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# 5. Eco-efficiency Measures for Sustainability

This chapter presents the sustainability aspects of Maris Habitats by looking at environmental, economic, and social impacts. It also explains how the product's life cycle is considered from material selection and production to maintenance and end-of-life.

## 5.1 Introduction

This chapter examines the environmental, economic and social dimensions of the project, as well as the product's life cycle, in order to assess its overall sustainability. The aim is to highlight the considerations taken to minimize negative environmental impacts when introducing artificial structures into marine ecosystems.

Particular attention is given to ensuring that the solution does not further disrupt or degrade existing ocean environments. This includes evaluating how the design, material selection, and long-term use of the product can prevent pollution and reduce ecological harm. By adopting a life cycle perspective, the chapter also addresses how the product can be managed responsibly from production to end-of-life.

## 5.2 Environmental

This section considers the environmental impact of the project using principles inspired by the butterfly diagram, a model that represents circular material flows **[1]**. The model distinguishes between biological processes, where materials safely integrate into natural systems, and technical processes, where products are maintained, reused, and recycled to extend their lifespan (see Figure 1).

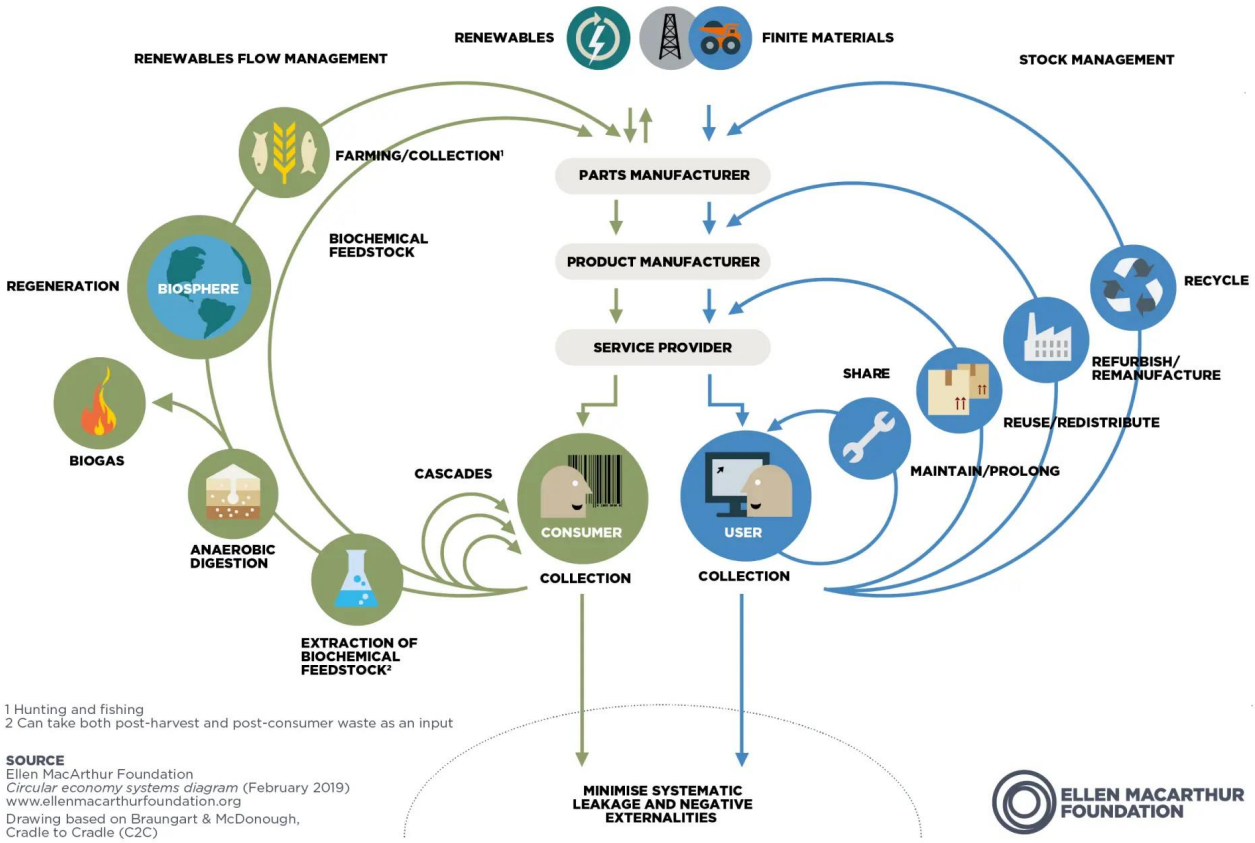


Figure 1: Butterfly diagram **[2]**

The Maris Habitats concept reflects these principles by combining long-term environmental integration with efficient use of technical components. From a biological perspective, the Reef Block is designed to support marine colonization over time. The use of non-toxic and durable materials allows algae, microorganisms, and small marine species to attach and grow on the structure, contributing to biodiversity enhancement **[3]**.

From a technical perspective, the system is designed with longevity and adaptability in mind. The Reef Block is intended to remain underwater for long periods, while the Smartlogger is designed as a removable waterproof housing for the monitoring components. The Smartlogger contains the battery, microcontroller, sensors, and data storage system, and it is held by the Smartlogger attachment on the Reef Block. Sensor probes remain exposed to seawater to measure environmental conditions such as pH, conductivity, pressure, and temperature. This modular design allows maintenance or replacement of electronic components without removing the whole Reef Block.

Maintenance requirements are reduced through the use of durable materials that can withstand harsh marine conditions. When maintenance is required, divers can retrieve the Smartlogger to collect stored data and replace batteries without disturbing the Reef Block. This reduces unnecessary material replacement and extends the operational life of the system.

The project also considers the reuse of technical components. If monitoring is no longer required, electronic components such as sensors, batteries, and storage devices can be removed and reused in future installations.

For the prototype, a cement-based casting method with a 3D-printed PLA mold may be used to reduce costs, while the final design uses basalt fiber-reinforced concrete to improve durability and corrosion resistance in marine environments. This approach reduces environmental impact while maintaining

long-term functionality.

## 5.3 Economic

The economic aspect of Maris Habitats is mainly related to the long-term benefits created through ecosystem restoration and its integration with existing marine infrastructure. By supporting marine biodiversity and fish population growth, the system may help increase fishery productivity over time. This can create economic benefits for coastal communities that depend on fishing as a source of income and food.

Previous studies have shown that artificial reefs can increase fish biomass and support the development of fisheries, which can lead to economic improvements in coastal areas **[4]**. In this project, this idea is applied through Reef Blocks that provide shelter and breeding areas for marine species.

The system is also designed to be integrated with existing marine infrastructure, such as offshore wind farms or coastal protection systems. This approach reduces the need for completely new structures and allows existing installations to gain additional ecological functions, improving resource efficiency.

The integration of the Smart Module adds another layer of economic value. The Smartlogger collects environmental data that can be used for research, monitoring, and decision-making. In this project, this data supports more efficient marine resource management and may help reduce costs related to ineffective environmental monitoring.

Another important aspect is the modular and scalable design of the system. Reef Blocks can be deployed gradually and adapted to different marine environments, reducing the need for large initial investments. This allows pilot projects to be tested before full-scale deployment.

The removable Smart Module also helps reduce maintenance costs. Instead of replacing or removing the entire Reef Block in case of failure, the Smartlogger can be inspected, repaired, or replaced separately. This improves operational efficiency and reduces long-term costs.

In addition, the project can benefit from collaboration with public institutions, research organizations, and environmental programs. Marine restoration and biodiversity protection are increasingly supported by sustainability policies and funding initiatives **[5]**. This creates opportunities for financial support through grants and public-private partnerships.

Although the initial investment may be relatively high, the project can create long-term value through ecosystem restoration, fishery support, and improved coastal protection **[6]**. For this reason, Maris Habitats can be considered both environmentally sustainable and economically viable in the long term.

## 5.4 Social

The integration of the Smart Module also creates social value by generating data that can be used by research institutions and environmental organizations for marine monitoring and scientific research. The Smartlogger can help improve understanding of marine ecosystems and support better environmental decision-making.

The project is also aligned with the market strategy by focusing on partnerships with offshore wind farms, coastal authorities, research institutions, and environmental organizations **[7]**. By integrating Reef Blocks into existing marine infrastructure, the project promotes collaboration between technical and environmental stakeholders while reducing the need for additional construction.

In the long term, this approach can support sustainable fisheries, marine conservation efforts, and stronger cooperation between organizations involved in ocean management.

## 5.5 Life Cycle Analysis

The life cycle of the project is considered from material selection to end-of-life, with the aim of reducing environmental impact while maintaining long-term functionality.

In this project, the material phase focuses on choosing durable and environmentally responsible materials. The final design uses basalt fiber-reinforced concrete. Basalt fibers are made from natural volcanic rock and are known for their resistance to corrosion and chemical stability in seawater, which makes them suitable for marine environments **[8]**.

During the manufacturing phase, the Reef Block is produced through concrete casting, while the monitoring components are assembled separately inside the removable Smartlogger. The Smartlogger contains the battery, microcontroller, SD card, and sensors. Keeping the electronic components separate helps avoid embedding electronics directly into the permanent Reef Block and reduces unnecessary material waste.

The testing phase focuses on checking both the structural performance of the Reef Block and the operation of the Smartlogger system. Special attention is given to battery life, waterproof protection, sensor accuracy, and reliable data collection because these factors affect maintenance needs.

The Reef Block is also designed for long-term use in marine environments. Its geometry includes cavities and irregular surfaces that help algae, microorganisms, and small marine species attach to the structure over time.

To reduce environmental risks, the Smartlogger is designed as a removable unit that is not cast into the main Reef Block. It is mounted on the Smartlogger attachment and secured to the Reef Block with a chain. This keeps the Smartlogger connected to the reef structure and gives the diver a clear point to attach a hook or line. During maintenance, battery replacement, data collection, or repairs, only the Smartlogger needs to be removed, while the Reef Block stays in place. This also helps reduce the risk of long-term marine pollution from electronic components.

At the end of its life cycle, the Reef Block is intended to remain in the marine environment and continue functioning as an artificial reef that supports biodiversity **[9]**. Electronic components can be removed and reused in future systems, which helps reduce waste.

## 5.6 Summary

This chapter has examined the environmental, economic, and social dimensions of the project, together with a life cycle perspective, in order to evaluate its overall sustainability. The analysis highlights the importance of minimizing environmental impact while ensuring long-term functionality, economic viability, and social value.

Based on this sustainability analysis, the team selected a modular Reef Block design combined with a removable Smart Module and basalt fiber-reinforced concrete as the primary structural material. This choice is supported by its durability, resistance to marine conditions, and suitability for long-term deployment while reducing environmental risks. In addition, the separation of electronic components from the main Reef Block contributes to reducing pollution risks and improving resource efficiency.

Consequently, the solution was designed with features that support sustainability throughout its life cycle. These include a Reef Block that can integrate into the marine ecosystem over time, a removable Smartlogger that enables maintenance without disturbing the Reef Block, and a design that supports marine colonization through varied shapes and surface characteristics. Together, these elements help the system reduce negative environmental impacts while supporting marine biodiversity and long-term ecosystem health.

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**[1]**, **[2]** Ellen MacArthur Foundation, 2021. *The Circular Economy System Diagram (Butterfly Diagram).*
**[3]** DipNDive, 2023. *The Ethical Debate Around Artificial Reefs: Conservation or Tourism Ploy?.*
**[4]** Hao-Tian Li, Ya-Jun Wang, Jian-Bao Zhang, Peng Yu, Yi-Tong Wang, Jun-Guo Li, Shu-Hao Zhang, Zi-Han Tang, Jie Yang, 2026. Research Progress and the Prospect of Artificial Reef Preparation and Its Impact on the Marine Ecological Environment. *Materials*, 19, pp.447.
**[5]** Andrew Deutza, Geoffrey M. Healb, Rose Niuc, Eric Swansonc, Terry Townshendc, Zhu Lic, Alejandro Delmard, Alqayam Meghjid, Suresh A. Sethid, John Tobin-de la Puente, 2020. Financing Nature: Closing the Global Biodiversity Financing Gap. *Paulson Institute*, na, na.
**[6]** Robert Costanza, Rudolf de Groot, Paul Sutton, Sander van der Ploeg, Sharolyn J. Anderson, Ida Kubiszewski, Stephen Farber, R. Kerry Turner, 2014. Changes in the global value of ecosystem services. *Global Environmental Change*, 26, pp.152-158.
**[7]** United Nations, 2015. *Goal 17: Partnerships for the Goals.*
**[8]** V. Fiore, T. Scalici, G. Di Bella, A. Valenza, 2015. A review on basalt fibre and its composites. *Composites Part B: Engineering*, 74, pp.74-94, ISSN 1359-8368.
**[9]** Blue is the new green – Ecological enhancement of concrete based coastal and marine infrastructure. *Ecological Engineering*, 84, 2015, pp.260-272, ISSN 0925-8574.

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