THE GREEN VESSEL PROJECT REPORT

CONTENT

The following document contain a summary, conclusion and perspectives on the green vessel project. The project is funded by Den Danske Maritime Fond

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1 Introduction

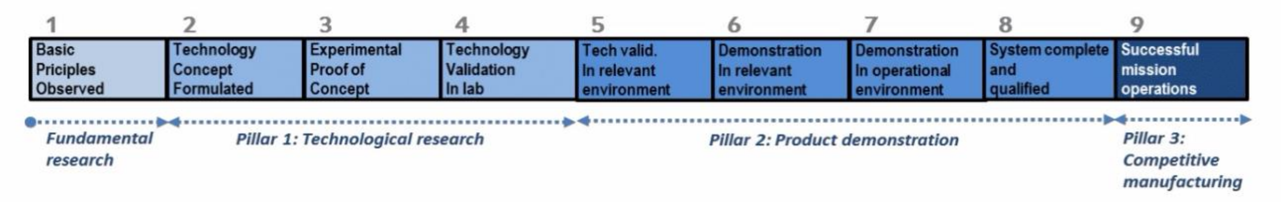
The Green Vessel project sought out to identify the best potential options, for the next step in transforming from fossil based to fossil free fuels on the Service Operation Vessels (SOV) used by Esvagt for Nearshore activities.

The project has investigated the most realistic technologies to support this goal, with focus on the on-board system and supply chain of the energy hereto. Each technology has been investigated and presented by experts within their own field and then compared by a non-biased third party. The technologies and experts are seen listed hereby:

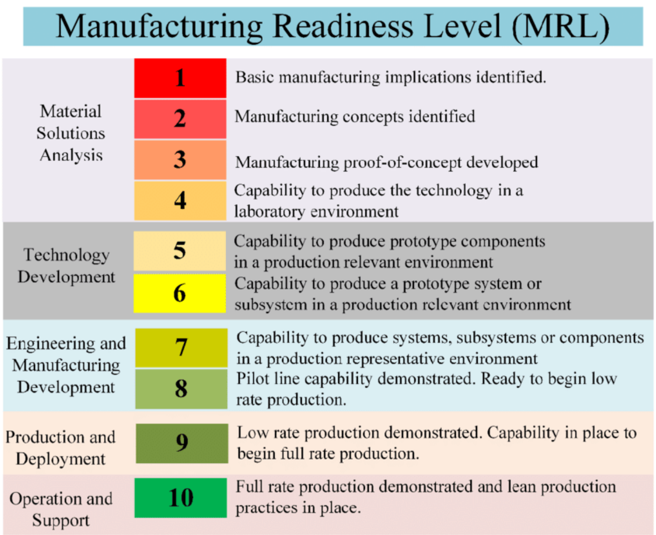
- Ammonia by Hydrogen Valley
- H2 technology by Ballard Power Systems Europe
- Battery power by CS Electric
- Land based power by Powercon
- E-fuel & Biofuel by the Danish Technological Institute
- Technology overview composition by Marlog
- Third party evaluation by Dansk Ingeniørservice

Each technology will be baselined towards ESVAGTs energy requirements for an SOV and the following points:

- Estimated Technology readiness level
    - Different propulsion options / types of fuels, and associated technology, are weighted according to the Innovation Fund's 2020 TRL scale.



- Estimated Manufacturing Readiness Level (MRL)
    - Different fuel types availability in relation to infrastructure, transport and production and serviceability for the products. Weighted by the MRL scale. Both at product level and system level



- Handling & safety
    - How the energy source can be handled safely by personnel without injury at bunkering and in daily operations.

- Toxicity
    - How the energy source can cause damage to personnel on both ship and shore side. As well as whether it can damage the surrounding environments.

- Environmental effect (Cradle to Grave)
    - The total environmental impact in connection with extraction of raw material, processing and ignition calculated in kg CO2e / kWh

2 Esvagt SOV requirements

The following baseline should be seen as an indicator for a baseline, as each vessel have its “own way of sailing” and thereby its “own” requirements. For the full Esvagt SOV Effect Overview, see appendix 1.

The SOV's are equipped with 4-6 diesel generators that provide electricity for hotel operation and propulsion. Esvagt are operation with two versions of the vessel, both based on 4-stroke diesel engines running as gensets.

One is equipped with 4 x CAT 3512C (4 x 1550 kW) engines. Another version is equipped with 2 x Cummins QSK 38DM (2 x 990 kW) and 4 x Scania DI16 090M (4 x 615 kW) engines.

Both versions are designed with redundancy, hence if one large generator fails, the vessel will still be fully operational.

An Esvagt SOV is typically at sea supporting a wind farm for a period of fourteen days before it returns to port for provisioning and rotation of technicians.

Every second time the ship is in port, the crew is swapped, a crew are on board for 28 days before swapping. It is also at this time the SOV re-fuel 86 - 136 tons depending on the windfarm, weather etc. The fuel today is marine gas oil.

Looking at the activity level while servicing the wind farms, the time is often divided into two different periods:

1. First period consists of 14 - 16 hours on Dynamic Positioning (DP), where all ship thrusters work together and maintain the position to e.g., very close to a wind turbine - typically 12 - 14 meters between SOV and wind turbine.
   The fuel & power consumption spend in this period depends heavily on the weather.

2. Second period consists of the remaining 8 - 10 hours. The SOV will typically be located outside the wind farm, either for anchor or in stand-by on DP but with reduced position accuracy, thereby drastically reducing power consumption.

As mentioned, SOV will go into port every 14 days for a change of technicians; this port call typically takes one day 86 - 8 hours, plus the transit time to / from port), which is why Charterer wants to limit the number of port calls to reduce the loss of possible working days in the wind farm.

3 Technology review Ammonia

The whole Ammonia report by Hydrogen Valley can be found in Appendix 2. The following section will provide a summary the key insights from this report.

Hydrogen Valley have investigated the different perspectives in ammonia as a marine fuel, hereby including the storage, handling and how it would match with the requirements from ESVAGT, by using a small Haber-Bosch plant.

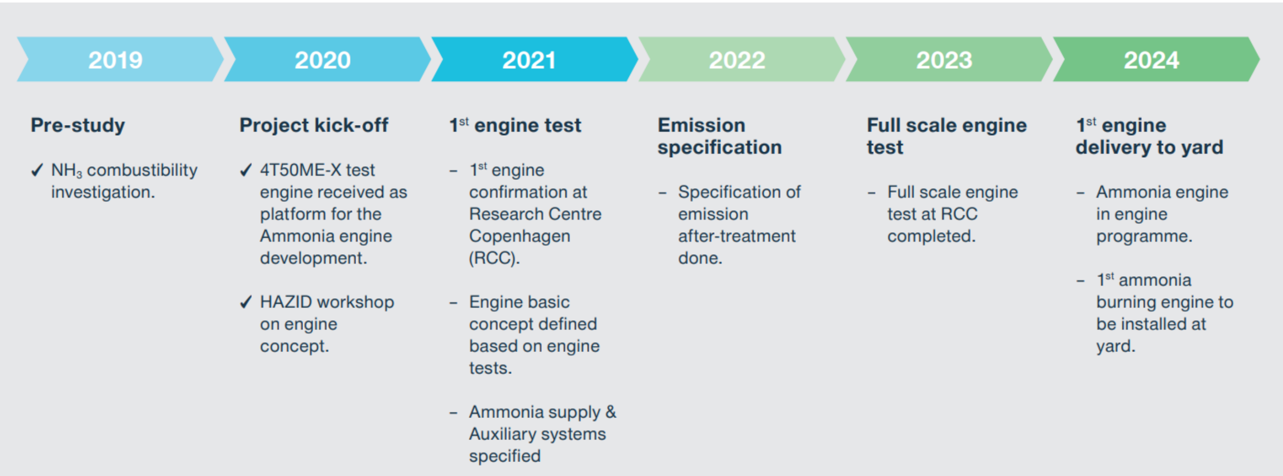
Furthermore, Hydrogen Valley have made an overview of the most prominent option of an ammonia propulsion option; the 2-stroke engine from MAN Energy have furthermore been investigated, to understand the requirements of a system running on ammonia.

3.1 Ammonia for ESVAGT SOV

3.1.1 Technology readiness

As seen in the report, ammonia as have the potential to become a marine fuel at some point when the technology has been matured. Ammonia has both advantages and disadvantages as a marine fuel. Compared to hydrogen and methanol, the most significant advantages are the storage and transportation and being low flammable compared to hydrogen and the fact that it does not contain any carbons compared to methanol.

At this current time the suggested ammonia-fueled marine two-stroke engine by MAN Energy Solutions is still in development and as seen hereby in the engine development schedule from MAN Energy, the first engine delivery is set to 2024.



Thus is the technology readiness level estimated to 5-6 for the fuel cell/drivetrain and TRL:<5 for the internal combustion engine. As the technology is known but in the marine industry it is still at the development and validation stage.

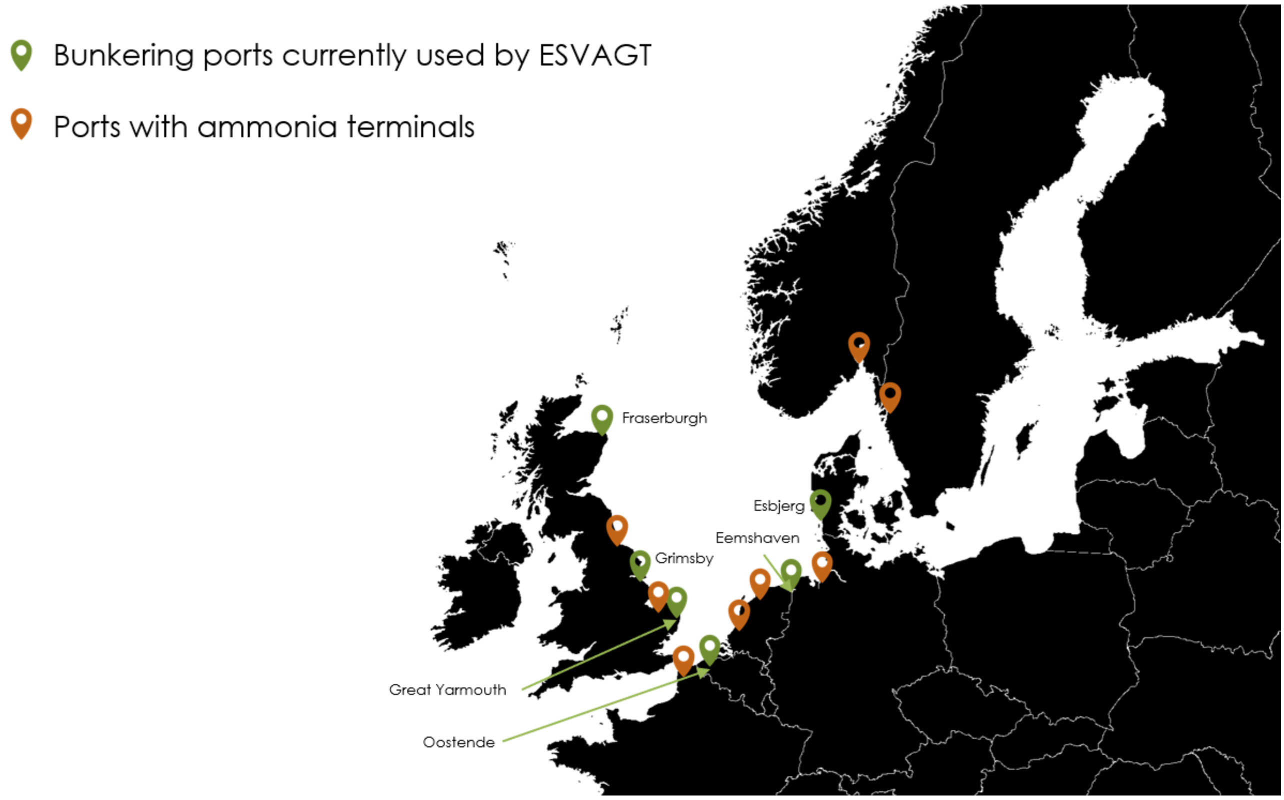
3.1.2 Manufacturing readiness

As ammonia have been used in different industries across the globe which means some of the required infrastructure is already in place. However, the use of ammonia as a marine fuel will require new/updated infrastructure to both the ship and the ports.

Anhydrous (without water) ammonia is distributed across the world via pipelines, railroads, barges, ships, road trailers and storage depos. Long term experience of ammonia distribution from the first quarter of the first century has facilitated the global deployment of ammonia, ensuring that well established distribution networks exist across the world.

With the current established world grid of ammonia terminals and storage, a bunkering grid could be established fast and cost efficiently by converting small gas tanker vessels to bunker barges. They would be able to utilize the existing storage facilities as base stations and from there approach the vessels requiring bunkering in the vicinity. The bunkering operation itself would be very similar to when bunkering other gaseous fuels, except the main hazard would be the fuel toxicity rather than flammability, and the procedures for ammonia bunker barges need to be developed.

By looking at the current facilities at hand in relation to ESVAGT it is clear that the ammonia terminals are there but it is assumed that only a few of them are capable of being "retrofitted" to ammonia bunkering terminals for fuel applications.



It is estimated that the manufacturing readiness level is 6< as the ports and supply chain towards ammonia in a marine application is still being developed and are at a prototype level.

3.1.3 Handling & safety

Ammonia requires special precautions and education of those who are handling it. However, as ammonia is being handled around the world today and is not seen as the most toxic cargo handled in shipping. Several industries have experience in handling and utilizing ammonia in conditions that are similar to the ESVAGT context. Handling today is done by following some "basic" actions:

- Training of personnel
- Wearing essential protective gear
- Regular inspection and maintenance of handling equipment
- Warning signs and emergency procedures

However as handling Ammonia as a marine fuel is not common today, it should be highly prioritized to ensure that the right safety measures are defined and rolled out in the marine environment as a common practice.

3.1.4 Toxicity

Various institutions have classified ammonia as a toxic substance, thus making it a chemical of high risk for health. However, due to its low reactivity, the hazards it presents from accidental combustion or explosions are much lower than other fuel gases and liquids.

Ammonia has a flammability limit that ranges from ~18 to 28% fuel mole fraction. Therefore-watering systems are needed to avoid this range when hot surfaces or combustion devices are in use nearby.

The risk of ammonia combustion hazards is mitigated by the fuel's slow reaction characteristics, particularly its relatively high ignition energy (2–3 orders of magnitude higher than common hydrocarbons) and low laminar burning rate more than four times less than methane (< 0.010 m/s). The main risks in relation to toxicity towards personal and vessel is listed hereby:

- Anhydrous ammonia is non-flammable. Ammonia vapor in air is flammable and may explode when ignited
- Chemically stable under normal conditions
- Emits poisonous fumes when heated to decomposition
- Exposure by any route may be dangerous
- Secondary contamination may occur
- Acute inhalation may result in irritation of eyes and nose with a sore throat, cough, chest tightness, headache and confusion
- Acute ingestion of ammonia solutions may result in burns to the mouth and throat
- Acute skin exposure may result in deep burns
- Acute eye exposure may cause inflammation, lacrimation and photophobia
- Chronic inhalation has been associated with increased cough, phlegm production, wheeze and asthma
- Dangerous for the environment

3.1.5 Environmental effect (Cradle to Grave)

By looking at the different options towards ammonia, it is clear that there are several ways of producing it. Each with its own effect on the total environmental impact in connection with extraction of raw material, processing and incineration the following CO_2 emission intensity are calculated in kg CO_2e / kWh and listed from worst to the best environmental impact.

Grey NH_3 is produced by combining gray H_2 with free nitrogen and release 263kg CO_2/GJ.

Orange NH3 consists of a 50/50 mixture of gray and green NH3 and release 147kgCO2/GJ.

Blue NH3 is gray NH3 but whereby carbon capture technology has been used in production and release 76kgCO2/GJ.

Green NH3 is produced from hydrogen extracted through electrolysis of wind, an ASU and a Haaber Bosch process supplied with green energy and release 30kgCO2/GJ.

As seen in the listing above the environmental impact from extraction of raw material, processing to combustion is highly related to the process of how the supply chain is set up. This is something in which ESVAGT should take into consideration if they suggest moving forward with this fuel technology.

3.2 Sub conclusion

Ammonia is inherently carbon- and Sulphur-free when used as a fuel. Seen in the light of the cost and low complexity of storage, and the already existing ammonia production facilities and infrastructure, ammonia is good candidate as a future marine fuel. The development of ammonia as a maritime fuel are however dependent on cost-effective and efficiency competitive solutions, which are lacking at the moment.

Potential first movers for ammonia propulsion could be LPG carriers, which also from time to time carries an ammonia cargo, and ammonia carriers, which already have the necessary auxiliary equipment and expertise on board. However, with the current technology roadmap shown by MAN Energy, we will most likely see the first ammonia driven engines in 2-4 years, which furthermore compromises the ESVAGT timeline and requirements.

4 Technology review E-fuel & Biofuel

The full report on E-fuels and biofuels by the Danish Technological Institute can be found in Appendix 3. The following section will provide a summary the key insights from this report.

The Danish Technological Institute have studied the possibilities for incorporating e-fuels and biofuels, with the aim of reducing CO_2 emissions, with the least possible conversion and highest reliability of the ships.

4.1 E-fuel & Biofuel for ESVAGT SOV

4.1.1 Technology readiness

The report shows that some of the fuel options can be used without or with very little changes to the drivetrain and the ships in general. . Ships with Cat 3500s, the Cummins QSK 990 kW and the Scania DI16 090M engines apply to this.

However, ships with Scania 615kW engines it is suggested that the engines are swapped for a 415kW converted methanol M97 engine which costs of ap-prox. 1.2 mil. DKK per engine. The engine can also be swapped for a 415kW Ethanol E95 optimized engine at the same approximate cost.

The following section will focus on the drop in fuels as these are a better fit for the ESVAGT requirements presented in section 2. For a full overview of the engine swap/rebuild, see appendix 3**.**

4.1.2 Drop in fuels

The identified drop in fuels is currently available in most ports and are allowed for the Cat and Cummins engines. A list of the investigated fuels is seen hereby:

- *Fatty Acid Methyl Ester / Rape-seed Methyl Ester*
  Fatty Acid Methyl Ester (FAME) has been used for decades as a diesel supplement. Many different types of FAME exist but most commonly, in Europe, rape seeds are used, thus Rape-seed Methyl Ester (RME) is the most available choice.
  It is considered a first-generation biofuel and is not ideally suited for high-speed marine engines.

- *Straight vegetable oil*
  Straight vegetable oil (SVO) was used as fuel by the inventor of the diesel engine. But it does not tolerate frost which have prevented it from widespread use, but with heated tanks and fuel lines it can work. It does not blend with MGO, so it would need to be used separately.

- *HVO (Hydrotreated Vegetable Oils)*
  A newer alternative to FAME. HVO has properties like synthetic diesel which is usually desirable. However, lubrication agents need to be added because HVO is low viscosity. HVO can be used in any blend with any kind of diesel engine. In recent years prices of HVO have increased to a level of 3-4 times as MGO.

- *Biomass-To-Liquids by Fischer-Tropsch*
  Biomass-To-Liquids by Fischer-Tropsch synthesis (BTL-FT) is a synthetic diesel fuel with properties like HVO. It is still rare on the market. The advantage over HVO is that it uses a greater variety of biomasses.

- *Biocrudes*
  A variety of thermochemical biofuels which are produced by pyrolysis or hydrothermal liquefaction. The properties of biocrudes are mostly like HFO, which is unsuited for the current engines, but some are available as MGO-like fuels or blends. The supply of biocrudes is still uncertain but smaller bathes are being delivered for tests on ships.

Based on the report by DTI it is Technology readiness level is estimated to 9 as the most promising drop in fuels, are available today at the bunkering companies.

4.1.3 Manufacturing readiness

As stated in the section above the technology readiness level deemed high as the suggested fuels are somewhat common today. However, when looking at the supply chain it is not as mature for all of the presented fuel options. Looking at the most fitting fuel for ESVAGT the HVO, the infrastructure is deemed high but as the price is high the current time, the supply of fuel is limited. The average manufacturing readiness level is estimated to 5.

4.1.4 Handling & safety

All of the suggested drop in fuels are or has been used in the maritime industry at a large scale. It is therefore assessed that the current safety measures and training is sufficient for handling the suggested drop in fuels.

4.1.5 Toxicity

The suggested drop in fuels is deemed "nontoxic" in relation to how the fuel will cause damage to personnel on both the ship / and shore side. As well as whether it can damage the surrounding environment. This is supported by the GESTIS Substance Database as the proposed fuels are categorized as >IV, outside of the framework that GESTIS has classified, due to minimal toxicity.

4.1.6 Environmental effect (Cradle to Grave)

The Hydrotreated Vegetable Oils (HVO) is the most fitting drop in fuel for ESVAGT hence the total environmental impact in connection with extraction of raw material, processing and incineration are 10,66-99,06kgCO_2/GJ (CO_2 emission intensity is calculated in kg CO_2e / kWh).

Reasoning behind the CO_2 range is due to the choice of manufacturing method. If the HVO is made by using palm oil the CO_2 footprint will be higher as the current production of palm tree farms is harmful for the environment due to the deforestation process which involves burning woodlands. However, the HVO can also be produced by using alternative non-food oils such as algae oils, animal fat, rape seed, etc.

4.2 Sub conclusion

By looking at the proposed drop in fuels as stated in the previous sections, the HVO is practically free of technical and delivery issues. The current cost, however, is 3-4 times the cost of MGO fuel used today.

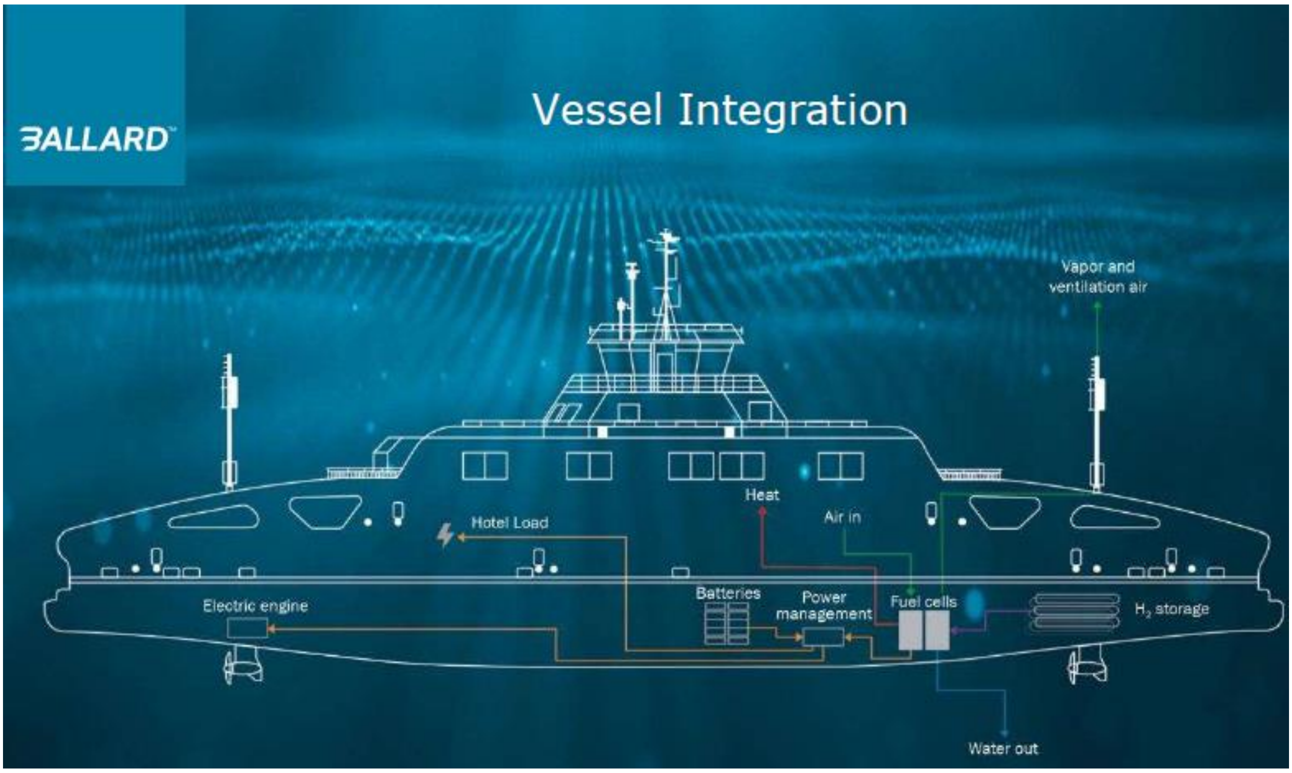
An alternative suggestion by DTI to ESVAGT is to request quotations for both an M97 engine, which is available from Scania/Scandinaos and a dual fuel conversion, which is available from Comap. With a dual-fuel conversion gaseous fuels become optional, which means that the engine could be fired with hydrogen in synergy with optional fuel cells on board. Operational reliability would be further secured by the MGO diesel system which remains on the ship in the case of a dual-fuel conversion.

5 Hydrogen & Electricity for ESVAGT SOV

Across the maritime sector, greenhouse gas (GHG) emission standards for vessels are being tightened. These emissions regulations will have a significant impact on vessels, and the businesses that operate them, such as ESVAGT.

Ballard points towards fuel cells as a key technology in helping marine industries address the GHG emissions. Batteries work well for vessels for very short routes, and which have frequent charging possibilities. For longer routes and larger vessels, hydrogen fuel cells are the most practical zero-emission solution.

Below picture show how the hydrogen system has been integrated on a Norwegian ferry.



5.1.1 Technology readiness

Hydrogen systems are a known technology on land-based applications but when applying to the marine challenges arise. "Most of the hydrogen technology we expect to see on board ships will have already been used in other applications such as cars, trucks and other modes of land-based transport and storage. So, we don't have to start from scratch. Some of the challenges include adapting this technology to the marine environment and making it safe to use in varying environmental conditions, in smaller spaces, and when personnel cannot be evacuated as easily as on land," says Gerd Petra Haugom, Principal Consultant Environment Advisory at DNV and Phase I Project Manager for MarHySafe[1].

Hereto should it be mentioned that due to the regulatory framework and different interpretations from country to country and port to part, developing a design that complies with all is a challenge.

If looking at the fuel cell technology in a marine application, Ballard have already proven their technology in:

- Megawatt scale systems for cruise ships with ABB
- HySeas III, the world's first sea-going renewables-powered ferry
- Hjelmeland ferry in Norway
- FLAGSHIPS project to power:
  - Norled ferry in Norway
  - River barge in France (ABB)
- ELEKTRA fuel cell river barges in Germany

The FCwave Fuel cell technology is a modular design where the fuel cell stacks are integrated into the vessel either together as a traditional drivetrain or as single power units close to where the power is needed.

As the technology are being matured and developed in the marine industry it is clear that the hydrogen will have a role to play in the propulsion of vessels. However as of right now, hydrogen fuel cells as main propulsion technology is still undergoing demonstration projects, the Technology Readiness Level is estimated to 6.

5.1.2 Manufacturing readiness level

Looking at the manufacturing process of hydrogen, as with Ammonia it can be done in several ways as seen hereby:

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[1] https://www.dnv.com/expert-story/maritime-impact/Five-lessons-to-learn-on-hydrogen-as-ship-fuel.html

Black H2; a product of an arbitrary process involving the use of an HC (LNG, LPG for example), where the CO2 formed in the process, is NOT captured.

Blue H2; a product of the steam methane reforming (SMR) process, where the CO2 that also occurs in the process, is captured using carbon-capture technology.

Green H2; a product of electrolysis where energy from either a renewable source (Wind, Solar, Etc.) or surplus energy from the energy grid is used.

The production of free H2 is estimated to scale up in the coming years, but at present day the green production is still on the drawing board. Blue H2, where the CO2 is captured in the process, is ongoing in major markets such as Australia and Japan.

Few land-based hydrogen filling stations are already operational, which expresses an increasing integration of hydrogen in DK.

Danish production of hydrogen is currently only enough to cover small ship types. If the larger container vessels should use hydrogen, at least two large hydrogen plants would be required.

The current gas lines are not designed to transport hydrogen, and therefore cannot be transported therein without a carrier. Mixing the hydrogen is an option, but the final fuel will not be pure hydrogen, but a gas with an increased rich value.

Hereto are that the hydrogen production near the port comes with a risk as it can raise the explosion class and the level of danger for the port in question.

If looking at the hydrogen manufacturing level based on the availability in relation to infrastructure, transport and production and serviceability for the products it is estimated to a manufacturing readiness level of 8-10.

5.1.3 Handling & safety

As hydrogen is a known technology in other industries and applications, it is estimated that the handling and safety procedures are somewhat in place. As with ammonia, it should be highly prioritized to ensure that the right safety measures are defined and rolled out in the marine environment as a common practice.

5.1.4 Toxicity

Hydrogen is estimated "nontoxic" in relation to how the fuel will cause damage to personnel on both the ship / and shore side. As well as whether it can damage the surrounding environment. This is supported by the GESTIS Substance Database as the proposed fuels are categorized as >IV, outside of the framework that GESTIS has classified, due to minimal toxicity. According to GESTIS contact with skin, eyes and other body parts there will be a risk of frostbite. Additionally, if a tank is punctured in a closed environment and the H2 consumes all O2 it is toxic for personnel.

5.1.5 Environmental effect (Cradle to Grave)

As stated in the Manufacturing readiness level section, Hydrogen can be produced in many different ways, each with its own GHG footprint depending on where the energy for the electrolysis comes from, which affects the total environmental impact in connection with extraction of raw material, processing and incineration the following CO2 emission intensity are calculated in kg CO2e / kWh and listed from worst to the best environmental impact.

Grey H2: 291kgCO2/GJ

Orange H2(50/50 mix of Grey and green H2): 145kgCO2/GJ

Blue H2: 46kgCO2/GJ

Green H2: ~0kgCO2/GJ

As seen in the listing above the environmental impact from extraction of raw material, processing to combustion is highly related to the process of how the supply chain is set up. This is something in which ESVAGT should take into consideration if they suggest moving forward with the H2 technology.

5.2 Sub conclusion

Hydrogen as a marine fuel is something we will experience in the forthcoming years, most likely in short term as a common practice on smaller vessels. On larger vessels such as the ones ESVAGT operates in this study, the hydrogen fuel cell technology is still at a stage were more research, development and testing throughout the supply chain is needed.

The hydrogen solution enables various scenarios. The presented FCwave fuel cell technology is a modular design where the fuel cell stacks are integrated into the vessel where the power is needed. This design can enable ESVAGT to provide green energy to some of the other energy consuming systems on their older wells as a proposal to their customers.

6 Conclusion

Marlog have composed and overview of the different propulsion options for ESVAGT. Marlog have included other technologies which have not been reviewed in depth for the presented requirements in section 2. However as many of them are similar to the proposed technologies, they are kept in the overview, as they can act as inspiration for new studies and projects.

The overview is based on facts from datasheets and interview with technology experts, for a detailed overview see appendix 5.

Oversigt	H2/LH2	Ammoniak	Methanol	LNG	LPG	El	HVO
Powertrain	FC=>Elmotor Forbrændingsmotor	FC=>Elmotor Forbrændingsmotor	FC=>Elmotor Forbrændingsmotor	Forbrændingsmotor	Forbrændingsmotor	Elmotor	Forbrændingsmotorer
Energidensitet, Volumetrisk	LH2: ~8MJ/L H2 700bar: ~5MJ/L	NH3: 12,7MJ/L LNH3: ~15MJ/L	CH3OH: 15,8MJ/L	LNG: 21,6MJ/L	LPG: 24,5MJ/L	Flowbatteri: ~0,09-0,6MJ/L	HVO: ~34MJ/L
TRL-TeknologiskReadinessLevel	TRL:5-6 FC TRL:	TRL: 5-6 FC TRL:<5 ICE	TRL:<5 FC TRL: 7-8 ICE	TRL:>8 Dual Fuel TRL:>9 Gasmotor	TRL:>8 Dual Fuel TRL:>9 Gasmotor	TRL:>9	TRL:9
CO2 Reduktion lokalt **CO2 Reduktion værdikæde**	-100% +61,9% / -100%	-81,2% * & *** +46,3% / -83,3%	-8,8%* +12,4% / -95,5%	-21,9% * -17,1% / -97,2%	-7,9% * -17,1%	-100% -76,9%	-53,5% -44,9% / -83,9%
MRL	MRL:8-10	MRL:6<	MRL:6-7	MRL:8-9	MRL:8-9	MRL:8-10	MRL:5
Sox	Ingen	Ingen	Ingen	Ingen	Ingen	Ingen	Lav
Nox	Ingen	Høj Lav ved FC	Lav ved forbrænding Ingen ved FC	Lav	Lav	Ingen	Lav
Sikkerhed	Lav	Lav	Medium	Medium	Medium	Medium	Høj
Giftighed	Lav	Høj	Medium-Høj	Medium	Medium	Høj	Lav
Particulate matter(PM)	100%	97-100%*	97-100%*	83%	83%	100%	-30%
Miljøskadelighed - "Luft"	Ingen	Ingen	Ingen	Høj	Medium	Ingen	-
Miljøskadelighed **Lokal forurening - "land/sø"**	Ingen	Medium	Høj	Lav	Lav	N/A	Ingen
CTG	Grå H2: 291kgCO2/GJ Orange H2: 145kgCO2/GJ Blå H2: 46kgCO2/GJ Grøn H2: ~0kgCO2/GJ	Grå NH3: 263kgCO2/GJ Orange NH3: 147kgCO2/GJ Blå NH3: 76kgCO2/GJ Grøn NH3: 30kgCO2/GJ	Grå methanol: 202kgCO2/GJ Blå methanol: 129kgCO2/GJ Grøn methanol: 8kgCO2/GJ	Grå LNG: 149kgCO2/GJ Blå LNG: 131kgCO2/GJ Grøn LNG: 5kgCO2/GJ	Grå LPG:149kgCO2/GJ	41,55kgCO2/GJ**	Palmeoliebaseret HVO: 28,97-99,06kgCO2/GJ

Based on the provided input, the recommendation to ESVAGT is to align with its owners 3I Infrastructures on where they want to move the company in relation to the "green profile", as many of the technologies comes with pros and cons.

If this report is to point toward an applicable technology, the suggested drop in fuel HVO would be recommended. As seen in the overview, the HVO is the "greenest" technology on short term. It can be discussed on the green image if palm oil is used as the main source for the HVO, but it is a first step, which can be applied across the complete Esvagt vessel fleet within a short period.

Many of the other promising technologies such as hydrogen and ammonia are still in the development phase, but is expected to mature significantly in 2022-2025. It is clear from the study that the future for maritime propulsion systems is yet to be defined, however many indications points towards a hybrid drivetrain utilizing the best benefits from the reviewed technologies in a combination.

The suggestion to ESVAGT is to engage with the different technology providers and align with their development roadmaps and see when it would be suitable for ESVAGT to change the traditional drivetrain for something completely new. This would provide Esvagt with several benefits, from being able to provide the most suitable solutions to their customers and continue to have a profitable business, within Service operational vessels.

7 Perspective towards the future

The project was to make a technology-neutral presentation of the possibilities for a greener propulsion for an Esvagt SOV. However, throughout the project a series of different reflections have been made which could be investigated further by additional projects.

These subjects relate to:

- The accessibility of green energy
    - All over the globe companies and countries talk about the green transition and how the industry must switch from black energy sources towards green alternatives. However, through this project is has become clear that even though many of the technologies are getting more and more mature as each day goes by, the supply chain is not following by the same speed. As the technology cannot stand by itself, the issue of having a steady supply chain should be seen as critical. It is therefore suggested that a project is scoped around the topic "A green supply chain for the green technologies".

- New futureproof vessel design
    - New technology today is obsolete tomorrow. Through the project is have become clear to the project group that the release of new and better technologies has increased trough the past ten years. When Esvagt deploy a new vessel today it is expected to function for the next 25 years at least. However, with the rapid improvements of technologies Esvagt is already experiencing that 5-year-old ships are doing equipment replacement because new and better solutions is available. When looking at the propulsion system and the reviewed propulsion technologies it

is clear that a newly commissioned vessel is likely to have its “black” powertrain retrofitted with a green alternative.

It is therefore suggested that a project is scope with the aim of identifying “how a vessel can be designed in such a way that the drivetrain and other critical components can be changed at a minimal cost.”

- Rules & regulation
    - Many of the reviewed technologies have been active in different applications in the land-based industry for many years, which means that the current rules & regulations are centered on land-based applications and not usage in the maritime sector. It is suggested that a project is initiated with the scope of defining “how land-based propulsion applications can be approved for maritime usage”.