STUDY

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European Parliament

Workshop on the European Green Deal – Challenges and opportunities for EU fisheries and aquaculture

Part I: Decarbonisation & circular economy aspects for fisheries

Fisheries

Policy Department for Structural and Cohesion Policies
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Workshop on the European Green Deal– Challenges and opportunities for EU fisheries and aquaculture

Part I: Decarbonisation & circular economy aspects for fisheries

Abstract

This study is the first research paper in a series of three, prepared for a PECH Committee Workshop. It gives insight on the challenges and opportunities arisen from the application of the European Green Deal to European fisheries. It identifies solutions that are currently being applied regarding decarbonisation and circular economy practices in fisheries and observed strengths and weaknesses of the regulatory framework. It provides policy recommendations to move towards the decarbonisation of the fishing fleets and circular European fisheries.

This document was requested by the European Parliament's Committee on Fisheries.

AUTHORS

AZTI: Oihane C. BASURKO, Martin ARANDA, Ainhoa CABALLERO, Marga ANDRES, Jefferson MURUA, Gorka GABIÑA

Research administrator: Marcus BREUER
Project, publication and communication assistance: Ginka TSONEVA, Kinga OSTAŃSKA, Stéphanie DUPONT, Anton KÜCH (trainee)
Policy Department for Structural and Cohesion Policies, European Parliament

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ABOUT THE PUBLISHER

To contact the Policy Department or to subscribe to updates on our work for the PECH Committee please write to: Poldep-cohesion@ep.europa.eu

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LIST OF ABBREVIATIONS

ALDFG	Abandoned, lost or otherwise discarded fishing gear
CEAP	Circular economy action plan
CFD	Computation Fluid Dynamics
CFP	Common Fisheries Policy
CLLD	Community Led Local Development
EC	European Commission
ECL	European Climate Law
EFF	European Fisheries Fund
EGD	European Green Deal
EMFAF	European Maritime, Fisheries and Aquaculture Funds
EMFF	European Maritime and Fisheries Fund
EOL	End of life
EPR	Extended producer responsibility
EU	European Union
EU ETS	EU Emissions trading system
FAD	Fish agreggating devices
FFL	Fishing for litter
FLAG	Fishing local action groups
FUI	Fuel use intensity (l fuel/t fish landed)
GHG	Greenhouse gas
GT	Gross tonnage
IMO	International Maritime Organization
JRC	Joint Research Centre

LAG	Local action groups
LNG	Liquified natural gas
LO	Landing obligation
LPG	Liquefied petroleum gas
MCRS	Minimum conservation reference size
MRV	Monitoring, reporting and validation
PRF	Port reception facilities
SUP	Single use plastic
TRL	Technology readiness level

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EXECUTIVE SUMMARY

Background

The European Green Deal (EGD) aims at transforming the EU into a resource-efficient, modern and competitive society. This can be achieved by making Europe carbon neutral by 2050. To facilitate a gradual transition, the EU must reduce its net greenhouse gas (GHG) emissions by at least 55 % by 2030 from its 1990 levels. All industrial sectors and society, in general, will have to contribute to this endeavour, and the fisheries sector is no exception. This study sheds light on two fundamental aspects of EGD: the decarbonisation and the circular economy of European fisheries. This study presents the policy framework, successful examples, observed challenges and some policy recommendations.

Decarbonisation of fishing fleet

The **decarbonisation of EU fisheries** will be achieved by having fleets consuming less fuel, using alternative energy sources, while fishing sustainable fish stocks. Over **20 solutions are presented** in this report as possibilities that could be applied by the fishing sector as part of its energy transition. Some of the solutions are targeting the (a) vessel's **strategy** (e.g. how the fishing vessel is operated), others, (b) the **vessel structure and** onboard **equipment**, and (c) energy efficient **fishing gear**, and the last group (d) focuses on **catchability**.

Defining the energy and activity patterns of a vessel is key to start outlining the **decarbonisation strategy** for any vessel. Nowadays, however, the selection of a solution is often made blindfolded. Installing an **energy monitoring device** and conducting **energy audits** should be, therefore, the first step in this process because they provide accurate information on how energy is consumed onboard, by which equipment, and their share during navigation and fishing phases.

Other successful implementations include the reduction of navigation **speed** for vessels presenting long navigation distances in their trips, the use of low emission or hybrid **engines**, alternative **fuels** and antifouling **coatings**, or a **bulbous bow**.

In terms of efficient **fishing gear**, the use of rolling wheel for trawl shoes or the SumWing have proven to be successful for beam trawlers. In contrast, for otter bottom trawls, the use of lighter netting designs, semi-pelagic trawl doors or remotely controlled doors are mostly recommended.

Despite the diversity of solutions, not all of them are suitable for all vessels. **Training** is needed to facilitate this energy transition amongst fishers and other stakeholders, and mechanisms to improve the **knowledge transfer**.

Circular economy in fisheries

Circular economy in the fisheries sector has been mainly focused on solutions addressing **fishing gear smart designs**, innovative approaches to **reduce the dumping of litter** at sea, marine **litter collection**, and efficient **recycling** channels. While circular design of fishing gear has a lot of potential and a long way to go, it is still at an early stage.

In contrast, the development of initiatives that address the recovery, reuse, recycling and upcycling of **marine litter** and end of life (**EOL) fishing gear** has been more popular, and the results are already being applied involving the fashion industry, with major fashion brands starting to produce garments made from marine plastic or EOL fishing gear. This growing number of initiatives not only indicates a new market niche and a new **production model**, but also changes in society's **consumption pattern**.

However, **few circular examples applied to small-scale fisheries** have been found, apart from engaging fisheries in active or passive fishing for litter (FFL) schemes, which aim at retrieving marine litter from the sea on a paid or voluntary basis. **Port reception facilities** should be improved across Europe, and local or regional **management schemes** for **EOL fishing gear** and **marine litter** are recommended to facilitate circular economy practices amongst the fishing sector and harmonise the approach towards a carbon neutral Europe.

Policy recommendations

The current implementation of decarbonisation solutions is on average very low in fisheries worldwide, also in EU fisheries. To guarantee an **effective energy transition** and to start **decarbonising the European fisheries sector**, the following policy recommendations can be given.

- Define a **fisheries roadmap towards decarbonisation**.
- **Revise EU's definition of the term fishing capacity**, because adding more GTs or kW does not necessarily increase a vessel's ability to fish, and is a *sine qua non* condition for applying some of the energy efficiency solutions.
- Embrace a simpler and **more flexible processes for funding** application for investment or installation of energy efficient solutions
- Promote the **implementation of a mixture** of energy efficient **solutions** due to there is no 'one-fit-all' solution applicable to all fishing vessels and fishing modalities.
- Promote the installation of **energy monitoring devices** in all fishing fleet segments.
- Make the **European Data Collection Framework** include detailed data on energy consumption of fisheries reported by energy monitoring devices.
- Encourage the inclusion of fishing vessels of different sizes in the energy efficiency policy framework of the **IMO** (MARPOL 73/78).
- Establish a **European cooperation platform** to address energy efficiency in fisheries, exchange successful stories, promote dialogue and cooperation, and facilitate the transference of information and sustainability awareness.
- Promote the development of **seafood labels**/eco-certifications incorporating the carbon footprint or Fuel Use Intensity (FUI) score of the fishery on food products.

Circular economy initiatives in the fisheries sector have been mainly focused on recycling of end of life (EOL) fishing gear and marine litter into garments or accessories. However, this is short-sighted as circular economy implies a wider consideration, which can promote job creation and additional income. Policy recommendations to **implement the circular economy in fisheries** are:

- Define sectoral **roadmap** to develop the **circular economy in fisheries' value chain**.
- Outline an agreed **definition for circular fishing gear** including targets for recycled content within the gear and associated legislation to enhance the design but also the implementation of circular gears onboard the fishing fleet.
- Establish a standardised approach to **mark and label the polymers and materials composing the fishing gear** to facilitate its final recycling.
- Define a **standardised collection, sorting, conditioning and recycling scheme** for EOL fishing gear and marine litter at European level. This implies: making **port reception facilities**

for EOL fishing gears and marine litter **ubiquitous in all European ports** regardless their size; including this type of waste in established **waste treatment streams**; and adding the collection, conditioning, sorting and recycling of marine litter and EOL fishing gear as part of the **service contracts** of port waste managers, so that fishers would not have to pay an additional fee for the management of such waste.

- Financially support programmes that promote the expansion of **fishing for litter** (FFL) **schemes across Europe**.
- Set **national minimum collection rates** for marine litter and EOL fishing gear.
- Develop a **reporting system**, which is appropriate for local fishers, to document the extent and location of abandoned, lost or otherwise discarded fishing gear (ALDFG), marine litter collected by FFL activities and EOL fishing gear discarded in port.
- Establish an **EPR scheme for fishing gear** with financial schemes and support, and with defined responsibilities.
- Establish mechanisms to **improve the logistics** associated with the full value chain for the recycling of marine litter and EOL fishing gear across Europe.
- Improve the **collaboration, cooperation, and dialogue amongst stakeholders** and between and within regions to establish responsibilities regarding the management for these waste types.
- Promote and finance **research and innovation** on circular economy in fisheries, e.g. circular design of gears, alternative management systems, conditioning and recycling technology, smart logistics, etc., by **supporting pilot projects**, and **synergies** between stakeholders (e.g. the fishing sector, businesses).
- Incentivise the **development of local circular solutions and projects** embracing the cooperation and partnerships between actors of the fishing industry's value chain, FLAGs, local waste managers, recycling companies and other entrepreneurs.
- Promote the **market for recycled fishing gear** and marine litter by, for example, fostering the green procurement of marine plastic-derived products.
- Promote the **traceability of products** made of marine plastic or other fishery-related wastes by, for example, establishing a label to define plastic of marine origin (link to digital product passport).
- Increase **awareness raising and training skills activities** for reducing the marine litter contribution from fisheries and increase the participation in circular solution practices.

1. STATE-OF-PLAY OF THE POLICY INITIATIVES OF THE EGD

KEY FINDINGS

- The European Green Deal (EGD) is the **roadmap for EU climate and environmental policies**, which are being aligned to transform Europe into a resource-efficient, modern and competitive society. This is achieved by making Europe carbon neutral by 2050.
- As part of the **decarbonisation path**, the European Commission adopted a set of proposals to facilitate a gradual transition towards carbon neutrality by setting an interim union climate target of **reducing Europe's greenhouse gas** (GHG) emission by at least **55% by 2030**, compared to 1990 levels. This applied to the fishing industry implies a need for decarbonising the **fishing fleets** through a GHG emission reduction of **30% by 2030** compared to 2005 levels.
- Not only an energy transition is needed to reduce GHG emissions from fuel combustion, but **circular economy** also plays an important role in shaping the future of Europe and the way products, materials and food are made. To achieve this, the **EMFAF and other funding schemes** are available to implement solutions within the fishing industry.

1.1. Overview of the European Green Deal package linked to decarbonisation and circular economy applied to fisheries

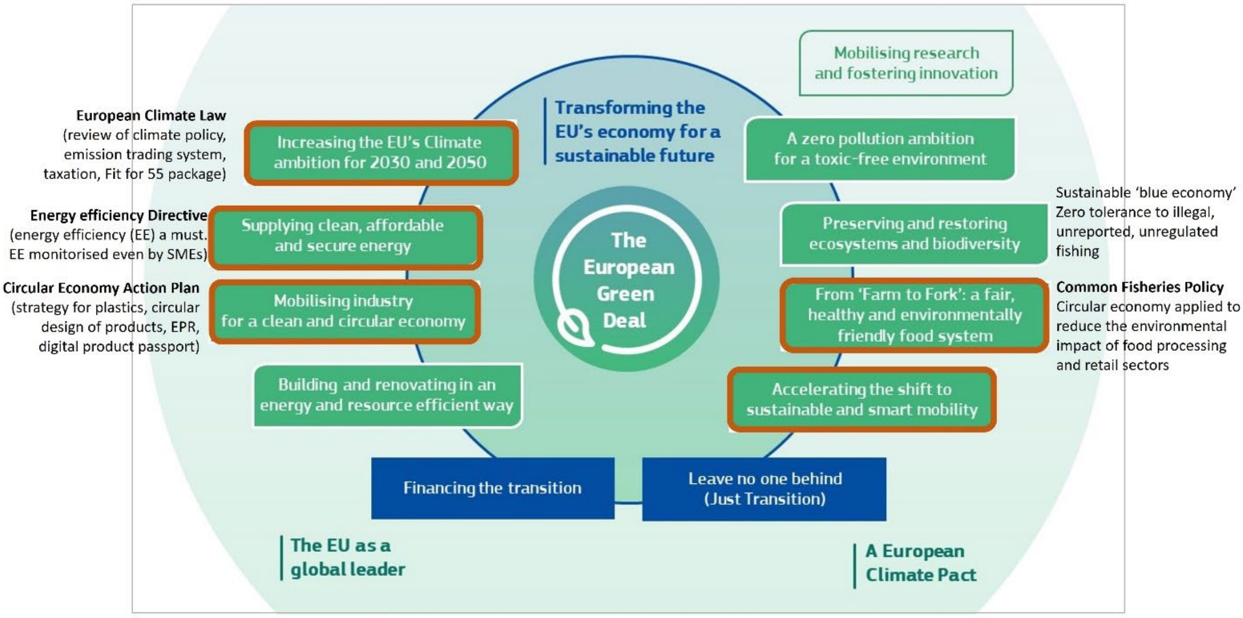
Climate change has become one of the major challenges of the modern world. To tackle its negative impacts, world leaders signed the **Paris Agreement**, a legally binding international treaty on climate change, at the UN Climate Change Conference (COP21) in Paris in 2015 (UNFCCC, 2016). The Paris Agreement called on countries to strengthen their commitments and global response to the threat of climate change over time to reduce their emissions. This included holding the increase in the global average temperature to well below 2 °C but pursuing efforts to limit the temperature increase to 1.5 °C. At the conference, the EU committed to carbon-neutrality by mid-21st century. As a result, in 2019, the Commission presented the European Green Deal as its flagship plan to make Europe climate neutral by 2050

European Green Deal (EGD) is the roadmap for EU climate and environmental policies. This growth strategy aims at "*transforming the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy society, where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use*". This is achieved by making **Europe carbon neutral**[1] **by 2050** (European Commission, 2019).

The decarbonising of the fishing industry has been approached from different angles within the EGD. This includes an energy transition within the climate ambition, a clean and competitive industry by making fisheries related products and practices circular, a "Farm to Fork" strategy in which the Common Fisheries Policy (CFP) is defined, and linking to sustainable smart mobility as fishing vessels are vessels in their own right (Figure 1).

[1] Carbon neutrality means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks.

Figure 1: Elements of the European Green Deal package, in orange those related to the decarbonisation of the fisheries industry according to the authors.



Source: adapted by the authors from the European Commission (2021)

1.1.1. Increasing the EU's climate ambition for 2030 and 2050

In order to achieve the climate neutrality[2] by 2050, the European Commission (EC) created the first **European Climate Law** (ECL) (Regulation (EU) 2021/1119)[3] to set climate neutrality into binding EU legislation and to ensure that all EU policies and sectors contribute to this goal. To facilitate a gradual transition towards climate neutrality, interim emission reduction targets were set, which imply a reduction of net greenhouse gas (GHG) emissions (emissions after deduction of removals) by at least 55% by 2030 compared to 1990. To achieve this, the Commission adopted the **'Fit for 55' package** in July 2021 (European Commission, 2023a), a set of interconnected and complementary proposals. Some of these proposals include the update of directives that target the maritime sector for the first time. They also embrace a tightening of the existing **EU emissions trading system** (EU ETS); increased use of **renewable energy**; greater **energy efficiency**; a faster roll-out of low emission transport modes and the **infrastructure** and **fuels** to support them; an alignment of **taxation** policies with the EGD objectives; measures to prevent carbon leakage; and tools to preserve and grow natural carbon sinks. The link to fishing and shipping is summarised in Annex A.1.

Furthermore, the most recent Communication on **energy transition** (COM(2023) 100) strengthens the need to **break away** from the **fossil fuel dependency**, with a dual objective: to increase future resilience of the fishing sector; and reduce the carbon footprint of fisheries products. This may be achieved by the uptake of energy efficiency investments in the short to medium-term, developing additional renewable and low-carbon energy sources in the medium to long-term, and always boosting the implementation of energy efficient solutions within the sectors. The energy transition is not without barriers. The Commission is planning to overcome these challenges by, for example, organising a conference devoted to energy transition, launch the Energy Transition Partnerships on EU

[2] 'Climate neutrality' by 2050 means achieving net zero greenhouse gas emissions for EU countries as a whole, mainly by cutting emissions, investing in green technologies and protecting the natural environment.

[3] https://eur-lex.europa.eu/eli/reg/2021/1119/oj

fisheries and stakeholders, stakeholder consultations, requesting studies on available energy efficient technologies, launching a user friendly web tool to assess the impact of fuel prices, set a platform to knowledge and best practice exchange, and promote grants under the European Maritime, Fisheries and Aquaculture Funds (EMFAF) and "blue carriers" calls.

1.1.2. Supplying clean, affordable and secure energy

EU's energy supply needs to be secure and affordable for consumers and businesses. However, the high energy dependence of different economic sectors puts Europe in a delicate situation before potential gas or fuel crisis events, such as the one occurred with Russia and Ukraine in 2022. To overcome this, **energy efficiency and renewable energies** have been placed at the core of the EGD's climate ambition strategy.

1.1.3. Mobilising industry for a clean and circular economy

The EU's industry has started the shift toward a circular economy, but it is still too "linear", meaning that there is still little concern about the ecological footprint and consequence when designing products and managing wastes. Only 12% of the materials used by the industry come from recycling (European Commission, 2019). In response, a new **circular economy action plan** (CEAP) was created to modernise the EU's economy and draw benefit from the opportunities of the circular economy domestically and globally. The CEAP will prioritise reducing and reusing materials before recycling them. It will foster new business models and set minimum requirements to prevent environmentally harmful products from being placed on the EU market. **Extended producer responsibility** (EPR) will also be strengthened (Directive (EU) 2019/904). The green digital passport intends to reduce the risk of green washing practices of the plastic industry. Two directives are leading the path. Directive (EU) 2019/904 is setting rules for **single use plastic** (SUP) for the top 10 SUP items found on European beaches, as well as for 'abandoned, lost, or otherwise discarded fishing gear' (ALDFG), and end of life (EOL) fishing gear[4]. Directive (EU) 2019/883 on **port reception facilities** (PRF) is regulating the handling of wastes from ships, including fishing vessels. It also is defining that fishers may discard passively fished waste ashore, in addition to waste generated onboard and cargo residues.

1.1.4. Accelerating the shift to sustainable and smart mobility.

Transport accounts for a quarter of the EU's GHG emissions, and is still growing. To achieve climate neutrality, a 90% reduction in transport emissions is needed. As regards the maritime sector, the adopted strategy will be coordinated with the IMO (International Maritime Organization), which is linked to the Fit for 55 package (Annex I) and the energy transition strategy.

1.1.5. From 'Farm to Fork': designing a fair, healthy and environmentally friendly food system.

Current food production system results in air, water, and soil pollution, contributes to the loss of biodiversity and climate change, and consumes excessive amounts of natural resources, while an important part of food is wasted. The Farm to Fork Strategy will strengthen and accelerate the transition to a more sustainable food system. The **CFP** is central to support these efforts while ensuring a decent living for fishers and their families. The last revision of the CFP recognised the need to support the **EU 2020 Strategy** and the achievement of its objectives. The first objective of the CFP regulation (Regulation (EU) 1380/2013) is "*Promoting environmentally sustainable, resource-efficient, innovative,*

[4] EOL fishing gear: fishing gear, nets, ropes sorted out and removed by fishers after the end of its useful operating lifetime, typically because of damage and loss of net or rope strength

competitive and knowledge–based fisheries", which implicitly includes energy efficiency as one of the goals. In addition, its Article 17 includes provisions for Member States to the development of incentives to energy efficient vessels, when it comes to the distribution of fishing possibilities. Thus, the basic regulation considers energy efficiency as a positive factor that can be rewarded since it reduces the environmental impact and thus should be promoted. The Farm to Fork Strategy will also contribute to achieving a circular economy by implementing solutions that reduce the environmental impact of the food processing and retail sectors including the transport, storage, packaging and food waste.

1.2. Other regulatory frameworks and funds

1.2.1. Policies linked to decarbonisation and circular economy in fisheries

In Table 1 below, other policies and strategies that have a direct effect on the decarbonisation of fisheries and circular economy practices at European and international level are shortly.

Table 1: European and international policies affecting the decarbonisation of fishing fleet and circular economy practices in fisheries

Level	Decarbonisation	Circular economy
International	• MARPOL Annex VI, Energy efficiency	• MARPOL Annex V, waste onboard, reporting and recovery of ALDFG
European Union	• Landing Obligation: landing of all catch, less profitability, looking for other fishing grounds can lead to fuel use increase; • Europe 2020 Strategy: Resource efficiency roadmap	• SUP Directive: including EOL fishing gears and marine litter; • PRF Directive: providing a sustainable management to all ship wastes; • EPR schemes; • others, such as: o plastic and recycling policies; o bans, taxes and levies on petroleum-based plastic or non-recyclable / non-degradable / non-compostable material; o resource efficiency regulations and programmes; o laws and regulations encouraging biobased materials; o packaging regulations; • Circular economy promotion packages.

a. Linkage to decarbonisation

At EU level:

- Climate change and energy efficiency were also highlighted as needs by the "**Europe 2020 Strategy**, a strategy for smart, sustainable, and inclusive growth". The Europe 2020 Strategy aimed at establishing a smart, sustainable, and inclusive economy with high levels of employment, productivity, and social cohesion, and it is aligned with the Millennium Development Goals and in particular to achieve environmental sustainability (resource-efficient and low-carbon economy). The Resource Efficiency Roadmap is part of the Resource Efficiency Flagship of the Europe 2020 Strategy (COM(2011) 21). The initiative provides a long-term framework for coordinated action in fisheries policy, amongst other sectors, supporting policy agendas.

- The **Landing Obligation** (LO). The EU fisheries regulatory framework for fisheries does not contain many provisions concerning energy efficiency, however, energy efficiency arises as a factor to be considered in the context of the LO. The LO may stand as a drawback for the profitability of the fishing fleets, since the fleets have to land all fish below Minimum Conservation Reference Sizes (MCRS), those fish subject to quotas restrictions, and, in the Mediterranean, species subject to minimum sizes. In such a context, it is convenient for fishing fleets to become more energy efficient because they may present similar fuel consumptions than before the LO implementation for landing lower (or no) marketable fish. Fish below MCRS cannot be traded for human consumption. In turn, some fish subject to quota management may not be easily marketed due to its low appeal for consumers. Currently, the obligation to land or be penalised means that the average revenue per trip will drop for the same fuel consumption, which may even increase if the decision is made to search for other fishing grounds where there are fish that is more valuable. This may undermine profitability even more in a scenario of rising fuel prices. These factors may stand as an incentive to non-compliance. In fact, the LO regulation as per Article 14 recommends using avoidance rules, which are applied to avoid areas where high concentration of juveniles or other undesirable catches occur. The size of vessels may also have implications on fuel consumption under the LO. Fitzpatrick et al. (2019) considered that small scale boats and smaller trawlers may incur in higher costs due to the requirements to store unwanted fish. Fishers are obliged to make more trips to land all fish and then return to the fishing grounds to continue working and searching for fish that are more profitable. The higher costs associated with the LO conditions such as extra work to sort out fish onboard, higher use of ice, fuel consumption, amongst others, require improvements in selectivity to diminish the number of unwanted fish, or the use of more energy efficient operations and equipment to reduce variable costs. Landing obligation may therefore have an effect on energy efficiency.

b. At international level:

- Sustainable maritime transport and sustainable fisheries are two global transboundary industries, which are highly interconnected and need simultaneous tackling (Martini and Allnutt, 2021). The **International Maritime Organization (IMO)** established the legal framework for the safety and security of ships, their crew, and environmental protection. The IMO dictates the exhaust emissions and energy efficiency policies related to the shipping sector, through the Annex VI of the **MARPOL 73/78 Convention** (International Convention for the Prevention of Pollution from Ships). While sulphur oxides content is directly related to the type of fuel in use and depends on the fuel suppliers, nitrogen oxides are directly related to the engine type and the age of the engine. GHG emissions are related to the energy efficiency of ships and their management.

c. Linkage to circular economy

At EU level:

- European **SUP** Directive: EU rules on single use plastic products aim to prevent and reduce the impact of certain plastic products on the environment, in particular the marine environment, and on human health. Regarding to the fishing gear, Member States would be required to set up national minimum annual collection rates of waste fishing gear for recycling and to monitor fishing gear placed on the market, as well as waste fishing gear collected, with a view to the establishment of binding quantitative EU-wide collection targets.

- Extended producer responsibility (**EPR**): Member States must ensure that extended producer responsibility schemes are established for fishing gear containing plastic placed on the market of the Member State. For this, it is necessary to have adequate port reception facilities and its subsequent transport and treatment are necessary.
- The **EMFF** also supported environmentally sustainable and creative ways to implement the circular economy in fisheries and aquaculture. FLAGs played an important role in identifying and investing in innovators and educating operators to rethink design, production, usage and recycling in a way that protects the environment, while increasing economic opportunities in the form of new jobs and businesses.
- The **EMFAF** contains provisions to support the European strategy for plastics in a circular economy, Article 25 contains provisions to support activities leading to biodiversity protection and ecosystem conservation with passive collection of gear and marine litter, and investments in ports facilities for the reception of lost gear and marine litter.

At international level:

- **MARPOL Annex V** (which prohibits the dumping of fishing gear at sea), and to promote the recovery of lost fishing gear, such as Council Regulation 1224/2009, Article 48, (fishing gear must be retrieved or the authorities must be notified).

1.2.2. Financial support to the fishing sector for the investment on decarbonisation and circular economy solutions for fisheries

The **EMFAF** (Regulation (EU) 2021/1139) is the current financial pillar of the CFP, and as its predecessor programmes i.e. European Fisheries Fund (EFF) and the European Maritime and Fisheries Fund (EMFF), it considers energy efficiency as an eligible aspect for funding, but with a few nuances. Article 19 establishes that in relation to the eligibility of the financial support for energy efficiency investments, replacement or modernisation of engines even a bulbous bow is possible, even if the individual gross tonnage (GT) of the vessel increases. However, these changes shall not lead to an increase in the Member States' overall fishing capacity and are undertaken for small-scale vessels, or vessels up to 24 m in length if it is proved that a 20 % of CO_2 emission reduction is achieved. Moreover, it excludes the acquisition of equipment that increases the ability of a fishing vessel to find fish. Finally, no mention is made of other types of solutions, such as those related to how the vessel is operated, monitoring of the consumption, solutions addressing energy consumers onboard (habitation, lighting), more energy efficient navigation by using antifouling coatings, efficient propellers, etc.

The **local action groups** (LAGs) play a pivotal role in channelling funds to support initiatives within coastal communities, including decarbonisation and circular economy initiatives in fishing communities. In 2020, a survey was carried out by FARNET amongst **fishing local action groups** (FLAGs) in relation to projects linked to the EGD. A total of 155 FLAGs across Member States replied to the questionnaires. Results highlighted that for the 2014-2020 period, 87% of the groups reported at least one project contributing to the EGD (Posti et al., 2020), that summed a total of 1 167 projects. Out of these projects, 59 % were linked to the objective of "Preserving and restoring ecosystems and biodiversity", 29 % to "Sustainable food systems", and 12 % to "Circular economy and clean energy". The latter (Circular economy and clean energy) only accounted for 141 projects, on average, less than one project per FLAG. Most of them (37 %) were related to energy efficiency, only 12 % were linked to circular economy practices, which suggest that circular economy is the least developed within all the initiatives, and this might be due to the state of technology, investment, production costs, and markets. Regarding circular economy, some initiatives focused on the revalorisation of ALDFG and other materials regarding clean energy, they were mostly related to reduction of fossil energy dependency, through the electrification of vessels, charging stations, and the use of solar panels for fisheries buildings and other port facilities linked to the fisheries cycle (FARNET, 2023). Based on these results, it seems that there is **still work to do to promote the full utilisation of the community led local development** (CLLD) projects linked particularly to the energy saving and circular economy aspects of the EGD.

2. DECARBONISATION ASPECTS FOR THE EU FISHING FLEET

2.1. State-of-play of solutions for the decarbonisation of fishing fleets

KEY FINDINGS

- The road towards decarbonisation of EU fishing fleets implies a **twofold objective**: to have **energy efficient**, and **low-carbon** fisheries. Energy efficiency is achieved by having fleets consuming less fuel and fishing sustainable fish stocks; low-carbon fisheries imply having fishing vessels consuming low-carbon alternative fuels or energy.
- Energy efficient solutions may be focused on improving the fishing **vessel operation**, the vessel **structure** and onboard equipment, the fishing **gears**, and the **catchability**.
- Implementation of energy efficient solutions are **still low within the fishing industry**.
- **Efforts** to reduce fuel consumption, costs, and emissions in fisheries **need to be tailored** to the nature of individual fisheries, even fishing vessels. However, solutions are often presented as one-fit-all solutions, and little insight and misleading messages are given to fishers, which hinder the decision-making towards the solutions.
- Fuel consumption **monitoring devices** together with **energy audits are key** to assess the feasibility of a solution and improve the reporting of GHG emissions.
- Solutions must be chosen based on a vessel's **energy and activity patterns**.
- Solutions are available but the **fisheries sector is reticent** to invest, implement and maintain energy efficiency solutions **due to different barriers**.
- **Training**, transparent **information** and **knowledge** transfer is needed.

2.1.1. Energy efficiency and decarbonisation

Commercial fishing is energy-dependent, but the level of dependence varies between fisheries (Parker et al., 2018; Parker and Tyedmers, 2015). Different indicators in the literature and regulations assess energy efficiency. 'Fuel use intensity' (FUI) also known as 'Fuel Intensity' is encouraged as a proxy for management effectiveness by providing the quantity of fuel consumed per quantity of fish landed (litre per tonne) (European Commission et al., 2021; Parker and Tyedmers, 2015). In general terms, **the fuel intensity of European fisheries has declined since 2009 but stagnated from 2014 and onwards** (European Commission et al., 2021). Despite showing a positive trend towards energy efficiency, the message may be misleading as the FUI at state level not only depends on overall fuel consumption of the EU fleet and landings, but in the effort, fleet size and other variables (Sala et al., 2022). Nonetheless, the indicator is more useful when disaggregated at vessel level or fisheries level. This enables **acting and measuring the improvements on decarbonisation practices**.

Onboard a vessel, main and auxiliary engines burn fuel (mainly marine diesel oil) (MEPC, 2020). The energy produced is used to propel the vessel or to power onboard energy consumers. GHG emissions, however, are directly linked to the type of fuel used and its consumption, as well as the leakages of the refrigerants used onboard for the cooling systems. The decarbonisation of fishing fleets, i.e. a reduction of GHG emissions of fisheries, can be driven by different means, such as reducing the fuel consumption, using alternative fuels/energy or refrigerants with a lower GHG emission factor or by increasing the catch within safe biological limits for the same amount of fuel consumed making the activity more efficient.

Energy efficient **solutions** need to be **tailored to the nature of individual fisheries** (European Commission et al., 2022) or even at the vessel level; however, solutions are often presented as one-fit-all solutions. Worse yet, the potential savings of a technology are often reported without detailing whether such saving is applicable to the whole fishing trip or to a certain activity mode (e.g. in navigation or fishing). For example, the use of semi pelagic trawl doors may present lower drag coefficient than traditional doors; hence, the vessel would consume less while trawling. This solution will only be applicable for trawlers using trawl doors and the savings will only occur while the vessel is using these doors, i.e. during fishing, not during the whole trip. Another clear example is the use of antifouling coatings. Certain antifouling coating manufacturers may suggest a fuel saving of 3 % by the application of the antifouling paint in vessel speed greater than 15 knots. It has to be clear that the saving will only occur when the vessel reaches these speed ranges; hence, this may not be a recommended solution for a great part of small-scale fisheries. Therefore, the real fuel saving, and the payback period of the investment may be unknown unless the energy and activity patterns of the vessel are defined, for example indicating if the vessel devotes a considerable amount of time during the trip to navigating at this speed range.

Fishing activity and energy patterns are some of the most critical factors determining fuel consumption. The first indicates the amount of time devoted by each of the engines onboard to a certain activity i.e., navigation, fishing, inactive at sea, in port; the latter provides information of the energy consumption or fuel consumption by the different engines onboard (main and auxiliaries) during the different activities (Basurko et al., 2013). In fact, defining a vessel's energy (or fuel consumption) and activity patterns are key to propose tailored solutions, as they can determine the efficiency of the solution and the payback period of the investment. Energy audits are seen as the process to obtain this information (Basurko et al., 2013; Thomas et al., 2010). The energy pattern is, in most cases, highly related to whether the fishery employs passive or active fishing gears. The active ones that require towing a gear, such as trawlers or Danish seines, tend to consume most of their fuel during the fishing mode (> 75 %). The same is observed in trollers that spend most of the fishing trip sailing at fishing speed while towing the gear. In the case of trawlers, solutions designed to reducing the fuel consumption while at fishing result the most cost-efficient, for example those aimed at reducing the drag while trawling. In contrast, purse seiners and pole and liners are more conditioned by their target pelagic species, which are migratory; hence, they spend a large part of their time and effort navigating to the fishing grounds or finding fish, thus navigating at higher speeds. This translates in presenting higher fuel consumption during the navigation stage; hence, solutions such as route optimisation and slow steaming may be most suitable (European Commission et al., 2022).

Research in this topic started in the 1980s but peaked in the late 2000s, thriving after worldwide fuel crisis events. Nonetheless, despite the funding opportunities and different efforts at international levels, the implementation of energy efficient solutions is still low within the fishing industry worldwide (European Commission et al., 2022).

2.2. Best decarbonisation practices in fisheries

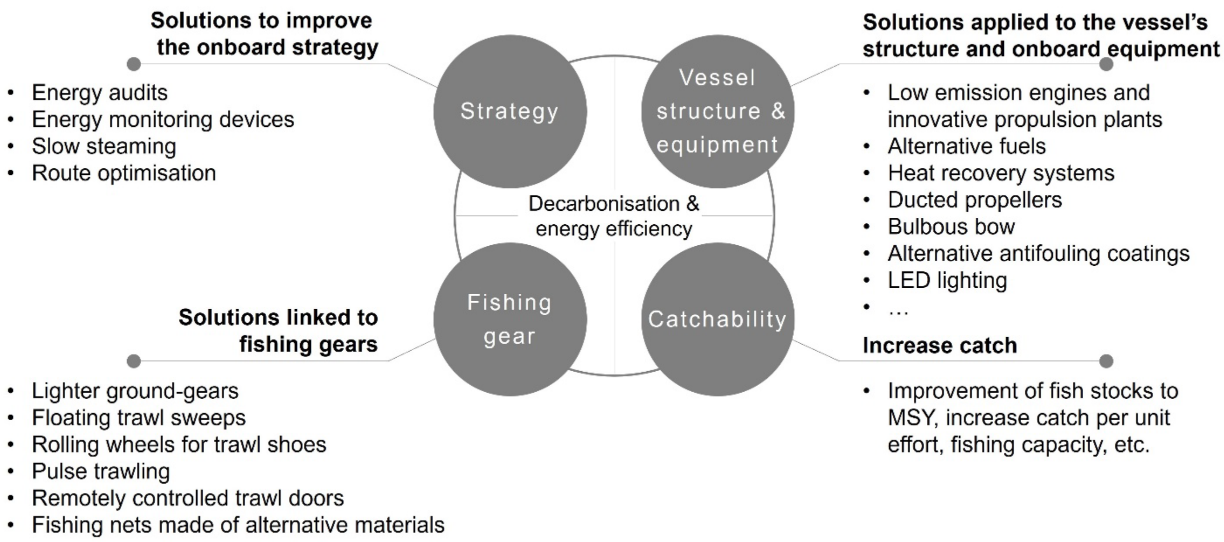
There is a wide range of **energy efficient solutions** that can be applied to start decarbonising fisheries (Figure 2, Table 2). Such solutions may be clustered in **four main groups** (European Commission et al., 2022):

(1) **Strategy**: solutions linked to how the fishing vessel is operated.
(2) **Vessel structure and equipment**: solutions focused on the vessel structure and onboard equipment (savings during the whole trip duration).
(3) **Fishing gear**: solutions applied to improve the energy efficiency of fishing gears (savings only during the fishing phase of the trip).
(4) Increasing **catchability**.

Reducing the fuel intensity by focusing on increasing catchability (option 4) is directly linked to the status of fish stocks and policies related to the exploitation of fish stocks, i.e. CFP. Due to this being out of scope from the present report, it has been omitted from the description of solutions.

Not all solutions are currently available in the market or present high **technology readiness levels** (TRL). The ones described below either have been tested or implemented onboard fishing vessels or are likely to be available in the short-term (European Commission et al., 2022).

Figure 2: Energy efficient solutions suitable for fishing vessels



Source: adapted from European Commission et al., 2022, p. 91.

2.2.1. Solutions to improve the onboard strategy

Energy audits: determine the energy performance of a fishing vessel (Cheilari et al., 2013; Guillen et al., 2016; Notti and Sala, 2014), i.e. how energy is consumed onboard, by which energy consumers, and during what activities (navigation, fishing, in port or inactive at sea) (Basurko et al., 2013). Based on the results of the energy audits, activity and energy patterns can be defined, and consequently tailored energy saving solutions including their payback period can be drawn. Despite not being very widespread along European fisheries, some of the Spanish and Italian, even Australian fisheries have benefited from them (Basurko et al., 2013; Sala et al., 2022; Thomas et al., 2010). EMFF and some working programmes have tried to boost their implementation. Whereas energy audits do not produce a direct fuel saving, they are together with onboard energy monitoring devices, a key instrument to measure the real saving of a solution.

Energy monitoring devices: these devices provide a real or simulated fuel or energy consumption of fishing vessels. The real measurements are based on fuel flowmeters or torque metres, and the simulations (a low-cost version) are based on the fuel consumption / RPM cubic curve of the engine, normally drawn from engine manufacturers or sea tests. They usually monitor the fuel consumption and other variables of the main engines, but in some instances also of auxiliary engines. The information provided by these devices is very useful for shipowners and skippers to keep a record and a better control of their consumptions and savings. Only by making skippers aware of the relative fuel consumption (i.e. L fuel/nautical mile) of their vessels Basurko et al. (2013) and Notti and Sala (2014) reported fuel savings between 5 to 15 % Despite their use is not common in small-scale fisheries, some larger fishing vessels such as tropical tuna purse seiners are currently using them to control the vessels but also their fleet consumption (Basurko et al., 2022b).

Slow steaming: this simple solution implies reducing the navigation speed until the optimal service speed. It is mostly applicable for those fishing modalities (e.g. purse seiners, gillnetters, handlines, and pole and lines) that are engaged in large navigation distances to fishing grounds; hence, large part of the fuel consumption occurs during navigation. The premise to apply this measure correctly is that the optimal service speed is known, which depends not only on the propulsion engine but also on the vessel's design and retrofits. Energy monitoring devices together with sea tests are a perfect combination to define this optimal service speed. Slow steaming may slightly increase the duration of the trip. Therefore, to assess the suitability of this solution, shipowners would need to balance the benefit of reducing the fuel consumption, in comparison to a reduction in fishing income (Basurko et al., 2013). A fuel saving of 15-20 % of the total fuel consumption of a fishing trip was reported by Basque purse seiners and trollers (by not exceeding 8.0 and 9.5 kn, respectively) (Basurko et al., 2013). The savings compensated the potential reduction of fish caught and the extended arrival time as they are still applying it.

Route optimisation: based on accurate and timely characterisation of global sea state, weather conditions and currents, an optimal route is proposed by an algorithm to make the most fuel-efficient trip to the fishing grounds. While route optimisation is quite common in the shipping industry, the planning and optimisation of routes for fishing grounds are not widely spread in the fishing industry (Granado et al., 2021). Nonetheless, route optimisation devices have started to be tested in the tropical tuna purse seine fleets, which incur in large navigation periods, under the name 'fishing route optimisation decision support systems' (Granado et al., 2021). Savings generated by these devices are expected but yet to be published.

2.2.2. Solutions applied to the vessel's structure and onboard equipment

Propulsion systems: a typical propulsion system consists of several components, including the diesel engine, shaft, a gear box system, and a propeller. In general, ship propulsion improvements can lead to reducing fuel consumption by 5 to 10 % (Notti and Sala, 2014). The replacement or modernisation of the propulsion system (e.g. vessel electrification, hybrid plants, dual fuel engines, retrofitted engines for alternative fuels), however, implies an extensive retrofit (i.e. high investment costs), and it is often considered a big challenge by fishing companies.

- **Low emission engines**: Replacing or modifying an old engine by a more efficient alternative is supported by the EMFAF (Articles 18 and 19) for vessels up to 24 m length, and under certain criteria. To be eligible, shipowners need to ensure that the same or less (certified) engine power is maintained and report a CO_2 emission reduction of 20 %, which must be subject to a physical verification. When the performance comparison between old and new engines cannot be made, other verification alternatives should be undertaken.

- The **fisher** requesting funding should demonstrate that:
  - the new alternative includes an **energy efficient** technology and that the **age difference** between the new and old engine system is of **at least 7 years**;
  - the type of alternative fuel or the new propulsion system **emits less CO_2 than the replaced** engine system; and
  - the Member State measures that the new engine **emits 20 % less CO_2** or **uses 20 % less fuel** than the replaced engine under the normal fishing effort of the implicated vessel.
- Even if the GTs are increased with the retrofit, the replacement will be eligible only if the overall fishing capacity of that vessel's fleet segment is not increased by the prior withdrawal of at least the same amount of fishing capacity without public aid from the same fleet segment and the (certified) engine power is not increased. Although not economically supported by the EMFAF, replacing, or modifying an old engine is possible in all vessels (at any length), but only if the engine power and the GT are not increased.
- **Hybrid energy plants**: hybrid diesel-electric engines and propulsion plants are alternatives to traditional marine diesel engines. They support several operating modes, to match speed and auxiliary requirements, enabling flexible and fuel-efficient operation (European Commission et al., 2022). Diesel electric systems may provide on average savings of 10 % (Gabrielii and Jafarzadeh, 2020). When batteries support the propulsion, 5-25 % of emission reductions are expected; however, they require space onboard, which is often difficult to obtain. Likewise, retrofitting existing vessels with new propulsion systems requires bigger fuel tanks or battery pack rooms, storage and use safety conditions, drafts and weights, energy conversion costs, the approval of the authorities, etc. Due to onboard space limitations, vessels' autonomy is compromised, thus, short fishing trips close to the port may be the most appropriate for such systems, e.g. those using passive gears (gillnets, longlines, pots, etc.).
- **Heat recovery systems**: waste heat produced from exhaust gases and cooling water of the engines can be recovered by using steam turbines or heat exchangers for power generation with an estimated fuel saving of 9-10 %. Some authors have even seen the possibility to recover it into cooling systems by using sorption technologies (Palomba et al., 2017), with 1 % saving for cold heat recovery (from the refrigeration system). In the frame of the EfficientShip project, one of such systems, the Organic Rankine Cycle, was installed onboard an Irish coastal trawler and obtained a 5-10 % GHG emission reduction. Yet, this solution implies challenges in relation to waste heat availability and sizing of heating and cooling equipment (Gabrielii and Jafarzadeh, 2020).

Alternative energy:

- **LNG** is being promoted in Norway, where its fishing vessels are being retrofitted to this fuel type (Gabrielii and Jafarzadeh, 2020). LNG fuel is estimated to reduce 20-25 % GHG emissions. However, the use of LNG as fuel presents several difficulties such as high initial cost of conversion (25 % more compared to oil-fuelled vessels), complexity, safety, and additional training needs to operate it safely (Jafarzadeh et al., 2017).
- Recycled **waste oils** from automotive lube oil have shown to be valid for fishing vessels. Tests onboard commercial Basque bottom otter trawlers provided promising results to reduce NO_X

emissions by 15 %; however, this trend was not observed in GHG emissions, which resulted in limited reductions (Gabiña et al., 2019; Uriondo et al., 2018).

- **Other fuels**: hydrogen can be used as a fuel for a combustion engine or as a fuel cell for electricity, and a 75 % emissions reduction may be obtained. Methanol may provide a GHG emission reduction of 10 %. Likewise, some biodiesels (e.g. hydrogenated vegetable oil) are expected to reduce the GHG emissions by 50 % (Gabrielii and Jafarzadeh, 2020).
- **Renewable energy**: wind-power is currently being used in shipping (http://bound4blue.com/en/). The use of sail assisted propulsion was studied for a coastal Scottish seine/trawler (27 m length) with positive results; onboard tests reported a potential annual saving of 20-25 %. Similar results were obtained for large German freezer trawlers (140 m) by using a Skysail™ solution based on kites. Nonetheless, a high investment cost (EUR 600 000) was needed (2008 data). The propulsive potential will depend on the type of sail used and the wind speed and angle (Schau et al., 2009). It should also be noted that the use of wind-assisted propulsion might affect the routines onboard and require a motivated and skilled crew (Ziegler and Hansson, 2003). Likewise, renewable energy (solar, wind) can also be used to power consumers onboard fishing vessels, when equipped with batteries to facilitate the storage of energy (Gabrielii and Jafarzadeh, 2020).
- **Electricity**: hybrid propulsion systems (diesel-electric). Coupling a diesel engine with an electric one is especially useful when vessels have large electricity demands, such as trawlers and or ships with a large variation in their operation profile (Gabrielii and Jafarzadeh, 2020). In 2021, a 22 m diesel-electric trawler vessel was delivered to a Brittany fishery (Baird Maritime, 2021), results are yet to be published.

Magnetic devices: these devices can be used for fuel treatment to improve the combustion, by helping align the fuel ions into straight chains. Tests carried out under real operation conditions onboard Basque commercial bottom otter trawlers indicated 2-6 % savings (Gabiña et al., 2016; Notti and Sala, 2014). Despite this saving being marginal in comparison to those suggested by manufacturers, they still provide a suitable and cost-efficient solution to reduce fuel consumption, as they do not require major structural changes onboard.

Frequency converters: these devices convert the fixed-frequency of the alternating current provided by the auxiliary engines into a variable frequency (i.e. variable-voltage output used to control speed of induction motors) used by electricity consumers onboard, such as condenser pumps, ice-making machine compressors, or refrigeration seawater pumps of the main engine. Tests conducted onboard commercial fishing vessels observed saving of 8 % (Lee and Hsu, 2015). However, these savings will depend on the running hours of the alternator per year.

Ducted propeller: ducted propellers, common in trawlers, contribute with more towing power and efficiency at low engine speeds (Martelli et al., 2017). Well-designed ducted propellers can provide savings of 15-30 % (Sala et al., 2012; Van Marlen, 2009).

Antifouling coatings: avoid the growth of fouling organisms on ship hulls that can lead to fuel consumption increase to keep the speed and navigation settings (Selim et al., 2017). Two options are currently available for fishing vessels. Firstly, foul release coatings and a new generation of silicone hydrogel foul release are useful for vessels with idle speeds over 15 and 13 kn, respectively, such as tropical tuna purse seiners. In contrast, the second option, fluoropolymer-based fouling release paint has shown to be effective at lower idle speeds, as tested onboard Mediterranean bottom trawlers with a fuel saving of 11 % at idle speeds less than 11 kn. This saving remained the same after 2 years of applying the antifouling (Notti et al., 2019).

Bulbous bow: these appendages contribute to improve the hydrodynamic optimisation of the vessel by reducing the drag force of the hull when cruising. The selection of a bow must be based on a thorough study of the activity pattern of the vessel and its working speeds and will be specific to a particular hull and vessel. Bulbous bows are more common in large vessels but could be installed in small-scale vessels too (i.e. www.flowbow.no). An optimised bulb can provide savings of 5-15 % (Basurko et al., 2013; Tran et al., 2021).

Onboard equipment:

- **More efficient consumers,** such as LED light for lighting or the use of electric machinery replacing mechanical-hydraulic counterparts, are suitable solutions for all fisheries. In the case of LED lights, this no-intrusive solution can save between 0.5-3 % of the yearly fuel consumption of a vessel (Basurko et al., 2013; Thomas et al., 2010).
- **Alternative refrigerants for cooling systems:** refrigerant leakages contribute to GHG emissions. Vessels built after 2004 are obliged by law (Regulations (EC) 2037/2000 and 1005/2009) to replace hydro chlorofluorocarbon R22 refrigerant by a more environmentally friendly alternative, such as ammonia (Sandison et al., 2021). Changes have started to be implemented in e.g. Norwegian fisheries (Ziegler et al., 2013).

2.2.3. Solutions linked to fishing gears

Gear related solutions have been focused on **gear's drag reduction,** mainly on trawl fisheries (European Commission et al., 2022).

a. Beam trawl fisheries

Tickler chain beamers:

- **Solutions addressing new gear designs**: Belgian trawl fisheries have successfully implemented solutions such as the replacement of the beam by a SumWing (a wing-shaped foil) (European Commission et al., 2022), which provides a fuel saving of 13-16 % (ICES, 2020; Turenhout et al., 2016; van Marlen, 2012). No substantial changes were observed in the catch efficiency across species (Huyghebaert et al., 2010). This solution is also in line with using lighter chain ticklers, which contributes to making the gear lighter and therefore reducing the contact drag.
- A solution to reduce towing speed may be to **shift from tickler chains to chain mats** with a 24 % fuel reduction, change that would imply a towing speed reduction from 6-7 kn to 3-5 kn (Van Marlen, 2009); nonetheless, this may also imply other changes, such as a change in target species, landings, economic performance and fishing ground suitability.

Chain mat beamers:

- Belgian fisheries have successfully implemented the replacement of trawl shoes by roller wheels with a 5 % fuel consumption reduction (European Commission et al., 2022).

Beamers in general:

- **Replacement of tickler chain or chain mat by pulse trawl**: it consists of stimulating target fish electrically with electrodes by inducing electric pulses instead of using a mechanical stimulation generated by tickler chains, bobbins, or chain mats. This technology showed increased target catches and reduced fuel consumption due to the use of lighter gear and towing speed (Poos et al. 2013), thus, it was widely implemented (Haasnoot et al., 2016). It was further refined by the integration of the SumWing (combination known as 'pulsering') instead of the beam on tickler chain beamers which further reduced fuel use for large vessels by 40 % (Taal and Klok, 2014). However, since July 2021 its use was banned following political debate and voting in the European Parliament (European Union, 2019).

- **Others**: use of outrigger trawl or switching to other active or passive fisheries such as twin rig otter trawl, Danish seining, fly-shooting or set nets are other alternatives (European Commission et al., 2022). While these gears may provide a fuel saving (40-70 % using outrigger trawl), they may also reduce the catch efficiency for sole species. In addition, shifting from active to passive fisheries would mean restructuring the whole fishery, including the fleet, crew and overall landings and economic performances, and policy support.

b. Bottom trawl fisheries

Almost half or more of the drag produced by a bottom otter trawl is due to the netting (45-63 %); 20-24 % due to the otter boards, and 4-12 % to the ground gear (Khaled et al., 2013; Valdemarsen and Hansen, 2006; Wileman, 1984). The number of implementation examples onboard otter trawl fisheries are still limited and often the TRL of the solutions is low or have not been tested onboard.

Alternative trawl gears:

- **New design of otter trawls**: Computational Fluid Dynamic (CFD) models indicate that new designs of otter trawls have a potential for fuel saving, but their TRL is nonetheless low. These are the cases of 'redesigned otter trawls' that use an automatic optimization procedure for panel cutting with a 16-52 % of fuel saving (Khaled et al., 2012) and W-trawl with a fuel saving of 8 % (Balash et al., 2015a, b), or Warp length optimization (8 % fuel saving). The effect on catch has not been checked yet.
- **Change from demersal to semi pelagic trawling doors**: selecting a more hydrodynamic otter boards by lifting them off the seabed has been pointed as one of the most interesting solutions by fishers in a survey taken across Europe (European Commission et al., 2022). Tests of this idea onboard commercial Basque otter bottom trawler reported a 7 % fuel saving during fishing (Basurko et al., 2013).
- **Remotely controlled trawl doors**: trawling operation using electric equipment to control the opening and displacement of the trawl door can reduce fuel consumption by more than 15 % (European Commission et al., 2022) and have a better gear control (ICES, 2020).

Midwater trawls:

Two solutions have been reported for midwater trawls regarding net modifications:

- The use of **helix ropes** that would allow maintain the same mouth opening but reducing the door size, thus making the gear lighter (Kebede et al., 2020).
- **Optimising the net design** by using hexagonal meshes, Dyneema as netting material or slotted type trawl doors, together proving a **fuel saving of 17 %** as calculated by CFD models (Lee et al., 2018).

Table 2: Examples of market ready energy efficient solutions

Solutions	Effect on*				Fuel saving (%)	Target fishing modalities**					
	N	F	I	P		SM	PG	PS	TL	T1	T2
STRATEGY											
Energy monitoring											
Energy audits	x	x	x	x	-	x	x	x	x	x	
Energy monitoring devices	x	x	x	x	5-15	x	x	x	x	x	
Route optimisation											
Slow steaming	x				15-20	x		x	x		
Route optimisation device	x				NA			x	x		x
VESSEL STRUCTURE AND EQUIPMENT											
Engine related											
Low emission engines	x	x	x	x	20	x	x	x	x	x	x
Diesel-electric energy plants	x	x	x	x	5-25	X					
Shore-power electricity				x	NA	x					
Heat recovery system	x	x	x	x	5-10			x	x	x	x
Alternative energy	x	x	x	x	10-25						
Ducted propellers	x	x			15-30				x	x	x
Magnetic devices	x	x			2-6						
Frequency converters	x	x			8						
Hull related											
Alternative antifouling	x				11			x	x	x	x
Bulbous bow		x			5-15	x	x	x	x	x	x
Energy consumers											
More efficient consumers	x	x	x	x	0.5-3	x	x	x	x	x	x
FISHING GEAR											
Trawl gear design											
Rolling wheels for trawl shoes		x			5-16					x	x
SumWing SumWing with pulsering		x			11-12 40					x	x
Pulse trawling		x			35-54					x	x
Shift from tickler chain to chain mat with roller wings		x			24					x	x
Alternative netting designs		x			2-40					x	x
Semi pelagic trawl doors		x			7						
Remotely controlled doors		x			>15					x	x

Source: own elaboration

Note: * Effect on: N – navigation, F – fishing; I – Inactive at sea; P – in Port.
** Target fishing modalities: SM – small scale, PG – Passive gears (gillnetters, longliners), PS – Purse Seiners, TL – Trollers, T1 – Coastal Trawlers, T2 – Long Distance Trawlers

2.3. Barriers and possible mitigation solutions

The fishing sector is only aware of about 50 % of all the potential technological solutions applicable to fishing vessels (European Commission et al., 2022). Solution transfer from research to the fishing sector is low, even once successfully tested and implemented, fishers may stop using them because they prefer traditional or known technology, and to a lesser extent because of the end of subsidies or the new technology requiring extra efforts from fishers. This may be due to five main groups of barriers: economic, human, regulation-related, technological, and information barriers (European Commission et al., 2022).

2.3.1. Barriers impeding the implementation of energy efficient solutions

a. Economic barriers

- **Lack of subsidies or funds to invest on energy efficient solutions**: the increase of fuel oil prices and the availability of funds to invest in energy efficiency solutions are the two most important reasons that make fishers opt for energy saving solutions (European Commission et al., 2022). Without the funds, fishers may have difficulties to cover the high investment and implementation cost of the solutions.
- **Funding available but only for purchased technology**. Some funding schemes require advance payment for the technology. Moreover, asking for a loan implies a long procedure and to pay interests, which is seen as a barrier by fishers (European Commission et al., 2022).
- **Funding available for research projects but not enough to compensate fishers.** Public funding is available for research projects (e.g. EU missions in Horizon Europe), in which tests onboard can be undertaken. However, these projects often do not include economic compensation to cover the risks taken by shipowners that may lead to lack of acceptance.
- **High investment/implementation costs**. Some of the solutions, especially those requiring a structural change, imply a high investment cost. Thus, investment costs may slow down the implementation of these technologies, mainly in small-scale fleets that usually have a lower turnover (European Commission et al., 2022). In addition, when an approximate payback period is unknown, this uncertainty leads to a lower willingness to invest.
- **Market is not ready for energy efficient fisheries**. Investing in energy efficiency should be reflected in the market price of fish, at least to compensate for the extra effort to be more environment-friendly and differentiate mindful fishers from those they are not. However, neither sustainable fishing related labels nor markets or consumers have adopted any measure to host energy efficient fisheries or demand fish products with a small carbon footprint (Alma-Maris, 2023; Parker and Tyedmers, 2015).

b. Human barriers

- **Traditional sector**: fishing, although evolving, is still a quite traditional sector. This results in a lack of proactivity towards innovations, making the sector reluctant to try new alternatives (Notti and Sala, 2014), unless the technology is used by other relevant members of the fishing community that serves as an incentive to encourage others to use it.
- **Shipowners and skippers have different objectives**: skippers that are fishing vessel owners (as often is the case in artisanal-vessels) are more likely to manage the vessel more energy efficiently than company-hired skippers (Abernethy et al., 2010; Basurko et al., 2013). Shipowners tend to consider several aspects (e.g. distance to port, weather) to minimise the

fuel consumption (Bastardie et al., 2013). Onboard large vessels (i.e. tuna purse seiners or trawlers) catch prevails over energy consumption, and though shipowners are conscious of the need to reduce fuel costs, skippers prioritise the catch as their salary is often proportional to the tonnes of fish caught. Hence, fuel consumption is not so important for skippers in their decision-making (Bastardie et al., 2013; Groba et al., 2020).

- **The lack of collaborative work with end users**. Often solution prototypes are developed by R&D&I institutions or by manufacturers and their validity is tested onboard at final stages of their TRL. This may generate reluctance towards the solution, lack of transparency, and low technological transfer process (Jafarzadeh and Utne, 2014).

c. Regulatory barriers

- **National and European regulations sometimes are not aligned or go at the same speed**: some national legislations are not fully aligned or take longer to change in comparison to European regulations. For example, retrofitting or modifying engines for fishing vessels in Greece, is still not allowed by law, as the policy that regulates this has not been changed since the 60's. Therefore, even if EMFAF promotes this solution, unless national production programmes include them and by law make them eligible, they will not be implemented (European Commission et al., 2022).
- **Solutions may increase GTs or engine power (kW) of the vessel**. Some solutions may imply an increase in engine power or GT increase as they are heavier and larger than the counterparts (e.g. alternative engines or propulsion systems). The 'capacity ceiling' is allowed by the EMFAF, under certain conditions. As long as they remain within the capacity ceiling, it will be up to the Member State to decide how to make the system operational (NSAC, 2022). Nonetheless, the definition of capacity should be revised to allow the EU fishing fleet to adapt to environmental and social challenges without increasing the ability of the vessel to catch fish (NSAC, 2022).
- **Only small-scale fisheries eligible for funding (in EMFAF)**: existing larger vessels (more than 24 m length) also need to decarbonise; however, the lack of funding for such fleet segments hinders their implementation onboard.
- **High administrative burden for asking for funds for implementing solutions**: small-scale fishing vessel owners, especially pointed this as deterrent to request funding for vessel innovations (European Commission et al., 2022). In a previous study, Ballesteros et al. (2019) also found out that energy efficiency and mitigation of climate change were measures of EMFF's of Union Priority 1 that were underperforming in terms of absorption rate of the fund[5] due to a combination of admissibility criteria and low aid intensity. In other EU funding schemes, such as EU missions in Horizon Europe, LIFE programme, etc., the process to have an end-user of technologies within a project consortium requires not only much paperwork but also a considerable time effort. As a result, unless they were a medium or large company with several vessels and administrative staff familiar with the funding process, participating in EU projects is often avoided.
- **Fishing industry is (mainly) exempted from IMO's regulatory framework:** fishing industry is exempt from global shipping emissions inventories such as the IMO's GHG Studies (Faber et al., 2020).

[5] Defined as the executed EMFF contribution compared to the total programmed.

Table 3: Barriers of decarbonisation and linked to mitigation measures

Barriers (linked to section 2.3.1)		Mitigation measures (linked to section 2.3.2)									
		Training	Labelling	Funding	Showcase	Objectives	Engagement	Accountability	Redefinition	Interaction	Certifications
Economic barriers	Lack of subsidies/funds to invest on energy efficient solutions			■				■			
	Funding available but only for purchased technology			■							
	Funding available for research projects but not enough to compensate fishers			■		■					
	High investment/ implementation costs		■	■							
	Market is not ready for energy efficient fisheries	■		■	■			■		■	■
Human barriers	Traditional sector	■	■	■	■	■				■	■
	Shipowners and skippers have different objectives	■	■	■		■		■		■	■
	The lack of collaborative work with end users	■		■	■		■			■	
Regulatory barriers	Regulations sometimes are not aligned or go at the same speed								■		
	Solutions may increase GTs or engine power (kW) of the vessel								■		
	Only small-scale fisheries eligible for funding (EMFAF)								■		
	High administrative burden for asking for funds for implementing solutions							■			
	Fishing industry are (mainly) exempted from IMO's regulatory framework							■			
Technological barriers	There is no one-fit-all solution	■	■	■	■		■		■		
	Space limitation onboard and increase of GTs								■		
	Barriers related to port infrastructure			■							
Information barriers	Misleading information or lack of information on technologies	■	■		■	■	■			■	
	Low knowledge transfer from manufacturers to end users	■	■				■			■	
	Poor communication among stakeholders	■	■				■			■	
	Wrong message is passed about the technology	■	■				■			■	

Source: own elaboration

d. Technological barriers

- **There is no one-fit-all solution:** not all solutions are valid for all fisheries, and even if they were suitable, the activity and energy pattern would have to indicate the real potential for a particular fishing vessel. If this information is unknown, selection of solutions will be done blindfolded. Often the poor information provided by the manufacturers and even policymakers can result in a misleading message, as solutions need to be adjusted to the nature of the fishery.
- **Space limitation onboard and increase of GTs:** some solutions such as retrofitting existing vessels with new propulsion systems and alternative oils require bigger fuel tanks, battery pack room, storage and use safety conditions, drafts and weights, energy conversion costs, the approval of the authorities, amongst others; hence it most probably will increase the vessel's GTs. For example, engines using LNG, methanol, biodiesel, H_2, and NH_3 will require an increase of 1.7, 2.4, 1.2, 4.5, 2.7 % (volume ratio), respectively, compared to marine diesel engines (MESD, 2020). These aspects should be easier to plan in new builds, but requires careful consideration in retrofitting cases (Alma-Maris, 2023).
- **Barriers related to port infrastructure**: new smart-grid infrastructures in ports (e.g. charging station, LNG storage, marketing logistics) are needed to switch from fossil fuels to greener energy sources and carriers. Thus, ports and harbours must be adapted to foster facilities that provide the alternative fuel bunkering or electric power supply points for such alternative propulsion systems. This has been promoted by COM(2021) 559 but given the complexity it seems that it would need to be a long term solution.

e. Information barriers

- **Misleading information or lack of information on technologies**: some stakeholders indicated that the information available on solutions is poor and not handy (does not reach the end-user) for the decision-making.
- **Low knowledge transfer from solution manufacturers to end users**.
- **Poor communication among stakeholders**.
- **Wrong message** (or not the adequate one) is passed about the technology (e.g. if saving occurs during navigation, fishing, during all the fishing trips, etc.).

2.3.2. Mitigation solutions

- Improve **training** to bridge the gap between the innovations and their use, and promote knowledge transfer to the sector. New solutions require qualified crew and managers.
- Improve the **labelling** or information sheets of the solutions (as products) by defining which fleets are most appropriate for the solutions or provide a more accurate saving estimate based on onboard testing.
- Enlarge the **funding** opportunities to other energy efficient solutions, beyond engine replacement or modification or adding a bulbous bow and small-scale fisheries.
- Promote and **showcase** commercial fishing vessels to test energy efficient solutions and exchange information within the sector to try to revert the opposition towards solutions.
- Promote the setting of clear **objectives** relating not only to catch but also to fuel costs by firm-hired skippers, instead of prioritising the catch to assess the performance of a skipper.

- **Engage** end users at the beginning of the development will improve their acceptance and help to adapt the solution to the particularities of the target fisheries.
- Improve the **accountability** of fuel consumption and emissions by fishing vessels by using energy monitoring devices.
- **Redefine** the **capacity** (engine power and gross tonnage) that would allow EU fishing fleets adapt to environmental and social challenges without increasing the ability of the vessel to catch fish.
- Develop mechanisms to promote **interaction** between stakeholders (scientists, technology manufacturers, fishing sector) in the decision-making regarding the transition to decarbonisation of the EU fishing fleet and to ensure the acceptability of the end users.
- Develop label or **certifications** that include carbon footprint or FUI as a certification criterion in the scoring system to benefit those that apply energy efficient practices.

2.4. Conclusions: lessons learnt and expected impacts for the transition to decarbonisation operations on EU fisheries

2.4.1. Lessons learnt from the decarbonisation efforts

Monitoring of energy consumption and operational profiles of vessels is key:

- Before choosing and investing on an energy efficient solution, the first step in the decarbonisation of the fleets is to have a well-established monitoring scheme of the vessels' activity and energy consumption.
- This monitoring would require installing energy monitoring devices onboard for all engines and in turn, it would facilitate reporting disaggregated fuel use data according to the vessel's activity and energy pattern (energy consumed by different engines during navigation, fishing or in port) and have a more efficient fleet management approach.
- The information provided by such devices also facilitates the automatic reporting to the Commission.
- The definition of energy and activity patterns will enable:
  - to develop tailored solutions that are key for a successful energy transition.
  - to estimate the real payback period of an energy efficient solution investment.
  - to help shipowners and skipper making decisions on the best solution for their vessels and fishing strategies.

Fishers need to be incentivised or motivated to adopt solutions:

- Fishing vessels owners, especially those who manage their vessels from land, should provide incentives to those skippers that engage in energy efficient practices. This may imply a shift from incentivising skippers based only on their catch to also those saving fuel.
- A good communication strategy about the solutions is needed, one that specifies the suitability of the solutions for each type of fishing vessel. This would involve explaining when the saving will occur, whether during the fishing phase, cruising, or during the whole fishing trip, etc. There is no one-size-fits-all solution, and the diversity of fishing vessels makes the selection of solutions complex without a correct information.

- Training, dialogue and cooperation are needed amongst stakeholders (fishing community, scientists, solution manufacturers, NGOs, national and international policy makers) to improve the knowledge transfer, encourage proactivity, and promote the adoption of responsible user behaviour towards energy efficient solutions.

Consumers can act as change-drivers:

- Consumers play an important role when asking for sustainable products from fisheries. It is important to promote the inclusion of fuel or energy efficiency related indicators in sustainable fisheries certification processes.

Energy transition requires funding:

- It is recommended to add more flexibility when it comes to financing the investment of other energy efficiency measures that are not included in the current EMFAF, if these do not increase fishing capacity.
- Energy efficiency is costly. National governments must encourage, guide, and allocate necessary resources for the transition towards decarbonisation.

2.4.2. Expected impacts from the decarbonisation of EU fishing fleets

Decarbonisation of the EU fishing vessels in the short-term may imply large investments and need for adaptation to the new energy efficient solutions. When this is done correctly, it will become a win-win solution not only for the environment but also for shipowners. In the mid-term, this could represent a more profitable activity, because fuel is one of the main costs in this sector. Aligning with more sustainable energy and environmental measures can lead the fishing sector to be an example of good practice.

3. CIRCULAR ECONOMY IN EU FISHERIES

KEY FINDINGS

- **Circular economy** in the **fisheries sector** have been focused on solutions addressing smart designs of **fishing gear**, innovative approaches to **reduce the dumping of litter** at sea, marine **litter collection**, and **efficient recycling** channels.
- Circular design of **fishing gear** should be one that facilitates an **easy disassembly** of the components and materials, uses **alternative materials** (recyclates, marine biodegradable, or natural), is **recyclable**, includes **marking** of the materials and avoids the use of **mixed** materials (e.g. polymers) and **harmful** materials (e.g. lead), without compromising the optimised **durability** and **performance** of the fishing gear.
- Current **port reception** facilities for **marine litter** and EOL fishing gears are **not enough** and should be **homogenised** across Europe.
- **Fishing for litter** schemes should be **easy** and **not costly** for fishers, promoted across Europe and supported financially.
- The **employment level in coastal communities** can be positively impacted by the need of personnel to **sort**, **manipulate**, and **manage** the **materials** coming from fishing gears at port facilities, and the creation of **innovative business to recycle** the materials into products, both from the fishing **gears** or retrieve marine **litter**.
- This increasing number of initiatives indicates not only a **new production model** but also changing **consumption patterns** in society.

A circular economy aims at '*…maintaining the value of products, materials and resources for as long as possible by returning them into the product cycle at the end of their use, while minimising the generation of waste*' (Eurostat, 2023). It can be achieved by the following **three principles**:

(1) **eliminating** waste and pollution;

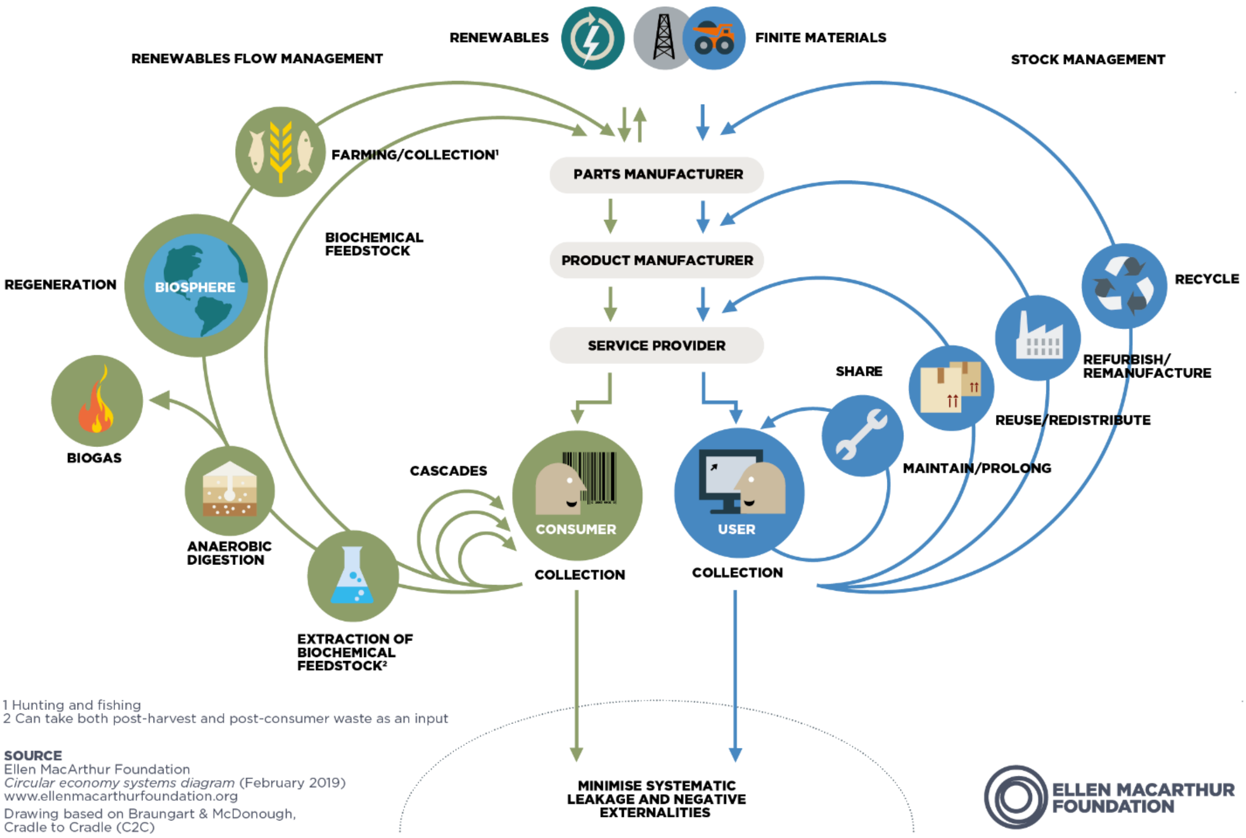
(2) **circulating** products and materials at their highest value, i.e. keeping materials in use, either as a product or, when that can no longer be used, as components or raw materials; and

(3) **regenerating** nature by shifting the focus from extraction to regeneration.

This systematic approach can be applied to many steps in a product's life (Figure 3). Often circular economy is misunderstood with/and limited to recycling, which is in fact the last stage of the technical cycle of the circular economy paradigm, because it means losing the embedded value of a product by reducing it to its basic materials (Ellen MacArthur Foundation, 2023).

In order to make products fit for a climate-neutral, resource-efficient and circular economy, as requested by the EGD; the adoption of a 6R's approach (Rethink, Refuse, Reduce, Reuse, Repair, and Recycle) is desirable. This approach is also complementary with designing sustainable products based on circularity principles. This means designing for **recovery** (recover and upcycle them to continue in circulation), **adaptation** (being able to break down the product in part and prevent obsolescence), **extension** (prolong the lifespan of products), **restoration** (use of materials that are save for the environment but also fit for the biological cycle), and **prevention** (minimal use of materials to avoid extraction of resources) (Ellen MacArthur Foundation, 2023).

Figure 3: Circular economy systems diagram showing the circulation of products and materials in two cycles: organic cycle (in green) and technical cycle (in blue)



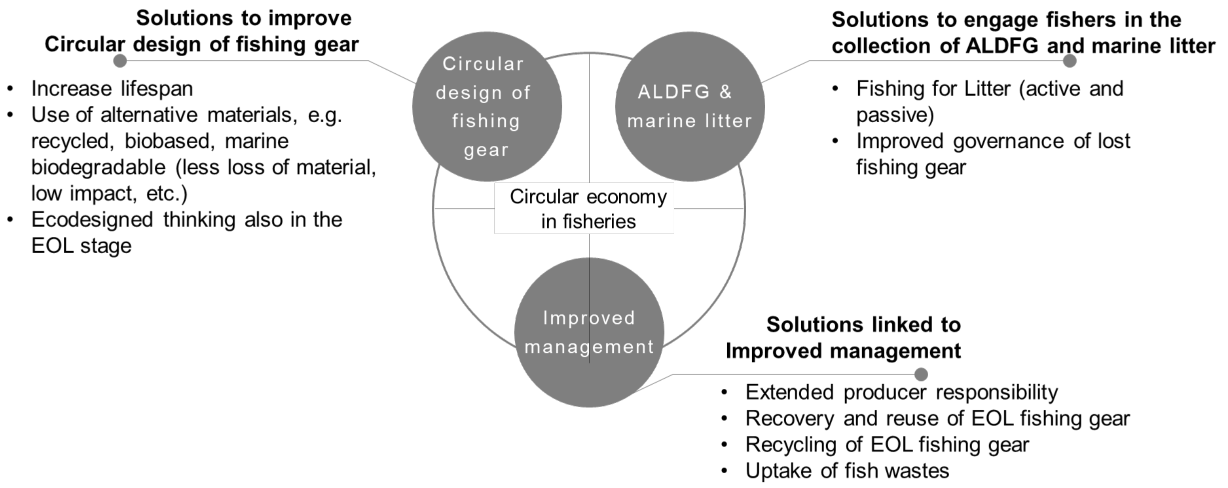
Source: Ellen MacArthur Foundation (2023)

This approach is already embraced by the Commission, which is working on a sustainable product policy legislative initiative, by making the Ecodesign framework applicable to all product developments based on sustainable principles (COM(2020) 98).

3.1. State-of-play of solutions for the application of circular economy in fisheries

The European Parliament stressed in its resolution of 10 February 2021 (P9_TA(2021)0091) that the **circular economy in the fisheries** sector should **focus on solutions addressing smart designs of fishing gear, innovative approaches to reduce the dumping of litter at sea, marine litter collection, and efficient recycling channels.** The scientific and grey literature on this subject, however, is limited, and only few examples of good practices have been found, mainly applied for larger vessels, rarely for small-scale fisheries. The scientific papers, particularly, deal with the whole value chain of the fish food, especially with bycatches, fish-waste potential applications and solutions, and with fish food packaging. In contrast, more diversity is found in R&D and demonstration projects, which have also started to include the circularity of fishing gears and marine litter and end of life treatments. Besides, there has been a boom in the development of circular solutions that are based on recycled and upcycled marine litter and EOL fishing gear and their demand by society has grown significantly (Dijkstra et al., 2021). It must be noted however, that despite the job employment creation derived from these initiatives, the traceability of these products is often complex to follow because apart from their goal and final product, no information is provided about their real sustainability performance, leading to misleading green claims (Andrés et al., 2022). EMFF, FLAG, LIFE programme and R&D funding have provided an opportunity to engage fishers into this type of initiatives, not only as fishers but also as agents related to fisheries and knowledge on fishing gear. The section below illustrates some of the examples found in grey literature and research projects addressing circular economy on fisheries (summarised in Figure 4).

Figure 4: Summary of solutions applicable to embrace circular economy practices within fisheries



Source: own elaboration

3.1.1. Circular design of fishing gear

Design is a fundamental stage in the life of a product, as decisions adopted during the design phase can later affect up to 80 % of its environmental impacts. The design stage defines crucial aspects such as the useful life of the product, whether it can be repaired, what it is made of and even how it can be managed at the end of its useful life (European Commission, 2023b). In the case of fishing gears, the design must be such that, without loss of fishing efficiency, the gear should have:

(i) as **long lifespan** as possible,
(ii) the **loss of material** at sea must be **minimal** (if not zero),
(iii) the materials used should have **low impact**; and
(iv) allows optimal **end of life management** possibilities.

All these considerations together will facilitate that the new generations of gears are durable, reusable, upgradable, and reparable and contain limited hazardous chemicals and likewise, contribute to energy and resource efficiency.

To address this need in an organised manner, the Commission commissioned a study on circular design of fishing gears and reduction of environmental impacts (MRAG, 2020), a key study which eventually laid the first cornerstone of what was to become a possible future standardisation request for the circular design of fishing gear (Draft Commission Implementing Decision amending Implementing Decision C (2021) 739).

Has as long a lifespan as possible: the design of the gear should prolong its service life; hence, minimise the need to conduct reparation of the gear or its full replacement. Commercial fishing in particular entails catching large volumes of fish; thus, gears endure high tensions during operation and friction with machinery and the sea bottom (in the case of trawlers). Consequently, repair and replacement of material takes place eventually. However, the duration of a gear is fishery dependent. For example, a couple of studies conducted on EOL fishing gears in Spanish ports, estimated that gillnets, which are rarely repaired, have a life span of 3 years and small-scale purse seine nets are continuously repaired and can last decades (Basurko et al., 2022a). In contrast, the purse seine nets used in tropical tuna purse seiners, despite being also repaired frequently; they are replaced fully every 2-3 years due to the high forces they are subjected to (Andrés et al., 2022). Innovation in the development of materials, fibres, design, and construction of netting, ropes and assemblage may greatly contribute to this end. For example, employing materials with high tenacity that allow reduction of the diameters of the twines and the use of knotless netting reduce towing resistance, thus reducing the need to repair and replace components as frequently, and consequently reducing idle material and costs, and even fuel use.

The loss of material at sea must be as low as possible (if not zero): the risk of losing the gear at sea due to bad weather or even during usual fishing operations is high (Richardson et al., 2021). Loss at sea can be prevented to some extent using materials with high tenacity, thus reducing breakage and loss of materials, or even sections. For example, demersal seine ropes are estimated to lose 20-30 % of their plastic mass (lost as microplastics) every season (which lasts for approximately six months) because of wear and tear; or in the case of dolly ropes in the North Sea, it has been estimated that 25 t of dolly rope threads end up in the ocean yearly (Gilman et al., 2021). Making the cover of the seine ropes biodegradable in the marine environment or making dolly ropes more durable could reduce their environmental impact (DollyRopeFree, 2023; Syversen et al., 2022). In addition, a smart design of gear with easily dismounting sections and the support of technological devices may allow identifying damaged sections easily and may facilitate reparation onboard, thus preventing loss at sea, and creating the need to bring nets to land. Tagging the gears with electronic devices can allow tracking lost gear so they can be recovered by the vessel. An idea encompassing a participatory approach to the problem of ALDFG is the engagement of the fishing sector as guardians of the seas, so they can contribute to retrieve marine litter including ALDFG and earn some income.

Materials used should have low impact: gears are made of several materials, often combining 1-3 polymers e.g. polyethylene, polypropylene, and polyamide, but of other materials such as metals (sinks, lures, rings, etc.), and floats made of polystyrene and other materials (MRAG, 2020). This varied composition together with the impurities (scales, sand, etc.) and contamination present (e.g. antifouling coating) in the nets make their disassembly and recycling quite complex.

Optimal possibilities of the fishing gear at the end of its life: Sections of the net should be easily dismounted, cleaned, and materials easily classified for further circular use in other industries. In some cases, classification of fibres is quite straightforward, e.g. in the case of purse seine netting material which are predominantly made of polyamide could be more easily classified, while ropes made of a mixture of fibres will imply more difficulties. A possible solution could take place in the production process of the fibre by employing colour marking, thus facilitating identification of the fibre employed. Innovative design of gear requires further multidisciplinary research on gear design, involving participation of skippers and gear technicians. Funds provided by EU funded research programmes, or supported by the EMFAF, can provide financial back up to these kinds of initiatives.

Some of the circular design solutions applied to the fishing industry are mentioned below.

- **Aquaculture longline ropes made of recycled polyamide and Polyolefin-based fishing nets**: EMFF funded the BLUENET project (https://www.bluenetproject.eu/) for developing longline ropes made out of recycled fishing nets. The ropes were tested under real conditions at an offshore aquaculture site (Mendexa, Spain). The circular ropes showed similar technical properties, improved environmental impact but were 2-4 % more expensive than commercial counterparts were. The consortium included a fishing gear manufacturer as partner.

- **Biobased materials for fishing gears**: Biobased and biodegradable polymers are also being used to produce fishing and aquaculture gear. The DSOLVE project (https://uit.no/research/dsolve-en) is currently producing and testing different biodegradable plastics for marine applications, including gillnets, pots and traps, longline ropes, dolly ropes, demersal seining ropes to reduce the contribution of these fisheries to marine litter and microplastics. The Glaukos project (https://glaukos-project.eu/) also presents a similar objective and is currently developing biobased fishing gear and eco-friendly fishing gear coating with increased biobased content. Likewise, the INdIGO project (https://indigo-interregproject.eu/en/) aims at developing fishing gear that is biodegradable in the marine environment, and at improving the recycling of fishing gear at the end of its life. All the above mentioned projects include a commercial fishing partner or gear manufacturer in the consortium to create, test or validate the new prototypes.
- **Alternative designs for dolly ropes**: the 'DollyRopeFree' project (http://www.dollyropefree.com/) aims to reduce the marine litter contribution from trawling fisheries using dolly ropes. To obtain this, two approaches are tested:
    - The use of **alternative materials**, such as natural (e.g. Yak leather) and biodegradable materials (e.g. PLA, Solanyl) or other materials (e.g. Polyurethane) that are less prone to wear and tear, instead of conventional polyethylene threads;
    - **alternative designs** for net protection in another form than strings but with the same kind of protective properties as conventional strings.

3.1.2. Collection of ALDFG and marine litter by the fishing sector

Sustainable exploitation of fisheries requires an ecosystem-based fisheries management approach (Howell et al., 2022; Curtin and Prellezo, 2010). The scope of this management should not be limited to the stock sustainability; it should also address other anthropogenic pressures such as their carbon footprint and plastic pollution as fisheries have become sources and sufferers of such pollution (Bastardie et al., 2021; Basurko et al., 2022c). According to Van Acoleyen et al. (2013), the damage produced by marine litter in European fisheries is equivalent to 1 % of their annual fishing revenues. Fishery related fishing litter is high in certain European regions such as in the Bay of Biscay (Veiga et al., 2016; EEA, 2016), where 55 % (in weight) of the coastal floating marine litter is fishing related, and constitutes 19 % of the seafloor litter (Ruiz et al., 2020; Spedicato et al., 2023).

Discarding unusable fishing gear overboard is prohibited; fishing vessels are obliged to notify national authorities or report (according to MARPOL 73/78 Rule 7, Annex V) when they lose fishing gear and to carry onboard the necessary equipment to retrieve it (Drinkwin, 2022). Even if the loss is involuntary, fishers are obliged to attempt to retrieve and, if unsuccessful, report it. However, discarding fishing gear at sea is still a practice in some regions of the world (Richardson et al., 2018). In Europe, losing a complete gear set is rare, but it can occasionally occur especially as a consequence of bad weather, bad practice (e.g. badly tied to the vessel), poor gear maintenance, interactions with other fishers or fauna, or getting stranded or stuck to the seabed (Olsen et al., 2020; Richardson et al., 2021). It is also quite common to reuse the old fishing netting to patch material in net repairs (Richardson et al., 2018).

Some of the solutions engaging fishers and their role in the retrieval of EOL fishing gear and marine litter are the following:

- **Fishing for litter (FFL):** fishers' attitudes (how they perceive and influence their behaviour and practices) towards marine litter and discarding EOL fishing gears has shifted in the last decades in Europe thanks to awareness campaigns (Olsen et al., 2020). **FFL** schemes are seen as a solution to engage fishers in marine litter removal from the sea; it also serves to raise awareness on the protection of the marine environment within the fishing sector. Under the FFL umbrella, fishers are equipped with big bags or bins to store the collected litter onboard, and port facilities (bins, cages) are placed in ports to collect the landed litter.

- There are **two types of FFL**: active (fishers are paid for doing it) and passive (it is done on a voluntary basis) (Andrés et al., 2021).
  - One example of **active FFL** is located in the South-East Bay of Biscay, in the Atlantic border between France and Spain, where local authorities subcontract a fishing vessel from Saint Jean de Luz (France) every spring and summer to clean the coastal area comprised between 300 m until 3 nm away from the coast (Andrés et al., 2021; Ruiz et al., 2020). The active FFL, which is recommended for small-scale fisheries due to their low operational costs, is compatible with the fishing activity. In fact, it can be seen as a diversification opportunity for their economic activity (Andres et al., 2021). However, fishers will only accept this solution if their main economic activity (i.e. fishing) is not interrupted (Andres et al., 2021). Likewise, the activity is attractive to local authorities if the region is prone to accumulate marine litter, as it is the case of the South-East Bay of Biscay (Basurko et al., 2022c).
  - In contrast, **passive FFL**, started by KIMO International in 2002, has gained importance and practitioners across Europe. The fishing sector from the UK, Germany, Norway, Ireland, Greece, Netherlands, Croatia, Italy, Spain and others are currently or have been involved in passive FFL in the past. It has played a major role in the inclusion of marine litter as a new waste category – passively fished waste (i.e. 'waste collected in nets during fishing operations') – under the recently adopted EU port reception facilities Directive (Mannaart and Bentley, 2022).
- **Improving the governance of lost fishing gear**: One of the solutions in high TRLs is the one proposed by EMFF funded project NetTag (https://nettag.ciimar.up.pt/), which developed a technological solution based on acoustic sensors and an autonomous remotely operated vehicle in order to locate and recover lost fishing gear at sea.

3.1.3. Management of fishery related waste and business initiatives

The PRF and SUP Directives dictates that a sustainable management has to be provided to the EOL fishing gear, fostering their recycling, and for that ports need to be equipped with the right infrastructure to be able to store all the ship-based waste landed, including marine litter brought to port by FFL initiatives. This implies a separate collection, transport, and a circular treatment, and setting a minimum collection rate of 50 % and a recycling target of 15 % for fishing gears by 2025 (Basurko et al., 2023). However, given that the reporting systems has yet to be established in Europe, the amount of EOL fishing gear and marine litter landed in European ports is still unknown, despite, some figures have been published for Spain (1 643 tonnes per year) and Norway (4 000 tonnes per year including ALDFG) (Basurko et al., 2023; Deshpande et al., 2020a). Furthermore, small percentage of the material that arrives to port gets recycled (according to the EU, 1.5 % (European Commission, 2023)) as most countries end up sending this waste streams to landfill or incineration, such as in Norway, where 19 % gets incinerated (Deshpande et al., 2020b).

Member States are called upon to set minimum annual collection rates of EOL fishing gear for recycling, and to monitor the fishing gear placed on the market (EPRS, 2019). Likewise, other policies such as the EPR schemes and MARPOL 73/78 Convention have also been updated to foster the correct management of EOL fishing gear and marine litter in general.

a. Extended producer responsibility

The extended producer responsibility (EPR) schemes, which are based on the “polluter pays” principle, means to “make the manufacturer of the product responsible for the entire life cycle of the product and especially for the take-back, recycling and final disposal”.

This often includes making producers accountable for financing EOL treatment cost (take-back and recycling) while providing incentives to producers, in order to:

(i) **prevent waste** at the source, and

(ii) design products that are **recyclable/reusable**.

The EPR is highlighted in the SUP Directive and suggested to be implemented by Member States. In fact, in January 2025 the EPR for Fishing Gear will enter into force in Member States. Producers and assemblers have responsibility to set up schemes to recycle gears, and national legislators will need to set up schemes for that. Moreover, a wide range of other stakeholders will need to be engaged in this process too (e.g. fishers, port authorities, waste managers, recyclers, SMEs, innovators, etc.). The newly developed regulatory framework has echoed the will of entrepreneurs and SMEs for new market niches and business opportunities based on recovered EOL fishing gears and marine litter in general (Dijkstra et al., 2021). The sustainable fashion industry has also approached the marine litter paradigm and has started to have products made from recycled marine plastic yarn and fabrics (Khandual and Pradhan, 2019). Some examples are Adidas-Parley Ocean Plastic, Prada, Converse, Ecoalf’s Upcycling the Ocean, Ternua Group, Inditex, H&M, Hérmes, and Patagonia.

b. Recovery and reuse of EOL fishing gear

EOL fishing gear needs to be in a good condition for its recycling; thus, it is of utmost importance to store and collect it properly. In Europe, NOFIR (https://nofir.no/) is a Norwegian company that specialises in collecting and conditioning fishing nets and fish farming material throughout Europe and Turkey. It is one of the most important in its sector with having conditioned more than 40 000 tonnes of nets from 17 countries all over the world. The collected material is transported to its factory in Lithuania or Turkey, where it is conditioned and repaired by the partners for chemical and mechanical recycling. However, not all EOL fishing gear produced by the European fleets are stored in Europe. For example, tropical tuna purse seiners employ fishing nets that weight around 93 tonnes (64 % of which is polyamide) and are replaced every few years due to loss of physical properties. This can imply large amounts of EOL fishing nets in their mother ports (Andrés et al., 2022). Until recently, these nets were used to build Fish Aggregating Devices (FADs) but the prohibition of net reuse in the construction of such devices in the Indian Ocean (IOTC-2021-WGFAD02-INF02, 2021) and by January 2024 in all oceans (ISSF Conservation Measure 3.7 (ISSF, 2023)), has made them look for alternative option to foster their valorisation, such as reuse in aquaculture rafts Chicolino S.L. (https://www.jjchicolino.com/) or recycling (SARETU brand: https://www.bermeotunaworldcapital.org/saretu/en/).

EOL fishing nets from purse seiners operating in European ports are also reused for different applications. Some examples are:

- “**Honsare Poltsak**” tote bags (@HonSare, Instagram), initiative launched by few female net menders, who are relatives of Basque purse seine fishers;
- **Bracenet** bracelets and other accessories (https://bracenet.net/en/), driven by entrepreneurs;
- **Football goal netting** made from EOL fishing gears, promoted by Real Sociedad football Club and in collaboration with female net menders (Real Sociedad, 2023).

c. Recycling EOL fishing gear

Any fishing gear before being ready to be recycled needs to be dismantled. The net, then, is subjected to different and reiterative conditioning processes, which include sorting, washing, cleaning from impurities, grinding, and extruding. Following the waste hierarchy, fishing gears should be recycled mechanically or chemically, or treated with energy recovery technologies such as incineration (Arandes et al., 2004); landfill should be the last option to consider. It must be noted that chemically recycled EOL fishing gear-derived yarn can cost 3-5 % more than raw counterparts (Andrés et al., 2022). Nonetheless, the increasing number of initiatives on upcycling EOL fishing nets indicates that this could create new business opportunities (Andrés et al., 2022).

- **PLASTIX** (conditioning and mechanical recycling of polyolefin-based fishing gear, https://plastixglobal.com): this Danish company has developed a unique technology, which enables the mechanical recycling of post-use plastic fibres and rigid plastics mainly from the fishing and aquaculture industry. They are a producer of high-quality recycled pellets, with a patented methodology, which allows them to produce the material according to specific customer requirements. Their products are: Oceanix HDPE and Oceanix PP pellets made of EOL fibres from fishing nets, ropes and trawls.

- **AQUAFIL** (chemical recycling of polyamide-based fishing gear, https://www.aquafil.com): this Italian company is specialises in chemical recycling of polyamide. As a result of the chemical recycling, Aquafil produces pellets and the Econyl® yarn (brand name of the yarn produced by Aquafil) by mixing pellets from fishing nets with those of recycled carpets. Econyl® yarn is widely used in the textile industry and by other collaborators to produce 'sustainable' garments, swimwear, sunglasses, and accessories among others. Aquafil and NOFIR have a collaboration agreement for the supply (NOFIR) and recycling (Aquafil) of conditioned fishing nets.

- **FISHY FILAMENT** (recycled polyamide-based monofilament fishing nets, https://fishyfilaments.com/): this Cornwall (UK) based company, which has been supported by a FLAG to secure infrastructure in port, is associated to Cornish Fish Producer Organisation. By recycling polyamide fishing nets from Cornish commercial fishers, produced ultra-low carbon supply of engineering grade Polyamide six pellets and filaments. They produce three pellets products: Porthcurno (suitable for homewares, wearables, fashion), Longships (same as Porthcurno but with higher variability in colour, base material for customer compounding and higher volume applications), and OrCA® (for engineering applications); and two filament types for Fused Deposition Modelling (FDM) 3D-printing applications (Porthcurno and OrCA®).

- **SARETU RECYCLING** (conditioning, recycling of fishing gear): this newly funded SME aims at revalorising EOL fishing nets, recycling and processing them into different products. Based in Spain, this start-up is the result of two projects (SARETU and SAREBIO (SARETU concept (https://www.bermeotunaworldcapital.org/saretu/en/) funded by the EMFF, the Basque Government and a private company (Bermeo Tuna World Capital), that introduced circular economy practices in the tropical tuna purse seine fisheries by testing biobased floats for purse seines and laid the foundations for the development of a local industry devoted to EOL fishing gear recovery, conditioning and recycling. As part of these projects, trucker hats, sunglasses and fishing bibs were produced (made with 100 % recycled material) and put in market under the SARETU brand by partner TERNUA GROUP; and SARETU RECYCLING was established. Currently, this SME has as funding partners, a fishing company (Echebastar), a fishing and aquaculture gear manufacturer (Grupo Eurored), and a R&D institution (AZTI).

- **FIL&FAB** (https://www.fil-et-fab.fr/): supported by the Cornwall & Isles of Scilly FLAG, this company from Brest (France) is devoted to recycling polyamide and producing polyamide pellets, branded as Nylo®, for different industrial purposes such as the keels for surfboards. Professional fishing associations from Le Conquet (France) are part of the consortium established to develop this initiative.
- **BUREO** (collection, conditioning, and recycling of fishing nets, https://bureo.co/): outside Europe, Bureo, which is based in the USA and Chile, is one of the most important SMEs devoted to fishing gear recycling. It includes recycling programmes in Chile, Argentina, Peru, Ecuador, Mexico, and the USA. It produced the NetPlus® material, made from 100 % post-consumer recycled fishing nets. It counts with NetPlus® brand partners such as Patagonia, Costa sunglasses, Carvers skateboards, Jenga® Ocean™, Futures fins, etc.
- Chemical recycling (Pyrolysis) of marine litter and EOL fishing gears: as part of the **marGnet** project (https://www.margnet.eu/), the pyrolysis of marine litter and EOL fishing gears was tested by Syntol SME to convert these wastes into ISO 8 217 compliant marine fuels (Faussone and Cecchi, 2022).
- Other initiatives address waste material from the distribution phase of fish such as expanded polystyrene from fish boxes, which is recycled to produce pellets for its use as raw material in different industries. This is the case of the project supported by **Thy-Mors FLAG** for the creation of Denmark's first recycling plant to process expanded polystyrene into plastic pellets (FARNET, 2018).
- Other products made from recycled fishing gear are being developed in the **INdIGO** project (http://indigo-interregproject.eu/en/, 2023).

d. Solutions linked to the uptake of fish wastes

- **Recycling fish skin into "marine leather"** (FARNET, 2015): Through cooperation with local fishers and designers, and inspired by traditional techniques from other fishing communities in Europe, a young French entrepreneur has developed an innovative fish skin tanning process and now sells her "marine leather" to fashion designers all around the country. Products made with this technique include bags, bracelets and other items for sale. This initiative was made possible thanks to the initial financial support provided by the Arcachon FLAG.

3.2. Challenges and opportunities for/from implementing a circular economy action plan in EU fisheries

3.2.1. Challenges

a. Challenges related to the circular design of fishing gear

- Currently, **fishing gear is made of a large mix of materials**. Some nets not only include panels of different polymers, they also include mixed polymers and metals. The composition of the materials conforming the nets, ropes or other fishing gear components are not marked. Furthermore, fishing gear may be discarded in ports of other countries. This makes the process of disassembly and sorting of fishing gear by component and material difficult, which ultimately, hampers their recyclability.
- **New generation of materials may present challenges at the end of life**. For example biodegradable and compostable gears, that unless a proper waste management is established

for them, including recovery and treatment, they would have to end up in landfill or incineration. Another example is Dyneema®, that although as material is very desirable due to its lighter and stronger properties compared to other polymers, its recycling stream and technology is yet to be defined (MRAG, 2020).

b. Challenges related to the collection of ALDFG and marine litter by the fishing sector

- **Lack of storage space onboard**. Small fishing vessels, in particular, present limited storage space onboard to keep marine litter retrieved from the sea (Olsen et al., 2020). Smaller size vessels not only lack space onboard to store large ALDFG but also, they do not collect it due to lack of time or personnel, although for others it may be due to poor attitudes (Olsen et al., 2020).

- **ALDFG and marine litter accumulation is often unknown.** Unless GPS-fitted tags are used to locate the lost fishing gear, the location of marine litter and ALDFG is often unknown. These lost gears and other marine litter tend to accumulate in aggregation structures such as marine litter windrows but while models predicting the distribution of floating litter at larger scales can describe overall patterns (Lebreton et al., 2012), there are still some limitations in higher resolution areas i.e. coastal areas (Madricardo et al., 2020; Ruiz et al., 2020).

- **Difficulties to land marine litter and EOL fishing gear**. Waste management for fishers should be easy otherwise; it may end up in the ocean. However, port authorities and waste managers have shown in particular instances **unwillingness to collaborate** and **lack of responsibility** towards establishing a management scheme for these waste types (Basurko et al., 2023; Olsen et al., 2020).

- **Inadequate port reception facilities**. Often ports are still lacking infrastructure and technological knowledge to handle EOL fishing gear and marine litter, especially small ports. Furthermore, ports include different fishing fleets, governance systems and socio-economic frameworks, which affect how EOL fishing gears are managed. The level and quality of port reception facilities differs not only within countries but also between cities and towns (Basurko et al., 2023; Olsen et al., 2020). This means that fishers have to carry the waste home, drive it to municipal waste facilities, or keep it onboard to take it to a different port.

- **Lack of selective waste management and recycling practices in land discourage fishers to manage them properly at sea**. Interviews with fishers in Norway and stakeholders in Spain highlighted that fishers show little motivation in participating in FFL initiatives or discard EOL fishing gear adequately if waste in land is not managed properly (e.g. all waste thrown to the same container) and relevant authorities and waste managers do not pay adequate attention. Likewise, fishers feel frustrated if ports do not have adequate port reception facilities or are used as general-purpose waste bins by port users. Having known professional waste managers' reception facilities in ports (e.g. NOFIR big bags, Ecoembes' bins…) helps to motivate fishers to sort waste before discarding and act accordingly (Basurko et al., 2023; Olsen et al., 2020).

- **Lack of awareness.** Retrieving, storing, and landing marine litter and EOL fishing gears in port reception facilities depends also on the good will of shipowners and skippers. However, not all skippers have the same level of awareness (Olsen et al., 2020).

- **Lack of training**. Fishers, port authorities, and waste managers lack experience in retrieving marine litter from the sea, as well as managing EOL fishing gear in port (e.g. storing, disassembling). This hampers the understanding of the dimension of the challenge associated with sustainable management.

- **Poor reporting**. Waste produced and delivered to shore is not widely reported. Coastal fishing vessels bring the waste generated onboard during the fishing day. For larger vessels that spend more days at sea, some have waste compressors and storage facilities, others just use onboard bins. However, there is little control on the waste brought to land after a fishing trip, which may be conducive to adopting bad practices such as throwing it overboard (Olsen et al., 2020).

- **Additional waste fee**. In some ports, fishers have to pay an additional fee to have their marine litter and EOL fishing gear managed by port authorities and/or waste managers (Basurko et al., 2023). Fishers request that this service of waste collection be included as part of their annual fee to port authorities. Some fishers are even willing to pay more to ensure that all ports are offering this quality service (Olsen et al., 2020).

c. Challenges related to recycling fishing gears:

- Products made of marine litter or EOL fishing gear often **lack traceability** and no information is provided on the environmental impacts to support green claims (Schneider et al., 2018). Reporting this information could help others develop products with less risk, shed light on green claims and obtain green passports (Andrés et al., 2022).

- **Few local recyclers and knowledge on how to recycle marine litter and EOL fishing gear** are available. It is more desirable to manage the waste within smaller geographical areas from its origin to reduce the environmental burdens originating from the transboundary export of waste (Havas et al., 2022). However, **waste stream quantities generated locally may be too low** for continuous recycling, which may jeopardise the economic profitability of recycling plants. More focus should be put on finding solutions in terms of volume, cleaning, and logistics. These problems result in most of these local waste streams ending up in landfills (Andrés et al., 2022; Deshpande et al., 2020b). However, a better collaboration between different stakeholders could promote the recycling and upcycling of these wastes.

- **Mixed composition of fishing gear**. The disassembly of fishing gear by component and materials is sometimes too complex, and this complexity ends up affecting the recycling possibilities (MRAG, 2020). There are numerous technologies available for the marking of the different materials used in fishing gear components (He and Suuronen, 2018), which could help in sorting the waste streams, but they are rarely used.

- **Recycling marine plastic and EOL fishing gear** is more challenging than recycling post-consumer plastic because it can contain a considerable amount of sand, salt, fouling, shells, algae, and marine plants (Ronkay et al., 2021), and also it costs more (Ronchi et al., 2019).

- **An unclear definition of the term producer for EOL fishing gear and marine litter** generates ambiguities and difficulties when trying to apply EPR schemes.

3.2.2. Opportunities

- Positive impacts are expected from a circular economy approach. In fact, recycled materials from fishing gear can be employed as raw materials for other industries. Thus, contributing to reduce the dependency on raw materials in a variety of industries, while contributing to a cleaner environment and to reduce harm to marine ecosystems.

- Other waste coming from the processing and commercialisation aspects of the fisheries value chain are also materials that can be recycled to provide secondary raw materials to other industries such, as for example, materials employed in the transport, storage, and conservation of seafood; or concerning organic materials to diminish garbage while providing materials for small-scale business.

- Employment level in coastal communities can also be positively impacted by the need of personnel to sort, manipulate, and manage the materials coming from fishing gears at port facilities. The creation of innovative businesses to recycle the materials, both from the fishing gears or from the waste of the processing activity provide a large array of options.
- The contribution of fishers as guardians of the seas collecting marine litter can also provide an alternative for income during closed fishing seasons or where other limitations impede fishing.

3.3. Conclusions: lessons learnt and expected impact

3.3.1. Lessons learnt from implementation of circular economy in fisheries

Fishing sector has experience on embracing circular practices, which are still limited:

- Fisheries have shown different possibilities to embrace circular economy practices and gain benefits, for example by participating in marine litter collection and recycling or upcycling of EOL fishing gears.
- Many circular economy initiatives exist engaging the fishing sector and new jobs have been created; however, the problem may be linked to guaranteeing the continuation of these activities in the long term.

Ports are key:

- Port reception facilities for marine litter and EOL fishing gear should be available in all ports, regardless of the size and who is responsible for its management. However, this is not widely applied, and the quality of such facilities differs widely from port to port.
- It is most desirable to have local marine litter and EOL fishing gear storage, conditioning, and recycling centres but if low volumes are produced it may jeopardise their feasibility.

Awareness raising and more controlled on practices is needed:

- Transparency is key to avoid green claims about new circular products.
- Although there seems to be a growing awareness of the plastic and marine litter issue, there are still practices and consumption patterns that ignore this problem. Awareness raising campaigns are needed for all involved stakeholders.

3.3.2. Expected impacts from the implementation of circular economy in fisheries

Positive impacts are expected from the implementation of the circular economy approach within European fisheries. From the socio-economic perspective, it has the potential to create employment and new and alternative income for coastal communities. In this line, the circular economy can provide business opportunities for the fishing communities by engaging them in the design, collection, sorting, recycling or upcycling of products made of recycled EOL fishing gears and marine litter as entrepreneurs, co-operatives and social enterprises in port cities or towns. From an environmental perspective, a circular economy will help to reduce the demand for raw materials, provide new sources of secondary raw materials for other industries, develop circular fishing gear, generate less waste and pollution regarding ALDFG and marine litter; and ultimately reduce the negative impacts of marine litter on blue economy related sectors. Likewise, by reusing materials produced by circular and local businesses, it allows to keep control over the raw materials that are being used, avoiding imports of less sustainable products.

4. POLICY RECOMMENDATIONS

KEY FINDINGS

- A more **inclusive energy transition** approach should be established by promoting a more diverse list of energy efficient solutions and making them eligible for funding.
- The purchase, installation, and use of **energy monitoring devices** onboard should be promoted for all size fishing vessels.
- Fishing vessel´s presence in **IMO greenhouse gas emission policies** should be fostered.
- A right **balance** between **fishing capacity** and implementation of **energy efficient solution** should be found, by establishing a scientifically based **definition of fishing capacity**.
- The **collaboration and cooperation** between national/international stakeholders regarding decarbonisation and adoption of **circular practices in fisheries** should be incentivised.
- National and international **roadmaps** for **energy transition** and inclusion of **circular economy in fisheries** with clear objectives should be defined.
- A **definition for circular fishing gear** should be established.
- **Waste reception facilities** across countries and in small to large ports should be improved.
- A **centralised** collection, storage, conditioning, sorting and recycling schemes for **marine litter** and **end of life (EOL) fishing gear** should be established, and logistics of these waste types improved.
- An **extended producer responsibility (EPR) scheme for fishing gear** should be established.
- A single **fishing for litter (FFL) scheme** across Europe needs to be promoted and funded.
- Define the **traceability** of products made of **marine plastic**.
- Establish **harmonised reporting system** for marine litter and EOL fishing gear.

4.1. Decarbonisation of fishing fleets

Decarbonisation and energy transition policies should include the following recommendations:

- A sectoral roadmap, i.e. **fishing roadmap to decarbonisation**, should be established.
- Since **limitations on fishing capacity** (installed kW and GTs) could be a bottleneck in the implementation of energy efficiency solutions, we recommend a revision of the EU definition of the term fishing capacity, due to adding more GTs or kW does not necessarily increase a vessel's ability to fish. A scientifically supported definition of fishing capacity would allow to establish a more realistic balance of capacity and fishing opportunities and thus to conduct fair decisions on who is eligible or not for aid on energy solutions.

- Applying for funding often involves having to advance the investment money and a high administrative burden, especially for those vessel owners that are skippers or crew members, such as the ones in small-scale fisheries. Therefore, in order to increase the level of implementation of energy saving measures and to take advantage of available funds, we suggest establishing **a simpler process for funding applications**.
- Energy transition will be achieved thanks to the implementation of a **mixture of energy** efficient solutions. Therefore, the **funding** established for energy transition should be **more inclusive** and contemplate all sorts of energy saving solutions related to fishing vessel structure, fishing gear and fishing strategy as the ones mentioned in this report.
- The Commission should **promote the installation of energy monitoring devices** in all fishing fleet segments.
- The **European Data collection** framework should include data on energy consumption of fisheries, which is also based on reported information by energy monitoring devices. This information should be used to report GHG emissions of fisheries to IMO's database.
- **Fishing vessels** are considered as 'special vessels' in the **IMO regulation**, and as such they are excluded from some of their environmental rules. We recommend revising their **inclusion** for the energy efficiency policy framework of the IMO such as including the need to have a Ship Energy Efficiency Management Plan for existing fishing vessels or Energy Efficiency Design Index for new builds.
- A **European cooperation platform** should be established engaging the fishing sector (e.g. Producer Organisations), ancillary industry, researchers, NGOs, and policymakers to address energy efficiency in fisheries, exchange successful stories, promote dialogue and cooperation, facilitate the transference of information and sustainability awareness.
- **Seafood labels** and certifications incorporating the carbon footprint or FUI score of the fishery on the food products should be promoted.

4.2. Circular economy in fisheries

The circular economy in fisheries may benefit from the following policy recommendations:

a. Fisheries sector roadmap

- A sectoral **roadmap** to develop the **circular economy in fisheries' value chain** should be defined.

b. Circular gears

- A **definition for circular fishing gears** should be agreed, including targets for recycled content within the gear and associated legislation to enhance the design but also the implementation of circular gears onboard the fishing fleet. A future design of circular fishing gear should be one that is durable, facilitates an easy disassembly of the components and materials, uses alternative materials (recyclate, marine biodegradable, or natural) and is recyclable. This should also include marking of the materials and avoid, when possible, the use of mixed (e.g. polymers) and harmful materials (e.g. lead), without compromising the optimised durability and performance of the fishing gear.
- A **standardised approach to labelling and marking of the polymers and materials composing the fishing gear** should be established to facilitate its final recycling.

c. Management of EOL fishing gear and marine litter

- A **standardised collection, sorting, conditioning and recycling scheme** for EOL fishing gear and marine litter should be defined at European level. This implies: making **port reception facilities** for EOL fishing gears and marine litter **ubiquitous in all European ports**, regardless their size. This type of waste should be also included in established **waste treatment streams**; and adding the collection, conditioning, sorting and recycling of marine litter and EOL fishing gear as part of the **service contracts** of port waste managers, so that fishers would not have to pay an additional fee for the management of such waste.
- Programmes that promote to the expansion of **FFL schemes across Europe** should be supported financially.
- Member States should set **national minimum collection rates** for marine litter and fishing gear.
- A **reporting system** should be developed, one that is appropriate to local fishers, to document the extent and location of ALDFG, marine litter collected by FFI activities, and EOL fishing gear discarded in port.
- An **EPR scheme for fishing gear** should be established with financial schemes and support, and with defined responsibilities.
- Mechanisms should be established to **improve the logistics** associated with the full value chain for the recycling of marine litter and EOL fishing gear across Europe and reduce environmental impacts and costs.
- **Collaboration, cooperation, and dialogue amongst stakeholders** and between and within regions should be improved to reduce the uncertainty and establish responsibilities regarding the management for these waste types.

d. R&D&I

- **Research and innovation** on the circular economy on fisheries, e.g. circular design of gears, alternative management systems, conditioning-recycling technologies, smart logistics, etc., should be promoted by **supporting pilot projects**, and **synergies** between stakeholders financially.

e. Market and business development

- The **development of local circular solutions and projects** should be incentivised, embracing the cooperation and partnerships between the actors of the fishing industry value chain, LAGs, local waste managers, recycling companies or other entrepreneurs.
- A **market for recycled fishing gear and marine litter** should be promoted by, for example, fostering the green procurement of marine plastic-derived products.
- The **traceability of products** made of marine plastic or other fishery-related wastes (including marine litter and EOL fishing gear) should be promoted by, for example, establishing a label to define plastic of marine origin (link to digital product passport).

f. Awareness raising and development of skills

- **Awareness raising and training skills activities** should be increased for reducing the marine litter contribution from fisheries and increasing the participation in circular solution practices.

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ANNEX I

Link between Fit for 55 package with the waterborne transport and fishing

Policy instruments	Linked to seaborne transport	Applied to fishing vessels
EU emissions trading system (ETS), COM(2021) 551	First time shipping emissions are included in the EU ETS scheme. Shipping companies should monitor and **report** their **aggregated emissions data** from maritime transport activities at company level in accordance with the rules in Regulation (EU) 2015/757. However, the rules for monitoring, reporting and validation (MRV) only apply to large emitters (> 5 000 GT ships going to and coming from Union ports).	Not at present.
European taxation Directive (ETD), COM(2021) 563 final	Proposes to align the **taxation of energy products** (such as fuels) with EU energy and climate policies. These objectives will be achieved by: (1) promoting clean technologies, such as shore-side electricity provided to vessels while at berth in ports, that can be exempt from taxation; (2) eliminating incentives or exemption for fossil fuel; (3) setting the taxation based on energy content instead of volume, therefore encouraging the take-up of electricity and alternative fuels (renewable hydrogen, synthetic fuels, advanced biofuels, etc.); and (4) a ranking of the fuels according to their environmental performance.	Yes, through the fuel or energy (electricity) tax. The minimum levels of taxation should be applied to fuel use. To incentivise their use, sustainable alternative fuels and electricity will have a taxation rate of zero for 10 years
Use of renewable and low carbon fuels in maritime transport Regulation, COM(2021) 562	The 'FuelEU Maritime' initiative aims to increase the **production and the uptake of sustainable maritime fuels** and **zero-emission technologies** for the maritime sector by setting a maximum limit on the GHG content of energy used by ships calling at European ports. This initiative focuses on highest emitters (ships > 5 000GT).	Not at present.
The alternative fuels infrastructure Regulation, COM(2021) 559	Promote the deployment of alternative fuels by setting obligations to provide the **infrastructure to supply the demand of sustainable alternative (renewable and low carbon) fuels**. Member States are obliged to set up national policy frameworks to facilitate ships having access to shore-side electricity or decarbonised gases (i.e. bio-LNG and synthetic gaseous fuels (e-gas) supply in major ports.	Indirectly.

Source: European Commission et al. (2022).

This study is the first research paper in a series of three, prepared for a PECH Committee Workshop. It gives insight on the challenges and opportunities arisen from the application of the European Green Deal to European fisheries. It identifies solutions that are currently being applied regarding decarbonisation and circular economy practices in fisheries and observed strengths and weaknesses of the regulatory framework. It provides policy recommendations to move towards the decarbonisation of the fishing fleets and circular European fisheries.

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