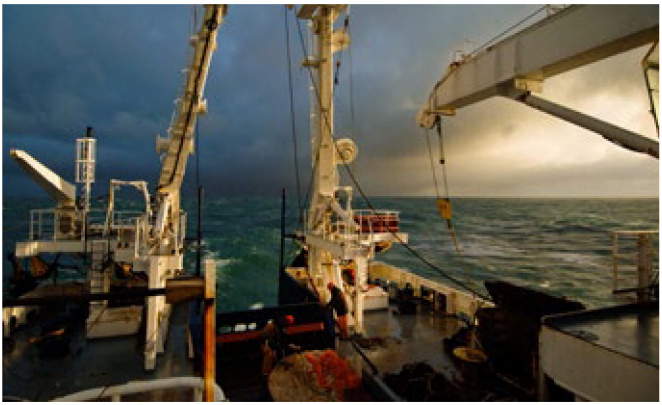

INNOVATIVE
MULTI-PURPOSE
OFFSHORE
PLATFORMS
MERMAID

INTRODUCTION

Increasingly, European seas and oceans are subject to the development of marine infrastructure such as offshore wind farms, energy extraction from tides and waves as well as marine aquaculture in order to meet the demand for energy and seafood. These novel offshore activities require specific technology and governance in order to address the challenges linked with the installation, operation and maintenance of these facilities. Moreover, the development and operation of marine infrastructure exert environmental pressure on the oceans, threatening marine ecosystems. In this regard, it is crucial that the economic costs, the use of marine space and the environmental impacts of these activities remain within acceptable limits. Offshore platforms that combine multiple functions within the same infrastructure can offer significant benefits in terms of economics, optimising spatial planning and reducing the impact on the environment.

EUROPEAN POLICY CONTEXT



The European Integrated Maritime Policy (IMP, COM (2007) 575) seeks to provide a more coherent approach to maritime issues, with increased coordination between different policy areas. It covers several cross-cutting policies, of which 'Blue growth' (COM (2012) 0494) and 'Maritime spatial planning' (COM (2013) 133) are of specific importance with regard to multi-use offshore platforms. Blue growth is the long-term strategy to support sustainable growth in the marine and maritime sectors as a whole, while maritime spatial planning is about planning when and where human activities take place at sea – to ensure these are as efficient and sustainable as possible.

The environmental pillar of the IMP is constituted by the Marine Strategy Framework Directive (MSFD, Directive 2008/56/EC), which intends to achieve the Good Environmental Status (GES) of the European marine waters by 2020 as well as the protection of the resources on which economic and social activities depend. In order to describe the GES, 11 descriptors were defined, several of which are relevant for the construction, operation and decommissioning of multi-use offshore platforms (e.g. seafloor integrity, hydrographic features and underwater noise and other forms of energy).

EUROPEAN POLICY CONTEXT

Besides the aforementioned integrated policy, sectoral legislation and policies exist with regard to the different user functions of the multi-use offshore platforms.

Europe has emphasized the importance of offshore wind energy to achieve its target to get 20% of Europe's energy from renewable sources by 2020 in several communications (e.g. COM (2008) 768). The European policy on aquaculture (incl. mariculture) is included in the Common Fisheries Policy (CFP). The strategy for sustainable development of European aquaculture was elaborated in COM (2009) 162 and COM (2013) 229. Furthermore, several other European directives are (indirectly) important for the user functions of multi-use offshore platforms, such as the Habitats Directive, Birds Directive or Water Framework Directive.

INTERNATIONAL POLICY CONTEXT

The United Nations Convention on the Law of the Sea (UNCLOS; UN 1982) is a universal system of laws and rules for the world's oceans and seas, covering extensively the use of the oceans and their natural resources. UNCLOS introduces some concepts and regulations which are of specific importance for the development of multi-use offshore platforms:

- Countries with coasts have sovereign rights in a 200-nautical mile exclusive economic zone (EEZ) with respect to natural resources and specific economic activities, and exercise authority over marine scientific research and environmental protection.
- With regard to navigation, UNCLOS stipulates that the coastal state may, in its EEZ or above its continental shelf, where necessary, establish reasonable safety zones around artificial islands, installations and structures in which it may take appropriate measures to ensure the safety of navigation and of the artificial islands, installations and structures.
- UNCLOS regulates the decommissioning of offshore installations, such as wind turbines, once production has ceased.

Furthermore, there are some conventions of the International Maritime Organization (IMO) with regard to maritime safety which are (indirectly) relevant for the development of multi-use offshore platforms, such as the Convention on the International Regulations for Preventing Collisions at Sea (COLREG) and the International Convention for the Safety of Life at Sea (SOLAS).

SOCIO-ECONOMIC IMPORTANCE

The social and economic potential of Europe's so-called 'Blue Economy' is immense. According to the European Commission, this economy represents 5.4 million jobs and a gross added value of just under € 500 billion a year. The MERMAID project addresses several sectors of the blue economy which are interdependent and may benefit from shared infrastructure and common skills. The social and economic size and potential of these sectors are elaborated below.

THE BLUE ECONOMY ACCOUNTS FOR 5.4 MILLION JOBS AND A GROSS ADDED VALUE OF APPROXIMATELY 500 BILLION EUROS

EU COMMISSION - DG MARITIME AFFAIRS & FISHERIES

In recent years, offshore wind power generation has expanded rapidly in Europe, partly as a result of the EU policy on renewable energy. By 2013, a total of 2,080 turbines had been installed and grid connected in 69 wind farms in the European seas and oceans. These turbines account for a total capacity of 6,562 MW, representing more than 90% of the offshore wind energy capacity worldwide. The annual investments in this sector range

between €4.6 billion and €6.4 billion (2013). It is envisaged that offshore wind could meet 4% of the EU electricity demand by 2020 and 14% by 2030 (EU communication on Blue Growth).

Offshore wave energy is still in a development phase, although its potential is huge. According to Cruz et al. (2008), the total available wave power of all coastlines in the world is comparable to the current world electricity consumption. Wave power devices are currently being demonstrated and underwater turbines driven by currents (tidal or other) are close to commercialisation. In total, 22MW of wave and current devices were installed in 2012.

On a global scale, aquaculture is the fastest-growing animal food-producing sector, contributing significantly to the overall improvement in human diet. Aquaculture production in the European Union is in the region of 1.3 million tonnes with an associated value of € 3.2 billion. This represents 2.3% of the total world aquaculture production in terms of volume and 4% in terms of value. 28% of Europe's aquaculture production concerns seawater fish while molluscs and crustaceans account for 50%. Most of the aquaculture businesses in the EU are SMEs, providing around 80,000 jobs.

Sources: Cruz et al. (2008) - Ocean wave energy: current status and future perspectives; EWEA Offshore Wind Energy Statistics 2013; GWEC Global Wind Statistics 2012; FAO The state of world fisheries and aquaculture (2012), Facts and figures of the CFP (2012) and COM (2012) 494 on blue growth

RESEARCH ON MULTI-USE PLATFORMS

The MERMAID project (EU-FP7, www.mermaidproject.eu) develops concepts for next-generation offshore platforms for multi-use of ocean space for energy extraction, aquaculture and platform-related transport. The project does not envisage building new platforms, but aims at examining different concepts, such as a combination of structures or completely new structures on representative sites under different conditions. In addition, project development guidelines will be produced for stakeholders and end-users, addressing a wide range of issues such as business and technical aspects and spatial socio-economic planning.

The MERMAID consortium consists of 29 European partners bringing together expertise from both science and industry.

WORK PACKAGES MERMAID

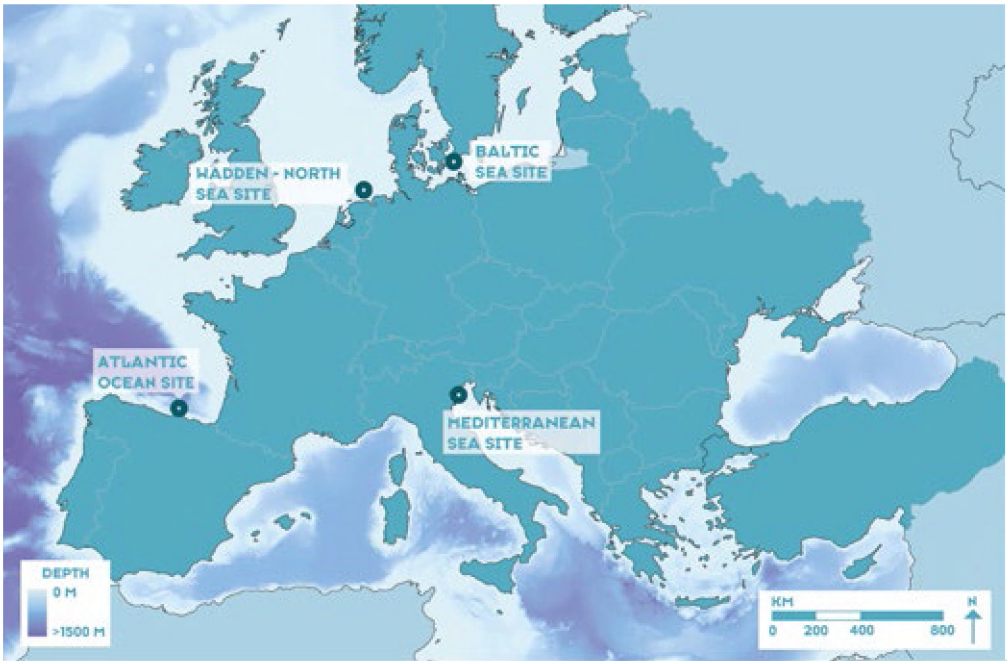
WP1 Project management
WP2 Assessment of policy, planning & management strategies
WP3 Development of renewable energy conversion from wind & waves
WP4 Systems for sustainable aquaculture & ecologically based design
WP5 Interaction of platforms with hydrodynamic conditions & seabed
WP6 Transport and optimization of installation, operation & maintenance
WP7 Innovative platform plan & design
WP8 Economical, technical & environmental feasibility of multi-use platforms
WP9 Project dissemination & outreach activities

Besides, the European Commission granted two other research projects with regard to multi-use offshore platforms:

- The H2OCEAN project (EU-FP7, www.h2ocean-project.eu), aimed at the development of a wind-wave power open-sea platform equipped for hydrogen generation with support for multiple users of energy.
- The TROPOS project (EU-FP7, www.troposplatform.eu), aimed at the development of a floating modular multi-use platform system for use in deep waters.

CASE STUDIES

The MERMAID project considers four offshore study sites for multi-use offshore platforms. Site-specific designs are being developed based on an extensive stakeholder consultation process and the environmental characteristics of each site. The various conceptual designs are presented in the next part of this booklet.



ATLANTIC OCEAN

COMBINATION USER FUNCTION & DESIGN

Based on the available resources and the characteristics of the Atlantic Site, a combination of offshore wind and wave energy extraction is opted for. The proposed scenario consists of an array of 5 MW wave energy converters and 2.5 MW wind turbines.

Due to the water depth in the study site, only floating devices will be taken into consideration. Hence, the latter concept will be of particular interest for countries with a narrow continental shelf. The design of this multi-use offshore platform is especially challenging due to the very rough wave and wind conditions in the Atlantic Site.

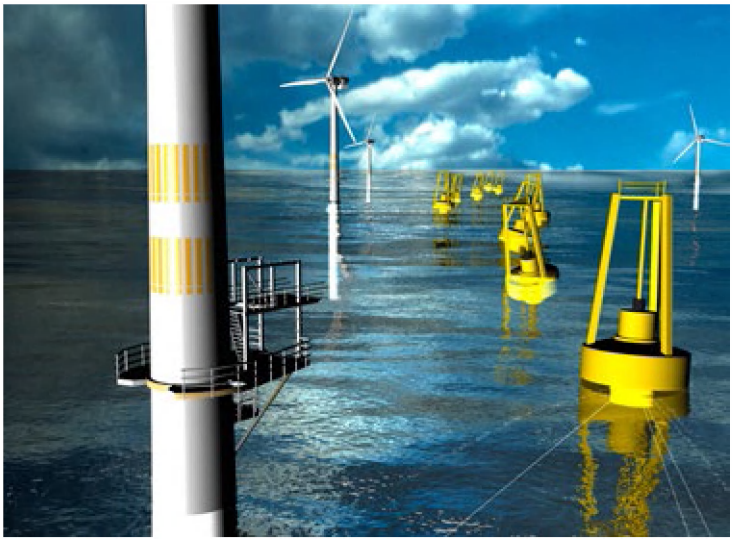
OUTLOOK & CHALLENGES

In the future, other user functions such as leisure and maritime transport may be integrated in the platform. Furthermore, the environmental impact of the converters, structures and foundations should be elucidated in more detail, and potential mitigation measures and eco-compatible design solutions should be identified.

A DEEP WATER SITE

ATLANTIC SITE FACTSHEET

Geographical location	Atlantic Ocean, north of Spain
Surface area of study site	100 km²
Offshore distance	3 - 20 km
Depth	50 - 250 m
Substrate	mix of sandy and rocky seabed
Water temperature	10 - 20°C
Max. tidal currents	1.5 cm/s
Wave heights	Mostly < 6 m
Mean wave energy potential	20 kW/m on 50 m depth
Average wind speed	7.5 m/s



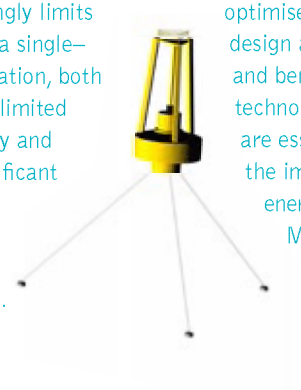
MEDITERRANEAN SEA

COMBINATION USER FUNCTION & DESIGN

The conceptual design of the platform in the Mediterranean site includes wave energy extraction, wind energy extraction and fish farming. Two wave energy extraction devices are being compared: A floating wave energy device measuring 15 m wide and 30 m long, and Wave Star, a fixed system on piles with floaters (3 arms measuring 80 m long and 8 m wide). These two types of wave farms may be combined with the following user functions:

- Large mono-pile turbines (e.g. Vestas V112, 100 m high), to be installed at the boundaries of the wave farm.
- Micro-wind systems, such as a horizontal axis Bergey EXCEL 10 turbine (measuring 25 m high), placed on top of the wave energy converters.
- Sea cages and cables for fish farming (e.g. Mediterranean sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus auratus*)) or mussel farming are being examined.

The study site is characterised by a relatively mild climate, which allows for a safe installation but strongly limits the benefits of a single–purpose installation, both because of the limited available energy and due to the significant distance from the shore as a result of the flat sea bottom.



A combination of several user functions is therefore required to create an economically viable solution.

OUTLOOK & CHALLENGES

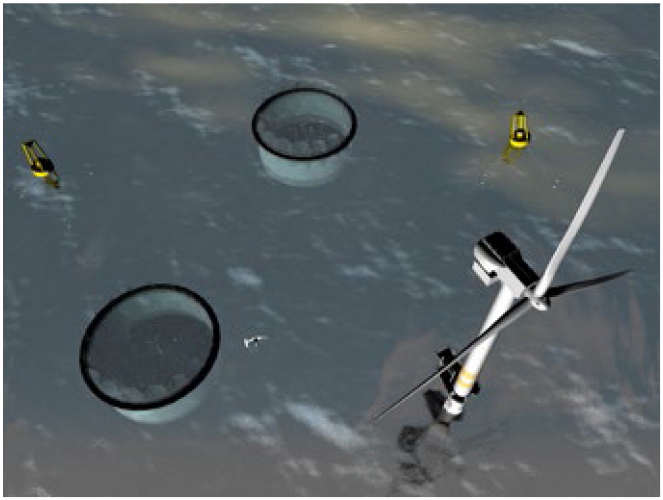
The proximity of maritime traffic routes and the harbor of Venice offers opportunities to integrate transportation and shipping facilities in the multi-use offshore platform. Furthermore, work is needed on the social perception of these multi-use platforms, the optimised integration of the design and a detailed cost and benefit analysis. The technological challenges are essentially related to the immaturity of wave energy development. More specifically, the design of the mooring system

A SHELTERED SITE

MEDITERRANEAN SITE FACTSHEET

Geographical location	Northern Adriatic Sea, off the coast of Venice
Offshore distance	16 km
Depth	16 m, gentle slope towards south east
Substrate	A mixture of sand and mud
Water temperature	14°C (+/-6°C)
Salinity	27.5 psu (+/- 1.5 psu)
Tidal range	0.5 m (+/- 0.15 m)
Mean wave height	1.25 m
Expected annual wave power	3 kW/m
Average wind speed	4.54 m/s
Expected annual wind power	Large turbines: 12.7 GWh/y / 4 Vestas V112 turbines

(for the floating wave energy devices), the verification of foundation stability (for Wave Star) and the improved design of the devices and farm layout to maximise energy production deserve further investigation. In addition, a major challenge is to limit the environmental impact. The selection of the construction materials and the maintenance plans should therefore be considered carefully.



WADDEN SEA - NORTH SEA

COMBINATION USER FUNCTION & DESIGN

In addition to wind energy, the combination with the following potential secondary functions will be studied and assessed:

- Seaweed farming: Seaweed will increasingly gain importance as a raw material and is currently already imported by Dutch companies from Asia and France. The most relevant benefit of local cultivation is the possibility to offer wet seaweed on the market.

- Shellfish aquaculture: The shellfish industry is looking for additional fishing grounds for mussel seed collectors and cultivation of mussels on longlines. An additional market for 50,000 tonnes of blue mussels is expected.

- Wave energy extraction: Wave energy may be an option; however, the first studies reveal limited energy production potential.

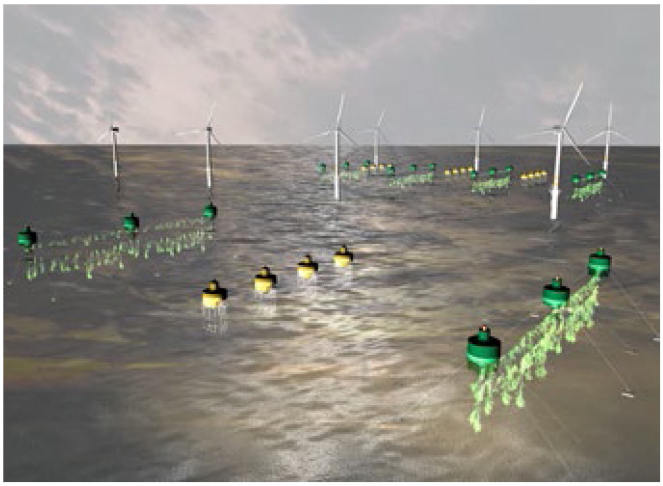
A modular approach will be used for the structures for seaweed and shellfish cultivation, enabling an easy extension of the activities. These structures will be located inside and outside the offshore wind farm and will not be connected to the turbines. An alternation of seaweed and shellfish structures is envisaged. Fish farming is not feasible in this study site due to the high temperature (> 18°C in summer) and the relatively shallow water (30 m).

OUTLOOK & CHALLENGES

In the future the multi-use platform may be extended to other user functions such as facilities for energy storage, tourism (recreational fisheries and diving trips) and fisheries (passive fishing gear).

Some of the key challenges that deserve further study are: the design of the seaweed/mussel farming system within the offshore wind farm (integration of the two types of aquaculture, design of harvesting equipment, etc.), the ecological challenges linked to aquaculture activities (e.g. risk assessment of

AN ACTIVE MORPHOLOGY SITE



environmental impact and the mitigation of diseases) and evaluation of the environmental and socio-economic benefits of this multi-use platform.

The operational challenges of this study site include the relatively high distance to the nearest main port (85 km) and the extreme wave heights which may occur during storms.

WADDEN SEA SITE FACTSHEET

Geographical location	North of the Netherlands (Gemini project)
Offshore distance	55 km
Depth	29.5 - 33.4 m
Substrate	Mainly sand (some thin clay layers)
Water temperature	2 - 20°C
Salinity	32.5 - 35.0 psu
Current magnitude	0 - 0.6 m/s
Mean tidal range	Approximately 2 m
Significant wave height	Generally lower than 2.1 m
Extreme wave height	10 m (1/50 yrs.)
Average wind speed	10 m/s

BALTIC SEA

COMBINATION USER FUNCTION & DESIGN

An offshore wind farm (75 turbines with a total capacity of 600 MW) is already scheduled for construction in this study site. The MERMAID project explores the theoretical possibility to combine this wind farm, which should be operational in 2020, with additional aquaculture activities:

- Fish farming: Total fish farming capacity is estimated at approximately 100,000 tonnes. Within 3-4 years, 10,000 tonnes of rainbow trout or Atlantic salmon can be produced annually, with a value of € 40 million.
- Seaweed farming: More specifically, the cultivation of *Furcellaria sp.* is investigated given that this seaweed can be cultured in waters with low salinity, as present in Kriegers Flak.

In the present plans, the wind turbines will be organised in two groups, separated by a sand extraction area. Two separate fish farm facilities are envisaged in between the two groups of turbines so that they are sheltered by the foundations of the monopiles. Each farm consists of 12-14 round cages (45 m in diameter and 12-15 m deep) and a feeding barge. Seaweed farming (*Furcellaria sp.*) will take place on submerged longlines, which will also reduce the wave impact on the fish cages.

OUTLOOK & CHALLENGES

One of the challenges of this study site is the significant distance to the nearest port. The combination of aquaculture and offshore wind energy will therefore provide significant benefits in terms of transportation and housing. Still, the operational difficulties when combining different users should be taken into account.

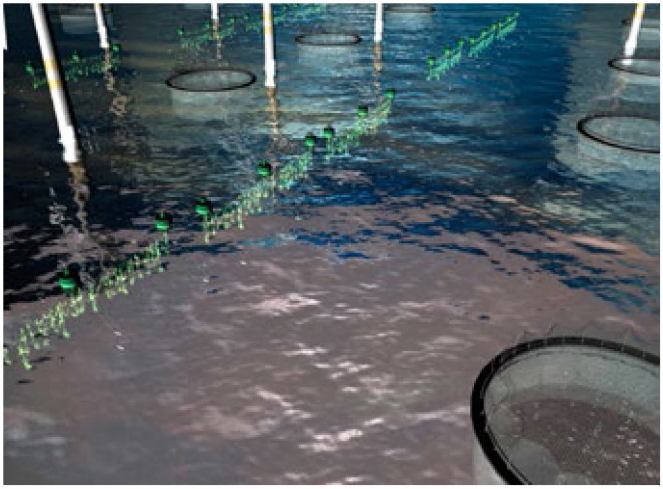
AN ESTUARINE SITE

BALTIC SITE FACTSHEET

Geographical location	Kriegers Flak, Western Baltic Sea
Offshore distance	15 km east of the Danish coast
Depth	18 - 40 m
Substrate	Sandy layer (thickness of up to 8 m)
Surface water temperature	0 - 20°C
Salinity	7 - 9 psu (upper 15 - 18 m)
Currents	Variable currents driven by wind, density gradients & differences in sea level
Mean tidal range	No tides present
Wave height	Mostly moderate (1 - 1.5 m)
Mean wind speed:	9.5 m/s

The main obstacle to large-scale fish farming could be the environmental impact caused by the release of nutrients. In this regard, a study will be conducted to examine the potential of sessile filter feeders living on the turbine foundation to sequester aquaculture waste.

Future use of macro-algal cultures for wave damping will require both innovation and small-scale field testing.



GENERAL CONCLUSIONS AND OUTLOOK

The integration of various user functions in a multi-use offshore platform provides significant benefits in terms of shared use of infrastructure (foundations, moorings, energy transfer, etc.), resources (staff, material, energy, etc.) and services (monitoring, maintenance, etc.). Hence, multi-use platforms may prove economically viable in cases where single-purpose platforms are not. It is envisaged that these integrated platforms will contribute to the fulfilment of the EU strategies on renewable energy and the expansion of sustainable aquaculture. The integration of multiple activities in one platform is also strongly encouraged in the context of maritime spatial planning. Moreover, this combination of activities generally results in a reduced environmental impact compared to several single-use platforms, which is crucial to reach the good environmental status of European marine waters by 2020.

Further research is needed to optimise the integrated design and involve potential new user functions such as tourism, maritime transport, energy storage and fisheries. Some of the key challenges are further reduction of the environmental impact by means of eco-compatible design solutions and elaboration of a detailed costs and benefit analysis.

SUPPORT FOR MULTI-USE PLATFORMS IN THE OCEANS WILL BE INCREASINGLY IMPORTANT AS WE GO FORWARD

MÁIRE GEOGHEGAN-QUINN, EUROPEAN COMMISSIONER FOR RESEARCH, INNOVATION AND SCIENCE

MERMAID PARTNERS

Disclaimer: The content of this brochure must not be taken as an expression of policies and strategies of the involved project partners, but as a theoretical study that has to be further elaborated and analysed before potential commercialization.

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www.mermaidproject.eu