



MAELSTROM Legacy Document



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Remove. Recycle. Give it a new use. Repeat.



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This document was made possible thanks to the valuable contributions of the MAELSTROM consortium and their commitment to honest accountability. Thank you!





Our Statement

The MAELSTROM Legacy Document is the result of four years of close collaboration among a consortium of fourteen European partners. During this time, we have collectively pushed boundaries to develop and implement innovative solutions to address the global marine litter challenge. Our most significant achievements are the result of the synergy, expertise, and commitment of our consortium's people.

However, as with any ambitious undertaking, we faced challenges along the way. Some aspects of the project did not unfold as smoothly as expected, and we encountered areas that required adaptation and recalibration. These challenges, while difficult, provided invaluable lessons, helping us refine our approaches and ensuring continuous learning and growth throughout the project. By capturing both the successes and the obstacles, this legacy document serves as a testament to what we have achieved and as a guide for future endeavours. By sharing these insights, we aim to support other projects addressing marine litter, helping them avoid similar obstacles and increasing their chances of success.

Additionally, we hope that the insights gathered in this document can serve as valuable input for the design and implementation of European and national level policies, targets and requirements to reduce marine litter, further contributing to long-term environmental sustainability.

The MAELSTROM team

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Project overview

MAELSTROM was 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 was compiled by a consortium of 14 international partners led by the Institute of Marine Sciences of the Italian National Research Council (CNR-ISMAR). Other partners spanned academia and industry, using the expertise of research institutes, enterprises, and NGOs from 8 European countries.

MAELSTROM's main goal was to reduce the impacts of marine litter in coastal ecosystems by identifying accumulation hotspots and removing the existing litter from the coastal seabed and the water column of rivers before it reached the sea. This action was supported and enacted through circular economy and societal-oriented solutions. In particular, the project:

01 Set 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

02 designed and manufactured scalable, replicable and automated technologies, co-powered with renewable energy and second generation fuel, to identify, remove and sort marine litter

03 evaluated over time the effectiveness of marine litter removal devices along with their impact on local ecosystems

04 integrated different technologies to track, sort and recycle all types of collected marine litter into valuable raw materials for future marketisation

05 assessed the economic and societal impact of the MAELSTROM solutions, providing also a comprehensive life-cycle assessment of the technologies and products

06 enhanced social awareness about the marine litter issue and engaged citizens and stakeholders in MAELSTROM activities

07 interplayed with similar projects to maximise innovation uptake for marine litter removal within and outside the EU

The project 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, co-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 that was successfully tested in the Venice coastal area with two cleaning campaigns in 2022 and 2023 collecting a total of 2240 kg of marine litter. An AI-driven robot was used to identify and segregate plastics collected from the two coastal environments, and three new processes have been used to recycle the retrieved plastic litter. These were transformed into higher-value materials whose characteristics, performance, and economic value were assessed for future entry into the market.

MAELSTROM contributed to increase scientific knowledge, develop research capacity and transfer marine technology and to improve professional skills and competences, through 10 MSc Thesis and 2 PhD programs.

The project focused also 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 carried 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 marine litter and the tools used in addressing the problem. The project team has also organized public demonstrations of the marine litter removal technologies at several national, European and international scientific conferences and High-Level meetings. The public demonstration and launch of the Robotic Seabed Cleaning Platform in the Venice lagoon occurred in June 2023. The Bubble Barrier in the Porto region took place in November 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 marine litter pollution to a broader audience.



Executive Summary

The present legacy document serves as a comprehensive record of the key challenges, opportunities, lessons learned, and outcomes from the MAELSTROM project. By documenting both challenges and opportunities, the legacy document aims that knowledge and experiences gained are preserved, serving as a foundation for addressing similar issues and seizing new opportunities in future projects. Specifically, it aims to identify:

Scientific Challenges

Challenges in identifying pollution hotspots and understanding marine litter dynamics in pilot locations, ecological interactions and assessing short and long-term efficacy of MAELSTROM's removal technologies.

Technical Challenges

Technical hurdles encountered during the design and development of marine litter removal technologies (es. integrating novelties/specific features, ensuring durability in harsh marine environments, etc.); technical issues with identifying, collecting and recycling marine litter.

Logistical Challenges

Logistical difficulties in deploying and operating MAELSTROM's technologies, including transportation to pilot areas, access to suitable test sites, coordination with local authorities and suppliers; management and transportation of marine litter to recycling and waste management companies. International logistics and subcontracting procedures.

Regulatory Challenges and Policy Gaps

Regulatory complexities related to marine litter removal activities, including permits for testing experimental technologies, compliance with environmental regulations, and liability considerations. Policy gaps regarding riverine litter and marine litter collecting and recycling procedures, and marine litter valorization.

Project Framework Challenges

(Administrative and Financial)
Project constraints including timeline, deliverables, reporting frameworks, budget limitations, cost overruns associated with research and development activities, etc.

Environmental Challenges

Environmental factors that posed challenges to the effectiveness of marine litter removal technologies, such as specific hydrodynamic conditions, sediment characteristics, water turbidity or unpredictable weather conditions.

Stakeholder Engagement Challenges

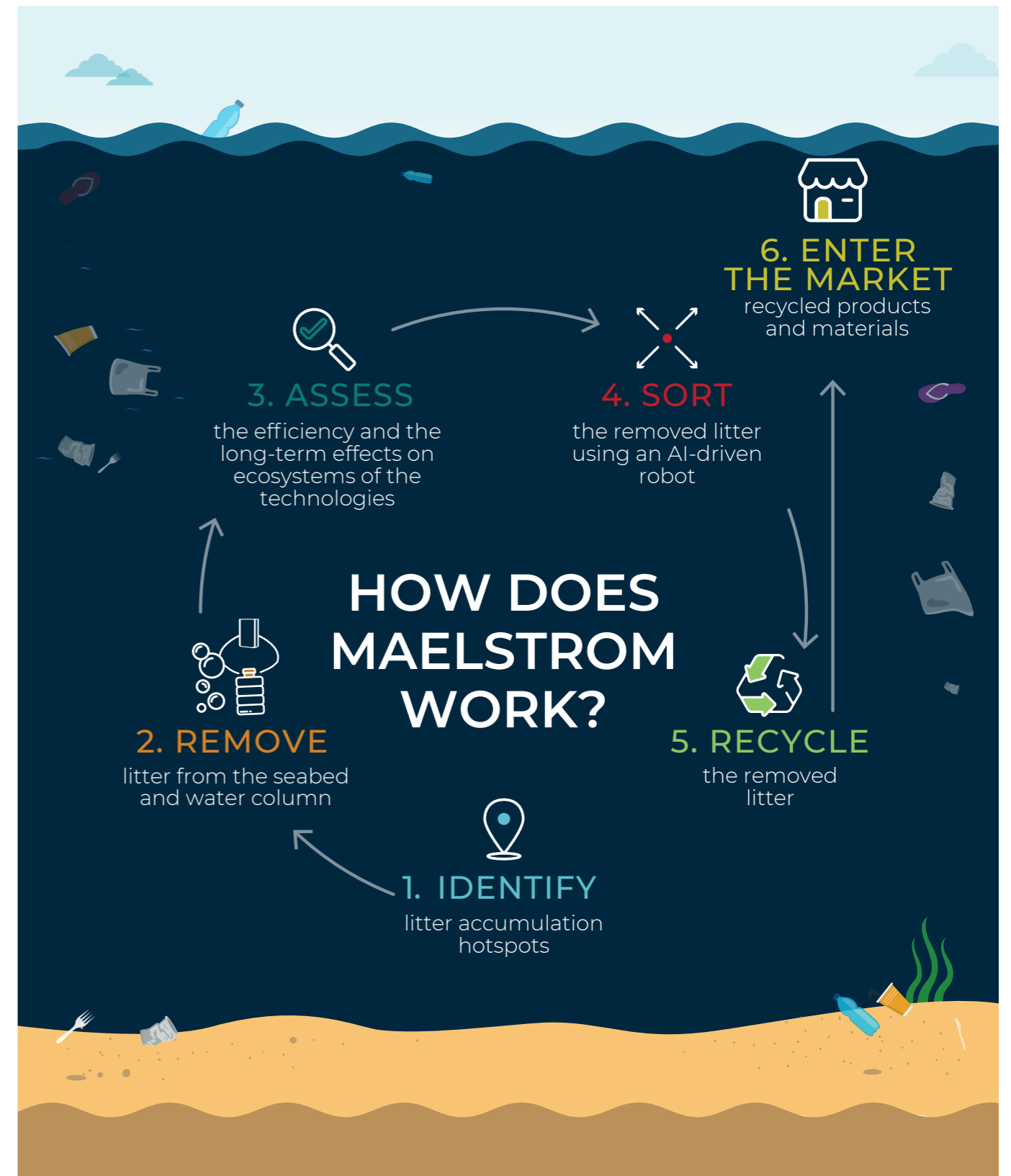
Challenges related to collaboration with stakeholders including differences in expertise, communication barriers, and conflicting priorities/expectations and awareness levels.

To streamline the partners' contributions, the legacy document has been structured according to the project's key phases:

1. **Site Selection and Assessment;**
2. **Technology Design and Development;**
3. **Implementation;**
4. **Litter Collection, Sorting and Disposal;**
5. **Monitoring;**
6. **Transformation;**
7. **Market Entry and Uptake**

Each section delves into:

- **What worked well;**
- **Challenges;**
- **What could have been improved;**
- **Opportunities and Suggestions (If relevant)**



MAELSTROM Legacy



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PARA UMA ECONOMIA CIRCULAR DE PLÁSTICOS
PORTUGAL

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COMO FUNCIONA O MAELSTROM?
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In search of Ocean Knowledge and Sustainability
RESEARCH & INNOVATION

Mar de Experiências
"Num lugar onde a terra encontra o mar sempre se fixaram pessoas que criaram um estilo de vida. Nesse limbo entre o mar e o seu impacto nasceu uma forma de lidar com a vida."
Valorizar a cultura, a história e o património
Sensibilizar e instalar

1. Site Selection and Assessment

Contributing Partners: CNR - CIIMAR - TGBB - TECNALIA - CNRS - DELTARES

What worked well:

Previously existing collaborations and networks with local, regional and national authorities in Venice and Vila do Conde, as well as other key stakeholders, were important to create trust, commitment and support throughout the project.

MAELSTROM created a **mutually beneficial scenario**, where the proposed solutions addressed the need of local municipalities in Venice and Vila do Conde to monitor or clean polluted coastal areas; this was specially felt in the Venice Lagoon and its coastal area.

The **early inclusion of key stakeholders** and authorities during the site selection process in Venice enabled a positive approach regarding research permits. In Vila do Conde, where engagement occurred later due to political changes, some aspects of the project, such as permits, experienced delays; however, the efforts from the consortium resulted in positive support from the municipality through the provision of additional resources and technical support.

The selected sites allowed for the collection of **new scientific knowledge**, the development of new numerical models to identify marine litter hotspots, and a better understanding of the health of the local ecosystems with the opportunity to contribute to national and European environmental databases.

The selected sites and active involvement of the local communities enabled MAELSTROM to identify, engage with, and **support existing local initiatives and environmental programs**. In Vila do Conde, for instance, the CMIA (Centro de Monitorização e Interpretação Ambiental) facility experienced a boost in public participation, while local schools expanded their environmental education and ocean literacy curricula, thanks to MAELSTROM's presence and contribution. Similarly, schools in Venice were actively involved in the project through awareness-raising efforts focused on plastic consumption and disposal also through collaboration with artists and art institutions.

Venice Lagoon, Italy



Challenges:

Communication challenges due to COVID-19 at the beginning of the project affected the initial engagement efforts with local authorities in both pilot areas.

Changes in site selection in the pilot case of northern Portugal, resulted in significant issues that affected the overall timeline and engagement with stakeholders.

Political changes during the project timeline caused significant delays in engaging the Municipality of Vila do Conde.

Complex permit procedures regarding permanent installations in transitional waters, as in the case of the Bubble Barrier in Vila do Conde, took much more time than short-term interventions, such as the Seabed Cleaning Platform in Venice.

Lack of a mandate to monitor or manage riverine litter management in Europe hindered engagement of national, regional and local authorities in the pilot of Vila do Conde. In general, entities and communities are less aware of the issue of riverine litter than marine litter.

Multiple stakeholders' involvement in the rivering environment made the permit issuing process more complicated and required more time than expected.

Inadequate time for stakeholder engagement created challenges in maintaining progress.

What could have been improved:

Involvement of stakeholders during the proposal stage, especially licensing authorities and relevant entities, would have ensured better alignment and support, optimizing time.

Better pre-application stage planning and development of contingency options. For instance, the initially proposed site in northern Portugal was found unsuitable after the initial assessment, resulting in a costly delay in a new site selection.

Opportunities / Suggestions:

Simplification of the normatives towards facilitating the permit-issuing process when multiple stakeholders are involved, in order to reduce bureaucratic delays and improve efficiency.

Development of policies for riverine litter at the European and national level, addressing riverine litter and focusing on prevention, management and cleanup efforts for environmental protection.

Vila do Conde, Portugal



2. Technology Design & Development

Contributing Partners: TECNALIA - TGBB - VLPF - ST - CIIMAR - CNRS-LIRMM

What worked well:

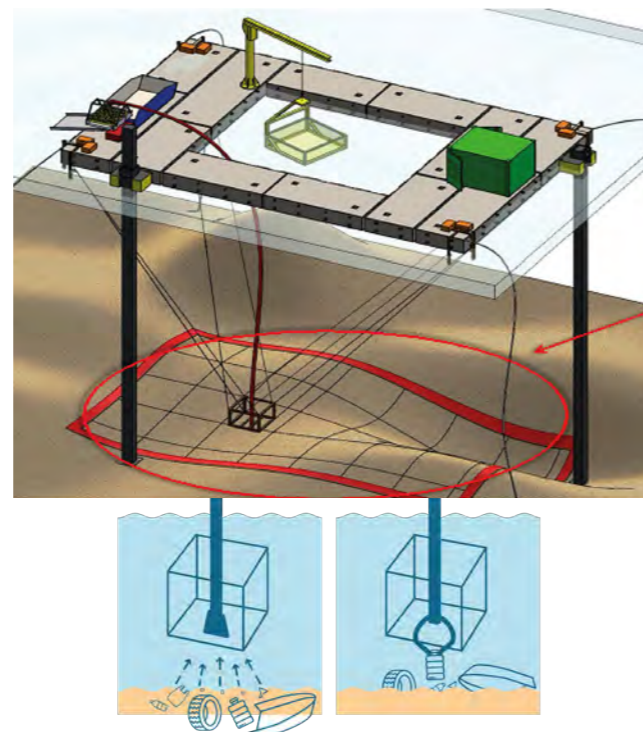
Local authorities' involvement in **co-designing the technological solutions** and providing financial support for project-related activities, such as the waste disposal in the case of the Bubble Barrier in Vila do Conde.

The design of the Robotic Seabed Cleaning Platform has greatly benefited from the extensive experience and **close collaboration among partners**, enabling the extremely short "time-to-prototype" required for design, manufacturing, and integration in line with the overall project plan.

The deployment and integration of the Robotic Seabed Cleaning Platform greatly benefited from the **diverse engineering skills** of MAELSTROM's multidisciplinary team. This collaboration enhanced functionality and effectiveness, allowing for real-time adjustments and the incorporation of unforeseen additional technologies to adapt to the differences between expected and actual operating conditions.

The presence of a **local industrial partner** (Servizi Tecnici - ST) has provided key knowledge about sites and operating procedures, as well as the necessary facilities and engineering support for the integration and initial testing of the Seabed Cleaning Platform before the actual cleaning campaigns.

The development and testing of the MAELSTROM App significantly improved beach monitoring and cleaning campaigns. Data collected through the app was readily available after surveys, facilitating communication and reporting. Additionally, the app enabled collaborative efforts during monitoring campaigns, allowing multiple operators to simultaneously **record litter items, following European protocols**.



Challenges:

Engaging local contractors for the installation of essential equipment and infrastructure posed challenges. Effective communication during execution, quality control, and post-delivery services required significant effort, and the outcomes were not always satisfactory.

The COVID-19 pandemic and the war in Ukraine severely disrupted **supply chains**, leading to significant increases in material and equipment costs. This escalation resulted in budget shortfalls for partners who needed to cover unexpected expenses, with no provision for adjustments under Horizon 2020 guidelines.

Potential **exploitation of the Robotic Seabed Cleaning Platform** by external companies is constrained until the project concludes, primarily due to existing financial regulations.

What could have been improved:

Earlier identification of local contractor needs during the budgeting phase, identifying which elements needed to be constructed by local contractors. This foresight could have helped the overall planning and execution.

Contract management costs, including travel expenses and time allocations, should have been factored into the budget.

Opportunities / Suggestions:

The **Robotic Seabed Cleaning Platform** has proven to be efficient. Its logistics and overall operation cost could be optimised to facilitate its adoption as an effective tool for underwater waste removal. Additionally, other commercial applications could be pursued to support its transition into a product that is also useful for waste removal.

In international contexts, consider appointing a **local technical liaison expert** dedicated to managing relationships with local contractors to facilitate communication, ensure quality control, and strengthen collaboration within the community.



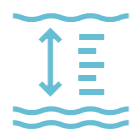
Teleoperated and autonomous modes



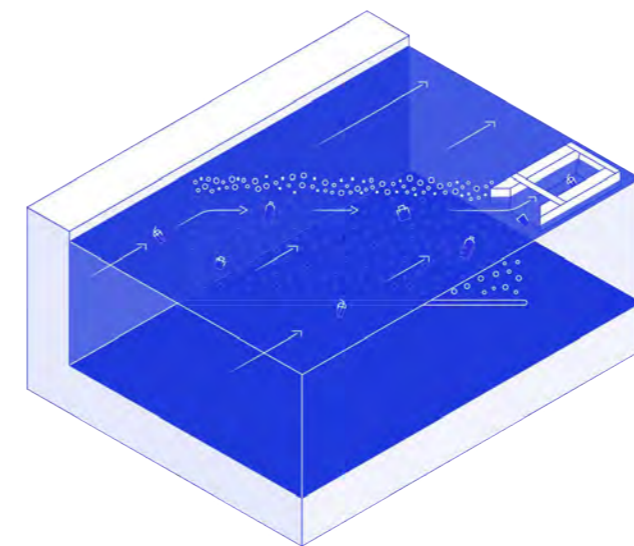
AI Smart Camera to identify the Marine Litter



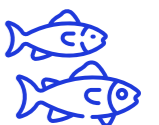
Efficient and selective removal to preserve the ecosystem



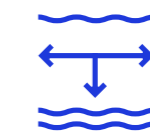
From surface to 20m depth (or more)



Allows ships to pass



Fish Friendly



Full depth and width of the river



Operating 24/7

3. Implementation of MAELSTROM Technologies

Contributing Partners: TGBB - TECNALIA - CNRS - ST - UNI MALTA - CNR - CIIMAR

What worked well:

During the deployment phase, Vila do Conde's **community showed a strong interest** in the project, fostering a sense of involvement and support.

During the implementation of the Seabed Cleaning Platform, **local authorities assisted** in carrying out the activities, providing support through their personnel. For example, divers from the Italian Coast Guard and State Police helped inspect the sites, while the local waste management authority facilitated the recovery of the collected litter in the Venice lagoon.

Challenges:

Implementing technologies in **real-world conditions in both pilot areas** introduced variables beyond our control, such as weather and seasonal changes. The **strict timeline** left little room for adjustments in response to these factors.

Involved **permit authorities** did not fully comprehend the project's scale until deployment began, resulting in new and additional requirements that complicated progress.

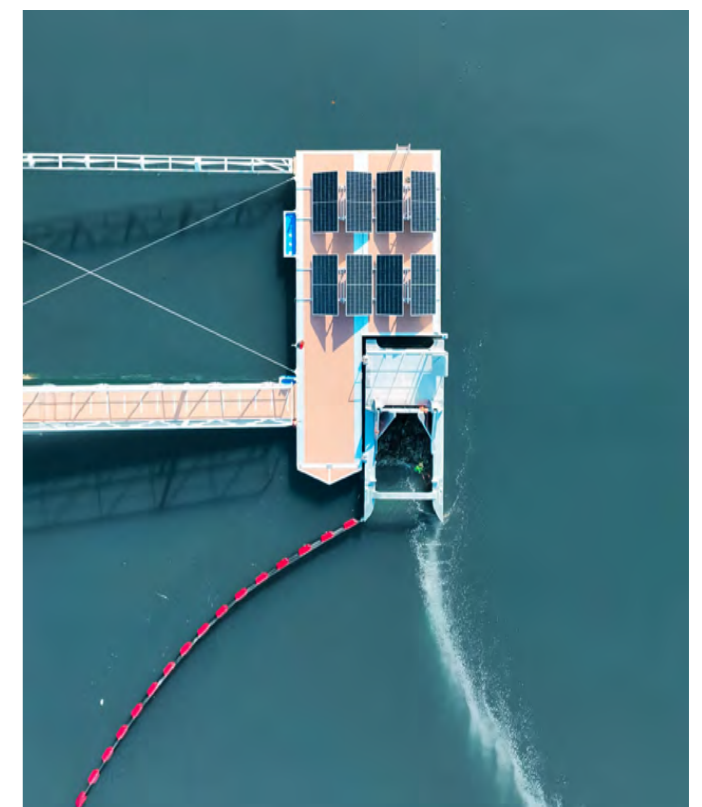
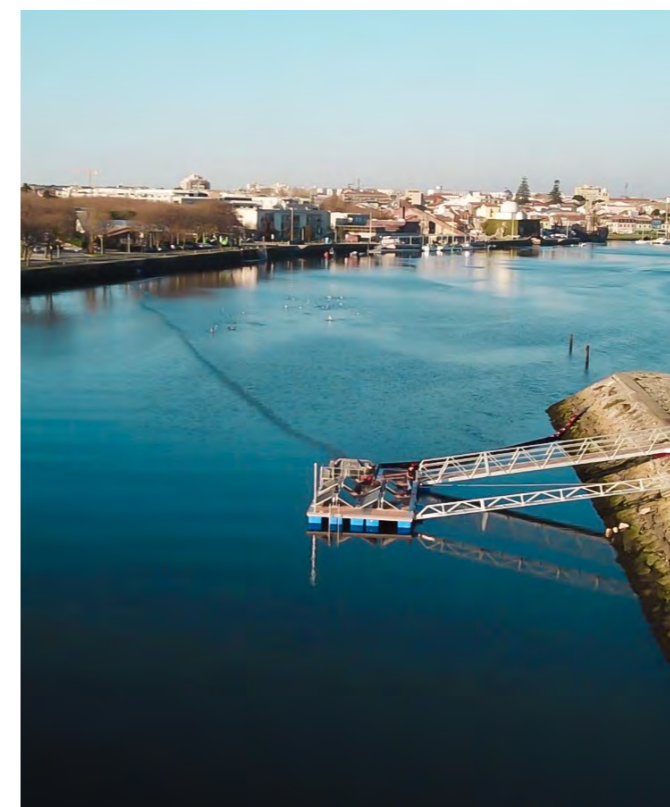
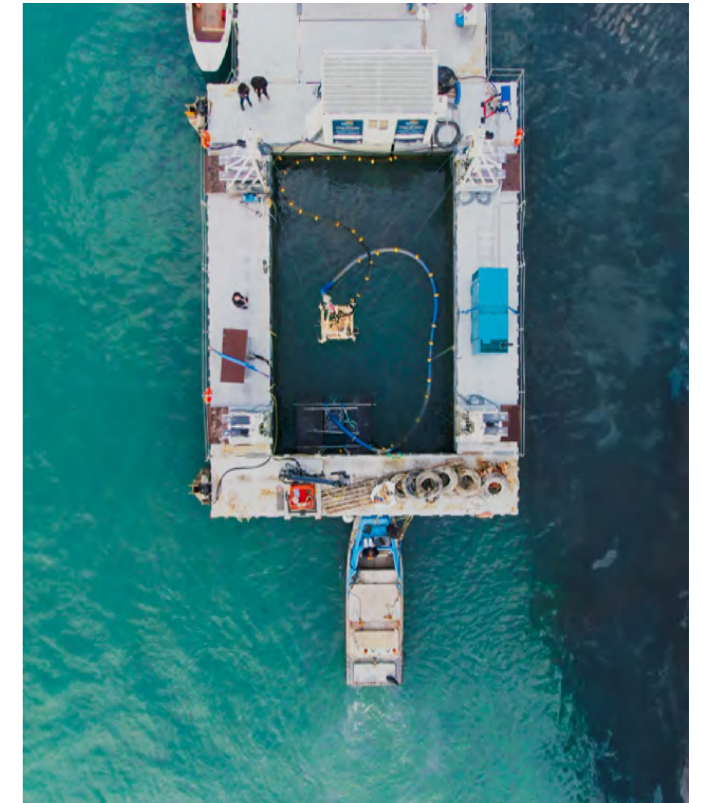
What could have been improved:

Developing a strategy to **effectively inform the local community** about the project's goals, scope, and timeline prior to implementation would have been valuable in both pilot locations. The active role of municipalities in this regard would have been beneficial.

Opportunities / Suggestions:

For every EU project, a specific Work Package focused on **engaging the local community** should be included. This package could outline strategies for communication, collaboration, and involvement throughout the project's lifecycle, ensuring that community interests and feedback are effectively integrated.

During the project application phase, partners responsible for "hard tech" tasks should define upfront conditions for proper deployment. This includes considerations for seasonality, weather, and various environmental factors (such as river flow velocity, in the case of the Bubble Barrier) to establish a clear time window for when these requirements are most likely to be met. If conditions are not fulfilled, the partner should have the option to propose an alternative time window without being held accountable for delays in project implementation. This approach would also protect other partners relying on the completion of these tasks, allowing for **more flexible planning and execution**.



4. Litter Collection, Sorting and Disposal

Contributing Partners: GEES - VLPF - CIIMAR - TECNALIA - CNR - ST

What worked well:

The development of the **MAELSTROM portal and app** significantly streamlined the collection, transport, and recycling processes. Their integration with waste tracking enhanced marketing efforts, and the concept is quickly being adapted for use in other areas, such as wind turbine recycling.

Gees' adapted shredding system demonstrated remarkable flexibility in **processing complex and problematic waste**, including marine litter and ghost boats.

Collaboration among partners was highly effective, fostering a productive working environment that generated the "Ghost Boats" spin-off permanent programme of partner Venice Lagoon Plastic Free for identifying, removing and recycling EOL boats in the Venice Lagoon, in collaboration with partner Gees Recycling.

Positive interactions with local authorities in Vila do Conde **facilitated external funding** and the contracting of a waste collection company to manage the recovery and disposal of collected marine litter.

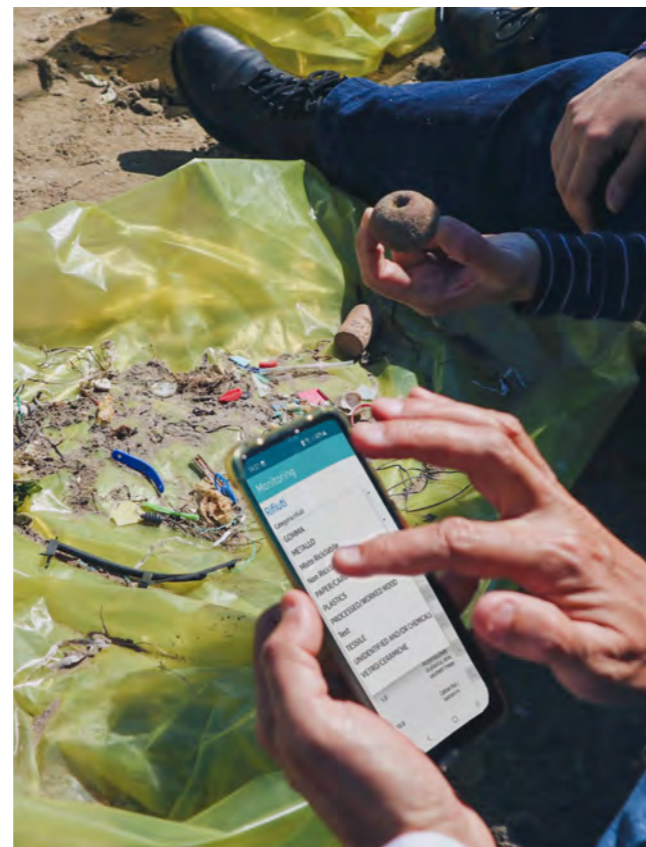
The development of the AI-driven waste sorting robot benefited from the marine litter provided by the project's partners, which served as key samples for training the robot's AI. The logistics required for the collection, classification, and transport of this marine litter had not been anticipated and were made possible through the **generosity of partners** both within and outside the project.

Challenges:

Navigating the **legal aspects of waste rules** posed significant challenges. Different countries have varying regulations, and the same type of plastic may only be processed by authorized consortiums, depending on its origin - whether from packaging, industry, or construction.

While we were fortunate not to encounter **contaminated marine litter**, salt contamination rendered some HDPE floaters unrecyclable through standard methods.

Without the support of volunteer efforts, some aspects would not have been feasible due to **financial viability**.



What could have been improved:

Enhanced **collaboration from authorities** would have facilitated project execution and compliance with regulations.

A **EU legal framework for waste removal** would have helped streamline processes and greater collaboration from authorities.

Greater **cooperation in marketing project outputs** would have amplified visibility and impact, ensuring that results reach a wider audience.

A **more in-depth analysis of the materials** collected would have provided better insights for effective processing and recycling.

Taking into account the **costs associated with sorting macrolitter**, such as ghost boats, would have improved budgeting and resource allocation.



Opportunities Suggestions:

There is a significant opportunity to **involve regional entities and SMEs**, including start-ups, to innovatively recycle and valorize products. By developing market-ready products from recovered marine litter, we can foster local economic growth and sustainability.

The collection of **organic marine litter** presents an opportunity to identify new resources for the circular economy. For example, developing fertilizers from water hyacinth recovered from the Bubble Barrier in Vila do Conde could create sustainable agricultural solutions.

5. Monitoring

Contributing Partners: CIIMAR - CNR - DELTARES

What worked well:

Long-standing **relationships with local contractors and national agencies** facilitated rapid processing of applications and effective implementation of monitoring campaigns, especially in Vila do Conde due to CIIMAR's positioning in the Portuguese context.

Successful facilitation of several national and international internships, as well as Bachelor's and Master's programs, resulted in the **publication and dissemination of numerous theses**.

Monitoring efforts effectively **engaged the local community in Vila do Conde**, raising awareness and understanding of environmental issues and the solutions being implemented.

Challenges:

The **short timeframe** for monitoring the environmental impact after the installation of technologies, in the case of the Bubble Barrier in Portugal, constrained our ability to conduct thorough evaluations. This limitation also affected the accuracy of the final cost-benefit analysis.

What could have been improved:

Standardized monitoring protocols at the international level would have enabled consistent data collection and comparisons with existing published and reported literature. This harmonization would enhance the reliability and applicability of findings across different contexts.

Strong collaboration among partners enabled the exchange of equipment, allowing for effective management of unexpected environmental and technical challenges. The development of a hydrodynamic model for the Ave estuary was crucial for implementing and evaluating the Bubble Barrier, as well as for anticipating future scenarios related to plastic litter impacts.

The functionalities of **the MAELSTROM proof-of-concept app**, developed by GEES and VLPP for beach litter monitoring (compatible with EMODnet), tracking, and cleanup, were further enhanced with additional features under the Mission Ocean and Waters Horizon Europe projects, REMEDIES and SeaClear 2.0.

Opportunities / Suggestions:

There is a valuable opportunity to implement **mid-to long-term monitoring and data collection efforts at local, national, and European levels**.



6. Transformation

Contributing Partners: GEES - TECNALIA - MAKEEN

What worked well:

The recycling process effectively demonstrated that it is indeed possible to **transform marine litter into new products**.

The **bonding agent** proved effective when working with salt-sand contaminated feedstock, enhancing the viability of recycling efforts.

Marine litter was successfully processed through pyrolysis, yielding valuable fractions for **analysis, learning, and market assessment**. Although the resulting pyrolysis oil was of low quality and had a few parameters out of specification, this outcome provided important insights for future improvements.



7. Market Entry and Uptake

Contributing Partners: ALPHA

What worked well:

The **cohesive approach** adopted by the Consortium, particularly the partners involved in the Pilots, resulted in effectively managing a diverse array of stakeholders with varying interests throughout the execution of the activities in Venice and Vila do Conde.

Strong open communication and collaboration within the Consortium were essential in ensuring the successful achievement of the project's objectives.

Actively **engaging with the private sector** supported the valorization of marine litter, while **outreach to the public** increased awareness and highlighted the importance of adopting solutions to address marine litter at local level.

Challenges:

Managing **relations with multiple stakeholders** posed a key challenge. Ensuring adequate and prompt communication was essential to keep everyone aligned. Collaboration was further complicated by differing interests and overlapping responsibilities among stakeholders.

Accessing **clear and coherent information** (e.g., official documentation on public spending budgets, expenditure on waste collection and remediation activities) was challenging, as some sources were hard to find and often unreliable. Official documentation frequently appeared outdated or inconsistent with other official sources, leading to confusion.

Operating and executing the Pilots while navigating the complex **legal frameworks for waste removal and treatment** presented significant normative gaps, such as the lack of mandates for addressing riverine marine litter.

What could have been improved:

Direct involvement of Municipalities as third-party beneficiaries or partners could have significantly reduced several issues and communication gaps, particularly regarding permit releases. This engagement would have been especially beneficial in the early stages of the Pilots, facilitating smoother collaboration and timely decision-making.

Opportunities / Suggestions:

Engaging the private sector, particularly SMEs and start-ups, is crucial in addressing marine litter as a common public issue. These entities can support public organizations in recycling and valorizing the litter collected, enhancing overall effectiveness.

Public entities have access to various **funding schemes at regional, national, and international levels**. Leveraging these opportunities can enhance valorization processes for marine litter, ultimately contributing to its removal from the environment.

For future follow-up projects, **direct involvement of Municipalities** is recommended. This engagement would facilitate pilot setup and execution while ensuring a direct communication channel and an accurate and coherent information flow, involving key decision-makers throughout the process.





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the report:



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