European Commission

POSSIBILITIES AND EXAMPLES FOR

# ENERGY TRANSITION OF FISHING AND AQUACULTURE SECTORS

EUROPEAN COMMISSION
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# POSSIBILITIES AND EXAMPLES FOR ENERGY TRANSITION OF FISHING AND AQUACULTURE SECTORS

*This document presents an overview of known initiatives for the energy transition of fishing and aquaculture vessels, up to January 2023. As a living document, it will be regularly updated. It begins with an introductory overview of wider developments in the maritime sector to "decarbonise" through the eventual use of alternative fuels and power sources. Examples are then given specific to fishing and aquaculture, along with other innovations, e.g. to fishing practices and gear, to reduce energy consumption and thereby also carbon emissions.*

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# 0. CONTEXT

As with other economic activities in the EU, there is **a growing need for fishing and aquaculture to transition and move away as soon as possible from fossil fuels**. This is not only as a contribution to the objectives of the European Green Deal,[1] including reducing GHG emissions[2], but also for the sector's profitability, sustainability and resilience. This need is further exacerbated by the Russian military aggression against Ukraine, notably because, for example, the resultant increase in diesel fuel prices has impacted severely the socio-economic performance of the EU's fishing fleet.[3]

The **challenges facing the fishing and aquaculture sectors** to undertake an energy transition, range from regulatory to technological. An **analysis for the Spanish fishing sector**,[4] for example, identified issues such as the obligation to comply with regulations and measures of restriction of fishing effort, as well as the current lack of viable engine and propulsion alternatives. It also stated that diesel is more efficient if other factors are considered and not only emissions. Other concerns are limited space available onboard a vessel; the lack of suitable port infrastructure; and the need for training.

**In France, a discussion amongst its fishing sector**[5] recognised that the high price of diesel jeopardizes the economy of French fishing, but that there is currently no significant practical solution to reduce the carbon footprint of the sector. In any case, it is in fishers' interest to reduce their consumption, since fuel typically represented 20% to 25% of a vessel's turnover. Now it is more like 40%-50%. The sector had already made efforts to reduce consumption via, for example, the Amarrée programme,[6] with savings between 5%-15%. For a significant energy transition, the fishing sector considered it necessary to exceed or change certain regulatory criteria. For example, because a hydrogen-powered engine would require up to 5x more space than a current diesel one, and with no other modifications permitted, there would be a need for a consequent reduction in the volume available to store fish. In turn, and for some vessels, this may then necessitate more voyages to catch the same volume of fish. Another issue identified is the lack of scale, e.g. transferring prototypes to more widespread, sea-proven use.

**What follows is an outline of developments and practical examples** currently existing, both in the wider shipping sector with then the potential for technology transfer, and specific to fishing and aquaculture. It **complements previous analysis**[7] which looked at the various technical means to reduce fuel consumption and summarised the different approaches and the reported gains in fuel saving. The **summary table** from this analysis is duplicated in Annex.

Clearly **not all options can apply to all vessels and practices**, instead the **examples given should be seen as outlining some current best available techniques**[8] **or**

1 COM/2021/240 final

2 Whilst it is estimated that CO2 emissions from international shipping amount to around 800 million tonnes of CO2 per year, representing approximately 2-3% of total global CO2 emissions *(Source: European Commission, SWD(2020) 82 final)*, that from fishing vessels (including inland vessels) is estimated to be about 172 million tonnes or 0.5% *(Source: FAO Fisheries and Aquaculture Technical Paper No. 627)*. The annual fuel consumption of the EU's fishing fleet leads to the emission of roughly 5.2 million tonnes of CO2 *(Source: European Commission, EU Blue Economy Report 2022)*.

3 https://oceans-and-fisheries.ec.europa.eu/news/2022-annual-economic-report-eu-fishing-fleet-sector-affected-high-fuel-prices-wake-war-ukraine-2022-10-11_en

4 https://industriaspesqueras.com/noticia.php?id=72020&s=03

5 https://lemarin.ouest-france.fr/secteurs-activites/peche/comment-decarburer-la-flotte-de-peche-44755?vid=2417714

6 Accompagnement des MARins pêcheurs pour la Réalisation d'Économies d'Énergie (Amarrée), https://amarree.fr/en/. See Section 3.1 for more details

7 See *Climate change and the Common Fisheries Policy: adaptation and building resilience to the effects of climate change on fisheries and reducing emissions of greenhouse gases from fishing*, including its *Annex 26*, July 2022, https://op.europa.eu/s/xiyD

8 Best Available Techniques (BAT) are an established approach used, in an EU context, to identify the available techniques which are the best for preventing or minimising emissions and impacts on the environment, see https://joint-research-centre.ec.europa.eu/scientific-activities-z/sustainable-production-best-available-techniques_en.

**approaches**.[9] In turn, they can serve to provide inspiration for developing tailor-made solutions to a specific vessel or fleet or application. Performing an energy audit[10] on a vessel, for example, would identify which techniques/modifications/change of practices/etc. may be best suited, when done in combination with a cost-benefit analysis.[11]

As a complementary measure, there is a **need for provision of training** on energy transition. For aquaculture at least, the **project EWEAS**, co-funded by the EU's Erasmus+ programme, developed an e-learning training program for aquaculture specialists based on a guidebook they developed.[12]

9 Complementary advice is also available from, for example, the North Sea Advisory Council, see https://www.nsrac.org/wp-content/uploads/2022/10/17-2122-NSAC-Advice-on-de-carbonisation-of-fishing-fleet.pdf, as well as the submissions to the Call for Evidence for the Energy Transition of Fisheries and Aquaculture Action Plan, see https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13619-EU-fisheries-and-aquaculture-energy-transition_en.

10 See, for example, Basurko et al., *Energy performance of fishing vessels and potential savings*, Journal of Cleaner Production, Volume 54, 2013, https://doi.org/10.1016/j.jclepro.2013.05.024.

11 In 2023, DG MARE will commission a study to analyse the economic and environmental costs and benefits of clean energy technologies and strategies that can be used for the Energy Transition of fisheries and aquaculture.

12 *Evaluation and Improvement of the Energy Efficiency of Installations in the European Aquaculture Sector*. Course material and guidebook available from https://eweasproject.eu/.

# 1. NEW MARITIME FUELS

There are many ongoing initiatives to develop **non-diesel fuels for maritime use in global shipping**, although the focus seems to be more for larger, ocean-going vessels and less for fishing or aquaculture vessels. Nevertheless, technologies and advances made for the wider maritime sector could be transferable to fishing and aquaculture.

Types of alternative fuels include (e- and blue-) ammonia, (e- and bio-) methanol, (e- and bio-) methane and bio-oils. In addition, there is also much work ongoing on developing hydrogen, wind, solar, plus batteries[13] as energy sources for ships.[14] Whilst not yet commercially available on a large-scale, one could anticipate that these alternative fuels and power sources would become more-and-more common in the near- to medium-future. As presented later, there are already some examples of fishing and aquaculture vessels using one or more of these sources.

Whilst not addressing fishing or aquaculture vessels directly, a useful analysis exists of **trends and policies promoting alternative fuel vessels and their refuelling infrastructure** in Europe.[15] A **detailed overview of alternative fuels** being considered and the associated challenges, primarily for other types of ships, is given in the European Maritime Safety Report (EMSAFE) 2022.[16, 17] Similarly, the Maritime Technologies Forum[18] and Lloyds Register[19] each produced a **comprehensive assessment to compare the feasibility and readiness** of alternative marine fuels, the former highlighting also the (increasing) **need for proper training** to accelerate safe maritime decarbonisation. An **earlier exploratory study[20]** gives an overview of the marine sector, including market share, emission related issues, fuel standards and legislation.

**Specific to fishing vessels**, the UK's National Federation of Fishermen's Organisations (NFFO) commissioned a **report *('Electrifying the Fleet')*[21]** looking into alternative ways of powering fishing boats. The report concluded that, while no off-the-shelf solutions are currently available, existing technologies could be used to build hybrid diesel-electric systems that would achieve significant energy and emissions savings for static gear fishing boats. An earlier **report on alternative fuels and propulsion systems for fishing vessels**,[22] which focussed more on the utility systems (cooling, freezing and heating) onboard fishing vessels, gives an overview of current (primarily Norwegian) propulsion systems and fuels, along with future scenarios for uptake of alternative fuels in the shipping sector. **Another report looked at the opportunities for generating various forms of energy on board**,[23] identifying a number of promising options (wind, solar, tides and waves, gravity, water discharges) that could be developed further. Another analysis[24] considered the **applicability to fishing vessels of different fuel types** currently used by other types of ships.

There are a number of useful **portals providing latest information and developments**

13 See, for example, Maritime Battery Forum, https://www.maritimebatteryforum.com/

14 For a reportage on some developments in Europe to use wind and electricity in the shipping sector to reduce emissions, see https://www.euronews.com/green/2022/12/20/full-green-ahead-sea-transport-is-ditching-diesel-engines-for-electric

15 Gomez Vilchez, J., Julea, A.M., Lodi, C. and Marotta, A., *An analysis of trends and policies promoting alternative fuel vessels and their refuelling infrastructure in Europe*, FRONTIERS IN ENERGY RESEARCH, ISSN 2296-598X, 10, 2022, p. 904500, https://publications.jrc.ec.europa.eu/repository/handle/JRC128898.

16 See Section 5.2 of report available at https://emsa.europa.eu/emsafe.

17 The European Maritime Safety Agency (EMSA) also produced (in October 2022), an *Update on Potential of Biofuels for Shipping*, https://emsa.europa.eu/newsroom/latest-news/item/4834-update-on-potential-of-biofuels-for-shipping.html, and on the *Potential of Ammonia as Fuel in Shipping*, https://emsa.europa.eu/newsroom/latest-news/item/4833-potential-of-ammonia-as-fuel-in-shipping.html.

18 https://safety4sea.com/wp-content/uploads/2022/11/MTF-Fuels-evaluation-2022_11.pdf.

19 https://maritime.lr.org/webmail/941163/648050943/b8b044ddb1008cf1288d515f1c2e791329fce067000edfbe90d283567530f8dc

20 European Commission, Joint Research Centre, Moirangthem, K., *Alternative fuels for marine and inland waterways*, Baxter, D.(editor), Publications Office, 2017, https://data.europa.eu/doi/10.2790/227559

21 https://www.nffo.org.uk/electrifying-the-fleet/

22 https://www.sintef.no/contentassets/f18e738f011347999884e200f817b956/coolfish-report-propulsion_and_fuels-signed.pdf

23 *New energy for the fishing industry – An exploration of alternative energy sources*, F.P.E. (Femke) Brouwer and B.E. (Bettina) Kampman (CE Delft), Innovation Netwerk report no 09.2.209, Utrecht, The Netherlands, June 2009, https://cedelft.eu/wp-content/uploads/sites/2/2021/04/4838_defrapportBKa_1247472729.pdf

24 *Decarbonising the EU Fishing Fleet: Lessons from today's Shipping Industry*, July 2022, https://stopfossilfuelsubsidies.eu/2022/07/11/decarbonising-the-eu-fishing-fleet-lessons-from-todays-shipping-industry/

**for the global shipping industry**. For example, the **Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping**,[25] which (in December 2022) published its *Maritime Decarbonization Strategy 2022*.[26] Others include the marine insurer North's **Decarbonisation in Shipping[27]** and the **Lloyd's Register Maritime Decarbonisation Hub's Zero-Carbon Fuel Monitor**,[28] which indicated (in July 2022) that zero-carbon fuel readiness is on the rise, but challenges remain and with methanol making headway.

A **Practical Guide to the Selection of Energy Efficiency Technologies for Ships[29]** was published by the Global Industry Alliance to Support Low Carbon Shipping. The Guide aims to support shipowners looking into retrofits, with helpful guidance on considerations and operational practices that should be taken into account when selecting relevant technologies.

## 1.1 Challenges of alternative fuels

Shipping is considered as one of those **"hard to abate" sectors**, where achieving net-zero emissions by mid-century is expected to be very difficult.[30] Amongst the major barriers to rapid change are the lack of commercially available mitigation technologies, plus large upfront costs combined with slow capital turnover rates and market competitiveness. **Other analysis[31]** argued that the perfect "zero emission" fuel does not yet exist, as the alternatives to fossil fuels come with **trade-offs** between technological innovation, operational measures and rethinking supply chains.

Another facet was highlighted in a study[32] (from May 2022) stating that the **world's renewable energy generation would need to increase up to 100%** just to supply enough (net) zero carbon fuel to power the shipping industry.

The **need for other actors to also play their part** in decarbonising the shipping sector is also identified. In particular calling on the technical readiness of the shipping industry to now be matched by fuel supply, regulatory clarity and the thorny issue of who pays for the cost differential in the zero-carbon energy transition.[33]

The **maritime sector**, as a whole, has come together to determine **how to address the challenges for achieving zero- or low-carbon fuels**. For example, the **Getting to Zero Coalition**,[34] is an alliance of more than 200 organisations (including 160 companies) within the maritime, energy, infrastructure and finance sectors, supported by key governments and Intergovernmental organisations. It was setup as a partnership between the Global Maritime Forum and the World Economic Forum. The coalition is committed to getting commercially viable deep sea zero emission vessels powered by zero emission fuels into operation by 2030 towards full decarbonisation by 2050.

The "Together in Safety" group produced a **risk assessment of the main alternative fuels** being considered, specifically liquified natural gas (LNG), Methanol, Ammonia and Hydrogen.[35] It is widely acknowledged that such fuels of the future will bring additional risks to seafarers. Within the constraints of the report's scope, they concluded that Methanol would require the least effort with regards to additional safety measures, followed by LNG, Hydrogen and Ammonia being the most

25 https://www.zerocarbonshipping.com/

26 https://www.zerocarbonshipping.com/publications/maritime-decarbonization-strategy/. Amongst its findings, it states that to replace 1 ExaJoule of fossil fuel, the number of vessels sailing on alternative fuels must increase from around 700 today to approximately 3 000 by 2030, including over 300 bulk carriers, around 1 300 container vessels, and nearly 200 tankers.

27 https://www.nepia.com/topics/navigating-decarbonisation/

28 https://www.lr.org/en/latest-news/zero-carbon-fuel-readiness-on-the-rise-but-challenges-remain/

29 Available from https://safety4sea.com/wp-content/uploads/2022/10/IMO-Energy-efficiency-tech-for-ships-online-2022_10.pdf. Produced as part of the IMO Norway GreenVoyage2050 Project.

30 *Mitigating Greenhouse Gas Emissions in Hard-To-Abate Sectors*, U. Utrecht, NL, July 2022, https://www.pbl.nl/sites/default/files/downloads/pbl-2022-mitigating-greenhouse-gas-emissions-in-hard-to-abate-sectors-4901.pdf

31 https://splash247.com/how-to-balance-trade-offs-when-decarbonising-the-shipping-industry/

32 International Chamber of Shipping, *Fuelling the Fourth Propulsion Revolution: An Opportunity for All*, https://www.ics-shipping.org/wp-content/uploads/2022/05/Fuelling-the-Fourth-Propulsion-Revolution_Full-Report.pdf

33 https://lloydslist.maritimeintelligence.informa.com/LL1142328/Why-its-time-to-stop-talking-about-shipping-decarbonisation

34 https://www.globalmaritimeforum.org/getting-to-zero-coalition

35 https://safety4sea.com/wp-content/uploads/2022/06/Together-in-Safety-Future-Fuels-Report-2022_06.pdf

demanding, but with all requiring inherently safer designs for implementation. Indeed for Ammonia, there is a concern over its potential (negative) impact on the marine environment in case of spills, [36] as well as on the global Nitrogen cycle.[37] There are now also **guidelines** for ships using alternative fuels.[38]

The **Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping**[39] has looked into specific emissions that need to be addressed **to increase alternative fuel pathway maturity**. They looked at current or potential emission levels, set reduction targets, and identified and mapped applicable technologies and solutions. From this, emission reduction potential is then determined and recommendations given to develop further the selected fuel pathways, including areas or concepts for further research and development.

To ensure global coverage, the **Global Centre for Maritime Decarbonisation (GCMD)**[40] is leading a consortium of 18 industry partners to launch a drop-in biofuels pilot project with a combined contribution of US $18 million to establish a framework for ensuring the **supply chain integrity of current and future green marine fuels**.

Looking to the future, the company DNV produced its **Energy Transition Outlook 2022**,[41] providing a detailed forecast of the demand and supply of energy towards 2050, as well as a pathway to reach net zero emissions. The report provides outlooks on drivers and regulations for decarbonisation; on ship technologies and fuels; on the readiness of onboard fuel technologies; on alternative fuel production and infrastructure; and on pathways for decarbonisation.

## 1.2 Examples of alternative fuel use and development

### *1.2.1 Biofuels*

There are a number of studies which have indicated that **biodiesel fuel** is suitable for use as an alternative fuel for marine engine applications.[42] Many reports have revealed that alternative fuels derived from vegetable oil and animal fats were found to be environmentally friendly, renewable, non-toxic, biodegradable, sulphur free and aromatic. The European Maritime Safety Agency (EMSA) also produced (in October 2022), an update on the potential of biofuels for shipping.[43] A biofuel from kelp harvesting and fish processing waste has also been developed.[44]

Commercially, the **Finnish oil refiner, Neste, has developed a biofuel**[45] that is said to cut greenhouse gas (GHG) emissions by up to 80%, without compromising product quality and performance.

The company *SeaH4*[46] has developed **biofuels generated from farmed algae** which is indigenous to the region it is farmed from, thereby avoiding as well any introduction of invasive species. This is presented as a carbon neutral alternative to fossil fuels enabling full and continued use of the existing fossil fuel infrastructure, whilst being protected from GHG emissions levies, taxes and penalties. They state that their fuels require no changes to engines nor the existing distribution network. Using well-established technologies, they produce some 15 000 t of bioLNG per year and their analysis gives a saving 2.8 t CO2-equivalent per ton of fuel consumed. There is a potential also to produce Compressed Natural Gas (CNG) or biodiesel, specifically for fishing vessels.

36 https://safety4sea.com/report-aquatic-environments-particularly-sensitive-to-ammonia-fuel-spills/
37 https://www.nature.com/articles/s41560-022-01124-4
38 https://www.classnk.com/hp/en/hp_news.aspx?id=6603&type=press_release&layout=1
39 https://cms.zerocarbonshipping.com/media/uploads/documents/MMMC_ERA.Intro.Paper_FINAL.pdf-1.pdf plus *Fuel Pathways | Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping*. https://www.zerocarbonshipping.com/fuel-pathways/
40 https://www.gcformd.org/press-release-dropin-biofuel
41 Available via https://download.dnv.com/eto-2021-download?&_ga=2.182377954.495836112.1662642925-790756920.1662476683.
42 For a review, see *Biodiesel as alternative fuel for marine diesel engine applications: A review*, C.W. Mohd Noor, M.M. Noor, R. Mamat, Renewable and Sustainable Energy Reviews, 2018, https://doi.org/10.1016/j.rser.2018.05.031.
43 https://emsa.europa.eu/newsroom/latest-news/item/4834-update-on-potential-of-biofuels-for-shipping.html
44 See https://www.pnnl.gov/news-media/waste-energy-biofuel-kelp-harvesting-and-fish
45 https://splash247.com/neste-claims-up-to-80-ghg-emission-reduction-with-biofuel-blend/
46 https://www.seah4.co.za/. They presented this work at the BlueInvest Africa event in September 2022, https://blueinvest-africa-2022.b2match.io/

The use of **marine fuels blended with these biodiesels can be considered as the proper way to reduce air pollution at sea** and simultaneously meet IMO regulations. However, there are some obstacles that arise, such as fuel stability, higher production and feedstock costs, material compatibility, cold flow properties and lack of marine-grade standards. A study[47] (from Nov. 2021) also highlighted that there is no clear green alternative fuel to fossil marine fuels at this stage. The technological readiness of fuel technologies was assessed as moderate to high, while the commercial readiness was in general low. Innovation, together with other market supporting measures, was needed to accelerate the readiness of technologies and support the commercialization of these technologies.

A **fishing vessel in New Zealand**, *Endeavour*, was constructed to run on biofuel, supplied wharf-side.[48] The trawler, 17.2 m long with a 6m beam and a displacement of 125 tonnes, has the capacity to carry up to 8 520 litres of fuel. It is claimed that, for every tonne of used cooking oil used to produce the biofuel, there is a corresponding two tonne reduction in $CO_2$ emissions. The biofuel is also able to reduce particulate emissions by up to 50% compared to conventional diesels.

### *1.2.2 Developments by industry (startups, shipbuilders and marine engine producers)*

In Italy, the company *Bi.Nav Consulting* via its **Horus Project** is developing battery-based vessels.[49] The project, supported also by the WWF and the Associazione Mediterranea Acquacoltori, aims to decarbonise aquaculture service vessels, notably for molluscs. Their vessels have a full electric system using batteries which can be charged when in dock, but also on board in case of emergency.

Also in Italy, the start-up company *Sea Opportunities* via its **ETICA IP** platform,[50] which is an Integrative Platform for Remotely Operated Vessels (ROV) and Unmanned Service Vehicles (USV), is completely powered by renewable energy with zero emissions. Its propulsion and power supply system is 100% electric, rechargeable directly from photovoltaic panels. They provide a large range of surface and subsea services for the Blue Economy industry, including aquaculture.

The Norwegian company, *ZeroKyst*,[51] aims to set into motion a **rapid technology shift for all vessel types** in the fisheries and aquaculture industry. They plan to develop and demonstrate a new zero-emission powertrain (Siemens Blue Drive and HybridZ), a new zero-emission vessel, 10 retrofitted vessels, services for retrofitting and maintaining zero-emission vessels, and a complete solution for a flexible supply of electricity and green hydrogen as maritime fuel.

Another Norwegian company, *Corvus Energy*,[52] is also active for the fishing and aquaculture sectors, specifically in developing **energy storage systems (ESS) that reduces fuel consumption, costs and emissions**, whilst enabling silent operations and contributing to increased safety. With such a system, a vessel may run only on battery-power during fishing and other similar low power operations. For higher power operations, the vessel gets the option to run diesel-electrical, thereby charging the ESS utilising generators and making it ready for all-electric usage later. The savings on fuel due to energy optimisation by an ESS on a fishing vessel is said to be typically 25%, whilst simultaneously reducing emissions by 25-40%.

Elsewhere, **hybrid diesel-hydrogen engines** are now commercially available,[53] including for the shipping sector,[54] and it is possible also to retrofit

47 *Innovation needs for decarbonization of shipping*, Technical annex report by Oxford Research, November 2021, http://mission-innovation.net/wp-content/uploads/2021/11/TECHNICAL-REPORT_Innovation-needs-for-decarbonization-of-shipping.pdf.
48 https://www.rina.org.uk/biofuel.html
49 http://www.binav.it/progetto_horus_category.php
50 https://www.youtube.com/watch?v=vcADeo9NgfI
51 https://zerokyst.no/en/
52 https://corvusenergy.com/segments/fishing-and-aquaculture/. Examples of vessels they have developed are given later in this document.
53 See, for example, BeHydro, https://www.abc-engines.com/en/news/behydro-hydrogen-dual-fual-engine-launched-in-ghent. Their analysis states that a 1 MW BeHydro hydrogen-powered engine reduces CO2 emissions by 3 500 tons per year.
54 See, for example, https://cmb.tech/divisions/marine and https://splash247.com/cmb-and-volvo-team-up-on-dual-fuel-hydrogen-engines/

an existing diesel engine,[55] although seemingly not yet for those on fishing vessels.

**Other major ship engine companies**, like *MAN* and *Wärtsilä*[56] are also **developing propulsion systems** that can run on alternative fuels or be adapted to run on alternative fuels. For example, MAN offers to retrofit new engines in preparation for future, climate-neutral operation and dual-fuel operation.[57]

### *1.2.3 New developments*

**Fuel Oil Emulsion (FOE) technology**[58] by the company *Blended Fuel Solutions* burns more completely than unmodified fuel and so uses less fuel, emissions are lower, and the engines run cooler and so should require less maintenance. This would reduce the use of fuel and the level of emissions as well as give a significant financial saving.

The company *Expleo* has developed a **closed-loop fuel solution** for shipping which they claim delivers a 92% reduction in greenhouse gas emissions and Operating Expenses savings of £1.4 million (approx. €1.6 m) a year, per vessel.[59] The solution uses **Solid Oxide Fuel Cell (SOFC) technology** partnered with a novel carbon capture and storage system, enabling a vessel to use its captured CO2 and green hydrogen to synthesise e-methanol. The green hydrogen in the solution could be produced at offshore wind farms, from surplus electrical energy or supplied in-port – ensuring the closed-loop remains as sustainable as possible.

Another example concerns using a **solid form of hydrogen** released from a salt called sodium borohydride (NaBH4), which is said to be far safer and easier to store than compressed or liquid hydrogen. A prototype vessel, *Neo Orbis*, is under construction in the Netherlands to test this approach.[60]

Also under serious consideration across the world is the development of **nuclear-powered vessels**, specifically using Small Modular Nuclear Reactors.[61] In Norway, as part of their *Research Council's Maritime 21 strategy*,[62] a project to design small modular nuclear reactors for the propulsion of large vessels was selected, with NOK 10 million of funding.[63] In a complementary manner, floating nuclear power plants are also under consideration. For example, the vessel *Ulstein Thor*, using a Thorium Molten Salt Reactor, operates as a mobile power/charging station for battery-driven cruise ships.[64] Samsung Heavy Industries has developed a conceptual design for a floating nuclear power plant barge, based on compact molten salt reactor (CMSR) technology.[65]

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55 See, for example, https://arstechnica.com/science/2022/12/mixing-diesel-and-hydrogen-provides-big-cuts-in-emissions/

56 https://www.wartsila.com/marine/products/engines-and-generating-sets

57 https://www.electrichybridmarinetechnology.com/news/power-and-propulsion/man-primeserv-conducts-lifecycle-upgrade-to-prepare-engines-for-climate-neutral-and-dual-fuel-operation.html and https://splash247.com/man-engines-can-now-be-retrofitted-to-become-climate-neutral/

58 See https://www.marineinsight.com/shipping-news/fuel-oil-emulsion-foe-technology-to-be-tested-in-ships-auxiliary-engines/

59 *Clean, green marine: a breakthrough solution for global shipping*, https://expleo.com/global/en/wp-content/uploads/2022/07/whitepaper_cmdc-final.pdf

60 https://www.rechargenews.com/energy-transition/solid-hydrogen-worlds-first-vessel-powered-by-an-h2-storing-salt-gets-construction-green-light/2-1-1269510

61 Small modular reactors (SMRs) are advanced nuclear reactors that have a power capacity of up to 300 MW(e) per unit, which is about one-third of the generating capacity of traditional nuclear power reactors. See https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs.

62 https://www.forskningsradet.no/siteassets/publikasjoner/2022/maritim21-strategy--executive-summary3.pdf

63 https://www.kystens.no/energi/vard-engasjerer-seg-i-prosjekt-for-a-utrede-kjernekraft-som-energibarer-for-fremtidens-skip/2-1-1362847

64 https://ulstein.com/news/ulstein-thor-zero-emission-concept

65 https://splash247.com/samsung-heavy-presses-ahead-with-floating-nuclear-power-plants/

## 2. EU-FUNDED INITIATIVES FOR ENERGY TRANSITION

The EU programmes given below support projects more directly relevant for fishing and aquaculture. Other opportunities, like via the Recovery and Resilience Fund[66] and via State Aid,[67] also exist, though mainly for other types of shipping.

### 2.1 Horizon 2020 / Horizon Europe projects for alternative fuels

There are a number of **Horizon 2020, and to come Horizon Europe, projects** of relevance. Whilst not specific to fishing or aquaculture, there is an overview of **Waterborne Transport Projects[68]** under Horizon 2020, the results from which might be transferable. Another overview looked at projects developing the use of renewables to power the clean future of inland shipping.[69]

The Horizon 2020 supported **European Research and Innovation Platform for Waterborne Industries (WATERBORNE)[70]** was set up as an industry-oriented Technology Platform to establish a continuous dialogue between all waterborne stakeholders, including with EU Institutions and Member States. It acts as a hub for all EU-funded research projects that contribute to achieving WATERBORNE's goals, including on Energy Efficiency and Zero Emissions, addressing several different possible fuel types.[71] There are no projects specific to fishing or aquaculture, but again the knowledge and innovations arising from the many projects may be transferable.

The **Clean Hydrogen Partnership[72]** is another initiative whose main objective is to contribute to the EU Green Deal and Hydrogen Strategy through optimised funding of R&I activities. Some of their projects are concerned with shipping, including developing an open standard for heavy-duty fuel-cell modules; development and validation of a 2 MW fuel cell liquid hydrogen ship; and defining a pre-standardization plan for hydrogen-based fuels passenger ships.[73] For example, the **project HyShip[74]** aims to design and construct a new ro-ro demonstration vessel running on liquid green hydrogen, as well as the establishment of a viable supply chain and bunkering platform.

The **Laurelin project[75]** aims to obtain **methanol as a renewable fuel** via advanced synthesis technologies, as well as to foster breakthrough innovation in advanced biofuels and alternative renewable fuels. Likewise, the **project HyMethShip** (Hydrogen-Methanol Ship Propulsion System Using On-board Pre-combustion Carbon Capture)[76] developed an approach to ship propulsion that could be based entirely on renewable energy with a solution to the challenges of on-board hydrogen storage. It aimed to innovatively combine methanol steam reforming and hydrogen separation in a membrane reactor with a CO2 capture system and a hydrogen-fuelled combustion engine in one integrated system.

**Other, complementary projects** include **CLean INland Shipping (CLINSH)**,[77] which aimed at retrofitting inland waters vessels, identifying potential financial mechanisms and technological solutions, plus putting into place a system to

66 For example, under Portugal's Recovery and Resilience Fund programme, and as part of their "Azores Sea Cluster," a new modern research vessel with high technological standards in terms of capabilities and equipment and with high energy performance, will be built. See https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/portugals-recovery-and-resilience-plan_en#portugals-recovery-and-resilience-plan

67 See, for example, Commission approves €500 million Italian scheme to improve environmental performance of vessels, https://ec.europa.eu/commission/presscorner/detail/en/ip_22_6487

68 https://cinea.ec.europa.eu/publications/h2020-waterborne-transport-projects_en

69 https://ec.europa.eu/research-and-innovation/en/horizon-magazine/ramping-renewables-power-clean-future-inland-shipping

70 https://www.waterborne.eu/

71 See projects listed at https://www.waterborne.eu/projects/energy-efficiency-and-zero-emissions.

72 https://www.clean-hydrogen.europa.eu/index_en

73 https://www.clean-hydrogen.europa.eu/projects-repository_en?f%5B0%5D=oe_project_title%3Aship

74 https://hyship.eu/

75 See https://cordis.europa.eu/project/id/101022507. The University of Tokyo is also a partner.

76 https://cordis.europa.eu/project/id/768945/reporting

77 Final layperson's report with main results and recommendations posted at https://www.linkedin.com/posts/ingrid-klinge-83022913_clinsh-laymans-report-activity-6874699054048129024-STjB/?trk=posts_directory.

stimulate vessels owners to participate. Again, lessons learned from this project could be transferable to fishing and aquaculture.

**An upcoming call for proposals** under Horizon Europe will address fishing vessels. Specifically, in the **Mission Ocean and Waters Work Programme 2023**,[78] it is planned to support research that will identify a set of suitable innovative and sustainable solutions, technologies, practices and processes to be tested, validated and demonstrated in real conditions to reduce emissions and fuel consumption of small-scale fishing vessels (less than 12 m in length).

## 2.2 European Maritime Fisheries (and Aquaculture) Fund (EMFF / EMFAF)

There are a number of projects for energy transition supported by the predecessor EMFF and now EMFAF programmes.

One activity within the **WestMed Initiative**, involving five EU countries and five African Neighbouring countries in the Western Mediterranean, is for green shipping.[79] Via a technical group, it implements innovative projects to support a greener and fully sustainable maritime transport in the Mediterranean. One of its pilot actions is for the adaptation of commercial vessels, which could be expanded to the fishing fleet.

The **fishing community of El Palmar in the Albufera lagoon**[80] in Valencia, Spain, worried about the environmental state of their fishing areas, wanted to investigate the possibility of moving from diesel engines to engines running on electricity. This would reduce not only direct pollution from fuel leaks, but also carbon dioxide emissions and noise levels around the lagoon. Analysis predicted that if the prototype vessel was replicated for all 1 000 boats in the lagoon, which operate on average 300 days per year with up to four trips per day, then there would be a yearly reduction of some 1 074 tons of CO2 emissions. The overall noise pollution would also be considerably reduced.

Another example involves support and coaching, provided via the **BlueInvest programme**,[81] to the **h2boat start-up company**[82] for the development of hydrogen technology that can be installed on smaller vessels, sailing or motorboats. Whilst their current focus is on yachts, they are planning to do a review, with the University of Genova, to assess the number, power, use profile etc. of the EU's fishing fleet to evaluate the possibility of introducing the technology in this sector.

[78] Call HORIZON-MISS-2023-OCEAN-01-05: *Lighthouse in the Baltic and the North Sea basins - Lighthouse in the Baltic and the North Sea basins - Green and energy-efficient small-scale fishing fleets.* See https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/horizon-europe-work-programmes_en#view-available-work-programmes

[79] https://westmed-initiative.ec.europa.eu/green-shipping/

[80] https://oceans-and-fisheries.ec.europa.eu/news/green-sailing-christmas-2022-12-21_en

[81] https://webgate.ec.europa.eu/maritimeforum/en/frontpage/1451

[82] https://oceans-and-fisheries.ec.europa.eu/news/h2boat-reaching-new-markets-thanks-blueinvest-2022-11-30_en

## 3. FISHING AND AQUACULTURE VESSELS WITH ALTERNATIVE POWER SOURCES

### 3.1 Fish Farming and Aquaculture vessel I: François Cadoret[83]

The first French oyster barge with electric propulsion, *François Cadoret*, was inaugurated in July 2022 for Breton oyster farmers.

The barge, 11.90 m long and 3.70 m wide, is powered by two 70 kW electric motors and has two 40 kWh batteries charged via solar panels and two small wind turbines. Construction cost €250 000. Later, it will be able to receive a hydrogen kit.

### 3.2 Fish Farming and Aquaculture vessel II: Astrid Helene[84]

This was one of the world's first (entered into service in 2017) fully-electric workboats with no engine noise, no diesel fumes and zero emissions. This is advantageous for aquaculture as the vessel avoids any environmentally hazardous emissions and has low noise.

It is 13.9 m long and 7.6 m wide with a battery power of 340 kWh. Estimated annual savings are 80% on maintenance costs, with 33 700 litres of diesel/year saved and with 90 tons CO2 emission reduction.

### 3.3 Fish Farming and Aquaculture vessel III: Hilde S[85]

The Norwegian aquaculture company, *Norcod*,[86] undertook a major project to implement electricity as an energy source for its Frosvika production plant. The company aims to advance sustainable cod farming by ditching fossil fuels as part of its ongoing electrification program.

The electrically powered service vessel, *Hilde S*, in use since April 2022, will enable savings of around 160 000 litres of diesel per year, which translates into a reduction of 420 tonnes in CO2 emissions related to the feed barge and the equipment supplying energy. In addition, the energy that powers *Norcod*'s feed barge has a guaranteed origin of clean hydroelectric power. The disconnection from diesel generators has also benefited fish welfare by reducing environmental noise.

83 https://lemarin.ouest-france.fr/secteurs-activites/peche/44219-mise-leau-dune-barge-electrique-pour-les-ostreiculteurs-bretons
84 https://corvusenergy.com/projects/astrid-helene/
85 http://www.ipacuicultura.com/noticias/ultima_hora/82235/norcod_avanza_hacia_la_electrificacion_de_sus_plantas_de_produccion_de_bacalao_en_noruega.html
86 https://norcod.com/

### 3.4 Fish Farming and Aquaculture vessel IV: Ronja Star[87]

The 87 m *Ronja Star* is the largest well boat fish farming vessel in Scottish aquaculture. The hybrid vessel is fitted with diesel electric propulsion[88] and a battery hybrid solution which reduces fuel consumption and emissions, all while generating less noise.

Other innovations include state-of-the-art life support systems, which includes high-capacity oxygen production, a carbon dioxide removal system, and a water-cooling system to ensure the fish are kept in optimal condition during treatment. In addition, it has an automatic cleaning system, alongside sensors and cameras to monitor fish and water quality.

Figure 1: Hybrid aquaculture vessel, Ronja Star (Source: FishFocus)

In addition, a number of other innovations in the ship design and build were done, namely on the hull shape, fishing techniques and handling, materials used and other onboard energy-saving measures. For example, the uninterrupted, automated fish processing and cooling ensures that this process goes faster and the fish stay fresh longer. A sister ship *MDV 2 'Metanoia'* was also constructed, entering into service in 2020.

### 3.5 Hybrid fishing vessel I: MDV-1 Immanuel[89]

This hybrid electric-diesel fishing vessel was specifically designed to be an innovative fishing vessel to test ground-breaking innovations in practice. The special shape of the ship and the diesel electric propulsion provide 60% fuel and CO2 savings compared to similar-sized fishing vessels.

### 3.6 Hybrid fishing vessel II: Karoline[90]

The 11-metre fishing boat *"Karoline"* was developed by *Selfa Arctic AS* (Norway) and Siemens for Norwegian fishing company Øra AS in 2015. The vessel has a large 195 kWh lithium battery pack and 50 kW diesel generator. It is designed to operate solely on battery power over a 10-hour period, and to charge overnight by plugging into the electrical grid. It will thus burn no fuel in normal operation, but, by having a generator on board, it will not be range-limited by battery capacity when making longer passages. The same designer also developed a successor *"Sundsbøen"*.[91]

### 3.7 Hybrid fishing vessel III: NB65 Hardhaus[92]

This 74.5 m long, 16 m wide purse seiner/trawler is equipped with the most efficient diesel engine (according to the Guinness World Records) supported with 1 017 kWh battery power for both peak

87 https://fishfocus.co.uk/bakkafrost-scotland-takes-delivery-of-the-largest-well-boat-in-the-scottish-aquaculture-industry/
88 In diesel-electric systems, multiple diesel engines, each driving an electric generator, produce the electric power that energizes the electric motors connected to the propellers as well as other electrical loads on the ship. Depending on electrical demand, not all diesel generators have to be operating at all times. See https://professionalmariner.com/diesel-electric-propulsion-pushes-ahead/ also.
89 https://masterplanduurzamevisserij.nl/nl/home
90 See https://www.vesselfinder.com/news/3890-Selfa-Elmax-1099-The-Worlds-First-Electric-Fishing-Vessel, https://corvusenergy.com/projects/karoline-2/ and https://maritimecleantech.no/project/first-electric-fishing-vessel/.
91 See https://www.fiskeribladet.no/nyheter/nye-sundsboen--denne-teknologien-ville-jeg-prove-selv-om-jeg-ikke-sparer-et-ore/2-1-783766.
92 https://www.cemreshipyard.com/en/news/purse-seiner-trawler-nb65-hardhaus-is-delivered-to-her-home-port-norway

and emergency sources of power. Winches are operated by battery power and the vessel can operate on battery in manoeuvring and in harbour to minimise noise and local pollution. The optimized hull shape minimises wave resistance, thereby saving energy. There is also an automatic heat recovery system and the vessel barely needs heating systems onboard.

### 3.8 Hybrid battery fishing vessel IV: Angelsen Senior[93]

According to the shipbuilder, the 21 m long *MS Angelsen Senior* is the world's first fishing vessel of this kind to have a battery hybrid solution. It reduces running hours on the engines by 75% and saves 25% fuel, equivalent to 75 000 litres of diesel and 200 tons of CO2, and more than 50% of the maintenance costs.

Batteries are charged while engines are running and in port. Running on electricity means less noise, less vibration and a safer work environment. The ship is designed to operate on battery power when there is a low power requirement, such as when laying to or hauling, and to switch to diesel-electric mode when shooting the gear or steaming at up to ten knots, which also provides an opportunity to charge the battery packs. There is also a heat recovery system to route excess heat to where it can be best utilised.

### 3.9 Hybrid battery fishing vessel V: Isafold[94]

The 87 m long pelagic trawler/ purse seiner, *Isafold* (DK), was built with diesel-electric propulsion, with both the twin propellers and the winch system based on high-efficiency permanent magnet motors. The combination of five medium-speed generators and a 1 130 kWh battery pack ensures optimal production and use of energy under any scenario, while the twin propellers require minimal energy and provide excellent manoeuvrability, especially for trawling.

### 3.10 Hybrid battery fishing vessel VI: W1100 Hybrid[95]

The company *Seigur Boats* (Norway) has developed a **transfluid hybrid propulsion system** for a fishing vessel expected to enter into service in 2023.

This hybrid system will be used in conjunction with a diesel engine plus 400 Ah battery bank, which can be recharged by the regeneration system of the hybrid system or with the onboard generator. With the special transmission, it is possible to integrate diesel engine power with the hydraulic and electric utilities on board and to cruise at approximately 8 knots in electric mode.


Figure 2: Seigur W1100 Hybrid fishing vessel (Source: Electric and Hybrid)

93 https://corvusenergy.com/projects/angelsen-senior/
94 https://mag.hookandnet.com/2022/11/07/2022-11isafoldb/content.html
95 Electric and Hybrid magazine, October 2022, https://secure.viewer.zmags.com/publication/f51b9039#/f51b9039/1

### 3.11 LNG-fired dual-fuel engine trawler I: Libas[96]

The Norwegian company, *Liegruppen*, is the first fishing company to have a trawler powered by liquefied natural gas (LNG), the *Libas*. The engines will run on both LNG and diesel, resulting in approximately 80% estimated NOX emissions reduction and 24% estimated CO2 emissions reduction.

The biggest challenge in designing the vessel was the space. In order to accommodate the large LNG tank, which had to be additionally insulated, and the associated equipment and still have sufficient space for the fish tanks, the ship had to be constructed larger than usual. It now has a length of 85 meters, which is almost 20 meters longer than its older siblings. In addition, the way a fishing trawler operates places special demands on the engine. The engine of a fish trawler has to be able to adjust well to constantly varying loads. For diesel engines, this is no problem, but it's difficult for a gas engine to cope with load changes.

But reducing a vessel's ecological footprint comes at a price. The LNG-powered trawler cost about 30% more than one with a conventional engine. In addition, there are the costs of training the crew.

### 3.12 LNG-fired dual-fuel engine trawler II: Sunny Lady[97]

The 86.50 m metre *Sunny Lady* is a LNG-powered pelagic vessel with hybrid propulsion provided by a 350 cubic metre LNG tank and a 1 024 kWh battery pack.

The battery arrangement provides for peak saving to optimise the main engine's operation, and also allows for energy regenerated from the winches and other systems to be routed to the battery and made available for use elsewhere.

### 3.13 Hydrogen-powered fishing vessels

Following a call for projects on hydrogen for fishing, the **Brittany (FR) regional authority** selected (in December 2022) two projects, named *Pilothy* (with €87 000 funding) and *Estebam* (with €249 000 funding).[98] They aim to establish, in less than a year, a technical, regulatory and economic roadmap for the integration of hydrogen fuel cells into existing vessels, the former for fishing boats, the latter for some 60 shellfish amphibious barges.

The **project *"Filhypyne"*[99] in France** has developed since 2014 a trawling vessel using hydrogen propulsion. While the project seems to be looking for financial support, it has already agreed a three-stage planning with the research and sectorial partners. The stages of the project are intended to validate the technical, economic, environmental and social performance of the hydrogen-fuel cell technology in actual professional operating conditions. After the installation of the propulsion system in the fishing boat demonstrator and its qualification in harbour and sea trials, the third stage would be coordinated by fishers and consist of a tour of France's ports, to have the demonstrator validated by its future users.

The Norwegian company *Skipsteknisk* designed what may be the **first hydrogen-powered fishing vessel**, the 70m Norwegian longliner, *Loran*.[100] While the vessel still has conventional diesel engines, it also has in addition two 185-kW hydrogen fuel cells and a 2 000-kWh battery bank. It entered into service in December 2022.

The vessel has multiple propulsion options — diesel and electric power to the main propeller, as well as a retractable azimuth propeller in the bow for when they are hauling the longline, and for redundancy, in case something ever happened to the main propeller.

The real challenge with hydrogen is sustainable generation and storage onboard. The hydrogen system is above deck as there are no safety

96 https://www.cemreshipyard.com/en/references/nb0064-libas
97 https://fiskerforum.com/latest-lng-powered-pelagic-catcher-heading-home/
98 https://lemarin.ouest-france.fr/secteurs-activites/peche/hydrogene-dans-la-peche-et-laquaculture-la-bretagne-selectionne-deux-projets-45627
99 Filière hydrogène pour la pêche polyvalente, see https://www.pole-mer-bretagne-atlantique.com/fr/naval-et-nautisme/project/filhypyne
100 See https://www.nationalfisherman.com/boats-gear/-we-are-the-pioneers-building-a-hydrogen-powered-fishing-vessel.

standards yet for putting it below deck. The hydrogen is stored as gas at 5 000 psi in ten 20-foot-long tanks aft of the wheelhouse, with the fuel cells close by.

The Loran project is subsidised by the Norwegian government and other investors. Enova, an agency of the Norwegian Ministry of Climate and the Environment, put over $10 million into the project. The hydrogen auxiliary power is expected to reduce fossil fuel use by 40% and is seen as a step toward a zero emissions future.

Figure 3: Project "Sailfish" wind-assisted fishing vessel (Source: MPENG, Barcelona)

## 3.14 Electricity and Sail in Catalonia

The Catalan maritime sector has two on-going projects to change energy sources depending on the size of fishing vessels.

The project "Sailfish"[101] is developing two prototypes in the framework of the 2030 Maritime Strategy of Catalonia. The vessels concerned by this technology would be between 17 m for purse seiners and 24 m length for trawlers. The sails would secure an alternative energy source for the vessel propulsion.

Another project is looking at the design of a fishing catamaran that would use solar panel for an electricity engine. The selected vessel is of 8 m length from an artisanal fisher collaborating with a research group of the Nautical University of Barcelona.[102] In addition to being silent, the annual reduction in CO2 emission reaches 1 600kg.

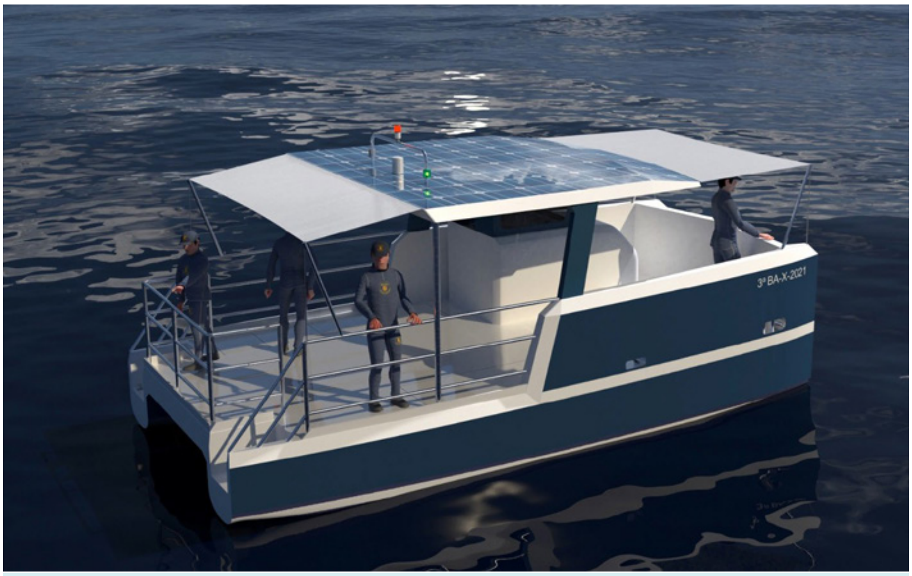

Figure 4: Design for solar-powered fishing catamaran (Source: Empordamar)

[101] https://mpeng.eu/projects/sailfish-2400/

[102] https://empordamar.com/projectes/, see Catamara Electric, https://drive.google.com/file/d/198AMSQyxoMsUD3bpoXvryrf09CjVLhqy/view

### 3.15 Wind-assisted propulsion

Wind energy is seen as one of the most promising sources of alternative energies for sea-going vessels.[103] A variety of methods/technologies have been explored to harness the power of wind energy, although currently mainly for larger ocean-going vessels.[104] These include fixed (or inflatable[105]) sails, Flettner rotors, skysails or kites.[106] Lloyds Register has approved a rotor sail for cargo ships.[107]

Some examples of developments for fishing vessels are outlined below. The *International Windship Association (IWSA)*[108] has done some consideration for fishing vessels and there are activities in Brittany (FR)[109] too.

#### *3.15.1 Fishing vessel, Maartje Theadora*[110]

With funding provided also by the earlier European Maritime and Fisheries Fund, a 160 $m^2$ SkySails[111] system was installed aboard Germany's largest fishing vessel – the 141m long ROS-171 *Maartje Theadora* – in 2010.

Because operating conditions on a fishing vessel differ greatly from those of a commercial cargo ship, especially during trawling operations, the key focus of the trials was on technically adapting the system to the circumstances specific to fishing operations. Its maiden voyage with SkySails propulsion took the ship across the Atlantic to South America and then into the South Pacific. However, since these trials it seems that the system is no longer installed on the vessel.

#### *3.15.2 Fishing vessel, Balueiro Segundo*[112]

The *Balueiro Segundo* from Vigo (ES), in 2021, was the first fishing vessel in the world to be equipped with an auxiliary wind-assisted propulsion technology and also the first vessel to install Bound4blue's eSAIL® technology.

The system uses the wind to propel the ship, thereby reducing fuel consumption and pollutant emissions released into the environment. It was developed within the framework of the Aspiring Wingsails project,[113] co-funded by the European Union (via EMFF), the Norwegian company *Kyma*, and the Spanish company *Bound4Blue*. It will monitor and validate fuel savings and reductions in emissions during sea trials in the Pacific Ocean (from Panama).

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103 For a review of its status (November 2022) see https://safety4sea.com/cm-wind-propulsion-in-shipping-where-we-stand/. Examples of different vessels which were adapted to use sail power may be found at https://news.mongabay.com/2021/03/new-age-of-sail-looks-to-slash-massive-maritime-carbon-emissions.

104 See examples at https://www.marineinsight.com/green-shipping/top-7-green-ship-concepts-using-wind-energy/.

105 See, for example, WISAMO, an inflated, foldable and automated wing. The wing can be adapted to any kind of vessel; new ones or the ones already operating: Ro-Ro, bulk cargos, oil and gas tankers, containers as well as sailing and yacht boats. See https://www.youtube.com/watch?v=BiaQV7kd8iM&t=130s

106 See, for example, Seawing (https://www.airseas.com/seawing) developed by the company AirSeas. It is an integrated solution combining kite-technology with an automated flight control system developed by the aerospace industry to harness the power of the wind. It is claimed that the system can be used easily by virtually any commercial ship to reduce emissions and fuel consumption by an average of 20%. For its testing on a transatlantic crossing with a 154 m ro-ro (roll-on roll-off) vessel, see https://safety4sea.com/watch-sea-trials-of-automated-kite-system-onboard-roro/.

107 https://www.lr.org/en/latest-news/norwegian-zero-emission-bulk-carrier-with-orca-lr-aip/

108 https://www.wind-ship.org/

109 See Prospective study of the Breton industrial sector :wind propulsion for ships, 2022, https://www.bdi.fr/wp-content/uploads/2022/09/2111110-BDI-Developpement-Innovation-Propulsion-par-le-vent-Brochure_en_def-1.pdf

110 https://seafood.media/fis/techno/newtechno.asp?l=e&id=35955&ndb=1 and https://bunkerindex.com/news/article.php?article_id=3806

111 https://skysails-power.com/

112 https://oceans-and-fisheries.ec.europa.eu/news/going-wind-2022-12-21_en and https://bound4blue.com/en/news/bound4blue-installs-its-esail-system-on-the-fishing-vessel-balueiro-segundo-78

113 http://aspiringwingsails.eu/

### *3.15.3 Adaptations to small fishing vessels to use wind power*

There do exist some start-ups promoting the use of sails and providing the means to convert fishing vessels.

Figure 5: Project Skravik's second-hand catamaran turned into a fishing laboratory (Source: Project Skravik)

The **Skravik project**,[114, 115] which receives EU EMFAF funding, aims at reviving wind propulsion for small-scale artisanal fishing. By adapting a prototype catamaran, the project aims to reduce the environmental footprint of fisheries in coastal areas by reintroducing sailing as a way of sourcing food sustainably.

The vessel is tested under real fishing conditions with traps, longlines, lines and nets in the maritime territory of Brest, France. It is also the intention to transfer experiences and lessons learnt to larger vessels, other fishing techniques and offshore fishing.

Two other examples, from **SailLine Fish** and from **Avel Tor Technology**, are presented below.

**SailLine Fish**[116] (UK) aims to develop a zero-emission fishing operation where wind energy both from sail and turbine generated can power fishing vessels and shore facilities. On route to this goal it developed the "Balpha Mast," a sailing mast system that can be retrofitted and easily raised and lowered while the vessel is at sea, thus enabling maximum use of this free resource.

**Avel Vor Technology**[117] (FR) installed automated sails on the laboratory boat Grand Largue, a former 16m length wooden trawler. Sea trials have shown that the sails allow decreases in fuel consumption (depending on wind conditions and heading) and that they consistently improved boat stability. They also work on sails shaped as an airplane wing, or wing sails, having a better efficiency.


Figure 6: SailLine Fish system, UK (Source: IWSA)

114 https://kengo.bzh/projet/3236/skravik
115 https://oceans-and-fisheries.ec.europa.eu/news/breton-fishing-vessel-shows-potential-sail-power-2022-11-29_en
116 See https://www.saillinefish.com/about-us
117 See http://www.avel-vor.fr/en/results/136-2/

# 4. ADAPTING FISHING PRACTICES

The International Council for the Exploration of the Sea (ICES) published, in October 2020, a **comprehensive review** defining then the **state-of-the-art fishing gear**.[118] As part of their analysis they also proposed a framework for assessing innovative gear, with rigorous approaches and methodologies identified to assess different levels of innovation and provide insight for possible adoption or approval of use, based on three major criteria: catch efficiency, gear selectivity and impact on marine ecosystems.

Other analysis (July 2022) has looked at **reducing the fuel use intensity** of fisheries through efficient fishing techniques to, for example, reduce drag by using lighter nets and/or larger mesh size, and via recovered fish stocks.[119, 120] More specific analysis looked globally at catch efficiencies of towed fishing gears targeting scallops.[121]

Some manufacturers have also invested in **new research and innovation in fishing gear**, like for trawl doors[122] and fishing nets,[123] so that they can be at the forefront of technological advancement and effectiveness, or developed more energy efficient ways to power onboard gear like, for example, compressed air systems[124] and LED lighting.[125]

These aspects and the examples which follow, serve to highlight the **necessity for science and fisheries to work together**, as done, for example, in the Mediterranean and Black Sea under the auspices of the *General Fisheries Commission for the Mediterranean (GFCM)*.[126] (Small-scale) fishers have a central role to play in the monitoring and data collection activities that inform the work of fisheries scientists. However, and recognising that there are difficulties with systematically integrating fishers' knowledge into advisory processes, the project Fishguider developed a web-based decision support tool.[127] Clearly, by increasing knowledge and understanding of the interactions between fisheries and marine resources, it provides the foundation for evidence-based sustainable fisheries management.[128]

## 4.1 Accompagnement des MARins pêcheurs pour la Réalisation d'Économies d'Énergie (Amarrée programme)[129]

This programme, which ran from 2019 to 2022, was designed to lower fishing vessels' fuel consumption. The programme consists of three major strategies: setting up a fuel economy observatory; installing econometers; and training in how to operate energy-efficient vessels. Some 181 professional ships were equipped (and seven maritime high schools) with analytical econometers, making it possible to monitor their consumption in real time and to adapt their ways of working. Savings are at least 5%, up to 15% in the best cases. A follow-up programme (Remove) will continue until 2025, focussing also on train-

118 https://www.ices.dk/news-and-events/news-archive/news/Pages/InnovativeFishingGear.aspx

119 See *Climate change and the Common Fisheries Policy: adaptation and building resilience to the effects of climate change on fisheries and reducing emissions of greenhouse gases from fishing*, including its *Annex 26*, July 2022, https://op.europa.eu/s/xiyD. Earlier work was also done by the Commission's Joint Research Centre, see https://stecf.jrc.ec.europa.eu/web/ee, and the European Fisheries Technology Platform, see http://www.eftp.eu/.

120 Bastardie Francois, Hornborg Sara, Ziegler Friederike, Gislason Henrik, Eigaard Ole Ritzau, *Reducing the Fuel Use Intensity of Fisheries: Through Efficient Fishing Techniques and Recovered Fish Stocks*, Frontiers in Marine Science, Vol. 9, 2022, https://www.frontiersin.org/articles/10.3389/fmars.2022.817335.

121 *A Global Review of Catch Efficiencies of Towed Fishing Gears Targeting Scallops*, Delargy et al., Reviews in Fisheries Science & Aquaculture, 29 Oct 2022, https://www.tandfonline.com/doi/abs/10.1080/23308249.2022.2139170.

122 See, for example, http://www.morgere.com/fr/actualites.html

123 See, for example, https://www.dsm.com/dyneema/en_GB/applications/nets.html

124 See, for example, development of an energy efficient marine compressed air system by the company, TMC Compressors, https://fishfocus.co.uk/vard-goes-green-for-newbuild-stern-trawler/

125 See, for example, https://www.visionx-europe.com/marine-lights.html

126 As part of the *Regional Plan of Action for Small-Scale Fisheries in the Mediterranean and the Black Sea*, https://www.fao.org/gfcm/activities/fisheries/small-scale-fisheries/rpoa-ssf

127 *Capturing big fisheries data: Integrating fishers' knowledge in a web-based decision support tool*, Kelly et al., Front. Mar. Sci., 12 December 2022, https://doi.org/10.3389/fmars.2022.1051879.

128 See https://fishfocus.co.uk/putting-the-science-into-fisheries-management/ for examples of the type of interactions done.

129 https://amarree.fr/en/. For final report on its outcomes, see https://lemarin.ouest-france.fr/sites/default/files/2022/09/23/cm_amarree_synthese_et_bilan_vf.pdf.

ing in eco-consumption, as well as research on new silicone paints.

### 4.2 Stopping sediment resuspension in the water column: modern trawl doors in Mediterranean Spain[130]

Since 2013, the fishers' guild (*"cofradia"*) in Palamós, Spain, has been involved in discussions on the necessary shift towards gears with less impact on the surface sediments of the trawling grounds along La Fonera Canyon flanks.

The comparison between six different trawling doors ("otter board") shows that the heavier otter boards that were in contact with the seafloor generated suspended sediment concentrations at 5m above seafloor up to 900 mg/l. On the contrary, the nets equipped with lighter material did not cause significant resuspension of sediments, thus favouring the long-term stocking of carbon.

### 4.3 Replacing traditional doors of a trawler with 'flying' doors[131]

The *Organization of Fisheries Producers (OPP) Owners of Puntal del Moral de Ayamonte (Huelva)* did a project with 'flying' doors, which do not touch the seabed. After testing the system in four vessels of different drafts and fishing areas, they found that it saves almost 20% of fuel and minimises the impact on the seabed. Savings were greater in vessels that fish several days in a row, reducing fuel consumption by 300 litres per day (from around 1 800 for these types of vessels) equating to a saving (in August 2022) of €225 per day per vessel.

Other benefits are that the use of the new system generates a lower demand for the machine, which translates into fuel savings and the consequent reduction of emissions, and significantly reduces the impact caused by the contact of conventional doors with the seabed. The 'flying' doors also do not diminish the ability to capture the fish and even allows greater control of the depth and position of the doors with respect to the rigging, thanks to sensors installed in the system.

### 4.4 Using trawl doors produced partly from recycled plastic[132]

A Brixham (UK) trawler, *Resolute* 10 m, switched to using Pluto trawl doors, produced partly from recycled plastic and weighing 95 kg, instead of standard steel trawl doors weighing a quarter of a tonne each.

As well as spreading and handling well, a big factor is a reduction in fuel consumption, as the lightweight Pluto doors mean that *Resolute* is towing with less effort. In fuel terms, the difference is as much as 30%.

The General Fisheries Commission for the Mediterranean (GFCM) is also conducting a pilot study in the Mediterranean with such Pluto doors to assess fuel savings and efficiency.[133]

[130] *Self-Regulated Deep-Sea Trawling Fishery Management In La Fonera Canyon (NW Mediterranean), Towards Reduction Of Sediment Resuspension And Seabed Impact*, MG44C -0389, Ocean Sciences Meeting 2018, https://digital.csic.es/handle/10261/186018

[131] Further details at https://www.europapress.es/andalucia/huelva-00354/noticia-armadores-ayamonte-huelva-destacan-uso-puertas-voladoras-ahorra-casi-20-combustible-20220829184220.html

[132] https://mag.hookandnet.com/2022/09/06/2022-09plutoeng/content.html

[133] DG MARE, European Commission

## 4.5 Reverting to wooden otter doors[134]

In the Chioggia port trawl fleet (Adriatic Sea, IT), some experimenting is ongoing with otter trawl doors design and material. After years of use of iron or stainless steel doors, a part of the fleet has reverted back to otter doors with a metal frame and wood panels. This lighter equipment still ensures a similar spread of the otter trawl net wings, while reducing seabed friction and fuel consumption. Precise figures of these benefits are not yet available, but a pilot study for this is underway.

Figure 7: Otter boards with wood panels in use in the Chioggia otter trawl fleet, Italy (Source: DG MARE, July 2022, Sept. 2022)

## 4.6 Using lighter nets

As well as developments for more environmentally-friendly nets, such as biodegradable nets[135] and an EU standard for sustainable fisheries, aquaculture and fishing gear,[136] there are innovations in net design to reduce drag.

The **commercially available Dyneema® nets** are promoted to be a proven and certified solution to replace steel wire, heavy ropes or outperform low-cost synthetics. They are strong yet light, reducing drag and thereby helping to cut fuel costs by 40%, while also making boats easier to handle and safer.[137]

The **Mazara trawler fleet (Sicily, IT)**[138] during their fishing trips work non-stop 24 hours a day, always keeping the main engines of the boat in action. This typically meant that a Mazara trawler consumed about 1.0-1.2 tonnes of fuel per 24 hours of action. Since the 2000s, with the progressive importance of deep-water red shrimp as a target species for the Mazara fleet, there has been a change in the characteristics of the nets used, which have become lighter (polypropylene instead of nylon) and with thinner meshes, being no less than a 50 mm opening. These changes, together with the need to reduce fuel consumption, led to a decrease of 0.8-1.0 tonnes of fuel per day.

## 4.7 Developing 'Twist Gear'[139]

This approach is experimenting with using rubber strings instead of ticklers chains in combination with roundheads – or twisters – hence the term 'Twist Gear.' This new approach could be an alternative to pulse fishing for beam trawlers, although it is (August 2022) at an early stage and would need more development with more vessels, on more fishing grounds. Initial results indicate that fuel consumption is reduced and that the gear is gentler on the seabed.

134 DG MARE meeting with Chioggia fleet, July 2022

135 See, for example, https://actu.fr/normandie/le-treport_76711/des-filets-biodegradables-testes-par-les-pecheurs-pour-limiter-la-pollution-en-mer-au-large-du-treport_54862391.html.

136 CEN/TC 466 'Sustainable fisheries, aquaculture and fishing gear' established in November 2020. The technical committee will develop standards for sustainability, circularity and Life Cycle Management, regarding sustainable fishing, aquaculture and fish products. This includes fishing gear and its components, freshness of products and marketing. See https://www.cencenelec.eu/news-and-events/news/2020/briefnews/2020-10-26-new-cen-tc-life-cycle-management-and-circular-design-of-fishing-gear/.

137 https://www.dsm.com/dyneema/en_GB/applications/nets.html

138 Information kindly provided via Personal Communication with L'Istituto per le Risorse Biologiche e le Biotecnologie Marine del Consiglio Nazionale delle Ricerche (IRBIM CNR), April 2022.

139 https://mag.hookandnet.com/2022/08/08/2022-08twisters/content.html

## 4.8 Use of Apps to optimise arrival and delivery to market

Smartphone Apps like, for example, **Rooser** (Rooser.eu) exist to connect seafood buyers and suppliers, including whilst at sea, giving them the right tools to trade efficiently, negotiate prices and process deliveries across Europe – all in real-time, at any time.

Another App developed in the Irish **IFISH project** (https://www.i-fish.org/) aims to investigate how new technologies and mobile phone apps could be used to share real-time information to help skippers avoid unwanted catches and reduce discards.

Other applications, like, for example, **Blue Visby** (https://bluevisby.com/) have also been created, though so far for South-East Asia. It is a multi-lateral platform for reducing GHG emissions by avoiding the practice of "Sail Fast, then Wait." By optimising arrival at destination, vessels can adjust their speed accordingly, thereby reducing its carbon footprint. Figures for the tanker fleet and bulker fleets estimate around 15% or overall 45 million tonnes of CO2 reductions. The GHG emissions reduction is not the only benefit of this Blue Visby Solution. It also reduces underwater noise pollution and whale strike risk; it improves the air quality outside ports; it reduces the risk of collisions and anchor loss at busy anchorages; and it reduces hull fouling, which in turn improves vessels' operational efficiency.

## 4.9 Use of Route and Planning Optimisation

In a similar vein, it is **becoming more common for ships at sea to make use of Route Optimisation**, which can be based on AI-based voyage analytics and also linked to a vessels' auto-pilot. For example, Inmarsat produced a report which looked at the why and how of route optimisation as part of digital decarbonisation.[140] Such route optimisation (Apps) can also integrate the weather conditions in which a vessel is working.[141]

Whilst used more commonly in the global shipping industry,[142] it seems to be **less-developed for the fishing industry**. For some vessels, even slow steaming or speed optimisation to/from fishing grounds could result in a fuel saving of 15-59%, with a potential further 3% from using an autopilot.[143] A **review of the state-of-the-art and challenges[144]** showed that there is a gap in the application of route and planning optimisation decision systems in fisheries, despite most of the existing technology being available. Some work would, however, be needed to adapt to fishing vessel needs taking into account their particularities.

[140] https://www.inmarsat.com/en/insights/maritime/2022/optimal-route.html. Other companies include, for example, Navtor (https://www.navtor.com/) and Sea Machines (https://sea-machines.com/).

[141] See, for example, the activities of METIS Cyberspace Technology SA, https://www.metis.tech/

[142] See, for example, Fleet Optimisation Solution (FOS) by Wärtsilä Voyage, https://www.wartsila.com/voyage/fos

[143] See Table 58 in Annex 26 of *Climate change and the Common Fisheries Policy: adaptation and building resilience to the effects of climate change on fisheries and reducing emissions of greenhouse gases from fishing*, July 2022, https://op.europa.eu/s/xiyD.

[144] Igor Granado, Leticia Hernando, Ibon Galparsoro, Gorka Gabiña, Carlos Groba, Raul Prellezo, Jose A. Fernandes, *Towards a framework for fishing route optimization decision support systems: Review of the state-of-the-art and challenges*, Journal of Cleaner Production, Volume 320, 2021, https://doi.org/10.1016/j.jclepro.2021.128661.

# 5. HULL MODIFICATIONS

Techniques and approaches to reduce vessel drag and in turn fuel consumption, include hull and rudder modifications; having a bulbous bow; using stabilizer fins of foils; applying antifouling coatings,[145] notably with eco-friendly paint;[146] plus cleaning the hull or adding a polyester covering (e.g. to a wooden hull).[147]

Below are given some examples of such modifications applied in practice or under development.

## 5.1 Reducing fuel consumption with a foil in France[148]

One of the four fishing catamarans in Sète, France, that are used for longline fishing or small purse seine (lamparo), was equipped (in Summer 2021) with a retractable T-foil.

This technology allows better stability of the vessel, reduced fuel consumption and a gain in speed to move to the fishing areas. Fuel consumption was reduced by up to 25% (depending on weather conditions).

## 5.2 Having a bulbous or an inverted bow

A **bulbous bow**, which is a protruding bulb at the bow of a ship just below the waterline, is not only an effective solution to reduce the total resistance or required power of the ships, but also enhances safety and economic-techno efficiency for seagoing ships, such as increasing speed, decreasing fuel consumption, improving stability and seakeeping.

Typically used on larger ocean-going vessels, there is nevertheless analysis for the design of a bulbous bow on fishing vessels.[149] There are several examples of newly-built fishing vessels fitted with a bulbous bow,[150] as well as retrofitted ones,[151] with two examples illustrated on this page.

The **inverted bow** is essentially the reverse of a conventional bow, with the top of the bow behind the bottom. They maximise the length of waterline and hence the hull speed and often have better hydrodynamic drag than ordinary bows. The shipbuilding company, *Ulstein*, has developed this concept further with its X-BOW®.[152] Through their design, instead of rising on the waves and then dropping, a vessel with an X-BOW® is able to distribute the force more evenly across its surface – enabling the ship to remain more stable during poor weather conditions. Since it uses less fuel to get through the waves, it also helps to save energy.

An **example of a fishing vessel** being constructed with an inverted bow is the *Nuevo Argos*.[153] The Nodosa shipyard, located in the port of Marín, Spain, is constructing this freezer trawler for operations in the South Atlantic. The trawler will have a length of 85m and will be used for the fishing and processing of Patagonian squid. The design of the ship has prioritised improving the safety and quality of life of the crew on board, respect for the environment and energy efficiency. It will also incorporate various elements on board to mitigate incidental mortality of birds and other marine species and the ship's refrigeration plant will use ammonia as the main refrigerant, eliminating the use of fluorinated gases, thereby reducing the environmental impact. The vessel is expected to be completed by the end of 2024, with then its first fishing campaign early the following year.

145 See also IMO Report on *Biofouling Management, Fuel Efficiency And GHG Emissions Outlines Important Findings*, October 2022, https://www.glofouling.imo.org/_files/ugd/34a7be_02bd986766d44728b85228c3ec9b95ee.pdf

146 See https://fishfocus.co.uk/eco-friendly-paint-most-effective-against-fouling-on-ships-and-boats/

147 For a comprehensive overview, see *Climate change and the Common Fisheries Policy: adaptation and building resilience to the effects of climate change on fisheries and reducing emissions of greenhouse gases from fishing*, including its *Annex 26*, July 2022, https://op.europa.eu/s/xiyD.

148 https://martinez-constructions-navales.fr/produits/catamaran-de-peche-deux-frere-6

149 See, for example, https://www.sciencedirect.com/science/article/pii/S2092678221000583

150 See, for example, https://fishingnews.co.uk/features/virtuous-fraserburgh-twin-rig-trawler-breaks-new-ground-for-scottish-prawn-fleet/.

151 See, for example, http://www.commodoresboats.com/past-projects/mystic-era-new-bulbous-bow-and-paint/

152 https://ulstein.com/innovations/x-bow

153 https://www.nodosa.com/boletines/control.php?sph=a_iap=51%%a_itp=2%%a_id=165%%s_idm=3

## 5.3 Air Lubrication[154]

The **Horizon 2020 project** *Air Induced friction Reducing ship COATing (AirCoat)*[155] aimed to develop a disruptive hull coating that reduces the frictional resistance of ships. By creating a permanent air layer, ship drag is reduced and it also acts as a physical barrier between water and the hull surface. In this way, in addition to reducing fuel consumption and thus ship emissions, the air barrier reduces the attachment of marine organisms (biofouling); the release of biocides from traditional coatings into the water; and mitigates ship noise pollution. Initial laboratory experiments with small samples indicated drag reduction in the range of 10-30%.

The company **Silverstream Technologies**[156] has installed their air lubrication system on the vessel of Norwegian Cruise Line.[157] It is the first commercial installation for improving operational and environmental efficiencies as a means of reducing emissions, fuel costs, and improving the sustainability of their operations.

The Silverstream System produces a thin layer of microbubbles that creates a single 'air carpet' along the hull of the vessel. This reduces the frictional resistance between the water and hull and improves the vessel's operational efficiency, reducing fuel consumption and associated emissions. The technology can be added to new build design or retrofitted to an existing ship within just 14 days. With the right ship hull design, the air lubrication system is expected to achieve up to 10-15% reduction of CO2 emissions, along with significant savings of fuel.

## 5.4 Fuel Saving Propeller adaptations

A number of these are currently on the market or under development.[158] For example, the company *Wärtsilä* has developed a **Controllable Pitch propeller system**[159] which allows operating at optimum pitch settings for various operating conditions, when both trawling and free-sailing performance are important. Key benefits are high propeller efficiency, reduced fuel consumption, minimum noise and vibration levels and reliability.

**Such propellors were also used** by the Horizon 2020 **LeanShips project**,[160] which aimed to demonstrate the effectiveness and reliability of these energy-saving and emission-reduction technologies at full scale. The project developed an energy-saving device that is suitable for use by ships with controllable pitch propellers which helped to achieve a 3.5% fuel saving for ships during sea trials.[161]

Similarly, the shipping company *Hapag-Lloyd* is making its existing fleet more efficient, including by **retrofitting new propellors**.[162] They state that this results in the ship saving between 10 - 13% fuel and CO2 emissions, depending on the sailing condition.

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154 For a brief explanation of how this works, see https://safety4sea.com/cm-how-blowing-bubbles-under-ships-can-reduce-emissions/.

155 See https://aircoat.eu/. Details of this project, and other Horizon 2020 projects, may also be found in *Waterborne Transport Projects - Horizon 2020 projects managed by CINEA and opportunities for synergies*, https://cinea.ec.europa.eu/publications/h2020-waterborne-transport-projects_en.

156 https://www.silverstream-tech.com/. See also https://www.nepia.com/articles/blowing-bubbles-to-lower-emissions/.

157 See https://www.marineinsight.com/tech/7-technologies-to-reduce-fuel-consumption-of-ships/. The China Merchants Energy Shipping (CMES) company also intends to install air lubrication technology on up to six new LNG carriers, see https://splash247.com/chinese-lng-newbuilds-getting-air-bubble-treatment/.

158 See, for example, https://www.marineinsight.com/shipping-news/nyk-to-collaborate-with-nakashima-propellor-and-fluid-techno-for-reducing-ghg-emissions-from-ships/?s=03

159 https://www.wartsila.com/docs/default-source/marine-documents/segment/brochure-fishing-vessels.pdf?sfvrsn=d61c6044_4

160 https://www.leanships-project.eu/home/

161 https://www.hellenicshippingnews.com/leanships-project-with-wartsila-partners-achieves-3-5-fuel-savings-for-ships-with-cpps/

162 https://www.hapag-lloyd.com/en/company/press/releases/2022/08/investing-in-sustainability--hapag-lloyd-to-make-existing-fleet-.html

Elsewhere, and under the Horizon 2020 project GATERS,[163] a **Gate Rudder System** was developed as an energy saving concept with excellent manoeuvrability. The project will explore retrofitting and its application to different kinds of vessels.

**One example** with a retrofitted high-efficiency propeller, along with upgrades to the engine and reduction gear, is the Anna PZ-657.[164] A 4 200 mm diameter high-efficiency propeller was fitted which, with the other modifications, gave a 25-28% saving in fuel consumption translating to a saving of around 125-130 litres per towing hour.

Figure 8: Gate Rudder System

## 5.5 Bio-mimetic dynamic wing with ultra-high energy conversion efficiency

The Horizon 2020 **SeaTech project**[165] aims to develop a renewable-energy-based propulsion innovation consisting of a **bio-mimetic dynamic wing mounted at the ship bow** to augment ship propulsion in moderate and higher sea states, capturing wave energy, producing extra thrust and damping ship motions. This would be **combined with** power generation based on the idea of achieving **ultra-high energy conversion efficiency** by precisely controlling the engine for achieving radically reduced emissions.

It is expected to offer shipowners a return-on-investment of 400% due to fuel and operational cost savings. The project estimates CO2 savings of 32.5 million tonnes annually if just 10% all EU short-sea vessels were retrofitted with this device.

[163] GATE Rudder System as a Retrofit for the Next Generation Propulsion and Steering of Ships, see https://www.gatersproject.com/
[164] https://fiskerforum.com/beamers-fuel-saving-refit/
[165] https://seatech2020.eu/

# 6. OTHER INNOVATIONS

## 6.1 Using latest technological innovations in the design and build of new vessels

The fishing company *Bluewild AS*, Ålesund (DK), along with the shipbuilder *Ulstein Design & Solutions AS*, Ulsteinvik (DK), have, together with several players in the maritime cluster, developed a concept for a new trawler: ECOFIVE which stands for "Eco-Friendly Fishing Vessel."[166] The central part of the innovation in the project lies in a **newly developed catch reception and handling of the trawl**. It is expected to enter into service in early 2024.

Figure 9: EcoFive vessel design (Source: ULSTEIN)

The vessel will have **hybrid power and propulsion system**, which combines the best features of diesel-electric and diesel-mechanical propulsion, is supported by a large battery pack and comes with two large propellers with rudder nozzles. **Fuel savings of at least 25% per kilo of fish product** are anticipated. In some operations, together with other energy-saving measures on board, **this figure can exceed 40%**.

Examples of **similar innovations** for new vessels were presented at the **Nor-Fishing event**[167] in August 2022. Information presented included a **Next-Generation Factory Trawler** with a high technology fuel saving system and on the **Ideal Trawler** in terms of energy and fishing efficiency based on the current best technologies.[168]

## 6.2 Digitisation

Digitisation, including Artificial Intelligence (AI), is being developed more and more for the shipping sector, though again it does not seem to have significantly impacted yet on the fishing and aquaculture sector. One example, for aquaculture, is the **Innovasea aquaculture management platform**.[169] It is an advanced, cloud-based platform that enables fish farmers to monitor, manage and control operations from anywhere, at anytime.

A review of **Artificial Intelligence and the Fisheries Sector**,[170] looked at the (potential) applications, finding that machine learning is used *inter alia* for sample analysis and processing; to automatically classify or determine fishers' behaviour; and for early warning systems and marine spatial planning. It was noted too that fishing vessels could improve energy efficiency and reduce CO2 footprint by using AI systems. A potential application here is to use a combination of AI and naval architecture knowledge to predict the expected operational fuel consumption of any type of vessel.[171]

166 Details at https://ulstein.com/news/the-ecofive-concept-for-sustainable-fishing. See also https://nor-fishing.no/en/2022/08/17/jury-ecofive-marks-a-shift-for-the-fishing-industry/ and https://www.marineinsight.com/shipping-news/ulsteins-trawler-nominated-for-innovation-award/.

167 See https://nor-fishing.no/en/

168 Special edition by Industrias Pesqueras, https://industriaspesqueras.com/noticia-71734-seccion-Naval.

169 https://rsaqua.co.uk/2022/12/innovaseas-new-aquaculture-management-platform/

170 https://research4committees.blog/2022/05/20/artificial-intelligence-and-the-fisheries-sector/

171 See, for example, https://safety4sea.com/ai-model-launched-to-help-shipping-reduce-emissions/

The **startup company**, **Intelligentica**,[172] based in Morocco, leverages the power of new technologies such as AI, Machine Learning and Big Data to deliver innovative solutions. This includes *Intelligent Fishing For Sustainable Resources* which combines fishing effort with environmental, ocean and biological indicators for fisheries stock assessment, in order to inform smart and optimised sustainable fishing.[173]

**Onboard electronic monitoring** is also under development.[174] For example, a pilot project with the **US Gulf of Alaska fishing fleet** reported an overall positive outcome.[175] Whilst some fishers were uncomfortable with having onboard cameras and there were technical challenges for the cameras to function in harsh weather conditions, nevertheless it gave greater confidence in counts of bycatch, thereby allowing for greater accountability. A future evolution being considered is to have sensors on gear that can automatically communicate when it is set, its location, depth, and other information. Elsewhere, the **company Thai Union Group along with NGO The Nature Conservancy** are also promoting electronic monitoring to improve in global tuna supply chains.[176]

Other developments include **Ecobuq**, which is a simulator that optimises the energy and environmental efficiency parameters of ships.[177]

## 6.3 Onshore solar panels

With support from EMFAF, solar panels were purchased by the fishermen's guilds of Cartagena, Mazarrón, Águilas and San Pedro del Pinatar (Spain) and placed on the fishermen's huts as a way to conserve energy use from fossil fuels.[178]

Similarly, a new fish market in the Valencian port of Torrevieja (Spain) was constructed with energy efficiency aspects, such as sustainable lighting via the installation of a partially translucent roof to give natural light to the interior, as well as photovoltaic panels.[179]

## 6.4 Offshore refuelling

Work is also ongoing to provide a **fuelling platform offshore** so that vessels would not need to enter port. One initiative is to place such a fuelling point alongside an offshore wind farm, thereby using in situ wind energy to produce, for example, hydrogen fuel and then store on a platform so that vessels can then come alongside and refuel.[180]

Another approach is to have **mobile refuelling barges** which can then come alongside ships and refuel them.[181] Likewise, developing floating production units is also being considered, like for green ammonia.[182]

## 6.5 Private financing

The **private sector financing** of adapting, retrofitting and for new ships is another consideration. For example, the **bank Abanca (ES) has a collaboration agreement with the Galician Federation of Fishermen's Associations**[183] aimed at facilitating access to financial products, as well as the promotion of sustainability. Specif-

172 http://www.intelligentica.net/

173 The company's work was presented at the EU's BlueInvest Africa event in September 2022, see https://www.linkedin.com/company/intelligentica/videos/.

174 Electronic monitoring is part of the European Commission's proposal, from May 2018, for the revision of the fisheries control system, aimed at modernising and simplifying the rules for monitoring fisheries activities and ensuring compliance with the Common Fisheries Policy (CFP). The proposed Regulation is currently under negotiation with the co-legislators, European Council and European Parliament, see https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-revision-of-the-fisheries-control-system.

175 https://www.fisheries.noaa.gov/feature-story/empowering-fleet-through-electronic-technologies

176 https://www.thaiunion.com/en/newsroom/press-release/1595/thai-union-and-the-nature-conservancy-release-first-partnership-progress-report-on-full-tuna-supply-chain-transparency

177 https://industriaspesqueras.com/noticia.php?id=72668

178 https://www.agrodiario.com/texto-diario/mostrar/4081078/cofradias-pescadores-contaran-370000-euros-placas-solares-subvencionadas-femp

179 https://industriaspesqueras.com/noticia-72531-seccion-Pol%C3%ADtica%20de%20Pesca?s=03#Puertos/

180 Need ref.

181 See, for example, the ELEMANTA H2 project, https://energynews.biz/first-high-power-hydrogen-barge-for-the-electrification-of-boats/

182 See, for example, https://safety4sea.com/approval-in-principle-for-green-ammonia-floating-production-unit/

183 https://industriaspesqueras.com/noticia.php?id=71468&s=03

ically, the agreement aims to improve sustainability and energy efficiency through the process of renewing the fishing fleet.

## Annex: Energy efficient technology usage reported in the scientific (S) and grey (G) literature and by questionnaire to stakeholders, commercial (CQ) and scientific (SQ)[1]

| Category | Target | Subcategories | Source of info* | | | | % Fuel saving potential |
|---|---|---|---|---|---|---|---|
| | | | S | G | CQ | SQ | |
| Vessel | Drag force reduction (hull) | **Hull and propeller improvements** | | | | | |
| | | Improved hull designs | | | | | 3 - 20 |
| | | Use of rudders | | | | | 5 |
| | | Addition of a bulb | | | | | 6 - 30 |
| | | Use of stabilizer fins | | | | | 2 (in drag) |
| | | Use of stern post | | | | | 11 (Antifouling) 0.8–5 (Hull cl.) |
| | | Antifouling coatings and cleaning | | | | | 26 |
| | | Polyester covering of hull to reduce friction | | | | | 3 - 20 |
| | Fuel consumption and GHG emissions | **Improved propulsion and auxiliary engines** | | | | | |
| | | Improved propulsion system | | | | | 5 - 100 |
| | | Renewable energy (sail-assisted propulsion) | | | | | 5 - 25 |
| | | Renewable energy (for onboard consumers) | | | | | *** |
| | | Improved maintenance (predictive maintenance) | | | | | 3 - 8 |
| | | Heat recovery systems | | | | | 5-10 |
| | | Magnetic devices | | | | | 2 - 6 |
| | | Frequency converters | | | | | 9.1 - 25 |
| | | Shore power/shore supply of electricity | | | | | 90 - 100 (consump. in port) |
| | | Shift from mechanical-hydraulic consumers to electric consumers onboard | | | | | 10 - 15 |
| | | **Energy consuming machinery** | | | | | |
| | | Led lighting | | | | | 26 - 55 |
| | | Alternative refrigerants for cooling system | | | | | 50 (in electricity) |
| | | **Improved fuel performance** | | | | | |
| | | Alternative fuels | | | | | 1.2 (1.9% for CO2 red.) |
| | | Additives | | | | | - |
| | | Autopilot | | | | | 3 |

[1] Taken from Table 58 of Annex 26 of *Climate change and the Common Fisheries Policy: adaptation and building resilience to the effects of climate change on fisheries and reducing emissions of greenhouse gases from fishing*, July 2022, https://op.europa.eu/s/xiyD. Sources for the fuel savings percentages given may be found in the original table in the Annex 26.

| Category | Target | Subcategories | Source of info* | | | | % Fuel saving potential |
|---|---|---|---|---|---|---|---|
| | | | S | G | CQ | SQ | |
| Strategy | Route optimization | **Route optimization (based on metocean data)** | | | | | |
| | | Slow steaming, speed optimisation | | | | | 15 - 59 |
| | | Fishing zone prediction systems | | | | | |
| | | Route planning systems, route optimisation | | | | | |
| | | **Change of fishing ground** | | | | | |
| | | Change the fishing ground based on the catch and changing the return day | | | | | |
| | Energy consumption control and management | **Onboard control and monitoring** | | | | | |
| | | Energy audits | | | | | ** |
| | | Onboard energy monitoring devices and operative advice | | | | | 3 - 15 |
| Gear | Drag force reduction (gear) | **New netting designs** | | | | | |
| | | New or improved designs | | | | | 17 - 22 |
| | | Alternative materials (DyneemaTM) | | | | | 2 - 40 |
| | | Different mesh size, type of knots, panel cuttings | | | | | 25 - 27 |
| | | **Operational improvement** | | | | | |
| | | Electronically controlled gears | | | | | >15 |
| | | **New gear designs** | | | | | |
| | | Change from demersal to semi pelagic trawling doors | | | | | 1.6 - 19 |
| | | Alternative designs of trawl doors, trawl net, Sumwing | | | | | 4.5 - 20 |
| | | Ground gear | | | | | ** |
| | | Alternative ropes (Helix ropes) | | | | | ** |
| | | Sledges | | | | | *** |
| | Fishing gear change | **From active to passive** | | | | | |
| | | Gear change: change from trawl to gillnet | | | | | *** |
| | | **Within active** | | | | | |
| | | Gear change: change from mid-water trawl to purse seine | | | | | 5 - 25 |
| | | Gear change: pulse trawling | | | | | 35 - 54 |
| | | Change the number of rigs from single trawling | | | | | 10 - 30 |
| | | Assisted fishing | | | | | *** |
| | Catchability and reduced mortality | **Improve catchability and reduce mortality** | | | | | |
| | | Selective fishing: led lighting | | | | | |
| | | Selective fishing: use of selective gears | | | | | 8 - 25 |
| | | Technology to increase catch efficiency | | | | | |

* Savings are reported for several measures together; ** No quantitative data is presented about the reduction in grey literature, ***There is a mention about the potential for saving but no quantitative data are shown.

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