MAELSTROM

Smart technology for MArinE Litter SusTainable RemOval and Management

D7.2

Best Practices Sheets Database

30/04/2024

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No [101000832]

MAELSTROM

General Information

H2020 call	CE-FNR-09-2020 Pilot action for the removal of marine plastics and litter
Grant Agreement #	101000832
Project Title	Smart technology for Marine Litter SusTainable RemOval and Management
Project Acronym	MAELSTROM
Project Duration	January 2021 – December 2024
Project Budget	6 809 461.25 Euros
Related work package	WP7
Related task(s)	Task 7.2. Mapping Best Practices for ML removal and valorisation
Lead Organisation	CIIMAR
Contributing Organizations	CIIMAR; CNR; GEES; ALPHA
Dissemination Level	Public

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

Authoring & Approval

Authors	Beneficiary
Luis R. Vieira	CIIMAR
Gary Kett	CIIMAR
Isabel Sousa-Pinto	CIIMAR
Isabel Iglesias	CIIMAR
Sara C. Antunes	CIIMAR
Vanessa Moschino	CNR
Giorgio Betteto	GEES
Elizabeth A. Nerantzis	ALPHA

Reviewers	Beneficiary
Isabel Gomes	CIMA

Approved by	Beneficiary
Fantina Madricardo	CNR

History of changes

Version	Date	Author	Description of changes
V1	01/03/2024	Luis R. Vieira	First Draft
V2	06/04/2024	Luis R. Vieira, Gary Kett	Second Draft
V3	22/04/2024	Luis R. Vieira, Gary Kett	Draft shared with partners
V4	26/04/2024	Luis R. Vieira, Gary Kett, Isabel Sousa-Pinto, Isabel Iglesias, Sara C. Antunes, Vanessa Moschino, Giorgio Betteto, Elizabeth A. Nerantzis	Document with partners contributions
V5	27/04/2024	Luis R. Vieira, Gary Kett, Isabel Iglesias, Sara C. Antunes, Isabel Sousa-Pinto	Final Draft shared for revision
V6	29/04/2024	Isabel Gomes	Review by CIMA
V7	29/04/2024	Luis R. Vieira, Gary Kett, Isabel Sousa-Pinto	Modified version after CIMA review
V8	30/04/2024	Luis R. Vieira, Fantina Madricardo	Final Version

Co-funded by the Horizon 2020 programme of the European Union

Executive Summary

The MAELSTROM project aims to test and evaluate innovative technologies for the removal of marine litter (ML) in different coastal environments, while also assessing their impact on the ecosystems in chosen demo sites and evaluating the economic and societal benefits of the MAELSTROM solutions within local economies. Treatments of the plastic litter for their recovery within a circular economy concept are also foreseen.

The good practices for ML removal and valorisation encompass a range of strategies aimed at effectively addressing the pervasive issue of ML. These practices typically involve a combination of proactive measures to prevent littering, targeted clean-up efforts to remove existing debris, and innovative approaches to recycle or repurpose collected waste. Key components of good practices include: Prevention, Monitoring and Evaluation, Removal, Recycling, Valorisation, Stakeholder Collaboration and Partnerships.

The main purpose of the Deliverable 7.2. is to summarise a list of good practices for ML removal and valorisation. This information is based on the joint efforts of networking and stakeholder engagement activities, as well as the projects and stakeholders identified so far. The criteria that will be considered include the type of technology used for removing marine plastic and litter, the potential impact on the marine ecosystem and biota, the possible use of removed ML in renewable energy and other circular bio-economy concepts, and the cost-benefit elements associated with the practice in terms of growth and job creation.

ATLANTIC PROJECT AWARD

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

Table of Content

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

List of Figures

List of Tables

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

Acronyms List

ACIVC - Vila do Conde Commercial Association

AI - Artificial Intelligence

AI-driven: Artificial Intelligence-driven.

AIR - Atlantic International Research Centre

AMU - Aix-Marseille University

APA - Portuguese Environment Agency

APLM - Association of the Plastic and Mold Industry (Portugal)

AU - Australia

AUVs - Autonomous Underwater Vehicles

CEPM - Committee on the Environment and Marine Pollution

CMIA - Vila do Conde Interpretation and Environmental Monitoring Centre (Portugal)

COGEVO - Waste management company in Venice, Italy

CONEPO - Waste management company in Italy

CR - Croatia

CVA – Clube de Vela Atlântico (Portugal)

DE - Germany

DG - Directorate-General

DTU - Technical University of Denmark

ECSDE - European Centre for Sustainable Development and Environment

EEA - European Environment Agency

EMODNet - European Marine Observation and Data Network

EPR - Extended Producer Responsibility

ESA - European Space Agency

EU - European Union

FOCA- Focus On Critical Actions

FCT - Foundation for Science and Technology (Portugal)

GEO - Group on Earth Observations

GES - Good Environmental Status

GESAMP - Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

GPAP - Global Plastic Action Partnership

HCMR - Hellenic Centre for Marine Research

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

HEurope - Horizon Europe

HK - Hong Kong

ICNF - Institute for Nature Conservation and Forests (Portugal)

IFREMER - French Research Institute for Exploitation of the Sea

IMO - International Maritime Organization

INC - Intergovernmental Negotiating Committee

INDAQUA - Water management company in Portugal

INSTM - National Institute for Marine Sciences and Technologies

IOCCG - International Ocean Colour Coordinating Group

IPMA - Portuguese Institute for the Sea and Atmosphere

ISPRA - Italian National Institute for Environmental Protection and Research

JRC - Joint Research Centre

LFIP - Lycée Français International de Porto (Portugal)

LIFE - The Financial Instrument for the Environment and Climate Action

LIPOR - Intermunicipal Waste Management Service of Greater Porto (Portugal)

MAELSTROM - Smart technology for MArinE Litter SusTainable RemOval and Management

ML - Marine Litter

MSFD - Marine Strategy Framework Directive

MSP - Marine Spatial Planning

NGO - Non-Governmental Organization

NOAA - National Oceanic and Atmospheric Administration

OECD - Organization for Economic Co-operation and Development

OEOO - One Earth - One Ocean

OGS - National Institute of Oceanography and Applied Geophysics (Italy)

OSPAR - Convention for the Protection of the Marine Environment of the North-East Atlantic

REMEDIES - Co-creating strong uptake of REMEDIES for the future of our oceans through deploying plastic litter valorisation and prevention pathways

RFM - Recycled Fibre Material

SDG - Sustainable Development Goals

SUP - Single-Use Plastics

TGML - MSFD Technical Group on Marine Litter

TTU - Tallinn University of Technology

UN - United Nations

Co-funded by the Horizon 2020 programme of the European Union

UNCLOS - United Nations Convention on the Law of the Sea

UNEA - UN Environment Assembly

UNEP - United Nations Environment Programme

UNIFARDAS - Textile company in Portugal

UNIPD - University of Padua (Italy)

UNIVE - University of Venice (Italy)

UP - University of Porto (Portugal)

WP - Work Package

WWF - World Wide Fund for Nature

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

1 Introduction to the MAELSTROM Project

MAELSTROM is a four-year project Funded by the European Commission, under the H2020 Programme - Topic CE-FNR-09-2020 Pilot action for the removal of marine plastics and litter. The project compiles a consortium of 14 international partners led by the Institute of Marine Sciences of the Italian National Research Council (CNR-ISMAR). The project partners span academia and industry, using the expertise of research institutes, enterprises, and NGOs from 8 European countries. MAELSTROM's main goal is to reduce the impacts of ML in coastal ecosystems by identifying accumulation hotspots and removing the existing litter from the coastal seabed and the water column of rivers before it reaches the sea. This action is supported and enacted through thorough circular economy and societal-oriented solutions. In particular, the project (i) sets out a reliable multidisciplinary and scientifically sound approach for the assessment of marine debris distribution and impact on marine life in highly valuable ecosystems and protected areas; (ii) designs and manufactures scalable, replicable and automated technologies, co-powered with renewable energy and second generation fuel, to identify, remove and sort ML; (iii) evaluates over time the effectiveness of ML removal devices along with their impact on local ecosystems; (iv) integrates different technologies to track, sort and recycle all types of collected ML into valuable raw materials for future marketisation; (v) assesses the economic and societal impact of the MAELSTROM solutions providing also a comprehensive life-cycle assessment of the technologies and products; (vi) enhances social awareness about the ML issue and engages citizens and stakeholders in MAELSTROM activities; (vii) interplays with similar projects to maximise innovation uptake for ML removal within and outside the EU.

Co-funded by the Horizon 2020 programme of the European Union

2 MAELSTROM Consortium

The MAELSTROM project consortium consists of:

CNR ISMAR Istituto di Scienze Marine	National Research Council	CNR	Project Coordinator Fantina MADRICARDO fantina.madricardo@ismar.cnr.it
Deltares	Deltares	Deltares	Frans BUSCHMAN Frans.Buschman@deltares.nl
L-Università ta' Malta	University of Malta	UOM	Luciano MULE' STAGNO luciano.mule-stagno@um.edu.mt
I.S.D.I GROUP	The International Sustainable Development Initiatives	ISDI	Manuel SCARPA m.scarpa@isdigroup.com
GEES RECYCLING	Gees Recycling Srl	GEES	Giorgio BETTETO geesretracking@gmail.com
Venice Lagoon Plastic Free	Venice Lagoon Plastic Free	VLPF	Davide POLETTO d.poletto@plasticfreevenice.org
cima Research Foundation	CIMA Research Foundation	CIMA	Isabel GOMES isabel.gomes@cimafoundation.org
tecnalia Member of Basque Research & Technology Alliance	TECNALIA RESEARCH & INNOVATION	TECNALIA	Damien SALLÉ damien.salle@tecnalia.com
Alpha Consult	ALPHA Consult	ALPHA UK	Emiliano SPALTRO es@alphacons.eu
ciimar	Interdisciplinary Centre of Marine and Environmental Research	CIIMAR	Isabel SOUSA-PINTO ispinto@ciimar.up.pt
ST Servizi Tecnici Società di Ingegneria	Servizi Tecnici	ST	Nicola FERRARI n.ferrari@stvenezia.com
The Great Bubble Barrier	The Great Bubble Barrier	TGBB	Philip EHRHORN philip@thegreatbubblebarrier.com
MAKEEN POWER	MAKEEN	MAKEEN	Anders BJORN ABJ@makeenenergy.com
cnrs Centre National de la Recherche Scientifique	National Center for Scientific Research	CNRS	Marc GOUTTEFARDE marc.gouttefarde@lirmm.fr

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

3 Aim of the Deliverable

This Deliverable identifies the main mapped policies, key projects and initiatives, and multisectoral stakeholders from a regularly updated database during the first three years of MAELSTROM. In this period, the project has implemented two innovative and environmentally sustainable technologies to achieve this goal. These technologies consist of a Bubble Barrier to intercept floating and sub-surface litter on rivers before they enter the oceans, powered by sustainable energy derived from innovative floating photovoltaic panels, and a completely new solution for the removal of small and large items from the seabed in the form of a Robotic Seabed Cleaning Platform, already successfully tested in the Venice coastal area. An AI-driven robot is used to identify and segregate plastics collected from the coastal environment, and three new processes have been used to recycle the retrieved organic and plastic litter. These are transformed into higher-value materials whose characteristics, performance, and economic value are assessed for future marketization. The project focuses on the involvement of the local, national, and international stakeholders, paving the way to the long-term adoption of the technologies by the local stakeholders in the pilot areas. MAELSTROM carries out several actions to enhance ocean literacy and community engagement. Frequent public clean-up events situated on beaches in Portugal, Spain, and Italy have provided an engagement and education platform for citizens to improve awareness around the issues of ML and the tools used in addressing the problem. The project team has also organised public demonstrations of the ML removal technologies at several national, European and international scientific conferences and High-Level meetings which are discussed in Section 4. The public demonstration and launch of the Robotic Seabed Cleaning Platform in the Venice lagoon took place in June 2023 and the launch of the Bubble Barrier in the Porto region took place in October 2023, involving, informing, and inspiring citizens across Europe. The project has delivered webinars and a freely available newsletter designed to communicate both the problems and solutions of ML pollution to a wider audience.

Stakeholders have been involved from the beginning of the project as core actors, each with particular and dedicated levels of communication and involvement. Actors such as environment management entities; waste management and remediation companies; local enterprises and commercial entities; local, regional and national governments; industry partners; civil society; and local schools and community groups, have been closely collaborated with in the design, coordination, and

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

implementation of the project, demonstrating enthusiasm and support for MAELSTROM's contribution to the ML problem. Citizen engagement was crucial in this project, fostering empathy towards the issue ML and promoting joint efforts to safeguard aquatic environments for future generations. Implementing effective strategies to address ML requires the early involvement of local management entities, such as those engaged in Vila do Conde, Portugal, and the Veneto region, Italy, as core stakeholders in the co-design and co-implementation of the new removal technologies. Additionally, the integration of the academic community into initiatives like MAELSTROM ensures access to cutting-edge research and expertise. Through strategic networking, event participation, and active engagement, projects can build a diverse community of knowledge-holders, experts, and professionals, fostering unbiased, multidisciplinary collaboration. This approach promotes the sharing of diverse perspectives, ultimately contributing to more holistic and sustainable solutions for tackling ML.

Based on this information, this Deliverable proposes a list of 100 **Good Practices** to tackle ML, also based on the experienced good practices from MAELSTROM and networking initiatives (webinars, workshops, building capacity and demonstrations) with other projects.

3.1 Definitions of the general context

Marine Litter (ML) refers to "any persistent, manufactured, or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment" (UNEP, 2005). This includes items made of various materials such as plastic, metal, glass, rubber, wood, paper, and textiles. ML can be originated from a wide range of sources, including land-based activities (e.g., improper waste disposal, littering), and maritime industries (e.g., shipping, fishing). ML poses significant threats to marine ecosystems, wildlife, human health, and economic activities, and addressing this issue requires coordinated efforts at local, national, and international levels to prevent, reduce, and mitigate its impacts.

Addressing ML requires a multifaceted approach encompassing detection, monitoring, collection, and valorisation. Several initiatives carried out at European Regional Seas level have sought to gather information on ML state-of-the-art and good practice measures in order to concretely support the implementation of the EU Marine Strategy Framework Directive.

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

An effective detection involves the use of various technologies such as remote sensing, aerial surveys, satellite imagery and the development of algorithms and artificial intelligence techniques to identify litter accumulation areas and track its movement patterns. Additionally, citizen science initiatives empower communities to contribute data on litter distribution through beach cleanups and shoreline surveys.

Monitoring efforts are essential for assessing the scope and impact of ML on ecosystems and wildlife. Regular surveys and standardised data collection protocols enable researchers and policymakers to understand trends, identify sources of pollution, and prioritise areas for intervention. Monitoring also involves the use of advanced tools like underwater drones and acoustic sensors to survey litter in hard-to-reach areas such as the seafloor.

Collection methods range from manual collection by divers from the seafloor, beach cleanups to automated systems deployed in rivers, harbours, estuaries and coastal areas. Volunteer-driven manual cleanup initiatives mobilise communities to remove litter from beaches and shorelines. Other cleanup initiatives can include specialised vessels equipped with nets and skimmers which target floating debris in marine environments. In addition to the classical activities there are also emerging technologies like ocean cleanup arrays and autonomous drones offer innovative solutions for large-scale litter removal.

Finally, valorisation is focused on transforming collected litter into valuable resources through recycling, repurposing, and conversion processes. Recycling facilities sort and process plastic waste into raw materials for manufacturing, reducing the demand for virgin plastics and diverting waste from landfills. Repurposing initiatives involve turning discarded materials into useful products such as eco-friendly textiles, construction materials, and artwork. Advanced valorisation techniques like pyrolysis and chemical recycling convert plastic waste into fuels, chemicals, and other high-value products, contributing to a circular economy model.

It must be enhanced that collaboration among stakeholders is essential for implementing effective litter management strategies. Governments, non-governmental organisations (NGOs), industries, academia, and local communities must work together to develop policies, allocate resources, and coordinate action plans to reduce the impact of ML on the environment. Public awareness campaigns and education programs (also including this issue in school curricula) raise awareness about the effects of ML and promote responsible waste management practices. Partnerships with industry stakeholders encourage innovation and

Co-funded by the Horizon 2020 programme of the European Union

investment in sustainable solutions, while community engagement fosters a sense of ownership and stewardship towards marine environments.

The promotion of **Good Practices** for ML detection, monitoring, collection, and valorisation require a comprehensive and coordinated approach involving technology, scientific research, community participation, and policy support. By combining these strategies, stakeholders can mitigate the environmental, economic, and social impacts of ML while working towards cleaner and healthier rivers, estuaries and oceans.

3.2 Policy context

ML is a complex issue with significant environmental, economic, and social implications. It requires immediate and coordinated action from local to global multisectoral stakeholders. Recognizing the urgency of this environmental challenge, several legislative frameworks focused on monitoring and valorising ML are already in operation, at both international and regional levels. These initiatives will be described below.

3.2.1 International level

Globally, the United Nations Convention on the Law of the Sea (UNCLOS, 1982) offers a legal foundation for ocean conservation and management, encompassing provisions concerning marine pollution, including ML. Similarly, the International Maritime Organization (IMO) plays a crucial role in setting regulations to prevent marine pollution from ships, including rules governing garbage disposal and management (MARPOL, 2017). These global initiatives represent concerted efforts to address the challenge of ML and underscore the importance of international cooperation in protecting the oceans. Furthermore, the recently established INC Plastic Treaty, formally known as the International Negotiations Committee on Plastic Pollution Treaty, represents a ground-breaking global initiative aimed at addressing the escalating crisis of plastic pollution. In March 2022, at the resumed fifth session of the UN Environment Assembly (UNEA-5.2), a historic resolution was adopted to develop an international legally binding instrument on plastic pollution, including in the marine environment. Resolution 5/14 tasked the Executive Director of UNEP to convene an Intergovernmental Negotiating Committee (INC) to craft a comprehensive instrument addressing the entire plastic life cycle. INC commenced in late 2022, aiming to conclude by 2024. Sessions included INC-1 in Uruguay (Nov-Dec 2022), INC-

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

2 in France (May-June 2023), and INC-3 in Kenya (Nov 2023). INC-4 was set for April 2024 in Canada, and INC-5 for Nov-Dec 2024 in Korea. As the world grapples with the environmental, economic, and health impacts of plastic waste, the treaty emerges as a pivotal step towards international cooperation and collective action to mitigate these challenges. At its core, the INC Plastic Treaty seeks to establish a comprehensive framework for the reduction, management, and eventual elimination of plastic pollution. It recognizes the urgent need to curb the proliferation of plastic waste in our oceans, rivers, and ecosystems, which poses a severe threat to marine life, biodiversity, and human health. Complementing these efforts are voluntary initiatives like the Global Partnership on Plastic Pollution and Marine Litter and the Clean Seas campaign led by UNEP, fostering international cooperation.

3.2.2 European level

The European Union (EU) has been actively tackling ML through a multifaceted approach, encompassing legislation, funded projects, and initiatives. Key legislative measures include the Marine Strategy Framework Directive (MSFD, 2008; 2008/56/EC), which mandates member states to achieve Good Environmental Status (GES) in European marine waters, incorporating specific provisions addressing ML, as well as other initiatives as the EU Plastic Strategy, EU Green Deal, EU Waste Framework Directive, Directive on single-use plastics, EU Action Plan Towards Zero Pollution for Air, Water and Soil.

The MSFD stands as a comprehensive legislative framework within the EU, aimed at ensuring the protection and sustainable use of marine waters across EU territories. MSFD aims to achieve and maintain a GES of the marine environment by 2020. The MSFD identifies 11 qualitative descriptors that characterise GES. These descriptors serve as criteria to assess the environmental status of marine waters across EU member states. Here are the 11 MSFD descriptors: (1) Biodiversity; (2) Non-indigenous species; (3) Commercially exploited fish and shellfish populations; (4) Food webs; (5) Human-induced eutrophication; (6) Seafloor integrity (7) Hydrographical conditions; (8) Contaminants; (9) Contaminants in seafood (10) ML; and (11) Energy and Noise. Recognizing ML as a significant environmental challenge threatening marine ecosystems, biodiversity, human health, and economic activities, the MSFD tackles this issue through its ML Descriptor. This Descriptor encompasses various dimensions including abundance, distribution and spatial extent, composition, impact on biotic components, and economic and social impacts, guiding member

Co-funded by the Horizon 2020 programme of the European Union

states in evaluating and addressing ML pollution comprehensively. By following these criteria, member states can conduct thorough assessments, identify priority areas for action, and implement targeted measures such as waste management policies, sustainable consumption and production practices. This should be performed by enhancing monitoring capabilities, and fostering international cooperation, ultimately striving towards achieving GES under the ML Descriptor to ensure the long-term health and sustainability of marine ecosystems for present and future generations.

The EU Plastic Strategy, initiated in 2018 (EC, 2018), is a holistic plan to combat plastic waste and pollution. It targets single-use plastics, encouraging alternatives to reduce waste. With Extended Producer Responsibility (EPR), manufacturers are accountable for recycling and disposal. Promoting recycling and a circular economy, it aims to increase plastic recycling rates and reuse packaging. To prevent ML, the strategy focuses on better waste management and awareness. International cooperation is crucial, advocating global initiatives. Innovation drives eco-friendly solutions, steering away from conventional plastics.

The EU Green Deal (Fetting, 2020) is a comprehensive plan launched by the European Commission in 2019 to transform Europe into a sustainable, climate-neutral economy by 2050. It encompasses various policy initiatives aimed at reducing greenhouse gas emissions, enhancing energy efficiency, promoting renewable energy sources, and fostering circular economy principles. The Green Deal also includes measures to protect biodiversity, improve air and water quality, and ensure a just transition for workers and regions affected by the transition to a green economy. Key components of the Green Deal include the European Climate Law, which enshrines the goal of climate neutrality by 2050 into law, the European Industrial Strategy for a clean and circular economy, the Farm to Fork Strategy for sustainable food systems, and the Renovation Wave initiative to improve the energy efficiency of buildings. The Green Deal emphasises the importance of investment in green technologies and infrastructure, as well as international cooperation to address global environmental challenges. Overall, the EU Green Deal represents a bold and ambitious vision for a sustainable future for Europe.

The EU Waste Framework Directive (Directive (EU) 2008/98/EC) sets out a legal framework for waste management in the EU. It promotes the hierarchy of waste management: prevention, reuse, recycling, and lastly, disposal. The directive aims to minimise the environmental impact of waste generation and disposal, encourage

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

resource efficiency, and foster the transition to a circular economy. It requires member states to establish waste management plans, monitor waste generation and treatment, and implement measures to prevent illegal dumping and hazardous waste management. The Waste Framework Directive was amended by the Directive (EU) 2018/851. The new Directive specifically recognises that ML is a particularly persistent problem and measures should be taken to reduce it.

The Directive on single-use plastics (Directive (EU) 2019/904) aims to reduce ML, particularly plastics, by imposing restrictions on the production and consumption of single-use plastic products and fishing gear made of plastic. It also includes measures to promote sustainable alternatives and improve waste management practices. The directive requires member states to take measures to achieve these goals, including setting reduction targets, implementing producer responsibility schemes, and raising public awareness. By addressing the most problematic single-use plastics, the directive seeks to minimise plastic pollution and promote a shift towards more sustainable practices.

The EU Action Plan Towards Zero Pollution (EC, 2021) is a comprehensive strategy to tackle pollution of air, water, and soil. It aims to reduce pollution levels to protect human health and the environment. The plan includes measures to improve air quality, reduce emissions from industrial activities, enhance water quality and management, and promote sustainable soil management practices. It also emphasises the importance of implementing pollution prevention measures, fostering innovation, and promoting international cooperation to address transboundary pollution issues. Overall, the plan seeks to achieve a cleaner and healthier environment for all EU citizens by minimising pollution levels and promoting sustainable development.

Additionally, the Directive on Port Reception Facilities (Directive (EU) 2019/883) obligates EU member states to establish facilities for ship-generated waste, including ML. The Circular Economy Action Plan further reinforces efforts by promoting a transition to a circular economy, reducing waste, and advocating sustainable resource use, including marine resources. At the regional level, agreements such as the OSPAR Convention and the Barcelona Convention, along with national legislation in many countries, contribute to ML management through waste management regulations and pollution prevention measures. These legislative frameworks form the foundation for monitoring ML, implementing preventive measures, and

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

promoting the valorisation of ML to reduce environmental harm, underscoring the collaborative approach required to address this global challenge effectively.

In addition to legislative frameworks and international agreements, the effective ML management also relies heavily on the adoption of good practices. Implementing these practices at all levels, from local communities to national governments and international organisations, is essential for achieving meaningful progress in tackling ML. Good practices encompass a range of measures, including improved waste management systems, sustainable consumption and production practices, enhanced monitoring and enforcement mechanisms, and the promotion of public awareness and engagement. By integrating these good practices into existing strategies and initiatives, such as the ones previously mentioned, we can strengthen the collective efforts to prevent, detect, collect and valorise ML, advancing towards an effective circular economy. Moreover, fostering innovation and collaboration among stakeholders will be crucial for identifying and implementing new solutions to address this pressing global challenge. By prioritising **Good Practices** and embracing innovative approaches, it will be possible to develop joint strategies towards a future to significantly reduce ML, ensuring the long-term ecosystems health and sustainability for generations to come.

3.3 Scope of this deliverable

This deliverable describes the reasoning and methods for the collection of "Good Practices" in ML management, and presents a collection of suggested good practices to be considered across four separate pillars, namely: "Prevention and Reduction", "Monitoring and Detection", "Removal", and "Recycling, Valorisation and Circular Economy". These practices are collated through MAELSTROM partner expertise, available literature, and strategic networking and engagement initiatives to share knowledge amongst the academic, civic sector, and industry-partner communities. All four pillars are considered throughout the lifecycle of plastic pollution, i.e. examining the problem with upstream and downstream actions, **upstream** being those that affect policy and the prevention of waste materials, and **downstream** actions the ones which focus on the collection, removal and reuse of litter.

It should be noted, that the term "Best Practices" as used in the Deliverable title, is not deemed entirely appropriate by the authors, due to the practices in question being

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

highly contextual, non-specific, and difficult to apply broadly. It is therefore recommended to utilise the term "Good Practices" as will be done for the purpose of this document. **Good Practices** are actions or behaviours which have been found, by experience, to result in positive outcomes in the topic or activity in question. They are being made available in order to be considered for ML management interventions, however, should not be thought of as universally the best options and care should be taken to include and value local conditions, indigenous knowledge, traditional conventions and other particularities of the region in which the project is being implemented.

4 Methods

This section describes the methodology employed to collect and analyse the good practices for the reduction of ML, focusing on the pillars of **Prevention** and **Reduction**", "**Monitoring** and **Detection**", "**Removal**", and "**Recycling** and **Valorisation**". The process involved several key steps, including the establishment of a comprehensive database including projects dedicated to addressing ML. Additionally, strategic networking initiatives were undertaken to ensure the inclusion of diverse perspectives and innovative strategies. Stakeholder engagement played a pivotal role, facilitating the identification and dissemination of good practices through collaborative efforts. Furthermore, a database of stakeholders was curated to foster ongoing and future dialogue and knowledge exchange.

4.1 Collecting the **Good Practices**

The collection of knowledge from experts, stakeholders, and practitioners of ML science, technology, and interventions has been carried out within the MAELSTROM project in a targeted and strategic manner through the work package 7 (Coordination and Integration of blue technology for EU plastic strategy) framework. This process involved the mapping of institutions, European projects, and key stakeholders, and engaging with them through the organisation of, and attendance at, events, workshops, webinars, and conferences. MAELSTROM has organised a total of 3 workshops, 4 webinars, and more than 20 events such as public information days, technology demonstration activities, and stakeholder meetings with administrative and other knowledgeable parties (section 4 and Deliverable 7.1.). These collective events were designed in a deliberate manner to acquire the knowledge of

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

stakeholders from a broad and multidisciplinary background. Workshops were focused on the "Opportunities and Challenges in ML Collection" in order to bring together individuals and groups actively working on the issue and gather the lessons learned from different ML interventions around Europe. Webinars were organised in a manner that allowed deep-dive discussions with experts from a diverse array of scientific backgrounds. Furthermore, MAELSTROM organised several meetings with local stakeholders including municipalities, waste management entities, educational institutions, and international NGOs and groups tackling the issue of ML. Here, advice was sought on effective practices, lessons learned, and helpful input of various forms. In addition to the events and activities organised by MAELSTROM, the networking and engagement team within WP7 also attended more than 10 events such as international forums, scientific conferences, and science-policy meetings (section 4.2.1. and Deliverable 7.1.). These events facilitated the collection of knowledge through discourse and networking.

4.1.1 Database of projects

The information gathered during the identification of ongoing EU projects focused on ML issues was summarised in Table 1.

Table 1 - Ongoing EU projects identified as highly relevant for ML prevention, detection, removal and valorisation.

Project name	Description	Coordinator	Active	Website
INSPIRE	Innovative Solutions for Plastic Free European Rivers	VLIZ, Belgium	2023 - 2027	inspire-europe.org
UPSTREAM	Circular and Bio-Based Solutions for the Ultimate Prevention of Plastics in Rivers Integrated with Elimination And Monitoring Technologies	AITIIP Technology Centre, Spain	2023 - 2027	aitiip.com/en/rdi/projects/project-upstream.html

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

REMEDIES	Co-creating strong uptake of REMEDIES for the future of our oceans through deploying plastic litter valorisation and prevention pathways	Kemijski Institute (KI), Slovenia	2022 – 2026	remedies-for-ocean.eu
SeaClear 2.0	Scalable Full-cycle ML Remediation in the Mediterranean: Robotic and Participatory Solutions	Technical University Delft (TU Delft), Netherlands	2023 – 2026	seaclear2.eu
SOS-Zero-Pol	Source to Seas Zero Pollution 2030	MaREI, University College Cork, Ireland	2022 – 2026	soszeropol2030.eu
NETTAG+	Preventing, avoiding and mitigating environmental impacts of fishing gears and associated ML	CIIMAR, Portugal	2023 - 2026	nettagplus.eu
POLYRISK	Understanding human exposure and health hazard of micro- and nano plastic contaminants in our environment	Utrecht University (UU), Netherlands	2021 - 2025	polyrisk.science
SEARCULAR	Circular solutions for fishing gears	Fundación AZTI, Spain	2023 - 2026	cordis.europa.eu/project/id/101112852

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

LabPlas	Understanding the sources, transport, distribution and impacts of plastic pollution	University of Vigo (UVigo), Spain	2021 – 2025	labplas.eu
LIFEMUSSELS	Life MUssel Sustainable production (re)cyCLES	Legambiente Nazionale APS Onlus, Italy	2021 – 2025	lifemuscles.eu
Plastic Busters MPA	Plastic Busters Marine Protected Areas	ISPRA, Italy	2018 – 2025	plasticbustersmpas.interreg-med.eu
NAUTILOS	New Approach to Underwater Technologies for Innovative Low-Cost Ocean Observation	CNR, Italy	2020 - 2024	nautilos-h2020.eu
ENZYCLE	Microbial enzymes for treatment of non-recycled plastic fraction	Itene, Spain	2020 - 2024	enzycle.eu
InNoPlastic	Innovative approaches towards prevention, removal and reuse of plastic ML	SINTEF AS, Norway	2020 - 2023	innoplastic.eu
Black Sea CONNECT	Coordination of Marine and Maritime Research and Innovation in the Black Sea	Middle East Technical University (METU), Turkey	2019-2023	cordis.europa.eu/project/id/860055

Co-funded by the Horizon 2020 programme of the European Union

SeaClear	SEarch, identificAtion and Collection of ML with Autonomous Robots	Technical University Delft, Netherlands	2020 – 2023	seaclear-project.eu
PLASTECO	Supporting EU regions to curb plastics waste and littering	Municipality of Rethymno, Greece	2019 – 2023	projects2014-2020.interregeurope.eu/plasteco
EUROqCHARM	Plastic pollution assessment and monitoring - standardising the methods	NIVA - Norwegian Institute for Water Research, Norway	2020 – 2023	euroqcharm.eu
LIMNOPLAST	Microplastics in Europe's freshwater ecosystems: From sources to solutions	Bayreuth University (UBT), Germany	2019 - 2023	limnoplast-itn.eu
CAPonLITTER	Capitalising good coastal practices and improving policies to prevent ML	NOVA School of Science and Technology, Portugal	2019 - 2023	projects2014-2020.interregeurope.eu/caponlitter
HOTMIC	Horizontal and vertical oceanic distribution, transport and impact of microplastics	GEOMAR Helmholtz Centre for Ocean Research, Germany	2020 – 2023	jpi-oceans.eu

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

FACTS	Fluxes and Fate of Microplastics in Northern European Waters	Aalborg University (AAU), Denmark	2020 - 2023	jpi-oceans-facts.eu
MicroplasticX	Integrated approach to the fate of Microplastics (MPs) towards healthy marine ecosystems	Royal Institute of Technology (KTH), Sweden	2020 – 2023	microplastix.org
ANDROMEDA	Developing techniques for quantifying nanoplastics & microplastics and their degradation in the marine environment	MIO - Institut Méditerranéen d'Océanologie, Université d'Aix-Marseille, France	2020 - 2023	andromedaproject.net
I-Plastic	Dispersion and impact of micro and nano plastics in the tropical and temperate oceans	Catalan Institution for Research and Advanced Studies (ICREA), Spain	2020 - 2023	jpi-oceans.eu/en/i-plastic-2020-2023
RESPONSE	Towards a risk-based assessment of microplastic pollution in marine ecosystems	Polytechnic University of Marche (UNIVPM), Italy	2020 – 2023	jpi-oceans.eu/response
MIX UP	MIXed plastics biodegradation and UPcycling using microbial communities	RWTH Aachen University, Germany	2020 - 2023	mix-up.eu/project

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

4.2 Strategic Networking

4.2.1 Webinars and workshops

To date, four webinars and three workshops have been organised by the MAELSTROM project in order to collect knowledge from academics and practitioners on their recommended "Good Practices" learned from previous experience. The three series of the workshops were carried out under a recurring theme of "Marine Litter Monitoring, Removal and Circular Economy: Challenges and Opportunities" involving the collaboration of EU-funded projects such as In-No-Plastic and ENDURUNS (H2020), SeaClear 2.0 and WINBLUE (HEurope) and DREAM (Life) (Table 1). The four webinars focused on topics such as "Building Capacity in detection and tracking ML", with the European Open Science Cloud; "Biodiversity and ML: Monitoring and co-detection", with the AIR Centre Biodiversity Networking Series; "Inspiring Science and Society to Tackle ML", with the UN Ocean Decade Laboratories as a satellite activity; and most recently the "One Ocean, One Health" webinar, with the BlueMissionAA CSA for the Atlantic-Arctic Lighthouse of the EU Mission Oceans (*for more information consult MAELSTROM Deliverables 7.1. and 7.3).*

4.3 Stakeholder engagement

4.3.1 Community engagement

The engagement of both civil and civic partners has been an important step in the collection of knowledge around good practices for ML. MAELSTROM has been exceptionally poised to foster relationships with citizens, administrations, authorities, and industry representatives from local to European levels. These engagements, carried out within the framework of co-design, collaboration, and community-building, have allowed stakeholders, including citizens, youth, and administrations, to be consulted on their knowledge and express feedback and opinions. This facilitated a co-learning environment where education occurred bi-directionally and lessons learned could be gathered from all stakeholders. These engagements primarily took the form of Beach Cleanups with Citizen Science, institutional information "open" days, and ML removal technology demonstrations. The MAELSTROM team has used these engagement opportunities to continuously improve the experiences and gather feedback from both practitioners (organisers) and participants of these events to establish some of the good practices laid out in section 5.

Co-funded by the Horizon 2020 programme of the European Union

4.3.2 Local, Regional and National Governments and Authorities

Local, regional, and national governments, administrations, authorities, and organisations played a crucial role in successfully implementing MAELSTROM technologies to address ML. Several meetings and workshops were organised to understand the requirements and gather input from governmental bodies, authorities, and communities. These meetings aimed to oversee the prevention, monitoring and address context-specific challenges, identify opportunities, and plan coordinated actions for collecting recycling, and valorising ML. Through collaborative efforts, consensus was reached to implement pilot technologies such as the Bubble Barrier in Vila do Conde, Portugal, and a Robotic Seabed Cleaning Platform in the Venice coastal Area, Italy.

4.4 Database of stakeholders

The main stakeholders involved in MAELSTROM activities were identified and summarised on Table 2. Many of the stakeholders, e.g. the local municipalities, had interest, expertise, and involvement in several pillars and so have been helpful in understanding the needs of various non-scientific organisations, the current practices of implementing ML waste management, and the areas where improvements can be made for effective prevention, detection, removal, recycling, and valorisation of ML.

*Table 2 - Main stakeholders involved with the MAELSTROM project, which participated in the outreach events, including the engagements which led to the creation of this **Good Practices** database*

Stakeholder Category	Entity	Primary Pillar of involvement
Government: Local authority	Municipality of Vila do Conde (PT) Vila do Conde Captaincy (PT) Municipality of Venice (IT)	Prevention, Monitoring Removal, Recycling

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

	Scuba Diving unit of the Italian National Police, Venice team (IT)	
Government: Regional authority	CCDR-N (PT) Veneto Region (IT) Provveditorato Interregionale per le Opere Pubbliche per il Veneto, Trentino Alto Adige e Friuli Venezia Giulia (IT) North Adriatic Sea Port Authority (IT)	Prevention, Removal, Recycling
Government: National authority	APA (PT) ICNF (PT) Docapesca (PT) National Maritime Authority (PT) ARPA Veneto (IT)	Prevention, Monitoring Removal, Recycling, Valorisation
Government: International authority	DG-ENV (EU) DG-CINEA (EU) DG-MARE (EU) DG-RTD (EU) JRC (EU)	Prevention, Removal, Recycling, Valorisation
International Research community	Horizon Programme Atlantic Stakeholders Platform Life Programme Biodiversa+ AIR Centre EU Mission Ocean	Prevention, Removal, Recycling, Valorisation
National Research community	FCT (PT) UPorto (PT) ISPRA (IT) OGS (IT) UNIVE (IT) UNIPD (IT)	Prevention, Removal, Recycling, Valorisation
Regional and Local business	ACIVC (PT) LIPOR (PT) UNIFARDAS (PT) Venice Chamber of Commerce (IT) VERITAS S.p.A (IT) CONEPO FACILITY (IT) COGEVO Venezia (IT) Cooperativa San Marco – Pescatori di Burano (IT)	Removal, Valorisation
International business	Blue BioEconomy (EU) Sustainable Blue Economy Partnership (EU) EU Business & Biodiversity Platform (EU)	Removal, Valorisation

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

Environmental Charity	Associação Bandeira Azul de Ambiente e Educação (ABAAE) (PT) Urban Nature Atlas (PT) FOCA (PT) The Portuguese Plastics Pact (PT) APLM (PT) MedSea Foundation (IT) VLPF (IT) WWF Veneto (IT) LEGAMBIENTE Venezia (IT) MIO – ECSDE (IT)European Green Foundation (EU)	Prevention, Monitoring, Removal, Recycling, Valorisation
Local Educational Institute	CMIA Vila do Conde (PT) Vila do Conde Schools Grouping (PT) Colégio do Forte (PT) LFIP - Lycée Français International Porto (PT) Porto British School (PT)	Prevention, Removal
International Education and Citizen Science	Plastic Pirates (EU) EU4Ocean (EU) UNESCO Open Science Hub (PT/EU) Eco-Escolas (EU)	Prevention, Removal
General Public	Clube Fluvial Vilacondense (PT) CVA (PT) BioDiversidade4All (PT) INDAQUA Vila do Conde (PT) SmartVenice (IT) Venice Sustainability Foundation (PT)	Prevention

5 Results

5.1 Strategies for addressing ML

Good practices to tackle ML encompass a holistic approach that addresses prevention, detection, collection and valorisation. **Prevention** strategies include public awareness campaigns, policy interventions, and investment in waste management infrastructure to reduce litter input. Cleanup efforts involve volunteer-driven initiatives that lead to awareness. **Detection** involves advanced technologies like remote sensing to identify litter accumulation areas. ML **Collection** requires the implementation of advanced technologies that can effectively remove ML from rivers,

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

estuaries and oceans (e.g. Trash Wheel, Bubble Barrier and Robotic Seabed Cleaning Platform). This process involves deploying specialised equipment designed to collect ML. To ensure success, advanced removal technologies must be combined with scientific monitoring campaigns, volunteer-driven initiatives, and stakeholder engagement. **Valorisation** transforms collected litter into valuable resources through recycling and repurposing, promoting a circular economy. This process minimises waste in landfills and oceans while conserving natural resources by reintroducing materials into the production cycle. ML valorisation initiatives create economic opportunities and drive innovation in sustainable waste management practices. By harnessing the potential of valorisation, we can address ML while advancing towards a more sustainable and resource-efficient society.

Collaboration and partnerships among governments, NGOs, industries, and communities enhance the effectiveness of litter management efforts. Education and awareness-raising campaigns empower individuals to adopt sustainable practices and become stewards of marine ecosystems. Together, these **Good Practices** contribute to a cleaner and healthier future for our oceans.

5.2 Prevention

5.2.1 Strategies for prevention

Strategies to prevent ML include public awareness campaigns, policy interventions, and investment in waste management infrastructure to reduce the input of litter into freshwater, estuarine and marine environments. This mission requires effective collaboration and partnership between all societal actors. Public-private partnerships promote innovation and investment in sustainable solutions, while cross-sectoral collaboration ensures a coordinated approach to tackling marine pollution. Capacity building and knowledge sharing initiatives empower stakeholders with the tools and resources needed to make informed decisions and take meaningful action. In addition, the formation and investment in business-policy advisory groups to guide industries in sustainable transition e.g. Global Plastics Policy Centre, Verra Plastic Program Advisory Group, GRID Arendal Science Policy Interface for Plastic Pollution, Global Plastic Action Partnership (GPAP), Rethink Plastic, Plastics Europe, have proven to be integral components in the transition to a waste-free environment.

Citizens and NGOs play a pivotal role in driving interventions to combat ML. They are deeply rooted in local communities, possessing a strong vested interest in fostering

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

a litter-free environment for the betterment of the local quality of life, economics, and health. Their close ties and familiarisation with the surroundings endow them with a deep and strong local knowledge of not only the environment but also the socio-cultural heritage. This also enables them to mobilise support from other community members, organisations, and businesses. Leveraging their established networks can energise new initiatives and highlight potential local leaders who can champion projects. Engaging with local thought leaders aids in refining goals and ensures alignment with the community's needs. Furthermore, these leaders can facilitate connections with government officials and private sector entities willing to contribute with resources to support anti-litter efforts. Additionally, local organisations can offer valuable insights into identifying litter hotspots within the community.

Education programs and Citizen awareness-raising campaigns empower individuals to adopt sustainable practices and become stewards of marine ecosystems. By promoting environmental literacy and fostering a sense of ownership, these initiatives contribute to building a sustainable future for our oceans. Public participation and collaborative efforts in scientific research play a crucial role in addressing the complex challenge of ML. Several researchers have highlighted the necessity for joint innovative approaches to collecting and analysing data regarding the volume, distribution, breakdown processes, and ecological impacts of plastic pollution in oceans (e.g. Campbell et al., 2019; Fraisl et al., 2023). Citizen science initiatives and community-driven activities, such as targeted cleanups and plastic source identification, serve as effective and economical mechanisms for data collection while also acting as platforms for raising public awareness (Bettencourt et al., 2023).

Global initiatives like World Cleanup Day, Earth Challenge, Marine Debris Trackers, and ML Watch demonstrate successful citizen science endeavours that extend beyond litter removal to include the identification of sources, pathways, and accumulation zones. Despite the absence of globally standardised guidelines, the latest UNEP report on ML (2021) emphasises the importance of citizen science and community initiatives, particularly beach cleanups, in enhancing data availability. These grassroots efforts have also led to the development of technological tools such as mobile apps, further enhancing citizen engagement. Effective collaboration in citizen science requires close interaction between scientists, researchers, and community-based groups. Activities and data collected through these partnerships often provide valuable resources for modelling ML distribution and understanding its local ecosystem impacts and societal implications. Moreover, inclusive engagement extends to various societal actors, including civil society organisations

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

and educational institutions. The integration of citizen science and community initiatives offers a multifaceted approach to addressing ML, emphasising both data-driven strategies and broader societal engagement. The recommended **Good Practices** for ML **Prevention**, collated through MAELSTROM partner expertise, literature, and the strategic networking and engagement are presented in Table 3.

*Table 3 - Recommended **Good Practices** for **ML Prevention**.*

Nº	Action	Measure Category	Recommendation	Projects / Initiatives
P1	Upstream	Cleanup campaigns	Promoting multidisciplinary cleanups, bringing together volunteers from diverse backgrounds and expertise to tackle environmental challenges collaboratively. Combine efforts from various fields such as environmental science, engineering, and community outreach to maximise impact and address the root causes of ML pollution.	Sunset Cleanup World Cleanup Day ACTnow

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

P2	Downstream	Art and creativity workshops	Host art exhibitions, workshops, and events using ML as a medium to raise awareness and inspire creative solutions	Greener Festivals Movements Hellenic Centre for Marine Research - "Transform Litter to Art" Marine Institute "Explorers Education Programme" Rethinking Plastic "Tangled" LIFE SeaBill project Break Free From Plastic
P3	Upstream	Interdisciplinary collaborations	Foster interdisciplinary collaborations between scientists, policymakers, local knowledge holders, and communities to develop holistic solutions for ML management.	EU Mission Forum Surfrider Foundation Institute for Global Environmental Strategies (IGES) Plastic Oceans International
P4	Upstream	Educational and awareness raising campaigns	Improve knowledge on plastic waste leakages from land-based sources and develop targeted measures to inform relevant parties and effectively tackle ML	EEA
P5	Upstream	Capacity building programs	Provide training and capacity-building programs for local communities to participate in ML monitoring, cleanup, and management activities.	EEA

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

P6	Upstream	Environmental education programs	Integrate ML education into school curricula and youth programs promoting ocean literacy via workshops, events, and online resources to increase public understanding of marine ecosystems and threats.	Ocean Literacy Networks Ocean Youth Ambassador programmes Science Communication organisations
P7	Upstream	Science communication initiatives	Communicate scientific research and findings on ML in accessible and engaging formats for the general public.	Science Communication organisations
P8	Downstrea m	Social media campaigns	Utilise social media platforms more effectively with targeted content and coordination of content creators, utilising existing popular influencers and climate promoters to disseminate information, share success stories, and mobilise support for ML initiatives	Digital content creators Trash Traveller EU Projects social media management Science Communication organisations EU Mission Ocean Mobile Journalists
P9	Upstream	Community-based waste management	Collaborate with local communities to develop community-based waste management systems and infrastructure	Prep4Blue Atlantic Arctic AGORA

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

P10	Upstream	Youth engagement programs	Engage youth in local communities through environmental education, leadership development, and youth-led initiatives to address ML.	EU Youth4Ocean All-Atlantic Ocean Youth Ambassadors Atlantic Plastics Pilot Network Sustainable Ocean Alliance
P11	Upstream	Community engagement	Spotlighting local "champions" promoting ML awareness. Identify influential figures, community activists and showcase their commitment to the cause. Utilise their platforms to amplify messages, organise events, and engage the community. Their endorsement can inspire others to join the effort and drive meaningful change.	Make EU Blue Awards Marine Institute Ocean Champions Projects
P12	Upstream	Prevention	Involving fishermen communities in implementing education and awareness programs, providing incentives for responsible waste management practices, promoting the use of sustainable fishing gear, establishing effective waste collection and recycling facilities at ports, and enforcing regulations to prevent littering at sea.	Projects with local, national and international fishermen associations Nettag+ EU Fishing for Litter
P13	Downstream	Educational and awareness raising campaigns	Awareness actions with school, walkers, centres and diving clubs for collection, classification and quantification of littergenerated in the course of daily fishing activities.	Eco-ports (Spain); The MARVIVA Fishing for Litter project;

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

P14	Upstream	Extended Producer Responsibility (EPR) schemes	Implementing "recycling" initiatives with Reverse Vending Machines (RVMs). Businesses, mainly retailers, collect beverage containers and later sell them back. Users are incentivized with money or discounts at participating businesses.	"We win by recycling" initiative Deposit-Refund Schemes
P15	Upstream	Plastic packaging reduction commitments	Reduce or ban single-use plastic packaging and implement reusable or compostable alternatives in product packaging. This can be achieved with developing and promoting plastic-free product lines and packaging options to minimise plastic pollution and support circular economy principles	EU Single Use Plastic Directive
P16	Upstream	Industry collaboration platforms	Establish industry-led platforms and partnerships to share good practices, collaborate on research, and address common challenges related to ML. This can be encouraged through the determined green procurement policies that prioritise products and suppliers with sustainable packaging and waste management practices. Civic sector should lead by example in this effort	Mission Ocean, Seas and Waters Implementation Support Platform OECD Science Technology and Innovation platform UN SDG Compass
P17	Upstream	Plastic-free product lines	Develop and promote plastic-free product lines and packaging options to minimise plastic pollution and support circular economy principles	The Green Marketing Academy Ecco-Verde PackHelp EcoEnclose

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

P18	Upstream	Voluntary commitments and pledges	Encourage companies to make voluntary commitments and pledges to reduce plastic pollution and support ML initiatives Encourage lifeguards, professionals active on beaches during the period of greatest human activity, to promote environmentally sustainable measures for waste on beaches	ACIVC LIPOR UNIFARDAS Venice Chamber of Commerce VERITAS S.p.A CONEPO FACILITY COGEVO Venezia Cooperativa San Marco – Pescatori di Burano
P19	Downstream	Innovation challenges and prizes	Host innovation challenges and prize competitions to incentivize the development of technologies and solutions for ML detection and cleanup.	Specific calls from European Research and Innovation projects for e.g. REMEDIES, SeaClear2.0
P20	Upstream	Industry certification programs	Certify businesses and products that adhere to sustainable practices and contribute to reducing ML pollution	Global Plastics Policy Centre
P21	Upstream	Cigarette litter abatement fee	Awareness campaigns to drive behaviour change among smokers regarding cigarette litter abatement and fees, through crafting compelling messages emphasising litter's environmental impact and proper disposal benefits, in social media, PSAs, and community events.	MyWaster BIN IT Campaign Keep Britain Tidy BinTheButt Campaign Clean Coasts Anti-Smoking Litter Campaign
P22	Upstream	Eco-labelling and Environmental Management	Encourage the restaurant industry to adopt more sustainable practices, zero-waste and disposable plastic, minimising their environmental impact.	Surfrider Ocean Friendly Restaurant

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

P23	Upstream	Promotion of Eco Practices	Promoting responsible ecotourism by engaging campers in waste sorting and encouraging the use of reusable bags during their stay. Encourage participation through educational initiatives and incentives, fostering a culture of sustainability within the camping community.	National tourism organisations
P24	Upstream	Promotion of Eco Practices	The Blue Flag initiative tackles ML by promoting sustainable practices among beachgoers. Through education and awareness, it encourages responsible waste disposal and the use of reusable items. Blue Flag beaches implement cleanup efforts and engage local communities to protect marine environments from litter.	Foundation for Environmental Education annual Blue Flag award Local harbourmasters, captaincies, and port authorities
P25	Upstream	Prevention	Implementing separate sanitation networks for wastewater and runoff can mitigate MLby preventing untreated sewage and urban runoff from reaching water bodies. This approach reduces the introduction of litter into marine ecosystems, preserving water quality and biodiversity.	Municipalities (e.g. Vila do Conde, Venice) Urban water cycle management companies
P26	Upstream	Awareness raising campaigns	Sewer drains free from litter campaigns aiming to prevent litter from entering stormwater drains, placing signs to inform citizens how they are connected to the sea and about ML	ullapoolseasavers.com/what-we-do/campaigns/drain-campaign

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

P27	Upstream	Awareness raising campaigns	Promotion of effective "Zero-plastic events" avoiding single-use plastics, opting for reusable or compostable alternatives to minimise environmental impact, and contributing to sustainability and responsible consumption practices by eliminating plastic waste from event operations.	Municipalities promotion (e.g. Vila do Conde; Venice) Associação Bandeira Azul de Ambiente e Educação (ABAAE) Urban Nature Atlas) FOCA The Portuguese Plastics Pact APLM MedSea Foundation VLPF WWF Veneto LEGAMBIENTE Venezia MIO – ECSDE European Green Foundation
P28	Upstream	Policy Support	Policy briefs and position papers providing recommendations and advocating international cooperation for regulations, directives alignment, waste management improvements, innovation for prevention, and awareness campaigns to adequately address river-marine litter.	MAELSTROM Policy Briefs (2022, 2024) Source to Seas Zero Pollution Policy Brief Interreg Policy Brief Halting ocean plastics pollution
P29	Upstream	Policy	Establish a consistent narrative on the importance of collective, cross-border action to address ML at source and throughout its passage to the sea. Underline the role of data and analysis in countering misinformation and making smarter policies to tackle root causes.	EEA

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

P30	Upstream	Capacity building and technical assistance	Provide capacity-building support. Stakeholder engagement platforms, and technical assistance to governments, organisations, and communities to strengthen their capacity for ML management and governance.	Zero Pollution Action Plan UN Environment Programme Marine Litter MED II Interreg PANACeA
P31	Upstream	Marine Spatial Planning (MSP)	Integrate ML considerations into marine spatial planning processes to minimise conflicts and enhance ecosystem health	European Maritime Spatial Planning Platform
P32	Upstream	Legislative Frameworks and Regulations	Enact laws and regulations to regulate the production, use, and disposal of plastics and other materials contributing to ML pollution.	EU Single Use Plastics Directive
P33	Upstream	National ML Action Plans	Develop and implement national action plans and strategies to prevent, reduce, and manage ML pollution	PALM 2026
P34	Upstream	International Treaties and Agreements	Negotiate and ratify international treaties and agreements to address ML pollution and promote global cooperation	Intergovernmental Negotiating Committee on Plastic Pollution

5.3 Monitoring and Detection

ML poses a significant threat to coastal areas, impacting the environment and local economies heavily reliant on marine resources. While coastal regions bear the brunt of the litter problem due to their proximity to land, the issue extends far beyond shorelines. Litter enters marine environments primarily from land and rivers, with estimates indicating millions of tonnes of plastic entering the ocean annually (Schwarz et al., 2019; Iglesias et al., 2023). Monitoring the presence and impacts of plastic litter is essential for understanding its extent, assessing its effects on marine ecosystems, and devising effective mitigation measures. Consistent and reliable monitoring methods are necessary to achieve meaningful results, however, a lack of

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

standardisation of methods makes it difficult both to assess and to compare litter densities within and across the different environmental compartments in time and space (Haarr et al., 2022). This gap underscores the need for comprehensive strategies to address the issue at its source.

5.3.1 Impacts on the marine ecosystem and biota

ML, mainly composed of plastics, poses multifaceted threats to marine ecosystems and biota, impacting not only environmental health but also human and animal health under the One Health concept. Reported impacts include the entanglement of marine organisms, ingestion of plastics leading to toxicological effects, suffocation, starvation, dispersal, and rafting. Along with the creation of new habitats and the introduction of invasive species, pose significant ecological threats that increasingly endanger biodiversity and trophic relationships (Thushari and Senevirathna, 2020; Thiel et al., 2018). In addition, chemical pollution from litter introduces toxins into the marine environment, affecting marine organisms and ecosystems. Microplastics, ingested by a wide range of marine life, amplify these impacts and can transfer harmful chemicals through the food web (Torres et al., 2021; Barboza et al., 2018). Furthermore, the economic impacts of ML affect both ecosystems and human well-being. Addressing ML from the One Health perspective requires collaborative efforts to mitigate its impacts on environmental, animal, and human health, emphasising the importance of integrated solutions to safeguard the health of both ecosystems and communities.

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

5.3.2 Global Commitments

The global community has recognized the urgency of addressing ML as evidenced by initiatives such as the United Nations Environment Assembly's resolution on marine plastic debris and microplastics (UNEP, 2019). The Scientists' Coalition, along with organisations such as the United Nations Environment Programme (UNEP, unep.org) and the Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP, gesamp.org), play key roles in shaping guidelines and good practices. Such discussions should also consider harmonised monitoring data and reporting requirements, as well as the substantial financial and technical support that will be required to support them. The Marine Strategy Framework Directive (MSFD) Guideline for Monitoring provides a comprehensive framework for assessing the status of marine environments, including the impacts of ML (Descriptor n° 10). Additionally, the Nairobi Convention, EMODNet (European Marine Observation and Data Network), and the Joint Research Centre (JRC) MSFD Technical Group on ML (TGML) contribute to data collection, analysis, and reporting efforts. Global initiatives such as the Group on Earth Observations (GEO) Blue Planet Initiative for ML Monitoring and the Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) Committee on the Environment and Marine Pollution (CEPM) are instrumental in coordinating international efforts and promoting good practices for monitoring ML impacts.

5.3.3 Good practices for **Monitoring** ML

Good practices for monitoring ML impacts include standardised data collection methods and protocols, integration of remote sensing and modelling techniques, engagement of stakeholders, and the use of bioindicators to assess ecological health of the ecosystems (Table 4). Leveraging the expertise and resources of various organisations and initiatives, it is possible to enhance our understanding of ML impacts and develop effective strategies to prevent and mitigate its adverse effects on marine ecosystems.

Table 4 - Good Practices for ML Monitoring.

N°	Action	Measure Category	Recommendation	Projects / Initiatives

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

M1	Upstream	Policy support	Strengthen connections between EU policy and localised actions, e.g. developing a 'scoreboard' for identifying and addressing gaps in ML management via targeted monitoring and reporting on sources and pathways.	EEA
M2	Upstream	Policy support	Advocate for national, international and trans-national policies and regulations that mandate regular monitoring of ML ensuring consistent and standardised data collection practices across regions.	MSFD
M3	Downstream	Emerging technologies	Explore the use of emerging technologies such as drones, autonomous underwater vehicles (AUVs), and machine learning algorithms to enhance monitoring capabilities and efficiency.	SeaClear2.0
M4	Downstream	Methodology standardisation	Standardise ML monitoring protocols to be comparable across regions.	EMODnet
M5	Downstream	ML definitions	Harmonise ML description and classification to be comparable across regions.	GESAMP
M6	Downstream	Developing a national or regional monitoring strategy	Design and implement monitoring programmes that are cost-effective and efficient to support programme longevity.	GESAMP
M7	Downstream	Developing a national or regional monitoring strategy	Prioritise the monitoring programme to address the most significant risks and associated indicators (i.e. scientific, technical, policy/social relevance and data requirements).	GESAMP

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

M8	Downstream	Developing a national or regional monitoring strategy	Encourage monitoring by organisations responsible for ML waste and leakage for e.g. industries, municipalities.	GESAMP
M9	Upstream, Downstream	Collaboration	Collaborate with international organisations, research institutions, and local communities to share data, expertise, and resources for comprehensive monitoring efforts.	Horizon Dashboard
M10	Downstream	Risk assessment	Chemical analysis for both macro- and microlitter associated pollutants, essential for comprehensive understanding and management of ML pollution and its associated risks to the environment and human health.	National and international environmental agencies
M11	Downstream	Integrative monitoring	Comprehensive and standardised monitoring including all the ecosystem main matrices (e.g. sediment, water, biota), providing insights into the distribution, abundance and impacts of both macro- and microlitter.	National and international environmental agencies
M12	Downstream	Co-monitoring; Bioindicators	Ensure the continuous monitoring of bioindicators for understanding the ecological impacts of ML and guiding effective management.	Mediterranean Biodiversity Knowledge Platform
M13	Downstream	Drift modelling	Use hydrodynamic models to simulate ML dispersion paths based on water currents and wind patterns, aiding in the prediction and identification of litter hotspots.	Research centres (academia) Governmental agencies (eg. IPMA (PT), Puertos de Estado (SP), IFREMER (FR)) MAELSTROM
M14	Downstream	Coastal monitoring	Implement regular monitoring programs in rivers, estuaries and the coastline to track the influx of ML.	National and international environmental agencies

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

M15	Downstream	Underwater surveys	Conduct underwater surveys using divers or remotely operated vehicles (ROVs) to assess ML accumulation on the seabed and in marine habitats.	SeaClear2.0 MAELSTROM
M16	Downstream	Acoustic monitoring	Use underwater acoustic technology to detect and track submerged ML, such as ghost nets and debris.	MarGnet SeaClear2.0 MAELSTROM
M17	Downstream	Citizen science	Engage the public in data collection through citizen science programs, encouraging individuals to report litter sightings and participate in beach cleanups.	Plastic Pirates MAELSTROM INSPIRE
M18	Downstream	Remote sensing	Utilise satellite imagery and aerial surveys to monitor large-scale patterns of ML distribution, identifying areas of high concentration.	AIR Centre, EuroGOOS
M19	Downstream	Remote sensing	Conduct aerial surveys using drones or aircraft to identify ML in remote areas	HCML, LitterDrones, INSPIRE
M20	Downstream	Machine Learning algorithms	Train machine learning algorithms to analyse satellite imagery and identify patterns of ML distribution.	IOCCG Task Force on Remote Sensing of Marine Litter GEO Blue Planet Marine Litter Group
M21	Downstream	Marine debris tracking apps	Develop mobile applications for users to report and track ML sightings and cleanup efforts.	MAELSTROM app NOAA Marine Debris Tracker EEA Marine Litter Watch
M22	Downstream	Smart buoys	Deploy smart buoys equipped with sensors to monitor water quality and detect floating ML in coastal areas.	UNIZG-FER Multifunctional Smart Buoys

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

M23	Downstream	Lidar technology	Promote the use of Lidar (Light Detection and Ranging) technology for high-resolution mapping of coastal topography and ML accumulation .	ESA Remote Sensing of Plastic Litter
M24	Downstream	Monitoring and reporting mechanisms	Establish monitoring and reporting mechanisms to track progress on ML reduction goals and targets at local, national, and international levels.	EMODnet, OSPAR, MSFD Technical Group on Marine Litter
M25	Downstream	Open Data	Data and information, resulting from the monitoring programmes, should be made available for interoperable use.	EMODnet

5.4 Removal of marine plastic and litter

With plastic waste accumulating in the ocean at an alarming rate, the need for sustainable and efficient solutions to remove it is urgent. Two solutions are possible: the development and deployment of technologies that prevent plastics from entering waterways, and the collection of marine and riverine plastic pollution.

Although local, regional, national, and international organisations and authorities play an important role, these efforts are more effective when combined with private industry action and technological innovation, given the global nature of the problem and the extent of stakeholders involved (Schmaltz et al., 2020). Public, for-profit, and non-governmental organisations (NGOs) are working together to reduce the negative impacts of plastic pollution by developing new technologies to remediate plastic pollution in the environment. However, it must be emphasised that these technologies are a complement of policy efforts to combat marine plastic pollution by tackling the entire life cycle of plastics, which are the key developments to be promoted in order to substantially reduce ML into the environment (Cordier and Uehara, 2019; Nasir et al., 2024). These joint efforts are in line with the UNEA Resolution 2/11, which considers that Member States should "cooperate regionally and internationally on cleanup actions of ML hotspots where appropriate, and, at the same time, develop environmentally sound systems and methods for such removal and sound disposal of ML" (Resolution 2/11 Marine plastic litter and microplastics) (UNEA, 2016).

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

5.4.1 Innovative technologies to remove ML

Given the significant influx of marine debris into our oceans, it is imperative to take measures to slow the release of plastic into the marine environment. Cutting-edge technologies are revolutionising the identification, collection and removal of ML in rivers, estuaries, and seas. Examples include autonomous surface and underwater vehicles and drones, large-scale booms, seabed cable robots, boats and wheels, detection aids, waterway litter traps, river booms, sand filters, and bubble barriers for both macro and micro litter (see Table 5). The implementation of these innovative technologies presents effective solutions to combat ML across diverse aquatic environments, thereby safeguarding the health of our waterways and oceans, significantly contributing to addressing this pressing issue. For a small number (n = 5) of the technologies listed in Table 5, the specific location, or site of implementation, could be found in the available reference material. All efforts were made to provide information as accurately as possible and web-links are provided for further research to the responsible projects.

*Table 5 - Some examples of ML **Removal** technologies.*

Project/ Initiative	Technology	Description	Locations (*developer*)
MAELSTROM maelstrom-h2020.eu	Bubble Barrier	Collects submerged items in the water column and from the water surface in rivers. It was implemented for the first time in an estuary (Ave River, Portugal).	Amsterdam -NE Vila do Conde-PT Harlingen-NE Katwijk-NE Wervershoof-NE (*The Great Bubble Barrier – NE*)
MAELSTROM maelstrom-h2020.eu	Robotic Seabed Cleaning Platform	Installed and operated from a floating barge it uses different tools: a drudge to collect small items laying on the seabed and floating in the water column; a gripper to grasp larger items which are deposited on the floating platform and several underwater sensors to identify the ML and to operate the system in a safe way. The ML is selectively collected avoiding any damage to the seabed. 2 Tn of ML eliminated in the first two cleaning campaigns	Venice-IT (*Tecnalia – SP*)
InNoPlastic innoplastic.eu	Archimedean Drum Screw	Screw filters filter litter and macroplastics while letting fish enter and exit safely.	(*FishFlow – NE*)
InNoPlastic	SEEKer Robot	Autonomous vehicle equipped with robotic hands able to collect plastic waste from beaches.	(*Probotica – CR*)
CLAIM claim-h2020project.eu/technologies	Floating barriers	Floating barriers prevent different kinds of plastics to enter the sea	Athens – GR (*New Naval Ltd - GT*)

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

CLAIM claim-h2020project.eu/technologies	Ferry Box	Automated seawater sampling device coupled with a passive flow-through filtering system, installed on ships.	Open sea (Baltic (TTU, DTU-aqua), West (AMU, INSTM) and East Mediterranean (HCMR)
River Cleaning rivercleaning.com	River Cleaning System	Intelligent floating modular barrier intercepts floating waste in streams through rotation.	Rosà – IT (*River Cleaning – IT*)
Waterfront mrtrashwheel.com	Mr. Trash Wheel	Semi-autonomous trash interceptor lifts litter out of the water and onto his conveyor belt.	Baltimore -USA (*Waterfront Partnership of Baltimore Inc-USA*)
Everwave everwave.de/en	CollectiX	Rubbish collection boat which can smartly analyse the garbage and collect ML through a conveyor belt.	(*Everwave GmbH – DE*)
Thomsea thomsea.fr	Thomsea	By drawing on the natural power of water and thanks to its trawls, it removes litter from rivers and seas.	Open Sea (*Thomsea-FR*)
Seabin seabin.io	Seabin Smart Tech	Seabin Smart Tech is a rubbish bin in the water. The catch bag V5 Hybrid works as a filter for both macro and micro floating waste. It is made of a 100% recyclable plastic mesh.	Sydney - AU Los Angeles - USA (*Seabin SP*)
SeaClear eaclear-project.eu	SeaCAT	SeaCat is a surface platform developed to deploy UAVs and ROVs to locate and collect ML from both the seabed and water column in the SeaClear project	Dubrovnik -CR (*Subsea Tech-FR*)
Clearbot clearbot.org	Clearbot Neo	Running on electric power. It can collect up to 15 L of oil and 200 kg of floating trash in a day. Clearbot Neo is a great option for organisations looking for a cost-effective and environmentally friendly way to clean up waterways.	(*Clearbot -HK*)
Ocean Cleanup theoceancleanup.com	Ocean Cleanup System	The system consists of a long, floating barrier made of a durable material such as high-density polyethylene (HDPE). This barrier is designed to float on the ocean's surface, forming a gentle U-shape, and is equipped with a skirt that hangs beneath the surface.	Open Ocean (*Ocean Cleanup-NE*)
Ocean Cleanup theoceancleanup.com	The Interceptor	Solar-powered catamaran autonomously extracts floating plastics from rivers, using barriers and a conveyor belt	Klang River-MY (*Ocean Cleanup-NE*)
Ranmarine www.ranmarine.io	WasteShark	Drone modeled after a whale shark skims the water and collects floating debris	(*RanMarine HQ-NE*)
Plastic Soup Foundation plasticsoupfoundation.org	SeaVax	Solar- and wind-powered ship collects plastic and other debris; sensors detect waste and sonar protects fish and other animals from being collected	Open sea (*Plastic Soup Foundation-NE*)

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

One Earth – One Ocean(**OEOO**) oneearth-oneocean.com	The SeeHamster	Small catamarans equipped with fold down nets or fishing gear collect debris from inland waters	Coastal area -DE (*OEOO – DE*)

Despite the great advance of the ML removal technologies, it must be stressed out that most of the proposed solutions have limitations. Some of them are not eco-friendly or sustainable, and sometimes their impact on the environment could be either positive or negative. Unregulated ML removal technologies may be immature for recycling and waste-to-energy, present malfunctioning, high costs of disposal, low recycling potential, low cost-efficiency, or even have unintended negative consequences on the environment. In addition, they can be associated with various concerns related to their technological challenges, environmental impacts, equity and justice, verifiability, market-based greenwashing, and distraction from more effective solutions like oriented-policies that promote the toxic-free, zero-waste, prevention and reduction rather than cleanup. Nevertheless, removal efforts are also needed in some places. For those cases, the ML removal technologies should be regulated to assess their benefits and avoid damages (Bergmann et al., 2023). Regulation requires a science-based accreditation system including environmental, socio-economic and financial impacts to verify the effectiveness of the ML removal technologies, minimise regrettable outcomes and provide the needed information for better-informed decision making (Cunha et al., 2023). Environmental impact assessments and life cycle analysis should be performed before the technology implementation and on a case-by-case basis, helping to determine their effectiveness and impact, and secure environmentally sound management. During the installation, monitoring and reporting of bycatch and litter catch-efficiency as well as waste management should be conducted to document cost-effectiveness and environmental impact. After the installation, additionally data collection on amounts and sources of litter would provide added value for research, education and outreach activities. So, it is recommended that the regulation policies include this evidence-based assessment to ensure that the proposed technologies are feasible and that ecological benefits outweigh the costs (Falk-Andersson et al., 2023). However, the inclusion of those regulations should be performed with care because these problems are multifaceted and complex, involving many actors with conflicting perspectives. Industry, tourism, fishing activities, vessel owners, environmentalists, consumers, financial institutions, governments, and other parties are affected, and their concerns should be taken into consideration in the decision-making process

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

(Cunha et al., 2023). So, collaboration among stakeholders is crucial for addressing marine plastic pollution, a multifaceted challenge requiring comprehensive solutions. While policy responses are essential, innovative technologies offer immediate cleanup options, particularly in high-risk areas. These technologies should complement preventative measures like sustainable materials and enhanced waste management systems (Worm et al., 2017))

Establishing good practices for ML removal is paramount to ensure effectiveness and efficiency in cleanup efforts. Research indicates that local-level public-private partnerships have shown promise in implementing effective solutions (Karasik et al., 2020), The promotion of good practices can contribute to the feasibility and effectiveness of deploying cleanup technologies alongside policy interventions, guiding both public and private investments. Examining the existing policies to identify incentives or disincentives for technology use is crucial. Several authors (e.g. Schmaltz et al., 2020; Garcia et al., 2019) suggest that governments can help reduce plastic consumption by offering subsidies or tax incentives to companies that adopt new technologies and practices. These financial incentives can be used to encourage the installation of these technologies or to scale up these efforts for industrial use.

Overall, addressing marine litter pollution requires a comprehensive approach integrating technology, policy, and advocacy, highlighting the importance of continued collaboration and the establishment of **Good Practices** in removal efforts (Table 6.).

Table 6 - Good Practices for ML Removal.

Nº	Action	Measure Category	Recommendation	Projects / Initiatives
R1	Upstream	Policy support	Develop national and transnational policy landscapes that allow for the upscaling, piloting, and expansion of removal initiatives between European countries.	EU Mission Ocean and Waters
R2	Downstream	Removal design	Promote ML removal initiatives being co-designed with academics, stakeholders, and affected communities to ensure good uptake, effectiveness, and ease of transfer.	MAELSTROM InNoPlastic Remedies INSPIRE

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

R3	Downstream	Community action	Organise community-led beach cleanups to remove ML from shorelines and coastal areas.	MAELSTROM Remedies InNoPlastic EU Blue Schools
R4	Downstream	Community action	Establish dedicated teams to regularly patrol shorelines and remove ML before it enters the ocean	Ocean Wise Shoreline Cleanups Clean Coasts
R5	Downstream	Community action	Collaborate with local communities to clean up rivers and waterways to prevent ML from entering the ocean	INSPIRE
R6	Downstream	Community action	Encourage individuals and organisations to adopt beaches and commit to regular cleanups and maintenance	Adopt-a-Beach Programs
R7	Downstream	Community action	Conduct regular cleanups of ports and harbours to remove ML and prevent pollution from shipping activities	Port and Harbor Cleanups
R8	Downstream	Community action	Organise cleanup expeditions to remote islands and coastal areas with high levels of ML accumulation	At-Sea Cleanup Expeditions
R9	Downstream	Community action	Mobilise scuba divers to conduct underwater cleanups and remove ML from coral reefs and marine habitats	Divers for Climate PADI AWARE Dive Against Debris
R10	Downstream	Community action	Partner with fishermen to retrieve lost or abandoned fishing gear (ghost gear) from the ocean and coastal waters.	Nettag+ MarGnet
R11	Downstream	Innovation	Deploy floating barriers and arrays to passively collect and concentrate ML for retrieval and removal	Ocean Cleanup Arrays INSPIRE
R12	Downstream	Innovation	Deploy robotic seabed cleaning platforms to remove selectively large and medium-size marine litter (up to 130 kg) without damaging the seabed	MAELSTROM

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

R13	Downstream	Innovation	Design and deploy specialised boats equipped with litter collection systems to skim surface debris from water bodies	Trash Interceptor Boats
R14	Downstream	Innovation	Develop underwater drones and robots capable of autonomously collecting ML from the seafloor and submerged environments	SeaClear2.0 Underwater Litter Collectors
R15	Downstream	Innovation	Utilise aerial drones equipped with cameras and sensors for real-time monitoring and surveillance of ML pollution	Drone Surveillance UAS4Litter INSPIRE
R16	Downstream	Innovation	Design cleanup technologies inspired by natural processes and organisms to enhance efficiency and sustainability	Bioinspired Cleanup Solutions
R17	Downstream	Innovation	Install smart trash bins equipped with sensors and compactors to optimise waste collection and prevent litter overflow	Smart Trash Bins

5.5 Recycling, Valorisation and Circular Economy Benefits

ML recycling and valorisation are crucial for mitigating the environmental impact of plastic pollution in oceans and coastal areas. Recycling involves collecting and processing ML to produce new materials and items, while valorisation focuses on extracting value from ML through various means, such as energy recovery or conversion into useful products. Traditional recycling methods are limited to pre-processed, sorted, and segregated polymer fractions that should be complemented with innovative approaches to tackle marine plastic pollution. Current technologies and approaches for valorising plastic ML include mechanical and chemical recycling, blockchain technologies that provide traceability, verification, efficiency and transparency throughout the recycling process, and public awareness programs and education (Râpă et al., 2024).

Co-funded by the Horizon 2020 programme of the European Union

In recent years, some recycling technologies have been developed and improved. Mechanical recycling, a common waste management method, has been applied to plastic ML, but its success varies depending on the properties of the material. For example, PET bottle waste, fishing gear, buoys, and electrical equipment have been mechanically recycled, but the process can impact the environment and lead to a decrease in material properties (Stapleton et al., 2023). Under the scope of MAELSTROM, different processes for mechanical recycling were tested. From all those processes the RFM, patented by Gees Recycling, should be enhanced. This process is initiated with particle reduction from different feedstocks. The particles were bonded together, even considering mixed polymers. The final materials present a panel shape that can be used to construct different products. This method has demonstrated the feasibility of transforming challenging to recycle plastic ML, like the mixed thermoplast-thermoset composition of fisherman nets and floaters or the abandoned GRP-made boats.

Additive manufacturing offers a promising alternative, enabling the direct fabrication of products from recycled plastics. Also, chemical recycling, which converts plastic ML into valuable chemical platforms and fuels, is a promising technology (Faussone and Cecchi, 2022; Kusenberg et al. 2022), although it can have challenges related to energy consumption and environmental impacts (Turcanu et al., 2022). Hydrothermal carbonization is a promising technology for converting plastic waste into fuel and adsorbent materials, with lower energy requirements compared to pyrolysis and gasification (Turcanu et al., 2022). Cleaner manufacturing processes, such as incorporating recycled plastics into bio-based matrices, offer opportunities for repurposing plastic ML into innovative materials with applications across various industries (Caniato et al., 2021). To understand the impact of the techniques and the usefulness of the products, blockchain technology is being explored, helping on plastic ML management and enabling transparent tracking and incentivizing cleanup efforts (Gong et al., 2022).

ML can be transformed into value-added products, such as construction materials, textiles, or composite materials. Innovative technologies and processes are being developed to utilise ML as a resource for producing high-value materials and products. In addition, public awareness and education campaigns play a crucial role in promoting responsible waste management practices, reducing littering behaviour, and increasing recycling rates.

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

To tackle marine plastic pollution and transition to a sustainable circular economy it is fundamental to combine innovative technologies and actions with policy interventions. Policy initiatives addressing plastic ML have evolved significantly over the past few decades, driven by growing awareness of the environmental and ecological threats posed by plastic pollution. Recycling policies have been integral to waste management strategies, with legislative acts such as the EU's Waste Framework Directive aiming to promote recycling and circular economy principles. Recently, the Commission proposed new EU-wide rules on packaging to reduce waste and improve packaging design. These rules advocate for clear labelling to promote reuse and recycling, and call for a shift to bio-based, biodegradable, and compostable plastics, demonstrating the commitment to advancing circular economy principles and fostering sustainable practices across various sectors. Extended Producer Responsibility (EPR) schemes have gained traction, shifting responsibility from consumers to producers for product disposal and recycling. However, challenges remain, particularly in developing countries where infrastructure and recycling capabilities are limited (Thushari and Senevirathna, 2020). Bans on single-use plastics (SUP) have been a common strategy, although their effectiveness in reducing plastic consumption and litter remains debated (Macintosh et al., 2020; Walther et al., 2021). No single solution exists, but there is a need for concerted efforts to strengthen policy implementation, enhance waste management systems, and promote innovation and research in recycling technologies. Financial support, technology transfer, and capacity building are crucial for developing countries to improve their recycling capabilities and address plastic pollution effectively (Râpă et al., 2024).

Addressing ML requires a comprehensive approach that involves policy interventions, public engagement, technological innovation, and international cooperation. This approach should target both sea-based and land-based sources of pollution while promoting circular economy principles and strengthening global partnerships. By implementing such strategies, we can effectively combat ML and protect our oceans for future generations.

5.5.1 Cost-benefit and good practices for economy growth and job creation

ML valorisation offers a dual solution to environmental challenges while unlocking economic opportunities. By recovering valuable materials from marine waste, such as plastics and metals, and repurposing them for their use in various industries, a valorisation of the materials will be promoted, reducing the reliance on virgin

Co-funded by the Horizon 2020 programme of the European Union

resources and, thus, promoting resource efficiency and cost savings (Tavares et al., 2020). This process drives innovation and technological advancement, leading to the emergence of new businesses and industries focused on waste management and sustainable materials production. The development of ML valorisation infrastructure, including recycling facilities, processing plants, and collection systems, requires a skilled workforce. Consequently, job opportunities are created in areas such as engineering, manufacturing, research and development, waste management, logistics, and green technology. Additionally, supporting industries such as consulting, education, and environmental services also benefit from the demand for expertise in sustainable waste management practices (Jambeck et al., 2015; Kunz et al., 2021). ML and, in general, blue-economy require different approaches and solutions strictly connected with local conditions, rules and shareholders role and opinions. As an example, it can be used with HDPE Buoys. It may make economic and ecological sense to create a workflow for local repair and re-use instead of trying to recycle them, which can produce local impacts due to seawater contamination.

5.5.2 Cost-effectiveness: Recycling and Valorisation as strategic Investments

While prevention remains the ultimate goal, effective removal strategies are essential to mitigate the existing problem and its devastating impact on the oceans. It is important to understand how recycling, valorisation (conversion of waste into valuable products), and embracing a circular economy can offer a win-win scenario for cleaner oceans, economic growth, and job creation.

Traditional marine litter removal, relying solely on landfill disposal, incurs significant costs associated with transportation, land acquisition, and long-term management. Landfills also pose severe environmental risks like leachate contamination and methane gas emissions. Recycling and valorisation offer a more strategic and cost-effective alternative. Recycled materials can be reintroduced into the production cycle, reducing reliance on virgin resources. This translates to a ripple effect throughout the economy, as lower production costs can lead to more competitive pricing for consumers. For example, a major clothing manufacturer utilising high-quality recycled polyester derived from recovered plastic bottles can offer to the consumers more affordable, environmentally friendly clothing options. Valorisation takes the concept a step further. By transforming waste into valuable products like energy or construction materials, it produces not only a reduction of waste but also

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

creates entirely new revenue streams. Like, for example, the concept of a state-of-the-art facility that utilises recovered fishing nets and ropes to generate clean-burning energy. This will not only tackle ocean plastic pollution but also provide a reliable source of renewable energy, potentially reducing dependence on fossil fuels and creating jobs in the clean energy sector.

The MAELSTROM project exemplifies this approach perfectly. By developing innovative technologies to capture and valorise marine litter, the project demonstrates the economic potential hidden within waste. Recovered fishing gear and plastics can be converted into high-quality building materials or sustainable fuel sources, tackling pollution while generating income and fostering a more circular economy. Fortunately, MAELSTROM is not alone in its mission. There are several other EU-relevant projects whose efforts are focused on addressing marine litter and promoting circular economy practices (e.g. CleanSea, MARLISCO, Circular Ocean, PlasticCircle, Blue Circular Economy, CleanAtlantic, Circular Plastics Alliance. By promoting recycling, valorisation, and sustainable practices, these projects contribute to a cleaner marine environment and support the transition towards a circular economy in Europe and beyond.

Based on experiences from projects like MAELSTROM and other initiatives that promote circular economy and job creation, a comprehensive set of good practices can be outlined for achieving cost-benefit, economic growth, and job creation in the context of marine litter management (Table 7).

Table 7 - Good Practices for ML Recycling and Valorisation.

Nº	Action	Measure Category	Recommendation	Projects / Initiatives
V1	Downstream	Investing in innovative technologies	Advanced tech for sorting, and reusing ML. Robotics and sorting innovations contribute to create green tech jobs and tackle environmental issues	MAELSTROM

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

V2	Downstream	Boosting Local and regional recycling	Establishing plastic recycling facilities and community-based centres enhances local recycling initiatives, fostering circular economy principles and job creation in waste management.	Interreg INTERWASTE EU Reuse and Recycling European Union Social Enterprises (RRUSE)
V3	Downstream	Promoting circular business models	Encouraging the adoption of circular economy principles for cost savings and innovation. Market incentives for recycled materials in manufacturing and construction boost recycling infrastructure and create jobs.	EU Circular Economy Action Plan
V4	Downstream	International cooperation and technology transfer	International collaboration to develop new methods and coordinated strategies to valorise ML and share good practices.	UNEA EuroSea Integrated Marine Debris Observing System (IMDOS)
V5	Downstream	Standardised regulations	International policies on plastic production, use, and waste management promote business accountability and sustainable practices.	EU Waste Directive Single Use Plastic Ban UNEP-INC
V6	Downstream	Capacity building	Assistance to developing countries in waste management training and infrastructure development	H2020 Integrated Waste Management Western Africa (IWWA) UNEP/EU - SWITCH Africa Green
V7	Downstream	Public-private partnerships	Government-business collaboration enables large-scale marine litter removal, benefiting waste technologies companies and creating green sector jobs.	Remondis Recycling The Recycling Partnership

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

V8	Downstream	Harmonisation of waste management practices	Regional collaboration on waste management protocols enhances efficiency and job creation.	Interreg INTERWASTE EU Circular Economy Action Plan
V9	Downstream	Infrastructure development	Invest in infrastructure for the collection, sorting, and processing of ML. Establish recycling facilities, waste-to-energy plants, and other infrastructure to facilitate the valorisation of recovered materials.	European Circular Economy Stakeholder Platform
V10	Downstream	Valorisation of collected fisheries materials and equipment Recycling of mixed ML and nets	Reduce HDPE buoy waste by offering repair and reintroduction schemes due to unavailability of conventional recycling techniques. Utilise RFM technology to process polymers from mussel farms, other aquaculture equipment, and ghost boats. Utilise R-PMMA technologies to recycle mixed ML and nets	MAELSTROM LIFE GREEN Project
V11	Downstream	3D printing with marine plastics	Explore the use of 3D printing technology to transform marine plastics into functional objects and prototypes.	Precious Plastic VivaLab
V12	Downstream	AI driven robotic sorting cell for classification of ML thermoplastics	Develop and deploy AI driven robotic sorting cell for ML thermoplastics to increase the efficiency of their further recycling	MAELSTROM

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

V13	Downstream	Innovative recycling techniques	Research and develop innovative recycling techniques for processing diverse types of ML materials. Recycle recovered marine plastics into synthetic fibres for use in textiles, clothing, and other fabric-based products	Ocean Waste CLEAN IMPACT TEXTILES OCEAN-LSAM Bionic Waste2Wear
V14	Downstream	Biodegradable packaging alternatives	Promote the use of biodegradable and compostable packaging materials to reduce ML pollution	Bio-Plastics Europe
V15	Downstream	Blockchain technology	Implement blockchain-based systems for tracking and tracing ML throughout the recycling and valorisation process	Waste2Wear
V16	Downstream	Market incentives:	Stimulate demand for products made from recycled ML. This may include government procurement policies favouring recycled materials, tax incentives for businesses using recycled materials, and certification schemes to verify the origin and sustainability of recycled products.	HEurope INCREACE Interreg PLASTECO
V17	Downstream	Monitoring and evaluation	Establish monitoring and evaluation mechanisms to track progress in the valorisation efforts. Collect data on the amount and types of ML collected, recycled, and reused, to assess the effectiveness of policies and identify areas for improvement.	MAELSTROM
V18	Downstream	Adaptability and flexibility	Regularly review and update policies based on scientific advancements, technological innovations	EU Circular Economy Action Plan
V19	Downstream	Integrated approach	Adopt a holistic approach that combines prevention, cleanup, and valorisation efforts. Policies should address the entire lifecycle of ML, from its initial entry into the ocean to its final disposal or reuse.	MAELSTROM

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

V20	Downstream	Entrepreneurship support	Encourage entrepreneurship in ML valorisation by providing support and resources to small and medium-sized enterprises (SMEs) and startups.	European Investment Bank Enterprise Europe Network
V21	Downstream	Diversification of industries	Promote the diversification of industries involved in ML valorisation to create a range of job opportunities across various sectors. This may include recycling facilities, manufacturing plants, research institutions, consulting firms, eco-tourism ventures, and more.	EU Sustainable Blue Economy Partnership OceanWise
V22	Downstream	Value chain development	Support the development of a comprehensive value chain for ML valorisation, from collection and sorting to processing and marketing of recycled products.	EMFF BlueNet EMFF Searcular
V23	Downstream	Innovation hubs and incubators	Establish innovation hubs, incubators, and technology parks focused on ML valorisation to foster collaboration, innovation, and entrepreneurship.	Interreg InnovaMare The Incubation Network
V24	Downstream	Long-Term sustainability	Ensure that job creation efforts in ML valorisation are aligned with long-term sustainability goals. Prioritise investments in green technologies, circular economy practices.	EU Circular Economy Action Plan EU Sustainable Blue Economy Partnership

6 Good Practices to Tackle ML: Conclusions and Future Outlook

The implementation of effective strategies to tackle ML requires multifaceted collaboration among key societal sectors. Governments, NGOs, industries, academia, and local communities must work together to develop policies, allocate resources, and coordinate and implement action plans. Public awareness campaigns and educational programs promote responsible waste management practices and build citizens' knowledge of the problems and solutions associated with ML and plastic pollution. Partnerships with industry stakeholders encourage innovation, and should strive to develop responsible business practices, while community engagement fosters stewardship and active citizenship towards marine environments.

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

The present deliverable presents a comprehensive collection of suggested good practices across four key pillars: **Prevention**, **Monitoring**, **Removal**, and **Valorisation**. These practices, compiled through collaborative efforts involving MAELSTROM partners expertise, literature review, and strategic networking to collect knowledge, demonstrate the importance of a multi-dimensional approach and the formation and financing of transdisciplinary teams to address the complex challenge of ML. Good Practices, as defined within this document, represent actions or behaviours that have demonstrated positive outcomes in ML management. They are contextual and may vary depending on local to global conditions, however they serve as valuable insights for ML interventions, emphasising the importance of inclusivity, adaptability, and collaboration. Effective ML management strategies encompass a spectrum of actions spanning science and society such as community engagement and public awareness campaigns, policy interventions, and advanced technologies and the innovation landscape.

Some strategies include:
i) Prevention efforts focusing on reducing waste through education, policy, and infrastructure development;
ii) Cleanup initiatives involving volunteer-driven activities and specialised equipment to remove existing litter;
iii) Early and effective detection strategies using remote sensing, citizen science, and advanced technologies to identify ML accumulation areas;
iv) Collection efforts leveraging innovative and sustainable technologies to effectively remove ML from rivers, estuaries, and oceans;
v) Valorisation processes transforming collected litter into valuable resources, promoting a circular economy and driving innovation in waste management practices.

Collaboration among governments, NGOs, industries, and communities is essential for enhancing the effectiveness of ML management efforts. Education and awareness-raising campaigns empower individuals to adopt sustainable practices and become stewards of marine ecosystems. Partnerships and innovation ecosystems foster knowledge sharing, resource mobilisation, and collective action, driving progress towards a cleaner and healthier future for aquatic ecosystems, in a One Health perspective.
The proposed **100 Good Practices** and initiatives encompass a wide array of interventions, in this deliverable, recommendations have been categorised into

Co-funded by the Horizon 2020 programme of the European Union

upstream and **downstream** actions across the four identified pillars of **prevention**, **monitoring**, **removal, and valorisation**. Although some differentiation naturally occurs here, for e.g. most prevention measures are classed as upstream i.e. reducing ML entry into the environment, while most removal and valorisation techniques are classed as downstream i.e. managing the ML after it has entered the environment, it is worth noting that many of the recommendations and Good Practices which emerge from this study can be applied transversely across pillars.

As such, the following can be considered as a brief summary of the **cross-cutting key takeaways** which, if implemented, could affect ML management across its lifespan addressing policy development, community engagement, technological innovation, and capacity building:

- **Education, Community Engagement and Local Initiatives for a wave of change**
  The ML situation is a highly suitable condition for the universal "Think Global, Act Local" slogan. In that a seemingly insurmountable challenge can and needs to be addressed at local levels to promote positive consumer choices, encourage responsible personal and household waste management, and foster environmentally-positive actions and ocean literacy. Educational and awareness campaigns are vital for encouraging behavioural changes and promoting sustainable practices. By raising public awareness about the impacts of ML and the importance of waste reduction and recycling, these campaigns empower individuals and communities to take action towards a cleaner and healthier ocean environment. Local initiatives, such as beach cleanups, recycling programs, and circular economy projects, play a pivotal role in addressing marine litter at its source. By engaging communities and building awareness, these initiatives can contribute to ML prevention and removal, while also stimulating active and knowledgeable citizenship including disseminating information on policies affecting pollution and giving citizens a space to voice their concerns around the issue. These initiatives also have the potential to stimulate economic investment and job creation in recycling, waste management, and entrepreneurial sectors.

- **Monitoring and Research**

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

Investing in monitoring and research initiatives is paramount for comprehensively tackling ML issues. These efforts aid in identifying the primary sources of litter, specifically monitoring leakages and polluting entities in land-based activities, or tracking the release and movement of ML from maritime industries. An improved understanding of the main drivers of ML pollution can allow policymakers to implement interventions for ML reduction, such as enhancing waste management systems or enforcing regulations on plastic usage and disposal. Additionally, monitoring programs furnish invaluable data on litter distribution across diverse regions and ecosystems, enabling the identification of accumulation hotspots and the tracking of debris movement via water lines. Furthermore, monitoring and detection research is vital for the evaluation of the ML ecological, economic, and societal impacts. Knowledge on the sources, dispersal, and impacts of ML will serve to improve the effectiveness of riverine, estuarine and coastal management strategies. This information is needed for the implementation of science-backed policies and should feed into international data exchange to strengthen multilateral agreements and stakeholder engagement. There are opportunities for Good Practice advancement in monitoring and research, particularly around method standardisation, policy alignment, technological development, and impact assessment. Ultimately, research and monitoring efforts serve as pillars for informed decision-making, driving sustainable management practices and safeguarding for both ecosystems and human health.

- **Technological Innovations and Infrastructure Development**
  Investments in technological innovations are crucial in revolutionising ML collection, sorting, and recycling offering efficient and scalable solutions to this pressing environmental challenge. Advanced technologies significantly improve the efficiency of litter collection processes, allowing for larger quantities of debris to be removed in shorter time frames. Moreover, these innovations offer cost-effective alternatives to manual cleanup efforts, as automated systems can operate continuously without extensive human supervision, thereby reducing operational costs over time. Equipped with sensors and data collection capabilities, many technological solutions provide valuable insights into litter distribution, composition, and accumulation patterns, enabling informed decision-making about cleanup priorities and intervention strategies. Moreover, the development of infrastructures for waste sorting and recycling, particularly in coastal regions and developing countries,

Co-funded by the Horizon 2020 programme of the European Union

is imperative for scaling up efforts to tackle ML effectively. It is crucial to ensure that technologies implemented are ecologically and financially sustainable and have a net positive impact on the environment. Barriers to innovation should be addressed through public-private partnerships, the use of suitable and effective funding mechanisms for SMEs and the fostering of a healthy and strong European innovation ecosystem. Continued research and development in waste management technologies, such as robotics, AI, and advanced recycling systems, will enhance the efficiency and scalability of ML removal and valorisation efforts. These efforts can be supported by research and actions to stimulate the value chain of recycled materials and the design and engineering processes of sustainable non-plastic products.

- **National and International Cross-Sector Collaboration**
  Collaboration between diverse socio-economic communities and between countries is vital for advancing innovative technologies and sharing best practices in ML management. International policies and agreements can facilitate coordination and knowledge exchange on a global scale. Collaboration across sectors, including government, industry, academia, and civil society, will be crucial for driving progress in combating ML. Effective policy measures, including EPR schemes and international collaboration agreements, are essential for combating ML on a larger scale. EPR schemes incentivize eco-friendly product design and promote circular economy principles, while international cooperation fosters knowledge sharing and resource mobilisation for targeted interventions. Efforts should be made to identify and address barriers to plastic pollution regulation and strengthen the negotiation and science-policy advisory mechanisms to ensure that effective policies can be implemented from local to global levels. Collaboration within and between sectors, including the processes of co-design, co-implementation, and co-ownership can support the uptake and effectiveness of interventions to reduce ML. Efforts to include all relevant sectors of society, including but not limited to communities, industry, academia, and decision-making, should be made in order to address the entire lifespan and value-chain ML in a holistic, impactful, and sustainable manner.

MAELSTROM

Figure 1. *Engaging community to tackle ML. Vila do Conde Sunset Cleanup 2023. Photo Credits - Vila do Conde Municipality.*

Addressing the complex issue of ML requires a holistic and collaborative approach, integrating policy, technology, education, and community engagement. Future efforts should focus on strengthening policy implementation, enhancing waste management systems, and promoting innovation in recycling technologies. International cooperation, together with financial support, technology transfer, and capacity building are crucial, particularly for developing countries with limited recycling capabilities. ML valorisation offers economic opportunities, driving innovation and job creation in sustainable waste management practices and green technologies.

By building on existing **Good Practices**, investing in innovation and collaboration, and prioritising sustainability in joint actions and policies, it will be possible to move closer towards a more sustainable future, reducing the litter in rivers, estuaries and oceans, towards a cleaner environment for generations to come.

7 References

Barboza, L.G.A., Vieira, L.R., Guilhermino, L., 2018. Single and combined effects of microplastics and mercury on juveniles of the European seabass (*Dicentrarchus*

Co-funded by the Horizon 2020 programme of the European Union

labrax): Changes in behavioural responses and reduction of swimming velocity and resistance time. Environmental Pollution 236, 1014-1019 https://doi.org/10.1016/j.envpol.2017.12.082

Bergmann, M., Arp, H.P.H., Carney Almroth, B., Cowger, W., Eriksen, M., Dey, T., Gündoğdu, S., Helm, R.R., Krieger, A., Syberg, K., Tekman, M.B., Thompson, R.C., Villarrubia-Gómez, P., Warrier, A.K., Farrelly, T., 2023. Moving from symptom management to upstream plastics prevention: The fallacy of plastic cleanup technology. One Earth 6, 1439-1442. https://doi.org/10.1016/j.oneear.2023.10.022

Bettencourt, S., Freitas, D.N., Lucas, C., Costa, S., Caeiro, S., 2023. Marine litter education: From awareness to action. Marine Pollution Bulletin 192, 114963. https://doi.org/10.1016/j.marpolbul.2023.114963

Campbell, J., Bowser, A., Fraisl, D., 2019. Citizen Science and Data Integration for Understanding Marine Litter. In: Data for Good Exchange, 15 September 2019, New York.

Caniato, M., Cozzarini, L., Schmid, C., Gasparella, A., 2021. Acoustic and thermal characterization of a novel sustainable material incorporating recycled microplastic waste. *Sustainable Materials and Technologies*, *28*, 12. https://doi.org/10.1016/j.susmat.2021.e00274

Cunha, M.C., Tsiaras, K., Marques, J.R., Hatzonikolakis, Y., Dias, L.C., Triantaphyllidis, G., 2023. A multi-criteria assessment of the implementation of innovative technologies to achieve different levels of microplastics and macroplastics reduction. Marine Pollution Bulletin 191, 114906. https://doi.org/10.1016/j.marpolbul.2023.114906

European Commission (EC), 2008. Waste Framework Directive Consolidated text: Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.ELI: http://data.europa.eu/eli/dir/2008/98/2024-02-18

European Commission (EC), 2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance). http://data.europa.eu/eli/dir/2008/98/2018-07-05

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

European Commission (EC), 2018, Directorate-General for Environment, O'Donnell, B., Travagnin, C., Camarsa, G. et al., LIFE and the EU plastics strategy, Publications Office, 2018, https://data.europa.eu/doi/10.2779/4462

European Commission (EC), 2019. Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. http://data.europa.eu/eli/dir/2019/904/oj

European Commission (EC), 2019. Directive (EU) 2019/883 of the European Parliament and of the Council of 17 April 2019 on port reception facilities for the delivery of waste from ships, amending Directive 2010/65/EU and repealing Directive 2000/59/EC. http://data.europa.eu/eli/dir/2019/883/oj

Faussone, G. C., & Cecchi, T. (2022). Chemical recycling of plastic marine litter: first analytical characterization of the pyrolysis oil and of its fractions and comparison with a commercial marine gasoil. *Sustainability*, *14*(3), 1235.

Fetting, C. 2020. The European Green Deal", ESDN Report, December 2020 ESDN, Office, Vienna.

Fraisl, D., See, L., Bowers, R., Seidu, O., Fredua, K.B., Bowser, A., Meloche, M., Weller, S., Amaglo-Kobla, T., Ghafari, D., Bayas, J.C.L., Campbell, J., Cameron, G., Fritz, S., McCallum, I., 2023. The contributions of citizen science to SDG monitoring and reporting on marine plastics. Sustainability Science 18, 2629-2647. https://doi.org/10.1007/s11625-023-01402-4

Garcia, B., Fang, M. M., & Lin, J., 2019. All Hands on Deck: Addressing the Global Marine Plastics Pollution Crisis in Asia (SSRN Scholarly Paper ID 3387269). NUS Law Working Paper No. 2019/012. http://dx.doi.org/10.2139/ssrn.3387269

Gong, Y.; Wang, Y.; Frei, R.; Wang, B.; Zhao, C.P., 2022. Blockchain application in circular marine plastic debris management. Ind. Mark. Manag. 2022, 102, 164–176. https://doi.org/10.1016/j.indmarman.2022.01.010

Haarr, M.L., Falk-Andersson, J., Fabres, J., 2022. Global marine litter research 2015–2020: Geographical and methodological trends. Science of The Total Environment 820, 153162. https://doi.org/10.1016/j.scitotenv.2022.153162

I. Iglesias, M. Lupiac, L. R. Vieira, S.C. Antunes, J. Mira-Veiga, I. Sousa-Pinto, A. Lobo, 2023. Socio-economic factors affecting the distribution of marine litter: The

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

Portuguese case study. Marine Pollution Bulletin, 193, 115168. doi: 10.1016/j.marpolbul.2023.115168

Karasik, R., T. Vegh, Z. Diana, J. Bering, J. Caldas, A. Pickle, D. Rittschof, Virdin, J., 2020. 20 Years of Government Responses to the Global Plastic Pollution Problem: The Plastics Policy Inventory. NI X 20-05. Durham, NC: Duke University

Kusenberg, M., Faussone, G. C., Thi, H. D., Roosen, M., Grilc, M., Eschenbacher, A., ... & Van Geem, K. M. (2022). Maximizing olefin production via steam cracking of distilled pyrolysis oils from difficult-to-recycle municipal plastic waste and marine litter. Science of The Total Environment, 838, 156092.

M. Cordier, T. Uehara, 2019. How much innovation is needed to protect the ocean from plastic contamination? Science of The Total Environment, 670 (2019), pp. 789-799. https://doi.org/10.1016/j.scitotenv.2019.03.258

M. Thiel, G. Luna-Jorquera, R. Álvarez-Varas, C. Gallardo, I.A. Hinojosa, N. Luna, D. Miranda-Urbina, N. Morales, N. Ory, A.S. Pacheco, M. Portflitt-Toro, C. Zavalaga, 2018. Impacts of marine plastic pollution from continental coasts to subtropical gyres—fish, seabirds, and other vertebrates in the SE pacific, Front. Mar. Sci., 5, p. 238. https://doi.org/10.3389/fmars.2018.00238

Macintosh, A.; Simpson, A.; Neeman, T.; Dickson, K., 2020. Plastic bag bans: Lessons from the Australian Capital Territory. Resour. Conserv. Recycl. 154, 04638.https://doi.org/10.1016/j.resconrec.2019.104638

Marine Strategy Framework Directive (MSFD), 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy. Off. J. Eur. Union L164, 19–40.

Nasir, M.S., Tahir, I., Ali, A., Ayub, I., Nasir, A., Abbas, N., Sajjad, U., Hamid, K., 2024. Innovative technologies for removal of micro plastic: A review of recent advances. Heliyon 10, e25883. https://doi.org/10.1016/j.heliyon.2024.e25883

Râpă, M., Cârstea, E.M., Şăulean, A.A., Popa, C.L., Matei, E., Predescu, A.M., Predescu, C., Donţu, S.I., Dincă, A.G., 2014. An Overview of the Current Trends in Marine Plastic Litter Management for a Sustainable Development. Recycling 2024, 9, 30. https://doi.org/10.3390/recycling9020030

Co-funded by the Horizon 2020 programme of the European Union

Schmaltz, E., Melvin, E.C., Diana, Z., Gunady, E.F., Rittschof, D., Somarelli, J.A., Virdin, J., Dunphy-Daly, M.M., 2020. Plastic pollution solutions: emerging technologies to prevent and collect marine plastic pollution. Environment International 144, 106067. https://doi.org/10.1016/j.envint.2020.106067

Schwarz, A.E., Ligthart, T.N., Boukris, E., van Harmelen, T., 2019. Sources, transport, and accumulation of different types of plastic litter in aquatic environments: A review study. Marine Pollution Bulletin 143, 92-100. https://doi.org/10.1016/j.marpolbul.2019.04.029

Stapleton, M.J.; Ansari, A.J.; Ahmed, A.; Hai, F.I., 2023. Change in the chemical, mechanical and physical properties of plastics due to UVA degradation in different water matrices: A study on the recyclability of littered plastics. Environ. Pollut. 2023, 334, 22226. https://doi.org/10.1016/j.envpol.2023.122226

The International Convention for the Prevention of Pollution from Ships (MARPOL), 2017. Guidelines for the implementation of Annex V of MARPOL, IMO, London, ISBN 9789280115642, SKU IC656E

Thushari, G.G.N., Senevirathna, J.D.M., 2020. Plastic pollution in the marine environment. Heliyon 6, e04709. https://doi.org/10.1016/j.heliyon.2020.e04709

Turcanu, A.A.; Matei, E.; Rapa, M.; Predescu, A.M.; Coman, G.; Predescu, C. Biowaste Valorization Using Hydrothermal Carbonization for Potential Wastewater Treatment Applications. Water 2022, 14, 2344. https://doi.org/10.3390/w14152344

UNCLOS, 1982.Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397.

United Nations Environment Assembly (UNEP), 2016 .Resolution 2/11 Marine plastic litter and microplastics. https://nicholasinstitute.duke.edu/plastics-policies/unea-resolution-211-marine-plastic-litter-and-microplastics

United Nations Environment Programme (UNEP), 2005. Marine litter: An analytical overview. Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organisation. Nairobi.

United Nations Environment Programme (UNEP), 2019. Compilation of United Nations Environment Assembly Resolutions on Marine Litter and Microplastics. https://wedocs.unep.org/20.500.11822/32238.

Co-funded by the Horizon 2020 programme of the European Union

MAELSTROM

Walther, B.A.; Yen, N.; Hu, C.S. 2021. Strategies, actions, and policies by Taiwan's ENGOs, media, and government to reduce plastic use and marine plastic pollution. Mar. Policy 2021, 126, 04391 https://doi.org/10.1016/j.marpol.2021.104391

Worm, B., Lotze, H.K., Jubinville, I., Wilcox, C., Jambeck, J., 2017. Plastic as a Persistent Marine Pollutant. Annual Review of Environment and Resources 42, 1-26. https://doi.org/10.1146/annurev-environ-102016-060700

Co-funded by the Horizon 2020 programme of the European Union