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Laura Brodbeck

Mechanisms to support the recycling/reuse of fishing gear and the prevention of gear becoming lost/abandoned at sea

Barrier assessment

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In pursuit of innovative and sustainable solutions for marine plastic waste, the Circular Ocean project seeks to inspire enterprises and entrepreneurs to realise the hidden opportunities of discarded fishing nets and ropes in the Northern Periphery & Arctic (NPA) region.

As increasing levels of marine litter is particularly pertinent to the NPA region, the Circular Ocean project will act as a catalyst to motivate and empower remote communities to develop sustainable and green business opportunities that will enhance income generation and retention within local regions.

Through transnational collaboration and eco-innovation, Circular Ocean will develop, share and test new sustainable solutions to incentivise the collection and reprocessing of discarded fishing nets and assist the movement towards a more circular economy.

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NTNU Trondheim
Norwegian University of Science and Technology
Department of Industrial Economics and Technology Management

Postal address: 7491 Trondheim
Visiting address: Alfred Getz vei 1
Phone: 73 59 35 11
Fax: 73 59 10 45
Org.nr 974 767 880

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Responsible: Department of industrial economics and technology management (IOT), Norwegian University of Science and Technology (NTNU)	Signature:

Summary: The report details a barrier assessment relating to mitigating loss of nets at sea and increasing recycling and reuse of fishnets and ropes. The assessment is undertaken as a literature review where reports, scientific articles and other documents such as regulatory rules are used to identify potential mechanisms and barriers preventing their success. The report will be further elaborated in future work with the addition of stakeholder interviews.

Key words: Circular economy, green enterprise development, innovation, marine plastic waste, fishnets and ropes (FNR), recycling and reuse, barriers

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Executive summary

This report assesses the problem of marine litter in a number of ways. First, the current state of marine litter data is discussed in the Nordic region. Next, the current legislation against marine litter and associated gaps is assessed. Finally, a barrier assessment is performed on three different topics: EOL life treatment alternatives for fishing gear, strategies for supporting recycling/reuse and strategies for preventing fishing gear from being lost/abandoned at sea.

Summary of the current state of marine litter

Overall, there is insufficient data on marine litter worldwide. This section describes the current state of marine litter in the Nordic region and makes potential recommendations for future action. A summary of the current state of marine litter is described below:

- The risk of marine litter increases in areas with high levels of fishing and aquaculture activities (Norway and Iceland). In Norway, it is estimated that approximately 1,605 kg of lost/abandoned fishing gear per capita enters the ocean each year.
- Norway monitors its marine litter in several ways: annual cleanup operations to retrieve derelict nets, video surveillance of litter around oil transects and fulmar (seabird) plastic ingestion studies.

Despite these monitoring efforts, there is still insufficient data on marine litter in the Nordic region. Recommendations are described below:

- Norway should follow the OSPAR-led monitoring methods yearly and continue to collaborate with oil companies to collect marine litter data at the sea floor.
- Communication of the marine litter problem is important to increase awareness. This influences behavioral and policy changes.

Summary of current legislation against marine litter and associated gaps

In theory, the legislation for dumping waste in the ocean is comprehensive. The EU legislation and corresponding Norwegian regulations prohibit discharge and mandate effective inspection regimes. In reality, however, gaps exist in exemptions, the fees system, the reporting obligations and the inspection enforcement. The report reviews the international, regional and Norwegian regulations against marine litter and identifies some of the weaknesses/gaps below. A more comprehensive table of relevant laws/regulations can be found in Appendix A.

- Fishing boats are exempt from many waste-handling regulations even though they account for a large part of total waste generated at sea. Fishing boats are exempt from: creating a waste management plan, recording waste deposits and paying into the ports' indirect fee systems.
- Ports lack information due to the decentralized nature of their waste handling services.
- Inspections and enforcement regimes are often ineffective due to the lack of waste handling information.

Recommendations:

- Remove the exceptions for fishing boats in waste handling regulations.
- Ensure that authorities collect and share accurate information on legal garbage disposal processes. Ports must gain control over waste handling activities to

centralize the processes for waste notification and delivery. This information could more effectively support inspection and enforcement regimes.

Barrier Assessments

Barriers associated with three different topics are investigated in this report. The identified barriers are grouped according to the following categories: acceptability, economic, infrastructural, regulatory, technical and environmental. See Appendix B for a complete table of identified barriers. Only the barriers are listed below; full descriptions of the strategies can be found in the report text.

EOL Treatments

Three end of life options for fish nets and gear are further investigated in this section. These include: landfilling, incineration/waste recovery and recycling/reuse. The recycling/reuse option is assessed in further detail because of its higher prioritization in the waste hierarchy. The main associated barriers are listed below.

- **Landfilling**: Norway has a high landfill tax. Nets get easily entangled in landfilling equipment. Marine plastic gear does not biodegrade, so it often takes up landfill space indefinitely while seeping plastic into the environment.
- **Incineration/waste recovery**: Transportation costs can be high. Pre-sorting is necessary to remove low-calorific value material. The public may not accept this option based on potential toxic fumes/bad air quality.
- **Recycling/reuse:** These programs may not be cost-effective because of the volatile polymer market, high transport costs and many partners involved. Regulations for a recycling/reuse scheme may be needed to require better data collection on fishing net waste handling and to implement national marine recycling targets. Technically, gear must be thoroughly washed to comply with Norwegian antifouling regulations and must be separated/sorted manually, which is time-intensive.

Strategies to support recycling/reuse

This section assesses strategies that could potentially support national recycling/reuse schemes.

- **Landfill tax**: The tax could lead to illegal dumping and therefore require enforcement.
- **Extended producer responsibility:** Regulations must be introduced to require manufacturers to comply.
- **Deposit refund schemes**: Infrastructure for a national recycling scheme is necessary to support the strategy. The gear may be in a poor, altered state when returned.
- **Reward schemes**: It is costly to retrieve gear. Regulations must specify who is responsible for providing rewards (local/municipal gov't etc.). The public may not accept their taxes funding such rewards. Removing gear from sensitive substrate could damage the environment.

Strategies to prevent lost/abandoned nets in the ocean

This section assesses strategies to prevent nets from being lost or dumped into the ocean. The barriers to preventing nets from being dumped are discussed first. Next, the barriers for preventing lost nets and gear entanglement are discussed.

Dumped/abandoned gear

- **Port waste fees**: Time delays are incentives to dump at sea (not just fees). Special receptacles are needed at ports to collect fishing gear. Fishing vessels are exempt from indirect fee systems. Indirect fee systems vary among ports and can become confusing.
- **Penalty scheme**: Good behavior is not rewarded. Ports may not enforce, because they view vessels as customers. Administration and enforcement resources are needed. Waste deposit information is not easily accessible or harmonized with other ports.
- **Environmental tax**: Manufacturers may be resistant and look for technical exceptions. A supply chain shift to selling greener, innovative products will take time. Tax rates and product specifications for such a tax must be regulated and clearly communicated.

Lost gear

- **Gear marking:** Fishermen may be resistant. Gear registration databases would be needed. More comprehensive regulations for gear marking is needed.
- **Navigational technology:** Technical devices can be expensive. New regulations and enforcement would be needed. Technology may not be appropriate for all types of fishing gear.
- **Spatial zoning:** Fishermen may ignore zoning notifications. Information about the coordinates of lost gear may not be available because many lost nets go unreported. Administration would be necessary to update gear “hotspot” zones. New regulations would be needed.

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1. ALDFG abandoned, lost or otherwise discarded fishing gear
2. EOL end of life
3. MBI market based instrument
4. PE polyethylene
5. PP polypropylene
6. WTE waste-to-energy

Introduction

The Problem

As fishing and aquaculture activities intensify around the world, so does the use of required gear such as nets, fishing lines and ropes. As this gear becomes worn out, the end of life (EOL) treatment must be considered.

According to the waste hierarchy, reduction/prevention of waste is the most sustainable option followed by reuse, recycling, recovery and landfilling. “Sustainable” in this context refers to the protection of the environment and the minimization of resource/energy consumption. Unfortunately, EOL treatment of old fishing gear today is not consistent with the waste hierarchy. Rather, fishing gear waste is often disposed in the “cheapest container”, which is often the sea (Sherrington et al., 2016).

The impacts of lost/abandoned fishing gear in the oceans

Derelict fishing gear in the ocean poses a significant threat to animals living at the water’s surface. For example, animals such as dolphins and sea turtles can get tangled in nets. Commercially valuable fish can also get caught in a drifting net, therefore decreasing the available fish stock to fishermen (Macfayden et al., 2009). In addition to affecting the animals in the sea, derelict fishing gear can also damage the habitats in which they live. Ropes and nets move with currents and tides, which can cause them to break or smother fragile aquatic habitats such as sea grass or coral communities (Brink et al., 2009). This derelict gear can also cause serious damage to vessels by getting tangled in the rudders or propellers.

Overall, derelict fishing gear can have serious economic and ecological costs. It is therefore important to investigate measures or strategies that could prevent or control such impacts. This is possible through the right combination of strong laws and policies, governmental and private enforcement, outreach and collaboration platforms and an appropriate support infrastructure.

Research focus

This report investigates the potential end of life options for nets and gear from the fishery and aquaculture industries. Two of these end of life treatments are analyzed in further detail: recycling/reuse and ocean-based dumping. Recycling/reuse is of particular interest because of its high prioritization in the waste hierarchy. Ocean-based dumping is also in focus because of its serious ecological and economic impacts. Overall, this report aims to assess known strategies for either encouraging recycling/reuse or discouraging ocean-based dumping. This goal is depicted in Figure 1 below. In the figure, the red dotted arrow represents a focus on preventative strategies while the green arrows represent a focus on supportive strategies.

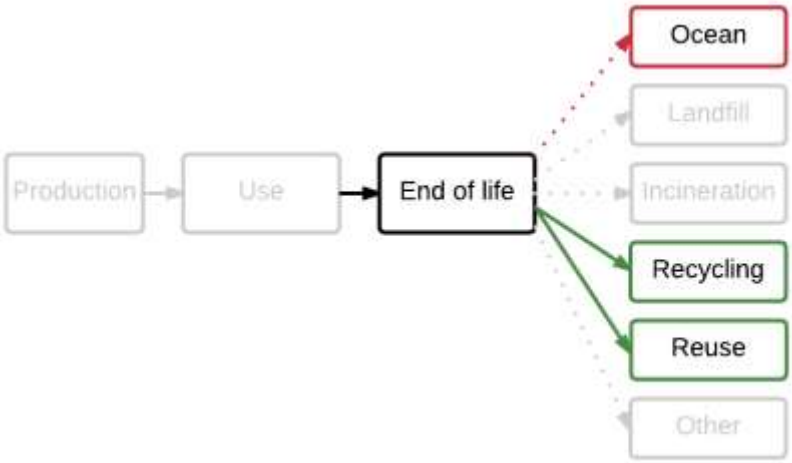


Figure 1. Visual depiction of this report's focus on two EOL treatments for used fishing gear.

Report structure

The aim of this report is to help stakeholders develop measures to combat ocean dumping while also encouraging recycling/reuse. These measures are put into the current legislative context. The outline of this report is illustrated in Figure 2 below.

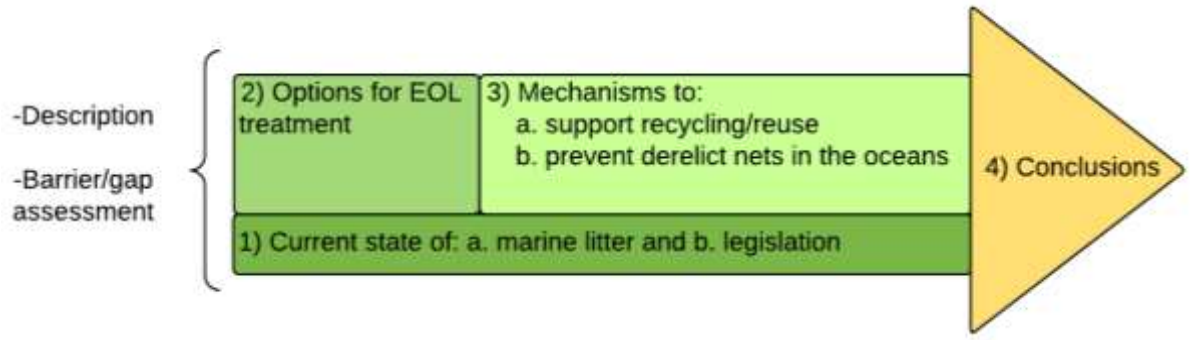


Figure 2. Illustration of the report outline.

The current state of marine litter in the Nordic region and relevant legislation against marine litter is described first in order to provide a general background to the report. One must first be aware of the current approaches against marine litter before additional, future strategies are considered. Gaps are also identified. The next section of the report discusses various EOL options for marine sector waste. The final sections involve assessing various measures or strategies for the two EOL treatments in focus: 1. Those that support recycling/reuse and 2. Those that discourage ocean-dumping. In each of the four sections (legislative, EOL, recycling/reuse, ocean-dumping), the topics are analyzed using the same approach. First the topics are described and then potential barriers or gaps are identified and discussed. In this way, the report aims to bring to light the opportunities and challenges of implementing the respective strategies. The overall feasibility of such strategies in the Nordic region is also discussed where possible.

Monitoring marine litter in the Nordic region

Before considering the legislation in place to combat marine litter, it is important to grasp an understanding of how much marine litter actually exists in the Nordic region. This process reveals what is known and unknown about marine litter in the region.

Mapping of marine litter

Derelict fishing nets and gear pose environmental problems in most of the world's oceans, but especially in areas with high fishing activity. Within the EEA, fish production is concentrated in a few countries. Norway and Iceland are the most important countries for fishing and Norway alone is the most important for aquaculture (Sherrington et al., 2016).

A fishing gear recycling project estimated that the annual tonnage of plastic equipment discarded from fishing and fish farming in Norway was estimated at about 15,000 tons (Nofir). Based on a calculation by Sherrington et al. (2016), the per capita generation of plastic waste of this type is about 1,070 kg per year. While this value represents the amount of gear that has reached the end of its lifecycle, another contribution to ocean litter is the accidental loss of plastic nets. Based on an estimation by Brown et al (2007), about 33% of a vessel's nets are lost each year. Therefore, the final estimate for total end of life and lost gear entering the oceans is approximately 1,605 kg/capita/year (Sherrington et al., 2016).

Data collection of marine litter

The Norwegian Directorate of Fisheries have organized retrieval surveys annually since 1980 (Directorate of Fisheries, 2015). Data lying on the sea floor has been documented through Norway's annual retrieval of derelict fishing gear (or gear components) that have been intentionally or unintentionally lost at sea. The registration includes gillnets, rope, fishing line, trawl wire, and other fishery-related items (Directorate of Fisheries, 2015). These cleanup operations also generate data on the number of entangled fish caught by derelict fishing. For instance in 2011, 14,000 kg fish and 12,000 crabs were registered from 1,100 derelict gill-nets and 54 crab-traps (Strand et al., 2015). In addition to these derelict fish net surveys, data is also gathered based on video surveillance along five pipelines in the North Sea and North Atlantic in the period from 1985 – 2009. These surveys found that fishing nets, along with hard and soft garbage, dominate the types of marine litter found along the five transects. It is important to note, however, that smaller litter is not registered in the surveillance, which means that fishing gear may be overrepresented (Strand et al., 2015).

According to Strand et al. (2015), no surveys of Nordic waters sample layers of the water column to determine the amount of existing macro-litter. As an alternative, OSPAR has suggested a different indicator for assessing litter in the water column—plastic ingestion by seabirds (fulmar). This species of bird often forages exclusively at sea and frequently ingests floating litter from the sea's surface, which therefore makes them a good indicator species for marine litter. Among the Nordic countries, Norway is the only country that has initiated national surveys on the stomachs of fulmars as a marine litter indicator.

Insufficient marine litter data in Norwegian waters

In general, there is insufficient data on the current status of marine litter in the oceans. Current knowledge of the quantities, degradation data and the impacts of marine litter are scarce (Chen

et al., 2015). The fishing sector produces a waste stream of fishing equipment, but this data generally has a high level of uncertainty. According to Sherrington et al. (2016), many figures in literature are outdated or related only to specific fisheries. The estimations in Table 1 below were calculated by disregarding some figures and combining others to provide an indication of scale of these losses currently within the EEA (Sherrington et al., 2016).

Table 1. Losses of fishing and aquaculture waste per annum in the European Economic Area (EEA). Data copied from Sherrington et al. (2016).

	Per year (tons)	**Total stock (tons)**
Fishing	1,700 – 12,000	130,000 - 550,000
Aquaculture	3,000 – 41,000	95,000 – 665,000

To increase the data certainty in Norway, there is a need to map the distribution and composition of litter on a yearly basis (Strand et al., 2015). To obtain this kind of data, it is recommended that Norway monitor its beaches and seas using the methods described by OSPAR (Strand et al., 2015). Collaboration with the oil industry is also recommended to increase data on marine litter at the seafloor (Strand et al., 2015).

Data on the quantity and impact of marine litter is useful for several reasons. Firstly, the communication of such data could help drive behavioral change to minimize marine litter. In addition, understanding the impacts of the marine litter could help decision makers select the most appropriate instrument to create the biggest impact (Newman et al., 2015).

Current legislation against marine litter

Description of current legislative instruments

Legislative instruments can vary in a number of ways. As Chen et al. (2015) describes, the measures can come in many forms including conventions, agreements, action plans, programs, regulations or programs. It is important to note that the instruments for tackling marine litter often overlap with other legislative mechanisms that address similar issues such as biodiversity or water quality. Although related, only those mechanisms specifically addressing marine litter are included within the scope of this review.

Several instruments that combat marine litter have been summarized in the following sections. These instruments were selected based on their relevancy to dumping at sea and waste-handling of fishing gear. Each instrument is introduced according to its level of implementation: international, regional and national. A more complete list and description of additional legislative regulations can be found in Appendix A.

International

The International Maritime Organization (IMO) developed the **MARPOL 73/78 Annex V** as a major international instrument that addresses ocean-based litter pollution from ships. Overall, this instrument bans discharge of all garbage from ships at sea with the exception of only a few defined circumstances. A recently revised Annex V sets a framework for managing garbage generated by ships. Ships >100 GT or ships certified to carry >15 passengers are required to provide a Garbage Record Book (GRB), which is meant to record all discharge of garbage made at both sea or reception facility. MARPOL Annex V also requires vessels to log the loss of any fishing gear by recording where the gear was lost, the characteristics of the lost items and which precautions were taken to prevent the loss. In addition, the MARPOL instrument requires ports to provide adequate waste reception facilities without causing a delay to ships. The Norwegian Maritime Authority has ratified the Convention and the Annexes of MARPOL and is therefore under the obligation to implement its regulations.

The **UNEP Regional Sea Programme** organizes and implements regional activities on marine litter world-wide. The instrument's main activities include: assessing the status of marine litter, organizing regional meetings with national authorities and marine litter experts and preparing a regional action plan for managing marine litter. This instrument provides a platform for cooperation and partnerships for managing marine litter between groups such as governments, UN agencies, donor agencies, private sector and others.

Regional

Article 5 of the **EU Control Regulation (EEC)** (no. 2847/93) provides detailed rules for fishermen to mark and identify their fishing vessels and gear. These rules came into force in 2005 and apply to passive gear such as gillnets, entangling nets, trammel nets, drifting gillnets and longlines. These detailed regulations require gillnet fishermen to mark each piece of gear and also use intermediary buoys.

The EU's **Port Reception Facility (PRF) Directive** came in response to MARPOL, which requires states to provide adequate waste handling facilities to ships. The PRF Directive requires ports to meet the following requirements: ports must develop and implement a waste reception and management plan, require waste deliveries, implement a type of cost-recovery system and establish a system for enforcement. Ship owners are required to notify ports of waste deliveries in advance. Member states are to ensure that costs of waste handling at ports are recovered through fees charged to the ships. All ships calling at an EU port must pay a fee irrespective of their actual use of the facilities. This is called an "indirect fee" versus a "direct fee" where payment is based directly on use/services. These indirect fees should provide a "significant" part of the port's waste handling fees. This "significant" amount has been defined as at least 30% of the total cost of ship waste handling. Some fishing and recreational vessels are exempt depending on the size.

OSPAR fits into the UNEP Regional Sea Program, and is a mechanism that legally requires cooperation among member states to protect the marine environment of the Northeast Atlantic region. OSPAR works on projects within the following main areas: protection of ecosystems and biological diversity, regulation of hazardous and radioactive substances, eutrophication and environmental goals and management mechanisms for offshore activities. Within the area of marine litter, OSPAR aims to harmonize PRFs and fee systems, implement "fishing for litter" projects, harmonize enforcement schemes and identify key waste items from the fishing industry and aquaculture. According to a Miljødirektorat report, Norway values this collaborative effort, because litter is a transboundary issue (Standal et al., 2014). Within the OSPAR action plan, Norway has committed to several tasks. These include: development of

best practices in relation to the fishing industry, reduction of sewage and storm related waste and the reduction of abandoned, lost and otherwise discarded fishing gear. To address derelict gear, OSPAR sets out to "identify the options to address key waste items from fishing the industry and aquaculture, which could contribute to marine litter, including deposit schemes, voluntary agreements and extended producer responsibility."

National

Norway's **Pollution Control Act** has been modified to enforce the regulations required by the PRF Directive (as described above) into Norwegian Law. The modified Chapter 20 now outlines guidelines for the delivery and reception of waste and cargo residues from ships calling port. As seen in the PRF Directive, it also addresses waste advance notification and the indirect fee system. The same exclusions in MARPOL/PRF Directive also apply to the Norwegian legislation where recreational and fishing vessels with fewer than 12 passengers are exempt from various waste management regulations.

Norway's **Marine Resources Act** (6/6/2008) is the main item of fisheries legislation in Norway. This legislation prohibits dumping of gear, moorings and other objects in the sea that may injure marine organisms, impede harvesting or damage gear. Any person that loses a net must attempt to remove the object from the sea. If this is not possible, this loss must be reported to authorities. These lost-gear reports help the coast guard effectively plan the annual clean-up campaigns (Standal et al., 2014). Any person that salvages gear is entitled to reward.

In addition to the aforementioned provisions, the Marine Resources act also addresses gear marking. It states that the Ministry can "adopt provisions on the design, marking, use and tending of gear and other devices in connection with harvesting." Additionally, the Ministry can adopt local regulations on the "placing and marking of gear" (Marine Resources Act, 2008). Chapter XVI under Norwegian legislation is similar to the EU regulations in that it requires that all fixed and drifting gear should be clearly marked. This includes gillnets, entangling nets, longlines and more. The gear marking legislation applies in the internal waters, territorial seas and economic zone of Norway with specific provisions outside 4 nautical miles and in the capelin fishery (FAO, 2016). For a summary of Norway's gear legislation, see Appendix C.

Gaps in current legislation and infrastructure

International, regional and national legislative instruments clearly address prohibiting the discharge of wastes, setting inspection regimes and imposing sanctions. However, a number of gaps and ambiguities threaten the effectiveness of such instruments. These include, for example: the framework for delivering waste to ports, the obligations for waste management and reporting and enforcement regimes. These weaknesses in the current legislation are further discussed below.

Exceptions in regulations for most fishing boats

According to MARPOL, vessels smaller than 100 gross tons and carrying fewer than 15 persons are exempt from a number of regulations. Based on the world's current fishing fleet, this exemption means that 99% of fishing boats are exempt from MARPOL's stringent waste handling regulations (Sherrington et al., 2016). Exemptions relevant to the fishing industry are summarized below.

Firstly, fishing boats are not required to make a garbage management plan. They are also exempt from carrying garbage record books (GRBs), which are meant to record all garbage

discharge operations. In addition, these fishing boats are exempt from the requirement to pay indirect fees to the port. Overall, these exceptions are a problem considering that fishing vessels contribute approximately 30% of the total waste generated at sea (Sherrington et al., 2016).

Ports lack a central role in waste handling activities

The Directive 2000/59/EC of the European Parliament sets out to enhance the availability and use of port reception facilities for ship-generated waste. According to the EU's PRF Directive, ports must provide facilities for receiving waste that are "available", whether in house or externally. The ports must also be "adequate" in that they must meet the needs of all users (all vessel sizes) and must do so without undue delay of ships.

These terms are often interpreted by ports in different ways. For example, it is difficult to assess how "adequate" or "available" port reception facilities are when most waste handling from ships is provided by private waste operators (Øhlenschlæger et al., 2013). Many ports expect ships to arrange for a third-party contractor to dispose of their waste (Sherrington et al., 2016). This prevents ports from playing a central role in waste management, because ships deal directly with the waste treatment contractor and not necessarily with the port authorities.

This situation leads to several negative effects. Firstly, the port authorities may never be notified about a waste delivery, because vessels may only take direct contact with private waste operators (Øhlenschlæger et al., 2013). This means that ports lack vital information about the disposal activities of vessels. This poses a problem for inspection authorities who would not have access to the information they need to detect potential waste handling offences. Another problem is that the administration burden of depositing waste at a port can be quite high for a vessel (Sherrington et al., 2016). Vessels must often coordinate with multiple actors to appropriately dispose of waste (port authorities, third-party waste handlers etc.). This process can lead to delays. Lost time often serves as a strong disincentive to using waste disposal facilities at a port.

Overall, a higher level of port authority involvement should be more clearly mandated by legislation (Sherrington et al., 2016). It is important to note that the port authorities at many Scandinavian ports play a central role in ship waste handling (Øhlenschlæger et al., 2013). This yields more transparency in the waste handling system and provides greater oversight of the port's waste handling activities.

Lack of inspections and enforcement

Inspections

The EU PRF Directive requires a minimum of 25% of the ships operating in an EU port must be inspected. The document recommends that port authorities pay particular attention to those ships suspected of not having delivered their waste in accordance with the directive. Although member states inspect ships, they often focus more on issues related to safety, security and labor conditions aboard rather than illegal waste discharges (Øhlenschlæger et al., 2013). The OSPAR regional action plan aims to identify best practices in the inspection protocols as outlined in MARPOL Annex V.

Enforcement

Gaps relating to information prevent inspections from being an effective deterrent. According to Sherrington et al. (2016), the current information available to enforcement agencies on ship garbage is not sufficient in order to detect illegal dumping. It is therefore difficult to obtain strong

evidence to bring ship owners to court on account of illegal dumping (Øhlenschlæger et al., 2013). This is especially the case for fishing boats, which are exempt from carrying garbage record books or making garbage management plans. To counter this gap, some countries like Denmark have introduced “administrative fines” that can be used to charge ships based on suspicion only (Øhlenschlæger et al., 2013).

Another problem is that port authorities have different interests. For example, they are interested in collecting waste notifications only to organize its waste collection activities and not necessarily to pursue cases of illegal dumping (Øhlenschlæger et al., 2013). In some cases, it has become apparent that port authorities see ships as their “customers”, and they therefore do not want to cause trouble with such inspections (Øhlenschlæger et al., 2013).

In the North Atlantic region, OSPAR has recognized the need for improvements in enforcement regimes against marine litter. In its regional action plan, OSPAR aims to analyze the penalties and fines for waste disposal offenses at sea (OSPAR Commission, 2014).

Barrier assessment

As discussed in the introduction chapter of this report, a barrier assessment is performed on each of the three topics: EOL treatment options for fishing gear, strategies to support recycling/reuse and strategies to prevent lost/abandoned fishing gear in the ocean. For this analysis, the barriers have been categorized into six types: acceptability, economic, infrastructural, regulatory, technical and environmental. These categories are further described in **Table 2** below. It is important to note that some barriers lie in more than one category. In these cases, both categories are denoted.

Table 2. Six types of barriers assessed in this report.

Barrier category	Questions to address
Acceptability	Would key stakeholders willingly accept and abide by the measure? If not, why?
Economic	Would the measure require significant economic investment to implement? If so, why?
Infrastructural	Would the measure require infrastructural changes? (new physical structures, databases, administration etc.)
Regulatory	Do current regulations support this measure? If not, what changes must be made? What gaps must be filled?
Technical	Are there technical challenges with the measure?
Environmental	Does the measure pose any environmental challenges?

End of life treatment options for fishing nets

The first barrier assessment in this chapter is performed on selected EOL treatment options for nets and other fishing gear: landfill, incineration and recycling/reuse (

Figure **3**). It is important to point out that the recycling and reuse treatments have been combined in this analysis, because they share many of the same steps and therefore have similar barriers.

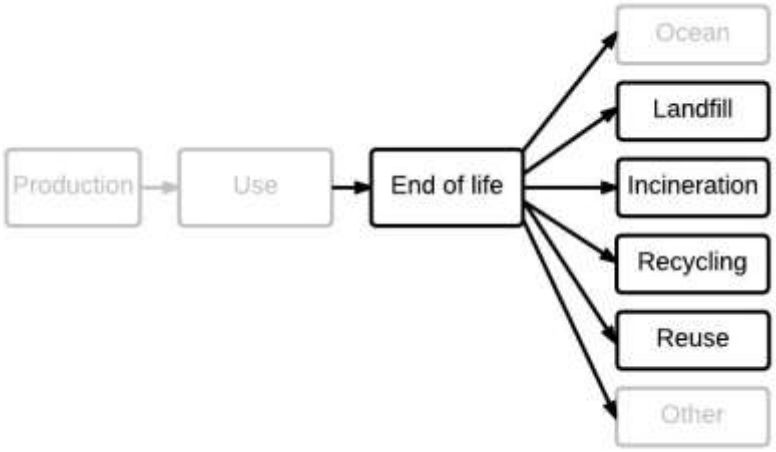


Figure 3. Three types of EOL treatments assessed in this report: landfill, incineration, recycling/reuse.

Landfill

In many cases, derelict fishing gear is sent to a landfill. In some countries, this treatment is often the cheapest and most logistically simple option.

Barriers

Economic: Norway introduced a landfill tax in 1999 (Fisher et al., 2012) to help decrease the amount of litter generated in the country. The taxes, fees and transport needed for landfilling fishing nets in Norway can be relatively high. Landfill fees and taxes in Norway cost approximately 280 euros/T (Sherrington et al., 2016). This means that a large 20 T fishing net could cost around 5,600 euros just to landfill (not including transportation).

Technical: Landfilling nets can cause technical problems at the landfill site. Old fishing nets can easy get tangled in the heavy equipment at the landfill site; they are also very difficult to bury (Macfayden et al., 2009). Because fish nets do not quickly biodegrade, they can occupy the landfill space indefinitely which can create disposal problems for other waste (National Research Council, 2009)

Environmental: Landfilling is of low priority in the waste hierarchy. In addition, fish nets and other fishing gear are often made of synthetic materials (polypropylene, polyethylene, nylon etc.). These materials do not biodegrade but rather break down slowly through solar radiation and thermal oxidation. The pieces of plastic, however, often break into smaller pieces, increasing the risk of plastic outflows into the environment.

Incineration/energy recovery

Nets are often sent to incineration plants where they are burned. Plastic is a product based on petroleum, so it has a very high calorific value when burned (Al-Salem et al., 2009). Due to this fact, plastic nets are often burned for energy recovery to produce heat or electricity. These kinds of facilities are called waste-to-energy (WTE) plants.

A case study in Honolulu, Hawaii is just one example of how a net collection/incineration program can work (Brink et al., 2009). In their model, fishermen retrieved the nets at no cost, and two organizations helped the fishermen offload the retrieved nets into storage containers

at port. Once the container became full, the nets were transported (free of charge) to a facility where they were incinerated and transformed into electric power for Honolulu.

Barriers

Economic: For a WTE plant facility to remain cost effective, it needs a constant input of waste to operate (National Research Council, 2009). For this reason, WTE plants are often centrally located because rural plants would not receive enough waste to burn. This could require high transport costs for ports lying far from central areas (National Research Council, 2009).

*Technical***:** Before fishing nets are burned, it is necessary to sort out the burnable waste from the waste with low calorific value. This means that the organic material stuck in the net should be cleaned out to ensure the highest energy harvest.

Acceptability/Environmental: Incineration/waste recovery is of lower priority in the waste hierarchy than recycling. In addition, burning nets to produce energy is not always the best option, because the combustion can create a toxic gaseous by-product. This was discovered in the Honolulu case study (Macfayden et al., 2009). Historically, incineration plants have been controversial in public opinion because of the air quality in the surrounding areas.

Reuse and recycling

The recycling and reuse of fishing gear is a relatively new focus area in the plastics recycling/reuse industry. A number of schemes exist in reusing fishing nets for a different function or recycling the plastic contents in the nets. For example, nets are being reused in agricultural activities in Taiwan, being recycled to harden vehicle tracks in Australia and are being reused for soccer nets (Macfayden et al., 2009). The nets used as input into the reuse/recycling systems are collected either from “fishing for litter” campaigns or from nets that were properly deposited at port receptacles. Two recycling case studies are described below to shed light on the logistics needed for such projects.

In Norway, the Nofir project was established in 2008 to collect and recycle discarded fishing gear. Nofir collects the nets in Norway which are available both for free or for payment depending on the location. The collected gear is then sent to Lithuania for dismantling and then sent to facilities in the EU and Asia for recycling depending on the material type (Sherrington et al., 2016). The second case study in focus is located in Iceland. In this model, much of the preparation work (cleaning & separating) is completed by deck hands. The vessel owner receives more money if the gear is properly cleaned, which incentivizes high quality preparation for recycling (Sherrington et al., 2016).

To describe the recycling process in Norway in further detail, the Nofir case is investigated based on the work by Hennøen (2016). The example case focuses on the recycling process of three different products from the marine sector: fishing nets, ropes, and fish farm nets. As seen in Figure 4 below, the first two steps in the recycling process for these products are identical. The products are first collected and then sorted. The “manual sorting” step also includes washing. This step cannot be automatized because of the nature of tangled nets and ropes. The fishing nets and ropes are washed by physically removing organic matter and sorted by stripping the nets with serrated knives. Technicians are trained to segregate polypropylene (PP), polyethylene (PE) and nylon fractions. After the manual sorting (and washing) steps, the PP and nylon fractions are sent to two different processes: mechanical recycling and chemical recycling respectively (Figure 4). The mechanical recycling process

produces granules as an end-product. The chemical recycling produces caprolactam, an organic compound that can be used in the production of Nylon 6.

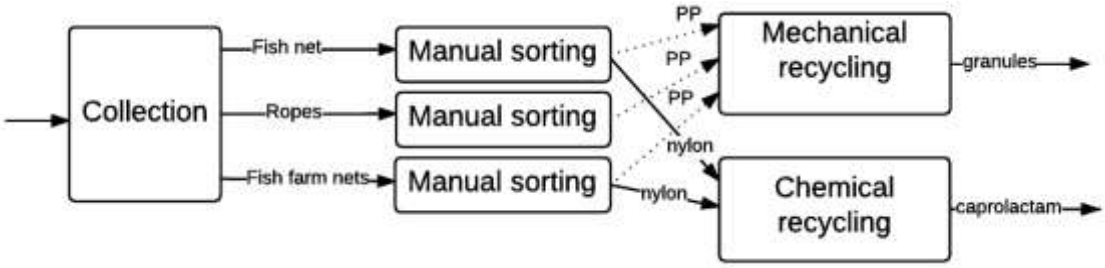


Figure 4. Diagram illustrating how fish nets, fish farming nets and rope can be recycled. Only material flows bound for recycled uses are illustrated (reuse, disposal and contaminant flows are excluded). Information portrayed in this diagram was adapted from Hennøen (2015).

Barriers

Technical/regulatory: Various barriers exist relating to such recycling and reuse schemes. Firstly, the synthetic material in fishing gear is likely to be mixed with organic matter (remains of entangled sea life). In addition to organic matter, approximately 10% of an average net's composition is made up of materials considered to be contaminants (Table 3). For example, plastic nets are contaminated by anti-foul coating which often contain heavy metal residues like copper (GI Waste Solutions, 2014). Nets are also often delivered with lead anchoring. Because of these types of contamination, fishnets may require special handling. For example in Japan, plastic fishing nets are considered "industrial waste" and must therefore be taken only to authorized disposal plants (Macfayden et al., 2009). In Norway, antifouling regulations require that the disposed nets must be washed and cleaned before recycling (Sandberg and Olafsen, 2006). This also implies a zero outlet limit on copper, which is the most important regulation regarding antifouling in Norway (Sandberg and Olafsen, 2006).

Table 3. Approximate polymer composition of marine nets. Table adapted from (GI Waste Solutions (2014).

1 ton of mixed marine net	**Approximate composition**
Nylon	15%
Polypropylene	38%
Polyethylene	37%
Contamination (metals, floats etc.)	10%
TOTAL	100%

*Regulatory***:** In order to assess a market's potential and attract investment, it is necessary to know exactly how many fishnets are available for recycling. Unfortunately, this data is not always available. In a case study in Scotland, it was found that most ports lack precise data on the net and fishing gear waste accumulation (GI Waste Solutions, 2014). This could be due to the fact that many ports do not play a central role in the waste handling activities as

described in the previous chapter. Without this data, it is difficult to make informed business decisions. For example, this data is necessary for justifying the introduction of a segregation and washing plant outside of a port (GI Waste Solutions, 2014). It is recommended that reporting waste delivery receipts should be made mandatory and that waste notification and delivery information at ports should be centralized.

Infrastructural: Currently, many ports collect derelict fishing nets and then send them to a landfill or incineration plant. Most often, these EOL options do not require special infrastructure or stringent preparation processes. However, recycling or reuse options often need special handling to avoid contamination with other waste. In a case study in Scotland, many ports indicated that they would need a clearly marked open-fenced area of hard standing to collect nets (GI Waste Solutions, 2014). The port authorities explained that open containers are more prone to misuse. For example, people may deposit drums containing oil or other such waste items that could soil nets meant for recycling. Ensuring that all ports have proper infrastructure to support recycling programs will require investment and infrastructural planning.

Infrastructural/economical: Another barrier is that the energy and resources necessary to recycle the fishnets and other marine equipment may cost more than the financial benefit of recycling. Many actors must be involved to appropriately recycle fishing nets. These include transport companies, dismantling companies, recycling plants for nylon, PE and PP, lead, steel and nets reuse services. Every step of the process involves transportation costs and each business partner gets a margin of the final profit. Most likely, all recycling partners do not lie within close proximity to one another. In the Norwegian and Icelandic case studies, this is not necessarily a problem because they are active in areas with high levels of fishing activity. The transportation costs in these areas are lower per unit because of the high density of waste collection. However, this may not be possible in other areas of the EU where fishing activities are less concentrated (Macfayden et al., 2009). For example, there are currently very few plastic reprocessing companies in Europe. Many companies are just brokers who ultimately send derelict nets to Asia (GI Waste Solutions, 2014). One way to decrease the cost of transportation would be to invest in local recycling options or to provide appropriate storage containers for recycling that are only picked up when full. It could also be possible to incorporate plastics from other industries into the same recycling system (GI Waste Solutions, 2014). For example, fish farms often use nylon nets to secure fish pens and PE polymer-based boxes to ship fish to processing facilities (GI Waste Solutions, 2014). Recycling facilities could therefore be designed to accept a variety of plastic products from the marine sector to increase input volumes and overall cost-effectiveness.

Economic: The global polymer market prices are volatile, which means that it is not always profitable to process PE or PP fractions (GI Waste Solutions, 2014). This is especially the case for those plants that have higher operational costs.

Technological/economic: Washing and separating a material is a crucial step before the material is recycled, because impurities can affect a material's properties and therefore its value. This can be quite challenging in recycling fishing nets, because they are multi-component items (nylon, PP and PE). Today's automatized technology is not yet applicable to sorting and washing fishing gear for recycling. Therefore, this process must be done by hand, which is time-consuming and consequently expensive. This is especially the case for Nofir in Norway, where labor costs are relatively high. Sending these nets to countries with lower wages is currently the only solution for maintaining the recycling business. A case study in Scotland also explored other alternatives such as involving the Scottish Prison Service to enlist offenders at a very low cost (GI Waste Solutions, 2014).

*Regulatory***:** Another barrier is that most countries lack recycling targets at a national level. According to Sherrington et al. (2016), minimizing plastic nets and other plastic marine litter should be counted towards a member state's environmental performance to incentivize such reuse or recycling activities.

Economic: Partnerships can pose a problem to a recycling program's long-term sustainability. For example, relying on cheap labor partnerships (Lithuania, Scottish prison service) weaken the business case for fishnet reprocessing, as these kinds of relationships may be volatile. Additionally, Nofir currently collects some nets at no cost. One must take note that if a market is created for such nets, partners may begin to demand payment for their old nets. This change should be accounted for in the future business plan as the recycling market grows.

Acceptability: The stakeholders necessary to implement a recycling or reuse program may not know about the importance of preventing plastic waste from entering the oceans. According to a Norwegian Miljødirektorat report, most local communities are not currently invested in addressing the marine litter problem (Standal et al., 2014). To help engage communities and important stakeholders, it is recommended that municipalities should both learn more about marine litter and also collaborate more with others. For example, municipalities could be given "information packages" where the background of marine litter is communicated (Standal et al., 2014). Municipalities could also enter more collaborative partnerships with organizations such as "the network of coast municipalities" (NFK) or the "municipalities international environmental organization" (KIMO).

Market-based mechanisms to support recycling/reuse

Market-based instruments (MBI) use market forces to address the marine litter problem. One basic concept –called the "polluter pays" principle—underlies market-based instruments. (Brink et al., 2009). This is a widely accepted framework for assigning the responsibility for addressing pollution to the polluter (Brink et al., 2009).

Selecting the most appropriate market-based instrument is much more complex than just considering which instrument is most cost-effective. There are in fact many factors to consider. Each mechanism has its own pros and cons. As seen in Table 4 below, Brink et al. (2009) recommends considering several regionally dependent factors before deciding upon a specific market-based solution.

Table 4. Factors to consider before selecting a market-based instrument (MBI). Information adapted from Brink et al. (2009).

Factor	Description
1. Feasibility	Does the MBI address: national environmental problems & priorities, national obligations, international objectives?
2. Effectiveness (2)	1. Does the economic instrument have the potential to offer significant environmental benefits?

	2. Is the instrument cost-effective (administrative, implementation, monitoring etc.)
3. Financial benefit	Will the MBI raise useful revenue?
4. Fairness	Is the MBI fair and equitable (i.e. “polluter pays” principle)?
5. Social impacts	What are the impacts across different income/social groups? Will the target audience be able to afford expenses?
6. Pricing	Does the instrument lead to efficient pricing (improving market price to become closer to resource/social pricing)?
7. Enforcement	Are there policy, administrative and infrastructural frameworks that will support the MBI? Are there barriers?
8. Acceptability	Is it understandable and credible to the stakeholders and public?
9. Economic consistency	How does the MBI interact with the budget deficit, competitiveness, inflation etc.?

In addition to those factors listed above in Table 4, Brink et al. (2009) mentions other insights as to what makes instruments work. For example, it is necessary to have a “champion” who is willing to provide leadership to make the new MBI work. Additionally, authorities wishing to implement a new MBI should collect feedback from relevant stakeholders in advance. Early consultation is critical for gaining “buy in” (Brink et al., 2009).

In the following sections, various market-based instruments are introduced. Each instrument is described in terms of its functionality and potential barriers. These instruments include: landfill tax, extended producer responsibility, deposit refund schemes and reward schemes.

Landfill tax

To further incentivize reuse or recycling, Newman et al. (2015) recommends a landfill tax. These kinds of taxes increase the price to landfill waste, which in turn encourages other forms of treatment (recovery, recycling, reuse) that are higher up in the waste hierarchy. These landfill taxes therefore not only cover the costs of a landfill’s operation and maintenance, but also offers incentive to reduce the amount of waste (Brink et al., 2009). As previously discussed, Norway currently has a relatively high landfill tax. Taxes in Norway vary depending on the waste delivered, which therefore creates an opportunity to charge more for marine litter deliveries. The collected money can be used to support efforts to combat the problem of marine litter. For example, Finland has increased its landfill tax, and the tax revenue is made available to fund contaminated land remediation (Brink et al., 2009).

Barriers

Acceptability/regulatory: A barrier related to the suggested landfill tax is that it incentivizes illegal dumping outside of landfills to avoid paying the tax (Newman et al., 2015). Estimates of

this kind of illegal disposal associated with marine litter are limited. Because illegal dumping may become a problem, regulations and enforcement must be put in place to deter such activities.

Extended producer responsibility

Extended producer responsibility scheme effectively makes the manufacturer responsible for the recycling/reuse treatment of their fishing gear products. In effect, this removes the inconvenience and cost factors associated with waste management from the fishermen. By linking the manufacturer to the products EOL stage, the scheme can also indirectly encourage more life-cycle focused product design (Sherrington, 2016). These kinds of schemes can also help trigger infrastructure development to support the EOL collection process (Newman et al., 2015). In Norway, the Ministry of Climate and Environment has announced their goal to introduce a producer responsibility scheme for fishing and discarded marine equipment from the aquaculture industry (Standal et al., 2014).

Barriers

Acceptability/Regulatory: This kind of scheme comes at an additional expense to manufacturers, which means that many will most likely be resistant. State legislation may therefore be necessary to force manufacturers to take responsibility for the EOL treatment of their products. Although Norwegian authorities have announced their goal of supporting such a scheme, specific regulations for specific products are necessary to move the scheme forward.

Deposit refund systems

A deposit refund system would require the consumer to pay a deposit upon the purchase of fishing gear. Once the gear reaches the end of life stage, the consumer could return the net and retrieve the deposit. A deposit refund scheme can incentivize fishermen to recycle the EOL nets/gear that would otherwise be burned, dumped or irresponsibly managed (Sherrington et al., 2016).

These instruments have proven to work very well for collecting EOL plastic bottles (Denmark, Malta, Germany etc.). The scheme has also been extended to include other products such as batteries, electronic equipment and cars (e.g. scrapping deposits in Denmark, Norway and Sweden) (Brink et al., 2009). As with the penalty scheme, the amount of the deposit fee must be enough to make the vessel lose money by illegally discharging at sea (Macfayden et al., 2009).

Barriers

Infrastructural/regulatory: An efficient fishnet recycling program must be established for the strategy to work. This kind of deposit scheme is not currently active in Norway, so new legislation would be needed (i.e. can/bottle return program).

*Technical***:** The state of the returned EOL fishing net may be of concern. Fishing nets are often bought and sold between fishermen. Additionally, most nets require repairing during its lifetime or may be combined with different gear (Sherrington et al., 2016). This makes it difficult for a fisherman to return the net to the manufacturer in relatively the same condition at purchase. As a solution, an equal volume or weight of net could be accepted instead (Sherrington et al., 2016).

Reward schemes

Reward schemes for collecting abandoned or lost fishing nets can be called “gear buy back” programs. Similar to “litter retrieval” and “litter retention” programs, these “gear buy back” schemes encourage fishermen or other authorities to collect marine litter and bring it back to shore for a reward and appropriate disposal. The major difference is that “gear buy back” programs offer a financial reward to those who return derelict gear, while the other programs enlist participants purely on a volunteer basis. In most schemes, authorities handle the transport and processing of the litter once it is brought back to shore (Sherrington et al., 2016). A recycling initiative could offer the same kind of reward system, but the source of money would be from the recycling market itself instead of taxes from local or regional governments.

The two following case studies highlight the different roles that fishermen can play in “gear buy back” programs. In a pilot project in Hawaii, fishermen are asked to report derelict fishing nets at sea. A team of trained volunteers then go to the reported location and remove the fishing gear. Once the gear is professionally retrieved, the commercial fishermen are awarded cash according to the weights of the reported derelict nets or gear (Brink et al., 2009). A similar program has been implemented in South Korea, but in this case, fishermen are responsible for reporting and retrieving the gear themselves. The program provides fishermen with durable bags to collect fisheries-related marine litter while at sea. The budget for this program is shared between the central and local governments (Macfayden et al., 2009). Over a 5-year period, over 29,472 tons have been captured (Sherrington et al., 2016).

Barriers

Acceptability: When a port is supported by a “good” behavior scheme, the reward for returning a net is often funded by local taxes. This may not be acceptable to all stakeholders in the community, as this results in costs to the community instead of the polluters themselves (Newman et al., 2015).

Economic: This kind of reward program may not be cost-effective because of the time cost of locating and removing the material. However, it could be worthwhile if the program targets very harmful gear such as gillnets (Sherrington et al., 2016).

Environmental: In the program that enlists fishermen to both report and collect fishery-related gear, there is concern about environmental damage. Because fishermen are not trained to remove lost nets, they could potentially harm the substrate to which the net is attached. For example, lost nets can become caught on sensitive reefs. Removing them could damage the underlying habitat (Sherrington et al., 2016). In addition, remove the litter could re-expose the features of the substrate that caused the net to get caught in the first place (Sherrington et al., 2016). This could ultimately lead to more nets getting caught in the future.

Regulatory: The Norwegian Marine Resources Act currently requires that all vessels report the location of fishing gear when it is lost at sea. Any person that salvage gear must furthermore report this to the owner as soon as possible. The owner must pay a reasonable reward to the salvager, not exceeding the value of the gear. The salvager may also keep any catch. In the case where it is impossible to determine owner or for other reasons may not take back their gear, it could be necessary to develop other supporting regulatory initiatives to ensure that detected gear is salvaged.

Strategies to prevent lost/abandoned nets in the oceans

This section assesses the potential strategies for preventing nets from being lost or abandoned at sea. The strategies' barriers for disincentivizing dumping at sea are introduced first. The following section explores strategies and barriers for preventing nets from getting lost at sea.

Market-based mechanisms to disincentivize dumping at sea

Port waste fee system

The collection and handling of marine waste is costly to ports. According to the polluter pays principle, these waste handling costs should be covered by the vessels depositing the waste. In this case, vessels would have to pay a waste handling fee that is directly correlated to the type and amount of waste. However, this "direct" fee creates an incentive to throw waste overboard as a free alternative (Newman et al., 2015). This is the reason that the PRF Directive/Norwegian Pollution Control Act require ports to charge vessels "indirect" waste handling fees. In this indirect port fee system, all vessels pay a set amount to use the port and its waste handling services. This means that all vessels pay the same no matter how much waste the vessels bring back to the port for disposal. The administrative burden on ports also decreases, because there is no need to calculate fees based on individual waste deliveries (Øhlenschlæger et al., 2013).

Barriers

Regulatory: Fishing vessels and small recreational vessels are currently exempt from these mandatory charges (indirect fees). However, the delivery of waste is still required according to MARPOL. This means that ports can legally charge the fishing vessels fees to cover the reception and disposal costs. In this way, they are allowed to charge fishing vessels based on the amount of waste they deliver ("direct fees"). As previously explained direct fees do not disincentivize fishermen from dumping at sea. This legislative exemption for fishing and recreational vehicles should therefore be reviewed.

*Regulatory***:** Although most EU member state ports have implemented an indirect fee as a part of their waste fee system, the implementation models can vary greatly (Øhlenschlæger et al., 2013). Even within the same country, the fee systems often vary from one port to another (Øhlenschlæger et al., 2013). For example, while the EU PRF directive requires ships to pay a minimum of 30% of total waste handling fees at the port, ports are free to charge up to 100% of the waste handling fees (Øhlenschlæger et al., 2013). This can ultimately confuse vessel owners as the rates change from one port to another (OSPAR Commission, 2014). Although the PRF Directive mandates fair and transparent fee systems, these terms can be interpreted in different ways at different ports. In addition, some ports have volume restrictions based on the ship size, and these rules are also dependent on individual port rules. For these reasons, the OSPAR regional action plan aims to make fee systems simpler and more standardized between ports in the North Atlantic region (OSPAR Commission, 2014).

*Infrastructure***:** This fee system requires that the ports provide suitable reception facilities for waste fishing gear that are easily accessible. For example, suitable bins would be required for collecting fishing net and fishing lines. These kinds of infrastructural improvements require investment. It is also important to note that not all ports accept all types of waste. For example, ports may accept sewage, food waste and fishing gear but not oily waste.

*Acceptability***:** The EU PRF Directive requires that waste handling procedures should not cause ship delay, but does not go into detail on what measures should be taken to ensure efficiency (Øhlenschlæger et al., 2013). As a result, many ports have organized their waste handling

systems focused on the needs of the ports rather than the ships (Øhlenschlæger et al., 2013). Unfortunately, these inefficient waste collection practices can increase the risk of illegally dumping at sea because of the convenience factor. Having to deal with both the port authorities and 3rd party waste handling companies also increases the chances of avoiding the waste management system altogether because of the time it takes to dispose of waste properly. One final important point is that the indirect fee system does not create a *positive* incentive to deposit waste at a port (Sherrington et al., 2016).

Penalty scheme

One way to dissuade vessel owners from dumping waste at sea is to introduce a penalty scheme. This scheme would impose a penalty on a vessel that does not discharge any waste at port (Sherrington et al., 2016). Penalties would be charged unless a vessel can provide a proof of delivery at another port. It is important to note that the penalty amount must be enough to make the vessel lose money by illegally discharging a net at sea (Macfayden et al., 2009). This added value can be used to finance awareness campaigns or to provide additional waste infrastructure (Brink et al., 2009).

Barriers

Economic/infrastructural: Collection and enforcement are necessarily for making these instruments work (Brink et al., 2009). The system would also require a more harmonized port delivery system, as ports must work together to provide vessels with more standardized waste deposits. It would also require trained enforcement teams to perform these inspections.

*Acceptability***:** The penalty scheme does not reward those vessels with good environmental performance. Fishermen therefore may view these as punitive measures, which can be demotivating. Additionally, ports often view vessels as “customers” and may be hesitant to enforce such a penalty scheme.

*Regulatory***:** As mentioned previously, one major barrier to implementing an enforcement scheme is the gaps relating to waste information. The current information available to authorities is not sufficient in providing evidence of illegal dumping. This is especially a problem in the fishing sector, where most fishing boats are exempt from MARPOL’s strict waste management schemes.

Environmental tax

The selling prices of today’s fishing and aquaculture products do not reflect the true environmental cost of the products. It is possible to internalize these environmental costs by increasing the final product’s selling price. The government could achieve this by implementing an environmental tax. This tax is designed to make the product more expensive to change consumer behavior and/or motivate producers to design more sustainable alternatives (Sherrington et al., 2016). These taxes can also generate revenue that could be used on marine litter projects such as beach clean-up activities or improving coastal waste management infrastructure (Brink et al., 2009).

Although there are currently no examples of such environmental taxes for fishing and aquaculture products (Sherrington et al., 2016), case studies do exist on products like plastic bags. Countries such as the Scotland, Denmark, Ireland and Wales have introduced extra taxes on one-use plastic bags (Newman et al., 2015). In all cases, the sale of such products have significantly reduced. This proof of concept could therefore be applied to those fishing and aquaculture products that are particularly harmful to the marine environment.

In the fishing and aquaculture industries, two product types have been in specific focus because of their negative impacts on the marine environment. These products are designed to break apart during their use in the ocean. First are the polystyrene floats and buoys, which slowly degrade throughout their lifetime and slowly leak plastic into the ocean. This can, however, be prevented by sealing them in a protective cover (Sherrington et al., 2016). Another harmful product is the dolly rope, which is used to protect nets from wear when they come into contact with the ocean floor. As trawl nets are dragged on the ocean floor, dolly ropes are designed to tear off and are ultimately lost in the marine environment. This impact can be avoided by ensuring that manufacturers use natural materials instead of plastic alternatives (Sherrington et al., 2016). In both of these examples, the government could apply an environmental tax on the more harmful alternatives. In this way, consumers would be encouraged to buy the more environmentally friendly solutions. Reducing the sale of these plastic components designed to be lost or break apart could effectively help reduce the impacts of plastic marine litter (Sherrington et al., 2016).

Barriers

Regulatory: Several EU regulations make it possible for member states to enact an environmental tax as described above. Article 7.2 of the Common Fisheries Policy allows the Union to implement technical measures to achieve objectives such as specifying fishing gear to minimize negative impacts on the environment. Article 17 encourages using fishing gear or using fishing techniques with reduced environmental impact. Although some regulations make it possible for Norway to implement an environmental tax on these harmful marine products, no such tax currently exists in Norway. More attention should therefore be given to help develop product standards that take into the negative impacts a product may have on the marine environment. To do this, the state would have to first select and describe the environmentally harmful products that would make the most impact. A tax rate must then be set to discourage consumption. Both the products and tax rates must be written into the current Norwegian regulations.

Economic: Some administrative overhead would be required to implement such an environmental tax. This overhead, however, could be supported by the newly created revenue stream from the collected taxes.

Acceptability: In a case study in Malta, authorities found it difficult to find an acceptable tax rate for environmentally harmful products. Spending time on assessing appropriate tax rates in the current market, therefore, would be necessary. In addition, it was found that some manufacturers found ways to evade the tax by avoiding certain product criteria in the regulation. Therefore, the product specifications should be clearly described in the regulations to avoid any uncertainty.

Infrastructural: The goal of this environmental tax is to discourage environmentally harmful products and encourage environmentally friendly alternatives. Because these cleaner alternatives are not common today, companies would need time to innovate and create new production lines and supply chains.

Strategies to prevent gear from getting lost at sea

The fishing sector is often seen as a producer of marine litter, but it must also withstand damage caused by such litter. Some of the more direct impacts involve repairing tangled propellers and rudders or un-blocking intake pipes. These activities require money and time away from fishing activities. A more indirect impact is the loss of fish stocks due to ghost fishing.

Gear marking

There are two types of gear marking. The first type is identification marking, which helps in identifying the ownership of lost or deliberately abandoned gear. By creating a link between the gear and the responsible vessel, authorities can better enforce penalties for intentionally dumping fishing gear and nets into the sea. Marking gear also creates an opportunity to return gear that was accidentally lost to the owner for reuse. The second type of gear marking is to increase the visibility of gear. For example, floating gear markings attached to stationary nets under the surface can help notify vessels about the risk of entanglement in the area.

As mentioned previously, the Norwegian Resources Act does in fact require fishermen in Norway to mark their stationary gear for visibility and identification purposes.

Barriers

*Acceptability***:** Gear marking can both help the fisherman locate his gear but can also get him into trouble if an unreported derelict net is found with his marking on it. This may dissuade fishermen from wanting to mark their gear at all. It is important, therefore, that gear marking is promoted in a positive way by highlighting the fact that it can help find gear that is temporarily lost rather than only as a potentially punitive measure post-recovery (Mcfadyen et al., 2009). Macfayden et al. (2009) recommends that the identification technology should be an intrinsic feature of the gear at the point of manufacture. In this way, fishermen would automatically use marked gear.

Economic/infrastructural: To implement an effective gear marking enforcement system, there would be a need to establish and maintain a database of gear ownership (Macfayden et al., 2009). Additionally, there would be a need for a comprehensive vessel and gear registration process as well as port inspection regimes.

Regulatory: The legislation in Norway currently requires all stationary gear to be labeled. To create a more comprehensive gear labeling system for all gear, more regulations must be introduced.

Navigational technology

GPS and sea-bed mapping technology can help fishing vessels avoid entanglement in derelict nets as well as aid in recovering their own lost gear. Fishermen can avoid accidental gear loss by attaching tracking devices, called transponders. These transponders use either radio channels or satellite systems to communicate their location in the water to the vessel.

Barriers

*Acceptability***:** These mechanisms can reduce navigational hazards, but many come at an added cost to the fisherman. For example, the transponders can be relatively expensive and would therefore only make sense in larger scale operations when there is more expensive gear at stake (Macfayden et al., 2009).

*Technical***:** Transponders may not be applicable to all types of gear (Sherrington et al., 2016). Additionally, effort is needed to ensure that the labeling does not restrict performance of the gear.

Regulatory: Regulations would be needed in areas where such technologies are not required by law. Regulations must be incorporated in inspection measures.

Spatial zoning

Areas with high levels of fishing activity often put fishermen at a higher risk for gear loss or entanglement. Zoning schemes or spatial management is one way to notify fishermen of these high-risk areas. These zoning schemes rely on reporting and derelict gear surveys in order to map out potential navigation hazards.

Barriers

Acceptability: Zoning procedures can ultimately cause fishermen to avoid setting nets in areas where the risk of gear loss or entanglement is high. That may lead fishermen to areas with lower fishing activity, lower densities of fish and ultimately lower catch rates and income.

Economic: Administration would be needed to constantly update spatial coordinates for derelict gear "hot spots" based on reports.

Regulatory: As previously mentioned, the Norwegian Marine Resources Act requires that all gear that is accidentally lost or salvaged be reported to authorities. This report should include specifications of what has been lost/salvaged and exactly where the gear was lost/found. In theory, this information is very useful for identifying local hot spots for gear conflict and then making corresponding spatial zoning decisions. However, the reporting system is not entirely standardized and often misses important information. For example, the type of net or the number of recovered nets is often not recorded in the current system. Therefore, more standardized monitoring and reporting methods are necessary for effectively mapping out lost gear hot spots. Officials in this area should therefore be given proper training and education on the importance of such reporting regimes (Sherrington et al., 2016). Regulations that specify the coordinates for these spatial zones would need constant updates based on available information.

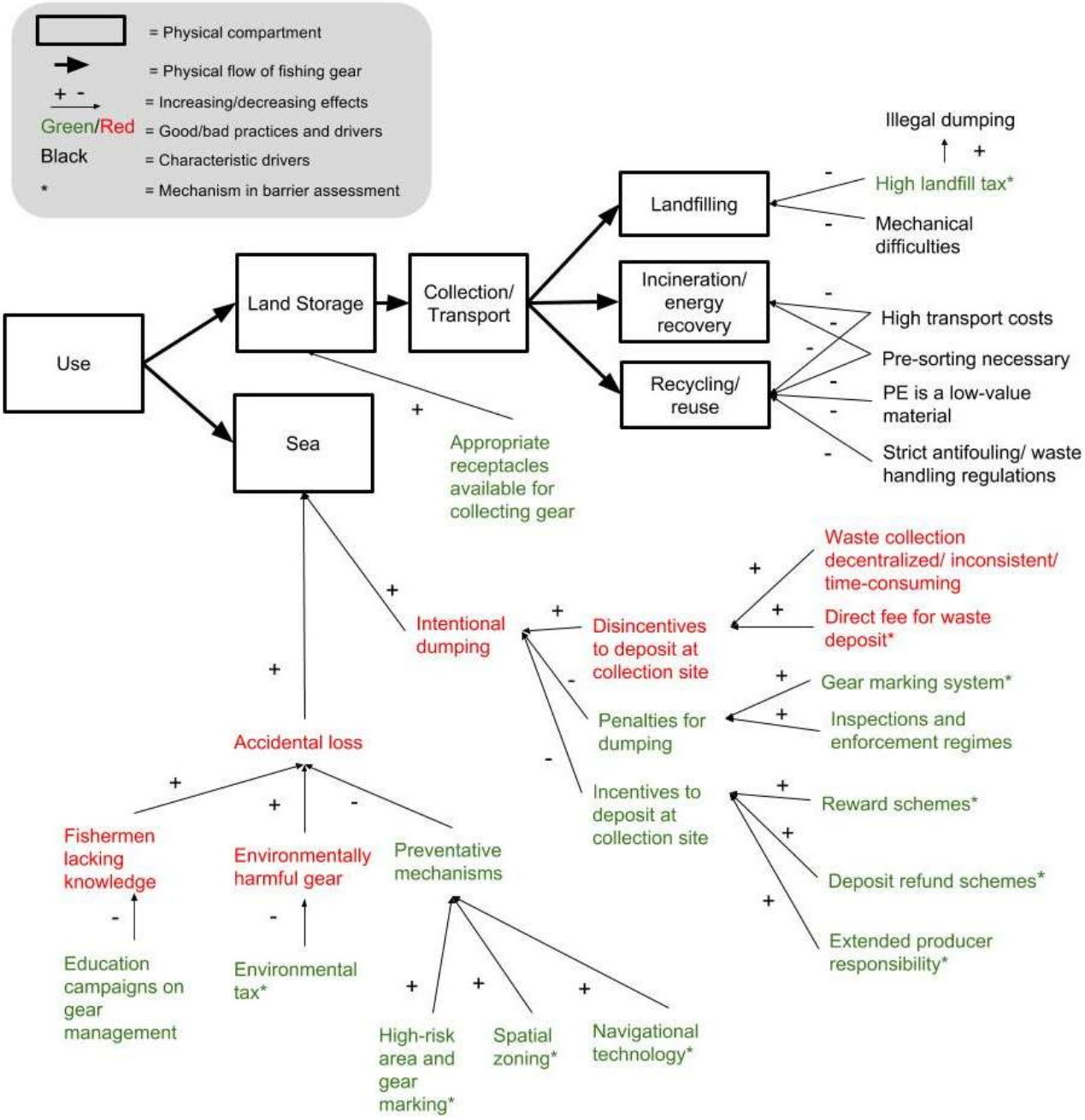
Economic/infrastructural: To implement a spatial zoning scheme, vessels would need clear and easily accessible geographical information that would map out potential gear hotspots. This process would therefore incur administration and communication costs. These costs could be lessened if fishermen had access to a centralized system integrated with ship navigation technology that made information sharing and reporting easier (Sherrington et al., 2016).

*Acceptability***:** Even if fishermen are equipped with the knowledge of gear hotspot areas, some fishermen will still access these areas (Macfayden et al., 2009). Increasing catch rates can outweigh the risk of entanglement.

*Acceptability***:** Setting the zoning boundaries highly depends on where derelict gear hotspots are located. This information solely relies on reports. As previously mentioned, reporting gear loss in Norway is mandatory according to the Marine Resources Act. It is estimated that approximately 80% of losses are reported through this system (Macfayden et al., 2009), but of course it is difficult to estimate the number of lost nets that go un-reported. Fishermen may choose not to report lost nets or gear for a number of reasons. For example, they may want to keep their exact fishing location confidential or they may have too much professional pride to admit to losing gear (Macfayden et al., 2009). For these reasons, recreational users are most likely to report lost gear to authorities.

Summary of barrier assessment

In the sections above, barriers were assessed for each of the three topics: EOL treatment options for fishing gear, mechanisms to support recycling/reuse and mechanisms to prevent lost/abandoned fishing gear in the ocean. As seen below, Figure 5 provides an overview of



these barriers and mechanisms. Figure 5 also illustrates where and how these aspects affect the overall flow of fishing gear from the use stage to the end-of-life treatment stages.

Figure 5. Flowchart summarizing the positive and negative drivers associated with fishing gear collection and end-of-life treatment.

Conclusion

This report reviewed both the current state of marine litter in the Nordic region and the current legislation against marine litter. Overall, more work must be done to gain a better grasp of both the quantities and coordinates of marine litter in the Nordics. This information could help lead to behavioral changes and more effective policy-making against marine litter. In addition, gaps exist in the legislation that do not hold fishing boats sufficiently accountable for their marine waste. More regulations are needed to harmonize waste-handling information sharing between ports and for implementing more effective enforcement regimes.

Barrier assessments were carried out for three different topics. First, barriers were identified for various EOL treatment alternatives for fishing gear. Landfilling and incineration/energy recovery are often logistically easy when compared to recycling/reuse. However, these alternatives are of low prioritization in the waste hierarchy. Recycling/reuse is a prioritized treatment, but there are many technical, economical and infrastructural barriers that must be overcome before implementation. The next two barrier assessments were performed to assess strategies that both encourage recycling/reuse and discourage ocean dumping/gear loss. Most strategies require strong collaboration between fishermen, ports and regulatory bodies.

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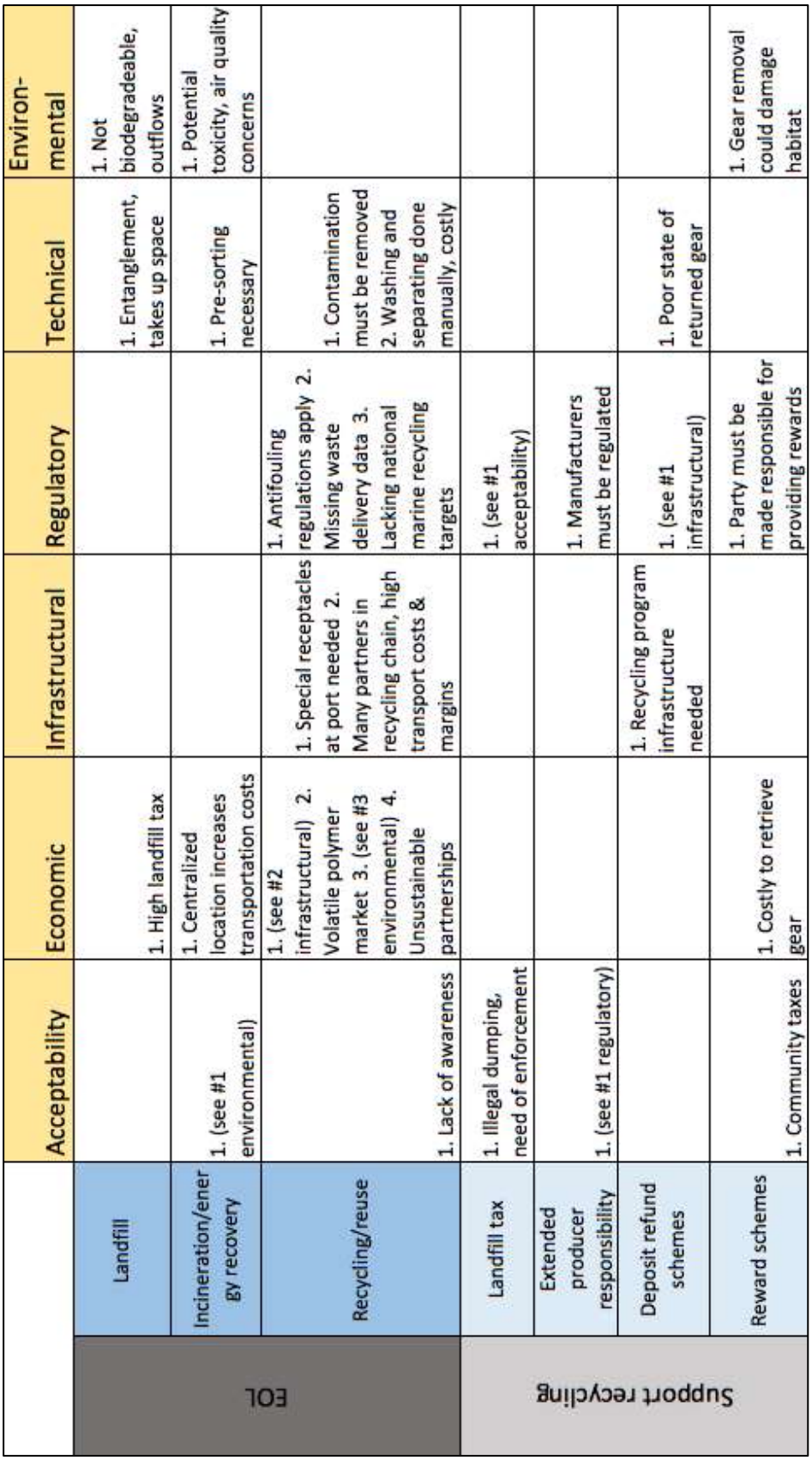
Appendix A: Summary of laws and regulations relevant to marine litter

	Legislative Instruments	Brief description	Year	Responsible body
1) International: explictly transposed into regional/national	UN Convention on the Law of the Sea (UNCLOS)	The UNCLOS is the international agreement that defines the rights and responsibilities of nations with respect to their world's oceans. The agreement establishes guidlines for geopolitics, commercial activities, the environment and the management of marine resources. The provisions do not specifically refer to marine litter, but they require that states protect and preserve the mamrine environment.	1994	UN
	MARPOL 73/78, Annex V	Annex V of MARPOL 73/78 is a major international instrument that specifcally addresses ocean-based litter from ships. The Annex V provides an updated framework for controlling garbage generated by ships. It imposes a general ban on all garbage dumping from ships at sea unless specifcially noted. Also, it requires that ships provide a garbage record book and that port reception facilities handle waste from ships without delay.	1988, 2006, 2011, 2013	International Maritime Organization (IMO)
	London Protocol	The London Protocol is an instrument that prohibits the dumping of industrial waste and other substances from manmade structures (ships etc.). The participating parties also are required to implement measures that prevent, reduce and eliminate contamination by dumping (where possible).	1996	member states, 47 parties
2) International: not explicitly transposed into regional/national	UNEP's Regional Sea Programme (RSP)	The Regional Sea Programme developed a Global Initiative on Marine Litter to organize and implement regional activities for addressing marine litter in 12 regional seas. These activities include: assessing marine litter, preparing a regional management plan for marine litter, organizing beach clean ups and meeting/collaborating with national authorities to address marine litter.	2003	UNEP; 12 regional seas; 4 commissions in Europe (Baltic, North, Mediterranean, Black)
	Guidelines on survey and monitoring of marine litter	To provide a long-term platform for monitoring marine litter, UNEP and IOC developed scientific guidelines on survying and monitoring marine litter. The created guidelines include: comprehensive beach assessments, benthic, floating litter and rapid beach litter assessments.	2009	UNEP & intergovernmental Oceanographic Commission (IOC)
	Guidelines on use of market-based and economic instruments	These guidelines serve as a practical reference for decision makers on how to select and implement market-based intruments for addressing marine litter. Several of the mentioned instruments include: rward systems, plastic bag tax, tourist taxes etc.	2009	UNEP
	Honolulu Strategy	The Honolulu Strategy was formulated at the Fifth International Marine Debris Conference in 2011. The framework has 3 goals and 19 strategies that serve as a practical reference for national parties. The 3 goals include: 1. reduce land-based litter 2. reduce sea-based litter including ALDFG and 3. Reduce impact of marine debris	2011	UNEP & US National Oceanic and Atmospheric Administration (NOAA)--> adopted by EU

	Legislative Instruments	Brief description	Year	Responsible body
Independent regional/national	Barcelona Convention	The Barcelona convention aims at protecting the Mediterranean marine and coastal environments. It prohibits dumping of wastes and other matter at sea (with some exceptions).	1976, 1995	Regional member states in Mediterranean
	EU Port Reception Facility (PRF) Directive	The PRF Directive was created in response to MARPOL's requirement for member states' ports to provide incoming vessels with adequate waste reception facilities. This PRF Directive requires advance notification of a vessel's waste deposit. It also outlines guidelines for reporting systems, cost-recovery fee systems and enforcement schemes.	2002	EU
	Helsinki Convention: Annex IV	The Helsinki Convention is a regional instrument which aims to protect the marine environment of the Baltic Sea area. Annex IV focuses specifically on the prevention of pollution from ships. The commision has agreed to raise awareness of negative environmental and economic effects of derelict gear.	1992	Regional member state (10) in Baltic Sea
	OSPAR	OSPAR fits into the UNEP Regional Sea Program, and is a mechanism that legally requires cooperation among member states to protect the marine environment of the Northeast Atlantic region. OSPAR aims to harmonize PRFs and fee systems, implement "fishing for litter" projects, harmonize enforcement schemes and identify key waste items from the fishing industry and aquaculture.	1998; 2014	OSPAR, regional member states
	EU marine strategy framework directive	The Marine Directive aims to achieve Good Environmental Status (GES) of the EU's marine waters by 2020. Indicators that define GES include: characteristics of litter and impacts of itter on marine life. It incorporates work by the Technical Subgroup on Marine Litter (TSG ML)	2008, 2010	EU and its 4 main regions: 1. Baltic Sea 2. North-east Atlantic Ocean 3. Mediterranean Sea 4. Black Sea
	Convention on Conduct and Fishing Operations in the North Atlantic	In the convention's preamble, that they state that they aim "to ensure good order and conduct on the fishing grounds in the North Atlantic Area." The convention covers rules for gear marking.	1967	North Atlantic States (including Norway)
	Bonn Agreement	The Bonn Agreement is a mechanism designed for the North Sea States and EU to work together in fighting marine litter in the North Sea Area. Its policies are mainly focused on preventing maritime disasters and chronic pollution from ships/offshore platforms.	1969, 2009	North Sea States (9 including Norway) and EU
	Global Partnership on Marine Litter (GPML)	(builds on Honolulu Strategy) Voluntary multistakeholder coordination mechanism which all agree to work together to further reduce and better manage marine litter. Mainly focused on land-based activities.	2012	UNEP
	The Marine Group (HAV) within the Nordic Council of Ministers (NCM)	Since 2013, HAV has prioritized environmental aspects of marine litter in nordic waters with projects including: plastic loading in Northern Fulmars, marine litter and its sources in Nordic waters etc.	2013	Environmental ministers in nordic region

	Legislative Instruments	Brief description	Year	Responsible body
National	Norway's Pollution Control Act	Norway's Pollution Control Act has been modified to enforce the regulations required by the PRF Directive into Norwegian Law. It outlines guidelines for the delivery and reception of waste and cargo residues from ships calling port	1981, 2003	Norwegain government
	Norway's Maritime Safety Act	Discharge from ships are regulated nationally by environmental safety laws	-	Norwegain government
	Norway's Marine Resources Act (6/6/2008)	Prohibits dumping of gear, moorings and other objects in the sea that may injure marine organisms, impede harvesting or damage gear. Any person that loses a net must attempt to remove the object from the sea. If this is not possible, this loss must be reported to authorities. Any person that salvages gear is entitled to reward. It also addresses gear marking.	2010	Norwegain government: Norwegian ministry of trade, industry and fisheries

Appendix B. Summary of barrier assessment chapter organized into specified barrier categories



		Acceptability	Economic	Infrastructural	Regulatory	Technical	Environ-mental
EOL	Landfill		1. High landfill tax			1. Entanglement, takes up space	1. Not biodegradeable, outflows
	Incineration/energy recovery	1. (see #1 environmental)	1. Centralized location increases transportation costs			1. Pre-sorting necessary	1. Potential toxicity, air quality concerns
	Recycling/reuse	1. Lack of awareness	1. (see #2 infrastructural) 2. Volatile polymer market 3. (see #3 environmental) 4. Unsustainable partnerships	1. Special receptacles at port needed 2. Many partners in recycling chain, high transport costs & margins	1. Antifouling regulations apply 2. Missing waste delivery data 3. Lacking national marine recycling targets	1. Contamination must be removed 2. Washing and separating done manually, costly	
Support recycling	Landfill tax	1. Illegal dumping, need of enforcement			1. (see #1 acceptability)		
	Extended producer responsibility	1. (see #1 regulatory)			1. Manufacturers must be regulated		
	Deposit refund schemes			1. Recycling program infrastructure needed	1. (see #1 infrastructural)	1. Poor state of returned gear	
	Reward schemes	1. Community taxes	1. Costly to retrieve gear		1. Party must be made responsible for providing rewards		1. Gear removal could damage habitat

			Acceptability	Economic	Infrastructural	Regulatory	Technical	Environ-mental
Prevent derelict gear in oceans	Abandoned	Port waste fee system	1. Time delays are unacceptable		1. Special receptacles needed at port	1. Fishing boats exempt from indirect fees 2. Indirect fee systems vary, causing confusion		
		Penalty scheme	1. Fishermen resistent, ports may not enforce	1. Administration and enforcement needed		1. (see # 1 economic) 2. Information gaps in waste deposits at port		
		Environmental tax	1. Manufacturers resistant	1. Administration needed	1. Infrastructure needed to support innovative products	1. Decision needed on product specification & tax rate		
	Lost	Gear marking	1. Fishermen resistent	1. Administration needed to build gear registry database		1. Needs more comprehensive gear marking requirements		
		Navigational technology	1. Expensive technology for small-scale fishermen			1. New regulations needed 2. Inclusion in inspection schemes	1. Technology not appropriate for all gear	
		Spatial zoning	1. Fishermen resistent because lower catch rates 2. Fisherman may not report lost gear	1. Administration needed to create centralized communication system and to constantly update gear "hotspot" information based on reports		1. More comprehensive and accurate reporting system needed 2. New regulations needed for creating spatial zones		

Appendix C. Summary of gear-marking regulations in Italy, Iceland and Norway (FAO, 2016).

Italy, Iceland and Norway

Country	Italy	Iceland	Norway
Fishery	Fixed nets and longlines (Regulation)	Anchored bottom-set nets for cod (Regulation)	Gillnets and longlines outside 4nm (Regulation)
Mast height above sea level	1 to 3m	Not specified	2m
Mast material	Wood	Not specified	Not specified
Float specification	Not specified	Not specified	Not specified
Counter weight type	Not specified	Not specified	Not specified
Weight of buoy	Not specified	Not specified	Not specified
Reflective band	No	Not specified	Mast or buoy or top sign must be equipped with light-reflecting material
Flag(s)	Yes	Not specified	Yes (2x)
Light(s)	Yes	Yes	Yes
Light specifications	Yellow, visible for 0.5nm	White flashing (only if nets set in an area where bottom trawling occurs)	Yellow, flashing, visible for 2nm and 3 sec interval
Western and eastern end of gear identification	No	No	Yes
Radar reflector	No	No	May be substituted for flag
Ownership markings	Yes	District and vessel registration	Vessel registration number
Cost to construct individual marker buoys	Not specified	Not specified	Not specified. Buoy requires type approval from Norway Directorate of Fisheries

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www.circularocean.eu

Contact:
Dr Neil James
Environmental Research Institute
Castle Street
Thurso
KW14 7JD

Tel: +44 (0)1847 889 579 info@circularocean.eu
Neil.James@uhi.ac.uk

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