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Abbreviations

D	Deliverable
EC	European Commission
EMFAF	The European Maritime Fisheries and Aquaculture Fund
FAME	Fatty Acid Methyl Ester
HEFA	Hydrotreated Esters and Fatty Acids
HVO	Hydrotreated vegetable oil
LFP	Lithium Iron Phosphate
NMC	Nickel Manganese Cobalt
ROI	Return on investment
SCP	Structure-Conduct-Performance Model
T	Task
WP	Work Package

Executive Summary

The SEAGLOW project (Sustainable Energy Applications for Green and Low-Impact Operation) focuses on reducing the carbon footprint of small-scale fisheries in the Baltic and North Sea Basin by implementing alternative energy sources and fuel-efficient technologies.

This study analyses the prospective market opportunities of low-carbon energy solutions installed on four demonstration vessels equipped with hybrid engines, biodiesel, marine diesel and e-coating.

The analysis is based on the "Structure-Conduct-Performance" (SCP) model, which explains a firm's performance through its economic conduct in incomplete markets.

The market structure analysis, which aims to gain a greater insight into the competitive landscape of alternative low-carbon energy solutions in fisheries, showed that:

- The barriers to entry are high since few economies of scale exist, switching costs from marine diesel to alternative low-carbon energy solutions are high, and regulatory uncertainty makes it difficult for fishermen to make long-term investments
- The suppliers are powerful and hold significant bargaining leverage over small-scale fishermen because of the low availability of low-carbon fuels
- The buyer power of fishermen is low since low energy demand; it is costly to distribute alternative fuels in rural areas, and harsh competition from other sectors
- The threat of substitution is medium since the development of solutions is in rapid growth, and no solutions have established themselves on the market

The market conduct analysis aimed to examine how companies involved in small-scale fisheries adapt to gain competitive advantages and interact with stakeholders in the value chain and other sectors.

Suppliers and ports have the most significant market opportunities. The opportunities for fishers include

- cooperation with the entire value chain to the brand decarbonisation concept to get a better price for the fish
- Cooperate with shipping on technology transfer to minimise the R&D costs
- Pool their buying power with sector-wide procurement agreements to minimise the costs

It is estimated that the implementation of low-emission solutions in the fishing industry will be gradual, primarily occurring through new construction, engine replacement, or retrofit, typically every 15 to 30 years. The retrofit market is expected to be the largest. Biodiesel is expected to grow the most in the short term, while hybrid and other new solutions will be phased in in the medium term.

The conversion costs are significant and must be accompanied by political incentives and support schemes if the sector is to meet its green objectives.

1 Introduction

The SEAGLOW project (Sustainable Energy Applications for Green and Low-Impact Operation) focuses on reducing the carbon footprint of small-scale fisheries in the Baltic and North Sea by implementing alternative energy sources and fuel-efficient technologies. Reducing dependency on fossil fuels addresses the urgent need for sustainable fishing operations.

Today, fossil fuels dominate the energy source used in small-scale fishing boats.

Fishers have worked for years to make their vessels more energy efficient. This is good for the climate and economically necessary and sensible. However, radical change is needed, and sustainable fuels are key to meeting the Paris Agreement.

Alternative low-carbon energy fuels, such as biodiesel, methanol, and electric batteries, are available.

This study analyses the prospective market opportunities of the low-carbon energy solutions installed on the four demonstration vessels in SEAGLOW (see table 1).

Table 1: Low-carbon energy solutions installed on four demonstration vessels

Country	Vessel	Hybrid electric motor	Biodiesel*	Diesel	e-coating
Denmark	T 247 Ester	X	X		X
Sweden	Valentina	X	X		X
Estonia	PMA-605	X		X	X
Norway	R-1-SS Anne Katharina			X	X

*Hydrotreated vegetable oil (HVO)

2 Methodology

The analysis followed the "Structure-Conduct-Performance" (SCP) model (1), which explains a firm's performance through economic conduct in incomplete markets. The SCP model is summarised in Figure 1.

Figure 1: The structure-conduct-performance model

2.1 The market structure analysis

The market structure analysis aimed to gain a deeper understanding of the competitive landscape of alternative low-carbon energy solutions in the fisheries sector.

The analysis followed Porter's 5 Forces tool, a framework for analysing the competitive forces within an industry (2). The five critical forces determining competitive power are competitive rivalry, supplier power, buyer power, the threat of new entrants, and the threat of substitutes.

The analysis was based on data generated in WP1 and WP3, as well as an online expert workshop held on 12 March 2025, which included 14 experts and participants from regional, industry, and technology perspectives (see Table 2).

The participants were invited via the Enterprise Europe Network, the Maritime Industries & Service Sector Group, or in person via email.

Table 2: List of participants at the online expert workshop on 12 March 2025.

Name	Organisation	Area of Expertise
Aleksanders Pavlovics	Department of Accident and Incident Investigation Authority, Latvia	Partner in H2-SEAS (Coastal fishing vessels powered by zero emission hydrogen fuel cell)
Arno Sijnesael	Impuls Zeeland	International business development, entrepreneurship, Advisor EEN
Christian Heidemann Andersen	Port of Strandby, DK	Business development within the Harbor industry
Dag Standal	SINTEF Ocean, N	Fisheries Governance

		Green transition Norwegian fishing fleet (several projects)
Dag Stenersen	SINTEF Ocean, N	Engine development (e.g. natural gas), testing
Francois Bastardie	DTU Aqua, DK	Fisheries expert, Member of energy transition partnership for EU Fisheries & Aquaculture, ETP)
Joanne Ellis	RISE, S	Sustainable shipping technologies, alternative marine fuels
Ken Ryrbo	Cetasol, S	AI-powered energy optimisation for marine sustainability
Lothar Hartmann	TUTECH, DE	Strategic Services+ communications, EE N Advisor
Kim Winther	Danish Technological Institute, DK	Green transport technologies
Marta Cavalli	Low Impact Fishers of Europe – LIFE, BE	Sustainable development in small-scale fisheries
Michael Rafn	NordDanmarks EU-kontor	International business development, Chairman of Enterprise Europe Network (EEN) Maritime Sector Group
Steffen Helledie	NorddDanmarks EU-kontor	International business development in the green transition, Coordinator SEAGLOW
Kersti Haugan	FBCD, DK	Sustainable innovation in food and bioresources, Leader WP5 SEAGLOW

2.2 Market conduct analysis

Market conduct analysis aimed to comprehensively examine how companies involved in small-scale fisheries adapt to gain competitive advantages and interact with stakeholders in the value chain and other sectors.

The analysis was based on the findings of the market structure analysis and interviews with experts and stakeholders in the region where the pilot cases and their testing sites are situated (Port of Hanstholm (DK), Risavika Port (N), Port of Gothenburg (S) and VOISTE Port (EE)).

Potential interviewees were identified and contacted via email, and 17 interviews were performed online from March to May 2025 (see Table 3). The participants were informed about the context, purpose, and content of the interview, as well as how the information gathered would be used. After obtaining informed consent, semi-structured interviews were conducted in the mother tongue, recorded, and transcribed, and lasted approximately one hour.

An interview guide and a semi-structured questionnaire were jointly developed (see Appendix 1).

Table 3: Participants in expert interviews

Country	Company	Name
Denmark	Port of Hanstholm	Port Director Søren Kanne Zohnesen
Denmark	Malik Energy A/S	COO Anders Jensen
Denmark	Hanstholm Skibssmedie	CEO Jesper Pedersen
Denmark	Nordhavn Power Solutions	CSO Jørk Rudolph
Denmark	University of Copenhagen, Department of Food and Research Economics	Professor Max Nielsen
Norway	Owner Anne Katharina	Fisherman Per Harald M. Skibstad
Norway	Knapphus Energi	Sales Manager Thor Ove Vistnes
Norway	Ydstebø Marine AS (Kvitsøy)	Owner Roar Ydstebø
Sweden	Kungshamns Fiskarna	CEO Mats Andersen
Sweden	Owner GG79 Jenna	Fisherman Hans Gøran Pedersen
Sweden	Ø-varvet	Daniel Hermansson & Emil Green
Sweden	Lund University – School of Economics and Management	Policy Officer Cecilia Hammarlund
Sweden	Gothenburg University – School of Global Studies	Researcher Milena Arias Screiber

Estonia	Ministry of Agriculture and Fisheries	Head of the commission for fisheries Indrek Adler
Estonia	Voistre Sadama OU	Argo Mengel
Estonia	The fisheries information sector connects decision-makers and the sector	Toomas Armulik and Erko Veltson
Estonia	Tallinn University of Technology, Estonia Maritime Academy	Rina Otsason

2.3 Market performance analysis

The market performance analysis aimed to assess crucial factors influencing the success of implementing low-carbon energy solutions in SEAGLOW, such as growth prospects, investment costs, socio-economic benefits, and regulatory push-pull policies and incentives.

The analysis was based on knowledge generated by the previous study.

3. Results

3.1 Market conduct analysis

The low-carbon fuels market is an emerging industry characterised by early-stage development, minimal competition, high growth potential, high risk, and volatility.

It involves new products or technologies and can be challenging to value due to the lack of established norms.

This analysis summarises the attractiveness and likely profitability of the solutions demonstrated in SEAGLOW.

3.1.1 Barriers to entry

The primary sources of barriers to entry are

- technological readiness and trust issues
- lack of fuel supply and infrastructure
- high retrofitting and new vessel costs
- economic pressures in the fishing industry
- policy and market barriers.

The fisheries sector has not fully developed or trusted the technology for alternative low-carbon fuels.

Biodiesels are available, but the price is too high compared to fossil fuels.

Electricity is technically feasible for some vessels, but fishers do not trust it due to concerns over battery reliability, capacity, and performance in harsh marine conditions.

Alternative fuel options are uncertain, and whether they can be used in existing engines or require significant modifications is unclear. The effectiveness of sails and hybrid propulsion is highly dependent on the type of fishing method used. Trawlers, for example, cannot easily switch to electricity, while some other vessels may find it easier to adapt.

The main challenges of adopting biofuels are their scalability, global availability, and high price level. The high price level of alternative fuels compared to traditional diesel makes the return on investment (ROI) negative for most fishers. There is a limited infrastructure in fishing ports to support alternative fuel refuelling and repairing and maintaining electric or alternative fuel engines requires specialised skills that many crew lack. Battery replacement costs and power supply remain a significant concern, as charging infrastructure is not widely available in remote fishing areas.

Whether retrofitting existing boats or building new vessels, both options involve significant costs that fishers may not be willing to take on. Retrofitting the boat with alternative fuels may impact its design, reducing storage space for catches or increasing weight, which in turn affects efficiency. Some fuels, such as ammonia, require engine modifications, while others, like DTL fuel, may be easier to implement if supply and cost challenges are addressed. Electricity is only viable if it becomes significantly cheaper than diesel, but it currently does not offer a competitive advantage.

Fisheries do not control the selling price of their catch, meaning they focus entirely on controlling operational costs. The high costs of alternative fuels and retrofitting make cost control difficult, leading to reluctance to adopt new technologies. Alternative fuel costs are too high compared to traditional fuels, mainly when assessed over the whole lifecycle assessment (LCA). Smaller fishing vessels account for less than 1% of fishing emissions, while large industrial vessels pose the real challenge; however, they currently have no viable alternative fuel solutions.

Regulatory uncertainty makes it difficult for fishers to make long-term investments in alternative fuels. Carbon pricing could be a tool to create incentives for change, but current policies do not make it financially attractive to transition. The market does not reflect the environmental impact of different fishing approaches, making it difficult for sustainable practices to compete economically. Consumer demand for sustainable fish is needed to drive industry change—without it, fishers are unlikely to invest in alternative fuels.

The conclusion is that the barriers to entry into the low-carbon fuels market for small-scale fishing boats are high. Few economies of scale exist, switching costs from marine diesel to alternative low-carbon energy solutions are high, and regulatory uncertainty makes it difficult for fishers to make long-term investments (see Table 4).

3.1.2 Bargaining power of fishers

The buyer power for fishers is determined by how easy it is to drive the price down and is driven by the

- number of fishers
- size of each order
- competition from other sectors.

Small-scale fisheries employ around 60,000 fishers in Europe; however, the energy demand for small-scale fishing boats is relatively low compared to other sectors, such as aircraft and deep-sea shipping.

Fishers typically place small orders, and since small-scale fisheries are commonly found in rural areas, it is costly for the supplier to distribute alternative fuels to them.

It is also harsh competition for alternative low-carbon fuels, making it difficult for fishers to compete. Airlines can pay significantly higher prices (up to 10 times) for paraffinic fuels, such as hydrotreated vegetable oil (HVO) and hydrotreated esters and fatty acids (HEFA) and take larger volumes. Regarding methanol, deep-sea vessels can take significant volumes, pay more, and have already secured most of the world's supply. By the end of this decade, Maersk anticipate that 25 of their vessels will be sailing on green methanol, saving a remarkable 2.75 million tons of CO2 emissions.

The conclusion is that the pressure small-scale fisheries can exert on the alternative fuels industry to lower product prices is estimated to be weak, indicating that price reductions will be challenging.

3.1.3 Supplier power

The ability of suppliers to drive up prices is driven by

- number of suppliers
- the uniqueness of their product or service
- their strength
- the cost of switching from one to another, etc.

In general, there are many established players in this field, holding a strong position due to their scale, expertise in sustainability, and investments in infrastructure. Smaller renewable startups offer innovation-driven differentiation but lack scale. Below are some examples of players in the biodiesel and methanol market

Fatty Acid Methyl Ester (FAME) and Hydrotreated Vegetable Oil (HVO) are the most established biofuels suitable for marine use. Several big companies produce FAME, like Arkema, BASF SE, Cargill, Elevance Renewable Sciences, and Wilmar International, which are significant players in the FAME market. Neste Oil (Finland) is the world's largest producer of hydrotreated vegetable oil (HVO). Other major players are Valero Energy (U.S.), ENI (Italy), and UPM Biofuels (Finland). Additionally, companies like World Energy (U.S.), Cepsa (Spain), Total (France), and REG (U.K.) are also involved in HVO production. Since the ability for marine use is limited, biodiesel suppliers can increase their prices.

There are many large-scale producers of standard methanol (> 140 million tons per year), and the current demand is met by producing synthetic gases using coal or natural gas as feedstock. Bio-methanol is produced using biomass feedstocks, and production volumes are currently low. Oberon Fuels is an example of a bioethanol producer. E-methanol is obtained by generating hydrogen through the electrolysis of water, combining it with captured CO2 emissions, and catalytically converting it into methanol. The European Energy is the leading producer of e-methanol, with the Kassø Power-to-X facility in Denmark being the world's largest commercial e-methanol plant. Currently, the shipping industry has dominated the market for bio- and e-methanol. Figure 2 shows the current and future methanol production by source (9). The key variable explaining the extensive projected growth of methanol production from sustainable feedstocks is the dramatic reduction in the cost of key drivers. Currently, the shipping industry has dominated the market for bio- and e-methanol.

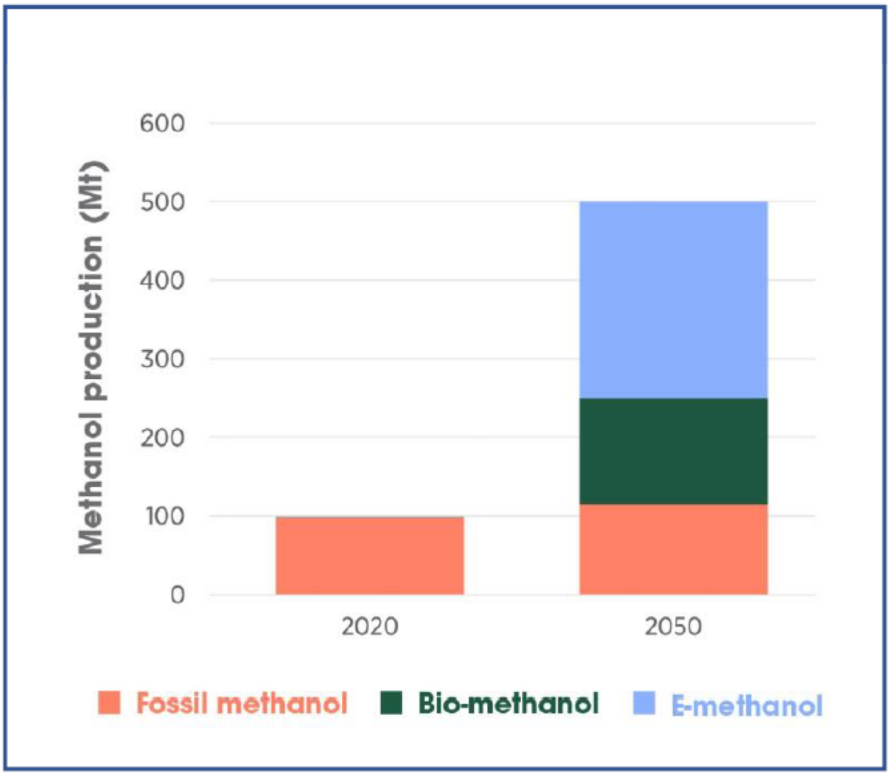


Figure 2 Current and future methanol production by source (9)

The conclusion is that suppliers are powerful and hold significant bargaining leverage over small-scale fishers, as the availability of low-carbon fuels is limited. Furthermore, investing in new low-carbon technology is costly and a long-term decision, and the fishers' ability to substitute is low.

3.1.4 Rivalry among existing competitors

The fisheries believe that realistic alternatives to diesel as a fuel are not yet available, and existing technology is expected to remain in use for many years.

Implementation has been at a standstill for the last five years, which has put pressure on companies that have invested in developing new green solutions.

The number of competitors in the biodiesel industry is moderate, but there is a shortage of production capacity.

A handful of competitors are on the market for bio-methanol and e-methanol. The potential for significant industry growth limits competition between companies.

The conclusion is that the market is dominated by a few providers, where one company's decision influences and is influenced by the decisions of the other companies.

3.1.5 Threat of substitutes

There is a significant price difference between fossil fuels and green fuels, making it challenging to establish large-scale production of low-carbon energy fuels.

Uncertainties around the availability of technologies are expected to delay the transition.

Ammonia is not expected to be an available technology for shipping until around 2027, primarily due to later developments in engine technology.

Green hydrogen has been identified as a fuel that could offer a 'near-zero' carbon solution on a well-to-wake basis. Due to hydrogen's low volumetric energy density, which would increase the storage needs onboard a ship, hydrogen-fuelled vessels may be a more suitable solution for short-sea shipping rather than deep-sea shipping.

Nuclear power is also a well-known and safe propulsion technology for submarines. The Danish nuclear company Saltfoss Energy (formerly Seaborg) is working intensively on developing small, so-called liquid and compact salt-nuclear reactors on molten salt and dissolved uranium. It is safer than traditional reactor types because cooling with liquid salt means the reactor stops if. For example, the power goes out. Therefore, it cannot melt down. If a leak were to occur, the reactor activity would not rise into the air as a vapour cloud but would remain in the salt, which would solidify into a crystal-like stone if it escaped the reactor. The reactor is expected to fit in a standard 20-foot mobile container and could propel ships. In addition to being CO2-neutral, nuclear power's significant advantages include, among other things, the security of supply (it is not dependent on when the wind blows or the sun shines) and significantly less land use for energy production.

The conclusion is that the strength of competition in the low-carbon energy fuels market for small-scale fisheries is evaluated to be low.

3.1.6 Conclusion of Porter's Five Forces

Figure 3 summarises Porter's Five Forces Analysis (2) for low-carbon energy fuel to small-scale fisheries.

Threat of New Entry (Barriers to enter are high))
-Technological readiness and trust issues -Lack of fuel supply and infrastructure

-High retrofitting and new vessel costs

-Economic pressures in the fishing industry

-Policy and market barriers

Supplier Power (high)

-The production capacity of biodiesel, biomethanol, and e-methanol is low, and suppliers can increase prices.

-Investment in new low-carbon technology is costly and a long-term decision, and the fishers' ability to substitute is low.

Competitive Rivalry

-The number of competitors is low to medium

-The potential for significant industry growth limits competition between companies

-One company's decision influences and is influenced by the decisions of the other companies

Buyer Power (low)

-Low energy demand

-Place a small order size

-It is costly to distribute alternative fuels in rural areas

-Harsh competition from other sectors

Threat of Substitution

(low – medium)

-The significant price difference between fossil diesel and green fuels makes it challenging to get large-scale production going.

-Ammonia is expected to be available for shipping around 2027.

-Green hydrogen and nuclear power will also be available in the future.

Figure 3 Porter's Five Forces Analysis for low-carbon energy fuel to small-scale fisheries (2)

The market structure analysis showed that

- The barrier to entry is high
- Buyer power for fishers is low
- Supplier power is high
- Rivalry among existing competitors is low to medium
- Uncertainties around the availability of technologies are expected to delay the transition.

The energy transition in small-scale fisheries is driven not solely by technological advantages or economic considerations, but by an environmental imperative, increasingly underscored by social pressure, policy, and regulatory demands to reduce emissions.

Decisions are being made today amid some commercial uncertainty, and the regulatory approach, rather than the economic one, will drive forward the change.

3.2 Market conduct analysis

The aim is to examine how companies involved in small-scale fisheries adapt to gain competitive advantages and interact with stakeholders in the value chain and other sectors.

Figure 4 shows the fish value chain.

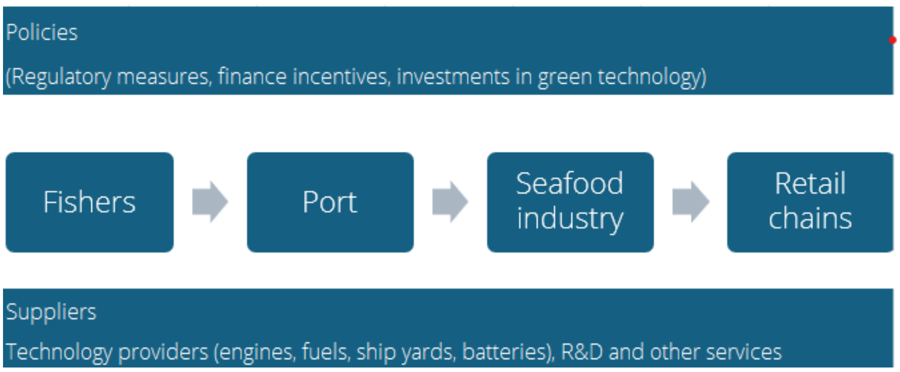


Figure 4: Fish value chain, simplified scheme (own work)

3.2.1 New opportunities for fishers

Today, the focus is on technological improvements, specifically diesel technology (new engines, filters, and hulls), which reduces fuel costs.

This means that those who use relatively little fuel tend to do better than those who use a lot. It also means that those who use less fuel are more environmentally friendly in terms of climate change.

There is limited communication and knowledge about low-carbon technologies. The fishers get information about the future's green solutions via

- the fishery association, which is involved in green projects
- Open-hours events, LinkedIn postings, and speaking at fishing fairs, etc., from the suppliers.

Small-scale fisheries are highly sensitive to weather and wind conditions in the North Sea, and any new alternative low-carbon solutions must be safe.

In the short term, biodiesel, which has already been produced in significant quantities, can be introduced. It is the cheapest way to reduce CO2 emissions without significantly modifying engines. The price level for HVO is more than 40% higher than marine diesel but mixing biodiesel with marine diesel will make the increased cost a minor part of the fishery's overall costs.

The main challenge of adapting biofuels is their availability. Today, 7 % of biodiesel is blended into vehicle diesel. As electric vehicles gain popularity, the availability of biodiesel will increase.

In the medium term, a hybrid dual-fuel technology with marine- or biodiesel/electricity could be an option for securing safety and reducing CO2 emissions.

In many ways, Norden pioneered environmental initiatives on ferries and ships with electric batteries. At first glance, the initiative appears to be less successful. The world's first electric fast boat, Medstraum, between the city islands outside Stavanger, was set to be a sensation. Still, a significant decrease in battery capacity and delays have affected it. With increased speed, Medstraum uses more electricity, and it cannot go fast at all.

The diesel could provide high-speed power to the fishery area where the battery lacks capacity, and the electricity could be used in the fishing operation to improve the working environment.

Fishers could pool their buying power through sector-wide procurement agreements to reduce fuel prices, minimise supply chain costs, limit administrative burdens for individual operators, send clear demand signals to producers, and maximise the fishers' share of limited suppliers in a competitive market.

Small-scale fisheries can also collaborate with shipping companies on technology transfer. This sector is further ahead in sustainable fuels than fishing and has greater opportunities to drive and implement these innovations.

Fishers' competitive advantages are shown in Table 4.

Table 4 SWOT Analysis of Fishers

Strengths	Weaknesses
• Focus on reducing fuel costs • Small-scale fisheries have shorter fishing trips, so implementing hybrid technology would be suitable • They often achieve better prices at the fish auction due to higher product quality • Already selling to the premium market, willing to pay extra	• There are not as many fish near the coast anymore • The vessels must go further out to sea, which makes fishing more weather-dependent and limits the number of fishing days (an increase in fuel consumption) • limited knowledge about low-carbon technologies • lack of space for new technology
Opportunities	**Threats**
• The entire value chain must work together to brand the decarbonisation concept • Cooperate with shipping on technology transfer to minimise R&D costs • pool their buying power with sector-wide procurement agreements to minimise costs	• Small vessels have a worse economy than large vessels and are the primary pressure factor • If fuel price rises, fishing will become too expensive, which will reduce fishing • Fishing vessels are getting bigger and bigger

3.2.2 New opportunities for ports

The ports will play an emerging role as hubs for the clean energy transition and are central to expanding infrastructure (pipelines, tank facilities, cable network, etc.) and areas for producing and storing green fuels for the fisheries.

The fishing boats of the future are green, and a cornerstone for developing green fuels is that production can take place near the vessels that will use them.

The ports see opportunities to meet the future need for producing green fuels in the port area and become green filling stations for ships, where they can refuel with green fuels. This will create new rental income for the port, jobs, and immigrants to the municipality.

At the same time, many smaller fishing ports, such as Tananger/Risavika, are attractive as residential areas, and several municipalities want to convert commercial port areas into urban and residential areas or build near port areas.

The market for green fuel remains uncertain, making it challenging for ports to upgrade their infrastructure for these new fuels.

Small-scale fisheries are often comprised of smaller operators in a port and may struggle to create sufficient demand for sustainable fuels. Therefore, they must cooperate with other port operators to develop new infrastructure for future solutions.

Several ports have the power capacity to quickly install charging stations for small vessels, but shore power cannot be installed for large fishing vessels. This will require significant investments in new infrastructure,

Shore power is expected to become available in the medium term in most major fishing ports in the Baltic and North Sea basins.

By 2030, many ports will have to meet EU requirements to deliver shore power (3). The requirements vary depending on the type of vessel berthed. There are currently no specific requirements for handling fishing boats. However, the EU is likely to prepare amendments in 2026, which could lead to additional requirements for ports to handle zero-emission fishing vessels.

Ports and companies can apply for EU funds to implement shore-side power systems through the EU Connecting Europe Facility (CEF) program (4).

When implementing electric fishing vessels, it is essential to be aware that there are problems getting electricity in some Baltic and North Sea basin ports, such as Finnmark in Norway. Many fish species have seasons with higher catch opportunities, such as Skrei in Lofoten. During large catches, vessels are queuing (on a swing) to deliver fish, and there will not be enough electricity or quay space/length for charging the batteries.

Filling operations for biodiesel are being developed and will be available to those who want them.

Green transition requires a new approach to infrastructure decisions.

Mobile solutions, such as flexible modular battery systems (see North Sea Container Line, ncl.no) and a mobile methanol plant that can be relocated between fishing ports, are an option during the transition.

The port and its owners, mainly municipalities, have managed the development well. Still, the growing demand for port infrastructure will necessitate funding from the community, new partners, and a revised ownership structure.

The Port's Competitive advantages are shown in Table 5.

Table 5 SWOT Analysis of Ports

Strengths	Weaknesses
• They are central to expanding infrastructure and areas for producing and storing green fuels • Several ports have the power capacity to install charging stations for small vessels quickly	• Limited infrastructure in place for low-carbon energy solutions • The growing demand for port infrastructure will require funds from the community, new partners and a new ownership structure
Opportunities	**Threats**
• The ports will play an emerging role as a hub for the clean energy transition • To meet the future need for producing green fuel in the port area • Become green filling stations for ships • Mobile solutions such as flexible modular battery systems and mobile green fuel plants are an option during the transition • Create new rental income for the port, jobs and immigrants to the municipality • Can apply for EU funds to implement shore-side power systems, such as the EU Connecting Europe Facility (CEF) program	• The market for green fuel remains uncertain, making it difficult for ports to improve their infrastructure for new fuels • The number of small-scale boats in ports is decreasing, and the port may prioritise other business segments and areas for urban and residential use. -

3.2.3 New opportunities for suppliers

A fishing port is home to many service companies that ensure an experienced and competitive service port.

Fuel supplier:

As a fuel supplier, their primary service is to ensure that the requested energy is available 24/7 when the customer needs it and that staff are present to assist in the fishing ports.

The fuel supplier can quickly assemble green energy solutions for ferries that sail from A to B and back to A. It can be more difficult for a fishing boat that changes patterns.

Today, fuel suppliers face a challenge regarding the tank plant, which is primarily designed to store marine diesel but can easily handle biofuel with the same flash point as diesel in existing pipelines.

Still, other fuel types in a different hazard class will require new technology at the tank plant and a transition period.

Deep-sea shipping transporters typically operate on 2-4 routes between global seaport hubs, where the infrastructure for ammonia, methanol, and other products are in place. This infrastructure can be scaled down and used as smaller ports.

A smaller setup, such as a mobile plant, can be established during the transition period. Truck delivery of other fuel types to customers is also an option.

Small fishing vessels' fuel sales (volume) do not significantly affect their economy since fishing is dominated by trawl fishing.

Shipyard:

The shipyard generally sees excellent business opportunities in introducing new technologies for sustainable maritime services.

They already have access to new knowledge through ISO standards on the environment, subsidy programs (such as Environmental, Social, and Governance, ESG), and companies selling low-carbon technologies and projects, like SEAGLOW.

Fishers have regular inquiries about green technology, but the installations are currently too expensive and unavailable (as methanol engines < 200 kW).

Shipyards mainly offer various technologies to optimise the diesel consumption by reducing the hull’s water resistance and improving the vessel’s propulsion system. Examples include hull and propeller design, new and improved propulsion systems, and antifouling paints.

It is recommended that more attention be paid to technologies for reducing NOX emissions in the future, such as installing a catalyst or reactor system.

It should be mentioned that the Norwegian shipyard Selfa Arctic (www.selfa.no) specialises in building hybrid vessels that run partly on batteries and partly on conventional engine power.

Engine suppliers:

Sales of diesel engine installations to small-scale fishing boats in the Baltic and North Sea basins were previously an essential segment for engine suppliers.

Now, the companies focus more broadly. In addition to fishing fleets, they deliver solutions for recreational boats, ferries, deep-sea shipping, tugboats, and other vessels.

The engine suppliers have chosen to develop green propulsion systems for the future, and they are seeing more significant interest from large vessels than from smaller ones, partly because marine diesel engines with an output of less than 130 kW are not legally required to emit greenhouse gases.

The Danish company Nordhavn offers a hydroelectric system consisting of an "e-machine" and an internal combustion engine. It also developed a methanol engine in cooperation with the Swedish company ScandiNAOS.

The American engine manufacturer Cummins recently introduced an engine that can run on diesel and methanol. This new dual-fuel solution addresses a growing need for flexibility, allowing owners of fishing vessels to switch between traditional and new green fuel types, as the market is not yet ready to transition to methanol. In addition to supplying new dual-fuel engines, Cummins has an innovative retrofit kit for their existing engines. This makes it possible for customers to convert a diesel engine to run on dual fuel - diesel and methanol - without the fishers having to invest in a completely new engine. This allows customers to choose the most sustainable solution when the market and infrastructure are ready for methanol.

The supplier's competitive positioning is shown in Table 6.

Table 6: SWOT Analysis of Suppliers

<table>
<tr><td>Strengths

• Product portfolio available for alternative fuel, engine and electric batteries
• Technology implemented on ships
• Tank facilities are available for use in biodiesel production, tank deliveries, and other purposes.
• Have the finances to invest in new R&D and new solutions if there is a business case</td><td>Weaknesses

• Sales of fuels (volume) and engines to small fishing vessels play a minor role in the economy – it must be a business case
• Are reluctant to promote green solutions for small vessels since the economic pressures on them
• Focuses on other segments, such as aircraft and larger ships with higher volumes and better prices</td></tr>
<tr><td>Opportunities

• Short-term blend in biodiesel and sale of engines that can be used for diesel, methanol, etc.
• Medium-term methanol (requires significant investments) and batteries when shore power is implemented</td><td>Threats

• It's going too slowly and many innovative companies are closing down.</td></tr>
</table>

3.2.4 New opportunities within the seafood industry

There is a significant price difference between fossil fuels and green fuels, and one opportunity for fishers is to identify segments willing to pay a premium for wild-caught fish and shellfish with an even lower climate footprint.

Today, most fish are sold via fish auctions, where buyers (typically the seafood industry) bid for the fish.

The selling price depends on size and quality, with fish from small-scale fisheries often receiving a better price because the fishing trip is shorter (resulting in fresher fish) and passive fishing gear is typically used, which is gentler than trawling.

Many small-scale fishers are also members of the scientifically based MSC certification and labelling scheme for sustainable fishing, which requires all links in the supply chain that sell certified fish and shellfish to meet the MSC's Chain of Custody Standard requirements.

The EU is working towards climate-friendly labelling for food to help consumers make more sustainable choices. This involves establishing a system that communicates the environmental impact of food products, potentially using a scale-based traffic light system.

Determining a fish's carbon footprint can be a daunting task for consumers. We consume around 100 to 200 different species of fish caught using various fishing gears, and each has a different carbon footprint. It will be an information problem to disseminate the message. For example, herring and mackerel, which are caught by the largest vessels, have the lowest carbon footprint.

Seafood is generally more expensive but has a lower carbon footprint than meat. Some niche markets may be willing to pay for the additional costs associated with sustainable fuel, which will have a relatively small impact on the price in the refrigerated counter. Most consumers are assumed to be unwilling to pay a premium for seafood with a marginally lower climate impact.

3.2.5 New opportunities within retail chains

The development of sustainable fuels for shipping is driven by its customer portfolio, which includes companies like Walmart and IKEA.

They market sustainable products with a low climate footprint, and in almost all cases, reducing CO emissions when transporting goods over longer distances is the easiest and cheapest way to start.

The market push for fish with a lower climate footprint must come from one of the larger retail chains, and the entire value chain must work together to brand the concept.

3.2.6 Policies

EU policies, particularly the European Green Deal, are key drivers in decarbonising the European Union.

These policies aim to achieve climate neutrality by 2050, with interim emission reduction targets, and involve a mix of regulatory measures, financial incentives, and investment in green technologies.

Regulatory measures:

In February 2023, the European Commission published a communication assessing the energy transition (5). The key drivers in this transition are improving energy efficiency, gradually shifting to renewable and low-carbon energy sources, and promoting low-impact fishing practices.

Although the energy transition of the fishing sector is not fully regulated, and the carbon intensity of fishing vessels remains uncontrolled, specific policies, such as revisions to the taxation directive, may have an impact on it. One of the most significant modifications affecting the fishing sector is that fossil fuels for intra-EU fishing will no longer be fully exempt from energy taxation in the EU (6).

As we approach the different milestones the European Commission sets for reducing GHG emissions, more regulations will be set to accelerate the energy transition in this sector. It is expected that in the upcoming years, fishing vessels will be required to meet some of the decarbonisation regulations already applied in the shipping industry (see WP1)

However, some country-specific regulations are already in place, mainly taxes on fossil fuels (carbon taxes) that can incentivise the use of green fuels by making them relatively cheaper and more attractive.

Denmark introduced a CO2 tax in fisheries on January 1, 2025 (7). The tax amounts to DKK 350 per ton of CO2 in 2025 and will increase by DKK 80 per ton of CO2 annually to DKK 750 in 2030 (based on 2022 prices). The government neutralised the tax as of February 3, 2025, because politicians found that fisheries could not afford it economically. Small fishing vessels must still pay the tax but will be refunded until 2030. This means the incentive for fishers to act now in Denmark is small.

The Norwegian government introduced a CO2 tax for the fishing fleet in 2020, aiming to encourage reduced fuel consumption and the development of alternative, low-carbon energy sources (10). In parallel, the Norwegian government established a CO2 compensation scheme to facilitate the transition in the fishing fleet. It was planned to be gradually phased out by 2025. Since fishers do not yet have real fossil-free alternatives, the scheme remains necessary, and the government has decided to strengthen it in 2025.

In 2023, Norway introduced a 6% turnover requirement for biofuel for fishing vessels, and by 2035, the proportion of biodiesel must be 30% (the requirement does not cover foreign shipping). This initiative will significantly reduce CO2 emissions from small fishing vessels (11).

Preferably, the government taxes should be based on the emitter paying the full price for adverse environmental and climate effects. This should apply regardless of whether taxes, a quota system, or similar measures are introduced. This means that all links in the value chain must pay for their emissions, i.e., the fisher who catches the fish, the transporter who transports the fish to the fish processing industry, the transporter of fish products to customers worldwide, etc. It is easy to say but extremely difficult to comply with in practice. Often, each of the 100-200 fish species has its unique value chain. An example is horse prawns: They are caught in the Wadden Sea, boiled and frozen in the local area, then transported by cargo ship to Morocco, where they are hand-peeled and pickled before being transported back to Europe. Precisely identifying the amount of CO2 emitted for each product is a challenging task. However, such a system would make it too expensive to transport the horse shrimp to Morocco, and the shrimp would have to be peeled closer to the fishing ground to benefit the environment.

Financial incentives:

Several funding schemes, such as the European Maritime Fisheries and Aquaculture Fund (EMFAF), are in place to accelerate the transition to a sustainable future.

The EMFAF supports low-carbon fisheries by funding projects that promote energy efficiency and the decarbonisation of fishing activities. This includes investments in technologies that improve energy efficiency and reduce carbon footprints, such as hydrodynamic optimisation, gear efficiency, alternative fuels, and bridge systems for engine control. The EMFAF also supports the development and deployment of innovative technologies to accelerate the transition to low-carbon fishing.

Program management is divided into shared management and direct management. The shared management—€5.311 billion—is provided through national programmes co-financed by the EU budget and EU countries, to which the Common Provisions Regulation 2021-2027 applies. The Commission offers direct management—€797 million—directly.

To determine if a project idea is eligible for EMFAF support, first consult with the national authority responsible for managing the operational program in your country. Then, follow the relevant application procedures so that the managing authority can assess your project's eligibility and determine whether it meets the appropriate selection criteria and investment priorities.

Introducing a scrap metal premium or deposit scheme for old diesel engines, such as those from old cars, could also be an option. This would provide fishers with a basis for purchasing a new, environmentally friendly propulsion system.

Investments in green technology:

Horizon Europe, the EU's key funding program for research and innovation, supports the energy transition in fisheries and aquaculture through various initiatives.

The policy's competitive positioning is shown in table 7.

Table 7: SWOT Analysis of Policies

Strengths -Vital role in driving green transition through policy, regulations, investments, etc.	Weaknesses -Political short-termism -Competing priorities for policies and funding -Economic pressure and industry lobbying
Opportunities -Can choose from various policy interventions and financing measures, such as tax rebates, subsidies, tighter regulations, new standards, and loans -Enter public-private partnerships	Threats - No incitement for fishers to move from fossil fuels -The decarbonisation of the fishing sector is still hardly regulated -Regulatory and policy uncertainty reduces private sector interest and innovation -Poor incentives that do not sufficiently consider the enormous upfront R&D costs and the lengthy, risky development period.

3.3 Market performance analysis

This analysis aimed to assess the factors influencing the success of implementing low-carbon energy solutions in SEAGLOW.

3.3.1 Growth prospects

The need to decarbonise the fishing fleet is recognised, and it's just a matter of time before implementing low-carbon energy solutions.

The speed of the transformation will largely depend on the authorities' requirements and the prices of fossil fuels.

Market potential is considered significant. The nowcasts for the EU-27 Small-scale coastal fleets (excluding Greece) for 2023 indicate that there are 30,800 active vessels with a total vessel power of 1.288 thousand kW and an energy consumption of 89.1 million litres (8).

Implementing new low-carbon energy solutions typically occurs when new ships are built, the engine is worn out and no longer performs optimally (typically after 15 years), or when existing engines are retrofitted.

The average lifespan of fishing vessels is at least 30 years. Even though the average age of small-scale vessels is high, the number of new vessel constructions is relatively low. The retrofitting market is therefore expected to see the most significant growth.

Fossil fuels will remain part of the energy mix for many years. In the short term, the most significant growth is expected in biodiesel, with hybrid electricity and diesel/biodiesel solutions anticipated in the medium term.

The future will reveal which fuel type ultimately dominates the market, but technologies are being developed for all fuel types.

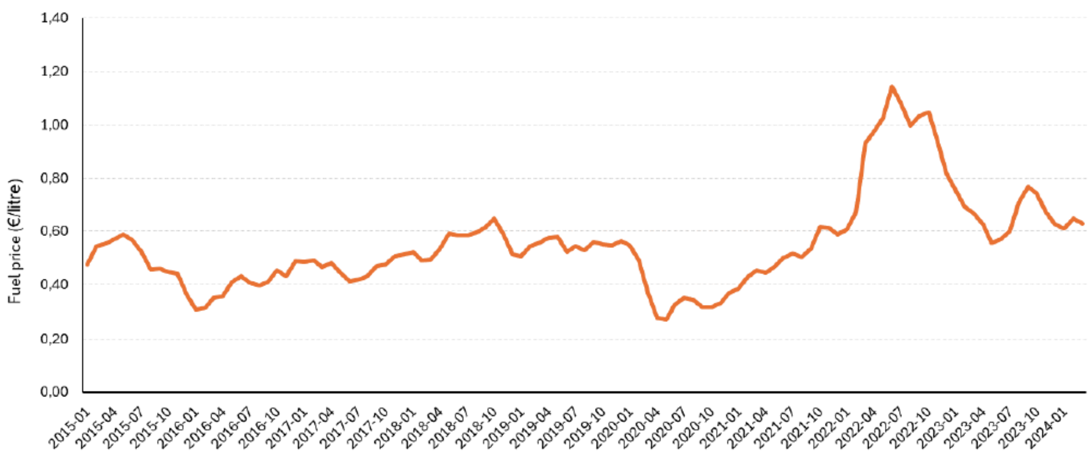
3.3.2 Investment costs

This section provides a brief introduction to the costs of investing in low-carbon energy solutions for small-scale fishing vessels, as well as the ongoing fuel costs associated with these investments.

Marine diesel:

Fuel represents a considerable proportion of operational costs for the EU fleet, and the fleet's profitability is sensitive to changes in the price of marine fuel. Fluctuations in fuel prices have a significant impact on the fleet's performance.

Figure 5 shows fluctuations of the average marine fuel oil price (in euros) for EU-27.



Data source: EUMOFA database. All monetary values have been adjusted for inflation; constant prices (2022).

Figure 5: The average marine fuel oil price (in euros) for EU-27 (8).

A CO2 tax on marine diesel is expected in the future, which, if the price is competitive, could make it more attractive to switch to low-carbon energy solutions.

HVO-biodiesel:

The transition from marine diesel to HVO-biodiesel is straightforward, as no or minor changes in engine specifications are required.

The energy content of HVO biodiesel is slightly lower than that of marine diesel, resulting in a slight increase in the required fuel tank capacity (approximately 5%); however, this is not considered significant in practice.

The primary cost difference between basic diesel-powered vessels and those using HVO biodiesel as fuel is the variation in fuel costs. The price of HVO biodiesel has increased significantly in recent years. According to the OK list prices valid as of June 24, 2025, it costs 40% more than traditional marine diesel.

Batteries:

LFP Batteries (Lithium Iron Phosphate) and NMC Batteries (Nickel Manganese Cobalt) are suitable solutions for small-scale vessels.

The table below shows key characteristics.

Table 8: Key characteristics of LFP and NMC batteries

LFP Batteries	NMC Batteries
Long Cycle Life High Safety Lower Energy Density Lower Cost Wider Temperature Range	Moderate Cycle Life High Energy density Higher Cost Good Temperature Tolerance

Current suppliers include BellMarine, Transfluid, and Fisher Panda, and a reasonable battery can be bought for 50,000 Euros.

El-biodieselhybrid:

Offers of €250,000 to €350,000 have been received for installing an electric-biodiesel hybrid on T47 Ester in SEAGLOW. This includes shore connection, shipyard costs, battery for energy storage, and a plug-in electric drive train with a modern combustion engine (see Figure 6).

Additionally, investments will be made in new engines and batteries throughout the ship's lifetime.

It is estimated that the price of a comparable diesel vessel will be XX% lower, and that only the engine will be replaced after around 15 years.

The price of fuels and their development play a central role in the costs associated with the different technologies.

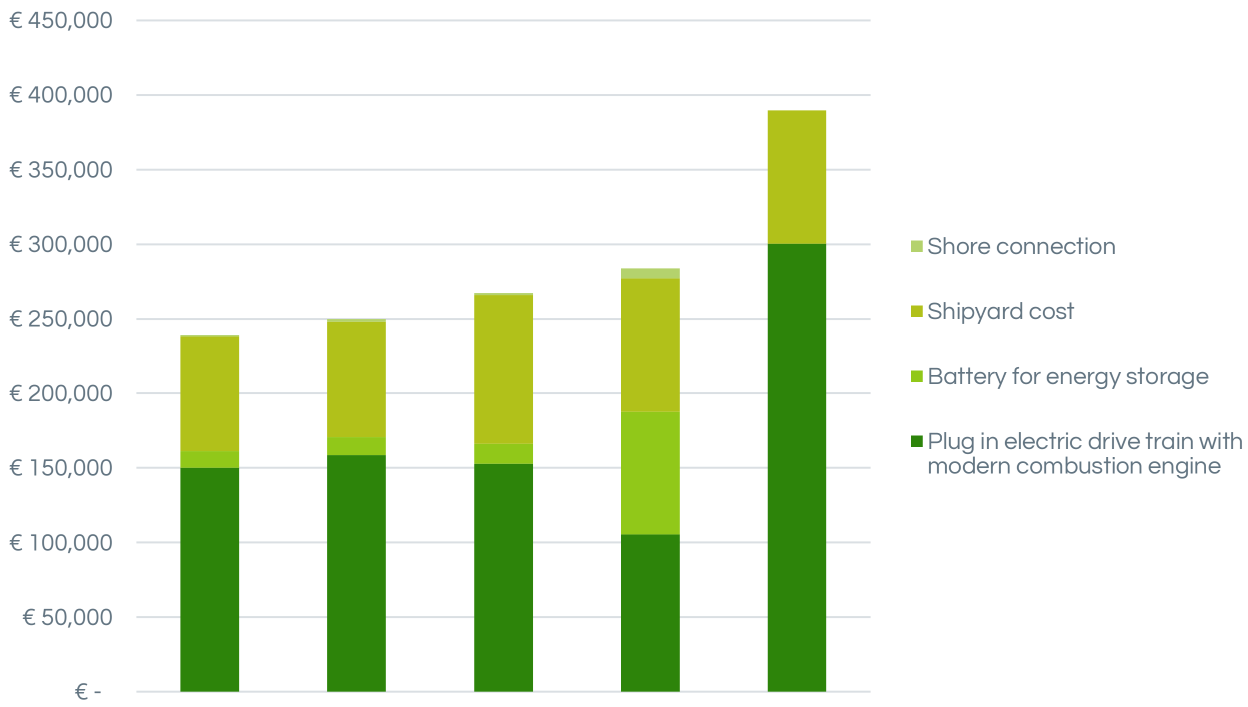


Figure 6: Offers received from 5 suppliers for conversion of the driveline at T47 Ester into an HVO-ready, rechargeable hybrid with a hydraulic pump/motor and a 24V power supply (SEAGLOW, WP3)

El-dieselhybrid:

The direct costs associated with investing in fishing vessels, including new engines and batteries during the vessels' lifetime, are expected to be at the same level as for the electric biodiesel hybrid.

3.3.2 Socio-economic implications

It has been assessed that the socio-economic consequences will be marginal.

Employment:

Jobs may be created in manufacturing, installing, and maintaining low-emission or electric propulsion systems, sustainable fuel production, and retrofitting services around the port.

Fishermen and marine engineers may also receive training in new systems, thereby enhancing their long-term employability and technical skills.

However, if the fuel price rises, fishing will become too expensive, resulting in reduced fishing activities and a decline in port operations.

Reduction of NOX, SO2 and particles:

Fossil fuel combustion on board ships produces carbon dioxide (CO_2), sulphur oxides (SO_x), nitrogen oxides (NO_x), soot, and water.

Research into cleaning diesel engine exhaust is making significant progress in areas such as exhaust filters, sulfur filters, and adding blue to the combustion process, among others. As a result, minimal pollution from diesel engines is expected in the long term.

Noise:

Today, the vessel's diesel-powered main engine and generator are used during energy-intensive unloading operations and cargo cooling when in port.

As mentioned, the Maritime Authorities will issue a new regulation within a year stating that the diesel engine must be switched off after 60 minutes at the port and that the ship must subsequently refuel with shore power.

With the establishment of shore power facilities and ships equipped to receive power, noise and emissions from the port will be significantly reduced.

4 Conclusions and perspective

Implementing low-emission energy solutions in small-scale fisheries is possible, but they face significant technical, economic, and political barriers.

Few suppliers characterise the market, significant price differences exist, and limited incentives exist for fishermen to take the first steps. Cooperation across the value chain, political will, and consumer demand for climate-friendly fish will be crucial to progress. Political incentives and support schemes must align with investments in infrastructure and technology development if the sector is to meet its green objectives.

It is recommended to

- Increase political pressure and support for infrastructure investments
- Strengthening cooperation and joint purchasing across the value chain, development and incentives for sustainable fish

- Further development of technologies for small-scale vessels and scaling up the production of alternative green fuels

The green transition of small-scale fisheries must be viewed as a collective responsibility for the entire value chain – from political decision-makers to ports, suppliers, individual fishermen, and consumers.

SEAGLOW will continue to work to accelerate opportunities for positive change by demonstrating the potential of these technologies in terms of cost-efficient fuel consumption reduction, environmental benefits, and closing knowledge and skills gaps.

Appendix 1. Interview guide and semi-structured questionnaire

Confidentiality: Any information gathered during this interview will only be used and published in a depersonalised form. We will not disclose any information that could lead to you or your company/organisation being identified.

Name of the interviewee	
Name of the organisation	
Area of expertise	
Date	
Permission to record	
Providing clean transcript translated to English (request if you wish to quote)	
Name of the interviewing party	

Part 1. Introduction

We invite you to participate in an interview for the EU-funded SEAGLOW project.

The SEAGLOW project aims to demonstrate the impact and potential of five technological applications for reducing fossil fuel consumption and GHG emissions on small North and Baltic Sea fishing boats (8.5 – 11.5 tons).

The goal of the interview is to understand your fishing community's needs and contexts to accelerate small-scale fisheries decarbonisation. We focus on below 12m and non-trawling fishing gear. By participating in the interview, you can influence the decarbonising of the fishing sector.

Furthermore, we offer:

- First-hand information on SEAGLOW results

- Opportunity to bring experts' perspectives to fine-tune the work program of the project and to comment on guidelines for commercialization
- Opportunity to connect and interact with other experts in the field

Part 2. Small-scale fisheries

- How important are small-scale fisheries in your local economies?
- What kind of challenges are small-scale fisheries facing in your region?
- What sustainability issues are important to you in small-scale fisheries?
- What opportunities do you see for small-scale fisheries to become more environmentally sustainable?
- How do fishers gain access to new knowledge about low-carbon technologies?
- What are the socio-economic implications (employment in fishing communities, reduction of pollution, noise reduction, etc.) of decarbonising the fishing fleet in your region?
- Are there any work environment issues you are particularly concerned about?
- What are the potential economic incentives to change to sustainable technologies?
  - Eg. Prize of different energy sources
  - Eg. Revenue from selling CO2 neutral fish

Part 3. Suppliers of green technology (boat manufacturer, fuel/battery supplier, shipyard, engine supplier etc.)

- Has demand for small-scale fishing vessels, fuel, or fishing gear changed recently?
- What possibilities do you see when introducing new technologies to small-scale fisheries?
  - What are the challenges?
- What measures would help to introducing new low-carbon technologies?
  - Which are the most significant barriers?
- How do you see these technologies impacting the business long-term?
- How will aftersales services and repairs be influenced by a technology shift?

Part 4. Seafood industry

- Has the supply of fish from small-scale fisheries changed over time?
- Are there quality differences between fish caught with different fisheries technology, and do they reflect in pricing?
- Is the market willing to pay a premium for fish products with low greenhouse emissions?

Part 5. Fishing port

- How can your local port be key in transitioning to green fuels in small-scale fisheries?
- What kind of business opportunities do you see being a green hub?
- Is there any infrastructure in place to aid sustainability transitions?
  - Providing electricity (quick chargers)
  - Providing different fuels
- What further investments are needed at the port, and how can this be financed?

Part 6. Policy Framework

- What are the most significant regulatory challenges for small-scale fishermen adapting new technologies?
- How do you see the role of government incentives or subsidies in promoting sustainable fishing?
- What barriers exist in enforcing fuel consumption, emissions, or sustainability regulations?
- How do you balance economic viability with environmental sustainability in fisheries policy?

7. Follow-up questions

- Do you have any additional questions or comments about the topic we have not considered so far?
- Are there any other experts you recommend I talk to?

THANK YOU!

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