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Guidance document on Conducting Techno-Economic Feasibility Studies for the Establishment of Port Reception Facilities for Plastic Waste

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Preparation of the *Guidance Document on Conducting Techno-Economic Feasibility Studies for the Establishment of Port Reception Facilities for Plastic Waste*

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This report is based on work conducted by Mr Guido Van Meel, under the technical supervision and coordination of the GloLitter Project Coordination Unit.

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Abstract

The problem of marine litter emanating from vessels requires both international action through treaties such as the International Convention for the Prevention of Pollution from Ships (MARPOL) and national laws and policies implementing these treaties. Key legal aspects in this regard include prohibitions on dumping at sea, requirements for port reception facilities, the designation of special areas, institutional capacity and legislation addressing specific waste types.

Over the past decades, considerable attention has been paid to abandoned, lost or otherwise discarded fishing gear and its impact on the aquatic environment as a result of the entanglement of marine species and the habitat damage caused by such "ghost gear". Additionally, the growth in aquaculture activities is contributing to marine litter. Plastics are used extensively in marine fish farming – for example, in pods, in coastal fish ponds and in shellfish farming. These plastics are susceptible to loss through extreme weather events, mismanagement of waste or deliberate discharges. As aquaculture continues to expand, the problem of plastic pollution is becoming increasingly urgent.

Port reception facilities are economic undertakings and consequently need to be able to cover the costs that they incur in collecting and treating the waste received from ships by charging direct and/or indirect fees, and by selling products derived from the waste. In smaller ports with limited vessel calls, it is essential that all ships contribute to the provision of reception facilities, including ships not actually using these facilities. Whereas reception facilities in large ports need to be on standby round the clock because ships calling at these expect the delivery of waste to take place without undue delay, in smaller ports this would be too costly.

In many developing countries the existing waste infrastructure and management practices are inadequate, and the waste collected from ships is often dumped in landfills that do not meet the necessary sanitary and environmental requirements. Accepting domestic and hazardous waste from ships can aggravate local environmental problems.

This Guidance Document outlines the costs of operating a port reception facility and the revenue that such facilities can generate. Case studies of waste reception facilities in different ports around the world (large and small) are used to illustrate the relevant income and expenditure flows. In view of the composition of marine litter, the focus is on plastic waste as part of ships' garbage, including fishing gear.

Abbreviations and acronyms

ALDFG	abandoned, lost or otherwise discarded fishing gear
EPR	extended producer responsibility
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GISIS	Global Integrated Shipping Information System
HDPE	high-density polyethylene
IMO	International Maritime Organization
LDPE	low-density polyethylene
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environmental Protection Committee (of IMO)
nm	nautical mile
PE	polyethylene
PET	polyethylene terephthalate
PP	polypropylene
PRF	port reception facility
PS	polystyrene
PVC	polyvinyl chloride

Executive summary

The International Convention for the Prevention of Pollution from Ships (MARPOL) obligates States parties to ensure the provision of adequate reception facilities for the different types of waste generated by the ships that normally call at their ports. Such port reception facilities (PRFs) may charge ships a fee to cover the cost of collecting, transporting, storing and properly treating their waste. Certain types of waste may additionally require pretreatment before they can be delivered to a treatment facility. Plastic waste from ships is classified under a single category in MARPOL Annex V, but in reality it is a mixture of different types of plastic that, depending on whether recycling or other options are selected, have implications for the collection methods that can be used and may sometimes necessitate additional investments.

This Guidance Document presents tools and guidance for conducting economic assessments and techno-economic feasibility studies with a view to establishing PRFs for plastic waste generated on board ships, including fishing gear. A PRF can collect plastic waste, including derelict fishing gear, alongside other solid wastes from ships, such as glass, metals, food waste, paper and cardboard. When the plastic waste is collected, the operator has to choose between the various treatment options that are available in the port's country or region, such as landfilling, incineration and recycling. However, plastic waste is a mixture of different types of plastic (for example, polyethylene terephthalate, low- and high-density polyethylene, polypropylene, polystyrene and polyvinyl chloride). To recycle plastics in a cost-efficient manner, it is important to segregate the different types. It should also be noted that the market for waste plastics is volatile and tends to be affected by fluctuations in the oil price, since most plastics are derived from crude oil. This is an additional burden for a PRF, which must cover all its costs (for collection, transport, intermediate storage and treatment) from the waste fees that it receives from ships. Especially in contexts where small volumes of waste are collected, the time taken from collection to delivery of waste for treatment and/or recycling can have an impact on the overall cost.

It is worth pointing out that the cost of incinerating plastics (with or without energy recovery) is often significantly lower than the cost of recycling them. In most cases, the cost of landfilling can also easily compete with that of incineration.

For PRFs located on small islands, landfilling is often the only option owing to the low volumes delivered. In such cases, reverse logistics may be better for the environment. Operators of ships may decide to invest in additional equipment for onboard waste treatment – for example, compactors to increase storage capacity – or for the onboard incineration of waste.

Fishing ports face specific challenges with regard to waste management. Fishing gear consists of a mixture of different types of plastic, which makes recycling difficult. As a result, most fishing gear has tended to end up in landfills. However, techniques have recently been developed that make it possible to recycle or reuse fishing gear. For example, nylon fishing gear is converted into yarn that can be reused. Introducing a waste solidarity scheme at fishing ports and establishing a dedicated fund can help to cover the costs of waste reception and the recovery of lost fishing gear.

To provide guidance on conducting economic assessments and techno-economic feasibility studies for the establishment of PRFs, the various types of costs involved have been identified in this Guidance Document and are listed below. It should be noted that this overview of costs refers to PRFs collecting all kinds of solid or liquid waste. Not all the costs listed are relevant to the collection specifically of plastic waste from ships.

Direct costs:

- provision of PRF infrastructure such as barges, trucks, waste bins, storage tanks and offices;
- rental or purchase of land in the port;
- operational costs of waste collection and treatment, including transport, maintenance, cleaning, remuneration of staff, energy use, waste analysis and insurance;

- final reuse, recycling or disposal of the waste;
- administration: invoicing, issuing of waste receipts, reporting, etc.; and
- publicity about the PRF (such as maps and flyers).

Indirect costs:

- developing and updating a waste reception and handling plan, including possible audit and consultancy costs;
- obtaining the necessary permits to collect, store and transport the waste;
- management of advanced notification and cost recovery systems, including electronic transmission to port community systems, information technology systems and statistical analysis;
- organizing public procurement procedures, issuing necessary authorizations;
- communication of information to port users; and
- other administrative costs.

On the basis of parameters such as the number and types of ship calling at the port, the generated (estimated) waste volumes and the number of collections, a PRF operator can calculate the level of investment and number of personnel required.

To address the problem of marine litter effectively, it is fundamental to provide appropriate incentives for the delivery of waste to PRFs, in particular plastic waste. This can be achieved through a cost recovery system based on the levying of an indirect fee. Several studies indicate that a "no special fee" system is likely to be the most effective for ship-generated waste. If a waste fee system is in place, the PRF operator can calculate its impact on the profitability of the undertaking. Nevertheless, enforcement of laws and international rules by the competent authorities remains important to deter ships from taking the risk of illegal dumping at sea.

1 Introduction

1.1 The problem

The GloLitter Partnerships Project[*] is funded by the Government of Norway and implemented by the International Maritime Organization (IMO) in partnership with the Food and Agriculture Organization of the United Nations (FAO). The GloLitter Project assists developing countries, including small island developing States and least developed countries, to prevent and reduce marine litter, especially plastic marine litter originating from the maritime transport and fisheries sectors, and to identify opportunities for the reduction of plastic use in both industries.

The GloLitter Project achieves its objectives by focusing on several areas identified in the IMO Action Plan to address marine plastic litter from ships, and on complementary actions set out in the FAO *Voluntary Guidelines on the Marking of Fishing Gear*.

Marine litter enters the marine environment because of a wide range of land- and sea-based activities, including maritime transport and the fishing industry. Plastic litter, comprising both macroplastics and microplastics, persists in the marine environment and has harmful effects on marine life and biodiversity, along with negative impacts on human health, safety and livelihoods. In addition, marine plastic litter adversely affects industries such as tourism, fisheries and shipping and, as a result, the local communities that rely on these. Marine litter, in its various forms, has significant negative implications for sustainable development. However, plastic waste material has the potential to be brought back into the economy through reuse or recycling. Various studies have found that despite the existing regulatory framework to prevent dumping and discharges of marine plastic litter from ships, discharges into the sea continue to occur.

IMO recognizes the importance of preventing pollution by garbage, including plastic, from ships, as evidenced by the adoption and entry into force in 1988 of Annex V to the International Convention for the Prevention of Pollution from Ships (MARPOL). Similarly, the Organization has spearheaded efforts to prevent pollution caused by the dumping of various types of waste, including plastics, into the sea through the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the "London Convention") and its 1996 Protocol (the "London Protocol"). These commitments were reinforced by the IMO Assembly at its thirtieth session in November–December 2017, which emphasized that the ongoing problem of marine plastic pollution, as addressed in MARPOL Annex V, required further consideration as part of a global solution within the framework of ocean governance to achieve target 14.1 under Sustainable Development Goal 14, namely, to prevent and significantly reduce marine pollution of all kinds by 2025.

The Marine Environment Protection Committee (MEPC) of IMO has also recognized the importance of continued efforts to tackle this global problem, adopting the Action Plan to address marine plastic litter from ships at its seventy-third session in October 2018. In addition, the thirty-eighth Consultative Meeting of Contracting Parties to the London Convention and the eleventh Meeting of Contracting Parties to the London Protocol in September 2016 adopted a recommendation to encourage action to combat marine litter.

Furthermore, FAO and its Members have identified and raised concerns about abandoned, lost and otherwise discarded fishing gear (ALDFG) as a significant component of marine litter which has a grave impact on habitats and stocks of fish and other marine species, particularly through "ghost fishing", and as a navigational hazard and risk to safety at sea. FAO recently published the *Voluntary Guidelines on the Marking of Fishing Gear* to support implementation of the FAO Code of Conduct for Responsible Fisheries. The Guidelines are intended to assist with the implementation of overarching fisheries management goals and address ALDFG through provisions dealing with gear-marking systems, the retrieval and reporting of lost gear, and appropriate disposal of end-of-life gear.

[*] See https://glolitter.imo.org

1.2 Introduction to MARPOL

The International Convention for the Prevention of Pollution from Ships, 1973, as modified by the 1978 and 1997 Protocols, is one of the most important international conventions protecting the marine environment. It was developed by IMO with the aim of preserving the marine environment by fully eliminating pollution due to operational discharges of oil and other harmful substances from ships, and by minimizing the accidental spillage of such substances.

Together with its six technical Annexes covering pollution by, respectively, oil, chemicals, harmful substances in packaged form, sewage, garbage and airborne emissions, MARPOL works as one whole: the articles of the Convention and its two Protocols deal mainly with jurisdiction, powers of enforcement and inspection, while more detailed anti-pollution regulations are set forth in the Annexes.

MARPOL contains provisions regulating the availability of adequate port reception facilities (PRFs), the types of ship-generated waste that can be legally discharged into the sea, onboard waste management, and enforcement and inspections.

Since the adoption of MARPOL, global environmental and societal awareness has increased, leading to the emergence of new ideas about how to manage operations in an environmentally sensitive and responsible way. Many shipping companies and port authorities have introduced environmental management systems to ensure that their operations are conducted in an environmentally sound manner.

Keeping the seas and oceans clean should be seen as the overriding goal of the establishment and use of PRFs. MARPOL includes regulations aimed at preventing and minimizing pollution from ships – both accidental pollution and that from routine operations. The basis for establishing and using PRFs is provided by the Annexes of MARPOL and the implementing laws and regulations of States parties.

The MARPOL requirements regarding the availability of adequate PRFs are contained in the following regulations:

- regulation 38 of Annex I;
- regulation 18 of Annex II;
- regulations 12 and 13 (passenger ships operating in special areas) of Annex IV;
- regulation 8 of Annex V; and
- regulation 17 of Annex VI.

In addition to the basic rules in the MARPOL Annexes, ships' operators need to be aware of national and regional requirements in some port States which may mandate that ships discharge certain types of MARPOL wastes and residues to PRFs. Individual port States may also specify the means of disposal to meet quarantine and other regulatory requirements. Operators should therefore always ensure that they have a complete and up-to-date overview of national and regional requirements relating to PRFs. Such information may be obtained directly from the PRF database in the IMO Global Integrated Shipping Information System (GISIS),[*] or via agents at the port, or from trade associations representing the shipping and/or port industries.

Of particular importance in the elimination of marine pollution from ships are the more restrictive requirements in force in special areas and emission control areas as defined in MARPOL. Since the discharge criteria for ship-generated wastes are stricter in special areas, ships sailing in such areas may not be able to meet them and may therefore be required to deliver their wastes to a PRF. States and port authorities should bear in mind the importance of complying with the discharge requirements in special areas.

An up-to-date list of all the MARPOL special areas can be found on the IMO website.[†]

[*] See https://gisis.imo.org/Public/PRF/Default.aspx.

[†] See https://www.imo.org/en/OurWork/Environment/Pages/Special-Areas-Marpol.aspx.

1.3 MARPOL Annex V

The revised MARPOL Annex V on Regulations for the prevention of pollution by garbage from ships entered into force on 1 January 2013. To facilitate implementation, IMO also adopted the *2017 Guidelines for the implementation of MARPOL Annex V* (IMO 2017). MARPOL Annex V and the 2017 Guidelines should be used in combination as the basis for drawing up a garbage management plan.

MARPOL Annex V applies to all ships (from merchant ships, through fixed or floating platforms, to non-commercial ships such as pleasure crafts and yachts), and lays down specific discharge requirements, including a prohibition on the discharge of most types of garbage, including plastics and fishing gear, into the sea. A few exceptions to this prohibition are provided for in Annex V, namely in regulations 3, 4, 5 and 6. In general, these exceptions are limited to food wastes, specific types of cargo residues, certain cleaning agents and additives, and cargo residues entrained in wash water which are not harmful to the marine environment. The general discharge prohibition does not apply in the following cases:

- the discharge of garbage from a ship necessary for the purpose of securing the safety of a ship and those on board or saving life at sea;
- the accidental loss of garbage resulting from damage to a ship or its equipment, provided that all reasonable precautions have been taken before and after the occurrence of the damage, to prevent or minimize the accidental loss;
- the accidental loss of fishing gear from a ship, provided that all reasonable precautions have been taken to prevent such loss; and
- the discharge of fishing gear from a ship for the protection of the marine environment or for the safety of that ship or its crew.

The *2017 Guidelines for the implementation of MARPOL Annex V* contain several provisions related to shipboard garbage handling, such as options for waste minimization and guidance on the management of fishing gear.

1.4 Plastic waste from ships

Effective onboard waste management helps to minimize ship-generated wastes and residues. When designing new ships, ship operators and shipbuilders should consider ways of enhancing waste treatment on board. They should also introduce operational measures to improve the efficiency of waste management in existing ships.

If there is enough space on a ship, onboard waste management plans should provide for waste segregation and recycling, the returning of waste under container deposit schemes (a refund is paid when returning, for example, empty plastic bottles or other package waste), reuse or the storage of passively fished waste. The segregation of garbage in line with the requirements of MARPOL Annex V – that is, into plastics, food wastes, domestic wastes, cooking oil, incinerator ashes, operational wastes, cargo residues, animal carcasses, fishing gear and e-waste – makes it possible for garbage to be delivered in specific recyclable categories.

To facilitate the landing of recyclable residues and waste, ship operators should consider concluding contracts with facilities at ports that are visited regularly. This would both fulfil the need to use an adequate and authorized facility in accordance with most environmental management systems and ensure that segregated waste can be discharged ashore during each port visit. Where adequate reception facilities for segregated and/or recyclable wastes are not available at a port, shipowners and ship operators are encouraged to request that such facilities be set up as part of developing the recycling capacity of the locality or region. This is important, since local installations will have a greater volume of inward materials, making it easier for them to commercialize outputs and recyclables.

Overview of MARPOL Annex V discharge requirements:

Simplified overview of the discharge provisions of the revised MARPOL Annex V which entered into force on 1 March 2018

DISCLAIMER: Additional requirements may apply.

(**Note:** The table below is intended as a summary reference. The provisions in MARPOL Annex V and the Polar Code, not the table below, prevail.)

Garbage type[1]	**All ships except platforms**[4]		**Regulation 5 Offshore platforms located more than 12 nm from nearest land and ships when alongside or within 500 metres of such platforms**[4]
	Regulation 4 Outside special areas and Arctic waters (Distances are from the nearest land)	**Regulation 6 Within special areas and Arctic waters** (Distances are from nearest land, nearest ice-shelf or nearest fast ice)	
Food waste comminuted or ground[2]	≥3 nm, en route and as far as practicable	≥12 nm, en route and as far as practicable[3]	**Discharge permitted**
Food waste not comminuted or ground	≥12 nm, en route and as far as practicable	**Discharge prohibited**	**Discharge prohibited**
Cargo residues[5, 6] not contained in washwater	≥ 12 nm, en route and as far as practicable	**Discharge prohibited**	**Discharge prohibited**
Cargo residues[5, 6] contained in washwater		≥ 12 nm, en route and as far as practicable (subject to conditions in regulation 6.1.2 and paragraph 5.2.1.5 of part II-A of the Polar Code)	
Cleaning agents and additives[6] contained in cargo hold washwater	Discharge permitted	≥ 12 nm, en route and as far as practicable (subject to conditions in regulation 6.1.2 and paragraph 5.2.1.5 of part II-A of the Polar Code)	**Discharge prohibited**
Cleaning agents and additives[6] in deck and external surfaces washwater		Discharge permitted	
Animal Carcasses (should be split or otherwise treated to ensure the carcasses will sink immediately)	Must be en route and as far from the nearest land as possible. Should be >100 nm and maximum water depth	**Discharge prohibited**	**Discharge prohibited**
All other garbage including plastics, synthetic ropes, fishing gear, plastic garbage bags, incinerator ashes, clinkers, cooking oil, floating dunnage, lining and packing materials, paper, rags, glass, metal, bottles, crockery and similar refuse	**Discharge prohibited**	**Discharge prohibited**	**Discharge prohibited**

1 When garbage is mixed with or contaminated by other harmful substances prohibited from discharge or having different discharge requirements, the more stringent requirements shall apply.

2 Comminuted or ground food wastes must be able to pass through a screen with mesh no larger than 25 mm.

3 The discharge of introduced avian products in the Antarctic area is not permitted unless incinerated, autoclaved or otherwise treated to be made sterile. In polar waters, discharge shall be made as far as practicable from areas of ice concentration exceeding 1/10; in any case food wastes shall not be discharged onto the ice.

4 Offshore platforms located 12 nautical miles from nearest land and associated ships include all fixed or floating platforms engaged in exploration or exploitation or associated processing of seabed mineral resources, and all ships alongside or within 500 m of such platforms.

5 Cargo residues means only those cargo residues that cannot be recovered using commonly available methods for unloading.

6 These substances must not be harmful to the marine environment.

1.4.1 *Plastic waste management*

Increasing amounts of litter end up in the world's oceans, harming the health of ecosystems and killing animals that become entrapped in the litter or ingest it. Human health is also at risk, as plastics break down into smaller pieces (microplastics and nanoplastics) that may subsequently contaminate our food. According to the waste management hierarchy known as "Lansink's ladder" (see Figure 1), the best option is to prevent plastic waste from being generated at all on board a ship. If prevention is impossible, recycling is the next preferable option, but if that is not possible either, plastic waste may be incinerated (with energy recovery). Dumping in a landfill should be regarded as the least favourable option.

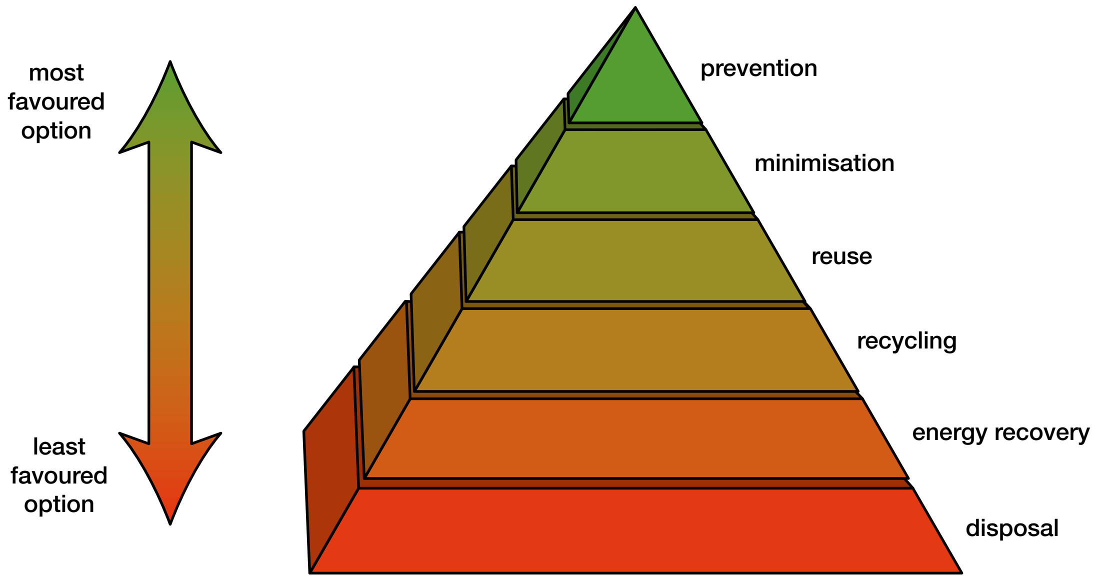


Figure 1: *Waste management hierarchy according to Lansink's ladder (Source: Ionel, 2010)*

Plastic waste can be generated on vessels of all types; it often originates from domestic provisions and supplies used for operations on board. Plastic waste typically comprises sheets, wrapping, bottles, drums, synthetic ropes, synthetic fishing nets, plastic garbage bags and empty chemical cans.

As noted in CE Delft (2017), the generation of garbage, including plastics, on board a ship depends on several factors. The amount of "hotel wastes" is proportional to the number of passengers and crew and to the consumption of material; it generally correlates with the standard of living on board. Provisions, packaging and galley waste are the main drivers of plastic waste generation. The report further points out that "plastic waste from cargo handling is limited to general cargo and depends entirely on the type and packaging of the cargo". Waste reduction before loading can affect the amount of plastic waste generated on board – for example, if plastic packaging is removed before cargo is loaded onto a ship. The online survey conducted to support the study also identified other drivers of plastic waste generation, including the trading area, the supplier, the policies of the companies buying and selling provisions and supplies, and the goods delivered to the ship (CE Delft 2017, 36).

Richardson et al. (2017) note that the plastics subcategory of waste dumped overboard by the fishery fleet includes salt bags, bait boxes, bait wrappings, strapping bands, food wrappers, bags and bottles. Plastics were found to account for the largest proportion of total pollution incidents. This finding was corroborated by

Leney, Blaha and Lee (2021), whose assessment of plastic waste generation by fishing vessels in the Western and Central Pacific Ocean focuses on the following main sources:

- for longliners: plastic liners and plastic straps on bait cartons and plastic bags for bagging tunas in refrigerated seawater and slurry tanks;
- for tuna purse seines: plastic bags for storing the salt used in brine tanks and plastics used in fish aggregating devices; and
- plastic waste from food and beverage packaging and living on board – referred to by the authors as operational and maintenance waste (this is a major source of plastic and other waste not only on board longliners but on all vessels at sea).

Prevention

Waste prevention practices reduce the amount and/or toxicity of wastes that are generated prior to recycling, treatment or disposal. Waste prevention may also be referred to as source reduction and waste minimization. Some examples of waste prevention on board ships are:

- replacing individual bottles of water with larger containers and replacing bottles of soft drinks with containers filled with syrup that is to be diluted with water;
- installing a water purifier in the ship's drinking-water system, which reduces the consumption of mineral water from plastic bottles;
- adopting reusable bottles for the storage of drinking water;
- voluntary ban on the use of single use plastics;
- making arrangements with the supplier/distributor of stores whereby the plastic packaging foil used to cover the ship's stores is to be taken back immediately after delivery by the supplier/distributor; and
- with regard to preventing ALDFG, implementing systems for the marking of fishing gear to promote responsible management by linking gear marks to the relevant registered vessel or fishing licence.

Other, more general initiatives are being undertaken by the Member States of the European Union (EU) and other countries – for example, a legal ban on single-use plastics. Measures such as restrictions on the production and consumption of single-use plastics and microplastics, in conjunction with the use of biodegradable plastics or alternative, more sustainable materials, may prevent marine litter, not least from sea-based sources such as shipping, fishing, aquaculture and offshore activities.

As for the reduction of marine plastic litter generated from, and retrieved by, fishing vessels, the IMO Action Plan* has identified the following measures:

- consider making the IMO Ship Identification Number Scheme mandatory for all fishing vessels over 24 metres in length through an amendment to the Cape Town Agreement of 2012 once it enters into force;
- consider making mandatory, through an appropriate IMO instrument (such as MARPOL Annex V), the marking of fishing gear with the IMO ship identification number, in cooperation with FAO;
- further investigate logging of the identification number for each item of fishing gear on board a fishing vessel;
- preparation of a circular reminding IMO Member States to collect information from their registered fishing vessels regarding any discharge or accidental loss of fishing gear;

* Action Plan to address marine plastic litter from ships, adopted by the Marine Environment Protection Committee as resolution MEPC.310(73).

- consider the development of best management practices to facilitate incentives for fishing vessels to retrieve derelict fishing gear and deliver it to PRFs, in collaboration with FAO;
- consider the issue of waste that has been collected during fishing operations, building on experience gathered from established projects;
- review the application of placards, garbage management plans and garbage record-keeping (regulation 10, MARPOL Annex V) by, for example, making the Garbage Record Book mandatory for ships of 100 gross tonnage and above;
- preparation of a circular reminding Member States to enforce MARPOL Annex V on fishing vessels through port State control measures; and
- encourage memoranda of understanding on port State control to develop control procedures that include fishing vessels.

It has been pointed out that if the marking of fishing gear with the IMO ship identification number were to be enacted in conjunction with a "waste bond" scheme, it would be possible to reward those who collected discarded fishing gear by drawing on the deposits of those who lost the gear (Leney, Blaha and Lee 2021, 15).

Recycling

Plastic recycling is the process of recovering waste or scrap plastic and reprocessing these materials into other functional and useful products.[*] It is crucial that plastic be recycled as part of global efforts to reduce plastic leakage into the environment, and to facilitate the transition towards a more circular economy.

Plastics should be recycled for several reasons, including the following:

- Plastic recycling helps to conserve resources and diverts plastics from landfills or unintended destinations such as oceans.
- Plastic recycling requires less energy than making plastic from raw materials and can reduce carbon dioxide (CO_2) emissions.
- Plastic recycling helps to reduce fossil fuel consumption, since virgin plastic is produced directly from natural gas or crude oil.
- Plastic recycling is less expensive and time-consuming than the manufacture of new plastic using virgin material.

Most post-consumer plastic waste is recycled using mechanical recycling technology. More specifically, mechanical recycling can be used to recover plastic materials comprising polypropylene, polyethylene or polyethylene terephthalate (PET). Mechanical recycling involves processes such as grinding, washing, separating, drying, re-granulating and compounding to break down waste into plastic flakes. Once dried, these flakes can be used to produce new plastic materials.

Since the recycling of plastics is a complex process, it is not a viable practice on board ships, and it is probably beyond the resources of most port facilities in developing countries.

Another technique, based on pyrolysis, involves the conversion of mixed plastics into oils. Depending on the specific process, the oils thus obtained can serve as raw material for the production of new plastics, or they can be used as a fuel. Some recycling plants employing this technique are profitable even at low capacities (recycling, for example, 1 tonne of plastic per day).

A further example of plastic recycling is the use of composite recycled plastic panels as a construction material. The recycled feedstock comes from a number of sources – polypropylene from various packaging-derived materials, such as bottle caps; PET from carbonated drink bottles; and polyethylene from packaging film. These waste plastics can be converted into high-performance structural composite panels on a commercial scale (IOM3 2004).

[*] See https://recyclinginside.com/plastic-recycling.

Some companies have developed technologies for the recycling of plastic and nylon fishing gear. For example, the Danish company Plastix has come up with a technique that enables the mechanical recycling of post-user plastic fibres and rigid plastics, primarily from the maritime industry. The process converts fibres from fishing nets, trawls and ropes that would previously have ended up in the ocean or on a landfill into high-grade and virgin-like plastic raw materials. The Aquafil Group transforms nylon fishing nets into new yarn that has the same characteristics as nylon made of virgin raw material.

Several new techniques have emerged in recent years that make it possible to reuse waste plastics in economically viable ways. However, on small islands, single-use plastics are not widely used (in supermarkets or elsewhere), and it would be difficult to set up a commercial-scale recyling plant because of the limited available quantities of plastic waste inputs. In such cases, options other than recycling may be more suitable.

Is recycling an economically viable solution?

In general, PRFs are economic enterprises which need to generate sufficient revenue to sustain their operations. A facility will therefore tend to choose the cheapest solution for processing its plastic waste. This may be recycling, incineration with or without energy production, and/or landfilling. The final choice depends on the costs and revenues involved, and on the locally available waste infrastructure.

In addition to the waste fees collected from ships, the potential revenue that can be recovered from the recycling of plastic waste needs to be taken into account. If certain types of plastic waste or the oils derived from the chemical conversion of plastic can be profitably sold, this should be factored in as an additional revenue stream.

Governments may subsidize the collection of plastic to prevent the generation of marine litter, especially when such litter impacts tourism and the quality and quantity of fish stocks as the basis of the fishing industry and aquaculture, which are important sectors in some countries. To support the fisheries sector, governments can provide financial incentives for the launching of activities aimed at collecting waste plastics, such as “fishing for litter” and beach clean-up campaigns.

Conversion of waste to energy

Sophisticated incinerators that burn plastic and other municipal waste can produce enough heat and steam to turn turbine blades and generate electricity for local grids. In the EU as a whole, where there are restrictions on the landfilling of organic waste, almost 27% of municipal waste was incinerated in 2019 (CEWEP 2021). According to the World Energy Council, the waste-to-energy sector is likely to witness steady growth in the coming years, especially in the Asia and the Pacific region (WEC 2013, 7b.6).

Energy recovery may be a valuable alternative for waste fractions rich in plastics that cannot be sustainably recycled because of factors such as:

- the amount, cleanliness and composition of the collected waste;
- the lack of available technologies for sorting; and
- market-driven requirements regarding the quality of and standards for recycled material.

For such plastics, energy recovery is more resource-efficient than landfilling or even forced recycling. However, waste-to-energy plants are expensive to build and operate, so they generally charge more than landfills. Additionally, given that plants run most efficiently if there are steady streams of waste, their operators will often need to import material from far away.

Large incineration plants can generate enough electricity to supply thousands of houses. However, studies have indicated that recycling plastic waste still saves more energy – by reducing the need to extract fossil fuels for the manufacture of new plastics – than can be obtained from the burning of such waste along with other household waste. Finally, waste-to-energy plants may emit toxic pollutants such as dioxins, acid gases and heavy metals.

Use of recycled plastics in roads

India was the first country to use waste plastics in road construction. A project in Australia and New Zealand is currently investigating the possibility of using recycled plastics in asphalt roads.* The project is evaluating various methods to blend such plastics with bitumen and asphalt. The recycling of plastics in this way could be a viable solution for countries without conventional plastic recycling industries.

1.4.2 *Fishing gear*

It is broadly assumed that 80% of marine litter comes from land-based sources, and plastics are estimated to make up between 50% and 80% of total marine litter. In general, data on marine litter are not standardized, making it difficult to obtain a comprehensive picture of the situation. According to the report *Sea-based Sources of Marine Litter* by Working Group 43 of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, "large knowledge gaps remain concerning amounts and rates of ALDFG on regional and global scales, and across many major gear types" (Gilardi 2021, 21). At the global level, there are no absolute figures on the weight, lengths or other quantitative metrics of ALDFG entering the world's ocean every year, although rate estimations do exist (Gilardi 2021, 27).

Fishing-gear pollution has serious impacts on marine wildlife, habitats and fish stocks while also reducing fishing profits, destroying marine resources, and increasing operational costs for vessel operators and authorities as a result of the gear replacement and retrieval efforts that they need to undertake. Once in the marine environment, fishing gear also represents a navigational and safety hazard, as floating nets and ropes can entangle propellers and spoil active fishing gear (EIA 2020, 2).

IMO has recognized the need to prevent plastic pollution from ships, including fishing vessels and gear. Several measures dealing with waste from fishing vessels were included in the IMO Action Plan to address marine plastic litter from ships adopted in 2018. Similarly, in 2019, FAO published the *Voluntary Guidelines on the Marking of Fishing Gear*, which seek "to improve the state of the marine environment by combatting, minimising and eliminating abandoned, lost or otherwise discarded fishing gear (ALDFG) and facilitating the identification and recovery of such gear" (FAO 2019, 1).

1.4.3 *ALDFG and passively fished waste*

ALDFG is an increasingly pressing problem. Various reports by specialized agencies of the United Nations contain recommendations on how to reduce ALDFG and marine debris in general, including the following actions (Macfadyen, Huntington and Cappell 2009, 87):

- promote lost gear recovery;
- develop affordable use of Global Positioning System transponders;
- facilitate onshore reception and disposal;
- set general limits on gear carried; and
- promote better gear design to reduce potential catches by lost gear (also known as "ghost fishing").

As pointed out by Macfadyen, Huntington and Cappell (2009, iv):

> The impacts of ALDFG … include: continued catching of target and non-target species (such as turtles, seabirds and marine mammals); alterations to the benthic environment; navigational hazards; beach debris/litter; introduction of synthetic material into the marine food web; introduction of alien species transported by ALDFG; and a variety of costs related to clean-up operations and impacts on business activities. In general, gillnets and pots/traps are most likely to "ghost fish" while other gear, such as trawls and longlines, are more likely to cause entanglement of marine organisms, including protected species, and habitat damage.[See also GGGI 2021a].

* Austroads project No. ATP6305, "Use of road-grade recycled plastics for sustainable asphalt pavements" (2020–22). https://austroads.com.au/projects/project?id=APT6305.

> The factors which cause fishing gear to be abandoned, lost or otherwise discarded are numerous and include adverse weather; operational fishing factors including the cost of gear retrieval; gear conflicts; illegal, unregulated and unreported fishing; vandalism/theft; and access to and cost and availability of shoreside collection facilities. Weather, operational fishing factors and gear conflicts are probably the most significant factors, but the causes of ALDFG accumulation are poorly documented and not well understood. A detailed understanding of why gear is abandoned, lost or discarded is needed when designing and tailoring effective measures to reduce ALDFG in particular locations. [See also GGGI 2021b].

Passively fished waste

During their fishing operations, fishers are often confronted with waste that has collected in their nets (referred to as "passively fished waste"). Some international non-governmental organizations have therefore developed the Fishing for Litter scheme,[*] the underlying idea of which is quite simple: instead of throwing the waste back into sea, fishers are encouraged to collect it on board and deliver it free of charge to a PRF when returning to port. In this way the amount of marine litter can be reduced. In addition, this scheme highlights the importance of good waste management among the fishing fleet.

Fishing for Litter measures have been included in several regional action plans on marine litter.[†]

Moreover, Directive (EU) 2019/883 of the European Parliament and of the Council of 17 April 2019 contains requirements related to the management of passively fished waste, which was included in the definition of "waste from ships". EU Member States are required to ensure the provision of adequate PRFs capable of receiving such waste. So that the costs of collection and treatment of passively fished waste are not borne exclusively by port users, Member States are expected to cover, where appropriate, those costs from the revenues generated by alternative financing systems, including extended producer responsibility schemes, and by EU, national or regional funding (art. 8).

Several countries have already implemented this measure and set up schemes for the reception of passively fished waste (Drinkwin 2022, 36).

In cooperation with regional and/or national stakeholders, participating vessels are given hard-wearing bags to collect marine litter that is caught in their nets during their normal fishing activities. Filled bags are deposited at participating ports on the quayside, where they are moved by port staff to a dedicated skip or bin for disposal. Operational or galley waste generated on board, which is the responsibility of the vessel, continues to be dealt with through established port waste management systems.

Under regulation 8 of MARPOL Annex V, States parties are required to ensure the provision of adequate reception facilities. As no distinction is made between different types of ports, this requirement is also applicable to fishing ports.

It is obvious that fishers catch not only fish in their nets but unintentionally also marine litter. To prevent this passively fished waste from being dumped back into the ocean, governments should adopt measures to encourage fishing boats to deliver the waste ashore.

Schemes have been introduced in certain countries to provide alternative financing to cover the costs of collecting and managing passively fished waste. Such initiatives should be welcomed, since the costs involved may otherwise deter fishing port communities from participating in the management of passively fished waste.

Reception facilities are provided at fishing ports where fishers can deliver their passively fished waste. As this type of waste is on the whole quite similar to ship-generated garbage, the PRF that can be used for its collection is also similar.

[*] See the website of the Fishing for Litter scheme, https://fishingforlitter.org/.

[†] For example, in the OSPAR Regional Action Plan for Prevention and Management of Marine Litter in the North-East Atlantic; the Regional Action Plan on Marine Litter of the Baltic Marine Environment Protection Commission; and the Pacific Regional Action Plan: Marine Litter 2018–2025 prepared by the Secretariat of the Pacific Regional Environment Programme.

Figure 2: *Big bags used for the onboard collection of passively fished waste in the United Kingdom (Photo credit: KIMO*)*

Figure 3: *Big bags used for the onboard collection of passively fished waste in the Netherlands (Photo credit: KIMO*)*

* KIMO is a network of local governments in the North-East Atlantic and Baltic regions, working together for healthy seas, clean beaches and thriving coastal communities.

2 Reception facilities for plastic waste from ships

Although MARPOL does not define PRFs, the *Guidelines for ensuring the adequacy of port waste reception facilities* (IMO 2000) state that "to achieve adequacy the port should have regard to the operational needs of users and provide reception facilities for the types and quantities of wastes from ships normally visiting the port".

According to Directive (EU) 2019/883 of the European Parliament and of the Council on port reception facilities for the delivery of waste from ships, a PRF is "any facility which is fixed, floating or mobile and capable of providing the service of receiving the waste from ships" (art. 2(6)). Such facilities need to have the capacity to receive the types and quantities of waste from ships normally using the port, taking into account:

- the operational needs of the port users;
- the size and geographical location of the port; and
- the types of ship calling at the port (art. 4(2)(a)).

To address the problem of marine litter effectively, it is essential to provide the right level of incentives for the delivery of waste to PRFs, in particular waste as defined in MARPOL Annex V (garbage). In the EU this is achieved through a cost recovery system based on the application of an indirect fee, which must be paid irrespective of the delivery of waste. The system includes a right of delivery for the waste without any additional direct charges based on the volume of waste delivered (art. 8(c) of Directive (EU) 2019/883). Given its contribution to the occurrence of marine litter, the fishing and recreational sector should also be subject to this indirect fee.

2.1 Activities at a reception facility

2.1.1 *Collection*

Procedures for collecting garbage generated on board should be based on the consideration of what can be legally discharged into the sea while en route, and whether a particular type of garbage can be delivered to facilities for recycling or reuse.

According to the *2017 Guidelines for the implementation of MARPOL Annex V*, the recommended garbage types that should be separated on board the ship are:

- non-recyclable plastics and plastics mixed with non-plastic garbage;
- rags;
- recyclable material:
  - cooking oil;
  - glass;
  - aluminium cans;
  - paper, cardboard, corrugated board;
  - wood;
  - metal; and
  - plastics (including styrofoam or other similar plastic material);
- e-waste generated on board (for example, electronic cards, gadgets, instruments, equipment, computers and printer cartridges); and
- garbage that might present a hazard to the ship or crew (for example, oily rags, light bulbs, acids, chemicals and batteries).

Consequently, PRF operators should try to segregate these waste types during collection, avoiding the manual sorting of mixed waste by using specific machinery. In some countries the sorting of waste into different categories goes even further. For example, in the port of Rotterdam the operator of the PRF for solid waste collects more than 100 different waste types. This requires the provision of waste containers for each type of waste collected or the direct collection of separate fractions in recipients placed on board a collection barge.

Figure 4: *Waste disposal area for solid waste from inland navigation at the port of Antwerp-Bruges, Belgium (Photo credit: Port of Antwerp-Bruges, Belgium)*

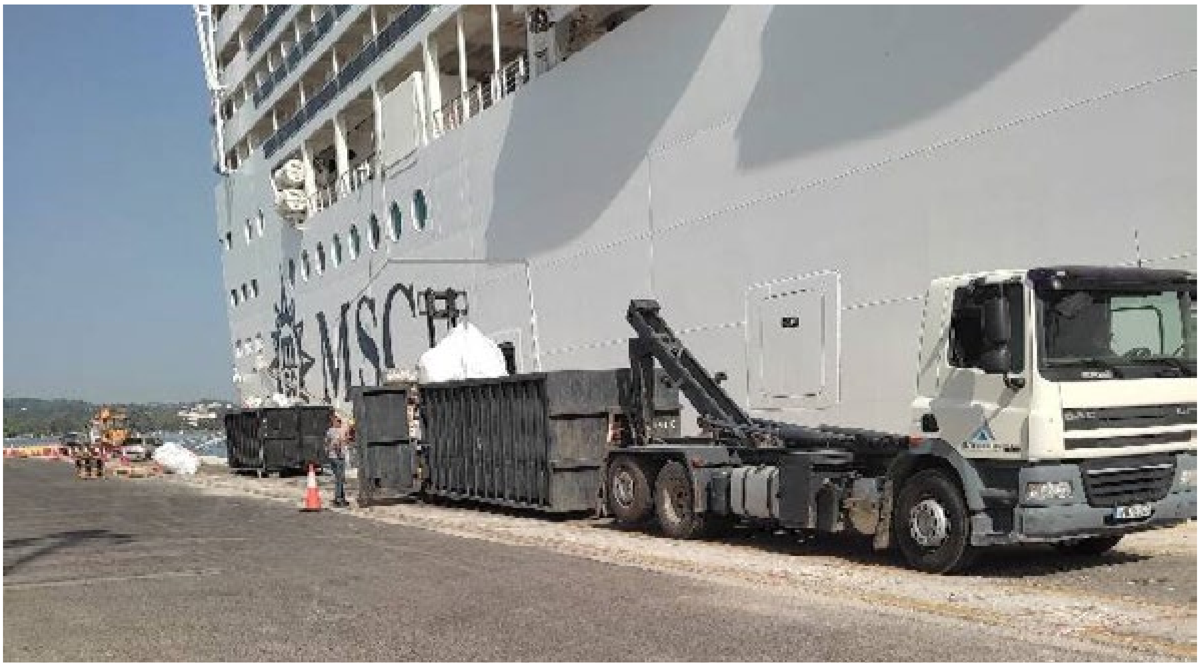


Figure 5: *Waste collection from cruise ships at the port of Piraeus, Greece (Photo credit: Antipollution, Piraeus, Greece)*

If a PRF is to be able to collect all types of solid waste (including plastics), it needs to invest in suitable recipients.

According to the *2017 Guidelines for the implementation of MARPOL Annex V*, it is recommended to separate certain types of waste on board the ship. Exceptions are made for small ships that do not have the required space to keep the waste separated. This means that a PRF needs to provide recipients for each different (solid) waste type, that is, for glass, paper and carton, aluminium cans, wood, metal, plastics, e-waste and certain types of hazardous waste such as paint cans and residues, and detergent bottles.

In Western Europe, the price of a waste container with a capacity of 1,100 litres is around €250. It is higher if there are additional requirements, such as putting a lock on the container, adding a radio-frequency identification chip, or installing a monitoring device for filling-level measurement to avoid unnecessary trips from the storage or treatment station to the port to collect an empty or almost empty waste bin.

For the segregated collection of solid waste, a PRF needs to provide around 10 different waste containers per ship. Depending on the port size and number of calls, multiple waste container sets are required.

Figure 6: *A waste bin that can be used for the collection of either one type of solid waste or mixed solid waste (Photo credit: SULO Benelux, https://sulo.be)*

Figure 7: *A waste bin allowing for separation of waste types to avoid sorting of waste in a storage area (facilitates potential recycling) (Photo credit: SULO Benelux, https://sulo.be)*

Containers can be equipped with separate holes for the collection of clear and coloured glass (see Figure 7).

Figure 8: *Waste bin for paper and cardboard (Photo credit: SULO Benelux, https://sulo.be)*

For the collection of paper, another type of throw-in hole can be provided (see Figure 8).

The specific construction of the container's lid can prevent contamination with other types of waste, making it easier to recycle the waste or obviating the need for additional sorting of the waste at the storage area.

If (small) volumes preclude the efficient recycling of certain waste fractions, larger containers can be provided.

Containers for mixed waste are available in different sizes. A container can be open or closed or fitted with a door; it may have been developed for a specific waste type (mixed waste, paper and cardboard, several types of plastics, and so on). These characteristics depend on the volumes of waste that the vessels have notified or indicated before calling at the port. Closing the waste container after use prevents the waste from being contaminated with waste from other sources (such as dockers' activities).

Cruise ships often deliver large volumes of certain types of waste. These ships are normally equipped with waste compactors on board, which means that the waste can be easily palletized and packed to facilitate transport.

2.1.2 *Storage*

The waste at a PRF is often ready to be almost immediately transported to a recycling facility. If recyclable waste is to be exported, it can be taken to its storage place and stuffed in containers.

Cargo ships, which are usually operated by small crews, sometimes arrive at ports with small quantities of solid waste. Specific waste containers have been developed for these small volumes to keep the different waste fractions separated. The small waste fractions then need to be bundled in an intermediate storage area or at the PRF. After being baled and palletized, the waste can be sent onward for recycling. In such cases the PRF needs to invest in additional equipment for compacting or baling.

If no recycling facilities are available, the mixed waste can be sent for incineration or landfilling. Since full truckloads are more cost-efficient in that regard, it is necessary to invest in intermediate storage space.

As noted in a recent United Nations Environment Programme study, an incinerator needs to be able to process at least 60,000 tonnes of waste plastics per year to produce oils if it is to be profitable (Nikiema et al. 2020, 8). For some developing countries it would be difficult to achieve such a capacity.

The PRF operator collects the waste recipients and brings them to an intermediate storage area, which may have an on-site treatment centre, though this is not the case at most PRFs. In this storage area batches of a certain waste type can be combined to optimize volume before the waste is transported in fully loaded trucks to a treatment centre. Operators may invest in trucks and carry out the collection and transport themselves, or they may outsource those tasks. Both options entail certain costs.

The waste collector will normally bring the ship's waste to an intermediate storage area, since the capacity of merchant ships, fishing vessels and recreational craft is in general limited. At the storage area the waste can be sorted into recyclable and non-recyclable fractions, and, if necessary, it can also be compacted and baled. If there are no opportunities for recycling, the collected waste can be taken directly to a landfill or incinerator (where available).

In some cases, intermediate storage of waste is important to optimize logistics for treatment. For example, while it may be irrelevant for a landfill operator whether in a given week the amount of waste is doubled or no waste is supplied at all, a waste incineration plant depends on a constant and consistent supply. Thermal waste recovery, therefore, requires the development of systems to store pretreated waste in an environmentally sound manner. Intermediate storage helps to balance seasonal fluctuations in waste production, to compensate for plant downtime and to bridge any periods during which additional facilities are being constructed.

Intermediate storage facilities are also necessary for certain material recovery procedures –for example, at glass and metal smelting plants, and for paper and cardboard recycling. To ensure a continuous supply it is often a standard procedure to keep recycling material in intermediate storage during a certain period (say, a few months) in order to be able to distribute these stocks in an efficient way across several locations. In Austria, for example, thermal waste treatment plants have intermediate storage bunkers with a capacity equivalent to the volume of a waste delivery over a period of 3 to 10 days to bridge short-term supply fluctuations (Austria, BMLFUW 2015, 81).

Figure 9: *Garbage and oily waste collection barge at the port of Antwerp, Belgium (Photo credit: Mac², http://www.mac-2.be)*

Figure 10: *Waste collection trucks in the port of Piraeus, Greece (Photo credit: Antipollution, Piraeus, Greece)*

2.1.3 *Sorting, pretreatment and treatment*

Within the PRF, the collected waste can be sorted into different fractions: recyclables, non-recyclables and waste that will be treated at the facility itself. Relatively straightforward treatment operations that can be conducted at a PRF include the treatment of wastewater and certain types of oily waste (bilge water, sludge or slops) via oil–water separation and further processing to obtain a base oil that can be used by industrial users (such as cement kilns) or sold as a product. In most cases, though, the treatment of solid waste, with a few exceptions, is performed outside the port area, while activities at the PRF are confined to separation and/or pretreatment of the waste, including activities such as compacting, baling, washing and disinfection.

To refer again to the waste hierarchy in Lansink's ladder (see Figure 1 in Chapter 1), some plastics, including waste fishing gear, can be recycled if they are sufficiently free of pollutants. However, for that purpose the plastics need to be sorted into separate fractions, such as PET, high-density polyethylene (HDPE), low-density polyethylene (LDPE), polyvinyl chloride (PVC), polypropylene and polystyrene. Subsequently these separate fractions need to be transferred to a specialized plastic recycling company.

Mixed plastics can be recycled into paraffin oil through pyrolysis. The plastic is shredded into granulates and converted, as a result of thermal decomposition, into the base oil (paraffin oil that can be sold to chemical companies), gas and a small residual fraction (see Figure 11). This process is profitable even when small amounts of plastic are converted (such as 1,000 kg of plastic per day).

Mixed plastics can likewise be incinerated with energy recovery. In addition to producing electricity, the steam thus generated can be used in greenhouses or to heat residential buildings. Some recycled plastics can also be used to make high-performance composite panels for the construction industry.

However, most plastics are still dumped in landfills because of a lack of recycling facilities or incinerators. Waste plastic in landfills can sometimes eventually end up in the ocean.

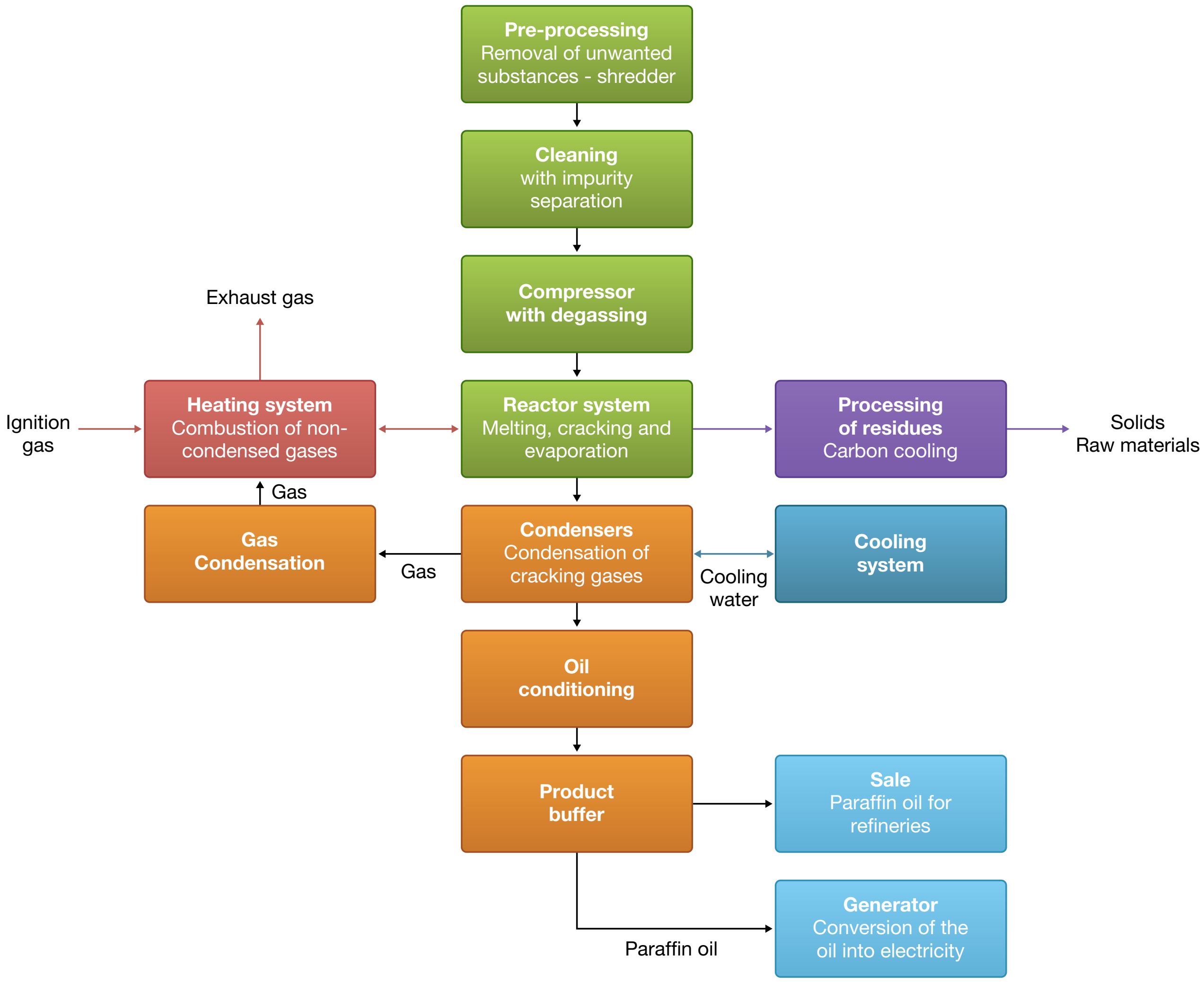


Figure 11: *Schematic representation of a plastic recycling unit based on pyrolysis technology (Source: Biofabrik, Germany)*

2.2 Adequacy of reception facilities

One of the prerequisites for the sound environmental management of ship-generated garbage (including plastics) on the basis of the *2017 Guidelines for the implementation of MARPOL Annex V* is proper delivery of the garbage and its disposal ashore. In this respect, the quality of the service provided and the waste fee applied by the PRF operator can determine whether or not disposal is successful (INTERTANKO 2017, 17). Improvements to the management of wastes in order to ensure full compliance with MARPOL are unlikely to be achieved simply through enforcement measures or auditing by States parties. In section 6.3 the Guidelines also recognize the value of economic and other incentives to encourage improved waste management. This has resulted in the launching of several initiatives whereby the harbour dues are reduced for ships whose environmental performance surpasses that prescribed by their legal obligations – for example, the Environmental Ship Index, the Green Award and the Clean Shipping Index. Some of these schemes provide for a discount on harbour dues if ship-generated waste is delivered regularly or if waste production is reduced through investment in incinerators, compactors, and reuse techniques.*

In 2014, IMO launched its *Consolidated guidance for port reception facility providers and users* (amended in 2018 and issued as MEPC.1/Circ.834/Rev.1). Although the Consolidated Guidance provides a good basis for best-practice procedures that can be followed by ships in the delivery of waste, additional options are available to shipowners who would like the waste to be received during every port call without undue delay. One of these options is to contract a waste management company with a network of facilities at the ports and terminals frequently visited by their ships. While this may not suit every vessel type on all trade routes, ships with regular and predictable patterns of activity can benefit from knowing that during each port call all their waste can be adequately received and managed. This reduces some of the financial uncertainty that arises when more difficult waste streams must be landed ashore (INTERTANKO 2017, 17).

If a ship cannot discharge waste to a reception facility, IMO strongly encourages the master and/or company to forward a report to the administration of the flag State, with a copy to the competent authorities in the port State. The standard format for reporting alleged inadequacies of PRFs can be found in appendix 1 of the *Consolidated guidance for port reception facility providers and users*.

It is also recommendable that ports, PRF providers and shipowners make use of the standard formats for the Advance Notification Form and Waste Delivery Receipt provided, respectively, in appendices 2 and 3 of the *Consolidated guidance for port reception facility providers and users*. The former allows the PRF to prepare to handle the waste of the notifying vessel in the best possible manner, while the latter serves to confirm that the ship has disposed of the waste types and quantities mentioned on the receipt.

2.3 Reception facilities for specific types of ship

2.3.1 *Merchant ships*

In the *Consolidated guidance for port reception facility providers and users* (IMO 2018) it is recommended that ships intending to call at a port notify the port authorities in advance of the types and quantities of waste that they wish to dispose of. This allows the PRF to start preparing for the collection of the waste. It is worth noting that this system of advance waste notification is not generally used at fishing and recreational ports.

If large quantities of a specific waste type are delivered, it is more likely that the waste can be recycled. If only small quantities are delivered, the higher cost entailed by manual or mechanical sorting of the various waste fractions will probably preclude recycling. In such cases, national authorities can help to prevent most of the waste from ending up in a landfill by adopting policy measures such as increasing taxes on landfilling.

For companies wishing to invest in a PRF at a particular port, the following table outlining the amounts of waste generated on board ships can be helpful when calculating the capacity of the planned facility.

* See https://www.environmentalshipindex.org/; https://www.greenaward.org/; https://www.cleanshippingindex.com/.

Table 1: *Overview of the amounts of waste generated, drivers and onboard treatment methods (Source: Adapted from CE Delft, 2017, 5–6)*

Type of waste	Generation rate	Driver	Onboard treatment
Oily bilge water	0.01 m^3 to 13 m^3 per day; larger ships generate larger quantities	Condensation and leakages in the engine room; size of the ship	The amount can be reduced by 65% to 85% by using an oil-water separator and discharging the water fraction into the sea.
Oily residues (sludge)	m^3 to 0.03 m^3 of sludge per tonne of heavy fuel oil 0 to 0.01 m^3 per tonne of marine gas oil	Type of fuel; fuel consumption	Evaporation can reduce the amount of sludge by up to 75%. Incineration can reduce the amount of sludge by 99% or more.
Tank washings (slops)	20 m^3 to hundreds of m^3	Number of tank cleanings; size of loading capacity	After settling, the water fraction may be discharged at sea.
Sewage	0.01 m^3 to 0.06 m^3 per person per day. Sewage is sometimes mixed with other wastewater. The total amount ranges from 0.04 m^3 to 0.45 m^3 per person per day.	Number of persons on board; types of toilet; length of voyage	Effluent from treatment plants is often discharged at sea where permitted under MARPOL Annex IV.
Plastics	0.001 m^3 to 0.008 m^3 of plastics per person per day	Number of persons on board	Often not incinerated. Dirty plastics (plastics that have been in contact with food) are often treated as a separate waste stream.
Food waste	0.001 m^3 to 0.003 m^3 per person per day	Number of persons on board; provisions	Where permitted under MARPOL Annex V, food waste is often discharged at sea.
Domestic waste	0.001 m^3 to 0.02 m^3 per person per day	Number of persons on board; types of product used	n.a.
Cooking oil	0.01 litres to 0.08 litres per person per day	Number of persons on board; types of food prepared	Although not permitted, cooking oil is sometimes still added to the sludge tank.
Incinerator ashes	0.004 m^3 to 0.06 m^3 per month	Use of incinerator; cost of using incinerator.	The incinerator is not used for all types of waste, mostly for paper, sometimes for oily sludge.
Operational wastes	0.001 m^3 to 0.1 m^3 per person per day	Size and age of ship; type of cargo	n.a.
Cargo residues	0.001% to 2% of cargo load	Type of cargo; size of ship.	n.a.

n.a. = not applicable

The practical example below illustrates that, in general, the volumes of ship-generated solid waste are rather small:

> A cargo ship with 20 crew members would be expected to generate on a trip of 14 days the following maximum volume of plastics: 20 persons x 14 days x 0.008 m^3 per person per day = 2.24 m^3. On cruise ships, where compactors are available, this volume can be significantly reduced.

Waste generation on a ship can also be influenced by the cultural background of the crew, as crew members from some countries tend to consume more individually packed goods (for example, ready-made food that can be heated in a microwave, soft drinks and beer), while those of other nationalities may prefer to use bulky food products when cooking their meals (such as rice bags weighing up to 50 kg) and to drink water from large containers. Mineral water can be bought in large containers (holding up to 50 litres), which reduces the amount of plastic packaging. Other products can be delivered in recipients that are able to be reused after cleaning and are accepted by the manufacturer.

2.3.2 *Cruise ships*

Over the past decade, cruising has become an integral part of the tourism industry. The bulk of the business caters to passengers from North America and Europe, but other regions such as Asia and the Pacific and the Middle East are catching up.

Cruise ships sometimes carry several thousands of passengers as well as crew members. Most of these passengers have two to three meals a day in the restaurant on board the ship, take a shower daily, and so on. This results in large quantities of garbage and sewage water (wastewater from kitchens, showers, toilets and laundries). In addition to the liquid waste, large volumes of solid waste are created (metal cans, glass bottles, paper, cardboard, etc.). Owing to the luxury nature of such voyages, the waste production is higher than normal.

A report by the Protection of the Arctic Marine Environment Working Group of the Arctic Council states that cruise ships carrying between 15 and 3,000 people on trips lasting 7 to 15 days or 15 to 30 days produce, respectively, between 210 kg and 90,000 kg and between 450 kg and 180,000 kg of MARPOL Annex V waste. It is estimated that passengers on cruise ships generate around 2.0 kg per person per day (PAME 2017, 14).

Since the adoption of MARPOL in 1973, cruise lines and port authorities have been implementing environmental management systems to ensure that their operations are conducted in an environmentally friendly manner. Cruise lines are endeavouring to reduce, sort and manage the waste generated on board in line with the provisions of MARPOL Annex V. An environmental policy goal of "zero discharge" for solid waste at sea has been endorsed by several of them. To attain this goal, cruise lines over the past few years have been striving to reduce waste generation almost by half. Similarly, cruise ports are seeking to implement solid waste management and to develop facilities, technologies and services aimed at ensuring continuity in the life cycle of cruise ships' garbage (Pallis, Papachristou and Platias 2017, 57).

The classification of garbage in MARPOL Annex V does not always reflect the differences between land-based and maritime waste management. For example, the former often requires the segregated collection of hazardous waste, a type of waste which is not defined in MARPOL. To avoid a discontinuity in the ship–shore interface, an integrated system for the management of solid waste on board and ashore is essential. Developing and implementing comprehensive programmes that consider all types of waste and all stages of the waste management process together is the best way of addressing the adverse impacts of waste management (Pallis, Papachristou and Platias 2017, 58).

According to the same authors, a holistic approach to waste management should be based on the following five principles:

- Waste management hierarchy – aimed mainly at preventing the generation of waste and reducing its harmfulness. Where this is not possible, waste materials should be reused, recycled, recovered, or used as a source of energy. As a final resort, waste should be disposed of safely.
- Self-sufficiency at the community level – this implies the establishment of an integrated network of waste disposal facilities.
- Implementation of the best available techniques without incurring excessive costs – so that environmental impacts are reduced to the greatest possible extent and in the most cost-efficient manner.
- Proximity – wastes should be disposed of as close to the source as possible.
- Producer responsibility – economic operators and particularly manufacturers must be involved in managing the entire life cycle of substances, components and products, starting from production and throughout their useful life until they become waste.

The survey of over 50 cruise ports in the Mediterranean conducted by Pallis, Papachristou and Platias (2017) indicates that this is a very diverse sector. Some ports collect the garbage separately and try to reuse or recycle the waste, while others are not yet so advanced owing to a lack of adequate treatment facilities for certain waste types. However, the new EU Directive 2019/883, which entered into force in 2021, 24 months after its adoption, requires the EU ports to increase their efforts to recycle cruise ships' domestic waste.

Members of the Cruise Lines International Association commit themselves to reducing waste as much as possible and to segregating their ships' garbage by waste types to enable reuse and recycling.*

During cruises, regular disposal of garbage is necessary. For cruise ships calling at ports according to a fixed schedule, tailor-made waste management arrangements can be made with individual ports to ease the operations and maximize the reuse and recycling of different waste types.

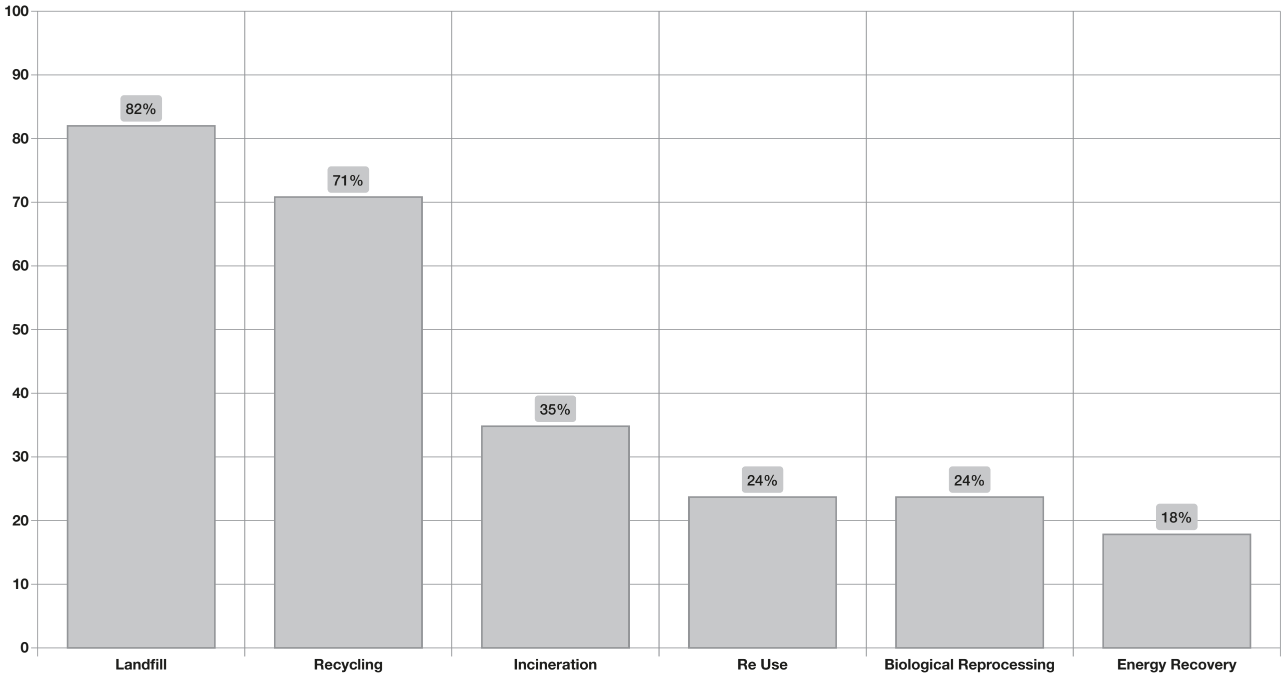


Figure 12: *Garbage disposal methods used at Mediterranean cruise ports, 2015 (Source: Pallis, Papachristou and Platias, 2017, 65)*

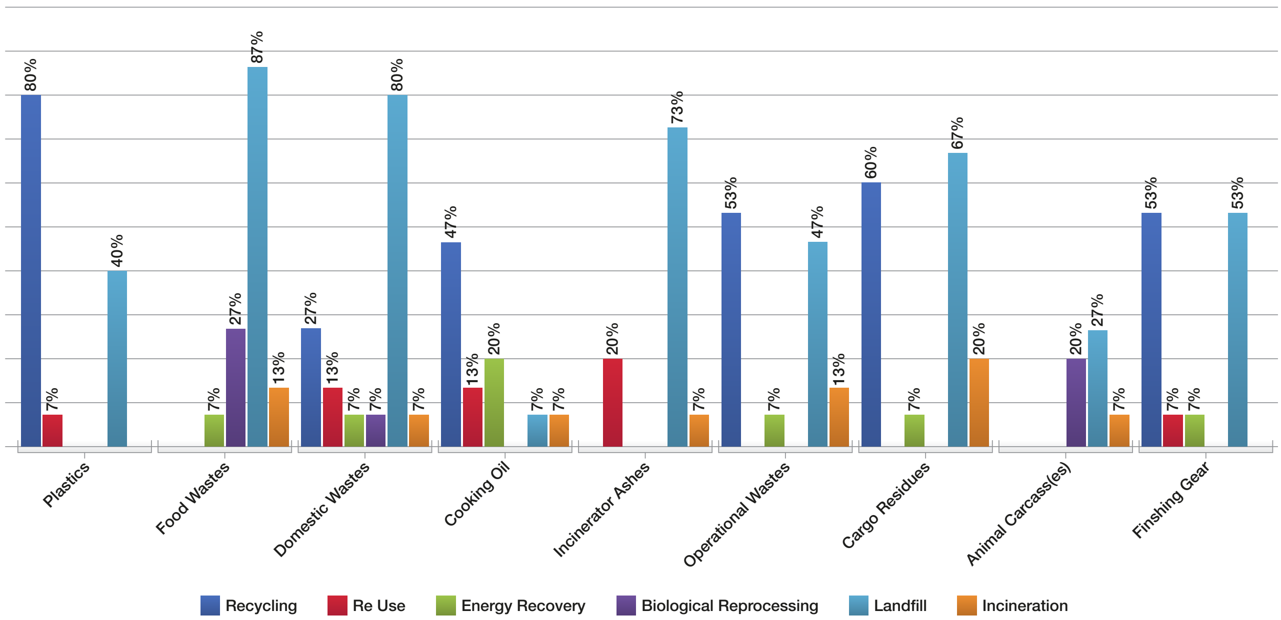


Figure 13: *Garbage disposal methods used at Mediterranean cruise ports, by garbage type, 2015 (Source: Pallis, Papachristou and Platias, 2017, 66)*

* See the Association's website, https://cruising.org/en-gb.

2.3.3 *Fishing vessels*

A "fishing port" is a port or harbour for the landing and distribution of captured fish. Such ports may be for recreational use, but in most cases they are commercial. A fishing port usually also has facilities for the storage, distribution, preparation and packing of fresh or deep-frozen fish.

The port is normally frequented by local fishing boats and, like any other port, should provide reception facilities for waste generated by these vessels. Special attention has to be paid to the collection of end-of-life fishing gear, retrieved gear, ALDFG and passively fished waste.

Under regulation 8 of MARPOL Annex V, States parties are required to ensure the provision of adequate reception facilities. This is also the case for fishing ports, as no distinction is made between different types of port.

The 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the "London Convention") and its 1996 Protocol (the "London Protocol") regulate the dumping of wastes at sea mainly from land-based sources. The disposal of plastics at sea is in effect prohibited by both the London Convention and the London Protocol, although the regime is stricter under the more recently adopted Protocol. Under the Protocol all dumping is prohibited except for the eight categories of waste set out in annex 1 to the Protocol, which may be considered for dumping at sea if a permit has been issued by the competent authorities following an environmental assessment.

The London Convention and Protocol also address such sources of marine litter as abandoned or drifting fish aggregating devices and polystyrene and Styrofoam buoys used in aquaculture, noting that source control and best practices are important in tackling these problems.*

The EU estimates that between 80% and 85% of marine litter is plastic and that commercial fishing gear accounts for 27% of all beach litter.† Fishing gear may only survive three to six months of heavy use. As it becomes worn it can get snagged, break apart and sink to the ocean floor. When old gear is returned to land it must be dealt with as a waste. Most fishing ports currently pay to send end-of-life gear to landfill. The use of fishing gear would be more sustainable if the material could be recycled into new products, but there are challenges to be overcome before this practice can become more widespread. For example, some smaller ports lack suitable storage facilities. Waste fishing gear is also difficult to recycle, as it is made up of many different types of plastic and other materials (Seafish, n.d.). Improvements should be made to gear design to prevent the whole or partial loss of fishing gear and its components. On the other hand, there is a growing number of companies that are able to recycle old gear.

It is obvious that fishers catch not only fish in their nets but unintentionally also marine litter. To prevent this passively fished waste from being dumped back into the ocean, governments should adopt measures to encourage fishing boats to deliver the waste ashore.

Schemes have been introduced in certain countries to provide alternative financing to cover the costs of collecting and managing passively fished waste. Such initiatives should be welcomed, since the costs involved may otherwise deter fishing port communities from participating in the management of passively fished waste.

2.3.4 *Recreational craft*

As noted by the US Environmental Protection Agency:

> Marinas and recreational boating are very popular uses of coastal waters. The growth of recreational boating, along with the growth of coastal development in general, has led to an increased awareness of the need to protect the environmental quality of our waterways. Because marinas are located right at the water's edge, there is a strong potential for marina waters to become contaminated with pollutants generated from the various activities that occur at marinas – such as boat cleaning, fuelling operations and marine head discharge – or from the entry of stormwater runoff from parking lots and hull maintenance and repair areas into marina basins. (EPA, n.d.)

* Specific *Fish waste assessment guidelines* (2014) have been developed within the framework of the London Protocol.

† See para. 5 in the preamble to Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment.

To reduce the financial burden involved in delivering waste, many marina operators have introduced a "no special fee" system whereby boaters may use their reception facilities at no additional cost after carrying out hull cleaning or repair works. Türkiye has developed a special badge (similar to a credit card) that all yacht owners need to purchase when they call at a Turkish marina for the first time. Each time the owner delivers waste (sewage, bilge water and/or domestic waste), this is electronically noted on the card. When a spill occurs in the neighbourhood of yachts, the coast guard can read the cards of the yachts to check whether they have regularly delivered their waste.

As noted by the Massachusetts Department of Environmental Protection (n.d.), the solid waste found in marinas includes:

- waste generated by boat maintenance and repair activities (for example, shipping boxes, board and metal scraps, cleaning rags, paper, old engine parts, fibreglass chips, sawdust, construction waste, sandblasting waste, floor sweepings, sanding dust, burned-out light bulbs, batteries, garbage, bottles, cans, sheet plastic, worn-out tarpaulin sheets and dirty filters);
- waste from offices and shops in the marina (for example, wastepaper, boxes, shipping materials, floor sweepings, cups, used office supplies, bottles, cans and garbage); and
- waste from the boats themselves (for example, drink containers, food scraps, garbage, fish cleaning waste, old fishing line, dirty cleaning rags, cigarette butts, papers, plastic bags, utensils and plates).

In most marinas a fixed fee is levied on the yachts calling there, which usually covers the use of electricity and drinking water and the disposal of domestic waste and sewage. Such a fee system removes incentives to dump waste illegally into the sea.

The end-of-life management of fibre-reinforced plastic vessels is becoming a major issue in many countries, especially those that do not have appropriate recycling or disposal facilities. Such vessels are often dumped at sea or left to disintegrate on the shoreline. The Contracting Parties to the London Convention and Protocol, in coordination with the United Nations Environment Programme, are developing a guidance document on how best to recycle and/or dispose of derelict fibre-reinforced plastic vessels (IMO 2021a, para. 4.5; IMO 2021b, paras. 10.5–10.9).

Solid waste with a hazardous component, such as acid from a leaking battery or toxic antifouling paint chips, must be disposed of as hazardous waste. Marinas provide special waste bins behind closed doors for hazardous waste. In such cases the marina operator has to check the type of waste that is to be delivered.

3 Economic analysis

3.1 Introduction

Since the adoption of MARPOL in 1973, global awareness of environmental problems has grown and evolved. New ideas have emerged about how to manage operations in an environmentally sensitive and responsible way. Many shipping companies and port authorities have implemented environmental management systems. Environmental targets are frequently set by companies to facilitate the ongoing reduction of their environmental impact. Coupled with this is a growing desire to incorporate the principles of sustainability and corporate social responsibility.

In addition to MARPOL, many port States have adopted national and regional requirements stipulating that ships should discharge certain types of MARPOL wastes and residues to PRFs. Port States may also specify the means of disposal that must be used to meet quarantine and other regulatory requirements. Operators should therefore ensure that they have a complete and up-to-date overview of national and regional requirements relating to PRFs. Such information may be gained directly from the port State authorities, or via agents in the port, or from trade associations representing the shipping and/or port industries.

Of particular importance in the elimination of marine pollution from ships are the more restrictive requirements in force in special areas and emission control areas as defined in MARPOL.

The overall cost of providing and operating a PRF depends not only on the costs involved in the collection of wastes from a ship but also on the cost of recycling, treatment and final disposal. In addition, there are also personnel and administrative costs.

Private businesses will only invest in equipment to facilitate the collection of waste from ships if the operation is profitable. The potential revenue is determined by such parameters as the number of ships calling at a particular port, the number of ships requesting a waste collection service, the amounts collected, and the waste fee received. Under a direct fee system, only ships that request such a service must pay for it.

It is therefore important to know the potential volumes of plastic waste generated on board ships and the specific types of plastic involved. This information gives an idea of the possible recycling or treatment options for the plastic waste. However, plastic is only one of several categories of garbage from ships: other waste types will also be collected.

In the sections that follow an overview is first given of how to assess the potential volumes of plastic. More details are then provided on the costs and revenues of a PRF (direct costs, indirect costs and net revenues). Depending on the volumes involved, suggestions are offered from a circular economy perspective as to what can be done with plastic waste (prevention, reuse and recycling). The selection of a specific technique for plastic recycling depends very much on the types and volumes collected in a port area (assuming that the ship-generated waste is dealt with similarly to the normal domestic waste from households living in the neighbourhood of that port).

The focus in this report is on different types of port, such as merchant or industrial ports, cruise ports, fishing ports and pleasure craft ports. The potential volumes of plastic waste are related to the number of crew and passengers.

3.2 Plastic waste on board ships

Several studies (for example, CE Delft 2017) present waste-related data from ship audits, interviews, literature reviews, online surveys conducted among stakeholders and audits of waste notification forms. For almost every type of ship-generated waste there is a variety of waste flows and onboard treatment methods. The empirical evidence gathered in these studies shows that ships use various treatment methods and often only treat part of a waste stream. Accordingly, the amounts of waste generated on board and the amounts discharged to PRFs are never identical: some waste is disposed of using onboard equipment and techniques such as incineration, evaporation of bilge water, compactors and shredders.

If a PRF operator needs to assess the potential waste streams to be collected, it can estimate the waste volumes by combining information on the ship type, size of the vessel, length of the voyage and the number of crew and passengers. The following paragraphs focus specifically on plastic waste.

According to the definition in MARPOL Annex V, "plastic" means:

> a solid material which contains as an essential ingredient one or more high molecular mass polymers, and which is formed (shaped) during either manufacture of the polymer or the fabrication into a finished product by heat and/or pressure. Plastics have material properties ranging from hard and brittle to soft and elastic. For the purposes of this annex, "all plastics" means all garbage that consists of or includes plastic in any form, including synthetic ropes, synthetic fishing nets, plastic garbage bags and incinerator ashes from plastic products.

This means that the plastic fraction within the total solid waste fraction of MARPOL Annex V consists of different types of plastic. For recycling purposes, the different plastic fractions need to be sorted.

The following table gives an overview of the different types of plastic and their uses, also indicating whether a given type of plastic may be incinerated on board and whether it is recyclable or not.

Table 2: *Different types of plastic found in ships' garbage (Source: INTERTANKO, 2020, pages 21–22)*

Name of plastic	Symbol		Uses	Remarks
Polyethylene terephthalate (PET or PETE)			Found in: soft drinks, water and beer bottles, mouthwash bottles, peanut butter containers, salad dressing and vegetable oil containers	PET plastics are the most common for single-use bottled beverages because they are inexpensive, lightweight and easy to recycle. Incinerate: yes Recycle: yes
High density polyethylene (HDPE)			Found in: milk jugs, juice bottles, detergent and household cleaner bottles, shampoo bottles, some trash and shopping bags, motor oil bottles, butter and yoghurt tubs, cereal box liners, laundry detergent bottles, oil bottles, pens, recycling containers, floor tiles, drainage pipe, lumber, benches, doghouses, picnic tables, fencing	HDPE is a versatile plastic with many uses, especially for packaging. It poses no risk of leaching harmful chemicals and is readily recyclable into many goods. Incinerate: yes Recycle: yes

Name of plastic	Symbol		Uses	Remarks
Polyvinyl chloride (PVC)	03 PVC		Found in: window cleaner and detergent bottles, shampoo bottles, cooking oil bottles, clear food packaging, wire jacketing, medical equipment, siding, windows, piping, deck panelling, flooring, cables, mats	PVC is tough and weathers well, so it is commonly used for piping, siding and similar applications. PVC contains chlorine, so its manufacture can release highly dangerous dioxins. If you must cook with PVC, do not let the plastic come into contact with the food. Incinerate: no, never incinerate PVC because it releases toxins Recycle: yes
Low density polyethylene (LDPE)	4 LDPE		Found in: squeezable bottles, bread, frozen food, dry cleaning and shopping bags, tote bags, clothing, furniture, carpet, trash cans, compost bins, shipping envelopes, panelling, and lumber	LDPE is a flexible plastic with many applications. It poses little to no risk of leaching harmful chemicals. Incinerate: yes Recycle: yes
Polypropylene	5 PP		Found in: some yogurt containers, syrup bottles, ketchup bottles, caps, straws, medicine bottles, signal lights, battery cables, brooms, brushes, auto battery cases, ice scrapers, pallets, trays	Polypropylene has a high melting point, and so is often chosen for containers that must accept hot liquids. It poses little to no risk of leaching harmful chemicals. Incinerate: yes Recycle: yes
Polystyrene	6 PS		Found in: disposable plates and cups, meat trays, egg cartons, carry-out containers, aspirin bottles, compact disc cases	Evidence suggests that polystyrene can leach potential toxins into foods. It can release styrene, also known as vinyl benzene and phenylethane. Incinerate: yes Recycle: yes
Miscellaneous / other	7 OTHER		Found in: three- and five-gallon water bottles, bulletproof materials, sunglasses, DVDs, iPod and computer cases, signs and displays, certain food containers, nylon, plastic lumber, custom-made products	A wide variety of plastic resins that do not fit into the previous categories are lumped into this category. Incinerate: yes Recycle: yes

3.3 Costs and revenues of a reception facility

3.3.1 *Direct costs*

Direct costs are operational costs arising from the actual delivery of waste from ships, including, as noted in REMPEC (2019, appendix, para. 78):

- provision of PRF infrastructure, including containers, tanks, processing tools, barges, trucks, waste reception, treatment installations, laboratories and offices;
- site leasing, if applicable, or the costs of leasing the equipment necessary for the operation of a PRF;
- operation of the PRF: collection of waste from the ship, transport of waste from the facility for final treatment, maintenance and cleaning of the facility, remuneration of staff (including overtime), provision of electricity, waste analysis and insurance;
- final reuse, recycling or disposal of the waste from ships, including separate collection of waste; and
- administration: invoicing, issuing of waste receipts to the ship, reporting.

Direct costs can be influenced by the availability of existing waste treatment infrastructure: ports that are in the vicinity of large industrial clusters may have better access to land-based waste treatment facilities (such as incineration plants and/or landfill sites), which may entail lower costs for the treatment of ship-generated waste because of the larger volumes that can be handled and reduced transport costs (REMPEC 2019, appendix, para. 79). In some EU countries, the disposal of plastic waste is subsidized by the government within the framework of the European Green Deal.

Ports located on small island developing States sometimes struggle with their own local waste management, and their landfills do not always meet international standards. Adding ship-generated waste to the domestic volumes is not a viable option at such ports, even if PRFs are available to accept waste, because of the lack of adequate treatment facilities. In a report prepared for the Pacific Islands Forum Fisheries Agency, Leney, Blaha and Lee (2021) advocated the introduction of a "waste bond" that is payable at the time of licensing. The authors recommend that fishing vessels keep their plastic waste on board for delivery at a port where such waste can be handled properly. By using compactors, the volume of waste can be reduced significantly.

Figure 14: *Compact waste compactor for paper and plastics (Photo credit: SULO https://www.tecnor.be)*

3.3.2 *Indirect costs*

Indirect costs are administrative costs arising from the management of the collection system for ship-generated waste in the port, including, as noted in REMPEC (2019, appendix, para. 80):

- development and approval of the waste reception and handling plan, including any audits of the plan and its implementation;
- updating the waste reception and handling plan, including labour costs and consultancy costs, where applicable;
- organizing the consultation procedures for the (re-)evaluation of the waste reception and handling plan;
- management of the advance waste notification and cost recovery systems, including the application of reduced fees for "green ships", the provision of information and communications technology systems at port level, statistical analysis and associated labour costs;
- organization of public procurement procedures for the provision of PRFs, and issuing of the necessary authorizations;
- communication of information to port users through the distribution of flyers, putting up signs and posters in the port, or publication of the information on the port's website, and electronic reporting of the information if required; and
- other administrative costs: monitoring exemptions and electronic reporting of this information if required.

3.3.3 *Net revenues*

Revenues are the net proceeds from waste management schemes and the national or regional funding available, including the following revenue elements, as noted in REMPEC (2019, appendix, para. 81):

- net financial benefits provided by extended producer responsibility schemes;
- other net revenues from waste management such as recycling schemes (for example, the sale of base oil or other oil products after the processing of waste oil, the sale of certain types of plastic to recyclers); and
- other funding or subsidies available to ports for waste management and fisheries (in Europe the national governments or port authorities often subsidize the free delivery of plastic waste).

In the case of a PRF, the "normal" gross revenue is a combination of the waste fees paid by ships and the revenue from waste that can be sold for recycling or waste that is transformed in such a way that it can be sold as a product. For example, if a PRF has won a public contract to collect waste from ships calling at a particular port, the contractual arrangements will be stipulated in the tender document. The fees generally depend on the size of the vessel, the number of crew members and/or passengers, and other specific characteristics. In several Scandinavian ports, the PRF invoices the port authority.

3.4 Key elements in economic and financial assessments

As already noted, private-owned PRFs, which are not generally subsidized by governments, need to be able to cover all their costs for the collection, transport and treatment of waste by charging users a waste fee. Reception facilities run by public authorities are sometimes financed from the general State budget (without being profitable).

3.4.1 *Reception facilities*

States parties to MARPOL are required to ensure the availability of adequate PRFs in each port visited by ships sailing on an international or domestic voyage. When the port is relatively small, the collection of waste from ships may be combined with the collection of household waste, since the solid waste generated on board is very similar to that generated by municipalities and cities.

If a port is visited only irregularly by ships, waste bins can be provided for the collection of segregated and/or mixed waste. These waste bins can be collected during normal working hours.

To increase the amount of waste landed ashore, an indirect fee system (such as a "no special fee" system) could be introduced, whereby ships pay a fixed fee for the delivery of garbage, irrespective of whether they make use of the reception facilities (REMPEC 2019). Such a system removes the incentive for ships to dump their waste at sea in order to avoid the direct cost for delivery of the waste. It also reduces the cost for users of a PRF, since non-users contribute to the provision of the reception facilities as well.

Merchant ships generate relatively small quantities of waste, which are difficult to recycle in a cost-efficient manner, since additional sorting of plastics is required. Only companies using technologies that enable them to obtain certain products from a mixture of different plastics will find it profitable to engage in such recycling. Alternatively, the mixed plastics can be incinerated for electricity production.

Cruise ports that are visited regularly by cruise ships receive large quantities of solid waste. In general, these waste types are well segregated, compacted and baled to facilitate transfer and transport. Owing to the volumes involved, the recycling of certain fractions, including plastics, may be more cost-effective than in merchant ports, where the volumes are significantly smaller, if the necessary recycling facilities are available.

In smaller ports such as **fishing ports** only limited amounts of ship-generated wastes tend to be delivered. The domestic waste from smaller fishing vessels can be collected through the municipal waste collection system, while specific wastes such as bilge water and small hazardous waste (for example, batteries, paint boxes and light bulbs) can be delivered to existing licensed waste operators. Large industrial fishing vessels, which are out on the high seas for several weeks or months and do not necessarily call at their home port only, have a completely different profile and are better suited to existing fee schemes such as indirect fees or direct fees based on the type and quantities of waste. If such fishing vessels are sailing in areas with limited resources for waste management and treatment (for example, in the waters around remote Pacific islands), a "reverse logistical approach" may be applied whereby the supply vessels that deliver provisions and fuel to the fishing vessels collect the waste generated by the latter. Such supply vessels are normally larger and equipped with more adequate waste facilities, including holding bins, compactors and incinerators that are compliant with MARPOL requirements (Leney, Blaha and Lee 2021, 56–57). Smaller fishing vessels not supported by supply vessels and sailing in the vicinity of their home ports can sometimes stay longer at the port, depending on the fishing season. This means that waste collection can sometimes be very irregular, with varying quantities. Waste collectors working in such an environment need to diversify their waste sources (for example, through waste collection from industry or storage companies) in order to stay in business.

Example:

Many EU ports operate indirect waste fee systems based on solidarity among the fishing fleet. The waste fee that each vessel must pay often depends on its size or the horsepower of its engine. Ships do not pay the waste fee each time they call at a port, but, rather, at regular intervals (monthly, quarterly, or yearly). The waste fee is not directly related to the quantities of waste delivered to a PRF, which provides a good incentive for fishers to deliver their waste ashore. The costs of waste collection and treatment are divided among all fishing vessels that have their home at a given port (solidarity principle).

In addition to "normal" types of waste such as garbage and oily waste, the PRFs at fishing ports also have to deal with **abandoned, lost or otherwise discarded fishing gear (ALDFG)**. Fishing gear is not so easy to recycle, but there are specialized companies offering such services. The recycling options very much depend on the types of fibre used in the gear (for instance, nylon).

A report on good practices to prevent and reduce marine plastic litter from fishing activities produced under the GloLitter Project includes several case studies that illustrate how ALDFG can be prevented, mitigated, and remediated (Giskes et al. 2022).

In addition to normal ship-generated waste, a PRF can also handle **passively fished waste** (waste unintentionally caught during fishing operations). It would not be fair to hold fishers responsible for the extra costs involved in managing the waste caught in their nets. If they were to be penalized for delivering such waste ashore, they might well be tempted to dump it back into the sea.

Given the economic impact of marine litter on tourism (because of polluted beaches that need to be cleaned up) and on fish stocks, it is appropriate for national and local governments to establish schemes that cover the extra cost of landing passively fished waste without passing on that cost to fishers.

As for **recreational ports**, an indirect waste fee system preferably should be implemented to incentivize the disposal of solid waste and sewage. Under an all-in fee system, boaters will regularly dispose of sewage and garbage in the facilities provided by the marina. Separate tariffs can be set for additional services such as hull cleaning and dry docking, to be paid for directly by boaters.

3.4.2 *Recycling*

Plastic recycling at a PRF is only possible if certain conditions are fulfilled, notably:

availability of plastic recycling industry in the neighbourhood of the port;

sufficient volumes of plastics (potentially combined with similar plastics collected in the city or municipality nearby), since the waste plastic needs to meet certain quality parameters. The plastics need to be sorted by product (PET, PVC, etc.), washed, compacted and baled before they can be properly recycled. Additionally, if mixed plastics can be used in the recycling process, a balance between different plastic products is required.

When the volumes of waste plastic are insufficient for recycling, the plastic waste can be incinerated to produce electricity as long as the necessary facilities are available, or it can be partly incorporated into bituminous pavement.

3.5 Practical examples of reception facilities collecting garbage in ports around the world

3.5.1 *Port A: a hub port in the Mediterranean Sea (Tanger Med, Morocco)*

Port A is a hub port with approximately 12,000 ship calls per year. It is located around one hour's drive from the nearest city and cannot benefit from the municipal waste collection.

The data used are based on assumptions and average waste production figures taken from previous studies.

Table 3: *Practical example: number and types of ship calling at port A and waste generation during one year*

Type of ship	Number	Average days at sea	Persons on board	Domestic waste (m^3)	Plastics (m^3)
Bulk carriers	113	10	25	706.25	141.25
Container ships	2 234	10	25	13 962.50	2 792.50
Ferries	9 949	0.5	500	62 181.25	12 436.25
Tankers	243	10	25	1 518.75	303.75
Liquefied gas carriers	43	10	25	268.75	53.75
TOTAL	**12 582**			**78 637.25**	**15 727.50**

Note: Based on waste generation data in NEA and PM Group (2009); EMSA (2015).

The potential volume of domestic waste generated on board ships calling at this port lies between 0.02 and 0.03 cubic metres per person per day (m^3/p/d). Let us assume 0.025 m^3/p/d for this example.

The potential volume of (waste) plastics generated on board lies between 0.001 m^3/p/d and 0.008 m^3/p/d. Let us assume 0.005 m^3/p/d for this example.

What can be concluded from these figures?

1 Number of ships calling at port A per day = 12,582 ÷ 365 = 35. Owing to seasonal influences, this figure could fluctuate between 26 and 43 ships per day (this can be checked with the harbourmaster's office).

2 The average volume of potential garbage for a ship is 6.25 m^3, of which plastics account for around 1.25 m^3 on average.

3 Domestic waste contains a certain amount of potentially recyclable wastes (glass, paper and cardboard, metal, etc.). The port in this example is a large port, so it is worth exploring the possibility of recycling some waste fractions. The PRF can consider investing in bigger recipients into which all types of waste can be dumped, but the sorting of the waste should take place on the facility's premises using manual or mechanical sorting equipment.

What is needed for the collection of waste from ships calling at this port?

If the port has only one service provider for the collection of solid waste, the PRF must invest in several waste bins. For example, it may be possible to recycle the following waste fractions near the port:

- paper and cardboard;
- plastics;
- aluminium;
- electronic waste (e-waste); and
- white and coloured glass.

This means that the PRF needs five specific waste bins for these fractions and one or two extra bins for mixed waste.

To serve each ship calling at the port on a given day, the PRF would need to have 50 sets of bins (in our example the maximum expected number of ships per day is 43), which at 7 bins per ship gives 350 bins.

If these bins cannot be emptied on the same day, the volume probably needs to be doubled. Let us assume that 500 bins would be sufficient and that each bin will last 5 years.

Investment cost:	500 bins x €250 = €125,000
	50 waste containers (15 m^3) x €1,500 = €75,000
Cost per year:	(€125,000 + 75,000) ÷ 5 years = €40,000

Number of trucks needed for the transport of waste from ship to PRF

Based on information gleaned from the port waste management plans of the main ports in Europe, almost 50% of the vessels calling at these ports (including Rotterdam, Antwerp and Hamburg) deliver garbage to PRFs.

If, in our example of a hub port in North Africa, 35 ships are calling daily, 17 to 18 ships will need to deliver their garbage. This means that a total of 34 to 36 round trips are required to bring waste recipients to each ship and collect the filled waste bins afterwards. Trips can sometimes be combined if vessels are moored closed to each other, reducing the total number of trips. If the waste collection is done in two shifts (between 6 a.m. and 10 p.m.), the number of trucks required to serve the total port can be easily calculated.

The second element is the number of trips that can be made by one truck during a shift. Depending on the location of the PRF and the vessel in the port, the duration of trips can be estimated. Let us assume that bringing the bins and collecting loaded bins takes one hour. A truck can do around six trips, including the issuing of waste delivery notes and other paperwork, offloading the waste bins at the PRF, lunchtime and other activities. This means that three trucks are required for one shift. However, the collected waste needs to be subsequently transported to recycling companies, incineration facilities or landfill sites. The PRF therefore has to invest in more trucks or outsource some of the transport.

Let us assume that a truck has a lifetime of 10 years.

3 trucks + 1 extra truck = 4 trucks x €100,000 cost price per truck = €400,000 investment cost

If the PRF works every day of the week, 5 or 6 drivers are needed.

Depreciation cost per year for a truck (without fuel, insurance, maintenance):

€400,000 ÷ 10 years = **€40,000**

Land surface that is required for the storage, sorting, packing and labelling of waste, analysis, parking, offices, etc.

The elements to consider are:

- administrative area (gate + office + laboratory);
- storage area depending on the type of waste, hazardousness, etc.;
- garage/workshop for trucks;
- parking area for personnel and visitors; and
- intermediate storage area.

The investment cost per square metre will vary depending on the location and the requirements laid down by the authorities with regard to preventing soil pollution, fires and accidents. If the average price per square metre for a warehouse, office, etc. is known, the construction cost can be calculated.

If the PRF prefers to collect mixed waste in bigger bins, the waste needs to be sorted manually or mechanically into recyclable fractions. This requires investments in equipment for sorting, compacting and palletizing the waste. When the choice is made, the cost of purchasing the equipment can be estimated.

MARPOL Annex V does not distinguish between different types of plastic. Even if the plastic fraction is collected separately, it should be noted that not all plastics are recyclable. The plastics will still need to be sorted into different fractions on the facility's premises. Recyclers prefer the plastics to have been washed (to remove contamination) and compacted into bales (typical dimensions: 1.8 m x 1.2 m x 1 m). In certain cases, the plastics are resized (shredded to obtain granulates). All this requires additional capital investment and/or labour. For the present calculations we have not taken these additional investments into account.

Overview of the entire investment cost (equipment, trucks, land, construction) of a PRF

To set up its business, a PRF operator needs sufficient land that can accommodate offices, a storage area, parking space for trucks, empty and loaded waste bins, sanitary facilities, energy supply infrastructure, etc. Transport arrangements also have to be made to collect the waste and take it to the facility.

The following paragraphs show how the capital and operating expenditures involved are calculated.

Capital expenditure

a) Investment in waste bins (see above)

Assuming that 500 bins are required and that the expected lifetime of each bin is 5 years, we arrived at an annual cost (total investment: 5 years) of **€40,000**.

b) Transport of collected waste to treatment facility

Recyclable waste fractions will need additional transport to the premises of the recycling company. As the price for certain types of plastic fluctuates over the year, this may have an impact on the necessary storage area, with more space being required if the PRF is not offered a favourable price by the recycling company.

For port A we have assumed that four trucks would be required, and calculated the annual depreciation for each truck as **€40,000**.

c) Rental of land

Let us assume that 2 hectares, or 20,000 m^2, of land are rented from the port authority at a cost of €3/m^2/year, which gives an annual cost of **€60,000**. Alternatively, the land can be purchased, in which case amortization should be taken into account.

Operating expenditure

d) Recycling of plastics is more expensive than landfilling

If all steps are taken into consideration (collection, transport, handling of the waste, delivery to a recycling company), the waste fee paid by the ship should cover the potential losses incurred during recycling. In general, the landfilling of waste is up to €200/tonne cheaper than recycling. The competent authority should accordingly take steps to compensate for those losses – for example, by imposing an additional tax on waste that is landfilled or incinerated.

In this example we do not take this extra cost into account.

e) Personnel

We have assumed that 10 staff are required for the administrative part (advanced waste notification, waste disposal forms, invoicing, coordination of tasks, laboratory work, sales), 2 or 3 staff for on-site waste handling, and 5 or 6 drivers for the trucks. This means that the PRF would need to have 20 to 25 staff in total.

Total direct cost

Capital expenditure per year

Waste recipients	**€40,000**
Trucks	**€40,000**
Rental of land	**€60,000**
Construction:	**€65,000**

– warehouse: 3,000 m^2 x €300/m^2 =	€900,000
– office/laboratory/shower facilities: 400 m^2 x €1,000/m^2 =	€400,000
Total: €1,300,000 x 5% depreciation =	**€65,000**

Operating expenditure per year

Transport cost for 4 trucks

Maintenance, tyres	€1,500/truck =	€6,000
Insurance	€2,000/truck =	€8,000
Miscellaneous	€1,500/truck =	€6,000

Fuel 100 km for 1 collection x ca. 300 vessels x €1.20/litre of gasoil x 25l/100km
50,000 km x €1.20/litre of gasoil x 25l/100km/truck = €60,000

Total transport cost: **€80,000**

Personnel: 20 staff (ca. €60,000/person, including social security, overtime, weekend work)

Total: 20 x €60,000 = **€1,200,000**

TOTAL COST of operating a facility (not including the cost of disposal or incineration): €40,000 (waste recipients) + 40,000 (4 trucks) + 60,000 (rental of land) + 65,000 (construction) + 80,000 (transport cost for 4 trucks) + 1,200,000 (personnel) = €1,485,000

Total ship-generated waste collected in a full year:

Total waste collected in port A: **78,637.25 m^3**

Plastics: 15,727.50 m^3

Residues (domestic waste) 62,909.75 m^3

According to an online waste calculator (https://avcalc.com/wp/), 1 m^3 of garbage is equivalent to around 481 kg.

If mixed waste is incinerated or dumped in a landfill, a tariff must be paid. In Belgium the incineration tariff for mixed waste is around €100/tonne, while the tariff for dumping such waste in a landfill is also around €100/tonne.

This means that the cost of disposing of the residual waste types is (62,909.75 x 0.481) tonnes x €100/tonne = **€3,025,958**. If only 50% of the ships calling at the port discharge their waste, this gives a disposal cost of ca **€1,500,000**.

TOTAL COST of the PRF, including disposal or incineration of waste: €1,485,000 + 1,500,000 = ca. €3,000,000

Revenues:

a) Waste fee for garbage: €200/ship

Assuming that every ship is required to pay a fixed indirect fee, irrespective of whether it discharges its waste in that port, and that 10% of the vessels are exempted from this fee for reasons of various kinds (such as being frequent visitors to the port or if they are naval ships):

With around 12,500 calls/year – 10% exempted ships (1,250), this gives a revenue of 11,250 ships x €200 as the indirect waste fee = **€2,250,000**

b) Revenue for the plastics that can be recycled:

15,727.50 m^3 of plastics is collected.

Assuming that all these plastics have been property sorted, they then need to be compacted into bales. Let us also assume that 1 m^3 of plastic can be compacted to one third of its volume.

15,727.50 m^3 ÷ 3= 5,242.50 m^3

1 bale (1.8 m x 1.2 m x 1 m = 2.16 m^3)

5,242.50 m^3 ÷ 2.16 m^3 = 2,427 bales. The weight of a bale may range between 200 kg and 325 kg, the average being 262.5 kg

2,427 bales x 262.5 kg = 637 tonnes

To estimate the potential revenue from the recycling of sorted plastics, we have used the indicative price list of the UK plastic recyclers for different types of plastic (dated May 2020). If we assume that all types of plastic are equally present in the collected plastic, we arrive at an average price of €246.62/tonne.

Revenue from the recycling of plastics = 637 tonnes x €246.62/tonne = **€157,096.94**

Grand total: €2,250,000 + €157,096.94 = €2,407,096.94

Conclusion:

The examples of the incineration and landfilling tariffs used in this exercise are for Belgium, which has some of the highest tariffs in the world. If the tariff for landfilling were just €40/tonne, rather than €100/tonne, the disposal cost would drop from €1,500,000 to €600,000 and the PRF would be able to make a profit.

If the PRF operator can further reduce its mixed waste, it can reduce its expenditure on landfilling or incineration on the one hand, and increase its revenue from recyclable fractions on the other.

3.5.2 *Port B: a small port in West Africa (Banjul, Gambia)*

The port of Banjul is situated in the Gambia which has a population of around 2.5 million. Industrial activity is limited. Domestic waste is landfilled, but the landfills do not meet international standards, which means that there is a risk of environmental pollution. At present there is no PRF in the port (based on the information in the GISIS database).

We can use the statistics provided by the harbourmaster's office to estimate the investments that would need to be made by the operator of a potential PRF.

Table 4: *Practical example: type, number and average gross tonnage of ships calling at port B (Source: Harbourmaster's office at port B)*

Type of ship	Total gross tonnage	Number	Average gross tonnage
Container ships	1 893 130	123	15 391
Roll-on/roll-off ships	1 359 656	26	52 294
Dry bulk carriers	492 793	91	5 415
Cruise ships/ferries	133 767	7	19 109
General cargo ships	91 171	10	9 117
Liquid bulk carriers	469 369	32	17 792
TOTAL	**4 539 886**	**289**	**15 709**

Note: The data refer to 2016.

By drawing on the Third IMO Greenhouse Gas Study (2014), it is possible to assess the average fuel consumption of these ships, taking into account their type and size. If the size of, say, a container ship or oil tanker is available, the average production of sludge can be calculated, since it is a certain percentage of the fuel consumption. Sludge is the main source of oily waste in port B, which is not visited by crude oil tankers.

The container ships have a regular schedule, calling at Algeciras or Tanger Med as the main port and at several African ports. They call at port B 15 days after the start of their voyage. For several ports in the sailing schedule, there is no information in the GISIS database as to whether they have PRFs.

The container ships have an average capacity of 2,500 twenty-foot equivalent units.

As already mentioned, the fuel consumption can be calculated from the average size of a ship, which allows us also to estimate the potential volumes of sludge generated on board. However, in this report we are focusing on solid waste and on plastics in particular.

The following assumptions are made with regard to garbage production on board these ships and possible waste collection needs:

- The average crew is made up of 25 seafarers.
- Most bulk trade involves cement from neighbouring countries.
- Liquid bulk consists of refined products coming from neighbouring countries.
- As there are no data on cruise ships (such as their sailing schedule and number of passengers), they have been left out.
- For container ships, the duration of the voyage to port B is 15 days; for the other ships, which come mainly from nearby countries, an average of 5 days at sea is assumed.

Table 5: *Waste generation during one year of ships calling at port B*

Type	Number	Average days at sea	Persons on board	Domestic waste (m^3)	Plastics (m^3)
Container ships	123	15	25	1 153.12	230.63
Roll-on/roll-off ships	26	5	25	81.25	16.25
Dry bulk carriers	91	5	25	284.37	56.88
Cruise ships	7	5	25	21.87	4.38
General cargo ships	10	5	25	31.25	6.25
Liquid bulk carriers	32	5	25	100	20
TOTAL	**289**			**1 671.86**	**334.39**

Note: The potential volumes are based on NEA and PM Group (2009).

The average volume of garbage from container vessels is between ca. 5 m^3 and 15 m^3.

As the annual waste volumes from maritime shipping are quite low, it would be difficult from an economic perspective to set up a dedicated facility for the collection and treatment of garbage from ships only. This means that practically all solid waste, including plastics, will end up in a landfill.

In general, the options for waste treatment in Africa are limited. If they are to be recycled, waste fractions often have to be sorted and transported to facilities abroad. However, this only makes sense if the price for sorted plastic waste is sufficiently high to cover the extra costs. The plastic waste to be disposed of is normally a mixture of different types of plastic, which need to be sorted manually or mechanically.

Conclusion: around 350 m^3 of plastic waste per year would result in 35 m^3 to 50 m^3 of compacted and baled plastic waste (one to two 20-foot containers). Considering the need for investments in machinery to compact and bale the plastic, personnel for the sorting operations and the transport costs, the PRF operator may prefer to bring the mixed waste to a landfill. In that case, either all the waste would be collected together, or the hazardous waste fractions would be separated if these are not allowed to be landfilled.

This waste can be collected by truck (if the different waste fractions are gathered into plastic bags) or in a container. One truck can be used to place a container alongside the ship, to collect the container after the ship's waste has been discharged into it and to bring the container to the landfill. However, if the ship has sufficient onboard storage capacity and the waste can be delivered to a PRF at one of the following ports on the ship's route, it may be better for the environment to keep the waste on board.

If the ships pay the same waste fee in Africa (that is, €200 for the garbage disposal), the PRF would collect 289 x €200 = €56,000 (assuming that all ships actually pay the fee)

Revenue: €56,000

Cost:
- Depreciation for a second-hand truck costing €25,000 that will work 5 more years = €25,000 ÷ 5 = €5,000
- Waste container: €2,500 ÷ 5 years = €500
- Insurance, maintenance of the truck: €1,500
- Fuel: bringing a container, collecting and going to the landfill

  100 km for 1 collection x ca. 300 vessels x €1.20/litre of gasoil x 25l/100km €9,000
- Personnel: truck driver (1.5 people); administration (invoicing, price calculation, waste delivery notes) (2.5 people): salary: €400/month (all included) = €400 x 12 x 4 people = €19,200
- Amortization cost of an office and warehouse: €10,000

– Cost of landfilling the waste: €100/tonne = 2,000 m^3 x 0.25 = 500 tonnes

500 tonnes x €100/tonne = €5,000

– Miscellaneous: €2,000

TOTAL: €52,200

With a minimum of investments and staff, a PRF in this port would break even. From the moment that it receives dangerous waste within the mixed waste requiring sophisticated treatment, the operator would lose money.

3.5.3 *Port C: an oil-loading port in Asia (Botaş Ceyhan, Türkiye)*

Port C receives oil from Azerbaijan by pipeline and is a relatively new terminal. In 2014, it received around 350 ships, or 1 ship per day. The total port area is 144 hectares and consists mainly of crude oil storage tanks and tanks which were used in the past for dirty ballast water. The port has built a jetty of 2.6 km into the sea, with two berths for simultaneous loading of two tankers of up to 300.000 deadweight tonnes (dwt).

The ships calling at Port C have a deadweight of approximately 100,000 dwt to 200,000 dwt.

If crude oil is transported to refineries in Western Europe, the length of the voyage is around 10 days.

Calculation of waste volumes:

Sludge:

Length of the voyage depends on the previous port. Going to Antwerp, Le Havre or Rotterdam is ca. 20 days sailing.

Assumption: if the average sailing time of each tanker is 20 days,

Fuel consumption: 40 tonnes/day x 20 days sailing x 0.5% (marine diesel oil) = 4 tonnes of sludge

Total: 350 ships x 4 tonnes = 1,400 m^3

Additionally, the port may receive slops (tank washings) from these tankers. If a ship needs to be cleaned every 6–8 voyages, there are potentially 350 slop disposals/year, or:

350 x 0.2%[*] of 100,000 = 70,000 m^3

Total required annual capacity to treat oily waters = ca. 70,000m^3

Sewage:

18 people x 230 litres/day x 20 days x 350 tankers = 28,980 m^3

Note: sewage can be legally discharged at sea (at a distance of more than 12 nautical miles from the nearest land), but the amount of sewage stored on a ship when it arrives at a port also depends on the sewage treatment system on board and whether the ship is sailing in a special area under MARPOL Annex IV.[†]

Garbage:

18 people x 20 days x 2 kg/person x 350 tankers = 252,000 kg = ca. 700 m^3 to 800 m^3

Of which plastic waste: 18 people x 20 days x 0.001–0.008 m^3/day/person x 350 ships = 125 m^3 to 1000 m^3 plastics annually (weight: ca. 30 tonnes to 250 tonnes per year). The collection of the waste

[*] By using the crude oil washing method, the slop volume can be reduced drastically. Several studies have shown that the slops (remaining cargo on board) can be reduced to ca. 0.15% of the quantity on the bill of lading. In imperfect conditions, 0.2% seems more realistic and has been used in the calculation above.

[†] Currently only the Baltic Sea is designated as a special area under MARPOL Annex IV.

from these tankers needs to be carried out using a tanker barge. If the jetty is accessible to trucks, the sludge and garbage can both be collected by truck.

This specific port is around two hours' drive from the nearest city. The volume of solid waste collected per day is ca. 2 m^3 (see calculation above), of which a small fraction is plastic waste. The reception and treatment procedures depend on the availability of waste infrastructure in the country/region. If the recycling of waste is poorly developed, incineration is to be preferred over landfilling. If recycling facilities are available, the use of intermediate storage facilities for recyclable fractions can be considered. Once every few days a truck can bring this sorted waste to a recycling facility.

3.5.4 *Port D: a port in South America*

Port D is a multipurpose deep-water terminal located in Latin America. It is one of the largest dry bulk ports in the country. One jetty in the terminal has a length of 187 m and a depth of 13.5 m. Ships of up to 100,000 dwt can be loaded or unloaded at this jetty, which is dedicated to the handling of coal and fertilizer. Another jetty has a length of 155 m and a depth of 10.5 m, and can handle ships of up to 30,000 dwt (tankers and other bulk carriers).

The following commodities can be stored at the port: coal, petroleum coke, clinker, pumice stone, fertilizers, grains and feed grains, vegetable oils and petroleum products.

Calculation of waste volumes:

The average duration of a voyage from the previous port of call is estimated at 10 days.

Sludge:

Theoretical waste production: 354 ships x 20 tonnes/day x 10 days x 0.5% = 300 m^3 to 400 m^3

Sewage:

354 ships x 15 people x 10 days x 230 litres = 12,213,000 litres or 12,213 m^3

Note: sewage can be legally discharged at sea (at a distance of more than 12 nautical miles from the nearest land), but the amount of sewage stored on a ship when it arrives at a port also depends on the sewage treatment system on board and whether the ship is sailing in a special area under MARPOL Annex IV.

Garbage:

354 ships x 15 people x 2–3 kg x 10 days = 106,200 kg to 150,000 kg or 531 m^3 to 800 m^3 per year

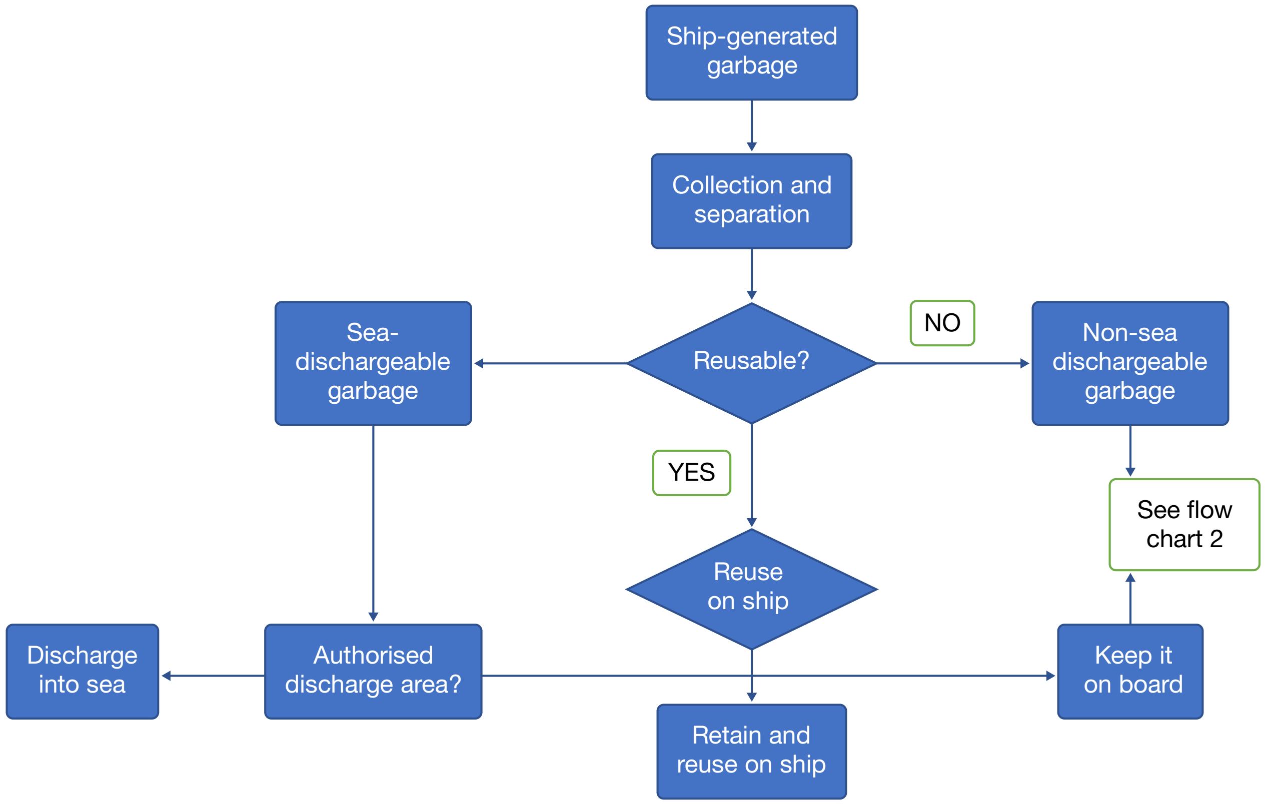
Of which plastics represent ca. 50 m^3 to 400 m^3 per year

Depending on the waste treatment infrastructure in the country/region, the waste collector may decide to bring the recyclable fractions to a recycling facility. Given the estimated volumes, the temporary storage of waste fractions would be required to ensure that full truckloads are taken to the recycling facility.

Conclusion: at this port a waste operator collecting only garbage from ships would not be interested in taking the risk of investing in the provision of a PRF. The collection of solid waste from ships would be profitable only for the municipal waste collector, which can take advantage of its economies of scale.

Sorting waste fractions in a stand-alone operation is not feasible owing to the additional investments required and the small volumes of waste. Recycling or incineration of ship-generated waste is viable only if the volumes increase or when the treatment can be combined with domestic waste.

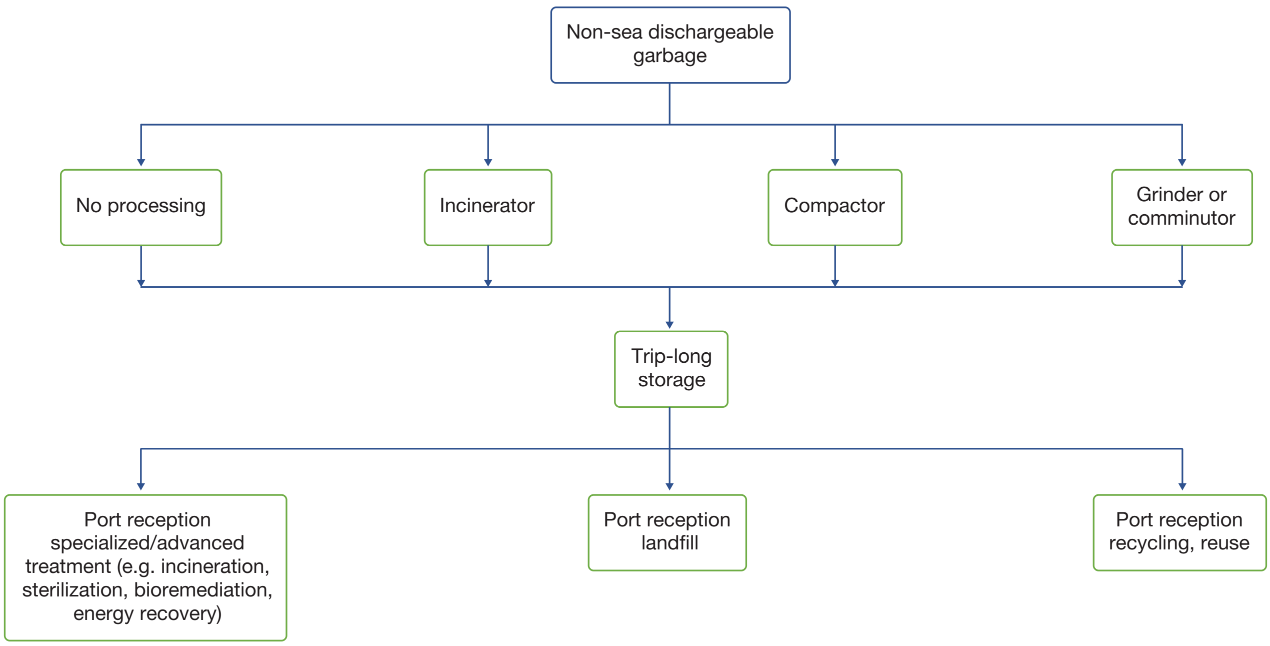
Flow chart 1 below gives an overview of the decision-making process for a ship seeking to ensure compliance with MARPOL and/or regional legislation in the handling of its garbage.



Flow chart 1: *Overview of options for onboard handling of ship-generated garbage (Source: Adapted from IMO, 2017, 10)*

Note: Sea-dischargeable waste is waste that may be discharged into the sea under the relevant MARPOL provisions.

The options for non-sea dischargeable waste are shown in Flow chart 2.



Flow chart 2: *Options for the handling of non-sea dischargeable garbage (Source: Adapted from IMO, 2017, 10)*

3.6 Small island developing States

In March 2012, IMO adopted amendments to MARPOL Annexes I, II, IV and V regarding regional arrangements for PRFs (resolution MEPC.216(63)). In accordance with these amendments, small island developing States may satisfy the requirements applicable to reception facilities through regional arrangements when, because of those States' unique circumstances, such arrangements are the only practical means to satisfy these requirements.

Parties participating in a regional arrangement are required to develop a Regional Reception Facilities Plan, taking into account the guidelines developed by IMO.

PRFs depend for their business on visiting ships using their services. If a port is located on a small island, the number of ships calling at that port will be relatively small. On the other hand, the investment required to collect and treat the volumes of waste from ships will be relatively high, especially if such services are to be provided without undue delay.

Most small island developing States do not have properly equipped landfills. To prevent further contamination of the soil and groundwater, it is better for ship-generated waste to be delivered at another more suitable port.

If no appropriate treatment facility is available on a small island, the PRF operator must dispatch the waste to an overseas facility, creating additional transport costs. Cooperation between small islands can therefore reduce the cost of collection and treatment of waste. Under such arrangements, waste collection is offered at a limited number of ports, and ships are informed of this beforehand.

Pacific islands are often not adequately equipped to deal with waste from foreign fishing vessels. If supply vessels are supporting them in these areas, the best approach is for the fishing vessels to transfer their waste to the former during transhipments. Supply ships generally have large holding bins for waste, and they can also be equipped with compactors to compress the waste (for stowing and shipment back to home ports) or incinerators that are compliant with MARPOL requirements.

3.7 Conclusion

A PRF will only decide to invest in the collection, separation and preparation of plastic waste for recycling if the required installations are readily available and if the operation is profitable. If not, a financial incentive should be created by the authorities to offset the cost difference between recycling and landfilling. Recycling can be made more financially attractive by increasing the taxes levied on the dumping or incineration of plastic waste, or by subsidizing the recycling sector.

The following table clearly illustrates the price difference between recycling and incineration.

Table 6: *Net costs of recycling and incineration in €/tonne of plastic and CO_2 emissions from recycling and incineration in tonnes of CO_2 per tonne of plastic (Source: UNEP, 2020, 9)*

	Recycling	Recycling	Incineration	Incineration
	Cost (€)	CO_2 emissions	Cost (€)	CO_2 emissions
Collection and transport	408	0.02	60	0.01
Net treatment	262	0.85	6	2.6
Opportunity energy production*	90	0.78	0	0
Opportunity plastic recycling*	0	0	495	0.20
TOTAL	760	1.66	561	2.82

* The opportunity cost is the cost associated with loss of other alternatives when one alternative is chosen.

As may be seen, incineration is cheaper than recycling by €199 per tonne of plastic. Landfilling is even cheaper. In the interests of achieving a circular economy, the competent authority needs to compensate for the price difference through taxation or other measures.

Table 7: *Opportunities and barriers regarding incineration (Source: UNEP, 2020, 9)*

Opportunities	Barriers
– Incineration can be applied to a waste mixture that cannot be recycled mechanically or chemically. – Does not require selective collection for waste (compared to recycling), which reduces the costs. – Typically, 70% to 80% of the energy from waste incineration can be recovered to produce hot water (steam). If there is interest in electricity only, energy recovery is 20% to 25%. In the case of co-generation, energy recovery totals 50% to 60% of the original energy released by waste combustion.	– Incineration is often viewed as an unsustainable solution which is not fully aligned with the transformation principles of the circular economy. – Some microplastics (typically 1.9 to 565 particles per kg of ash formed) are found in the ashes resulting from the process. These ashes represent 10% to 25% of the input mass (and need to be landfilled). – Noxious gases may be released during incineration.

Several EU ports provide their PRFs with financial compensation for the collection of plastic waste from ships free of charge in order to incentivize delivery to reception facilities and prevent illegal discharges into the sea. Other ports have launched environmental schemes that cover regular waste disposal (for example, the Clean Shipping Index, the Green Award and the Blue Angel scheme). Ships meeting certain criteria are entitled to discounts on port dues and/or waste fees. Most of these schemes were introduced by the port authorities to address potential environmental problems, to fulfil their social responsibility and to increase sustainability in general.

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5 Annexes

Annex 1	Toolkit on reception facilities for plastic waste from ships
Annex 2	Handling of plastic waste
Annex 3	A policy pathway to reduce or retrieve abandoned, lost or otherwise discarded fishing gear

Annex 1 Toolkit on reception facilities for plastic waste from ships

All States parties to the MARPOL Convention are required to ensure the provision of adequate reception facilities for the ships regularly calling at their ports. The toolkit in this appendix focuses exclusively on plastic waste.

During voyages, ships generate domestic and operational waste the amount of which is in proportion to both the number of crew and passengers on board and the length of the voyage. This waste contains all kinds of plastics, including empty bottles of mineral water, plastic packaging and other products.

Ships transporting packed goods can generate, after unloading, a certain amount of shrink wrap. In addition to plastic packaging waste, ships also generate empty plastic bottles, drums and single-use plastics. Fishing vessels generate waste fishing gear, which contains different types of plastic.

Since the discharging of plastic waste into the sea is prohibited, it should be disposed of at a port reception facility (PRF). The recycling of plastics at such facilities can contribute significantly to the reduction of carbon dioxide.

In addition to plastics, a PRF accepts other waste types, including food waste, glass, metals, paper and cardboard, and cooking oil. Depending on the waste management infrastructure in the relevant country or region, the PRF has several options for dealing with plastic waste.

To improve the sustainability of PRFs in small ports in particular, all ships calling at a port should contribute to the provision of reception facilities by paying a waste fee, irrespective of whether they actually use these facilities.

The focus in the following scenarios is on plastic recycling. If the different types of plastic are segregated on board a ship, the collection arrangements should be adapted so as to avoid the need for the plastics to be sorted a second time in the storage area of the PRF.

Scenario 1: The country/region where the PRF is located offers several recycling options for plastic

A. *Recycling of plastic by reusing the plastic or by recycling the separate plastic fractions*

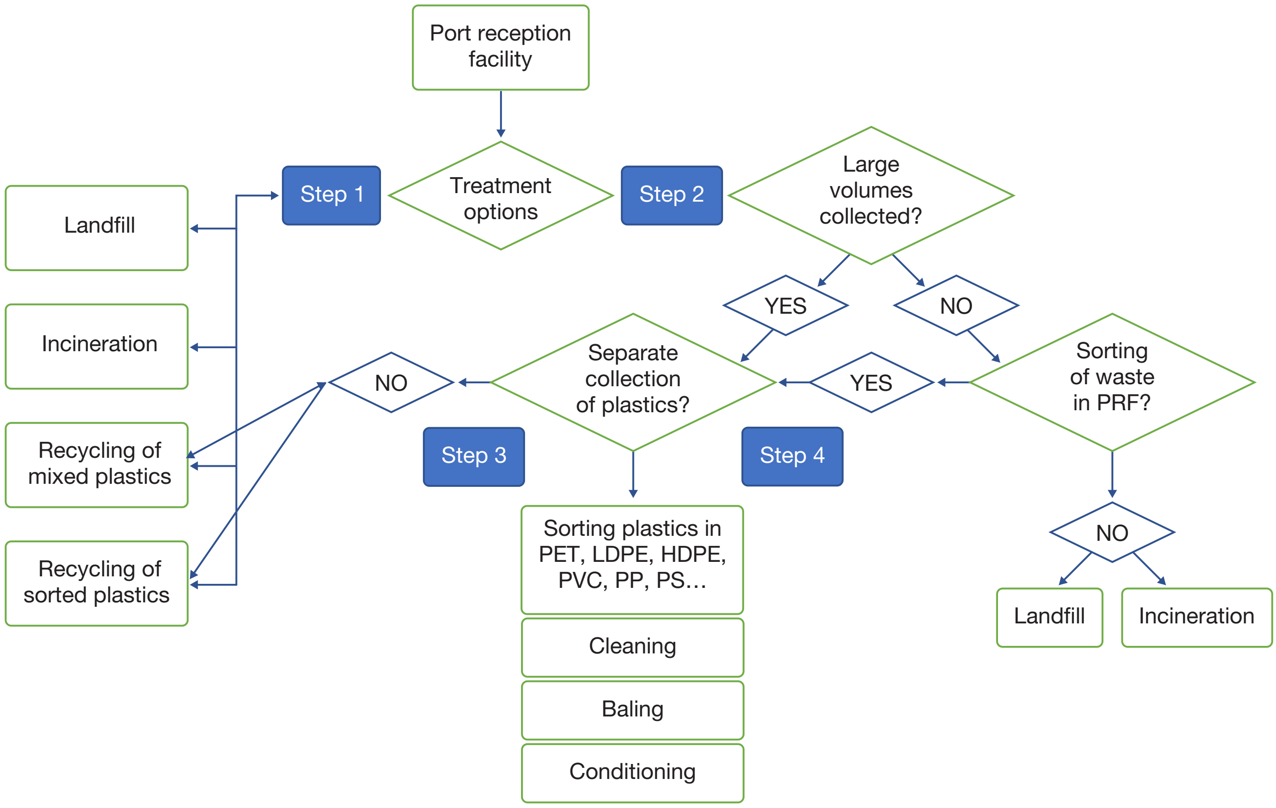
The PRF operator can decide, taking into account the volumes that it collects, whether to take the separated plastics – mainly polyethylene terephthalate (PET), polypropylene, low-density polyethylene (LDPE) and high-density polyethylene (HDPE) – to a recycling company.

If the port is visited by modern cruise ships, the PRF will probably receive the waste fractions separated, baled and/or palletized. Modern cruise ships sailing in the Caribbean and the Mediterranean are equipped with compactors, balers, shredders and incinerators. Owing to the volumes involved and their well-trained crews, these cruise ships are able to manage the waste optimally. If the bales contain a single type of plastic, there is no need for further treatment and the waste can be transported directly to the plastic recycler. If not, the bales will be sent to an intermediate storage area for further sorting (if required).

If the port is visited by merchant ships, the different types of plastic are normally mixed but kept separate from other waste types. In such a case, the PRF may need to additionally invest in:

- manual or mechanical sorting of plastics into various recyclable fractions, such as PET, polypropylene, LDPE, HDPE and polyvinyl chloride; and
- a baler (equipment to press the sorted plastic in the required format before it is brought to the plastic recycler; the resulting bales have specific dimensions that can be checked with the recycler).

After sorting, washing and baling, the PRF can transport the plastics to the recycler. Depending on the market conditions, the PRF may receive additional revenue for the waste.



Flow chart 3: *Schematic representation of the recycling of plastic into new plastic products*

B. *In the country/region there are only facilities for the conversion of petrol-based plastics into fuel oil or paraffin oil*

Several techniques can be used to convert plastics into a base oil or paraffin oil. Most of them are suitable for the treatment of mixed plastics, and they can even be used on plastics contaminated with organic material (such as food residues or biofouling). In general, the plastics are shredded and converted, via pyrolysis, into oil, a small volume of gas that can be used for heat generation, and small quantities of solid residues. The oily residues can be used as fuel or as paraffin oil to produce new plastics. Paraffin oil attracts a higher price ($500 to $700 per tonne than fuel oil ($100 to $200 per tonne), but production of the former is more complex and requires higher-purity waste. The specific requirements of the plastic recycler should be discussed before starting the whole process of sorting and cleaning.

Depending on the technology used, plastic recycling can be carried out profitably with a throughput ranging from 1,000 kg to several tonnes per day.

In this scenario the PRF can transport the mixed plastics that it has collected directly to the recycler. The PRF should use a type of waste bin that allows separate collection of different waste types as defined in MARPOL Annex V (if the price of oil is high, the PRF can get a high price for the plastic granulates).

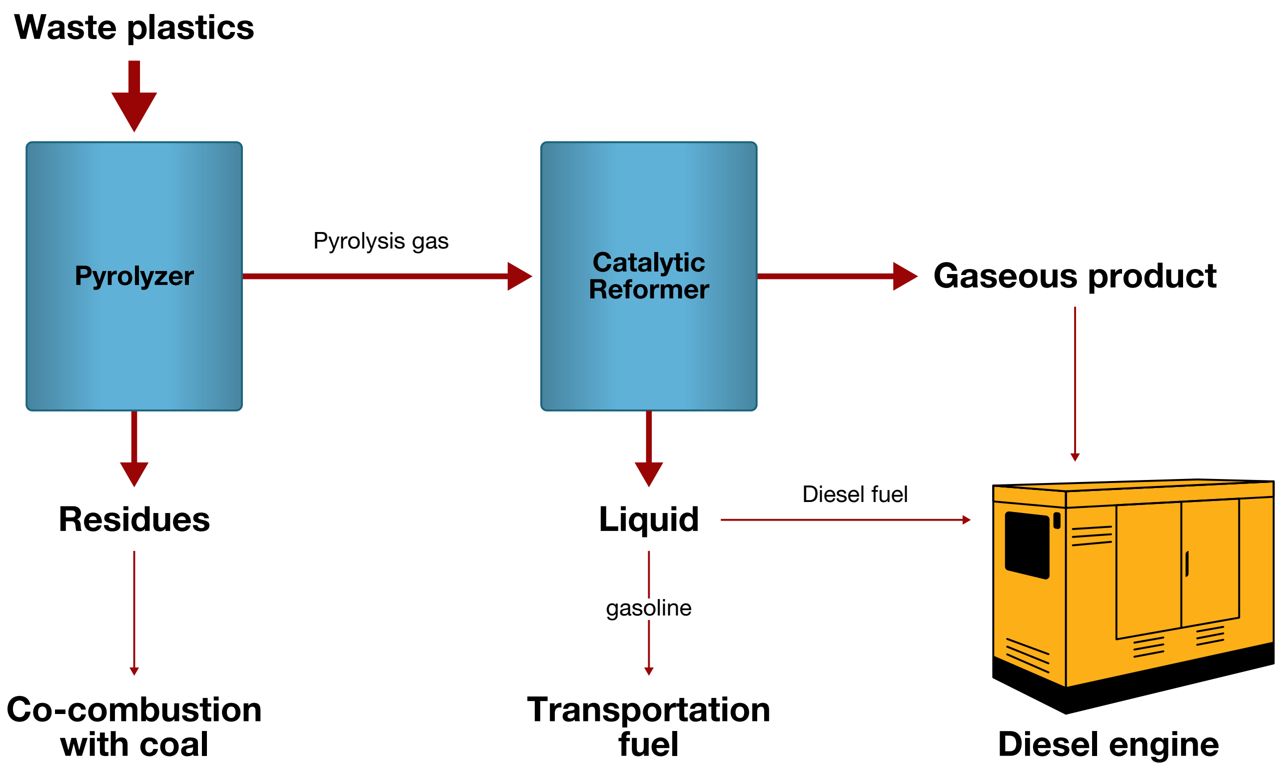


Figure 15: *Schematic diagram of a system for the conversion of waste plastics into fuels (Source: Syamsiro et al., 2014, 45)*

C. ***In the country/region there are only facilities for the incineration of waste, including plastics, with energy recovery (production of heat and electricity)***

If plastic waste can be incinerated together with other waste fractions, then probably all garbage will be brought to the incineration facility. A large container for mixed waste can be used to collect the ships' garbage in this case.

Scenario 2: The country/region where the PRF is located has no plastic recycling facilities

The PRF has the following options:

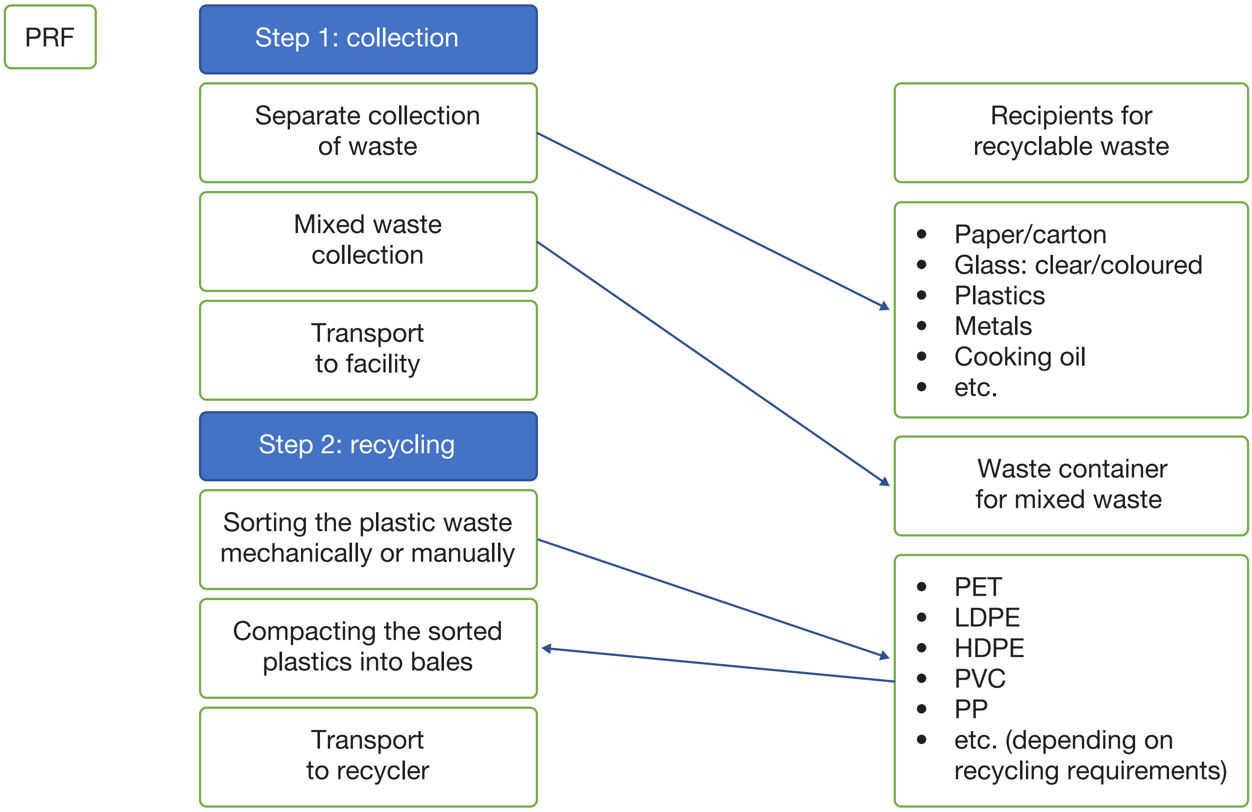
- incineration of waste (including plastics) with or without energy recovery;
- landfilling; and
- reaching an agreement with other ports on the vessel's route that are able to accept the plastic waste (for recycling or because they have better treatment facilities).

The last of these options is especially relevant for remote small island developing States, where landfills generally do not meet international standards. In such cases it is better for ships to keep their plastic waste on board. To reduce the volume of waste before reaching the next port of call, a small compactor or incinerator could be installed on board.

Figure 16: *Waste incinerator in the port of Antwerp, Belgium (Photo credit: Indaver, Belgium)*

Note: The heat obtained from the burning of waste is used mainly to generate electricity; the remaining heat is transported by pipeline for the heating of houses in the surrounding area.

Annex 2 Handling of plastic waste



Flow chart 4: *Decisions in plastic waste collection*

STEP 1: Treatment options

A port reception facility (PRF) will need to base its waste management strategy on the availability of existing treatment facilities and the potential revenue from recyclables. If plastic waste recycling facilities are available, the PRF will normally obtain revenue for the recycled plastics, depending on the cleanliness of the waste and the quantities. Since the recycling of plastics can be complicated, the PRF and the recycling company should work together closely. This may require additional investment by the PRF operator.

The treatment possibilities for plastic are:

- landfilling;
- waste incineration with or without energy recovery;
- conversion of mixed plastics into oil; and
- recycling of sorted plastics to produce similar plastics again.

STEP 2: Volumes collected?

Are the volumes of plastic waste collected sufficient to justify additional investment in workers or equipment?

No. If the volume of garbage from the ships visiting the port is small and the number of port calls is limited, the only viable solution may be incineration with or without energy recovery. If no incineration facility is available, plastics can be dumped in a landfill, or the port could reach an agreement with other ports on the ships' routes that are willing to accept plastic waste. In that case the plastic waste can stay on board, if there is sufficient storage capacity, and be disposed of in another port.

Yes. If the combined volumes of plastic waste generated by the ships and by land-based activities in the port are high, mixed plastic may be incinerated (co-incineration of waste, where plastic replaces virgin fuel oil) or recycled.

Ships separate waste into different fractions in line with the requirements laid down in MARPOL Annex V. That means that, in general, plastics are a separate stream. Depending on personnel costs and/or the cost of recipients, the plastic waste can be collected separately from the other wastes. For example, a large container with separate holes into which the different wastes are dropped may be used, or a number of bins can be set up on the quayside, or the waste can be collected separately in a barge or truck by personnel from the waste contractor.

It is also possible to collect all waste together and to sort it later at the storage place of the waste contractor. The sorting can be manual or mechanical.

STEP 3: Mixed plastic or mono streams

The plastic volumes can be recycled by means of conversion into oil.

The PRF brings the mixed plastic to the plastic recycler. Normally, the plastic needs to be baled to facilitate transport and handling of the plastic waste in the factory.

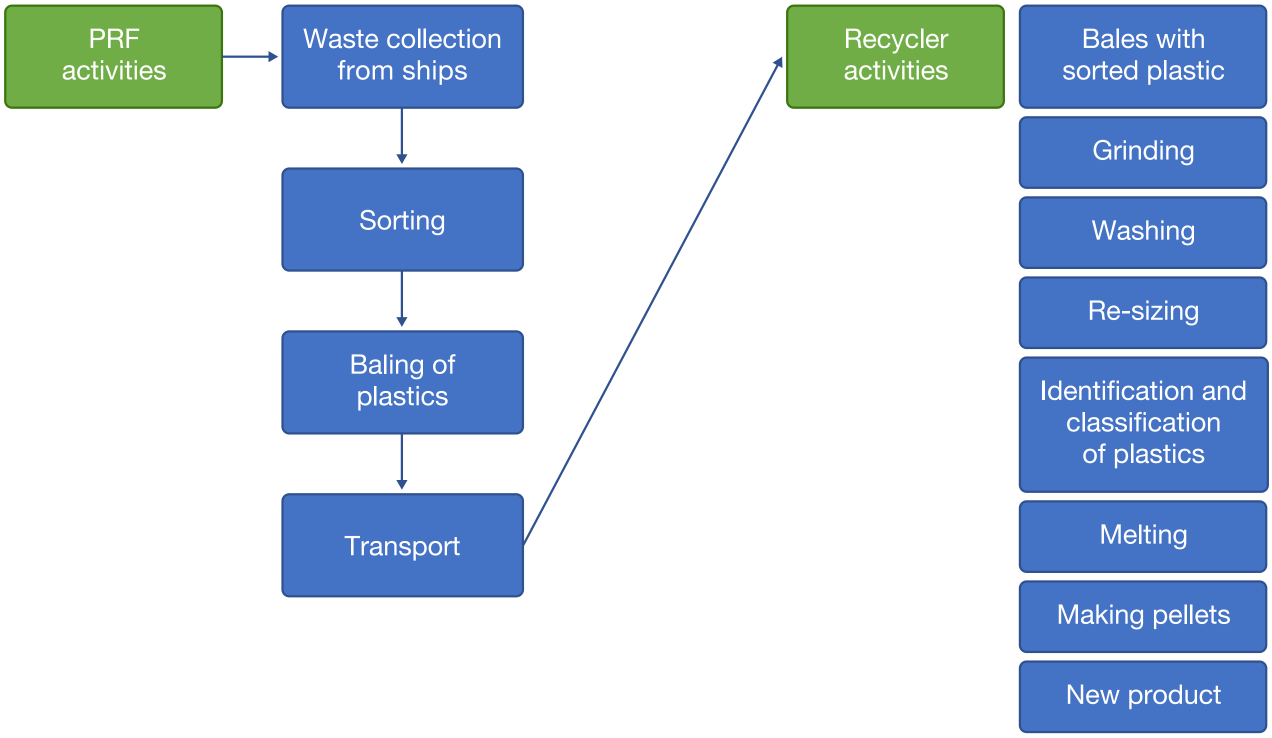
For conversion into paraffin oil, the mixed plastic waste needs to contain a good balance of different fractions of plastics, since the recycling of mono-material streams is difficult. The mixing of the different plastics will normally be done at the recycling factory.

STEP 4: Large volumes of mono streams of waste plastic

The plastic is recycled according to the plastic type (polyethylene terephthalate (PET), polypropylene, etc.). This recycling step is the most complex, since it requires mono-material streams of plastics.

The requirements for bringing plastic waste to a recycling plant are more demanding than under the previous steps. In particular, the plastic needs to be free of pollutants. After washing, the plastic waste is shredded into smaller pieces and baled. The bales are subsequently transported to the recycling unit.

Flow chart 5 gives an overview of the impact of the decisions regarding the recipients to be used for the collection of waste and the recycling of plastics. Normally, waste on board a ship is separated into paper and cardboard, glass, plastics, metals, cooking oils, and so on. The PRF needs to sort the plastics in the storage area into recyclable fractions (polypropylene, PET, polyvinyl chloride, etc.), clean the plastics (if required), bale them in formats that are acceptable to recycling companies and transport the bales to the recycler(s).



Flow chart 5: *Steps at a port reception facility that is willing to recycle plastics if financially interesting and viable*

Annex 3 A policy pathway to reduce or retrieve abandoned, lost or otherwise discarded fishing gear

Prevention

- Gear design to reduce whole or partial loss of fishing gear and its components.
- Redesigning fishing vessels and other approaches to reduce gear loss.

Mitigation

- Gear design to reduce the incidence and duration of ghost fishing.

Remediation

- Create and strengthen requirements and incentives for fishers to retrieve gear that they lose, if safe to do so, and to carry appropriate tools and equipment on their vessel for the retrieval of lost gear. Fishing gear could be produced with surface markers or other devices that indicate its position, nature and extent.
- Develop identifiers that allow relevant authorities to identify the party ultimately responsible for the deployment of the fishing gear.
- Support programmes and recycling initiatives such as Fishing for Litter to facilitate the collection and proper disposal of abandoned, lost or otherwise discarded fishing gear (ALDFG) encountered during active fishing and end-of-life fishing gear.
- Support the retrieval of gillnets lost at sea.
- Support the retrieval of lost traps and pots by participating fishers.
- Develop ALDFG reporting systems and registries appropriate for local fisheries to document the extent and locations of lost fishing gear, and to inform prevention and remediation activities.
- Members of regional fisheries management organizations should promote binding measures for ALDFG reporting and retrieval.
- The legal framework for extended producer responsibility (EPR) should be expanded to include all products containing plastic that are placed on the market.
- Ensure that EPR schemes cover the full costs of collection, transport, sorting and recycling of plastic litter.
- Introduce regulations that incentivize closed loops for different plastic waste streams.
- Most Pacific Island ports visited by foreign fishing vessels are not adequately equipped to deal with their waste. A better option would be for the supply ships of these fishing vessels to take over their waste during transhipments.

Recycling

- Gear buy-back schemes, together with offers of discounts on new gear, can foster the refurbishment or recycling of old gear.
- Deposit scheme: some gear components, such as plastic pots and buoys, could attract an end-of-life refund when returned to the manufacturer.
- Increase opportunities for recycling fishing gear.

Fishing ports

- Introduce a waste fee based on solidarity among the fishing community.
- Promote sustainable fishing through initiatives whereby fishers are obliged to report and/or try to retrieve lost fishing gear.
- Introduce expanded EPR schemes where possible.

GloLitter
partnerships

This Guidance Document is part of the GloLitter Partnerships Knowledge Products Series. The GloLitter Partnerships project is implemented by the International Maritime Organization (IMO) and the Food and Agriculture Organization of the United Nations (FAO). GloLitter assists developing countries in reducing marine plastic litter from the maritime transport and fisheries sectors.

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