital cost of batteries, the potential need for these to be regularly replaced, and issues relating to the availability of suitable infrastructure.

- Methanol creel vessel: This modified creel vessel has been developed with a steel hull which is wider than the parent vessel. A steel hull was chosen as it allows for easier integration of the methanol tank, the additional beam to support the extra weight, and for side cofferdams to be added to the methanol tanks. Key challenges with this transition relate to safe fuel storage and handling systems, the availability of equipment, and the associated increased cost.

- Methanol Nephrops trawler and whitefish trawler: The resultant designs for the methanol versions of the Nephrops and whitefish trawlers incurred very similar outcomes and challenges. Both vessels needed a moderate lengthening to fit the methanol tankage and associated cofferdam spaces. As with the methanol modified creel vessel, key challenges for both trawlers relate to safe fuel storage and handling systems, the availability of equipment, and the associated increased cost.

- Liquified Natural Gas (LNG) Nephrops trawler and whitefish trawler: For both LNG modified trawler vessels, very similar outcomes and challenges were identified. Both vessels needed an extensive lengthening to accommodate not only the cryogenic LNG tankage, but also the associated cofferdam spaces and fuel preparation systems. Key challenges for both vessels regarding this transition relate to safe fuel storage and handling systems, the expense of specialist equipment, and the greatly increased overall costs.

Whilst the concept designs included in this report show clear and plausible ways to build net zero fishing vessels, there are a number of technical, regulatory, and financial issues that need to be addressed before it is reasonable to expect owners to invest in the transition from diesel. The challenges associated with each have been summarised as follows:

- The main technical challenges relate to the availability and development timeframe for certain equipment. There are also significant questions regarding the development of alternative fuel infrastructure, especially for methanol and LNG, and, crucially, whether these fuels will be produced in sufficient quantity and at a viable cost for the fishing sector.

- The regulatory compliance of these vessels is difficult to determine mainly due to the uncertainties over which rules and safety systems would need to be utilised. Whilst this is very challenging for first of class vessels, this should become a much less significant issue once regulators, yards, and designers have an evidence base which demonstrates that net zero vessels can operate safely. In general, compliance with regulators should be possible, but it should be noted that this will come at additional cost to the project when compared to a diesel vessel.

- The key financial issue is that all the modified vessels incur a greatly increased capital cost for the same fishing capability. In addition, uncertainties on fuel prices and availability for methanol and LNG make it hard to analyse through life costs. For the battery electric vessels charged from shore power, these should make a significant saving in operational expenditure but, given the additional capital cost, a significant period of time may need to fall before this can be offset.

One final key issue of specific note, especially for the modified trawlers, is that the gross tonnage has increased. Due to the fixed amount of gross tonnage for the UK fishing fleet currently in place, should this remain, the fishing capacity of the fleet will be reduced as a result of the increased vessel tonnage. This therefore represents a major barrier to transition. There is also the potential for the cost of tonnage to rise significantly as owners try to maintain their current fishing potential and move to larger alternative fuel vessels. This results in a critical disadvantage and cost for any alternative fuel early adopters competing in a market with diesel vessels.

A number of proposed next steps have been set out in the report for future consideration. These include: a review of harbour infrastructure to support a battery electric fleet; the investigation of retrofitting options for existing vessels; the development of additional concept designs using hydrogen as an alternative fuel; the study of infrastructure plans for net zero production and delivery in the UK; the establishment of a database of trawlers' power data to support the transition; and the translation of the concept designs into a built demonstration vessel.

PARENT VESSEL DETAILS

The below section of the report sets out the outline specification of each of the parent vessels studied to determine whether a new vessel could be built which replicates these capabilities whilst utilising alternative fuels, power systems and drivetrains to achieve net zero. For the purpose of the exercise, the aim was to match the fishing gear, space requirements for gear, processing and hold capacity, safety of arrangement and the load cycle of the parent vessels. Parameters which were open to modifications included length, beam, depth, and tonnage.

Less than 10m creel boat

GRP displacement hull of 'Cygnus GM32'[2] style with forward wheelhouse and open deck

Length Overall		9.98m
Beam		3.5m
Draft		1.6m
Engine	abt.	100kW inboard
Fuel	abt.	1200 Litres

Hydraulic pot hauler
Catch / pots stowed on deck

Operating cycle: In general, the cycle consists of approximately three to four hours per operation (of which 25% represents transit to grounds, 50% hauling and shooting pots, and 25% transit back to port).

The daily cycle is to target the same point of tide – this usually consists of approximately three to four hours operating, followed by eight hours in harbour before the next voyage. Refuelling typically takes place every five to seven days.

[2] CYGNUS GM32 - Cygnus Marine

Approximately 15m Nephrops trawler

Based on ‘Antares BF27’ – see figure 1.
Designed by Macduff Ship Design and built at Buckie Shipyard in 2000.

Length Overall		16.70m
Length BP		14.35m
Beam Moulded		6.40m
Amidships Depth Moulded		3.60m
Fuel Capacity	abt.	9000 litres
Fresh Water Capacity	abt.	1500 litres
Main Engine Power		350kW
Auxiliary Engine Power		120kW

Hold, processing and fishing gear/equipment spaces as per the General Arrangement plan of the vessel.

The vessel cycle will assume shore factory ice and has a chilled hold.

The trawler has two operating cycles, as follows:

Operational cycle one: These ‘short three-day trips’ consist of an assumed half a day steaming to grounds, two days at grounds towing and hauling, and then a final half day steam back to port. This vessel will spend as little time in port as required to offload fish, refuel, and fill water (if needed), and to take on supplies before proceeding back to sea for another trip.

Operational cycle two: These ‘long six-day trips’ consist of an assumed one day steaming to grounds, followed by four days at grounds towing and hauling, followed by a final one day steaming back to port. In general, it is assumed that the vessel is not typically turned around for immediate departure when undertaking long trips.

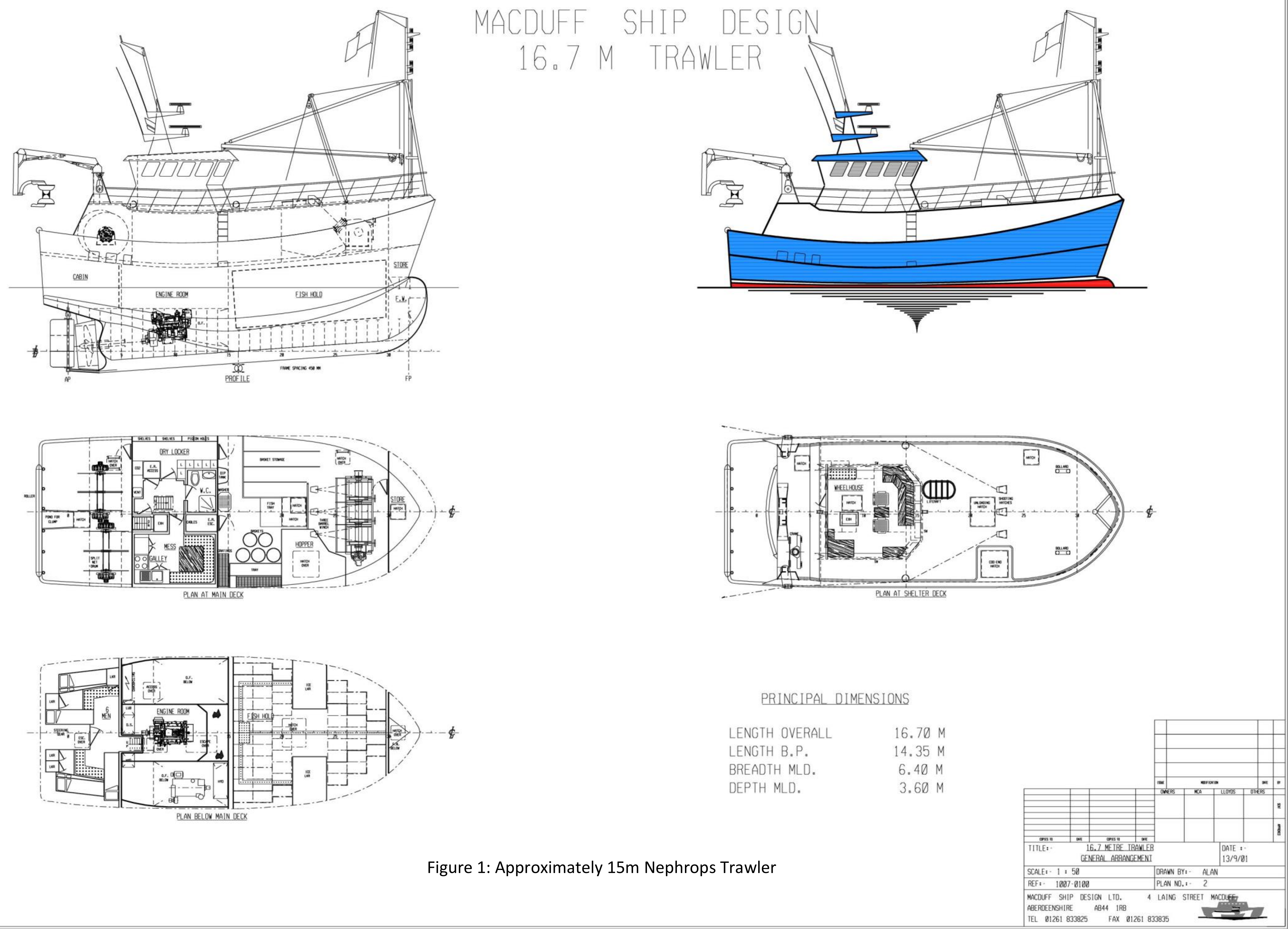


Figure 1: Approximately 15m Nephrops Trawler

Less than 24m registered whitefish trawler

Based on 'Crystal Sea SS118' – see figure 3.

Designed by Macduff Shipyards & Macduff Ship Design, and built at Macduff Shipyard in 2020, yard number 686. This was the first of four vessels built to this design with two sisters vessels registered in Banff and the final sister vessel registered in Fraserburgh. Many thanks to Macduff Shipyards for allowing the use of this vessel and its design information to be utilised within this report.

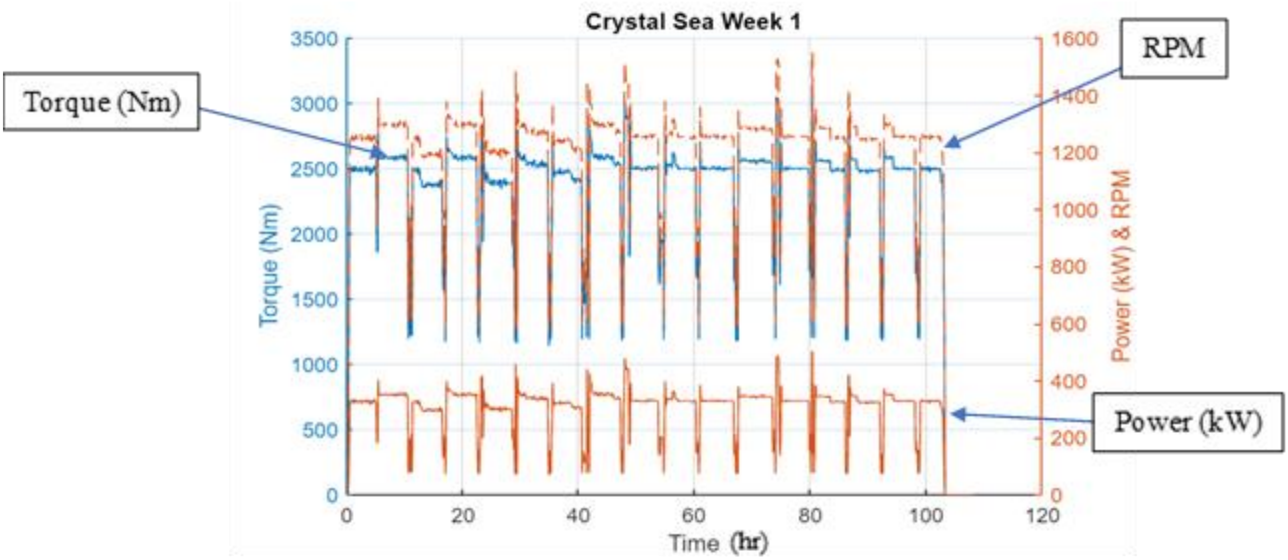
Length Overall		24.500m
Length BP (registered)		22.950m
Beam Moulded		7.600m
Depth moulded midships		4.300m to main deck
		6.600m to shelter deck
Fuel Capacity	abt.	21,000 Litres
FW Capacity	abt.	24,300L Litres
Main Engine Power		500kW
Auxiliary Engine Power		285kW for Hydraulics
		2x 81eKW electrical

Hold, processing, and fishing gear/equipment spaces as per the General Arrangement plan of the vessel.

The vessel has an ice plant, and a chilled hold.

The vessel has an operational cycle consisting of assumed eight-day long trips, comprising one day steaming to grounds, six days towing and hauling at the grounds, and a final one day steaming back to port.

The University of Exeter's 'Centre for Future Clean Mobility' (CFCM) fitted a torque/power measuring device to the Crystal Sea's shaft to make a detailed record of the vessel's power use during its operation – typically termed the 'duty cycle'. This device stayed aboard for two separate fishing trips recording the duty cycle. Figure 2 below shows the duty cycles measured.



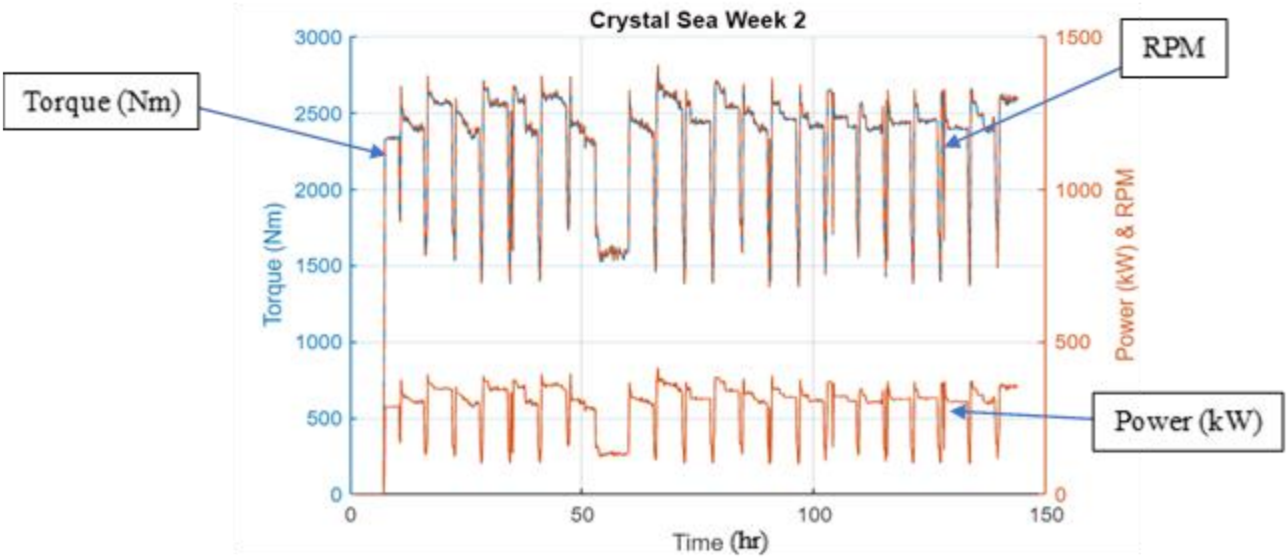


Figure 2: Measured duty-cycles for Crystal Sea (13/04 – 17/04 & 10/04 – 24/04)

This information allowed the CFCM to analyse the power output of the diesel power plant, and, utilising their database of zero emissions powertrains, advise on the best options for a replacement vessel to achieve net zero.

The data showed that, whilst in operation, the vessel's diesel main engine managed to maintain its most efficient range of load and rpm for a large proportion of the trip. Therefore, it achieves a very good efficiency for a high-speed internal combustion engine.

Analysis showed that whilst a hydrogen system could theoretically achieve the power and endurance to match the Crystal Sea, 4,600Kg of hydrogen (200,000+ litres at 300 bar) would be needed, which would not be practicable in a vessel similar to the Crystal Sea.

Please see page 38 of this report relating to the methanol powered whitefish trawler for a further exploration of the options highlighted from the analysis of this vessel.

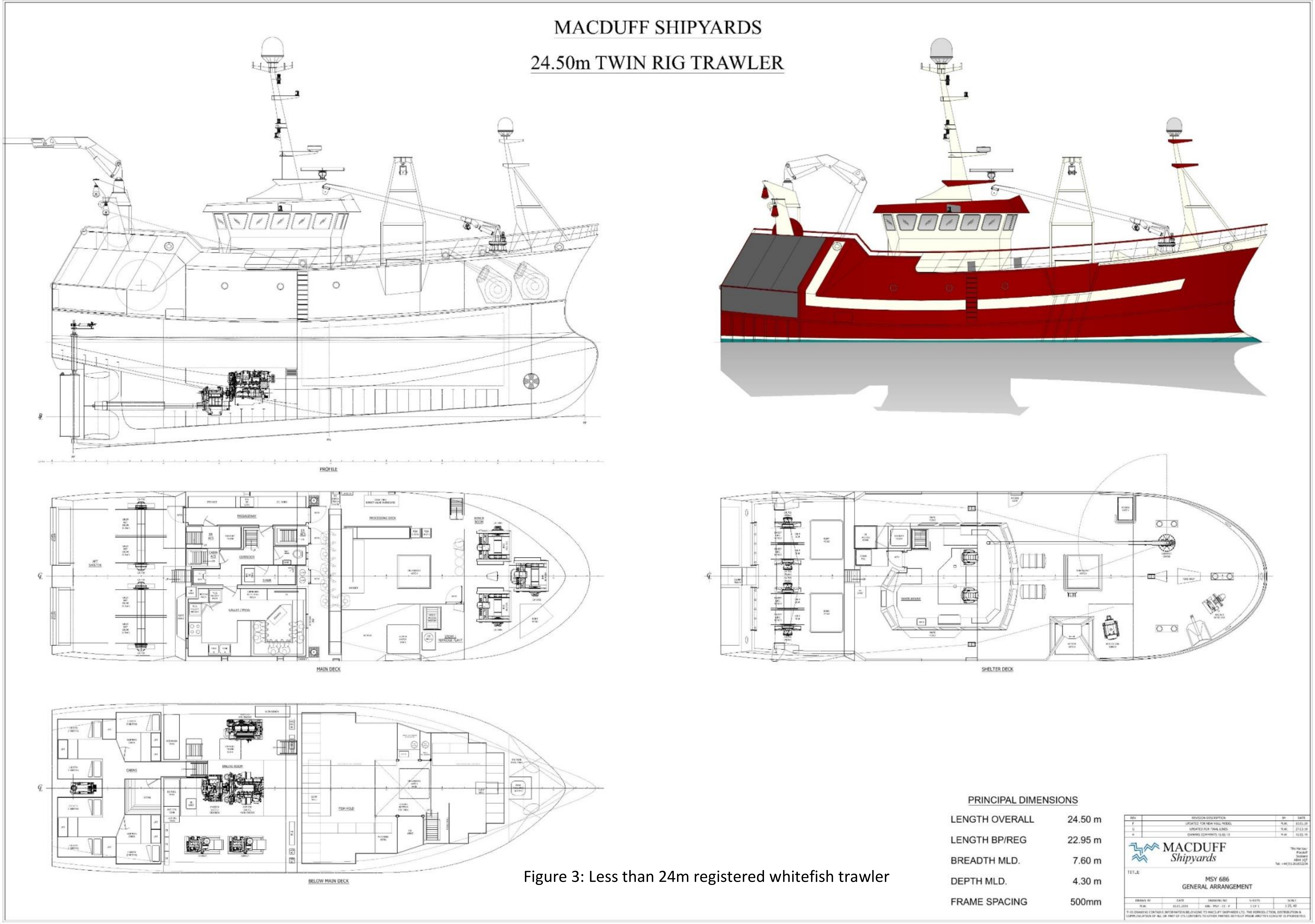


Figure 3: Less than 24m registered whitefish trawler

MODIFIED DESIGNS: SPECIFICATION AND ANALYSIS

This section of the report sets out for each potential modified vessel the Design Specification, General Arrangement, a short description, and an overview of the changes required from the parent vessel. An analysis of the potential technical, financial, and regulatory issues related to each modified design has also been provided.

It is important to note that, in all cases, there may be a number of alternative ways a designer could approach the vessel, and several different designs could indeed be developed for each option. Every effort has been taken to ensure proof of concept, vessel safety, and the ability to build the vessel as shown. Much of the technology is currently in development and there is a possibility that vessels could become more compact than shown or equally require additional space to mitigate risks that are not known at this time.

The modified designs set out below are as follows:

- <10m creel boat – Battery Electric
- <10m creel boat – Methanol
- ~15m Nephrops trawler – Methanol
- ~15m Nephrops trawler – Liquified Natural Gas (LNG)
- <24m registered whitefish trawler – Methanol
- <24m registered whitefish trawler – Liquified Natural Gas (LNG)

<10m creel boat – Battery Electric

Specification

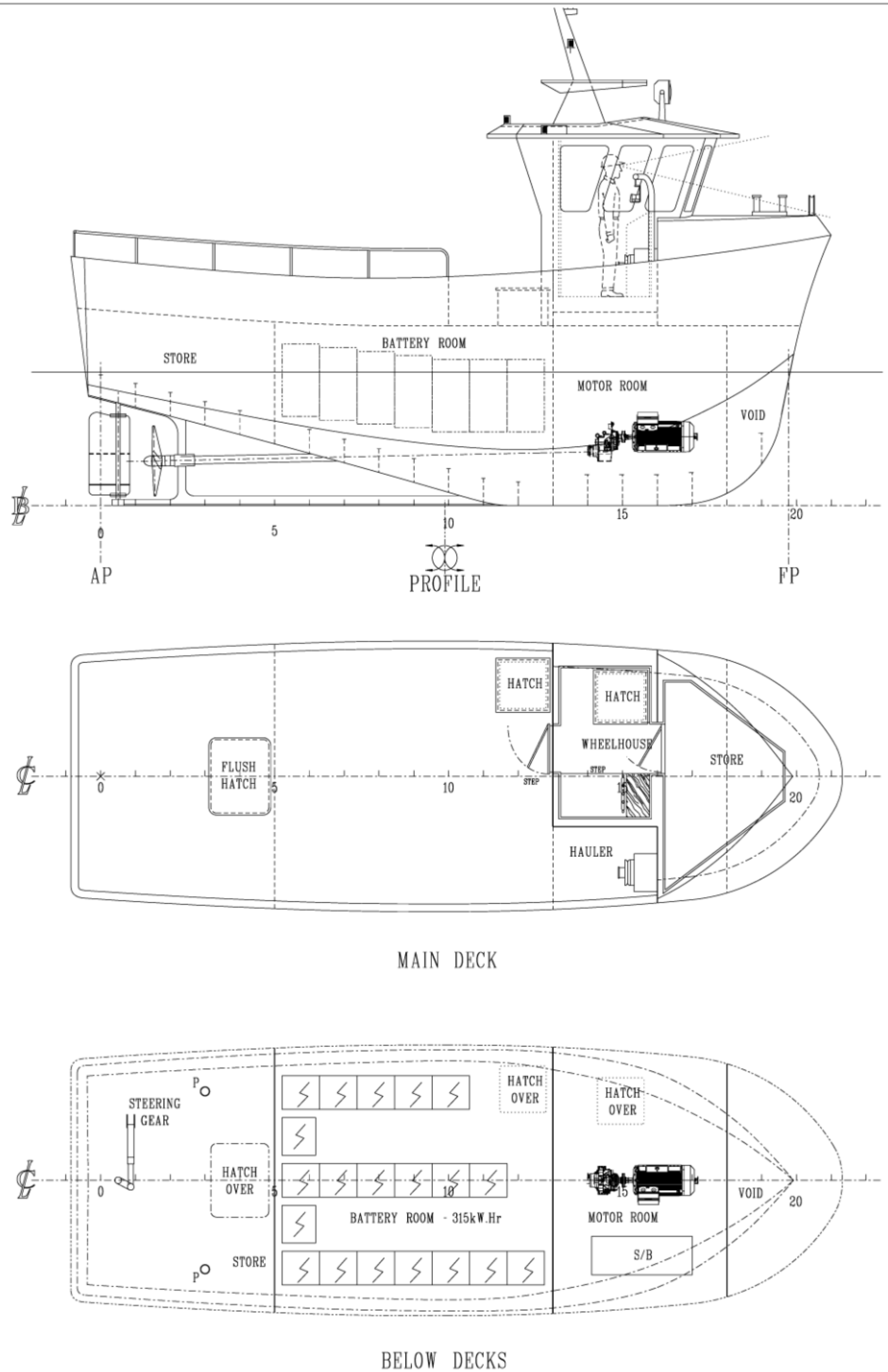
This vessel is a creel boat with hauler and block to starboard. Catch is assumed to be stowed on deck. See figure 4.

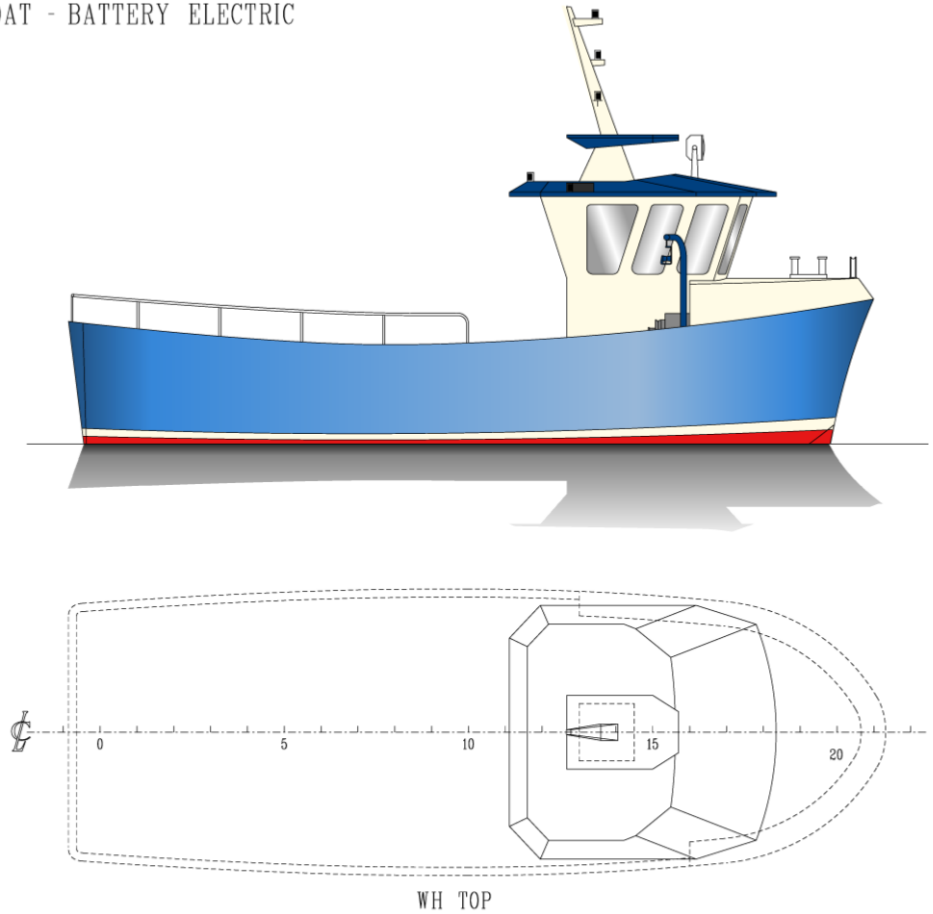
		Compared to parent vessel
Length Overall	9.950m	[No Change]
Beam	4.200m	[No Change]
Battery Capacity	315kW.h	
Motor	100kW electric motor	
Gross Tonnage	13	[No Change]
Regulations	MGN 628 (construction)	[No Change]
	MSN 1871 (Safe Working Practice)	[No Change]
	MGN664 (battery electric)	[to use BV batt/elec. rules]
	BV NR467 (battery electric)	[for battery electric system]

Figure 4

FIS CONCEPT DESIGN PROJECT

CREEL BOAT - BATTERY ELECTRIC





PRINCIPAL DIMENSIONS

LENGTH OVERALL	9.950 m
LENGTH B.P.	8.900 m
BREADTH MLD.	3.500 m
DEPTH MLD.	2.325 m

REV.	MODIFICATION	BY	DATE	CHKD.	DATE

APPROVED BY:-
DATE:-

TITLE:- FIS CONCEPT DESIGN - CREEL BOAT ELECTRIC GENERAL ARRANGEMENT

REF:- -
DRAWING NO :- 001
REVISION :- -

DRAWN BY:- MYLES | CHECKED BY:- DB
DATE:- 24-03-23 | DATE:- 27-03-23 | SCALE:- 1:33⅓ @ A1

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Report

The vessel was developed to emulate the operation of a Cygnus GM32 set up for creel fishing. Unfortunately, exact design details for the GM32 were not available and it is understood that most of these vessels are finally finished and outfitted to suit individual owner requirements. The extensive database of design information held by Macduff Ship Design Ltd. was utilised along with additional open-source information to support the development of this modification.

Due to the vessel being fully electric, powered by batteries, there are a number of significant differences to the diesel parent vessel. In particular, energy storage in batteries requires considerably more space than storage via diesel. Therefore, in order to make this option plausible, a compromise has been made to limit the storage impact by requiring the vessel to recharge after every operation. With sufficient infrastructure, this is technically possible, but it should be highlighted that this would require significant harbour investment into charging facilities.

The batteries have been sized to allow for two four-hour operations. This means if the charging infrastructure fails, the vessel can still undertake its next operation. As batteries can degrade over time and have lower energy potential, the sizing also accounts for this reduction.

The three primary benefits associated with utilising a battery electric boat are:

1. Electric systems typically require less maintenance than internal combustion engines
2. Electric motors are more efficient across a larger speed range than diesel engines
3. Electricity is cheaper per unit of delivered power than diesel and therefore operational costs may significantly reduce.

The analysis shows that whilst the Cygnus GM32 can take the weight of these batteries, a question remains as to whether there is sufficient space under deck. The vessel selected for this modification is heavily inspired by the GM32, but ultimately has a depth to suit the fitting of the batteries.

The use of a 100kW continuous output prime mover has been maintained in this design modification, although it is considered that, with more detailed analysis, this could be reduced, as could the battery size.

An example of electrification of a Cygnus 21 has already provided early indications of success. The project, undertaken by Hans Unkles – a boatbuilder and fisherman from Tayvallich– is nearing completion and authority approval. The battery size and motor for this vessel were carefully selected for this specific operation with a view to keeping both as small as possible to keep costs down, whilst also remaining at a sufficient level to undertake operations successfully with enough spare capacity for unexpected issues.

Analysis

The key potential technical, regulatory, and financial issues associated with this modified design are summarised below.

Technical

- Challenges are associated with the production of a sufficiently simple battery/switchboard/drive system for the vessel.
- Many components are not easily cross compatible. As such, it is important to ensure that the items utilised (voltages/power draws/systems) are compatible.
- Charging infrastructure is required to make this option viable. For the designed vessel, whilst a 22kW charger would be acceptable, 50kW or 100kW would be significantly better.

Regulatory

- There is an uncertain path to approval, and therefore subsequent uncertainties regarding what will be required when MGN664 is utilised.
- Currently, there are no international rules for fully electric vessels (only diesel battery hybrid).
- There is a level of uncertainty as to whether first of class vessels would need backup propulsion. This uncertainty will remain until proven either way. For this vessel, this could be provided by outboard if required.

Financial

There are a significant number of potential financial implications and limitations presented by this modification. Additional costs anticipated for this design modification relate to:

- Energy storage needs which are more complex than those of the parent vessel.
- The need for a HAZID table and the associated uncertainties of a one-off approval procedure.
- The cost of batteries/electric motor versus diesel engines.
- The need for safety systems for the batteries/electrical systems onboard.
- Approval for utilising MGN664.
- Training of shipyard staff in batteries/electric power systems and the need for retention of those staff.
- Contingencies for the designer/yard to cover uncertainties and changes during the approval and build process.
- The use of charging facilities in harbours. Availability of such facilities also presents potential issues.
- Potential additional maintenance and through life costs as electrical systems need trained professionals to perform such tasks. While electric drive systems have evidence of needing less maintenance and having less breakdowns than diesel internal combustion engines, the need for specialist technicians and the inability of owners to undertake maintenance themselves could increase maintenance and through life costs.

- Battery replacement (depending on battery type, supplier, and chemistry, this replacement period could range from 3-20 years).

While some of the financial costs may fall to the shipyard, designer, or other suppliers, it is assumed that these will be passed onto the vessel owner as part of the purchase price of the vessel or the cost of associated through life services.

<10m creel boat – Methanol

Specification

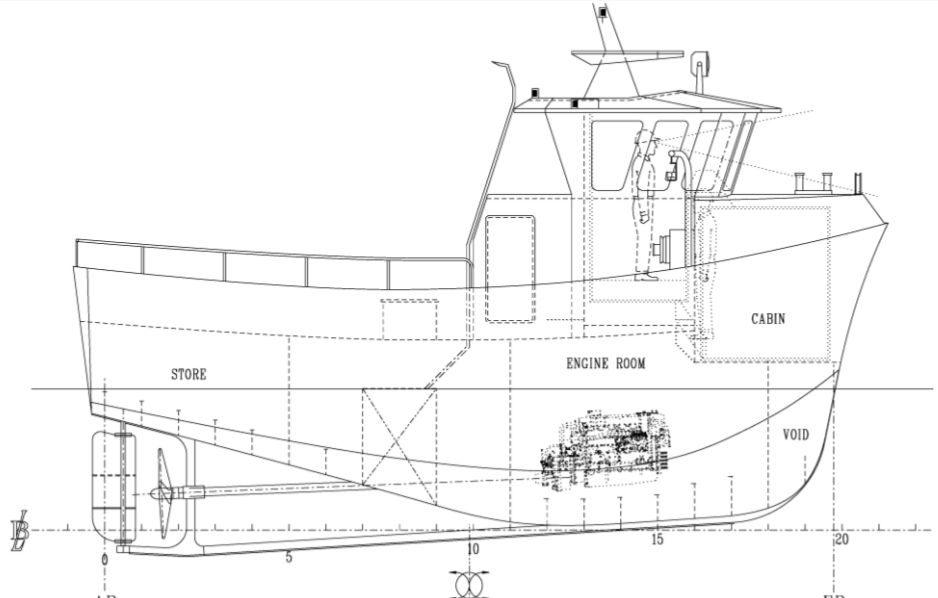
This vessel is a creel boat with hauler and block to starboard. Catch is assumed to be stowed on deck. See figure 5.

		Compared to parent vessel
Length Overall	9.950m	[No Change]
Beam	4.200m	[+0.700m / 20%]
Fuel (Methanol) Capacity	2,400L	[+1,200L / 100%]
Lightship Displacement	22 Tonnes	
Steel Weight	10 Tonnes	[previously GRP]
Engines	100kW High Speed Methanol Engine	
Gross Tonnage	20	[+7GT / 53.8%]
Regulations	MGN 628 (construction)	[No Change]
	MSN 1871 (Safe Working Practice)	[No Change]
	MGN664 (Methanol Fuel)	[to use BV Methanol rules]
	BV NR670 (Methanol Fuel)	[For Methanol systems]

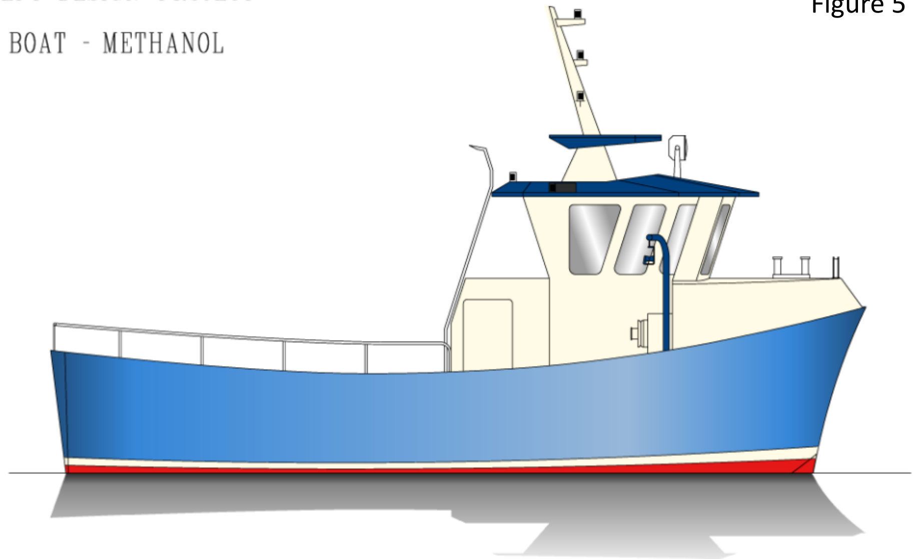
Figure 5

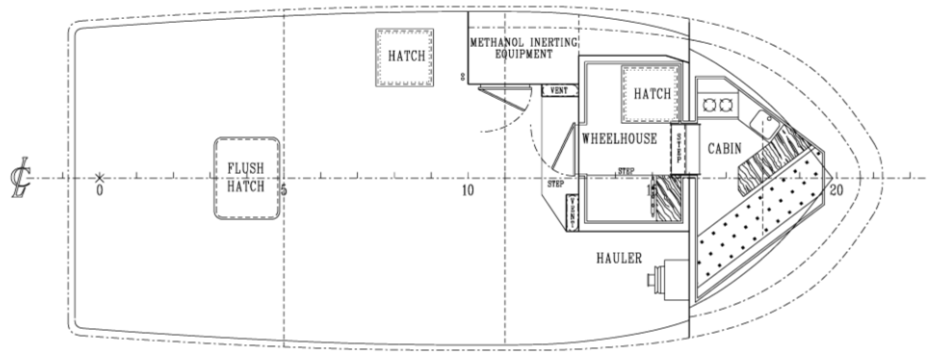
FIS CONCEPT DESIGN PROJECT

CREEL BOAT - METHANOL

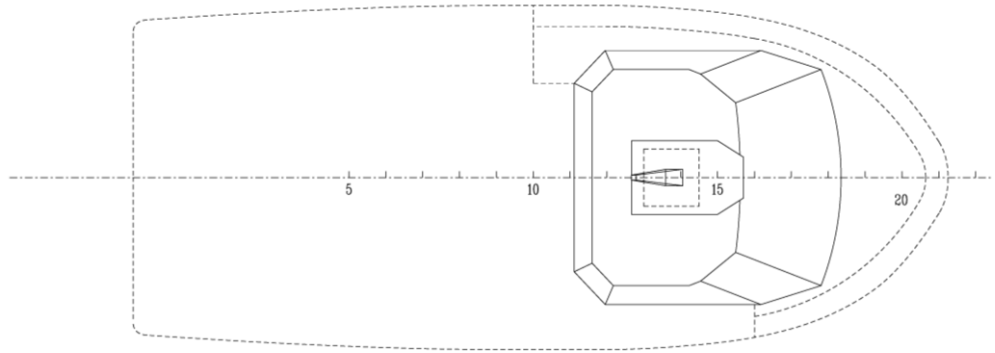


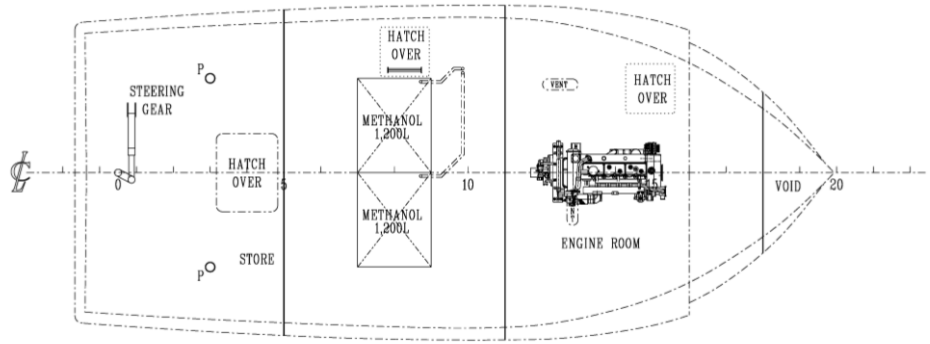
PROFILE





MAIN DECK





BELOW DECKS

PRINCIPAL DIMENSIONS

LENGTH OVERALL	9.950 m
LENGTH B.P.	8.900 m
BREADTH MLD.	4.200 m
DEPTH MLD.	2.325 m

REV.	MODIFICATION	BY	DATE	CHKD.	DATE

APPROVED BY:-

DATE:-

TITLE:- FIS CONCEPT DESIGN - CREEL BOAT METHANOL GENERAL ARRANGEMENT

REF:- -

DRAWING NO :- 001

DRAWN BY:- MYLES   CHECKED BY:- DB   REVISION :- -

DATE:- 03-03-23   DATE:- -   SCALE:- 1:33⅓ @ A1

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ISO 9001 : 2008 REGISTERED FIRM

Report

The vessel was developed to emulate the operation of a Cygnus GM32 set up for creel fishing. Unfortunately, exact design details for the GM32 were not available and the majority of these vessels are bespoke to individual owner requirements. Macduff Ship Design Ltd.'s design database was utilised along with additional open-source information to inform this modification.

The key difference between a diesel driven vessel and a methanol powered vessel relates to fuel storage. Methanol is a low flash point fuel and there are also concerns regarding its toxicity, especially when vaporized. It also has approximately half the energy density of diesel, with the result that increased care is needed in selecting the tank, pipework, and pump locations. On the modified vessel, the tanks also need to be double the volume of the diesel tanks to achieve the same range and operation as the parent vessel. Due to the nature of methanol, steel tanks are preferred, and it is understood that steel is also a better hull material for the methanol installation.

It is important to also note that the BV Methanol guidance requires the tanks to have a cofferdam separating them from machinery, accommodation, or service spaces to mitigate the risks associated with methanol's toxicity and low flash point. As such, a decision was made to locate the tank inside a cofferdam space aft of the engine room. BV rules allow piping and pumps to be fitted within this space without the added safety measures required (double walled or trunked) should these be fitted in the machinery space. Based on this, a 900mm cofferdam space was arranged at both ends of the tank to allow for both the pumps and pipework, with the aim of having minimum piping inside the engine room. On the design, tanks are positioned 800mm from the side shell, which ultimately has resulted in the beam of the vessel increasing from 3.500m to 4.200m.

Due to space restrictions, this cofferdam space can only be accessed from open shelter deck with no internal access from the engine room or aft peak. It is assumed that the engine room would remain the same size. While the amount of fuel piping and pumps would reduce, the engines would be slightly larger, and the main engine would need a larger exhaust system to provide the CO2 gas to inert the methanol tanks. A small additional section of deckhouse is needed on the port side to assist with inerting equipment and venting of the tanks and cofferdams. This ultimately does not change the deck area compared to the parent vessel when the additional beam is considered.

The tanks and cofferdam need much more extensive venting systems to ensure any methanol vapours are clear of crew and sources of ignition. These have been shown on the wheelhouse top in the General Arrangement plan, but final positioning, height and design would need to be developed using Computational Fluid Dynamics (CFD) vapour and explosive analysis.

Preliminary analysis shows the new design has good stability characteristics, requiring no additional ballast for the new vessel to meet the statutory stability criteria within acceptable margins.

A hybrid option has not been considered as the added complication of a battery and electric motor would not be achievable within the space allowed. Whilst there may be a fuel saving achieved from this type of system, the additional capital expenditure and difficulty to house the equipment safely means this has not been considered at this point.

Analysis

The key potential technical, regulatory, and financial issues associated with this modified design are summarised below.

Technical

- Prior to development, the vent design would need detailed analysis from specialists to confirm suitability.
- There are currently no suitable high-speed engines available on the market suitable for this vessel, although it is understood that these are in development. However, this may impact the ability to develop such a vessel to this specification in the immediate future.
- At present, there are no suitable tank inerting systems available off the shelf. As such, specialist, custom made options would need to be sought and availability of these is uncertain.
- Standard bunkering connections would be preferable to reduce and minimise spillage. However, there are no such connections currently available for methanol.
- Currently, there is no port infrastructure for methanol bunkering, although this could be done utilising lorries as is currently the case for much of the diesel fleet.
- A lack of experience in shipyards in the UK for the fitting or maintaining of methanol systems of this size presents a capability gap. Similarly, once installed, there is currently a lack of crews experienced in maintaining and operating methanol systems.
- The majority of methanol currently available is not net zero. Whilst the use of fossil-fuel based methanol currently available on the market incurs no operational issues, the critical point is that the vessel will not achieve net zero until it can operate on a net zero source methanol.

Regulatory

- This modified vessel would not be able to be certified using standard regulations; therefore, MGN664 should be used to show equivalence for the methanol sections of design with BV NR670 used as the equivalency regulation. It is currently unclear whether the Maritime and Coastguard Agency (MCA) would need any additional mitigation to what is advised in NR670, and this would not be clarified until the project commences.
- NR670 is designed to be used with vessels significantly larger than the design considered. Cofferdam sizes and clearances in the regulations may be larger than those actually required for safe practice on the size of vessel considered.
- The tonnage of this vessel has necessarily increased yet is not accompanied by an increase in fishing capacity. As tonnage for fishing vessels is limited for the UK fleet, if all vessels have similar changes, the fishing capacity of the fleet will reduce.
- Uncertainty remains regarding whether the MCA would have any additional requirements for skipper/engineer qualifications due to the use of methanol as a fuel.

Financial

There are a range of anticipated costs associated with this vessel, relating to:

- Additional costs of design due to a) the increased size of the vessel in comparison to the parent vessel, b) the need for a vapour/explosive analysis, and c) the need for a HAZID table and associated uncertainties of a one-off approval procedure.
- Additional cost of the vessel due to a) its increased size and associated heavier steel weight, b) the need for premium cost methanol engines which are more expensive than those of diesel engines, and c) the need for additional safety systems onboard due to the use of methanol.
- Approval costs for utilising MGN664.
- Costs for shipyards to train staff in methanol systems and to ensure staff retention.
- Additional contingency costs for the designer/yard to cover uncertainties and changes during both the approval and build processes.
- Additional costs to the owner for a) licence and tonnage on a larger vessel and b) crew training and skilled staff retention.
- Uncertainties on both the cost and availability of methanol as a fuel.
- Additional maintenance and through life costs associated both with the larger vessel and the methanol system in comparison to the diesel systems on the smaller parent vessel.

Whilst some of the financial costs may fall to the shipyard, designer, or other suppliers, it is assumed that these will be passed onto the vessel owner as part of the purchase price of the vessel or the cost of associated through life services.

~15m Nephrops trawler – Methanol

Specification

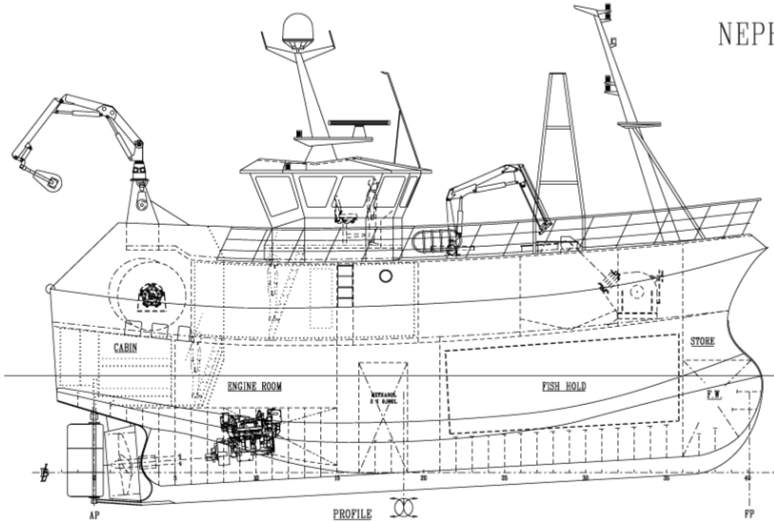
This vessel is a Nephrops trawler, implementing the same Twin Rig Trawl system as the parent vessel 'Antares BF27'. Fish hold volume, fish processing space and equipment, fishing gear spaces and fishing gear remain identical to the parent vessel. The shaft, propeller and nozzle are also assumed to be the same as the parent vessel. See figure 6.

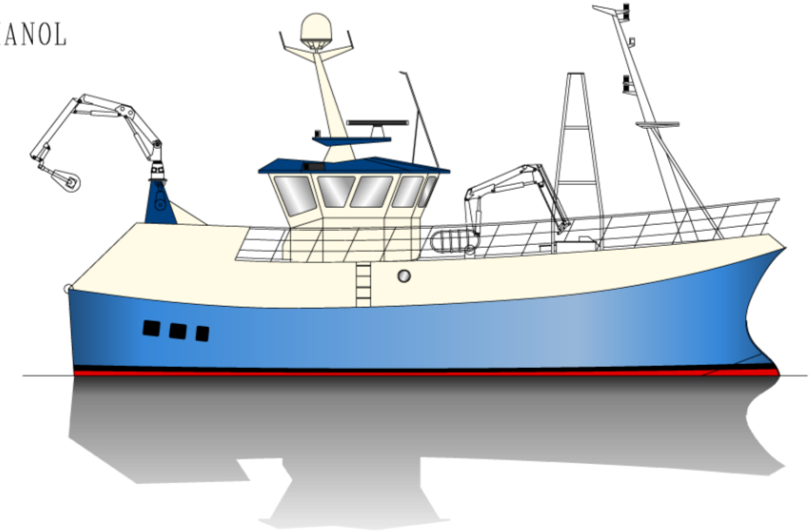
		Compared to parent vessel
Length Overall	19.950m	[+ 3.250m / 19.5%]
Length Registered	18.200m	[+ 3.850m / 26.8%]
Beam	6.400m	[No Change]
Depth	3.600m (to Main Deck)	[No Change]
Fresh Water capacity	1,500L	[No Change]
Fuel (Methanol) Capacity	18,000L	[+9,000L / 100%]
Lightship Displacement	170 Tonnes	[+30T / 21.4%]
Steel Weight	70 Tonnes	[+15 Tonnes / 27.3%]
Alu Weight	5 Tonnes	[No Change]
Ballast Weight	30 Tonnes	[No Change]
Engines	350kW High Speed Methanol Engine	
Gross Tonnage	135	[+29GT / 27.4%]
Regulations	MGN 629 (construction)	[No Change]
	MSN 1872 (Safe Working Practice)	[No Change]
	MGN664 (Methanol Fuel)	[to use BV Methanol rules]
	BV NR670 (Methanol Fuel)	[For Methanol systems]

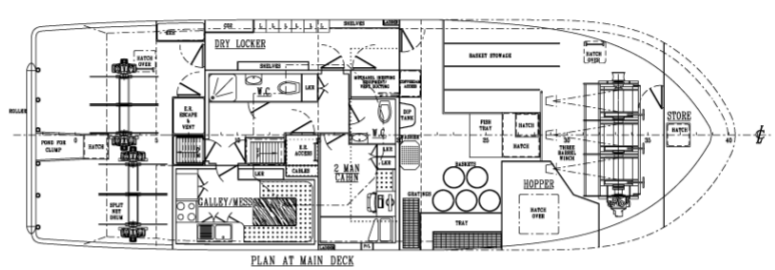
Figure 6

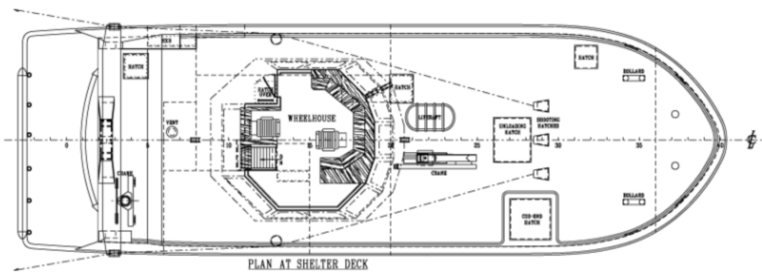
FIS CONCEPT DESIGN

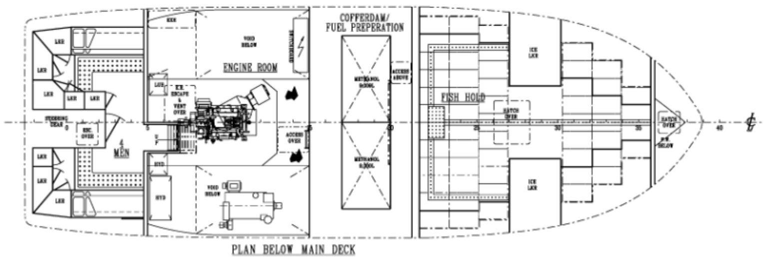
NEPHROPS TRAWLER - METHANOL











PRINCIPAL PARTICULARS

Length O.A.	19.95 m
Length B.P.	18.20 m
Breadth Mld.	6.40 m
Depth Mld.	3.60 m

REV.	MODIFICATION	BY	DATE	CHKD.	DATE

APPROVED BY:-

DATE:-

TITLE:- FIS CONCEPT DESIGN - NEPROPS METHANOL GENERAL ARRANGEMENT

REF:-

DRAWING NO :- 001

REVISION :-

DRAWN BY:- MYLES | CHECKED BY:- DB

DATE:- 08-03-23 | DATE:- -

SCALE:- 1:75 @ A1

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ISO 9001 : 2015

Report

This vessel was developed from the parent vessel of the Antares BF27, utilising the hull model, design drawings and stability data from this vessel, as well as the extensive database of information held by Macduff Ship Design Ltd.

The key difference between a diesel driven and methanol vessel relates to fuel storage. Methanol is a low flash point fuel and there are also concerns with its toxicity, especially when vaporized. It also has approximately half the energy density of diesel. The result of this is that increased care is needed in selecting the tank location and areas where pipework and pumps can be located. The tank also needs to be twice the volume to achieve the same range and operation as the parent vessel.

The parent vessel's fuel tanks were located inside the engine room space. This is prohibited by the BV Methanol guidance which requires tanks to have a cofferdam separating them from machinery, accommodation, or service spaces to mitigate the risks associated with methanol's toxicity and low flash point.

As such, the decision was taken to locate the tank between the engine room and the fish hold, creating a cofferdam space here. BV rules allow piping and pumps to be fitted within this space without added safety measures required (double walled or trunked) should these be fitted in the machinery space. Based on this, a 900mm cofferdam space to be arranged at both ends of the tank to allow for these pumps and pipework was considered, with the aim of having minimum piping inside the engine room. Tanks have been positioned 800mm from the side shell and 600mm below or aft of the deckhead and fish hold bulkhead respectively. Ultimately, this has resulted in a 3.25m lengthening of the vessel.

Due to space restrictions, this cofferdam space can only be accessed from open shelter deck with no internal access from the main or below deck spaces. The engine room is assumed to remain the same size as the parent vessel. While the amount of fuel piping and pumps would reduce, the engines would be slightly larger, and the main engine would need a larger exhaust system to provide the CO_2 gas to inert the methanol tanks.

Whilst the tank space has used room below deck, there is very little methanol machinery above deck, freeing up additional space on the main deck. Initially, this has been shown as an additional cabin to improve living quarters, although it could be utilised for alternative purposes such as improved processing facilities or the addition of an ice machine.

Although the displacement has increased, it has risen less than the extra volume added by lengthening the hull form. This means that in equivalent load cases, the new vessel floats with a shallower draft than the parent vessel. This gives scope to fine off the hull lines and improve hull resistance to keep powering similar to, or even better than, the parent vessel.

The bow has been updated to keep the collision bulkhead within the location permitted by the regulations. This contributes 0.4m of the lengthening of the vessel.

The tanks and cofferdam require much more extensive venting systems to ensure any methanol vapours are clear of crew and sources of ignition. These have been shown on the wheelhouse top in the General Arrangement plan, but final positioning, height, and design would need to developed using CFD vapour and explosive analysis.

Preliminary analysis shows the new design has good stability characteristics and needs no additional ballast to that fitted to the parent vessel to maintain suitable margins to the statutory stability criteria.

The vessel has been assumed to be a direct drive from the methanol engine through the gearbox and shaft line to the propeller. Fitting a hybrid system with a battery could incur a saving of 4-10% in fuel use. Given the space available, this could be very challenging and may require additional length to be added. Whilst this would result in a good reduction to fuel costs for the vessel, this would have to be considered and analysed alongside the increased capital cost for the equipment and through life costs associated with its maintenance and repair.

Analysis

The key potential technical, regulatory, and financial issues associated with this modified design are summarised below. As with the methanol <10m creel boat, this vessel anticipates the same issues, plus some additional issues associated with its increased registered length.

Technical

- Prior to development, the vent design would need detailed analysis from specialists to confirm suitability.
- There are currently no high-speed engines available on the market suitable for this vessel, although it is understood that these are in development. However, this may impact the ability to develop such a vessel to this specification in the immediate future.
- At present, there are no suitable tank inerting systems available off the shelf. As such, specialist, custom made options would need to be sought and availability of these is uncertain.
- Standard bunkering connections would be preferable to reduce and minimise spillage. However, there are no such connections currently available for methanol.
- Currently, there is no port infrastructure for methanol bunkering, although this could be done utilising lorries as is currently the case for much of the diesel fleet.
- A lack of experience in shipyards in the UK for the fitting or maintaining of methanol systems of this size presents a capability gap. Similarly, once installed, there is currently a lack of crews experienced in maintaining and operating methanol systems.
- The majority of methanol currently available is not net zero. Whilst the use of fossil-fuel based methanol currently available on the market incurs no operational issues, the critical point is that the vessel will not achieve net zero until it can operate on a net zero source methanol.

Regulatory

- Due to the increase in this vessel's registered length above 16.5m, the skipper would need additional certification compared to the parent vessel.
- This modified vessel is not able to be certified using standard regulations; therefore, MGN664 would need to be used to show equivalence for the methanol sections of design with BV NR670 used as the equivalency regulation. It is currently unclear whether the MCA would need any additional mitigation to what is advised in NR670, and this would not be clarified until the project commences.
- NR670 is designed to be used with vessels significantly larger than the design considered. Cofferdam sizes and clearances in the regulations may be larger than those actually required for safe practice on the size of vessel considered.
- The tonnage of this vessel has necessarily increased yet is not accompanied by an increase in fishing capacity. As tonnage for fishing vessels is limited for the UK fleet, if all vessels have similar changes, the fishing capacity of the fleet will reduce.
- Uncertainty remains regarding whether the MCA will have any additional requirements for skipper/engineer qualifications due to use of methanol as a fuel.

Financial

There are a range of anticipated costs associated with this vessel, relating to:

- Additional costs of design due to a) the increased size of the vessel in comparison to the parent vessel, b) the need for a vapour/explosive analysis, and c) the need for a HAZID table and associated uncertainties of a one-off approval procedure.
- Additional cost of the vessel due to a) its increased size and associated heavier steel weight, b) the need for premium cost methanol engines which are more expensive than those of diesel engines, and c) the need for additional safety systems onboard due to the use of methanol.
- Approval costs for utilising MGN664.
- Costs for shipyards to train staff in methanol systems and to ensure staff retention.
- Additional contingency costs for the designer/yard to cover uncertainties and changes during both the approval and build processes due to the new technology.
- Additional costs to the owner for a) licence and tonnage on a larger vessel b) crew training and skilled staff retention, and c) the increased skipper qualification required for a vessel of this size.
- Uncertainties on both the cost and availability of methanol as a fuel.
- Additional maintenance and through life costs associated both with the larger vessel and the methanol system in comparison to the diesel systems on the smaller parent vessel.

Whilst some of the financial costs may fall to the shipyard, designer, or other suppliers, it is assumed that these will be passed onto the vessel owner as part of the purchase price of the vessel or the cost of associated through life services.

~15m Nephrops trawler – LNG [Liquified Natural Gas]

Specification

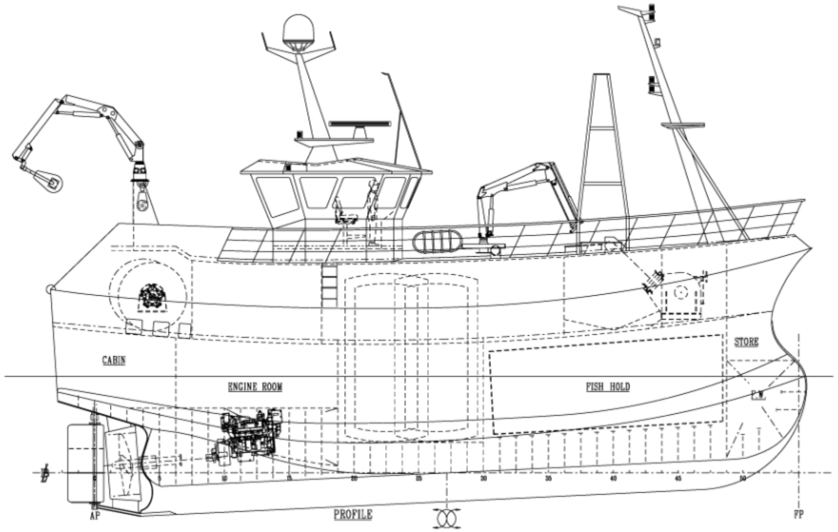
This vessel is a Nephrops trawler, implementing the same Twin Rig Trawl system as its parent vessel 'Antares BF27'. Fish hold volume, fish processing space and equipment, fishing gear spaces and fishing gear remain identical to the parent vessel. The shaft, propeller and nozzle are also assumed to be the same as the parent vessel. See figure 7.

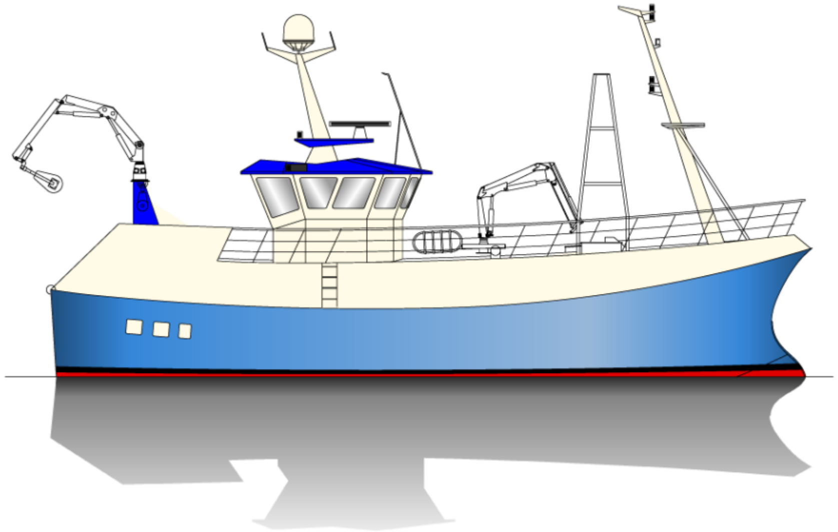
			Compared to parent vessel
Length Overall		21.150m	[+ 4.450m / 26.6%]
Length Registered		19.550m	[+ 5.200m / 39.0%]
Beam		6.400m	[No Change]
Depth		3.600m (to Main Deck)	[No Change]
Fresh Water capacity		1,500L	[No Change]
Fuel (LNG) Capacity	Total	20,000L	[+11,000L / 122.2%]
	Usable	14,000L	[+5,000L / 55.6%]
Lightship Displacement		215 Tonnes	[+75T / 53.6%]
Steel Weight		72 Tonnes	[+17 Tonnes / 30.9%]
Alu Weight		5 Tonnes	[No Change]
Ballast Weight		45 Tonnes	[+15 Tonnes / 50%]
Engines		350kW High Speed LNG engine	
Gross Tonnage		145	[+39GT / 36.7%]
Regulations		MGN 629 (construction)	[No Change]
		MSN 1872 (Safe Working Practice)	[No Change]
		MGN664 (LNG Fuel)	[to use BV LNG rules]
		BV NR529 (LNG Fuel)	[For LNG systems]

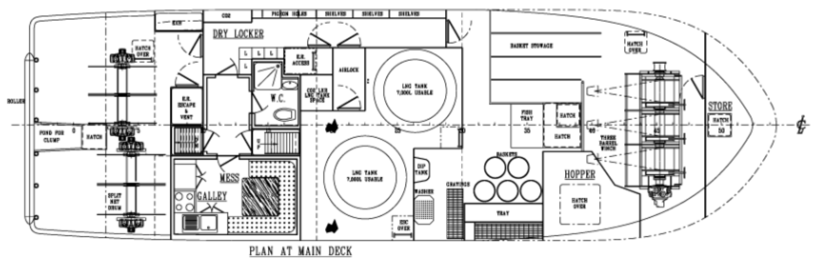
Figure 7

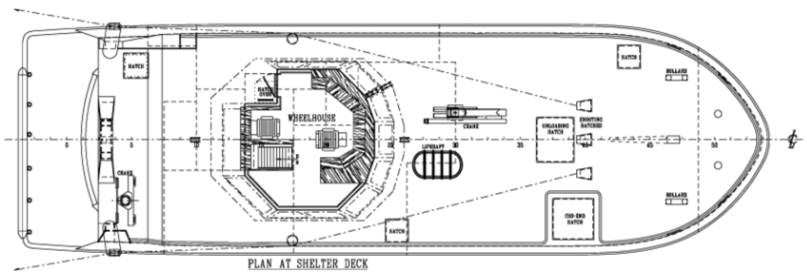
FIS CONCEPT DESIGN

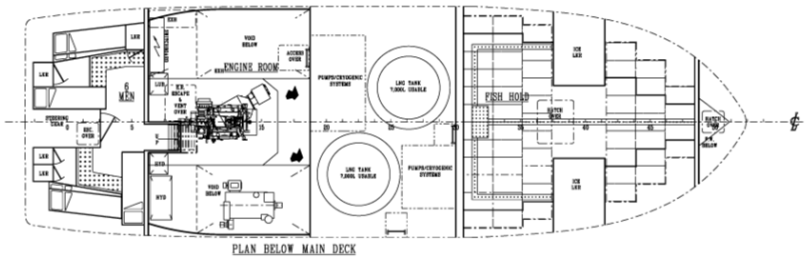
NEPHROPS TRAWLER - LNG











PRINCIPAL DIMENSIONS

LENGTH OVERALL	21.15 M
LENGTH B.P.	19.55 M
BREADTH MLD.	6.40 M
DEPTH MLD.	3.60 M

REV.	MODIFICATION	BY	DATE	CHKD.	DATE

APPROVED BY:-			
DATE:-			
TITLE:- FIS CONCEPT DESIGN - NEPHROPS LNG GENERAL ARRANGEMENT		REF:-	
		DRAWING NO :-	001
DRAWN BY:- MYLES	CHECKED BY:- DB	REVISION :-	
DATE:- 09-03-23	DATE:- -	SCALE:-	1:75 @ A1

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ISO 9001 : 2015

Report

The vessel was developed from the parent vessel of the Antares BF27 and utilised the hull model, design drawings and stability data from this vessel alongside the extensive database of information held by Macduff Ship Design Ltd.

The key difference between a diesel and a liquified natural gas (LNG) driven vessel relates to fuel storage. LNG is a low flash point fuel and needs to be stored cryogenically at -153 degrees centigrade and under pressure to maintain a liquid state. It also has approximately 60% the energy density of diesel with the result that increased care is needed in selecting the tank pipework and pumps location. The tank also needs to be designed carefully to accommodate the required temperature of the fuel and its need to be stored under pressure.

The fuel tanks on the parent vessel were located inside the engine room space. Under the BV LNG guidance this is prohibited, as LNG tanks are required to be positioned in their own tank space, separate from machinery, accommodation, or service spaces.

A decision was taken to locate the tanks between the engine room and the fish hold, creating a cofferdam space here. BV rules allow piping and pumps to be fitted within this space without the added safety measures required (double walled or trunked) should these be fitted in the machinery space. The tanks are cylindrical items which are separate to the ship structure. These tanks require large double wall thickness, with the interstitial space between insulated and vacuum sealed to ensure the tank contents maintain their cryogenic temperature. The tanks are also pressurised. As a result, a larger internal volume is required to ensure the usable volume required to maintain the vessel's operational characteristics. These factors combined mean the tanks' footprint is larger than had originally been considered in stage one of concept development.

The tanks have been positioned vertically, from the floors of the vessel, through main deck level terminating near the shelter deck beams. The circular nature of the cross section of the tanks is less efficient than that of the square corners that would typically be used with fuels that are liquid at ambient conditions.

In addition, the vessel has been lengthened by 4.450m to allow the proposed tanks to be fitted. The port tank has been kept 1000mm from ship side to maintain an access passage on the port side of the shelter. The starboard tank has its inner skin 800mm from ship side to comply with BV regulation. The tank room spanning from vessel floors to shelter deck has been designed with sufficient space for the pumping and piping from the tanks, with only delivery fuel lines needed to be fitted within the machinery space.

This tank space would be accessed from the open shelter deck or from an air lock entrance on the main deck port access corridor. It is assumed that the engine room would remain the same size as the parent vessel. Whilst the amount of fuel piping and pumps would reduce, the engines would be slightly larger, and the main engine would require a larger exhaust system arranged to provide the CO_2 gas to inert the LNG tanks.

The majority of the additional volume added to the hull, both above and below main deck, is dedicated to the fuel tanks and fuel systems. This means that despite the significant increase in size of vessel, the accommodation and processing space remains largely the same as on the original vessel.

In addition, the displacement has increased and has risen approximately equivalent to the extra volume added by lengthening the hull form. This means that in equivalent load cases the new vessel floats with a similar draft to the parent vessel. As such, there is no scope to improve the lines of the vessel, and a small increase in powering requirement may be seen. This is believed to be small and should not significantly affect the fuel needed to achieve the same operation as the parent vessel.

In order to keep the collision bulkhead within the location permitted by the regulations, the bow has had to be updated, contributing 0.4m to the lengthening of the vessel.

The tanks and cofferdam require much more extensive venting systems to ensure any LNG vapours are clear of crew and sources of ignition. These have been shown on the General Arrangement plan as on wheelhouse top, but final positioning, height and design would need to developed using CFD vapour and explosive analysis.

Preliminary analysis shows the new design has reduced stability characteristics to the parent vessel and needs additional ballast to that originally fitted. An additional 15 tonnes of ballast compared to that fitted to the parent vessel is needed to meet the statutory stability criteria within acceptable margins.

The vessel has been assumed to be a direct drive from the LNG engine through the gearbox and shaft line to the propeller. Fitting a hybrid system with a battery could result in fuel use savings of 4-10%. Given the space available, this could be very challenging and may result in the need for additional length to be added. Whilst it would make a good reduction to fuel costs for the vessel, this should be considered and analysed alongside the increased capital cost for the equipment and through life costs associated with its maintenance and repair.

Analysis

The key potential technical, regulatory, and financial issues associated with this modified design are summarised below. As with the vessels modified for methanol fuel, this LNG fuelled vessel anticipates many similar issues, plus some additional issues specifically associated with the nature of LNG as a fuel.

Technical

- Prior to development, the vent design would need detailed analysis from specialists to confirm suitability.
- There are currently no high-speed engines available on the market suitable for this vessel. Refitting of a diesel engine could be possible, but such an approach may fail to achieve full approval.
- At present, there are no suitable tanks, cryogenic and pumping systems, and tank inerting systems available off the shelf for a system of this size. As such, specialist designed tanks would be required to maximise space. Custom made options are currently available on the market.
- Currently, there is no port infrastructure for LNG bunkering. Bunkering for LNG is more difficult than diesel as the fuel is cryogenic and therefore requires specialist bunkering options.
- A lack of experience in shipyards in the UK for the fitting or maintaining of LNG systems of this size presents a capability gap. Similarly, once installed, there is currently a lack of crews experienced in maintaining and operating LNG systems.
- The majority of LNG currently available is not net zero, and there is a degree of uncertainty as to whether net zero LNG will even be produced. Whilst the use of fossil-fuel based LNG currently available on the market incurs no operational issues, the critical point is that the vessel will not achieve net zero until it can operate on a net zero source LNG.

Regulatory

- Due to the increase in this vessel’s registered length above 16.5m, the skipper would need additional certification compared to the parent vessel.
- This modified vessel would not be able to be certified using standard regulations; therefore, MGN664 would need to be used to show equivalence for the LNG sections of design with BV NR670 used as the equivalency regulation. It is currently unclear whether the MCA would need any additional mitigation to what is advised in NR670, and this would not be clarified until the project commences.
- NR670 is designed to be used with vessels significantly larger than the design considered. Cofferdam sizes and clearances in the regulations may be larger than those actually required for safe practice on the size of vessel considered.
- The tonnage of this vessel has necessarily increased yet is not accompanied by an increase in fishing capacity. As tonnage for fishing vessels is limited for the UK fleet, if all vessels have similar changes, the fishing capacity of the fleet will reduce.

- Uncertainty remains regarding whether the MCA would have any additional requirements for skipper/engineer qualifications due to use of LNG as a fuel.
- The vessel has also increased past 20m, and as such, navigation light regulations will also have changed.

Financial

There are a range of anticipated costs associated with this vessel, relating to:

- Additional costs of design due to a) the increased size of the vessel in comparison to the parent vessel, b) the need for a vapour/explosive analysis, and c) the need for a HAZID table and associated uncertainties of a one-off approval procedure.
- Additional cost of the vessel due to a) its increased size and associated heavier steel weight, b) the need for premium cost LNG engines which are more expensive than those of diesel engines, and c) the need for additional safety systems onboard due to the use of LNG.
- Approval costs for utilising MGN664.
- Costs for shipyards to train staff in LNG systems and to ensure staff retention.
- Additional contingency costs for the designer/yard to cover uncertainties and changes during both the approval and build processes due to the new technology.
- Additional costs to the owner for a) licence and tonnage on a larger vessel b) crew training and skilled staff retention, and c) the increased skipper qualification required for a vessel of this size.
- Uncertainties on both the cost and availability of LNG as a fuel.
- Additional maintenance and through life costs associated both with the larger vessel and the LNG system in comparison to the diesel systems on the smaller parent vessel.

Whilst some of the financial costs may fall to the shipyard, designer, or other suppliers, it is assumed that these will be passed onto the vessel owner as part of the purchase price of the vessel or the cost of associated through life services.

<24m registered whitefish trawler – Methanol

Specification

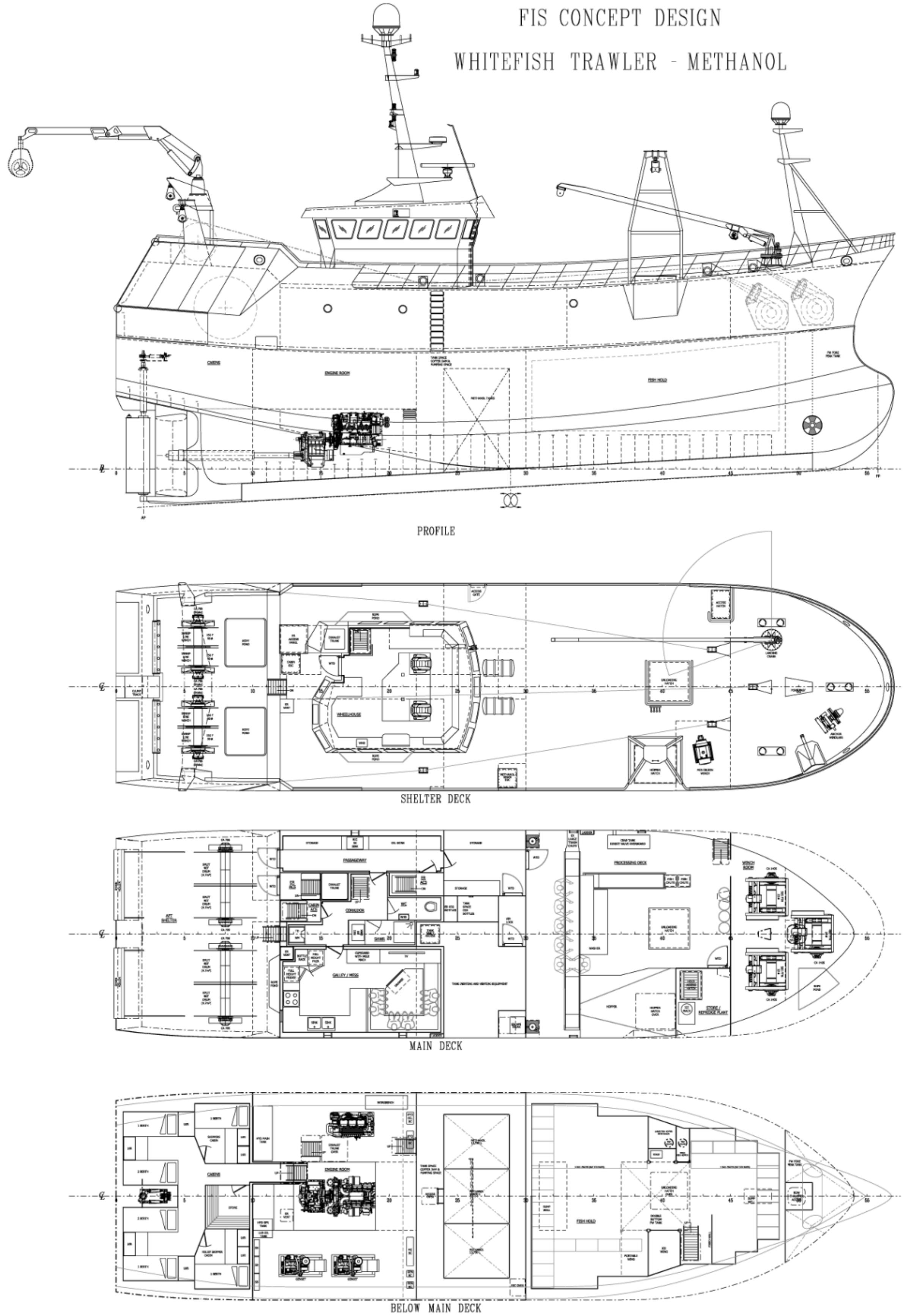
The vessel is a whitefish trawler, implementing the same Twin Rig Trawl system as its parent vessel 'Crystal Sea SS118'. Fish hold volume, fish processing space and equipment, fishing gear spaces and fishing gear remain identical to the parent vessel. The shaft, propeller and nozzle are also assumed to be the same as the parent vessel. See figure 8.

		Compared to parent vessel
Length Overall	28.500m	[+ 4.000m / 16.3%]
Length Registered	26.900m	[+ 3.850m / 17.2%]
Beam	7.600m	[No Change]
Depth	4.300m (to Main Deck)	[No Change]
Fresh Water capacity	24,300L	[No Change]
Fuel (Methanol) Capacity	44,150L	[+23,150L / 110%]
Lightship Displacement	332 Tonnes	[+54T / 19.4%]
Steel Weight	139 Tonnes	[+20 T / 16.8%]
Ballast Weight	58 Tonnes	[+7.15 T / 13.7%]
Engines	500kW High Speed Methanol Engine	
Gross Tonnage	295	[+48GT / 19.4%]
Regulations	BV NR600 (Construction)	[as vessel >24m registered]
	BV NR467 (Outfitting & Stability)	[as vessel >24m registered]
	MSN 1873 (Safe Working Practice)	[as vessel >24m registered]
	MGN664 (Methanol Fuel)	[to use BV Methanol rules]
	BV NR670 (Methanol Fuel)	[For Methanol systems]
Cost increase (purchase price)	25-45% more expensive than diesel parent vessel	

Figure 8

FIS CONCEPT DESIGN

WHITEFISH TRAWLER - METHANOL



PRINCIPAL PARTICULARS

Length O.A.	28.50 m
Length B.P.	26.90 m
Breadth Mld.	7.60 m
Depth Mld.	4.30 m

REV.	MODIFICATION	BY	DATE	CHKD.	DATE

APPROVED BY:-

DATE:-

TITLE:- FIS CONCEPT DESIGN - WHITEFISH METHANOL GENERAL ARRANGEMENT

REF:-

DRAWING NO :- 001

DRAWN BY:- MYLES | CHECKED BY:- DB | REVISION :-

DATE:- 13-03-23 | DATE:- - | SCALE:- 1:75 @ A1

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ISO 9001 : 2015

Report

The vessel was developed from the parent vessel of the Crystal Sea SS118 and utilised the hull model, design drawings and stability data from this vessel as well as the extensive database of information held by Macduff Ship Design Ltd.

The key difference between a diesel and methanol driven vessel relates to fuel storage. Methanol is a low flash point fuel and there are also concerns with its toxicity, especially when vaporized. It also has approximately half the energy density of diesel. As a result, increased care is needed in selecting the tank location and areas where pipework and pumps can be located. The tank also needs to be twice the volume to achieve the same range and operation as the parent vessel.

The parent vessel located the fuel tanks inside the engine room space. This is prohibited by the BV Methanol guidance which requires the tanks to have a cofferdam separating them from machinery, accommodation, or service spaces.

A decision was taken to locate the tank between the engine room and the fish hold, creating a cofferdam space here. BV rules allow piping and pumps to be fitted within this space without the added safety measures required (double walled or trunked) should these be fitted in the machinery space. Based on this, a 1000mm cofferdam space arranged at both ends of the tank to allow for these pumps and pipework has been considered, with the aim of having minimum piping inside the engine room. Tanks have been positioned 800mm from the side shell and 600mm below or aft of the deckhead and fish hold bulkhead respectively. As a result, the vessel has been lengthened by 4.000m.

The cofferdam space can be accessed from either the open shelter deck or from an air lock on the main deck from the port access passage. It has been assumed that the engine room would remain the same size as the parent vessel. Whilst the amount of fuel piping and pumps would reduce, the engines would need to be slightly larger, and the main engine would require a larger exhaust system arranged to provide the CO_2 gas to inert the methanol tanks.

Although the tank space has used room below deck, the amount of methanol equipment on deck allows space above deck that can be utilised to improve the vessel. Initially, this has been shown to provide a larger galley/mess and an extra metre in the processing space. However, this space could be utilised for other options to suit individual owner requirements.

Whilst the displacement has increased, it has risen less than the extra volume added by lengthening the hull form with the result that in equivalent load cases the new vessel floats with a shallower draft than the parent vessel. This provides scope to fine off the hull lines and improve hull resistance to keep powering similar to or better than the parent vessel.

The tanks and cofferdam will require much more extensive venting systems to ensure any methanol vapours are clear of crew and sources of ignition. These have been shown on the General Arrangement Plan on the wheelhouse top but final positioning, height and design would need to developed using CFD vapour and explosive analysis.

Preliminary analysis shows the new design has good stability characteristics and needs a small amount of additional ballast to that fitted to the parent vessel. An additional 7.15 tonnes have been added, equivalent to fitting scrap steel in the lengthened section of box keel. This modification ensures the vessel maintains the statutory stability criteria within acceptable margins.

It is estimated that the cost to purchase this vessel would be 25-45% more expensive than for the diesel parent vessel. This does not include the additional costs associated with the increase in tonnage, changes in licence requirements, or any operational costs. Fuel prices and the availability of alternative fuels at present, alongside uncertainties over their future, make it challenging to analyse and determine through life costs. It should be noted that this projected increase is an initial estimate and that the first vessels of this kind could significantly exceed estimations due to the lack of established supply chains, and the need to source some equipment not yet currently available on the market via specialist manufacture. In addition, yards, designers, and suppliers will all incur additional contingency costs to cover any unexpected issues that occur during the build.

The vessel has been assumed to be a direct drive from the methanol engine through the gearbox and shaft line to the propeller. Based on the data measured and analysis undertaken by the University of Exeter's Centre for Future Clean Mobility, fitting a hybrid system with a 320kW.hr battery and 400kW motor should increase the vessel's efficiency from 39% to 42.4%. This would equate to a fuel saving of 8.4%. In such a system, the motor is fitted to a power in, power out gearbox.

It should be noted that on this modified vessel, a fixed pitch propeller and separate hydraulic engine is proposed. This is a simple and robust system, however, when the main engine is operating at an inefficient power and RPM (i.e., while hauling nets) the hydraulic engine is running at high power. If the vessel was to have a controllable pitch propeller and a power take off from the gearbox to run the hydraulics – a common but more expensive system – this would help to keep the main engine at its optimum power output and RPM for more time, thereby improving the efficiency of the system. This system makes a similar change to the efficiency of the main engine as fitting a hybrid system like that noted above. As such, if this system was fitted, the efficiency savings of also fitting a hybrid system would be significantly lower than those noted in the above paragraph.

Given the space available, it could be challenging to fit the hybrid system, and, unless additional length is added, it may reduce the service spaces around the equipment in the engine room. Fuel savings within a hybrid system could be increased by utilising more electrical deck equipment on the vessel like winches and net drums. When paying out nets and wires from these, they can charge the batteries as opposed to conventional hydraulic deck equipment which would use fuel to provide power to these items during such operations.

While hybrid systems or running the hydraulic systems from the main engine can make a reduction to fuel costs for the vessel, this would have to be considered and analysed alongside the increased capital cost for the equipment and through life costs associated with the maintenance and repair of such a system. Initial estimates would suggest the additional cost of equipment is 5-9% of the purchase cost of the vessel for the hybrid system described. It should also be noted that this system could affect licencing, crew requirements and certification for the vessel as the vessel would, in effect, have more propulsion power than if it were only driven from the engine.

Analysis

The key potential technical, regulatory, and financial issues associated with this modified design are summarised below. As with other methanol modified vessels, this vessel anticipates the same issues, with some additional issues associated specifically with the increased registered length above 24m.

Technical

- Prior to development, the vent design would need detailed analysis from specialists to confirm suitability.
- There are currently no high-speed engines available on the market suitable for this vessel, although it is understood that these are in development. However, this may impact the ability to develop such a vessel to this specification in the immediate future.
- At present, there are no suitable tank inerting systems available off the shelf. As such, specialist, custom made options would need to be sought and availability of these is uncertain.
- Standard bunkering connections would be preferable to reduce and minimise spillage. However, there are no such connections currently available for methanol.
- Currently, there is no port infrastructure for methanol bunkering, although this could be done utilising lorries as is currently the case for much of the diesel fleet.
- A lack of experience in shipyards in the UK for the fitting or maintaining of methanol systems of this size presents a capability gap. Similarly, once installed, there is currently a lack of crews experienced in maintaining and operating methanol systems.
- The majority of methanol currently available is not net zero. Whilst the use of fossil-fuel based methanol currently available on the market incurs no operational issues, the critical point is that the vessel will not achieve net zero until it can operate on a net zero source methanol.

Regulatory

- Due to the increase in this vessel's registered length above 24m, the skipper would need additional certification compared to the parent vessel. In addition, due to this increased registered length above 24m, the vessel would need to be in class instead of the MCA survey and would also need either a rescue boat or to seek exemption from this requirement.
- This modified vessel would not be able to be certified using standard regulations; therefore, MGN664 would be used to show equivalence for the methanol sections of design with BV NR670 used as the equivalency regulation. It is currently unclear whether the MCA would need any additional mitigation to what is advised in NR670, and this would not be clarified until the project commences.
- NR670 is designed to be used with vessels significantly larger than the design considered. Cofferdam sizes and clearances in the regulations may be larger than those actually required for safe practice on the size of vessel considered.
- The tonnage of this vessel has necessarily increased yet is not accompanied by an increase in fishing capacity. As tonnage for fishing vessels is limited for the UK fleet, if all vessels have similar changes, the fishing capacity of the fleet will reduce.
- Uncertainty remains regarding whether the MCA would have any additional requirements for skipper/engineer qualifications due to use of methanol as a fuel.

Financial

There are a range of anticipated costs associated with this vessel, relating to:

- Additional costs of design due to a) the increased size of the vessel in comparison to the parent vessel, b) the need for a vapour/explosive analysis, and c) the need for a HAZID table and associated uncertainties of a one-off approval procedure.
- Additional cost of the vessel due to a) its increased size and associated heavier steel weight, b) the need for premium cost methanol engines which are more expensive than those of diesel engines, and c) the need for additional safety systems onboard due to the use of methanol.
- Approval costs for utilising MGN664.
- Costs for shipyards to train staff in methanol systems and to ensure staff retention.
- Additional contingency costs for the designer/yard to cover uncertainties and changes during both the approval and build processes.
- Additional costs to the owner for a) licence and tonnage on a larger vessel b) crew training and skilled staff retention, and c) the increased skipper qualification required for a vessel of this size.
- Additional costs associated with class society approval, and subsequent costs related to this such as through life costs for maintenance in class, machinery as class certified, and additional items required by class above that required if a <24m vessel was registered in the MCA survey.
- Uncertainties on both the cost and availability of methanol as a fuel.
- Additional maintenance and through life costs associated both with the larger vessel and the methanol system in comparison to the diesel systems on the smaller parent vessel.

Whilst some of the financial costs may fall to the shipyard, designer, or other suppliers, it is assumed that these will be passed onto the vessel owner as part of the purchase price of the vessel or the cost of associated through life services.

<24m registered whitefish trawler – LNG [Liquified Natural Gas]

Specification

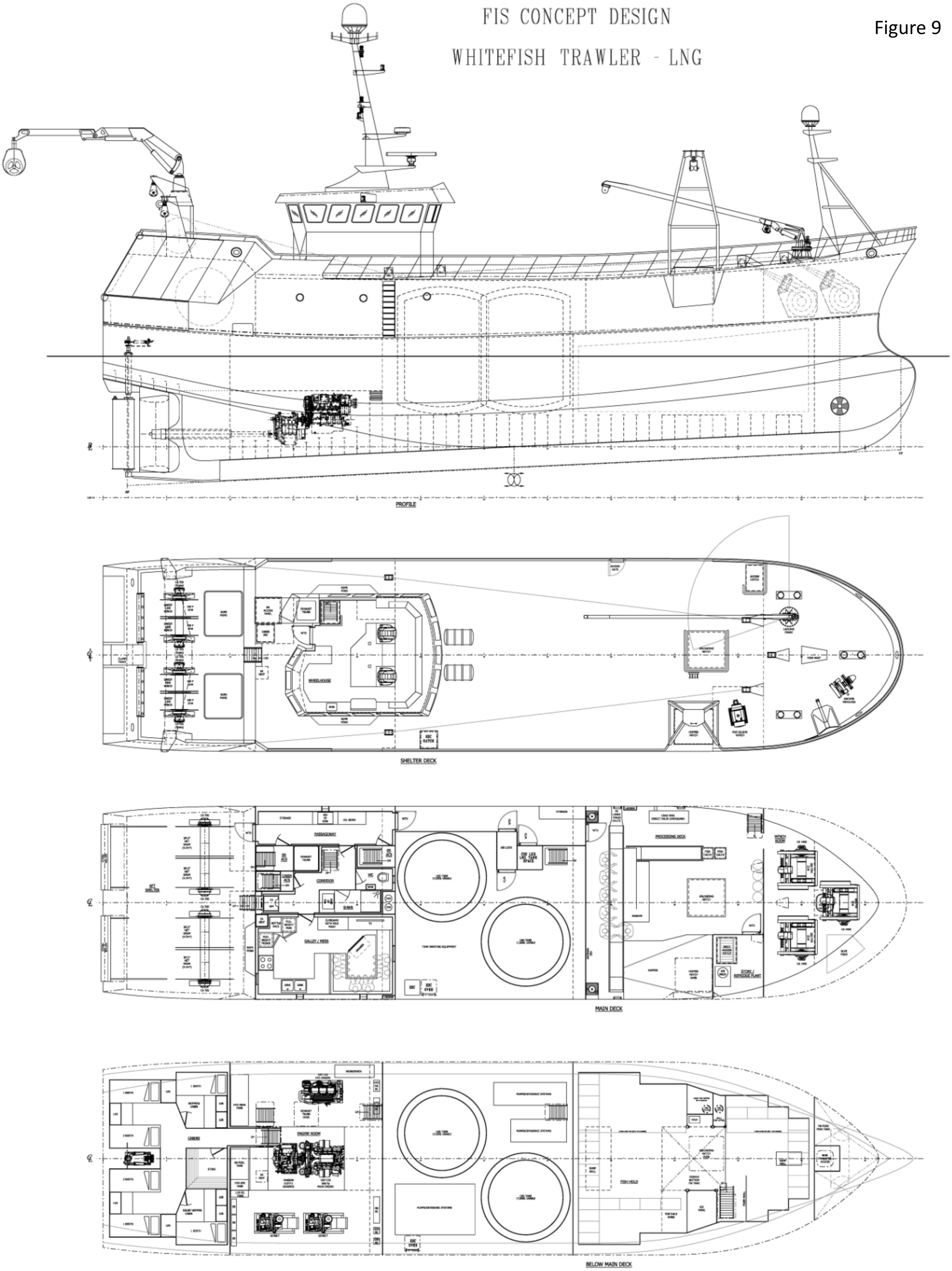
This vessel is a whitefish trawler, implementing the same Twin Rig Trawl system as its parent vessel 'Crystal Sea SS118'. The fish hold volume, fish processing space and equipment, fishing gear spaces and fishing gear remain identical to the parent vessel. The shaft, propeller and nozzle are also assumed to be the same as parent vessel. See figure 9.

			Compared to parent vessel
Length Overall		32.000m	[+ 7.500m / 30.6%]
Length Registered		30.450m	[+ 7.500m / 32.7%]
Beam		7.600m	[No Change]
Depth		4.300m (to Main Deck)	[No Change]
Fresh Water capacity		24,300L	[No Change]
Fuel (LNG) Capacity	Total	45,000L	[+24,000L / 114.3%]
	Usable	34,000L	[+13,000L / 61.9%]
Lightship Displacement		421 Tonnes	[+143T / 51.4%]
Steel Weight		155 Tonnes	[+36 Tonnes / 30.6%]
Ballast Weight		77 Tonnes	[+26 T / 51.0%]
Engines		500kW High Speed LNG Engine	
Gross Tonnage		338	[+91GT / 36.8%]
Regulations		BV NR600 (Construction)	[as vessel >24m registered]
		BV NR467 (Outfitting & Stability)	[as vessel >24m registered]
		MSN 1873 (Safe Working Practice)	[as vessel >24m registered]
		MGN664 (LNG Fuel)	[to use BV LNG rules]
		BV NR529 (LNG Fuel)	[For LNG systems]
Cost increase (purchase price)		80-100% more expensive than diesel parent vessel	

Figure 9

FIS CONCEPT DESIGN

WHITEFISH TRAWLER - LNG



PRINCIPAL PARTICULARS

Length O.A.	32.00 m
Length B.P.	30.45 m
Breadth Mld.	7.60 m
Depth Mld.	4.30 m

REV.	MODIFICATION	BY	DATE	CHKD.	DATE

APPROVED BY:-

DATE:-

TITLE:- FIS CONCEPT DESIGN - WHITEFISH LNG
GENERAL ARRANGEMENT

REF:-

DRAWING NO :- 001

REVISION :-

DRAWN BY:- MYLES   CHECKED BY:- DB

DATE:- 14-03-23   DATE:- -

SCALE:- 1:75 @ A1

MACDUFF SHIP DESIGN Ltd. LOW SHORE MACDUFF
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Report

The vessel was developed from the parent vessel of the Crystal Sea SS118, utilising the hull model, design drawings and stability data from this vessel as well as the extensive database of information held by Macduff Ship Design Ltd.

The key difference between a diesel and LNG driven vessel relates to fuel storage. LNG is a low flash point fuel and needs to be stored cryogenically at -153 degrees centigrade and under pressure to retain a liquid state. It also has approximately 60% the energy density of diesel. As a result of this, increased care is needed in selecting the pipework and pumps location. The tank also needs to be designed to accommodate the required temperature of the fuel and pressure needs.

Whilst the parent vessel had the fuel tanks inside the engine room space, this is prohibited by the BV LNG guidance which requires LNG tanks to be positioned in their own tank space, separate from machinery, accommodation, or service spaces.

A decision was taken to locate the tanks between the engine room and the fish hold and to create a cofferdam space here. BV rules allow for piping and pumps to be fitted within this space without the added safety measures required (double walled or trunked) should these be fitted in the machinery space. The tanks are cylindrical items which are separate to the ship structure. These tanks require a large double wall thickness, with the interstitial space between insulated and vacuum sealed to ensure the tank contents maintain their cryogenic temperature. The tanks are also pressurised which means that a larger internal volume is needed to ensure the usable volume required to maintain the vessel’s operational characteristics. These factors combined mean the tanks’ footprint is larger than had originally been considered in stage one of concept development.

The tanks have been positioned vertically, from the floors of the vessel, through the main deck level terminating near the shelter deck beams. The circular nature of the cross section of the tank results in a less efficient use of space than the square corners typically used for fuels that are liquid at ambient conditions.

In order to fit the proposed tanks, the vessel needed to be lengthened by 7.500m. The port tank has been kept 1000mm from ship side to maintain an access passage on the port side of the shelter. The starboard tank has its inner skin 800mm from ship side to comply with BV regulation. The tank room spanning from vessel floors to shelter deck has sufficient space for the pumping and piping from the tanks, and only delivery fuel lines would need to be fitted within the machinery space.

This tank space would be accessed from the open shelter deck or from an air lock entrance in the main deck port access corridor. It is assumed that the engine room would remain the same size. While the amount of fuel piping and pumps would reduce, the engines would need to be slightly larger, and the main engine would require a larger exhaust system arranged to provide the CO_2 gas to inert the LNG tanks.

The tank space and tanks have used space both below deck and on the main deck. There is very little additional space that can be utilised to improve the vessel layout.

The displacement has increased and is nearly equivalent to the extra volume added by lengthening the hull form which means that in equivalent load cases the new vessel floats with a similar draft to the parent vessel. As a result, there is no scope to improve the lines of the vessel and a small increase in powering requirement may be seen. This is believed to be small and should not significantly affect the fuel needed to achieve the same operation as the parent vessel.

The tanks and cofferdam require much more extensive venting systems to ensure any LNG vapours are clear of crew and sources of ignition. These have been shown on the General Arrangement Plan on the wheelhouse top but final positioning, height and design would need to developed using CFD vapour and explosive analysis.

To maintain bow visibility to minimum requirements the wheelhouse has been lifted 400mm.

Preliminary analysis shows the new design has reduced stability characteristics to the parent vessel and would therefore need additional ballast to that fitted. An additional 26 tonnes of ballast compared to what was fitted to the parent vessel would be required to meet the statutory stability criteria within acceptable margins.

The estimated cost to purchase this vessel is 80-100% more expensive than the diesel parent vessel. In addition, this does not include the extra costs associated with the increase in tonnage, changes in licence requirements, or any operational costs. Fuel prices and availability of alternative fuels at present, alongside uncertainties over their future, make it very difficult to analyse and determine through life costs. The most significant item that increases the cost of this vessel is the LNG tank and systems which accounts for about half of the increase in price due to its specialist nature and the need for detailed engineering parts and expensive materials. It should be noted that this is an initial estimate of the increased costs, and the first vessels of this kind could significantly exceed this due to a lack of established supply chains and the need for specialist manufacture of some equipment not yet available on the market. In addition, yards, designers, and suppliers would all have additional contingency costs in their pricing to cover any unexpected issues that occur during the build.

The vessel has been assumed to be a direct drive from the LNG engine through the gearbox and shaft line to the propeller. Based on the data measured and analysis undertaken by the University of Exeter's Centre for Future Clean Mobility, fitting a hybrid system with a 320kW.hr battery and 400kW motor should increase the vessel's efficiency from 39% to 42.4%. This would equate to a fuel saving of 8.4%. In such a system, the motor is fitted to a power in, power out gearbox.

It should be noted that on this modified vessel, a fixed pitch propeller and separate hydraulic engine is proposed. This is a simple and robust system, however, when the main engine is operating at an inefficient power and RPM (i.e., while hauling nets) the hydraulic engine is running at high power. If the vessel was to have a controllable pitch propeller and a power take off from the gearbox to run the hydraulics – a common but more expensive system – this would help to keep the main engine at its optimum power output and RPM for more time, thereby improving the efficiency of the system. This system makes a similar change to the efficiency of the main engine as fitting a hybrid system like that noted above. As such, if this system was fitted, the efficiency savings of also fitting a hybrid system would be significantly lower than those noted in the above paragraph.

Given the space available, it could be challenging to fit the hybrid system, and, unless additional length is added, it may reduce the service spaces around the equipment in the engine room. Fuel savings within a hybrid system could be increased by utilising more electrical deck equipment on the vessel like winches and net drums. When paying out nets and wires from these, they can charge the batteries as opposed to conventional hydraulic deck equipment which would use fuel to provide power to these items during such operations.

Whilst hybrid systems or running the hydraulic systems from the main engine can make a reduction to fuel costs for the vessel, it would have to be considered and analysed alongside the increased capital cost for the equipment and through life costs associated with its maintenance and repair. Initial estimates would suggest the additional cost of equipment is 5-9% of the purchase cost of the vessel for the hybrid system described. It should also be noted that this system could affect licencing, crew requirements and certification for the vessel as the vessel has, in effect, more propulsion power than if it were solely driven from the engine.

Analysis

The key potential technical, regulatory, and financial issues associated with this modified design are summarised below. As with the vessels modified for methanol fuel, this LNG fuelled vessel anticipates many similar issues, plus some additional issues associated with the nature of LNG as a fuel and its increased registered length above 24m.

Technical

- Prior to development, the vent design would need detailed analysis from specialists to confirm suitability.
- There are currently no high-speed engines available on the market suitable for this vessel. Refitting of a diesel engine could be possible, but such an approach may fail to achieve full approval.
- At present, there are no suitable tanks, cryogenic and pumping systems, and tank inerting systems available off the shelf for a system of this size. As such, specialist designed tanks would be required to maximise space. Custom made options are currently available on the market.
- Currently, there is no port infrastructure for LNG bunkering. Bunkering for LNG is more difficult than diesel as the fuel is cryogenic and therefore requires specialist bunkering options.
- A lack of experience in shipyards in the UK for the fitting or maintaining of LNG systems of this size presents a capability gap. Similarly, once installed, there is currently a lack of crews experienced in maintaining and operating LNG systems.
- The majority of LNG currently available is not net zero, and there is a degree of uncertainty as to whether net zero LNG will even be produced. Whilst the use of fossil-fuel based LNG currently available on the market incurs no operational issues, the critical point is that the vessel will not achieve net zero until it can operate on a net zero source LNG.

Regulatory

- Due to the increase in this vessel's registered length above 24m, the skipper would need additional certification compared to the parent vessel. In addition, due to this increased registered length above 24m, the vessel would need to be in class instead of the MCA survey, and would also need either a rescue boat or to seek exemption from this requirement.
- This modified vessel would not be able to be certified using standard regulations; therefore, MGN664 will be used to show equivalence for the methanol sections of design with BV NR670 used as the equivalency regulation. It is currently unclear whether the MCA would need any additional mitigation to what is advised in NR670, and this would not be clarified until the project commences.
- NR670 is designed to be used with vessels significantly larger than the design considered. Cofferdam sizes and clearances in the regulations may be larger than those actually required for safe practice on the size of vessel considered.
- The tonnage of this vessel has necessarily increased yet is not accompanied by an increase in fishing capacity. As tonnage for fishing vessels is limited for the UK fleet, if all vessels have similar changes, the fishing capacity of the fleet will reduce.

- Uncertainty remains regarding whether the MCA would have any additional requirements for skipper/engineer qualifications due to use of LNG as a fuel.

Financial

There are a range of anticipated costs associated with this vessel, relating to:

- Additional costs of design due to a) the increased size of the vessel in comparison to the parent vessel, b) the need for a vapour/explosive analysis, and c) the need for a HAZID table and associated uncertainties of a one-off approval procedure.
- Additional cost of the vessel due to a) its increased size and associated heavier steel weight, b) the need for premium cost LNG engines which are more expensive than those of diesel engines, and c) the need for additional safety systems onboard due to the use of LNG.
- Approval costs for utilising MGN664.
- Costs for shipyards to train staff in LNG systems and to ensure staff retention.
- Additional contingency costs for the designer/yard to cover uncertainties and changes during both the approval and build processes.
- Additional costs to the owner for a) licence and tonnage on a larger vessel b) crew training and skilled staff retention, and c) the increased skipper qualification required for a vessel of this size.
- Additional costs associated with class society approval, and subsequent costs related to this such as through life costs for maintenance in class, machinery as class certified, and additional items required by class above that required if a <24m vessel was registered in the MCA survey.
- Uncertainties on both the cost and availability of LNG as a fuel.
- Additional maintenance and through life costs associated both with the larger vessel and the LNG system in comparison to the diesel systems on the smaller parent vessel.

Whilst some of the financial costs may fall to the shipyard, designer, or other suppliers, it is assumed that these will be passed onto the vessel owner as part of the purchase price of the vessel or the cost of associated through life services.

Combined analysis

There is a clear difference in the number of changes required from the parent vessel to facilitate net zero fuel types depending on the fishing method employed. For the creel boat using static gear, the concept designs are much closer to the existing parent vessel. However, for the Nephrops and whitefish vessels which trawl, significant additional size is required to hold the amount of fuel needed to match the operation of the parent vessel.

For the creel vessel, while both options look plausible, the battery/electric version appears to hold an advantage due to its relative similarities to the parent vessel, its use of technology that is largely available commercially and proven safe in the marine environment, and its use of a fuel (electricity) which has more certainty in relation to availability than all other options. The primary challenge associated with this option would be the lack of infrastructure required for these vessels, namely, the need to plug into charging infrastructure of sufficient power to recharge the vessel between each operation.

The methanol creel vessel provides an option that can genuinely replicate the capabilities of the parent vessel, and which could be adaptable for longer operations, especially if the creels are further offshore or a significant distance along the coast from the vessel's home port. This option would also allow additional fisheries, such as lining for mackerel, to be utilised. In comparison, the battery range may prevent the battery/electric version undertaking such operations.

Both vessels would require an increased capital expenditure to the parent vessel. Whilst the rest of the vessel remains a similar price, the battery and electrical motor system on the battery electrical version is anticipated to be six to eight times the cost of the engine and diesel system installed on the parent vessel. For the methanol version, there are a number of bespoke equipment requirements that will clearly be more expensive. However, these are difficult to quantify due to a lack of off the shelf options, and additionally a steel hull in this size would notably increase the cost. In relation to operational and through life costs, predictions would show a significant saving when utilising electricity over diesel. Methanol availability and pricing makes a comparison for this option impossible at this time.

For both Nephrops and whitefish trawlers, the resultant concept designs incurred similar differences, per fuel option, from the parent vessel. The methanol versions appear to hold an advantage due to the need for less additional length and steel requirements, lower complexity of fuel systems in comparison to those required for LNG systems, the ability to refine and improve the hull, and additional usable space to improve the vessel on the main deck. They key issue when comparing this vessel to other net zero options is whether sufficient methanol will be produced to ensure that its use in internal combustion engines is net zero, and whether costs will be prohibitive, based on availability.

On the methanol creel vessel, a hybrid system would likely require too many components to make it an attractive or practicable solution, although this should be reviewed as technology develops.

For both whitefish and Nephrops vessels, operating as either LNG or methanol, a hybrid system was a possible addition to the arrangements provided. From the real data recorded from the Crystal Sea, an estimated reduction in fuel use of 8.4% could be achieved. A guidance of 4-10% improvement may be reasonable to assume for twin-rig trawlers, with the possibility for further savings if an electrical deck package is utilised. The biggest issues are the additional space requirements for the batteries and switch boarding, capital cost for installation, and the increase in systems on vessels which require maintenance through life.

The pricing section of the whitefish vessels showed some of the anticipated scale of the increased costs associated with purchasing a vessel operating on alternative fuels. It also showed that as the methanol vessel was not significantly lengthened and has simpler tank and fuel systems than the LNG vessel, it has a substantially less significant increase to the purchase price, at approximately 70% of the cost of the LNG vessel. It is, however, 25-45% more expensive than the diesel parent vessel, therefore still representing a large increase in cost relative to the current status quo.

Conclusions

While the concept designs included in this report show clear and plausible ways to build net zero fishing vessels, there are a number of technical, regulatory, and financial issues that need to be addressed before it is reasonable to expect owners to invest in the transition from diesel to alternative fuel sources.

Most of the technical challenges relate to the availability of equipment and the harmonisation of the standards of this equipment. In general, this is currently being addressed by the suppliers of these systems and, as such, it is anticipated that these issues will likely be largely resolved in the coming years. However, a key factor relating to methanol and LNG remains; namely, whether there will be sufficient quantities of these fuels produced to ensure they are available to the fishing sector.

It can clearly be seen from the analysis that the regulatory challenges incur significant uncertainty relating to the viability of these vessels. This uncertainty will inevitably act as a barrier to the first of class vessels, making securement of investment and quotations for builds very difficult. As the concept designs for the trawling vessels have notably increased in size, this has pushed them into higher classes of regulation which will certainly cause a challenge. However, this ultimately should be achievable but a significant impact on the costs associated remain.

All of the concept designs incur significant additional capital expenditure, which makes it very difficult to understand how and why an owner would make such an investment. This is even more challenging for the methanol and LNG vessels, where it is very difficult to assess their future availability and cost. For the battery/electric vessel there is an argument that over its life the electric version would have similar or reduced costs to the parent vessel due to the reduced operational expenditure. However, finding the capital needed to build the boat would remain a significant challenge for an owner when it is making relatively significant compromises against the diesel version and especially given the uncertainty over the availability and reliability of the necessary underpinning charging infrastructure.

One key issue, especially for the trawlers, is the increase in gross tonnage. At present, there is currently a fixed amount of gross tonnage for the UK fishing fleet, and if this remains, the fishing capacity of the fleet would be reduced due to this increase. There is also the potential for the cost of tonnage to rise significantly as owners try to maintain their current fishing potential and move to larger alternative fuel vessels. This will also be another disadvantage and cost for an early adopter to alternative fuels who is competing in a market with diesel vessels.

Further analysis

With battery electric options looking like a plausible way forward for the static gear sector, the following analyses or reviews could assist the sector's transition to this technology:

- Review of harbour infrastructure and how this could be developed for a fleet of battery electric creel vessels. It is recommended that both a large commercial harbour with a large fleet of creel vessels and a small harbour with 2-10 vessels be reviewed. Inclusion of as many harbours and ports as possible in this review would be advantageous.
- Review larger static gear vessels (15-24m) to see if battery electric is a suitable option for these[3].
- Review of the suitability of hydrogen to increase the range of a battery electric creel boat, similar to the vessel included in the report. The largest drawback with the battery version currently is the loss of range when compared to the diesel parent vessel. This could affect a significant number of these vessels, especially if charging facilities are only located in main ports and transits to and from creels could be further than the assumed voyage cycle in this report.
- Work with an owner or yard to build a vessel like the concept design within a CMDC (Clean Maritime Demonstrator Competition), ZEVI (Zero Emissions Vessels and Infrastructure) or similar scheme to act as a pilot and to provide proof of concept that this provides a suitable replacement option to those like the parent vessel.

Methanol options could be a plausible way forward for the mobile gear sector across sizes. A transition for this sector would rely on methanol infrastructure. There is a need for a study into infrastructure plans for net zero methanol production and delivery in the UK. Coupled with analysis of likely costs for methanol production, this could greatly assist development of methanol designs.

As hydrogen would appear to be a fuel that will be available, and is likely to be at a lower cost point than methanol or LNG in their net zero production, a concept design for a trawler utilising this fuel may be a good addition to the suite of existing concept designs included in this report. This would be best as a new design, as opposed to a replication of an existing vessel, and refined to see what voyage cycle and hold capacity could be achieved within set dimensions.

A database of trawlers' power data – like that measured for the Crystal Sea in this report – would be very useful for both vessel and powertrain designers. Such a database could help to minimise the change needed to move these vessels to alternative fuels. Expansion of this database to include static gear vessels as well as potentially aquaculture vessels would greatly assist those sectors.

All options in this report are based on new vessels. A review into retrofitting an existing fishing vessel to methanol powertrain and a cost-benefit analysis of this against the costs associated with building a new vessel would provide valuable information to diesel vessel owners on their options to transition to net-zero powertrains.

[3] Smaller vessels than our review have been proven by Hans Unkels and Douglas Chirnside.

Fisheries Innovation & Sustainability

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