NSAC North Sea Advisory Council

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1 Background

The effects of climate change on the oceans and the seas such as the rise of temperature and sea level, acidification, occurrence of (invasive) alien species and migration of species are becoming increasingly noticeable. There is a clear necessity to adapt to the unavoidable consequences of global warming while taking measures to mitigate its effects. With the announcement of the EU Green Deal in December 2019, the European Commission put climate and environmental action as one of its key priorities. A set of proposals was adopted to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.

In February 2022, the geo-political tensions culminating in Russia's invasion of Ukraine exposed European Union's vulnerability in terms of energy dependence from unreliable external sources. The fisheries sector highly reliant on fossil fuels was greatly affected by the soaring fuel prices. As a reaction, the objectives of EU Green Deal were coupled with the urgency of ending dependency on (external) fossil fuels and a speedy transition to sustainable alternatives was spurred.

In this context, the NSAC established a Climate Change Focus Group (March 2022) aimed at providing the Commission with informed, fisheries-focused advice on adoption of climate mitigation and adaptation measures that are both relevant and feasible in the North Sea context, with possibility for further application to other eco-regions and/or sectors. As a policy interface between the regulators, the fishing industry and other interested parties, the NSAC has a unique role to play as facilitator and vehicle for discussions, ensuring that important considerations are taken onboard and consequently contributing to legitimacy of measures and facilitating buy-in by the end-users.

The Climate Change FG set out to contribute to Commission's endeavours to address energy transition, its implications for the fishing industry and the industry's role in bringing about decarbonisation as a matter of priority, following DG MARE request at the Inter-AC meeting on 29 April 2022. To this end, the Climate Change Focus Group organised a series of meetings with presentations by relevant experts aimed at:

- Understanding EU framework on energy transition and the related initiatives with a focus on blue sectors.
- Providing a state of play of research, knowledge and on-going projects relating to the decarbonisation of the maritime sectors especially of the fishery sector.
- Tackling the issues of alternative to fossil fuels and energy efficiency for the fisheries sector.
- Providing information on the different funding possibilities for the fisheries sector to transition.

This paper provides for an overview on the knowledge acquired by the Focus Group during these meetings as well as recommendations to the Commission and Member States on the way to move forward on the decarbonization of the fisheries sector. This, while highlighting the importance of eliminating overfishing and ensuring healthy stocks as a solution for carbon emissions. More available stocks mean that less time and economical effort put into reaching fish stocks, which leads inevitably to both higher profits and less emissions.

We hope that this paper will also provide technology end-users with a valuable overview of existing and developing technologies, methodologies and strategies for improved energy efficiency and final transition to zero emissions, as well as the NSAC members' take on their concrete applicability. It must be noted that given the time constraints, the NSAC had to choose to focus on certain energy efficiency measures, alternative fuels and methods, and the selection is by no means exhaustive. It also does not signal a preferred choice between one or the other technology. We remain available to explore further aspects of decarbonisation of the fishing sector in the months and years to follow.

2 State of play, challenges and opportunities

2.1 EU initiatives on energy transition

With the EU Green Deal announced in December 2019, the European Commission put climate and environmental action as one of its key priorities. A set of proposals was adopted to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.

The EU fishing sector is faced with challenges today that put at risk fleets' overall profitability, sustainability and resilience. It is therefore imperative to act fast and in alignment with the objectives of sustainable blue economy and the EU Green Deal. The EU is preparing an Action plan to promote and support energy transition of the sectors, due by the end of 2023, with practical guidance on how vessels and their operations and the management of fisheries might be adapted and how European Maritime, Fisheries and Aquaculture Fund (EMFAF) and other funding sources can support this transition.

The EU has launched several initiatives to mitigate climate change in the long run and to offset the consequences of rising fuel prices due to war in Ukraine in the short term. This, while bearing in mind that emergency crisis measures adopted by the EU to aid the fisheries sector in the short term must not in any way impede the long-term efforts towards structural energy transition of the fishery and aquaculture sectors to achieve the objectives of the European Green Deal.

2.1.1 REPoweR EU

The aim of the REPoweR EU strategy proposed by the Commission is to reduce dependence on fossil fuel from Russia to zero by 2027, to prepare for the winter by anticipating storage of gas, diversification of supply and use of Liquefied Natural Gas (LNG) and to improve energy savings and efficiency. To this end, the Commission called for a push to solar energy (roof-top initiative), wind energy and heat pump, green hydrogen. Additional investments of 210 billion EUR between now and 2027 are envisaged, as well as the revision of the Recovery and Resilience Facility.

A set of measures was presented to the NSAC to reach these objectives. In short-term measures, the following aspects were exposed:

- A common purchase of gas, LNG and hydrogen via the EU Energy Platform.
- New energy partnerships.
- EU-coordinated demand-reduction plans in case of gas supply disruption.
- Fill the European gas storage to 80% capacity by November 2022.

The medium-term measures consist of:

- Increased EU-wide target on energy efficiency for 2030 from 9% to 13%.
- Increase the European renewables target for 2030 from 40% to 45% in the overall energy production (the previous goal was set at 32% for 2030).
- New legislations and recommendations for faster permitting of renewables, especially in dedicated “go-to areas” with low environmental risk, starting from revisions on legal framework, particularly of the Renewables Directive.

According to the European Commission, renewable energy is not only crucial to fight climate change, but also to obtain energy price reductions, ensuring security of supply for the Union and to decrease the energy dependence on fossil fuels. In order to reach such objectives, the EU considers offshore wind production a pillar for the energy transition, being the most developed in terms of planning and regional cooperation through Maritime Spatial Planning (MSP). All Member States in the North Sea have adopted a plan where they considered fishing activities in offshore wind platforms. Another aspect worth exploring is the production of green hydrogen from these offshore facilities.

The main objective of the Renewable Energy Directive (RED) is to recognise renewable energy as an overriding public interest. The modifications to the original document include setting targets for renewable energy by Member States, with a revision of the National Energy and Climate Plan by next year, also specifying the ambitions in terms of renewable energy and biotechnology. One other important aspect is the implementation of dedicated “go-to” areas for renewables that should be in place by Member States with shortened and simplified permitting processes in areas with lower environmental risks (Article 15 of the RED). In view of this, a series of measures need to be carried out:

- Mapping of areas necessary for national contributions towards the 2030 Renewable Energy Strategy (RES) target.
- Member States prioritizing multiple use of the available areas (energy and food production, nature conservation etc.).
- Establishing rules for the renewable go-to areas, including the mitigation measures.
- Access to information, public involvement in decision-making, and access to justice in environmental matters, remain applicable ("Aarhus Convention").

2.1.2 EU funding possibilities for the fishing sector

Various EU funds are available in order to help the sector through the transition.

- EU Horizon Europe: In the framework of EU Horizon Europe, there is a Partnership on Zero Emission Waterborne Transport[1] providing and demonstrating zero-emission solutions for all main ship types and services before 2030. Mission Ocean objective #3: 'Making the blue economy sustainable, carbon neutral and circular', includes decarbonisation of the blue economy and provides funding opportunities in the future for higher 'technology readiness level' (TRL) research and innovation[2]. There is currently no specific call for fisheries, but it could provide opportunities for innovation and research and the sector should monitor these for relevant calls for proposals.
- Innovation Fund: In addition to Horizon Europe, Innovation Fund[3] provides support for innovative low-carbon technologies with commercial demonstration to help bring new solutions to the market. It comprises large (> 7,5 mio EUR) and small-scale (<7,5 mio EUR) projects. The total budget for 2020-2030 is 10 bn EUR.
- European Maritime, Fisheries and Aquaculture Fund (EMFAF): EMFAF[4] offers funding possibilities for development of low carbon and energy efficiency technology, (e.g. energy efficiency audits, feasibility studies on new technology, test and trial of new technology with prototypes and demonstrators, and dissemination and transfer of technology and innovation) and investment in mature technology (improving energy efficiency and reducing the carbon footprint (e.g. hydrodynamic optimization, gear efficiency, alternative fuels, bridge systems for engine control), replacement/modernisation of engines (only for small scale fishing vessels under conditions preventing increase in power, and additionally for other vessels up to 24m under conditions that the new engine releases at least 20% less CO2 and preventing increase in power), increase in volume of vessels to install energy-efficient engines (only for vessels smaller than 24m, and under conditions preventing increase in fishing capacity of the vessel).

While the list is not exhaustive, these funding opportunities are aimed at helping to develop technologies and finding outlets to the market. Indeed, the Commission's role is to mobilise resources, steer private investments and remove existing bottlenecks, and to cater for a price

[1] https://www.waterborne.eu/
[2] https://europa.eu/!jvHjx9 and for Work Programme, https://europa.eu/!8Jmx8p
[3] https://ec.europa.eu/clima/eu-action/funding-climate-action/innovation-fund_en
[4] https://oceans-and-fisheries.ec.europa.eu/funding/emfaf_en

decrease when technology matures, and the role of the private sector is to be a catalyst for this change.

2.2 Energy efficiency and alternative to fossil fuels

The EU fishing industry, and more notably, the demersal sector, is a small contributor to greenhouse gas (GHG) emissions compared to other emitters. However, this should not discourage it to take action in reducing emissions. A much greater responsibility for emissions is naturally placed on the larger marine emitters such as marine transport and shipping, which are regulated by International Maritime Organization (IMO) and EU GHG instruments. Indeed, the IMO plans to implement more stringent controls of GHG emissions, targeting a reduction of CO_2 emissions by at least 40% by 2030 and 70% by 2050 (compared to 2008)[5].

Due to regulatory pressure and the need for accountability as well as greater investment capacities, these industries are progressing faster when it comes to addressing the necessary reduction of GHG emissions and the fishing industry's logical next step is to turn to these in search for technologies and measures potentially applicable to their own specificities.

According to Bastardie et al. (2022)[6] active fisheries (pelagic and bottom trawls) consume most fuel during their fishing operations. It therefore makes sense, cost-wise, to adopt measures tackling energy efficiency during fishing. When asked to list potential solutions, stakeholders from bottom-trawl fisheries covered measures in all aspects, such as engine change, strategic measures such as the use of auto-pilot, changes in strategy such as route optimisation and slow steaming as well as behavioural changes of the skipper, more efficient propulsion system, improved maintenance, shift to electric powered mechanisms from mechanical-hydraulic mechanism, use of LED lights and fuel monitoring devices.

If complete phasing out of GHG emissions is to be achieved, available concepts should be utilized in combination. These are:

- Technical energy efficiency (hull and superstructure (2-20% GHG reduction), speed optimization (<75% GHG reduction), concept, speed and capability (2-50% GHG reduction), power and propulsion systems (5-15% GHG reduction)
- Direct use of Renewable energy; sails (<100% GHG reduction)
- Alternative fuels (hydrogen and other synthetic fuels (80-100% GHG reduction), ammonia, biofuel 3rd generation (90% GHG reduction), bio-LNG/LPG (35% GHG reduction), electricity (50-90% GHG reduction))
- Operational energy efficiency (fleet management, logistics and incentives (5-50% GHG reduction); voyage optimization (1-10% GHG reduction))

Operational energy efficiency upgrades are:

- Transport capacity (deadweight decrease by ship size, material and lightweight structures, e.g. existing fibber ship project)
- Design speed reduction (slow steaming, reduced power demand)

[5] https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx
[6] https://www.researchgate.net/publication/228664618_Is_there_a_way_out_for_the_beam_trawler_fleet_with_rising_fuel_prices

- Hydrodynamic optimization (reduction of resistance (hull form optimization, air lubrication, antifouling solutions), improved propulsion (propeller optimization, appendages))
- Reduction in installed energy (direct use of wind energy (sail), direct use of solar energy, waste heat recovery)
- Reduction of specific fuel consumption (SFC) (improved energy converters, fuel cells)
- Alternative fuels (hydrogen, uranium, e-methanol, ammonia etc. Synthetic liquid fuels are favourable for transition).

Alternative fuels currently on the market tend to be more costly per unit as traditionally used fossil fuels. In order to remain cost-efficient, these need to be combined with other operational energy efficiency upgrades.

Carbon emissions in fishing sector dropped by 50% in 2017 compared to 1990. Furthermore, a drop to 59% of the engine power compared to 1990 has been recorded. This is due to the progress in technology which has improved fishing vessels' efficiency significantly. Furthermore, sustainable fisheries management has been an important factor in increasing fish biomass in European waters. This contributes to an overall decrease in the ratio of emissions produced and fish mass obtained, decreasing from 3.4kg of emissions per kg of capture to around 2.2kg since 1990[7].

2.3 Applied/applicable technical solutions

The scope of tailor-made solutions involves application of scientific knowledge and utilization of technological advances, including from other sectors, facilitation of transfer and adaptation of technologies and practices using EU funds (and other financing sources, if available), close cooperation with all stakeholders (fishing sectors, governments, scientific and shipbuilding communities) and compiling solutions already in development/on the market.

Some of the applied innovations with hybrid (diesel-electric) solutions, wind and solar propelling and alternative fuels are: Dutch vessel MDV-1 Immanuel[8] with its special shape of the vessel built with light materials and the diesel electric propulsion provides 60% fuel and CO2 savings compared to comparable fishing vessels. Karoline[9] from Norway is equipped with two battery packs of 195kWh and a 500-litre diesel engine. Diesel can be used to reach the fishing grounds, switching to electricity for fishing operations, loading and unloading. Project Sailfish[10], M. Penna Engineering, from Catalonia, Spain, and Balueiro Segundo[11] with eSAIL® system from Vigo, Spain, and co- funded via EU Aspiring Wingsails project, use wind power to augment diesel proportion. The Nautical University of Barcelona has developed combined solar panels and electric engine propulsion in trawlers with a reduction of 1600kg

[7] STECF (2022) Monitoring the performance of the Common Fisheries Policy; STECF-AdHoc-22-01 https://stecf.jrc.ec.europa.eu/reports/cfp-monitoring/-/asset_publisher/oz5O/document/id/26714692?inheritRedirect=false&redirect=https%3A%2F%2Fstecf.jrc.ec.europa.eu%2Freports%2Fcfp-monitoring%3Fp_p_id%3D101_INSTANCE_oz5O%26p_p_lifecycle%3D0%26p_p_state%3Dnormal%26p_p_mode%3Dview%26p_p_col_id%3Dcolumn-2%26p_p_col_pos%3D1%26p_p_col_count%3D2

[8] https://masterplanduurzamevisserij.nl/

[9] https://corvusenergy.com/projects/karoline-2/

[10] https://mpeng.eu/projects/sailfish-1700/

[11] https://bound4blue.com

of CO2 annually. Loran[12] is a 70m Norwegian longliner with two 185-kW hydrogen fuel cells and a 2,000-kWh battery bank, as well as conventional diesel engines. Loran will be operational end of 2023. Endeavour[13] from New Zealand is constructed to run on biofuel. It is claimed that, for every tonne of cooking oil used to produce the biofuel, there is a corresponding two tonne reduction in CO_2 emissions.

In terms of hull and fishing modifications, Martinez Constructions Navales[14] from Sète, France, developed a hull design and T-foil (that could be lowered or raised depending on conditions) in longliners and purse seiners offering 25% reduction in fuel consumption. IRBIM CNR from Mazara, Italy, is developing lighter fishing gear material in trawlers (e.g. using polypropylene instead of nylon) promising fuel consumption reduction from 1,2 tonnes to 0,8 tonnes per day.

Currently the most implemented GHG/fuel reduction solutions in fishing (gear category) are the use of more efficient gear and materials such as dyneema, Sumswing, pulse trawl, optical monitoring of the trawling operation, replacement for lighter gears and components producing less bottom contact (e.g. trawl shoes with wheels) (Bastardie et al. 2022)[15].

2.3.1 Alternative fuel: E-methanol

The NSAC explored e-methanol (renewable methanol) as one of the potential alternative fuels replacing carbon-based fuels. Other e-fuel options are liquid hydrogen, ammonia, methane and e-diesel/gasoline/jet fuel. Renewable e-methanol is produced from green energy (stranded H_2 from industry or generated green H_2 by electrolysis through the co-called Emissions-to-Liquids technology) and recycled CO_2 (recycled CO2 waste from emissions). Over the whole product lifecycle, from extraction and production through to end use, e-methanol can achieve carbon emission reductions of more than 90% compared to fossil fuels[16].

Methanol is a liquid, which makes it easier to establish a supply chain. The e-methanol is easy and safe to handle and engine technology for its utilization is readily available (see Wärtsila, MAN, Scania engines) and some sectors are already producing methanol engines (e.g. car and truck industry). According to Carbon Recycling International (CRI) several fleet owners (such as Waterfront, Stena Proman Bulk, Stena Line, Maersk) are already investing in e-methanol ships and there are over 100 harbors where e-methanol can be bunkered. With the current fuel crisis and expansion of the market, e-methanol is becoming more financially attractive and if taken up by the industry, would be able to compete with traditional diesel fuel. The global market for methanol as a fossil substitute is predicted to be 500mt by 2050[17][18].

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[12] https://www.nationalfisherman.com/boats-gear/-we-are-the-pioneers-building-a-hydrogen-powered-fishing-vessel
[13] https://www.rina.org.uk/biofuel.html
[14] https://martinez-constructions-navales.fr/foil-navire-de-peche
[15] https://www.researchgate.net/publication/228664618_Is_there_a_way_out_for_the_beam_trawler_fleet_with_rising_fuel_prices
[16] https://www.carbonrecycling.is/co2-methanol
[17] Ibid.
[18] https://www.carbonrecycling.is/news-media/2020/3/5/propelling-sustainable-shipping-renewable-methanol-as-a-future-marine-fuel-gewfh

Compared to other competing alternative fuels, like hydrogen and ammonia, e-methanol has advantages with regards to storage conditions (e-methanol requires a temperature of +65°C to turn to liquid; hydrogen -253°C and ammonia -33°C), volume of the tank compared to gasoil (2,2x for methanol, 2,8x for ammonia and 4,1x for hydrogen), technological availability (currently no engine manufacturers offering marine engines commercially for hydrogen and ammonia, while there are multiple for e-methanol). In terms of toxicity for marine life, ammonia is 35x more toxic than gasoil, compared to 0 for hydrogen and 0.004x for e-methanol. This is of particular importance in the event of leakage.

Low energy density of carbon-free fuels is an issue because for their storage complex containment systems are required implying certain safety issues. This is particularly the case for hydrogen and batteries, but also for ammonia. Gas fuel and batteries remain only an option for close-to-shore sea shipping, due to the need of refueling or recharging.

Methanol at the point of writing remains significantly more expensive than traditional fuel, though with the rising fuel prices and with achieving economies of scale by wider adoption, methanol could become an optimal solution for energy transition. Given the minimum retrofitting (and thus financial investment) needed to run a vessel on methanol – a retrofit/change of engine which is readily available – methanol seems like a go-to short term solution in transition to zero emission energy.

2.3.2 Wind propulsion

In search of zero emission propulsion systems for vessels, application of renewable energy to vessel propelling has gained traction in recent years. Although simple, this technology based on the use of direct wind to push vessels, has been used for hundreds of years and was only replaced worldwide in the last century. Until recent progress in the field due to mentioned driving forces (climate change, rising fuel prices etc.), it seemed unlikely that wind-dependent technologies would be reconsidered as vessel propelling mechanisms. Nevertheless, organisations such as the International Wind-Ship Association (IWSA) have listed solutions capable of assisting, and in some cases, fully replacing the use of fossil-fuel-based engines.

Wind Propulsion Technologies (WPTs) are engineering products and mechanisms designed to assist or fully propel ships with the use of wind. One of the key aspects of this technology is the concept of Direct Wind Propulsion (DWP) which is reasoned by the direct use of wind into propulsion instead of relying on a supply chain that will have energy losses of around 90% (extraction, refining, thermal losses in engines, etc.). Wind is considered a “pure zero energy source”, meaning it is free of costs (production, transportation, and transformation costs). Apart from zero GHGs emissions, the use of wind also tackles other issues problematic for shipowners such as, for example, the storage capacity. WPT have the advantage of either being incorporated in the design of the vessel (in the case of newbuilds) or being fitted on the deck of an operating vessel at any given time. The second option might compromise some porting operations, but it can easily be resolved by foldable or retractable actions as foreseen by manufacturers. In addition, recent developments in WPTs allow these wind-powered structures to be functional without additional crew or trainings. The Return On Investment (ROI) of these systems is rapid and the technology is readily available.

A vessel retrofitted to equip WPT could produce savings between 5%-20% in fuel usage, and 30% if fully optimised. However, in the case of a newbuild, the savings could be as high as

80% due to changes in the traditional design. However, these numbers vary depending on the type of route the vessel takes (higher saving rates are correlated with longer voyages). Currently, there are about 21 ocean-going vessels equipped with wind powered systems, from which 20 are small sail cargo, fisheries and cruise vessels and one is wind-ready. According to experts at the IWSA, it is expected that this number will double by the end of 2023. Projections show that the number of wind-assisted vessels could reach 11.000 ships by 2030.

The different designs of WPT, according to specialists, revolve around seven types of mechanisms:

- Rotor Sails: wind-powered rotational cylinder that revolves around an axis which moves at around 300rpm by using the Magnus effect (which is based on different air pressures on different sides of a rotary object). They can reach up to 35m and 5m of diameter.
- Suction Wings: non-rotating wing with an internal fan that generates a suction effect which then enhances the propulsion of the ship by moving the surrounding air. Its size can vary from 10 to 17m.
- Hard Sail / Hybrid Sail: Inspired in the racing hard sails, these types of sails act as ordinary sails in their physical principle, but present solutions regular sails can't, such as movable flaps or solar panel coatings. Hybrid sails present both options, rigid and soft sails. Up to date, these sails range from 2mx 9m to 15m x 35m.
- Traditional Soft Sail: They are both used in commercial vessels with fully automated systems which eliminates the need of additional crew. Commercial applications require foldable or retractable masts.
- Kite: It works as a regular kite that is deployed at over 200m above the vessel and assists with the propulsion of the vessel by pulling it. They take advantage of the constant winds of high elevations and can work passively by maintaining a single position or dynamically by performing an 8-figure to maximize thrust. Dependening on the wind direction, there could be issues with deployment and retrieval. They can vary from 500m2 to 1000m2 in size.
- Turbine: These marine adapted wind turbines can either generate electric energy or a combination of electric energy and thrust. They are designed to be both vertical and horizontal. They can be the size of normal containers or just freely standing.
- Hull Form: This is a type of design that elevates the whole ship's hull in order to function as a large "sail" capturing the wind power to generate thrust. When applying this system, issues with stability, extreme weather performance and applicability almost exclusively to newbuilds, could be expected.

The main downside of these technologies is the availability of deck space, ability to retract when entering ports, line sight obstruction and the durability of some of the materials applied. However, most of these issues can partially be resolved with minor adjustments such as rail systems to move the structures and foldable mechanisms to retract them when needed. Additionally, containerised versions of WPT are currently under development and experimental stage, which will allow the possibility of managing when and how much power units are needed in a certain route, and the option of not carrying any in the following journey, if so desired. This opens opportunities for leasing solutions and other related possibilities, such as the use of vessels for energy production to be used on land or onboard when needed (e.g. in the case of poor wind conditions).

In the future it might be possible to operate carbon-negative vessels, like the "Wind Hunter"[19]. Such a vessel will not only be capable of using the wind as its only source of power but will also harvest the excess energy produced and store it in the form of hydrogen which will then be delivered to land ports. Other examples of fishing vessels that incorporate versions of these technologies are: *Balueiro Segundo*, a 41m vessel operating in the waters of Peru under Spanish flag, uses an eSAIL; a suction wing system that enhances the performance of the ship by creating boundary layer around the vertical wing, which is only possible due to an internal fan that sucks air inside. Regarding soft sail mechanisms, the *Grand Largue*, a 16m trawler from France, uses two bipod masts with automated sail systems that help in the overall fuel consumption and in decreasing rolling consistently. In the future, there are rigid sail options being considered for this type of vessel. Last but not least, the *SailLine Fishing* which is a system that can be adapted to numerous types of small vessels. Due to its ambiguity and smart design, it can be retracted and folded, which makes it suitable for a variety of small vessels.

2.4 Challenges in applying new technology and measures

Between 30 and 50% of the gross revenue of beam trawlers goes to fuel. Fuel consumption is often a defining factor in operation of a (demersal) fishing vessel and measures are necessary to reduce this cost (Depestele et al, 2007)[20]. Many fishing vessels have recently been tied up in ports with fishing operations becoming unviable due to rising fuel costs. It is therefore understandable that any new technologies requiring additional investments and/or alternative fuels exceeding the price of traditional fuels mean an additional strain on already limited budgets and should therefore be incentivised. Bastardie et al. (2022)[21] note that implementing existing energy-efficient technologies would require improved uptake of innovations and demonstrations to stakeholders of reduced fuel costs and increased (or at least stable) catch rates.

Hybrid technologies are the most mature type of technology available to date. However, these are not yet optimally deployed and used due to the lack of experience, additional construction costs and the need for additional space for engines and batteries. Liquified Natural Gas (LNG) is a technology commonly used in large shipping vessels due to its broad availability. On the other hand, they are of limited use for the fishing fleet due to the large size containers that don't fit in smaller vessels, regulation not allowing storage of LNG cylinders on board, the need for additional crew members, specific security parameters, and gross tonnage limitations hindering the adoption of architectures and technologies that minimize environmental impacts.

In what concerns hydrogen and electric power, there is still a challenge to achieve reasonable autonomy levels. In the short term this technology can be equipped in small vessels, however about 10 to 20 years of development is needed to reach comparable performance between hydrogen/electric powered ships and diesel ones. This is due to the fuel cells not being

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[19] https://www.mol.co.jp/en/pr/2020/20080.html

[20] https://www.researchgate.net/publication/228664618_Is_there_a_way_out_for_the_beam_trawler_fleet_with_rising_fuel_prices

[21] Ibid.

adapted to all engines and fleets (hydrogen cells are currently in a testing phase (in France)), regulatory limitations, and no autonomy for vessels at sea for longer periods.

In terms of volume of alternative fuels compared to traditional fossil fuels, in the case of LNG 1.75 m3 would be needed to replace 1m3 of fossil fuel, 2.63 m3 for methanol (CH3OH), 3 for ammonia (NH3) and 4.6 m3 of liquid hydrogen. Other differences are in storage temperature, type of emissions, toxicity, and fuel availability. Storage capacity presents a challenge due to capacity ceilings introduced in the Common Fisheries Policy.

Technological progress and adoption are slow in the sector due to the low acceptance of crew, safety issues, additional training required and the fact that risks of transitioning to new technologies are carried out by the shipowners, who often pay the price of being first movers. Public funding is mainly directed to research projects, not covering the risk taken by the shipowners, which leads to a general lack of acceptance. Among other aspects hindering adoption of new technologies are port equipment (charging stations, LNG storage) and marketing logistics.

Finally, it might prove difficult to encourage fishing companies to invest in green technologies that are not yet mature. As mentioned, the main limitation is the adaptation of technologies to the size of fishing vessels and to the different fishing techniques. The so-called capacity ceiling is a measure whereby any entry of capacity (gross tonnage and engine power) in the fleet must be offset by a decrease in the general capacity (entry/exit system). In order to improve energy efficiency of a vessel by e.g. replacing engine, one might need to increase the gross tonnage resulting in increased capacity. It is up to individual Member States how they make the system operational, as long as they remain within the ceiling. Some Member States have a system of reserve, reallocating capacity later, some reallocate it to the same operator, while some decide to dismantle fishing capacity altogether (known as overcapacity reduction tool). A margin between actual capacity and the ceiling offers opportunity for reallocation. As stated in the NSAC Advice on the Report of the CFP[22], there is a need to reflect on the definition of capacity that would allow EU fishing fleet to adapt to environmental and social challenges without increasing the ability of the vessel to catch fish.

Further investigation of the degree of maturity of new technologies and their degree of adaptation/limitations is required. It is imperative that discussions at EU level take place between all stakeholders involved (policymakers, engine manufacturers, fisheries representatives, NGOs etc). It is also sensible that fuel taxes are not introduced before considering the availability of new propulsion technologies. Furthermore, opening of the legislative framework to allow for modernisation, installation, and use of these technologies is a necessary prerequisite for technological adoption.

It is also important to note that some perceived solutions may be leading to new problems. For example, it is agreed that vessel speed reduction can work as a measure to fight carbon emissions, however a question remains what might happen to the quality of the product. Questions on the ban and use of unique fishing gear and on “fishing closer to the coast”-policies are also relevant.

Bastardie et al. (2022)[23] support the NSAC observation that despite existing and trialled energy efficiency mechanisms and technologies there is no consensus yet on its applicability

[22] https://www.nsrac.org/wp-content/uploads/2022/05/10-2122-NSAC-Advice-on-CFP-Report.pdf

[23] Ibid.

to fisheries sector and consequently their uptake is lagging. Author also observed that the North Sea beam trawl flatfish fishery (covered by the NSAC) has seen fuel use intensity decrease in the last 20 years, with no changes to fuel efficiency. Decrease in fuel intensity derives from innovations improving the catch and reducing energy use in fishing activity. As we go forward, fuel use monitoring is essential to determine energy savings in the transition period.

One of the emissions-reduction objectives in the Paris Agreement states that every ship designed and built today must operate with a Net-Zero-Emissions scenario at the end of their service. This arises many questions in the sector, as there is currently no clear guidelines on any specific path to follow in order to accomplish this goal. Members of the fishing industry argue that the use of alternative fuels is either non-available or too costly to implement. However, it is believed by the experts in the Energy Transition Council[24], that in a scenario where 20 % of fuel could be saved until 2030, the savings would be enough to pay for the entire decarbonisation of shipping by 2050 (infrastructure and alternative fuels). The NSAC believes that development of industry guidelines on availability of zero emission technology and their applicability to the sector would prove beneficial.

Before adoption of any one type of technology, a comparative and SWOT analyses would be highly beneficial. The key challenge for a third-party comparative analysis of the different systems is that the number of variables involved makes it a highly complex endeavour and there are currently no public third-party data on installations in a way that a definitive study can be undertaken. This is expected to change in the next couple of years. There are, however, some studies that have carried out related work:

- EU DG Clima report from 2016/17 https://cedelft.eu/publications/study-on-the-analysis-of-market-potentials-and-market-barriers-for-wind-propulsion-technologies-for-ships/
- The EU Interreg WASP project covering three different technologies and an overview assessment of others: https://vb.northsearegion.eu/public/files/repository/20210111083115_WASP-WP4.D5B-NewWPTALiteratureReviewofRecentAdoptions-Final.pdf
- An independent assessment of wind-assisted propulsion: https://www.finoceanltd.com/wind-assisted-propulsion-the-book/
- There are a number of IWSA members that will carry out analysis for clients – e.g. MARIN, SSPA, SINTEF, HSVA, Blue WASP etc.

The NSAC believes that a comparative study commissioned to an independent third party would prove beneficial for developing a roadmap for fisheries energy transition.

2.5 Opportunities

The 2008 fuel crisis presented one of the opportunities for improved energy efficiency in beam trawl fisheries resulting from gear modifications. In response to the crisis, beam trawls with chain mats had installed roller wheels to lessen the drag on the seabed and beam trawls with tickler chains applied the SumWing to reduce seabed contact points. Soon after considered controversial, pulse trawl was one of the presented solutions for reduced fuel use by using

[24] https://www.seforall.org/system/files/2021-11/ETC-Strategic-Priorities.pdf

electricity to catch fish, until this method was prohibited in 2021 (Bastardie et al. 2022)[25]. It is worth noting that frequent regulatory changes could cause vessel owners to become increasingly reluctant to invest in technology, which might be overruled by regulation coming in place in the future.

Other modifications include new netting designs and materials for otter trawls, use of twin trawl or multi-rig and replacement of bottom-contacting trawl doors with lighter and more hydrodynamic pelagic doors. The authors suggest that a joint application of these innovations could cater for substantial (up to 40%) reduction in fuel us and/or catch efficiency (Bastardie et al. 2022)[26].

To monitor and account for the saved fuel resulting from the application of novel technologies or strategies, fuel monitoring tools will be essential to collect data. Pilot studies will be important vehicles for informing research needs and policy direction through data collection and their interpretation (Bastardie et al. 2022)[27]. These will also act as direct promotor for industry uptake of technologies that effectively reduce fuel consumption, fuel intensity and improve overall catch efficiency.

The first step on the way to adoption of existing techniques is effective communication, exchange of information and cross-pollination of ideas between various sectors and the EU and international policy-makers (such as the IMO). Some of the direct incentives from other sectors and applicable to fishing industry leading to reduced fuel consumption according to Bastardie et al. (2022) are: taxation or other benefits based on performance in saving fuel (also see: energy performance contracting), fuel tax, restrictions to engine power, restrictions to gear, improvement of fish stocks, fish quota systems, increase in fuel price, eco-certification, reduction of effort, improved skippers' skills, and good practice reward system.

In terms of financing, the NSAC firmly agrees with Bastardie et al. (2022) that funding for energy efficiency improvements should be secured by the EU and its dedicated EMFAF fund with accompanying market strategies. As already underlined, any additional investments would present a disadvantage for many of the (demersal) fleets and some are not viable to take upon any additional financial strains. It is therefore crucial that financial support is provided by the existing and future EU instruments dedicated to decarbonisation of its industries.

3 NSAC Advice and Conclusion

This paper aims to collect information and establish a form of factual state of play with existing, applied and applicable tools for energy transition in the fishing sector. This is the first step in what will inevitably be a long process of deliberation, with an increasing number of factors considered, weighed and negotiated. Given the current difficult economic situation of the demersal fishing fleet, high prices of fuel and new technologies, and regulatory uncertainty, the NSAC is not in a position to determine a way forward that would be most optimal and viable for the fleet. We do, however, provide interested parties with many important information that should serve as a starting point for further deliberation. As the Commission is working

[25] Ibid.
[26] Ibid.
[27] Ibid.

towards publishing its Action Plan to promote and support energy transition of the sectors in 2023, we appeal to the legislators to remain in close contact with the sector and other fisheries stakeholders at all stages of the process. We remain open to providing further feedback to future proposals.

Considering the above, the NSAC members advise:

- To further include stakeholders in the decision-making regarding the transition of the EU fishing fleet towards decarbonization as to ensure the legitimacy of the measures and the acceptability for the end-users.
- To take into account the enormous investments technologies related to energy efficiency and alternative to fuel represent for the EU fishing fleet which highlights the need for external funding, tax and market incentives, as well as legislative certainty.
- To introduce realistic objectives in term of decarbonization of the sector, taking into account the level of knowledge and scientific research, the cost of transition and the funding available.
- To focus, in the short term, on improving the energy efficiency of the existing fleet with the objective of reducing fossil fuel consumption (new type of gears, solar and wind propulsion, vessel design, etc.) while further research on the fuel alternatives is ongoing and the costs of new technologies are becoming more affordable.
- Before adoption of any one type of technology, to conduct a comparative and SWOT analyses of the different technological solutions. A third-party comparative analysis of the different systems should consider a number of variables, including their technical characteristics and challenges, technology's maturity, price, applicability to fishing sector and other defining factors.
- To clarify if the intention is to include the fishing sector in Emissions Trading System (ETS) in the near future.
- To accelerate fundings of research projects on decarbonization of the fishing fleet (energy efficiency and fuel alternative) as they so far mainly concern the shipping sector and the adaptability to fishing sector is not yet certain. In this regard, the European Commission could work more closely with the European Investment Bank to ensure alignment of priorities between the two institutions.
- One of the emissions-reduction objectives in the Paris Agreement states that every ship designed and built today must operate with a Net-Zero-Emissions scenario at the end of their service. There is currently no clear guidelines on any specific path to follow in order to accomplish this goal, therefore we call on the relevant bodies to establish these in collaboration with the sector.
- To evaluate the definition of capacity (gross tonnage and engine power) with regards to the space and weight that new types of engines using fuel alternatives may require without compromising conservation objectives.
- To bear in mind that new engines technologies using alternative fuels will engender new types of skills for the seafarers and will considerably change day-to-day working methods. In that regard, training should be encouraged and funded via the European Maritime, Fisheries and Aquaculture Fund (EMFAF).

- To ensure that, while considering alternative fuel, all consequences for the marine ecosystems (biodiversity, toxicity, noise, etc) are taken into account as to not engender new threats for the environment. In that regard, the Commission should envisage environmental impact assessments of these technologies.