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Targeting the challenge of plastic pollution in ports and maritime companies in the Philippines

Screening of examples of solutions to tackle plastic waste in ports and maritime companies

Deloitte Norway
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Contents

Disclaimer

This report has been produced by Deloitte Norway for the project '*Clean Ports, Clean Oceans: Improving Port Waste Management in the Philippines*', funded by the Grieg Foundation and implemented by WWF-Norway, WWF-Philippines in partnership with the Grieg Group. The findings and recommendations of this report are those of Deloitte Norway, and do not represent Grieg Foundation's, WWF Norway's, WWF-Philippines's, nor Grieg Group's position with respect to the solutions and their implementation.

Executive summary

The objective of the report is to identify and screen solutions and initiatives aimed at tackling plastic pollution and implemented by ports and maritime companies. The report will contribute to the project '*Clean Ports, Clean Oceans: Improving Port Waste Management in the Philippines*' funded by the Grieg Foundation and implemented by WWF in partnership with the Grieg Group, that aims to reduce plastic waste leakage in three ports in the Philippines: the port of Batangas, the port of Cagayan de Oro and Manila North Harbor. In particular, the report will provide inputs to roundtable discussions to be held at the end of 2021 in the three aforementioned ports, with the purpose of defining an action plan to reduce plastic waste leakage.

The content of the report is gathered primarily through interviews with ports and maritime actors, as well as desktop research. The 17 solutions presented in this report are evaluated based on two selection criteria:

- the level of impact (environmentally, socially and/or economically) and
- the potential for scalability.

The solutions are divided into five categories: closing the tap; closing the loop; stopping plastic leakage; clean-up; and training, awareness, research and development. The solutions with limited information are presented as snapshots, while solutions with more information gathered through interviews are presented as case studies.

From the 17 solutions in the report, 9 recommendations are presented in the final section. These are categorized based on their implementation time:

- Short term solutions are defined as solutions that are feasible within a year. These solutions include:
  - buyback programs where public authorities purchase marine litter voluntarily brought by fishermen, and floating receptacles for marine litter, installed in and around ports;
  - engagement of local community in clean-up programs;
  - installations and devices that help collect waste; and
  - education and awareness programs.

- Medium term solutions are defined as solutions that are feasible within three years. These solutions include:
  - development of waste bins that match the requirements of the International Convention for the Prevention of Pollution from Ships (MARPOL);
  - incentive systems for the disposal of plastic waste for ships in ports; and
  - the collection of data and the development of reporting systems.

- Long term solutions are defined as solutions that are feasible within five years. These solutions include:
  - the ban of single-use plastic items in ports and onboard ships;
  - the development of a partnership between public and private entities to use empty shipping containers to transport recyclable waste from ports, without sufficient space and resources to process waste, to ports with eligible recycling facilities.

Solutions listed as recommendations meet the selection criteria and are considered most relevant taking into account the current situation in the Philippines. The recommendations can be implemented as individual measures or be combined to complement each other and create synergies for greater impact.

Findings

A significant finding of the report is the high number of measures and initiatives implemented by ports and maritime companies to handle the growing challenges of marine plastic litter. However, there is both limited data available and few platforms for knowledge sharing. These are considered to be two of the main contributing factors as to why successful solutions are rarely widely adopted. Another challenge is that solutions that have been effective in one location are not necessarily effective elsewhere, due to local differences.

It is apparent that closing the tap is the most effective way of combating marine plastic litter on a global scale, as it reduces or potentially eliminates new inflow of plastic. The potential effect of successfully closing the tap is evident in that single-use plastics and plastic from land-based sources are the major contributing sources of plastic in the ocean. To effectively combat the problem one must consider the entire plastic value chain, as the level of ocean plastic is dependent on how the waste is handled in the

society as a whole. However, as the focus of this report has been on ports and maritime companies, the recommendations consider measures feasible for implementation by these actors.

Maritime companies engage in closing the tap by reducing their consumption onboard vessels, as well as training and awareness for their crew. Ports, on the other hand, are leaning more toward stopping plastic leakage and focus on clean-up measures in the port basin and surrounding area. The difference in approach between ports and maritime companies is natural, considering differences in how they experience and are affected by the issue of plastic pollution. Thus, they will have different ways of most efficiently contributing to reducing their own pollution and responsible waste management respectively.

Due to the limited availability of data on the three Philippine ports and pending the upcoming baseline studies, conclusive recommendations suitable for the respective ports are challenging to decide on. Hence, future studies on this topic is recommended to focus on concrete measures to be taken to tackle plastic pollution in the port of Batangas, the port of Cagayan de Oro, and Manila North Harbor.

List of abbreviations

Abbreviation	Definition
3R	Reduce-Reuse-Recycle
BBP	Buffalo Bayou Partnership
BPP	Blue Port Project
CAPEX	capital expenditure
CNCo	The China Navigation Company
COBSEA	Coordinating Body on the Seas of East Asia
COVID-19	Coronavirus disease 2019 (SARS-CoV-2)
EJF	Environmental Justice Foundation
EPR	extended producer responsibility
EU	European Union
EUR	Euros
GISIS	Global Integrated Shipping Information System
IMO	International Maritime Organization
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
KFPA	Korea Fisheries Infrastructure Promotion Association
KOEM	Korea Marine Environment Management Corporation
LCA	life-cycle assessment
MARPOL	International Convention for the Prevention of Pollution from Ships
MLTM	Ministry of Land, Transport and Maritime Affairs
MRF	materials recovery facility
NEDA	National Economic and Development Authority
NFS	Net Free Seas
OPEX	operating expenditure
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
PET	polyethylene terephthalate
PIC	prior informed consent
PICT	Pacific Island Countries and Territories
PO	polyolefin
PP	polypropylene
PPA	Philippine Ports Authority
PTO	permit to operate

Abbreviation	Definition
R&D	research and development
RCCL	Royal Caribbean Cruise Line
SDS-SEA	The Sustainable Development Strategy for Seas of East Asia
SPREP	Secretariat of the Pacific Regional Environment Programme
SRF	shore reception facility
SUP	single-use plastics
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
USD	United States Dollars
WWF	World Wide Fund for Nature
YES	Youth Employment Services

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Part 1 – Introduction and background

Project introduction

In October 2020, WWF-Norway launched the project '*Clean Ports, Clean Oceans: Improving Port Waste Management in the Philippines'*, funded by the Grieg Foundation, to address the problem of plastic pollution in Philippine ports. The project is conducted and implemented by WWF-Norway and WWF-Philippines, in partnership with the Grieg Group, carried out across three ports: Cagayan de Oro, Batangas, and Manila North Harbor.

The project seeks to:

- help achieve 50% reduction of plastic waste leakage in nature in the three aforementioned Philippine ports,
- provide input to the Philippine National Plan of Action on Marine Litter to highlight the importance of the port industry in addressing plastic pollution, and
- document port waste management models to enable scaling up to other ports in the Philippines and globally.

The project will run over three years. In the first period, the project aims to develop a strategic plan based on the baseline studies that will be developed for the three ports. This plan is an essential element of the project because it will define the strategy for reducing plastic waste leakage in the three ports, and it will be implemented in the second part of the project.

Objective of the report and methodology

As part of development of the strategic plan, Deloitte has been engaged to prepare this report with the aim of assessing and providing recommended solutions that can best achieve the outlined project objectives above. This report presents existing solutions developed by ports and actors in the maritime sector to reduce plastic pollution. The selected solutions showcase measures for targeting plastic waste across different stages of its life cycle, as well as how they are initiated. The report will consider solutions which can be utilized by ports or maritime companies.

The report also discusses the current situation in the Philippines as well as relevant maritime regulations, in order to provide contextual background for the solution designs and the regulatory environment they must comply with. The description of the current situation in the Philippines is based on data and information from the ongoing baseline studies, as of July 2021.

The solutions are selected based on two main criteria:

- the level of impact (environmentally, socially and/or economically) and
- the potential for scalability.

In addition, the report will identify critical success factors for selected solutions and discuss the potential for implementation of these. The solutions presented are categorized as listed below. The terminology aligns with WWF's No Plastic in Nature initiative framework [1], with the addition of two further categories:

- Closing the tap: reduction of plastic waste generation.
- Closing the loop: segregation, redesign, reuse, recycle, and measures to lengthen the use of plastic items in the operations.
- Stopping plastic leakage: collection, disposal of plastic waste, and measures to avoid plastic waste from ending up in nature.
- Clean-up: capture and clean-up of the environment.
- Training, awareness, and research and development (R&D): increase awareness about the threat from plastic pollution, change consumer behaviors, and R&D.

Final recommendations are presented in the last section of the report. These results are intended to provide input for the discussions during the forthcoming roundtable discussions in the three ports in the Philippines.

1.1 Plastic pollution – A major threat for marine wildlife and the environment

Plastic pollution is one of the fastest growing global environmental problems. It threatens species and ecosystems and is especially harmful to marine life. Nearly a thousand marine species are known to have been negatively affected by entanglement and/or ingestion of plastics [2] [3].In addition, plastic degrades into microplastic particles which have been shown to alter soil conditions, contribute to coral degradation, and impact the health of marine life [4] [5]. Plastic pollution also has public health and development impacts, and vulnerable communities are disproportionately affected by environmental degradation caused by plastic pollution from production to waste [6] [7]. Plastic pollution also threatens various economic activities, such as commercial fisheries and aquaculture [8].

Between 2000 and 2015, humans produced more plastic than in all preceding history [9], with a significant amount ending up in the oceans as marine litter. In 2015, it was estimated that only 9% of the plastic generated had been recycled, 12% incinerated, and 79% had ended up in landfills or in nature [10]. Every year, 300 million tons of plastic is produced, of which half is single-use plastic products [11]. Estimates show that the current total yearly amount of plastic waste that ends up in the ocean is over 11 million tons and that this annual flow of plastic could nearly triple by 2040 [11] [12].

Several strategies are in place for solving this issue. Short-term measures, such as clean-ups, are important to help mitigate the problems caused by plastic pollution and maintain the esthetic value of tourist destinations. “Closing the tap” which means reducing the total generation of new plastic waste, and “closing the loop” on plastic to achieve a circular economy are seen as the best strategies to stop plastic pollution and reduce greenhouse gas emissions linked to the production and incineration of plastic waste.

Plastic waste enters the marine environment through land-based and sea-based activities. It is generally understood that the majority of plastic waste entering the oceans comes from land-based sources. In 2010 alone an estimate of 275 million metric tonnes was generated by 192 coastal nations [13]. It is estimated that 80% of marine plastic litter comes from land-based activities and 20% comes from sea-based activities. But while research has been working to estimate global inputs of plastic waste into the oceans from land, there is less data regarding the inputs of marine litter from sea-based sources [14].

The Philippines is one of the world’s largest contributors of plastic pollution in the oceans, with a generation of 0.28-0.75 million metric tons of plastic marine debris every year [15]. Single-use and throwaway packaging for products are often highlighted as the cause of the dramatic increase of plastic waste. These often end up in unmanaged landfills and, ultimately, in the ocean after weather storms or floods. A recent WWF study revealed that about 2.15 million tons of plastics are consumed by Filipinos in a year, from which 9% are recycled and 35% leaks into open environment [16].

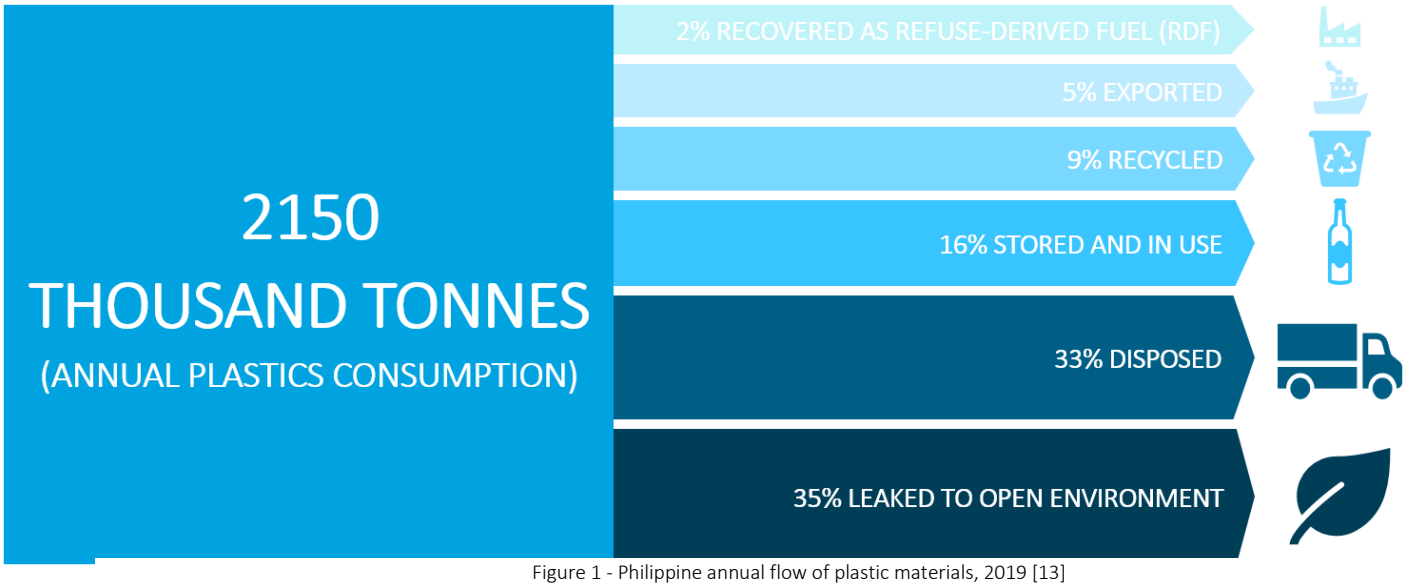

Figure 1 - Philippine annual flow of plastic materials, 2019 [13]

1.2 Laws and regulations

There are various laws and regulations that address different aspects of plastic pollution. The implementation and enforcement of these laws and regulations are a central component to reducing pollution [17] [18]. This section will give a brief overview of relevant international and national laws and regulations that apply in the Philippines and to ports and maritime companies.

Table 1 - Overview of laws and regulations

Category	Laws and regulations	Philippines became a party in	Applicable for…	Implementing or/and enforcing actor
International Laws & Regulations	UNCLOS	1984	The contracting parties of the convention	The 168 contracting States Parties to the Convention
	MARPOL 73/78 Annex V	2001	Ships registered in any of the parties to MARPOL Annex V	The 150 contracting State parties to the Convention
	London Convention and Protocol	1973 for the Convention 2012 for the Protocol	Ships with waste loaded in the territory of a contracting party, and ships registered in the territory of a contracting party	The 87 contracting State parties to the Convention and Protocol
	Basel Convention	1993	The contracting parties of the convention	The 188 contracting State parties to the Convention
Philippine Laws & Regulations	Ecological Solid Waste Management Act of 2000 (RA 9003)		Stakeholders involved in land-based waste management in the Philippines	National government agencies, and local government units
	Toxic Substances and Hazardous and Nuclear Wastes Control Act (RA 6969)		All entities that have activities related to the importation, manufacture, processing, handling, storage, transportation, sale, distribution, use and disposal of substances and hazardous and nuclear wastes covered by the act.	National government agencies
	Single-Use Plastic Products Regulation Bill (pending in the Senate)		All businesses, enterprises, and governmental entities in the Philippines	The Department of Environment and Natural Resources in coordination with the National Solid Waste Management Commission
	Interim guidelines on the issuance of permit to operate for Shore Reception Facilities in the Philippines		Service providers for shore reception facilities/waste disposal for government and private ports within the jurisdiction of the Philippine Port Authority	The Philippine Port Authority

Relevant plan of action and planned initiatives	IMO Action Plan to address marine plastic litter from ships		All ships	IMO Secretariat and State parties
	COBSEA Regional Action Plan on Marine Litter		The countries of the Coordinating Body on the Seas of East Asia	The State parties
	National Plan of Action for the Prevention, Reduction, and Management of Marine Litter		All relevant players in the Philippine solid waste management system	Varies per target
	ASEAN Regional Action Plan for Combating Marine Debris in the ASEAN Member States		ASEAN Member States.	ASEAN Member States

1.2.1 International laws and regulations

United Nations Convention on the Law of the Sea (UNCLOS)

The United Nations Convention on the Law of the Sea (UNCLOS) deals with the protection and preservation of the marine environment. According to this convention, all States Parties must adopt or establish laws and regulations to prevent, reduce, and control pollution of the marine environment from land-based sources and sea-based sources. The laws and regulations that must be adopted or established are on a national scale, as well regional or global.

UNCLOS covers most matters related to the management and use of the ocean. However, it does not go in detail about how pollution at sea should be prevented. The enforcement of the convention is assigned to the contracting State parties to the convention [19].

International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) Annex V

The Annex V of MARPOL aims to prevent and minimize garbage pollution from ships. Today more than 150 countries have ratified MARPOL Annex V, including the Philippines. All ships registered in these countries must comply with the convention. The MARPOL Annex V prohibits the discharge of all plastics into the sea. Additionally, there are guidelines and requirements that all vessels and port reception facilities must follow. These are related to garbage handling in the port as well as implementing a garbage management plan on ships to specify procedures and ensure efficient handling and storage of garbage. Regulation 7 of MARPOL Annex V says that each party needs to build “adequate waste reception facilities” at ports and terminals.

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) and its 1996 Protocol (the London Protocol)

The London Convention aims to prevent marine pollution from dumping of waste and other matter into the ocean. In 1996 a new Protocol to the London Convention was adopted to reduce dumping of waste. The protocol further prohibits the dumping and incineration of waste at sea, including plastic, and establishes a so-called “reverse list” that prohibits dumping of all waste except those specifically listed, provided that the responsible party has obtained a permit to do so. The Philippines has ratified the London Convention. The regulations in the London Convention and Protocol apply to all ships with waste loaded in the territory of a contracting party, and to all ships registered in the territory of a contracting party.

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention)

The Basel Convention is a multilateral environmental agreement between 189 participating parties, including nation states and the European Union [20]. The Philippines is one of these countries. The convention establishes rules for the transboundary movement of hazardous and other wastes, and for their disposal. Based on the concept of the prior informed consent (PIC), the convention requires that, before an export may take place, the authorities of the state of export must notify the authorities of the prospective

States of import and transit, providing them with information on the intended movement. The movement may only proceed if all States concerned have given their written consent. The convention imposes the duty to ensure safe disposal of the waste. At the fourteenth meeting of the Conference of the Parties in 2019, the parties of the Convention approved an amendment that makes plastic waste subject to the Convention's PIC procedures. The waste covered by this Convention is waste moved across borders, while waste derived from the ships' normal operations are excluded from the scope of the Convention.

1.2.2 Philippine laws and regulations

Republic Act 9003 or the Ecological Solid Waste Management Act of 2000

The Ecological Solid Waste Management Act of 2000 regulates all land-based waste management in the Philippines. This is done through source reduction and waste minimization measures, before collection, treatment, and disposal in appropriate solid waste management facilities. Key objectives of the act are to ensure segregation, collection, transport, storage, treatment, and disposal of solid waste. This is done through the formulation and adoption of the best environmental practice in ecological waste management, excluding incineration.

This law provides guidelines on how land-based waste are to be managed, as detailed in a 10-year Solid Waste Management plan that local government units are mandated to provide. The ports, which are within the cities and municipalities, should work with the local government to implement plans and programs that are mandated by this law.

Republic Act 6969 - Toxic Substances and Hazardous and Nuclear Wastes Control Act

The Toxic Substances and Hazardous and Nuclear Wastes Control Act covers the importation, manufacture, processing, handling, storage, transportation, sale, distribution, use, and disposal of all unregulated chemical substances and mixtures in the Philippines, including entry, transit, as well as storage and disposal of hazardous and nuclear wastes into the country for any purpose. This act implements the Basel Convention in the national legislation.

Single-Use Plastic Products Regulation Bill

On the 28th of July 2021, the House of Representatives in the Philippines agreed upon the document titled as the "Single-Use Plastic Products Regulation Bill". This Bill is currently pending in the Senate. It aims to reduce the consumption and increase recovery for recycling and treatment, or proper disposal of single-use plastic products in the Philippines. Selected plastic products will be phased out over a one-year period, while others will be phased out over a four-year period.

Table 2 - Overview of single-use plastic products that will be phased out after the adoption of the Single-Use Plastic Products Regulation Bill

Phase out over a period of (1) year	Phase out over a period of four (4) years
• Drinking straws • Stirrers • Sticks for candy, balloon, and cotton bud • Buntings • Confetti • Packaging or bags of less than 10 microns in thickness	• Plates and saucers • Cups, bowls, and lids • Cutlery like spoons, forks, knives, and chopsticks • Food and beverage containers made of expanded polystyrene • Oxo-degradable plastics • Film wrap, packaging, or bags of less than 50 microns in thickness • Sachets and pouches that are multilayered with other materials

In addition to phasing out single-use plastic, the bill has provisions on the extended producer responsibility (EPR) approach. The EPR approach instills accountability on producers for the full life cycle effect of their plastic products in the market. All producers and importers of single-use plastic items shall recover or divert into their value chains at least 50% of their single-use plastic item, within three years after the act goes into effect [21].

Interim guidelines on the issuance of permit to operate for Shore Reception Facilities in the Philippines

The Philippine Ports Authority (PPA), the national government agency in-charge of overseeing operations in Philippine ports, has developed interim guidelines on the issuance of permit to operate for "Shore Reception Facilities (SRF) /Waste Disposal Service

Provider" [22]. This complies with MARPOL. These guidelines apply to both governmental and privately owned ports. Having an adequate SRF in each port is essential for the waste management in the port. The SRF is important to ensure that the waste is collected and do not pile up and affect port operations.

1.2.3 Relevant plans of action

International Maritime Organization (IMO) Action Plan to address marine plastic litter from ships

The International Maritime Organization (IMO) has developed an action plan to address marine plastic litter from ships. The plan aims at identifying opportunities to enhance the existing policy and legal frameworks while introducing additional supporting measures for addressing the issue of marine plastic litter from ships. IMO's Marine Environment Protection Committee agreed on actions to be completed by 2025, which relate to all ships, including fishing vessels. The action plan includes mechanisms to identify specific outcomes, and actions to achieve these outcomes in ways that are measurable.

Coordinating Body on the Seas of East Asia (COBSEA) Regional Action Plan on Marine Litter

The countries (Cambodia, People's Republic of China, Indonesia, Republic of Korea, Malaysia, Philippines, Thailand, Singapore and Viet Nam) of the Coordinating Body on the Seas of East Asia (COBSEA) have developed a Regional Action Plan on Marine Litter to tackle challenges related to marine litter in the East Asian Seas. The action plan includes:

- preventing and reducing marine litter from land-based sources,
- preventing and reducing marine litter from sea-based sources,
- monitoring and assessment of marine litter,
- activities supporting the implementation of the COBSEA Regional Action Plan on Marine Litter.

Association of Southeast Asian Nations (ASEAN) Regional Action Plan for Combating Marine Debris in the ASEAN Member States (2021-2025)

The ASEAN member States have adopted a Regional Action Plan that proposed the phased implementation of a systematic and integrated response to guide regional actions in addressing the issue of marine plastic pollution in ASEAN for the period 2021-2025. The Regional Action Plan includes four components: i) policy support and planning; ii) research, innovation and capacity building, iii) public awareness, education and outreach; and iv) private sector engagement.

Philippine National Plan of Action for the Prevention, Reduction, and Management of Marine Litter

The overarching goal of the Philippine National Plan of Action is "*Zero waste to Philippine waters by 2040".* General consumption and production falls under the Philippine Action Plan for Sustainable Consumption and Production developed by the National Economic and Development Authority's (NEDA), while land-based waste management is implemented through the Ecological Solid Waste Management Act of 2001. Meanwhile, maritime-based policies on litter are anchored on international agreements (i.e. MARPOL). The National Plan of Action for the Prevention, Reduction, and Management of Marine Litter seeks to bridge the gap between the two spheres, land and sea, as well as expand possible actions to be taken by introducing other elements such as research and development, and multi-stakeholder implementation. The National Plan of Action includes several strategies and actions, one of which focuses on "Reducing maritime sources of marine litter". This strategy includes reviewing existing maritime, fisheries, aquaculture, and biodiversity conservation policies with a marine litter lens. It also includes cooperation and information sharing between agencies, harmonization of policies, and the presence of systems to ensure ship waste management, transport, recovery, processing, and disposal.

1.3 Current situation and initiatives in the Philippines

The existing situation and initiatives in the three Philippine ports are currently being mapped in the baseline studies conducted by WWF. As a result, there is limited information available on the issue.

The following section will elaborate on the three Philippine ports in question and associated waste streams based on data currently available from the ongoing baseline studies, as of July 2021.

1.3.1 Brief overview of ports

This section will provide a brief overview of the ports and the available information of their current situation. These overviews will include the ports' location, type of port, any ongoing projects or implemented systems, and if any communities are residing within the ports.

The ports mentioned in this section are managed by the Philippine Ports Authority (PPA). There are also other national public stakeholders that have responsibilities in the ports, such as the Maritime Industry Authority (MARINA), responsible for integrating the development, promotion and regulation of the maritime industry in the Philippines; the Philippine Coast Guard (PCG), responsible for performing maritime search and rescue, maritime law enforcement, maritime safety, marine environmental protection and maritime security; and the Bureau of Customs.

Figure 2 Map of the Philippines including the three relevant ports

The Port of Batangas is a port located in Barangay Santa Clara, Batangas City in the Calabarzon region of the Philippines. The port has both passenger and cargo terminals. The port was developed to ease out traffic in the Manila Ports.

The port has ongoing projects with the Partnerships in Environmental Management for the Seas of East Asia (PEMSEA). PEMSEA works with implementing the Sustainable Development Strategy for Seas of East Asia (SDS-SEA) and studies the waste collection fee system in the Philippines. This port has received the Green Port Award for its previous efforts within environmental strategies [23]. The Green Port Award System is a green evaluation system for ports in the Asia-Pacific Economic Cooperation (APEC) region [24]. All the collected waste from the port are directly brought to the Sanitary Landfill located in San Jose Sico in Batangas City.

The Port of Cagayan de Oro is the busiest government port in Northern Mindanao measured in cargo throughput. Out of the three ports selected for the project, it has the largest passenger terminal building which during peak season can accommodate approximately 3000 passengers.

The port has also received the Green Ports Award. They work with adjacent communities in reducing and properly managing their solid waste through eco-bricking, a method for packing plastic bottles combined with used plastic into reusable building blocks.

According to information given in the stakeholder interviews by the SRF providers at this port, recyclable plastics are diverted at the materials recovery facility leaving the low-quality plastics, such as plastic bags, in the landfill.

Manila North Harbor is the port of the capital City of Manila and the main port in the Philippines. Of the three ports in this study, this is the only one which has a community residing within port premises. The baseline study is yet to confirm the level of waste generation for this community.

Similar to the other ports, Manila North Harbor is located within a highly urbanized city. The City of Manila implements the Anti-Littering Law, which prohibits littering, illegal dumping, illegal garbage disposal, piling up of garbage outside buildings, and spilling, scattering, and littering of waste by public utility vehicles [25].

Waste collected by the SRF service providers show that approximately 50% of solid waste collected in vessels prior to COVID-19 are plastics, including PET bottles, cup noodles, and biscuit wrappers. This estimate came from 300-400 cubic meters of solid waste collected from the Manila North Harbor as indicated in the stakeholder interviews.

1.3.2 Current situation of waste streams covered in the ongoing baseline studies

Different waste streams related to the Philippine ports are analyzed in the ongoing baseline studies. The content of this section is based on the preliminary findings of these studies. Through stakeholder interviews and the initial data collection, some insights were gathered on the vessel- and port- generated waste. The details of the community-generated waste are also covered in the ongoing baseline studies.

Vessel-generated waste

During the stakeholder interviews it was mentioned that when ships dock at ports, an accredited SRF service provider ensures waste is collected from the ships. The waste generally enters the city waste management system after it is collected at the port, prior to disposal in sanitary landfills. Thus, if sorting and recycling are practiced, this happens outside of port premises.

Through stakeholder interviews, it has been discovered that in Manila North Harbor and the Port of Batangas, waste from vessels is brought directly to sanitary landfills for disposal. On the other hand, in the Port of Cagayan de Oro, waste is sent through the central materials recycling facility before being brought to Sanitary landfills. In the materials recycling facility, recyclables that are of value are sorted out to be sold in junkshops or used for other purposes.

The most common types of plastic waste collected from the vessels are polypropylene (PP) food containers and polyethylene terephthalate (PET) bottles, both high value plastics. In the WWF study from 2020 on EPR scheme assessment for plastic packaging waste in the Philippines, it was found that the Philippines have a low recycling rate for high-value plastics and that these plastic types often end up in landfills or even in nature [16].

Port-generated waste

Data is still being gathered on the waste management practices for port-generated waste. However, the PPA has required all Port Management Offices to practice 3Rs – reduce, reuse, and recycle – in their respective offices [26].

Stakeholder interviews also indicate that waste from port offices are usually segregated and brought into a collection area. Each port has contracted a service provider to haul their waste, which, like vessel waste, enters the city waste management system. Ports with a materials recycling facility within their premises (e.g. Cagayan de Oro) also facilitate partnerships with junkshops to sell recyclables, such as cardboard, PET bottles, and aluminum cans.

Community-generated waste

Communities located within the premises of a port coordinate with the city government for waste collection. According to RA 9003, they are mandated to have a materials recycling facility where they conduct sorting, recycling, composting, and other waste diversion mechanisms. Due to the lack of space and funding, having a materials recycling facility is often difficult for these communities. Barangay 20, the community within Manila North Harbor, has at least four junkshops within its community without having a materials recycling facility. Residents in this community segregate their waste at home and sell recyclables into these junkshops.

1.3.3 General aspects highlighted by the entities interviewed

Through the interviews and research conducted, the following general elements have been highlighted. While there is no information regarding the application of these aspects to the situation in the three ports of the project in the Philippines, they need to be taken into consideration to better understand the situation.

- While port statements indicate that the waste disposals from vessels are not commonly segregated, maritime companies state that they follow MARPOL guidelines for onboard sorting of waste. These statements may be conflicting, as compliance with MARPOL would result in the waste being segregated. This is an interesting discovery and might be partially due to a lack of monitoring and standardizations of waste categories. Several maritime companies mention that it is a priority to reduce waste onboard, while others prefer to concentrate their efforts towards improving waste management. They often highlight that the recycling capacity at the destination is an important element to them. [23]
- An issue uncovered through the interviews is that the waste segregation onboard the vessels does not match the ports' recycling systems. This could be a major issue contributing to more of the waste being sent directly to landfills, even though it has been separated according to MARPOL regulations onboard.
- Ports operate at the intersection of two spheres: land and sea. This unique position represents a challenge for ports to address the issue of plastic pollution, especially to determine the origin of pollution, the responsible entities, and the relevant measure to adopt.

1.4 General overview of stakeholders' respective interest related to plastic pollution in ports

There are different stakeholders involved in or affected by port operations. The table below shows common stakeholders in ports, and their respective mission or interest. Their role regarding the plastic waste problem is displayed from both sides: reasons or incentives to take responsibility, and what is keeping them from doing so.

Table 3 - Stakeholder overview

Stakeholder in ports	Mission or interest	Incentives to handle plastic waste adequately	Reasons not to or obstacles in the way of handling plastic waste adequately
Government	Meeting targets of reducing plastic pollution	Responsibility towards citizens and businesses	Too costly, lack of space and other infrastructural requirements
Ports	Port operations	Comply with regulations, facilitate operations, contribute to corporate social responsibility	Insufficient infrastructure, lack of space, too costly
Maritime companies	Running a profitable business	Comply with regulations, economic incentive of possibly reduced port fees, contribute to corporate social responsibility	Too costly, consumers' demand
Waste management operators	Collection, recycling and disposal of waste	Efficiency, compliance.	Insufficient recycling facilities and regulations, mixed waste
Local communities	Live in or near the ports	Income from selling plastic waste, preserve nearby nature	Lack of incentives for segregating and recycling, insufficient infrastructure, lack of resources, convenience
NGOs (WWF, etc.)	Collaborate with relevant stakeholders to create sustainable ports, ocean clean up, taking care of wildlife and ecosystems	Environmental, social, human rights goals and advocacy	Insufficient funding, stakeholder participation
Commercial actors and certification organizations targeting sustainability challenges in ports or marine environment	Create profit through sustainable goals	Part of their operations	Regulations, investment requirement from target stakeholders

Part 2 – Categorization and analysis

2.1 Selection criteria for solutions and definitions

The included selection of solutions and measures are based on given selection criteria with respect to *environmental impact, social impact, economic impact, scalability, implementation time and efforts*, and *cost*.

The main criteria for the presented solutions are that they should exhibit potential for high environmental impact and high scalability. Some high environmental impact solutions are low in scalability but are still included due to their high social or economic impact.

2.1.1 Definitions of selection criteria

Impact and scalability

- Environmental impact is defined as the positive impact in terms of lessening (preventing) plastic pollution relative to the situation prior to (without) implementation of the solution.
- Social impact is defined as the positive impact on communities, in terms of increased living conditions, education, employment or wealth of the local community within or around the port, relative to the situation prior to implementation of the solution.
- Economic impact is defined as the positive impact in terms of economic value creation or commercial potential for the involved stakeholders.
- Scalability is the potential for expanding the solution when the right resources are provided and demand increases.

Implementation and operation

- Implementation time and efforts is a presentation of what resources and time were needed for the implementation of the solution. This measure is not necessarily transferable to the local situation in other ports, where infrastructure, political, technological, and economic conditions are likely to be different.
- Cost is the solution's implementation cost (capital expenditure (CAPEX)) and operational costs (operating expenditure (OPEX)). Numbers are provided wherever data is available. Elsewhere, estimation and reasoning are performed.
- Responsible party is the stakeholder that is involved in the implementation and/or operation of the solution.

The parameters for impacts and scalability are assessed on a low-medium-high scale with Deloitte's explanation presented below.

2.1.2 Explanation of categorization and presentation method

The solutions are predominantly categorized following WWF's framework and theory of change for the No Plastic In Nature Initiative [1], with the addition of two categories. The categories are *closing the tap, closing the loop, stopping plastic leakage, clean-up,* and *training, awareness, and research and development (R&D).* The solutions are presented in one of two ways: as either *snapshots* or *case studies*, depending on the quality and quantity of information discovered. Following is an explanation of the categories and the presentation methods for the solutions.

Categories

- Closing the tap: reduction of plastic waste generation.
- Closing the loop: segregation, redesign, reuse, recycle, and measures to lengthen the use of plastic items in the operations.
- Stopping plastic leakage: collection, disposal of plastic waste, and measures to avoid plastic waste from ending up in nature.
- Clean-up: capture and clean-up of the environment.
- Training, awareness and R&D: increase awareness about the threat from plastic pollution, change consumer behaviors, and R&D.

Figure 3 - Solution categories

Snapshots

Snapshots are based on written reports, documents, online articles, email-correspondences with representatives, or interviews where only limited information was provided. However, the information was considered adequate for assessing the solutions on the aforementioned parameters, and each snapshot is schematically assessed according to these.

Case studies

Case studies are based on interviews with representatives for the solution, where sufficient information from primary sources for an in-depth description were available. The cases typically present a project or initiative, by explaining the background for the problem, the methods used for handling it, and the results after implementation. The critical success factors are also addressed.

2.2 Overview of solutions

The table presents an overview of the selected solutions presented in this report.

Table 4 - Overview of solutions

Categorization	Solution	Environmental impact	Social impact	Economic impact	Scalability	Assessment type
Closing the tap	Banning and restricting single-use plastics	High	Low	Low	High	Snapshot
Closing the loop	Port of Brisbane: Target Zero Strategy; zero waste to landfill – recycle instead	High	Low	Low	Low	Snapshot
	Buyback programs for used fishing gear and litter	Medium	High	High	High	Snapshot
	Potential solution using pyrolysis to create oil products	Medium	Low	Low	Medium	Snapshot
	Port Esbjerg: Development of waste bins matching MARPOL	High	Low	Low	High	Case study
	Environmental Justice Foundation: Net Free Seas Project	High	High	High	High	Case study
Stopping plastic leakage	Systems for screening and evaluation of ports by maritime companies	High	Low	Low	High	Snapshot
	South Korea: Dedicated floating receptacles for marine litter	Medium	Low	Medium	High	Snapshot
	The Moana Taka Partnership (public-private partnership)	High	Low	Low	High	Case study
	Incentive system for the delivery of plastic waste for sea-going vessels in Port of Rotterdam and Amsterdam	High	Low	Low	High	Case study
Clean-up	Port of Houston: Clean-up initiatives	High	Low	Low	High	Snapshot
	Blue Port Project	High	High	Low	High	Case study
	Water Witch: Versi-Cat skimmer	High	Low	Low	High	Case study
	Port of Rotterdam waste management practices: Shoreliner pilot	High	Low	Low	High	Case study
Training, awareness, and R&D	Solomon Ports: 3R (Reduce-Reuse-Recycle) Campaign	High	High	Low	High	Snapshot
	Data collection system for ports	High	Low	High	High	Snapshot
	Training and raising awareness of employees in ports and aboard maritime vessels	High	High	Low	High	Snapshot

2.3 Snapshots and cases

2.3.1 Closing the tap

Closing the tap refers to solutions that aim to reduce the generation of plastic waste, such as banning single-use plastic items or using reusable water bottles instead of PET bottles.

Banning and restriction of single-use plastics

The banning and restriction of single-use plastic products is a measure which have gained much traction among companies, countries, and organizations in recent years. Single-use plastic products are more likely to end up in the sea than reusable alternatives, and alongside fishing gear, they represent the majority of all marine litter in the European Union (EU) [27]. In 2019, EU addressed this issue through a directive on single-use plastic, Directive (EU) 2019/904, directed towards 10 specific plastic items, and focusing on limiting other single-use plastic products [27].

> *"The 10 most commonly found single-use plastic items on European beaches, alongside fishing gear, represent 70% of all marine litter in the EU"* [27].

According to a 2018 review performed by the United Nations Environment Programme (UNEP), 27 countries in "all regions of the world" have "enacted legislation banning either specific products (e.g. plates, cups, straws, packaging), materials (e.g. polystyrene) or production levels." [28]. Small island States are more likely than larger States to have national bans, with 10 out of the 27 countries belonging to this group. The countries within Asia and the Pacific that have imposed national bans and restrictions on single-use plastic products are China, Marshall Islands, Pakistan, Republic of Korea, Sri Lanka, Tuvalu and Vanuatu [28]. Since the review in 2018, the number of nations that have banned single-use plastic products has increased including the Philippines [21] [29].

A measure banning or limiting the use of single-use plastic items can be adjusted to different situations for different types of actors. It is scalable in the sense that it can be implemented in everything from a small business to large corporations.

National ban on single-use plastic items onboard vessels in India

Through the Order No.5 of 2019, India has taken the measure of banning certain single-use plastic items in the maritime sector. [30]. According to the Order, certain single-use plastic items are prohibited to be used on board Indian ships and foreign ships when such ships are at port or place in India. Foreign flagged ships that operate in Indian waters are required to keep all their single-use plastic items locked in a storage during their stay in both territorial waters and in ports. To ensure compliance, Indian ports require a log entry that identifies the single-use plastic items available onboard, as well as when and where the items were stored [29] In addition, the order mentions that single-use plastic items cannot be discharged to port reception facility in ports in India.

Kuwait is another country which has joined India in banning single-use plastic items onboard all ships. The Kuwait Ministry of Communications issued Circular No. 08/2019 on 28th of November 2019, which also prohibits incoming vessels to discharge single-use plastic items at Kuwait ports [31] [32].

Swire's measures against single-use plastics

Swire, a British conglomerate also including a shipping division (Swire Shipping), has taken several measures against plastic pollution, including a ban of 0.5L single-use plastic bottles. The company installed several water tanks with drinkable water and gave every cruise member a reusable water bottle. Swire representatives stated that crew members were skeptical to the portable water at first, because they thought it was not safe to drink. With the right training they adapted, and this measure led to a 95% reduction of PET bottles in two years. The company also ensures that all catering providers deliver food without single-used plastic packaging [33].

Royal Caribbean Cruise Lines

Royal Caribbean Cruise Lines (RCCL) carries out a three-phase program to reduce single-use plastic onboard their vessels [34]. It consists of the following:

Phase one

- Elimination of single-use plastic items for passengers' and crew's drinks and beverages, i.e. straws, stirrers, and picks. From 2018, these items were only offered upon request.

- From 2019, introduction of paper straws, Forrest Stewardship Council-certified wood coffee stirrers, and bamboo garnish picks as sustainable alternatives.

Phase two

- Elimination of plastic items such as condiment packets, cups, and bags. However, information on preferred alternatives is limited.
- The program was supposed to be advancing to the next phase by 2020, but due to COVID-19 the progress has been halted, and they are still in the second phase.

Phase three

- The third phase concerns elimination of larger items, such as plastic bottles, larger food containers, etc. Alternatives are not definitely decided upon, but RCCL representatives mentioned aluminum bottles and refill water stations as alternatives.

Table 5 - Assessment of Banning and restricting single-use plastics

Impact and scalability	Implementation and operation
Environmental: High • A ban or restriction on single- use plastics has the potential to reduce the amount of harm caused to the marine environment from plastic pollution.	**Implementation time and effort** • It varies depending on the current situation, desired scale, and availability of resources. • Monitoring compliance requires efforts and resources.
Social: Low • The solution does not contribute to engage or involve local communities.	**Cost** • The cost will depend on the availability of sustainable alternatives.
Economic: Low • For now, there is limited commercial potential for the parties complying with it.	**Responsible party** • Entity that adapts the solution.
Scalability: High • The measure could always span larger, e.g., include another type of plastic, include a bigger part of a company, range across industries, etc.	

2.3.2 Closing the loop

Closing the loop refers to solutions for lengthening the use of plastic items in operations. Segregation, redesign, reuse, and recycling are all measures that belong in this category.

Port of Brisbane: Target Zero Strategy; zero waste to landfill – recycle instead

Target Zero Strategy is a sustainability program which aims to reduce the overall carbon footprint of the port. It was implemented in 2017 and has set a zero waste to landfill target by 2030. The strategy was developed in-house, where the port sets up a staff Committee to develop internal champions to drive the strategy.

The solution consists of segregation bins for different waste streams as well as a waste management hub with soft plastic recycling capability. Moreover, the port is also participating in the Containers for Change initiative [35]. This is a state-wide container refund scheme, which provides the general population with an incentive to collect and return aluminum, glass, steel, and paperboard beverage containers for recycling in exchange for a small refund payment. The government initiative offers depots, bag drops, vending machines, and pop ups as returning alternatives for recyclable containers [36]. The Port of Brisbane has collected 10 011 containers from July 2020 to June 2021, where 5 914 were plastic based. The port has also had a roll-out of the Containers for Change program to other businesses across the port. Education and awareness campaigns for port workers contributing to behavioral change is also central to the Target Zero Strategy, and will become increasingly more important in the coming years [37].

The solution requires relatively low up-front and operational costs, as they are limited to internal education programs and procurement of minor items, such as new bins. Port of Brisbane representatives state that the main critical success factors are suitable infrastructure and access to sufficient funding to deliver the desired outcomes [38].

Table 6 - Assessment of Port of Brisbane: Target Zero Strategy; zero waste to landfill - recycle instead

Impact and scalability	Implementation and operation
Environmental: High • Through proper handling and recycling, waste is diverted away from landfills and from potentially ending up in the sea.	**Implementation time and effort** • Implementation time can be chosen individually, based on the current situation and desired scale.

	• Implementation time can be high as this is a complex strategy, that needs organization. • Necessary infrastructure and sufficient funding are vital for succeeding.
Social: Low • It does not contribute to engage or involve local communities. • It contributed to roll-out the containers for change program to other businesses.	Cost • Relatively low up-front and operational costs, as they are limited to internal education programs and procurement of minor items, such as new bins etc.
Economic: Low • As of now, the solution has limited commercial potential.	Responsible party • Port.
Scalability: Low • Not very scalable, besides the possibility to adapt the solution in other ports.	

Buyback programs for used fishing gear or litter

The Republic of Korea (South Korea) South Korea implemented a buyback program for marine litter and fishing gear to reduce the amount of debris in the ocean [39]. It was established by the Korean central government's Ministry of Land, Transport and Maritime Affairs (MLTM) and was operating between 2003 and 2013 [40].

The program was directed towards fishermen returning to port. Previously, fishermen that encountered ghost gear normally only disentangled it from their own gear and threw it back into the ocean. This practice harmed marine wildlife and threatened safety of vessels and fishing operations. By encouraging fishermen to collect and return encountered ghost gear in exchange for a small monetary reward, the program aimed to target this practice [41]. The collected gear was sent to incineration to produce energy [40].

Organization-wise, the program was a collaboration between MLTM, local municipalities, the fisheries cooperative union, Korea Marine Environment Management Corporation (KOEM) and Korea Fisheries Infrastructure Promotion Association (KFPA). Local municipalities applied for the program, MLTM evaluated and potentially accepted the application, allocated funds, and developed a project guide. KOEM and KFPA helped with the practical waste disposal, such as distributing sacks and funding the fisheries cooperative union [39].

The program had several benefits; not only was it cost-effective and an efficient way to collect marine litter, but it also strengthened awareness among fishermen and provided them with an extra income [39]. Between 2009 and 2012 the total amount of ghost gear purchased by the government was 30 959 tonnes, amounting to a total investment of $20 million USD [41].

Other incentive schemes

Similar incentive schemes have also been applied elsewhere in the world.

Norway has developed a profitable system, the Nofir project, for collecting and recycling discarded fishing and fish-farming gear and has expanded to cover six European countries. Moreover, the Healthy Seas Initiative, an industry NGO consortium in Europe, collects fishing nets in the North, Mediterranean, and Adriatic Seas. The nets are converted into polymer yarn, which is suitable for production of clothing and carpets. [40]

Table 7 - Assessment of Buyback programs for used fishing gear and litter

Impact and scalability	Implementation and operation
Environmental: Medium • Reduction of abandoned fishing nets in the ocean improves conditions for marine wildlife and nature. • Carbon emissions due to incinerating of the collected gear.	Implementation time and effort • Requires government funding. • The system needs to be designed by the involved stakeholders.
Social: High • The program contributes to increased income for fishermen. • Increased awareness among the threats of plastic pollution and marine debris.	Cost • Paying the fee to the fishing collectors is small in comparison to the government collecting the debris directly.
Economic: High • Increased income for fishermen could increase the wealth of fishing communities to some degree.	Responsible party • Governments and local municipalities.
Scalability: High • When the program organization and funding are established, it would be easy to include more fishermen in the country.	

Potential solution using pyrolysis to create oil products

After collecting the plastic, the remaining challenge is to let it successfully re-enter the value chain to achieve circularity.

One of the techniques used for plastic waste is pyrolysis. Pyrolysis is the thermal decomposition of waste materials at temperatures beginning around 200°C without the addition of air or oxygen, resulting in solid and/or liquid residues as well as a gaseous mixture [42] .

Pyrolysis is a technology employed for many years and can be used to create fuels, such as oils and diesels. The outputs resulting from the pyrolysis of plastics could be used to create new polymers however not, with a couple of exceptions, directly. The outputs are char, oil, tars and gas with mixed hydrocarbon molecules containing a range of contaminants, which must be subject to much the same processes and refinement as crude oil requires before it can be developed into polymers.

Pyrolysis can be a solution for plastics that cannot otherwise be recycled, given that the plastic otherwise will be landfilled or burned for energy recovery. Except for the energy value recovered from plastic waste, the conversion of plastic to fossil fuels also maintains the linear economic framework that consists of extracting, producing, and then disposing (combusting). To achieve circularity and reduce emissions, pyrolysis of plastic waste should aim to turn the recovered fuels into new plastics.

Commercialization of chemical recycling

Quantafuel and Rudra Environmental Solutions are two private companies which apply pyrolysis. They convert plastic waste into new oil-based products that can replace those from virgin oil.

Rudra, an Indian company established in 2009, produces poly-fuels such as synthetic oil, gas and carbon. The produced fuel is suitable for kerosene stoves, boilers, furnaces etc. The char may be used as an additive for road filling with bitumen [30]. According to their website, typical plant capacity can range from 300 kg to 5 tonnes of plastic waste per day [43]. Thus, it can be customized to the local situation of ports or other suppliers of plastic waste.

Quantafuel is a similar company which converts plastic waste into low-carbon synthetic chemical products, which can be used in production of new plastic products and other chemical substances. The company has a plant in Skive in Denmark, which are fed by a continuous supply of plastic waste optimal for chemical recycling.

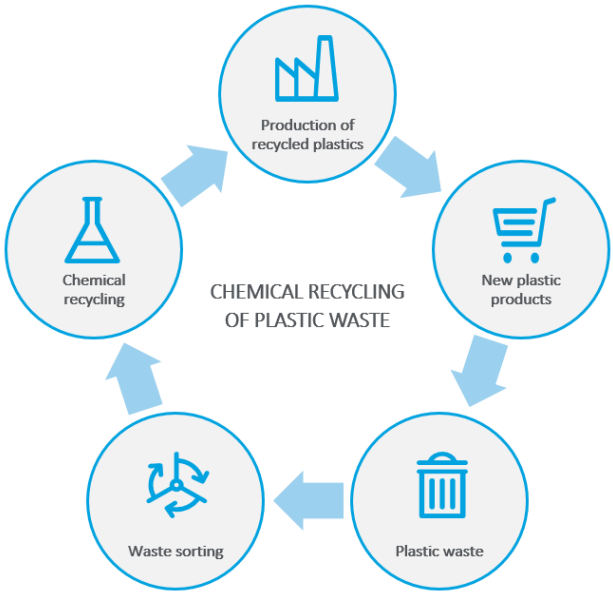

Figure 4 - Chemical recycling process

Table 8 – Assessment of potential solution using pyrolysis to create oil products

Impact and scalability	Implementation and operation
Environmental: Medium • Reduces the production of virgin oil products by including plastic waste. • Emissions may be lower than incineration plants where pyrolysis plants are well managed, but there is a risk of higher pollution where it is not the case. • Pyrolysis requires high energy consumption, often requiring the use of additional source of energy. • This process can potentially result in an increase of emissions of key pollutants, especially when mixed-plastic inputs are used. • There is still uncertainty about the environmental effects.	**Implementation time and effort** • The technology and processing are complex and require sufficient waste infrastructure and skills.
Social: Low • The factories require workers, most of which are high-skilled. • Where plastic is collected as a separate stream for a pyrolysis facility treating only plastics, there may be additional jobs at the separate collection stage. • As it is the case with incineration facilities, key pollutants could result in health impacts to the local community where these plants are operating.	**Cost** • Substantial capital is required for the solutions to operate at larger scales.
Economic: Low • High cost, especially for the processes that are producing chemicals or plastics where various processing steps are likely to be required. • Costs are likely to be higher than those of conventional incineration and will be higher than the cost of landfills. • The solutions commercialize plastic waste, by upgrading it to valuable products which are in demand.	**Responsible party** Private actors are responsible for the technology and cooperate with port authorities as well as local and national governments for waste supply.
Scalability: Medium • Requires a developed and well-functioning sorting and recycling system to allow for a steady flow of inputs. • As volume output is increased by increasing input factors, the solution might become scalable.	

Case study – Port Esbjerg, develop waste bins matching MARPOL

Background

Port Esbjerg is one of Denmark's largest commercial ports, and as part of Nordic Ports for a Sustainable Future they strive to be one of the leading ports in improving maritime sustainability. The port has implemented several measures to become more environmentally friendly. These range from joining the global "Getting to Zero Coalition", to smaller initiatives like engaging local students and youth to collect waste from the beaches and harbor-area. One of these initiatives was a project in collaboration with EGGS Design, aiming at designing a more sustainable waste sorting system.

Method

To improve the sustainability of the waste sorting system, the existing solution was analyzed and staff onboard ships and at the docks were interviewed. The old system occasionally experienced that waste was sorted incorrectly and that waste containers were only sporadically used.

The interviews revealed that this was mainly due to ships and the port not operating with compatible sorting systems. The ships were segregating according to MARPOL, while the port was sorting according to the local waste management regulations. Considering this, port authorities and EGGS Design decided that the focus areas of the new system would be:

- the standardization of sorting systems according to MARPOL;
- distinct and highly visible waste sorting containers; and
- the development of supporting app to facilitate the correct sorting of waste.

This has led to a waste sorting system of where accessibility, awareness, and ease of segregation are essential aspects [44].

Results

The implementation of the new sorting system has strongly improved waste management in Port Esbjerg. According to Port Esbjerg the amount of incorrectly sorted waste has dropped significantly. In addition, the new system is more frequently used due to increased awareness and accessibility [45].

An additional benefit of the new sorting system is that the plastic waste that is sorted is now cleaner, and thus has a higher value as a downstream resource. This could either be sent to recycling facilities and be used for new products. [45].

Case study – Environmental Justice Foundation: Net Free Seas project

Background

The Net Free Seas (NFS) project was initiated in 2020 by the Environmental Justice Foundation (EJF) and is financed by the Norwegian Retailers' Environment Fund and the Rufford Foundation. The project aims to reduce and recycle the vast amount of abandoned, lost or otherwise discarded fishing equipment in the waters of Thailand [46]. It is estimated that 640 000 tonnes of this lost equipment, otherwise known as "*ghost gear"*, enters the ocean every year, threatening and killing animals, fish, and coral reefs [47]. The plastics used in the nets are highly durable and can persist in the ocean for several decades, some even up to 600 years [47].

Method

The NFS project engages fishing communities in Thailand to collect used and abandoned fishing nets for recycling. NFS recycling partners buys the fishing nets from the artisanal fishing communities, who receive a compensation for collecting and washing them. The money is either transferred to a village fund and community conservation projects or given directly to the individuals who perform the collection and cleaning. The local community is consulted when deciding which economic model to follow [46].

Local communities help collect and clean used fishing nests and are paid by buyers.

Used nets are dropped off at collection containers installed in communities, such as local ports.

The used nets are cleaned, shredded and melted into pellets by recycling partners.

The recycled fishing pellets are sent to companies to be used in the production of high-quality consumer goods e.g., water sport equipment, household wares, COVID-19 face shields and carpets

Figure 5 - Net Free Seas supply chain [48]

The collection is conducted in one of two ways depending on the available manpower. One way of collecting is engaging the local communities to gather and deliver their own used fishing nets. The other collection method is based on scuba diver instructors collecting the fishing nets from the seabed. Fishing nets are cleaned with water and dried. Then the clean and dried nets are transported to recycling facilities. [49]. Currently, NFS in Thailand is partnering up with companies that have incorporated a circular approach to their value chain.

NFS works also as a facilitator in setting up the contracts between the partnering companies and the communities and conduct training for the communities to equip them with relevant knowledge. They approach the companies that seem relevant for partnerships and set up the connection with the communities. The partnering company pays directly to the communities, without NFS taking any part in this, since they receive funding from Norwegian Retailer's Environment Fund and the Rufford Foundation. The goal of NFS is to develop a sufficient market and partnerships for the supply chain to be self-sustaining after funding ends in 2023.

Ghost gear [46].

Results

NFS has so far engaged 105 of Thailand's over 3 000 fishing communities. 15 of these have contributed to gathering and delivering over 17 tonnes of discarded fishing nets for recycling [49]. NFS representatives highlighted the untapped potential for engaging more of the fishing communities [49].

The most critical success factor for implementing the program is to find the right recycling partner: a company who is willing to invest in recycling and production. Another very important success factor is to involve communities in decision making of the project implementation. They play a critical role in the supply chain and their inputs must be treated equally as inputs of any other stakeholders. NFS's overarching goal is that communities and producers can collaborate without them as organizers ensuring the enhanced sustainability of the program. In addition, the demand for the products made from recycled materials was regarded as the most important factor for upscaling the program and the supply chain [49].

2.3.3 Stopping plastic leakage

Stopping plastic leakage is about preventing plastic waste to end up in nature. Solutions focusing on adequate collection and disposal of plastic waste belong in this category.

Systems for screening and evaluation of ports by maritime companies

Several maritime companies have implemented systems for evaluating ports and their sustainability performance, and only landing their waste at certified ports which fulfill certain requirements. As cruise lines do not have waste facilities aboard their vessels, they are dependent on partnering up with ports that are responsible and transparent in their waste handling.

Royal Caribbean Cruise Line
Royal Caribbean Cruise Line (RCCL) have developed a Green Hub certification which is only given to ports that handle their waste, including plastic waste, adequately. Through agreements engaged directly with entities in each port, the company can decide where to dispose of the waste on land and have control of the entire cycle. In North America, all ports RCCL utilizes are certified Green Ports. Still, relevant regulations are not universal, and will depend on the region they operate in. This poses a challenge for RCCL in ensuring that their waste is handled in the most environmentally friendly manner possible. In Asia, they experience less transparency with respect to the landed waste's life cycle after it is delivered [34].

Grieg Star
Grieg Star, a shipping company, has made the decision to land their plastic waste based on countries' levels of mismanaged plastic waste [50] [51]. By applying data from Jambeck et al. (2015) [15], a traffic light system approach has been developed. For green nations, the Grieg vessels can deliver plastic waste, for yellow they should avoid if possible, and for red nations, they are not allowed to deliver their waste.

One could see that these types of systems would incentivize ports to strengthen their sustainability efforts to increase traffic. Yet, RCCL does not share the certification criteria due to competition considerations. Some insight in the selection process could be gained from the IMO's Global Integrated Shipping Information System (GISIS), a repository offering information about reception facilities in all ports in the world. However, RCCL representatives stated that this is not a system which they apply, as they have developed their own system [34]. Moreover, it is unknown to what extent other cruise companies do.

Wilhelmsen
Wilhelmsen is a global maritime group that provides products and services to the merchant fleet, along with supplying crew and technical management to vessels [52]. In 2020, Wilhelmsen developed a system designed to map how hundreds of ports globally handle and recycle waste, including plastic. Today only 50% of waste from vessels is recycled in ports. In addition, the significant number of national and local regulations is challenging to navigate in and comply with. This situation encouraged the need for a tool to map vessel waste management practices in individual ports. The system can provide information on how each port handles waste and what types of recycling the country can provide. Currently, 162 ports are included, but the ambition is to map over 2000 ports globally. The insight is visualized in a dashboard with drill down functionality on the individual ports, simplifying the decision-making process while the vessel is in operation. The tool is still in a development phase but will be made available with open access to the public [53].

Table 9 - Assessment of systems for screening and evaluation of ports by maritime companies

Impact and scalability	Implementation and operation
Environmental: High • If more cruise lines implemented similar approaches, more plastic waste would be handled adequately.	Implementation time and effort • Implementation time for other maritime companies would be relatively high if information is not shared across the cruise/shipping industry, or if it's no easily accessible. • Ports would need time and effort to comply with the standards.
Social: Low • The measure would not directly affect social factors or communities, except for indirectly through less mismanaged waste.	Cost • No data on specific costs for developing a certification or database system.
Economic: Low • The solution would most of all impact the ports' economy to comply with the standards, as they become more attractive for shipping companies focusing on this.	Responsible party • Maritime companies
Scalability: High	

Impact and scalability	Implementation and operation
• Scalability is seen as high. When a certification system is in place, the same controls could easily be used to assess more ports. • More conscious ship owners could potentially increase the demand for responsible waste management, incentivizing ports to upgrade their systems.	

South Korea: Dedicated floating receptacles for marine litter

To tackle the increasing problem of ghost gear and marine litter from fishing activities, dedicated floating receptacles have since 2008 been installed near ports and harbors in South Korea [41]. After the initial deck barges were installed in Haenam-gun, Cheollanam-do, South Korea, it was well-received by the local fishermen, as it proposed a simple and accessible way of discarding fishing gear in a responsible manner. Dedicated barge-type receptacles were stationed near the port, where the fishermen could pile up their used nets and farming gear when returning from sea. Due to its relatively small size, the barge can easily be towed, handled, and unloaded within the port [39].

Floating receptables in Haenam, Republic of Korea, 2009 [41].

Since preliminary results of the solution were deemed successful, the Ministry of Land, Transport and Maritime Affairs (MLTM) made plans of expanding the program. This planned expansion was to comprise 11 additional coastal local governments, with each receiving three receptacles yearly. With the cooperation of local governments, the program went nation-wide in 2009 [39].

In 2013, there were 179 installation sites along the coast [41].The receptacles made it easier for fishermen to unload their debris and thus reduce the likelihood of dumping. In addition to this, the solution significantly reduced the collection cost of marine debris and increased the voluntary recovery [39].

Table 10 - Assessment of South Korea: Dedicated floating receptacles for marine litter

Impact and scalability	Implementation and operation
Environmental: Medium • Relative to the situation prior the implementation of the solution, the environmental impact of the solution is considered to be high. The barges were well-received by the local communities which voluntarily used them actively. • There is limited information on where the waste ends up. It might be incinerated, which will leave carbon emissions. Thus, the score is set to medium.	**Implementation time and effort** • The barge is a fairly simple installation but will require some construction time. It can be put into operation shortly after assembly.
Social: Low • The solution does not significantly contribute to employment or other types of engagement of local communities.	**Cost** • Each unit costs around $25 000 USD to build.
Economic: Medium • Negative externality of ghost gear is substantially reduced through the solution. Haenam-gun, the first area to implement the solution, reduced the collection cost for marine debris by 30%.	**Responsible party** • State government is responsible for initiation, and local government for maintenance and operations
Scalability: High • As volume output is increased by increasing input factors, the solution is scalable.	

Case study – The Moana Taka Partnership

Background

The Moana Taka Partnership is a public-private partnership signed by The China Navigation Company (CNCo) and the Secretariat of the Pacific Regional Environment Programme (SPREP) in March 2018, to address the critical waste management issues in the Pacific Islands [54]. SPREP is representing 26 Pacific Island Countries and Territories (PICT). The PICTs have considerable amounts of waste with limited options for proper handling or recycling. The partnership helps alleviate the burden of waste on these islands by utilizing empty containers from Swire Shipping vessels, the liner business division of the CNCo, to transport non-commercial recyclable waste to suitable facilities [55].

Method

The Moana Taka Partnership provides parts of the logistics as well as container hire and shipment of eligible waste between Swire Shipping service ports. Swire Shipping has several empty containers in PICTs which need to be frequently repositioned to other locations, generally at the Pacific rim [56]. Instead of shipping the empty containers, the partnership offers an opportunity to utilize the capacity by shipping recyclable waste from any waste recycler (government or private sector) in the 13 PICTs to other locations with suitable facilities for handling and recycling.

First step of this process is for the recycler to contact SPREP to apply for and organize the shipment in terms of timeline, budget, quantity, etc. If approved, SPREP will coordinate the next steps between CNCo and the applicant. Then the container must be loaded and brought to the port where CNCo will pick it up and export it. When the container has reached its final destination, the applicant must coordinate unloading logistics, including completing relevant paperwork, ensure delivery to and from a suitable facility and cleaning the container. The Moana Taka Partnership will cover the costs of container hire and shipment, while logistics, wharf fees, and insurance must be covered by the shipper, which is the waste recycler who is sending the cargo.

Results

Since the signing of the Moana Taka Partnership in 2018, CNCo has shipped approximately 686 tonnes of low-value recyclable to countries with appropriate recovery, management, or disposal facility [57]. From just three total shipments in 2018, the partnership succeeded in expanding to fifty shipments from four islands Fiji, Marshall Islands, Papua New Guinea, Samoa to six

suitable countries, such as Australia, Malaysia, New Zealand, Singapore, Vietnam in 2019 [54]. 616.3 tonnes were shipped in 2019, of which 180.2 tonnes was plastic [58]. As the program has gained more attention, further expansion is expected in the coming years to increase the contribution to a circular economy.

Representatives from Moana Taka Partnership pointed out that one of the biggest challenges is to meet the increasing demand for transportation from the PICTs. The most important critical success factors for the partnership were: infrastructure of receiving country, financial support, and other actors to cooperate with willing shipping service [59].

According to CNCo representatives, this measure is an easy way for shipping services to help waste issues occurring in countries with poor waste management. The process barely affects them, as Moana Taka Partnership covers container hire and shipment, and the containers would have been shipped anyways. They encourage other companies to engage in similar initiatives, and stated that their process is open source and available to everyone [33].

Case study – Incentive system for the delivery of plastic waste for sea-going vessels in Port of Rotterdam and Amsterdam

Background

Port of Rotterdam and Amsterdam has since 1st of January 2016 offered free disposal of plastic waste in unlimited quantities for sea-going vessels. This is one of several measures implemented to reduce the amount of ship-generated waste released into the sea, and is sparked by an increase in waste disposed in Dutch seaports following the EU Directive 2000/59/EC on adequate port reception facilities for ship-generated waste and cargo [60].

Methods

The instrument is designed to incentivize ships to accumulate separated plastic waste. There is a fixed fee for disposing any waste in the ports of Amsterdam and Rotterdam, depending on the ship's size or engine capacity. After paying this fee, the ships are granted disposal of 6 m^3 garbage. Only when exceeding this limit will the ship receive an invoice from the collection company. This means that whenever ships want to dispose more than 6 m^3 waste, they will benefit from separating the plastic waste from the rest and deliver this for free. Thus, ships are incentivized to gather and deliver as much clean plastic waste as possible in order to maximize benefits from this instrument [60].

The waste treatment companies and the port reception facilities compensate for the decrease in revenues by the rates charged to the port authorities (for the 6 m3 'free' waste) and to the ship owners/agents (for other types of waste exceeding the threshold of 6 m3). In the end, only the ship owners pay, but there is a cross-subsidy to plastic waste from other types of waste [60].

For the plastic waste to be disposed it should be clean, adequately separated and delivered simultaneously with other waste from the ship [60]. While the ships do the sorting and keep clean waste separated from contaminated waste, the role of the port is to ask the collector to register the waste separately [61]. Representatives from Port of Rotterdam highlighted awareness and the will to operate and handle the waste accordingly to be key factors for the scheme to successfully function [61].

The free delivery of plastic for sea-going vessels in Port of Rotterdam and Amsterdam was in accordance with European Union Directive 2000/59/EC and is in line with European Union Directive 2019/883 that repealed Directive 2000/59/EC [62].

Results

Since the Port of Rotterdam and Amsterdam did not register the disposal of clean plastic waste before the measure of free disposal, the total impact is not known. However, in 2020, 1 002 m^3 of clean plastics were collected and recycled in Port of Rotterdam [61].

2.3.4 Clean-up

The clean-up category refers to solutions for capturing and cleaning up plastic waste already in nature.

Port of Houston: Clean-up initiatives

Port of Houston has implemented several Clean-up initiatives that work together to help maintain a port with little to no marine plastic pollution. Three of these initiatives are Dock Clean-up by Maintenance, The WasteShark, and Clean and Green Program [63].

Dock Clean-up by Maintenance
Dock Clean-up by Maintenance is an initiative where the maintenance personnel in the port perform clean-ups on the docks. These clean-ups are funded by introducing a monetary charge for clean-up of the docks by the users. The clean-ups were initiated due to occasional pileups of waste in the docks, and the implementation of this initiative has helped the port keep the nearby waterways cleaner.

The WasteShark
The WasteShark is an electric water drone produced by RanMarine that collects waste floating in the port basin. The WasteShark is fully electric, can clean up to 1 000 m^2/h and can carry up to 160 liters of waste per deployment. This allows for a one-man team to deploy and capture up to 1 tonne waste per day. The WasteShark can either be controlled manually with WasteShark Class M (8 hours battery life) or be autonomous with WasteShark Class A (10 hours battery life). In addition to the WasteShark itself, it can be combined with SharkPod and SharkSlider to create a fully autonomous operation where the WasteShark can empty the waste itself. Another additional product one can combine with WasteShark is DataShark. DataShark allows for monitoring and controlling the drone, and for collecting water parameters and data in real-time [64].

Clean and Green Program
Clean and Green Program is a cooperative initiative where involved stakeholders together pay a nonprofit organization, the Buffalo Bayou Partnership (BBP), to come clean the waste from the port area using their boats. Involved parties are Port Houston, City of Houston, and Harris County which pay the BBP to clean the water every day. The BBP has employed a boat captain, however, most of the people cleaning the water are working as community service workers. In addition, the BBP hosts corporate groups that want to help with voluntary work. To facilitate more efficient waste collection, BBP has posted booms in the water where the waste normally is collected.

All these initiatives are working in tandem, which is one of the reasons that the waste clean-up in Port Houston is efficient and has provided satisfactory results. The Dock Clean-up by Maintenance helps to prevent the waste getting into the water, the WasteShark can remove large amounts of the marine litter, and Clean and Green Program can manually target the remaining waste that is not collected by the WasteShark.

Table 11 - Assessment of Port of Houston: Clean-up initiatives

Impact and scalability	Implementation and operation
Environmental: High • The combination of the different initiatives in Houston that complement each other, leads to a high potential environmental impact.	Implementation time and effort: • Implementation time and efforts for the Dock Clean-up by Maintenance is relatively low. • Implementation time and efforts for the WasteShark is higher as it includes the production, shipping and assembling of the products, but not anything major apart from this. • Clean and Green Program requires longer implementation time and efforts as one first needs to both gather the stakeholders and align their interests, before deciding on a third party to organize the actual cleaning.
Social: Low • Not all the initiatives have a social impact, but the Clean and Green Program may contribute positively as this solution includes people working as community service workers.	Cost • Dock Clean-up by Maintenance has relatively low costs apart from the salaries of the workers. • For the WasteShark, the manual model costs approximately $17 000 USD, and the autonomous model costs approximately $23 000 USD (2018 estimates). There are few operational costs apart from maintenance [65]. • Clean and Green Program has low cost as most workers are working as community service workers. However, the program needs continuous funding to organize the clean-

Impact and scalability	Implementation and operation
	ups and cover their costs, but this will be shared among all stakeholders, thus lowering the costs for each party.
Economic: Low • This will not generate any economic results, apart from indirectly through cleaner and more valuable waste downstream in the value chain.	Responsible party • Port authority in collaboration with a nonprofit organization. • Port Houston, City of Houston, and Harris County funds the program.
Scalability: High • More dock workers can be assigned to perform clean-ups, to further improve the results. • Additional WasteSharks can be bought to further improve results. • Increased funding of the Clean and Green Program can lead to more boats and thus more workers/cleaner to further improve the results.	

Case study Blue Port Project

Background

The Blue Port Project (BPP) is an initiative originating from WILDTRUST targeting plastic waste and marine litter in the Port of Durban, South Africa [66]. The port is one of the largest and busiest on the African continent in terms of cargo [67] and is bothered by large amounts of plastic and other solid waste flowing in from the river and during storm flooding and heavy rain [68]. Blue Port Project aims to build *socio-ecological resilience* for the port through different initiatives.

Methods

BPP employs several initiatives for tackling marine and plastic litter floating in and around the port [68]. At the core is the employment of local youth for waste collection. These youth are working in the port on the other solutions for litter and plastic waste. These solutions are utilizing app monitorization for tracking and notification of spillage, installing, maintaining, and gathering waste from waste trapping installations, and production of ocean pavers from non-recyclable plastic.

- Employing local youth for waste collection

The Youth Employment Services (YES) program was initiated by the South African government and funded by NedBank. Today, the program is operational across South Africa. Since 2019, BPP has employed around 100 local youth on their payroll through the YES program. Forty – three (43) of these are currently enrolled in the program.

Blue Port project's youth employment program [67]

- App monitoring

The BPP has also developed a mobile application for reporting waste hotspots and other incidents of waste and plastic pollution in the water. The app was used by the ports' operators, commercial actors, and recreational users, as well as the employed youth. Its use allowed for easy communication and tracking of current plastic hotspots and notification of spillages.

Due to loss of funding, the app was shut down and is currently not in operation. However, according BPP representatives, they would like to shortly resume the use of the app due to its useful tracking functionality.

- Waste trapping installations

Two types of passive waste trapping solutions have been installed by the Blue Port Project.

One of them is a bamboo installation in the inflow that filters macro plastics from flowing into the port basin. It is reported to be highly efficient, durable, and has low installation and operational costs. The installation is canalized, where a diagonal structure across the inflow funnels the waste into a gully for future collection. The structure is biodegradable due to being built from organic material only. This reduces the environmental impact in case the structure is lost at sea during the strong typhoons the area is exposed to.

The other installation is a type of containment booms. These operate in the water surface and confine the space to trap floating waste. These typically cost approximately $1 000 USD.

Blue Port project boom installation [67]

Blue Port project bamboo installation [67]

- Production of ocean pavers

There has also been taken measures to reuse the port's plastic waste that would normally be seen as non-recyclable. Through collaboration with innovation centers in South Africa, ocean pavers have been developed and entered production. All the previously considered non-recyclable plastic collected through the BPP thirty thousand kilograms (30 000 kg) were recycled into 5 000 ocean pavers. The solution has thus significantly reduced the amount of plastics being sent to landfills.

While the goal is to find a way to use the pavers in building materials, the product has not yet been certified and is currently only approved for internal use.

Production of ocean pavers [67]

Placing ocean pavers [67]

Results

Since the program's inception, 55 000 kg of waste have been collected from Durban port. Of these, 30 000 kg were plastics.

According to BPP representatives, the most critical success factor for Blue Port project is the model of public partnerships. This has enabled sufficient funding for realizing the program. The other critical success factor is their close relationship with port authorities, which enables the project's operation and success.

Case study – Water Witch Versi-Cat Skimmer

Background

Water Witch has since its foundation in 1966 worked with environmental and government organizations to develop cost-efficient solutions for gathering marine litter. Their different designs range from fully electric skimmers to surface dredgers, with the current fleet comprising over 200 debris and trash retrieval workboats. The main mission is to clean ports, marinas and rivers to reduce the inflow of plastics and marine litter into the ocean. Over 1 million tonnes of marine litter has been removed by Water Witch vessels world-wide.

Water Witch Versi-Cat Skimmer [69]

Method
Bristol Harbour Authority is a port who has owned and operated the 0.7m Water Witch debris collection vessel, Versi-Cat Trash Skimmer, since 2007. Inspired by how whales filter the ocean for food, the Versi-Cat drives into the litter, collecting it between two hulls. A filter compresses the litter, which can later be sorted into bins by the working crew before it is transported to land for recycling and further handling. For safety reasons, two people are required to operate the vessel, it is however a very low-skill requirement. The Versi-Cat Skimmer is designed with the capacity to gather up to 1 tonne/2.4 cubic meters, although the plastic and trash collected is naturally lightweight and small.

In Bristol Harbour the boat is operated by port workers four times a week. The port is also engaged in Clean Up Bristol Harbour, which is a campaign for businesses, residents and organizations near the port. The campaign arranges monthly clean-ups to pick up floating waste in the port, where volunteers get to go out on the Skimmer to fish for plastic.

In addition to the mission of its operations, the boat itself is built to be environmentally friendly and sustainable. Being fully electric and zero-emission, the boat can operate for 6-8 hours on one full charging. It is made from aluminum, with low maintenance and operating costs, and has a lifespan of well over 20 years.

Water Witch's typical customers are ports, organizations, or other waterfront operators, with locally employed people in the port operating them on a daily basis.

Results
Results from the implementation in Bristol Harbour showed that the Versi-Cat collected a half-full basket for each deployment, equivalent to 1.5 cubic meters of litter. Further it's stated that most of the collected waste is from the city, either from a busy night or is washed ashore from storm drains. The port does not get any waste from the rivers because the rivers' estuaries to the port are sealed off. This demonstrates that most of the waste in the waters of Bristol Harbour is from land-based sources. They have experienced most of the waste to be bottles, food containers, syringes, and single-use plastics [70].

Attention around the Versi-Cat contributed to engaging wide-ranging and practical clean-up campaigns engaging the local community [71]. Bristol Harbour states that they have seen "a huge increase in members of the public wanting to do something practical to address the issues of marine litter". They believe this is a great way of engaging the communities, individuals and raise awareness [70].

Director of Water Witch mentions several important functions to be in place for the successful implementation and operation of Water Witch boats. Once ashore, proper planning and systems in place for handling the waste are key. Among these are reception facilities with the ability to lift the gathered waste onto the port, which is not an uncommon feature in cargo ports. Satisfactory communication between port crew and those operating the boats is necessary to ensure safe and efficient collection. Greater impact may be achieved by combining the use of the Versi-Cat with data from tracker apps to enhance the collection efficiency [69].

Case study – Port of Rotterdam waste management practices: Shoreliner pilot

Background
Port of Rotterdam has several initiatives in place for preventing and catching plastic waste. The overarching Port Waste Catch project was initiated by the Port of Rotterdam Authority with the aim of becoming the most sustainable port in the world, and has engaged the private sector to develop systems for removing floating plastic waste from in the port before it drifts out at sea [72].

The Shoreliner pilot project, which was first implemented in late 2016, has been voted Most Sustainable Port Project in Rotterdam [73]. The Shoreliner is developed in a collaboration between the port and Tauw, which is a technical consultancy firm concentrating on sustainable systems and devices [74]. Through developing and testing during the pilot project, the capacity has been enlarged and the construction itself is more solid than earlier versions [73].

Method
The Shoreliner is a static collection system that catches plastic waste before it is removed and recycled. The system is typically placed at the end of the port basin, catching floating waste that is accumulating in the less trafficked area [61].

The Shoreliner can also monitor plastics and nurdles (small plastic pellets) in the surface water. Data insight from the system gathered over several years can be utilized to determine the scope of the problem and how effective measures against plastic marine litter is [73].

Port basin overview with Shoreliner
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ShorelinerInvalid
source specified.

Results

Throughout the pilot project, from 9.12.2016-15.10.2018, the Shoreliner gathered in total 1 166.24 kg of floating litter. Of those, 163.4 kgs were plastics [75]. The relatively low result can be explained with there already being little plastic in the water.

Statistics for the different plastic types are shown in the graph below. It can be noted that the largest categories of caught waste are 1) ropes, 2) PET bottles and hard polyolefin (PO) plastics, 3) Styrofoam/polystyrene (PS) foam, and 4) weathered soft plastic/PO soft [75].

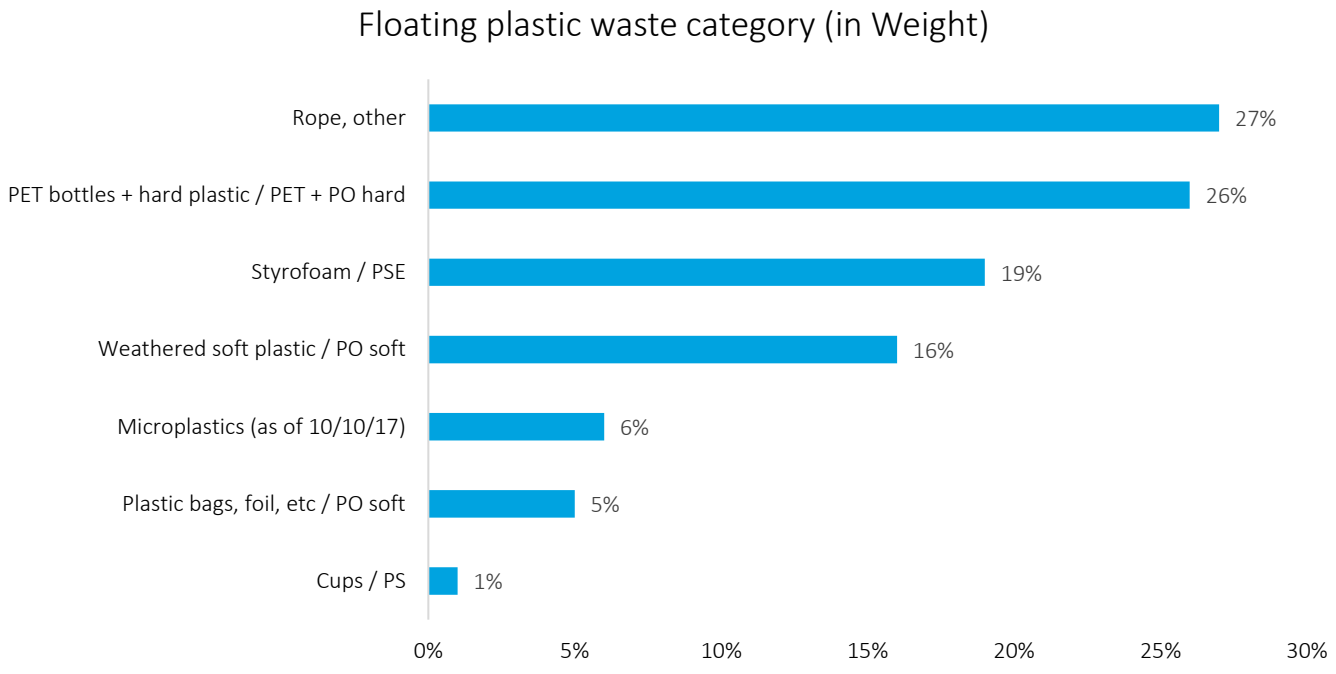

Figure 5 - Floating plastic waste captured by Shoreliner categories sorted after weight [75]

2.3.5 Training, awareness, and R&D

Training, awareness and R&D solutions refers to efforts for increasing awareness and educating people about the threat of plastic pollution, changing consumer behavior, and R&D solutions.

Solomon Ports: 3R (Reduce-Reuse-Recycle) Campaign

The 3R Campaign was one of the first initiatives against plastic pollution on the Solomon Islands. As the national waste management on the islands does not have a separate waste stream for recyclable plastic, the port authorities have taken the lead on how to tackle the issue. At the start of this project Solomon Ports placed out bins to make people segregate their waste into three categories:

- General waste
- Cans, bottles, and plastic
- Food waste

Along with the bins are signs to guide the public in discarding their waste sustainably. These bins were placed outside the port to be available to the community, and in six schools to encourage youth and raise awareness. Solomon Ports are responsible for collecting the bins regularly.

Currently, the Solomon Islands has recycling facilities for aluminum cans, but not for plastic. Instead, the plastic is temporarily stored in a facility in the port. A solution for how the plastic should be processed further is not yet in place, and the only viable alternative is to ship it to a location with proper recycling facilities.

Solomon Ports have initiated several additional measures to optimize the effect of the bins. Most of the citizens only have access to radio, which in addition to social media, is the preferred platform to broadcast information and spread awareness.

For schools they have more interactive methods, such as awareness training and interventions. When placing new bins at a school, the port authorities hold a presentation to enlighten the students about the initiative. Each school selects student champions as a part of the project, which purpose is to lead by example and guide other students in discarding their waste responsibly. The chosen students are champions for a school year before new students are selected. They receive a badge and certificate for their effort.

The Solomon Ports stated that the students at the schools have had a positive attitude, which is reflected in the outcome showing predominantly satisfactory results. However, the community bins have not been as successful, of which those in the capital, Honiara, is believed to be the worst performing. The collected waste is often mixed, which leaves the task of segregation to the port workers after collection. Going forward it is proposed to use visual signs on the bins instead of just text to improve the segregation effort [76].

Table 12 – Assessment of Solomon Ports: 3R (Reduce - Reuse - Recycle) Campaign

Impact and scalability	Implementation and operation
Environmental: High • Compared to the current situation where large amounts of waste go to the landfills and potentially end up in the ocean, collecting and possible recycling is a substantial improvement. • This solution raises the awareness of the people, making them segregate and act. As a result, more businesses have started segregation initiatives and clean-up programs.	**Implementation time and effort** • Implementation time can be long, as the solution covers a substantial area. Handling of the plastic after collection is seen as a key challenge. • The solution requires a combination of efforts, where both the location of bins, public awareness and education, collection and suitable export alternatives are necessary. • Financial funds are required to implement a similar measure. This solution did not have any external financial aid, but this might be possible to get.
Social: High • The solution contributes to engage and involve people. Both by being a good example to other actors and raise awareness among the local community and in the schools	**Cost** • Approximately $37 000 – $50 000 USD for the implementation of the system in the six schools, the bins in the community, and the awareness signs.

Economic: Low • Implementing the solution will not necessarily have a high economic impact. However, it can potentially contribute to a future circular economy, where other companies can find value in the segregated plastic waste.	Responsible party • Port.
Scalability: High • Waste can be sorted into more categories, and more bins can be installed to collect larger volumes.	

Data collection system for ports

As the world becomes more and more digitalized, people find new applications for the data they have available. Improved data collection and use of available data is a valuable initiative that is implemented in several ports around the world to different degrees.

Port of Rotterdam

Port of Rotterdam is one of the ports that have implemented an advanced data collection system. The port authority in Rotterdam has a digital system where the ships register the amount they are going to dispose before they arrive in the port. This information is then used to communicate with the waste collectors to ensure the waste is collected adequately [61].

Port of Auckland

Port of Auckland has also implemented a data collection system. The port authority in Auckland has implemented routines for measuring how much waste is collected from different sources, and how much waste is transported to different locations. This is done both through scales at the disposal locations and the bins, and also through weighbridges for weighing the waste trucks. The data from these measurements are stored and used for different applications. E.g. A Power BI[1] dashboard developed to analyze and visualize the waste streams, the sources of waste and the amounts of different types of waste [77].

Port Esbjerg

Improved data collection was also highlighted by the Port of Esbjerg. The importance of quantifying the amount of different types of waste, to be able to attract potential business partners that could have interest in the plastic waste, was emphasized. Plastic recycling facilities are not common in all areas of the world, and thus to attract such actors (or others that could have interest in the plastic) one should be able document a large amount of collected plastic waste, that could potentially be supplied to a recycling facility [45].

The data can be used for analysis of the waste streams and waste sources. This can be useful for optimizing the current routines and operations, for mitigating the sources of plastic waste, and for handling the existing plastic waste in an efficient manner.

Table 13 - Assessment of Data collection system for ports

Impact and scalability	Implementation and operation
Environmental: High • If implemented and used correctly in monitoring and reporting, this could have high impacts regarding closing the tap, closing the loop, and stopping plastic leakage.	Implementation time and effort • Implementation time can be relatively high if the system is advanced, but simpler systems would require less time. • Implementation requires technology for measuring and storing data, and knowledge of analyzing and using the data.

[1] https://powerbi.microsoft.com/en-us/

Social: Low • Social impact could be increased if the data is applied to facilitate other initiatives with higher social impact.	Cost • Variable depending on the complexity of the system. The system from Rotterdam costs approximately €200 000 EUR each year to operate, while simpler solutions are much less costly.
Economic: High • Could help optimize routines and operations, lowering costs for the port.	Responsible party • Port authority.
Scalability: High • Possibility of implementing a simpler system with an option to expand at a later stage.	

Training and raising awareness of employees in ports and aboard maritime vessels

One common initiative among ports and maritime companies is training their employees in waste segregation and raising awareness about marine litter.

Port of Rotterdam

Port of Rotterdam is an example of a port that has focus on training and raising the awareness of the employees. This is done through information films and training courses that is made part of the formal training of the employees [61].

Maritime companies must be MARPOL compliant and thus need to perform waste segregation and handling of waste in accordance with MARPOL regulations. The sailors and employees onboard the vessels are integral parts of this as they are the ones that sort and segregate the waste onboard. The employees often have mandatory training courses to be allowed to work onboard the vessels. Training in waste segregation and learning about marine litter is part of the curriculum to pass this training.

The Grieg Group

The Grieg Group includes waste segregation as part of their employees' training. They have also implemented campaigns aboard the ships to raise the awareness regarding the consequences of marine plastic litter. This is seen as an important initiative as the attitude and mindset of the seafarers will be the driving force for them to segregate their waste properly [50].

Table 14 - Assessment of Training and raising awareness of employees in ports and aboard maritime vessels

Impact and scalability	Implementation and operation
Environmental: High • The improved knowledge of waste segregation will contribute to more waste being sorted correctly.	Implementation time and effort • Initiation time of initiatives will not be very high, but seeing the effects of the initiatives will take longer time.
Social: High • Contributes to increased awareness. • Potential ripple effect on family and community of employees who adapt their attitude and mindset outside of work.	Cost • Some initial costs of producing the training material, but operational costs will not be of any significance.
Economic: Low	Responsible party • Port authority or maritime company.

- This will not generate any economic results, apart from indirectly through cleaner and more valuable waste downstream in the value chain.

Scalability: High

- Training activities can be implemented step by step.

Part 3 – Recommendations and conclusion

This report presents measures to address the problem of plastic pollution in ports and the maritime sector. It is important to note that no solution is universal and local conditions significantly affect the relevance and impact of a given solution. This is because solutions often depend on existing infrastructure and resources. As such, due to the lack of information about local conditions, port systems and infrastructure in the three Philippine ports due to the ongoing baseline studies, final recommendations are not definitive. However, based on the analysis in Part 1 and 2, this section presents examples of solutions believed to be the most suited.

The following table presents a selection of solutions considered most applicable in tackling the challenge of plastic pollution in the Philippine ports and maritime sector. The measures cover all the categories explained in section 2.1.2. The recommendations include solutions for both preventing and reducing plastic pollution.

The solutions have been selected based on their potential impact, implementation time, and required operational efforts. Solutions are also grouped by their assumed implementation time: short-, medium-, and long-term.

Furthermore, the recommendations represent a broad range of solutions, with a variety of approaches. If two solutions are similar, the one with the easiest implementation effort and time is preferred. It is not intended that all solutions should be adopted, although the adoption of several could yield synergies.

3.1 Recommendations

Table 15 - Recommendations and associated stakeholders that could initiate them

Timeline	Recommended solution	Port authority	Maritime company	Local gov	National gov	Private actors	NGO
Short	Buyback programs and floating receptacles for ghost gear	✓					
	Engage local community in clean-up programs	✓		✓			✓
	Waste collection installations	✓				✓	
	Education/awareness program	✓	✓	✓			
Medium	Develop waste bins matching MARPOL	✓					
	Incentive system for the disposal of plastic waste for ships in ports	✓	✓				
	Data collection and reporting systems	✓					
Long	Banning single-use plastic	✓	✓	✓	✓	✓	✓
	Public-private partnerships – Moana taka partnership for exporting waste to recycling facilities	✓	✓		✓		

3.1.1 Short term – feasible within a year

Buyback programs and floating receptacles for ghost gear (containers for lost fishing equipment)

These initiatives target ghost gear and can have impact for several actors. The buyback program has the potential to positively engage local fishermen, private actors, and the government. This solution has high economic impact as the collection of ghost gear saves the government of potential marine litter clean-up and increases the income of the fishermen. There is an economic incentive to use the buyback program, while using the floating receptacles is a voluntary action. Implementation of the buyback program requires the successful engagement of relevant stakeholders. It is not given who should take the lead on this, but the program presented in this report was a collaboration between the government, local municipalities, a union, and an association. The floating receptacles on the other hand are relatively easy to install and adopt.

Engage local community in clean-up programs

By engaging local communities in clean-up program, both environmental and considerable social impact are achievable. These low-cost solutions are fairly simple to implement and require few upfront resources. The environmental impact will depend on the number of people engaged and the subsequent processing. Nevertheless, community clean-up programs are local initiatives and have limited potential to reducing the problem of plastic pollution in terms of volume.

On the other hand, engaging the local community could result in long term impact as this will increase the awareness of the public. While clean-up programs may be led successfully by multiple actors, this report presents a governmental one.

Clean-up programs could act as a catalyst in initiating more complex solutions requiring more efforts. Organized clean-up programs could achieve increased scale and impact if workers are presented with an incentive. In the Blue Port Project, the clean-up program contributed to job creation when the sufficient funding to pay wages was available. The project also provided local upcycling of collected plastic waste by producing ocean pavers, which is another example of a long-term possibility.

Waste collection installations

Waste collection installations generally have lower implementation time, but higher investment costs and space requirements. These solutions can be divided into two categories: Static and Dynamic. Static waste collection systems are usually less expensive than their dynamic counterparts but are also in most cases less effective. Static waste collection systems range from booms in the water that guide the waste to collection areas, to a Shoreliner that traps the waste in the far end of the port basin. Dynamic waste collection systems are boats and water drones that can be used to actively collect the waste from the waterways. These dynamic solutions can either be manually driven like the Versi-Cat from Water Witch, or they can be autonomous such as the WasteShark from RanMarine.

Generally, waste collection systems have a high environmental impact. Moreover, some of the man-driven solutions also contribute to community engagement, and thus some extent of social impact. These solutions are normally highly scalable, as adding additional resources, in the form of more installations, will result in a higher impact.

Different static and dynamic waste collection systems can work well in collaboration with each other. Combining multiple of these can both help increase the efficiency of the others, as well as complement each other on their shortcomings.

Education/awareness program

The solutions related to education and awareness programs target the root cause of plastic pollution, with the aim to change the behavior and mindset of today's society. By educating and making the population aware of the problem and its related solutions, one can achieve high environmental impact in the long run. The social impact is also considered to be high, as it has the potential to reach thousands and create engagement through today's technology. There are multiple different approaches to this solution, and it can be adjusted to the specific situation of any party that has interest in implementing this. While this solution should be feasible to initiate within a year, results would be expected after a longer period of time.

3.1.2 Medium term – feasible within three years

Develop waste bins matching MARPOL

The potential environmental impact of the measure is considered to be high. However, it will require both effort and resources from the port to ensure successful implementation and operation. If the segregation system in the port is matched with the one onboard the maritime vessels, it would result in less waste from ships being sorted in the wrong bin. The effect of this measure is highly dependent on how the waste is processed after it is segregated. Transportation of the waste to a recycling facility either in the Philippines or abroad would be preferable.

Incentive system for the disposal of plastic waste for ships in ports Free plastic disposal for ships in the port would create incentives for maritime vessels to dispose plastic waste adequately. The solution can be hard to adopt because it requires infrastructure, solid waste management, and sufficient staff to oversee the operations. The costs related to further handling may be covered by the ships, by raising other fees in the port. Thus, the solution's success is dependent on multiple factors which can result in longer implementation time. Implementing an indirect fee system similar to the system from Directive (EU) 2019/883, could be seen as a first step of implementing free plastic disposal for ships. This is a required part of the complete solution and can thus be implemented as a step in the process and have an effect in itself.

Data collection and reporting systems
There are limited efforts required to implement a system for data collection and reporting, and it can be tailored depending on situation and accessibility of resources. This solution has high scalability, as it can start out as a relatively simple solution and increase in complexity at a later stage to improve impact. This measure is considered to have potential for high environmental impact if it is implemented and used correctly.

3.1.3 Long term – feasible within five years

Banning single-use plastic
As stated in section 1.2.2, the Philippines are already in the process of banning certain single-use plastic items. However, other actors in the Philippines can act in addition to this legal framework. The measure may be easier to implement for single actors, rather than on a larger national scale. Banning single-use plastic items can be challenging if there are limited sustainable and affordable alternatives and is therefore categorized as a long-term solution. Certain actors might find it easier to aim at a reduction of single-use plastic rather than a complete banning, as this is easier to achieve and has shorter implementation time. As documented in this report, there are multiple examples of maritime companies taking the approach of reducing or banning single-use plastic items. However, little research or examples have been found on ports adapting these measures. Hence, it is challenging to say anything concise about the feasibility of potential implementation in ports. However, regulations that affect ports exist, such as in India and Kuwait. These prohibit the usage and discarding of single-use plastic items for vessels in their ports. A similar regulation could be implemented to cover Philippine ports.

Public-private partnerships – Moana Taka partnership for exporting waste to recycling facilities
Public-private partnerships is a forward-looking solution to engage more stakeholders and encourage cooperation across business- and expertise areas. Public-private partnerships could be initiated by both governments and private actors, as long as the respective interests of stakeholders are sufficiently aligned. Implementation is both time and resource consuming, as agreements could be complex and involve multiple parties. However, the measure has substantial potential environmental impact. If implemented, the plastic waste could be shipped to other areas with facilities suitable for recycling to optimize the resource utilization.

3.2 Conclusion and final notes

The mapping and analysis of this report have made it clear that the problem of marine plastic litter is complex and requires wide stakeholder engagement to be overcome. However, stakeholders may have conflicting interests and responsibilities, making successful cooperation challenging. An example of this is that the waste aboard maritime vessels is segregated according to MARPOL, but when the waste is landed ashore it is often segregated and handled according to local waste regulations. Thus, in certain cases, the efforts made by the maritime companies in compliance with MARPOL do not have any effect.

A significant finding of the report is the high number of measures and initiatives implemented by ports and maritime companies to handle the growing challenges of marine plastic litter. However, there is both limited data available and few platforms for knowledge sharing. These are considered to be two of the main contributing factors as to why successful solutions are rarely widely adopted. Another challenge is that solutions that have been effective in one location are not necessarily effective elsewhere, due to local differences. Different locations have different amounts of marine plastic litter as well as different legislations, infrastructure, and handling of the waste streams. Thus, the level of impact and implementation efforts associated with the solutions presented in this report will vary depending on the location in which the solution is adopted.

It is apparent that closing the tap is the most effective way of combating marine plastic litter on a global scale, as it reduces or potentially eliminates new inflow of plastic. The potential effect of successfully closing the tap is evident in that single-use plastics and plastic from land-based sources are the major contributing sources of plastic in the ocean. To effectively combat the problem one must consider the entire plastic value chain, as the level of ocean plastic is dependent on how the waste is handled in the society as a whole. However, as the focus of this report has been on ports and maritime companies, the recommendations consider measures feasible for implementation by these actors.

Maritime companies engage in closing the tap by reducing their consumption aboard vessels, as well as training and awareness for their crew. Ports, on the other hand, are leaning more toward stopping plastic leakage and clean-up measures in the port basin and surrounding area. The difference in approach is natural, considering how maritime companies and ports experience and are affected by the issue. Thus, they have different ways of most efficiently contributing to reducing their own pollution and responsible waste management respectively.

Due to the limited availability of data on the three Philippine ports and pending the upcoming baseline study, conclusive recommendations suitable for the respective ports are challenging to decide on. Hence, future studies on this topic is recommended to focus on concrete measures to be taken to tackle plastic pollution in the port of Batangas, the port of Cagayan de Oro, and Manila North Harbor.

Bibliography

[1] WWF, "No Plastics in Nature Initiative Strategy 2020-2025," WWF.

[2] Kuhn and van Franeker, "Quantitative overview of marine debris ingested by marine megafauna," *Marine pollution bulletin,* vol. 151, 2020.

[3] Convention on Biological Diversity, "Marine debris: understanding, preventing and mitigating the significant adverse impact on marine and coastal biodiversity," Technical Series No.83, 2016.

[4] A. A. d. S. Machado, W. Kloas, C. Zarfl, S. Hempel and M. C. Rillig, "Microplastics as an emerging threat to terrestrial ecosystems," *Global Change Biology,* 2017.

[5] United Nations Environment Programme (UNEP), "Marine Plastic Debris and Microplastics - Global lessons and Research to Inspire Action and Guide Policy Change," 2016.

[6] Ciel, "Plastic & Health: The Hidden Costs of a Plastic Planet," 2019.

[7] UNEP, "Neglected: Environmetal Justice Impacts of Marine Litter and Plastic Pollution," Nairobi, 2021.

[8] N. J. Beaumont, M. Aanesen, M. C. Austen, T. Börger, J. R. Clark, M. Cole, T. Hooper, P. K. Lindeque, C. Pascoe and K. J. Wyles, "Global ecological, social and economic impacts of marine plastic," ScienceDirect, 2019.

[9] H. Ritchie and M. Roser, "Plastic Pollution - Our World in Data," Global Change Data Lab, September 2018. [Online]. Available: https://ourworldindata.org/plastic-pollution. [Accessed 5 August 2021].

[10] R. Geyer, J. R. Jambeck and K. L. Law, "Production, use, and fate of all plastics," Amarican Association for the Advancement of Science, Washington, DC, 2017.

[11] International Union for Conservation of Nature (IUCN), "Marine plastics," [Online]. Available: https://www.iucn.org/resources/issues-briefs/marine-plastics. [Accessed August 2021].

[12] The Pew Charitable Trusts and SYSTEMIQ, "Breaking the Plastic Wave A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution," SYSTEMIQ, Washington, 2020.

[13] Jambeck and others, "Plastic waste inputs from land into the ocean," *Science,* vol. 347, no. 6223, 2015.

[14] Food and Agriculture Organization, "Sea-based Sources of Marine Litter – A Review of Current Knowledge and Assessment of Data Gaps ((Second Interim Report of GESAMP Working Group 43)," 2020.

[15] J. R. e. a. Jambeck, "Plastic waste inputs from land into the ocean," *Science,* vol. 347, no. 6223, pp. 768-771, 2015.

[16] WWF-Philippines, "EPR Scheme Assessment for Plastic Packaging Waste in the Philippines," WWF-Philippines, 2020.

[17] *UNEP representative.* [Interview]. 13 July 2021.

[18] UNEP, "Environmental Rule of Law: First Global Report," United Nations Environment Programme, Nairobi, 2019.

[19] UN, "United Nations Convention on the Law of the Sea," United Nation, Montego Bay, Jamaica, 1982.

[20] Secretariat of the Basel Convention, "Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal," [Online]. Available: http://www.basel.int/?tabid=4499. [Accessed 27 October 2021].

[21] Republic of the Philippines House of Representatives, "An Act Regulating the Production, Importation, Sale, Distribution, Provision, Use, Recovery, Collection, Recycling, and Disposal of Single-Use Plastic Products," House of Representatives, Quezon City, 2021.

[22] Philippine Port Authority, "Interim Guidelines on the Issuance of Permit to Operate (PTO) for Shore Reception Facilitites (SRF) / Waste Dispoal Service Provider," Philippine Port Authority, Manila, 2018.

[23] Container News, "Batangas port gets Green Award," 6 September 2018. [Online]. Available: http://container-news.com/batangas-port-green-award/. [Accessed 29 October 2021].

[24] APEC Port Services Network, "Green Port Award System," APEC Port Services Network, 2021.

[25] Economic Research Institute for ASEAN and East Asia, "Waste Management: Preventing Littering," [Online]. Available: https://rkcmpd-eria.org/goodpractices/27/management/preventing-littering. [Accessed July 2021].

[26] *Stakeholders representatives from ongoing baseline study.* [Interview]. June 2021.

[27] European Commission, "Single-use plastics," [Online]. Available: https://ec.europa.eu/environment/topics/plastics/single-use-plastics_en. [Accessed August 2021].

[28] UNEP, "Legal limits on single-use plastics and microplastics," 06 December 2018. [Online]. Available: https://www.unep.org/resources/report/legal-limits-single-use-plastics-and-microplastics. [Accessed August 2021].

[29] Gard, "India bans single-use plastic onboard ships," 24 October 2019. [Online]. Available: https://www.gard.no/web/updates/content/28558453/india-bans-single-use-plastic-onboard-ships. [Accessed July 2021].

[30] Directorate General of Shipping, Mumbai, "DGS Order No.05 of 2019: Prohibition on use of Single Use Plastics," Government of India, 2019.

[31] Gard, "Kuwait joins India in ban on single-use plastic onboard ships," Gard, 22 January 2020. [Online]. Available: https://www.gard.no/web/updates/content/28793701/kuwait-joins-india-in-ban-on-single-use-plastic-onboard-ships. [Accessed August 2021].

[32] Kuwait Ministry of Communications, "Circular no.8/2109 Plastic Substaince & Waste," State of Kuwait, 2019.

[33] *Swire Pacific Offshore representative.* [Interview]. 9 July 2021.

[34] *Royal Caribbean Cruise Line representatives.* [Interview]. 8 July 2021.

[35] Port of Brisbane, "Target Zero," Port of Brisbane, [Online]. Available: https://www.portbris.com.au/sustainability/planet/target-zero/. [Accessed August 2021].

[36] Containers for Change, "Where to Return," Containers for Change, [Online]. Available: https://www.containersforchange.com.au/qld/where-to-return. [Accessed August 2021].

[37] Queensland Government, "About Containers for Change," Queensland Government, 3 August 2020. [Online]. Available: https://www.qld.gov.au/environment/pollution/management/waste/recovery/reduction/container-refund/container-refund-about. [Accessed August 2021].

[38] *Port of Brisbane representative.* [Interview]. 9 July 2021.

[39] C. Morishige, "Marine Debris Prevention Projects and Activities in the Republic of Korea and United States: A compilation of project summary reports," NOAA Technical Memorandum MOS-OR&R-36, 2010.

[40] Secretariat of the Convention on Biological Diversity, "Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity," Technical Series No. 83, 2016.

[41] Northwest Pacific Action Plan, Marine Environmental Emergency Preparedness and Response Regional Activity Centre, "Best Practices in dealing with Marine Litter in Fisheries, Aquaculture and Shipping sectors in the NOWPAP region," Regional Seas, Yuseong, Daejeon, 2015.

[42] Muffett et al. , "Plastic & Climate The Hidden Costs of a Plastic Planet," 2019.

[43] Rudra Environmental Solutions, "Rudraenvsolution.com," Keshav Sita Trust, [Online]. Available: https://rudraenvsolution.com/productplantdetails.html. [Accessed 13 August 2021].

[44] EGGS Design, "Danish port takes sustainability to a new level," [Online]. Available: https://eggsdesign.com/work/case/danish-port-takes-sustainability-to-a-new-level. [Accessed August 2021].

[45] *Port Esbjerg representative.* [Interview]. 3 August 2021.

[46] Environmental Justice Foundation, "Net Free Seas: The community project in Thailand cleaning up the oceans," 18 May 2020. [Online]. Available: https://ejfoundation.org/news-media/new-project-collecting-and-recycling-ghost-gear-in-thailand . [Accessed August 2021].

[47] World Animal Protection, "Fishing's Phantom Menace," World Animal Protection International, London, 2014.

[48] Environmental Justice Foundation (EJF), "Net Free Seas project - update as of February 2021," 2021.

[49] *Environmental Justice Foundation, Net Free Seas Project representative.* [Interview]. 2 August 2021.

[50] *Grieg Star representative.* [Interview]. 12 July 2021.

[51] Grieg Star, "Grieg vessels will only unload plastic waste in countries with high-level waste management.," 10 February 2021. [Online]. Available: https://www.griegstar.com/grieg-vessels-will-only-unload-plastic-waste-in-countries-with-high-level-waste-management/. [Accessed July 2021].

[52] Wilhelmsen, "About Wilhelmsen," [Online]. Available: https://www.wilhelmsen.com/about-wilhelmsen/. [Accessed 18 October 2021].

[53] Wilhelmsen, "Pioneering plastic recycling project," 4 November 2020. [Online]. Available: https://www.wilhelmsen.com/media-news-and-events/news/2020/pioneering-plastic-recycling-project/. [Accessed 18 August 2021].

[54] Sustainable Islands Platform, "Secretariat of the Pacific Regional Environment (SPREP) Moana Taka Partnership," [Online]. Available: https://www.sustainableislandsplatform.org/innovation/sprep-moana-taka-partnership/. [Accessed August 2021].

[55] Secretariat of the Pacific Regional Environment Programme (SPREP), "Moana Taka Partnerships - A Guide for Pacific Island Countries & Territories," Secretariat of the Pacific Regional Environment Programme (SPREP), Samoa, 2020.

[56] Moana Taka Partnership, "Moving recyclable waste out of the Pacific Islands," China Navigation, 2021.

[57] IISD, "Shipping Partnership Advances Waste Management in Pacific Islands," International Institute for Sustainable Development, 7 April 2020. [Online]. Available: https://sdg.iisd.org/commentary/policy-briefs/shipping-partnership-advances-waste-management-in-pacific-islands/. [Accessed August 2021].

[58] China Navigation Sustainable Development Department , "Waste Recycling Project in the Pacific Islands," China Navigation , [Online]. Available: https://www.swirecnco.com/SD/SD_Report_2019/waste-recycling-pacific-islands.html. [Accessed August 2021].

[59] *SPREP representative.* [Interview]. 14 July 2021.

[60] F. Oosterhuis, "Free plastic waste disposal in the ports of Rotterdam and Amsterdam," Institute for European Environmental Policy, 2016.

[61] *Port of Rotterdam representatives.* [Interview]. 6 July 2021.

[62] The European Parilament and the Council of the European Union, "Directive (EU) 2019/883 of the European parilament and the council of 17 April 2019 on port reception facilitites for the delivery of waste from ships, amending Directive 2010/65/EU and repealing Directive 2000/59/EC," *Official Journal of the European Union,* 2019.

[63] *Port Houston representatives.* [Interview]. 7 July 2021.

[64] Drone Solutions Services, "The WasteShark," Drone Solution Services, [Online]. Available: https://dronesolutionservices.com/wasteshark. [Accessed August 2021].

[65] E. Swan, "Dubai is now home to a trash-eating 'shark' drone," CNN, 2018.

[66] IUCN, "MARPLASTICCs video series: Blue Port Project, a Circular Economy initiative of the WILDTRUST in South Africa," IUCN, 18 February 2021. [Online]. Available: https://www.iucn.org/news/eastern-and-southern-africa/202102/marplasticcs-video-series-blue-port-project-a-circular-economy-initiative-wildtrust-south-africa. [Accessed August 2021].

[67] *WILDOCEANS, Blue Port Project representative.* [Interview]. 9 July 2021.

[68] GreenPort, "Port of Durban Tackles Solid Waste Imports," GreenPort, 3 October 2019. [Online]. Available: https://www.greenport.com/news101/africa/port-of-durban-tackles-solid-waste-imports. [Accessed August 2021].

[69] *Water Witch representatives.* [Interview]. 7 July 2021.

[70] T. Moore, "Versi-Cat Trash Skimmer: Working to rid the plant's oceans of pollution," 2021.

[71] *Water Witch Case study - Bristol Harbour Authority,* 2021.

[72] "Port waste catch," Port of Rotterdam, [Online]. Available: https://www.portofrotterdam.com/en/doing-business/port-of-the-future/innovation/cases/port-waste-catch. [Accessed August 2021].

[73] TAUW, "Shoreliner voted most sustainable port project," [Online]. Available: https://www.tauw.com/news/news/shoreliner-voted-most-sustainable-port-project.html. [Accessed August 2021].

[74] TAUW, "TAUW - What we do," [Online]. Available: https://www.tauw.com/whatwedo/. [Accessed August 2021].

[75] TAUW, "Shoreliner Rotterdam - Overzicht vangsten van de Shoreliner," Tauw.

[76] *Solomon Ports representative.* [Interview]. 4 August 2021.

[77] *Ports of Auckland representative.* [Interview]. 4 August 2021.

[78] Grieg Group, "GRIEG SUPPORTS WWF'S WORK AGAINST PLASTIC WASTE," Grieg, 14 October 2020. [Online]. Available: https://grieg.no/news/grieg-supports-wwfs-work-against-plastic-waste/. [Accessed 14 August 2021].

[79] S. E. C. J. F. Patricia Villarrubia-Gómez, "Marine plastic pollution as a planetary boundary threat – The drifting piece in the sustainability puzzle," *Marine Policy,* vol. 96, pp. 213-220, 2018.

[80] A. V. Uhrin and J. Schellinger, "Marine debris impacts to a tidal fringing-marsh in North Carolina," *Marine Pollution Bulletin,* vol. 62, no. 12, pp. 2605-2610, 2011.

[81] C. B. M. H. B. e. a. Rochman, "Classify plastic waste as hazardous.," *Nature,* vol. 494, p. 169–171, 2013.

[82] M. R. Gregory, "Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions," *Philophical Transactions of the Royal Society,* vol. 364, pp. 2013-2025, 2009.

[83] S. B. Werner, v. F. J. A. A., F. Galgani, G. Hanke, T. Maes, M. Matiddi, P. Nilsson, L. Oosterbaan, E. Priestland, R. Thompson, J. Veiga and T. Vlachogianni, "Harm caused by Marine Litter (MSFD GES TG Marine Litter - Thematic Report; EUR 28317)," European Union, Luxembourg, 2016.

[84] A. Vila, "Philippines plastic pollution: why so much waste ends up in oceans," South China Morning Post, 18 October 2018. [Online]. Available: https://www.scmp.com/lifestyle/health/article/2168819/philippines-plastic-pollution-why-so-much-waste-ends-oceans?module=perpetual_scroll&pgtype=article&campaign=2168819. [Accessed August 2021].

[85] WWF, "Tackling Marine Plastic Pollution," WWF International, Gland, 2019.

[86] Philippine Ports Authority, "Port of Cagayan de Oro," [Online]. Available: http://www.pmocdo.ppa.com.ph/port-profile/port-of-cagayan-de-oro/ .

[87] Quantafuel, "Our Technology," [Online]. Available: https://www.quantafuel.com/our-solution/technology/. [Accessed August 2021].

[88] J. Merriman and M. Vargas-Gonzales, "Life Cycle Assessment of circular systems: Guide & case studies," International Council of Chemical Associations, Belgium, 2021.

[89] Handelens Miljøfond, "Innsamling og gjenvinning av spøkelsesgarn," 10 July 2020. [Online]. Available: https://handelensmiljofond.no/prosjekter/innsamling-og-gjenvinning-av-spokelsesgarn-i-thailand. [Accessed August 2021].

[90] Rudra Environmental Solution (India) Ltd, "Pyrolysis Thermo Catalytic Polymersation," Rudra Environmental Solution (India) Ltd, India, 2021.

[91] World Wild Fund for Nature, "No plastic in nature," [Online]. Available: https://wwf.panda.org/discover/our_focus/markets/no_plastic_in_nature_new/. [Accessed August 2021].

[92] The Pew Charitable Trust, SYSTEMIQ, "Breaking the Plastic Wave," Science, 2020.

[93] Sustainable Islands Platform, "SPREP - Moana Taka Partnership Addressing critical waste managment issues in the Pacific Islands," [Online]. Available: https://www.sustainableislandsplatform.org/innovation/sprep-moana-taka-partnership/. [Accessed 20 October 2021].

Deloitte.