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DELIVERABLE 3.2

ASSESSMENT FRAMEWORK TO DETERMINE ECONOMIC FEASIBILITY OF MULTI-USE PLATFORMS

Work Package 3
Economics of Multi-Use Platforms

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Abstract	This report aims to develop an economic assessment framework to guide the economic evaluation of the added value of Multi-Use Platforms in Europe. The framework is structured to

	assess the financial costs and revenues of multi-use and co-location (MUCL) of marine space, in short ‘ocean multi-use’, and to assess their economic efficiency.
Keywords	Economic framework, business framework, decision support tools, cost-benefit analysis, business model canvas

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LIST OF ACRONYMS

AB	Averting behaviour
CBA	Cost-benefit analysis
CEA	Cost-effectiveness analysis
CICES	Common International Classification of Ecosystem Services
DSS	Decision support system
EDA	European Defence Agency
EEA	European Environment Agency
EF	Ecosystem functions
EIA	Environmental Impact Assessment
EMFF	European Maritime Fisheries Fund
EPA	Environmental Protection Agency (US)
ESS	Ecosystem services
FAT	Factory acceptance test
FEGS	Final Ecosystems Goods and Services
FPP	Floating power plant
FPV	Floating solar photovoltaic (energy)
GDP	Gross domestic product
GIS	Geographic information systems
GVA	Gross value added
GW	Giga watt
HPPM	Hedonic Pricing applied to the property market
iCEA	integrated Cumulative Effect Assessments
IMP	integrated maritime policy
iRBIA	integrated Risk Based Impact assessment
IPCC	Intergovernmental panel on climate change
MCA	Multi-criteria Analysis
MEA	Millennium Ecosystem Assessment
MPA	Marine protected area
MSFD	Marine Strategy Framework Directive
MSP	Marine spatial planning
MUCL	Multi use and co-location
MW	Mega Watt
NDA	Nuclear Decommissioning Authority (United Kingdom)
NPV	Net Present Value
OWF	Offshore wind farm
PESTEL	Political, Economic, Social, Technological, Environmental, Legal, (assessment method)
ROI	Return on Investment
SAT	Sea acceptance test
SWOT	strengths, weaknesses, opportunities, threats (assessment method)
TCM	Travel cost method
TRL	Technology Readiness Level
UNEP	United Nations Environment Programme
WP	Work Package
WTP	willingness to pay

EXECUTIVE SUMMARY

Introduction

Marine space is a scarce resource and its allocation needs to be carefully considered as it becomes a limiting decision-making factor. When a portion of ocean space is allocated to an exclusive activity or a combination of activities, that same location cannot be allocated to other types of uses. Framed under the question of opportunity costs, it becomes a necessity to allocate available marine space to those uses that are deemed most valuable.

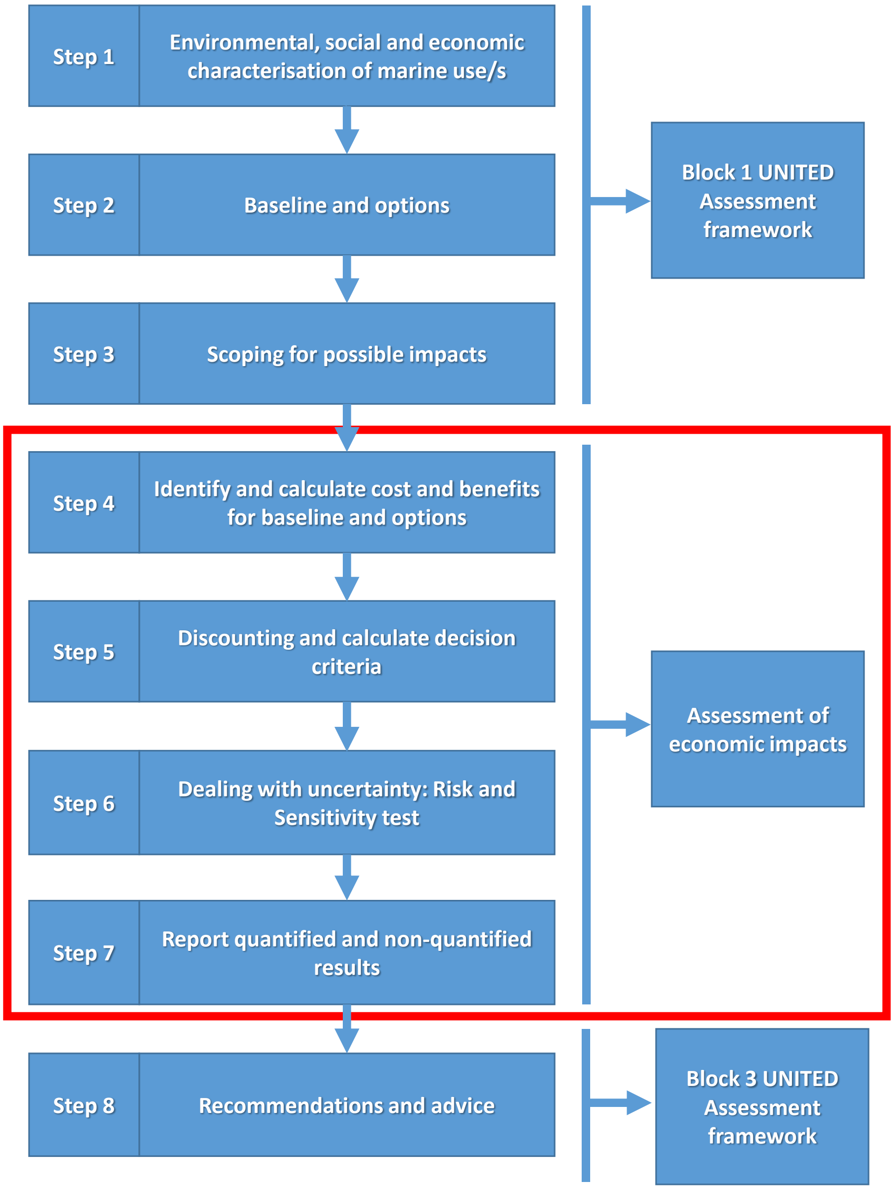
Based on the review of available knowledge on the use of marine space in Europe, this report presents an economic assessment framework to guide the economic evaluation of the added-value of ocean Multi-Use in the UNITED pilots. The framework investigates how to assess the financial costs and revenues of ocean multi-use and their economic efficiency (i.e. ensuring that they deliver social benefits in excess of their costs). We propose guidance protocols to assess the economic efficiency of multi-use accounting for different types of costs, benefits and other relevant economic impact indicators (e.g. employment, ecosystem services). In addition, we explore the role of impact assessments in private business decision-making. By acknowledging the distinction between Public (e.g. decision makers, local authorities) and Private Sector decision-making practices (e.g. project developers, lenders and investors), we divide the framework and the guidance for its application into two distinctive, yet compatible, blocks: 1) The UNITED economic assessment framework and 2) The UNITED business analysis framework.

1) The UNITED economic assessment framework

Not all marine activities are compatible with other uses and therefore some cannot be combined. Competing uses may be seen as exclusive or incompatible with other uses (in a given location), for instance due to existing regulations, or because the activities of one use interfere considerably with others. We employ an economic characterisation of different types of uses of maritime space which takes into consideration their degree of compatibility with other uses. For this, we part from the most economically relevant sectors from the EU Blue Economy Report that are *marine-based* in order to identify the broad variety of maritime uses that can theoretically compete for or be integrated with others as multi-use on a given oceanic space. Based on these, we identify specifically and characterise those that are compatible for multi-use. This is an important base for the economic assessment framework and helpful for defining the baseline and different options of use combinations, as well as the opportunity costs associated to them.

Based on previous evidence collected in the project pilots (D3.1 – Van Duinen et al., 2020), the UNITED economic assessment framework proposes using a partial cost-benefit analysis as the key decision support tool to enable decision makers to weigh up the costs and benefits of different marine use options. The sequence and list of steps that are necessary to conduct an economic assessment in the UNITED pilots are illustrated in the figure below.

Our guidance lays out the foundations to apply cost benefit analysis in the UNITED pilots and illustrates typologies of relevant impact indicators in terms of their expected financial and economic costs and benefits. The report further expand the cost and benefits typologies with a tentative list of specific impact indicators and proposed methods to assess them. Special attention needs to be paid to the consideration of all significant relevant impacts, including those that affect other marine users (externalities) and that may be of a positive or negative character.



2) The UNITED business analysis framework.

The aim of this block is to provide a business analysis framework to support the development of viable business models for ocean multi-use pilots by providing a methodology that allows the systematic evaluation of ocean multi-use pilots including their financial performance. The business analysis framework will be used to identify potential economic barriers, risks, and opportunities during the development and implementation of the pilot. The proposed framework consists of six different steps that are presented below:

- STEP 1: Describing the combined activities in the pilot and scoping current and expected TRL levels.
- STEP 2: Mapping the pilot context though the use of the PESTEL (Political-Economic-Social-Technological-Environmental-Legal) technique to assess the external factors influencing the pilot.
- STEP 3: Business model canvas to evaluate how the multiuse platform creates, delivers and captures value.
- STEP 4: A SWOT (Strengths-Weakness-Opportunities-Threats) analysis to identify the internal factors that influence the pilot.
- STEP 5: Financial analysis and risk analysis to conclude is the multiuse concept in the pilot is feasible.
- STEP 6: Evaluation and control as a step to assess the commercial readiness of the pilot.

Next steps

Next steps will include the development of detailed guidance protocols to apply and test the proposed frame-works in the five UNITED pilots. The information will be useful for other tasks in the project. Specifically, the analysis of business necessities (task 1.3), their associated financial requirements for investment (task 7.1), their social acceptability (task 8.2), as well as the socio-economic implications of their environmental impacts (Work Package 4). In addition, this task results and methods will feed the development of the Commercialisation Roadmap (Work Package 9) and the economic assessment of technological solutions (task 8.1) and the assess-ment of the Technology Readiness Levels (task 8.4).

1. INTRODUCTION

1.1. UNITED: Introducing the project

The H2020 project UNITED aims to provide practical promising designs, technological proposals and models for combining offshore activities, by implementing ocean multi-use concepts in five pilots across European regional seas. Business models of offshore multi-use combinations and insight in their financial viability and socio-economic impacts, will be developed to support the effective design, optimization and implementation of multi-use concepts in the pilots and to enhance their up-scaling potential and the possibility to seize emerging commercialization opportunities.

The UNITED activities will be based in five real-life ocean multi-use pilot sites (see figure 1.1), where different combinations of activities are already being carried out or are currently at the implementation stage:

- German pilot – offshore wind farm (OWF), cultivation of blue mussels and seaweed
- Dutch pilot – OWF, floating solar and seaweed cultivation
- Belgian pilot – OWF, cultivation of flat oysters and seaweed, and restoration of oyster ecosystems
- Danish pilot – OWF and organised visits to wind turbines (tourists including professionals in the wind energy sector as well as academia, etc.)
- Greek pilot – aquaculture (fish farm) and leisure scuba diving.

Figure 1.1: location of the five UNITED pilots

Source: https://www.h2020united.eu/pilots

1.2. Objectives of this report

Work Package 3 of the project has the remit to develop economic frameworks and business models that are fit-for-purpose for the effective design, optimization, and implementation of multi-use concepts. This does not only concern their application in the UNITED pilots as final outputs of the project, but also the enhancement of their transferability to other locations and sites and up-scale potential, for instance in terms of commercialisation opportunities.

Under the remit of task 3.2, this report aims to develop an economic assessment framework to guide the economic evaluation of the added value of Multi-Use Platforms in Europe. The framework is structured to assess the financial costs and revenues of multi-use and co-location (MUCL) of marine space, in short 'ocean multi-use'[1], and to assess their economic efficiency (i.e. ensuring that they deliver net social benefits in excess of their costs).

The objective of this report is to deliver methodologies and guidance protocols to assess the economic efficiency of multi-use accounting for different types of costs, benefits and other relevant economic impact indicators (e.g. employment, ecosystem services (ESS)). One objective of applying this framework (methodologies and protocols) on existing pilot approaches is to test the applicability of proposed models and indicators. In this respect, task 3.2 will assess, with the help of the pilots, the role of impact assessments in private business decision-making. This will consider a review of existing sectoral business models and impact assessments as they are present in the activities included in the pilots (e.g. off-shore wind platforms, aquaculture, tourism, solar off-shore, etc.)

In addition to Work Package 3 objectives, the information on multi-use pilots provided in this report will be useful for other tasks in the project. Specifically, the analysis of business necessities (task 1.3), their associated financial requirements for investment (task 7.1), their social acceptability (task 8.2), as well as the socio-economic implications of their environmental impacts (Work Package 4). In addition, task 3.2 results and methods will feed the development of the Commercialisation Roadmap (Work Package 9) and the economic assessment of technological solutions (task 8.1) and the assessment of the Technology Readiness Levels (task 8.4).

1.3. The overall UNITED Assessment Framework

To assess the impacts of ocean multi-use projects, several dimensions need to be accounted for. These are the different pillars in the UNITED project which are represented by different Work Packages (WPs) (see figure 1.2).

Figure 1.2: The thematic pillars that pave the way for the research work in UNITED

Source: WP8 concept paper (Kerkhove et al., 2020)

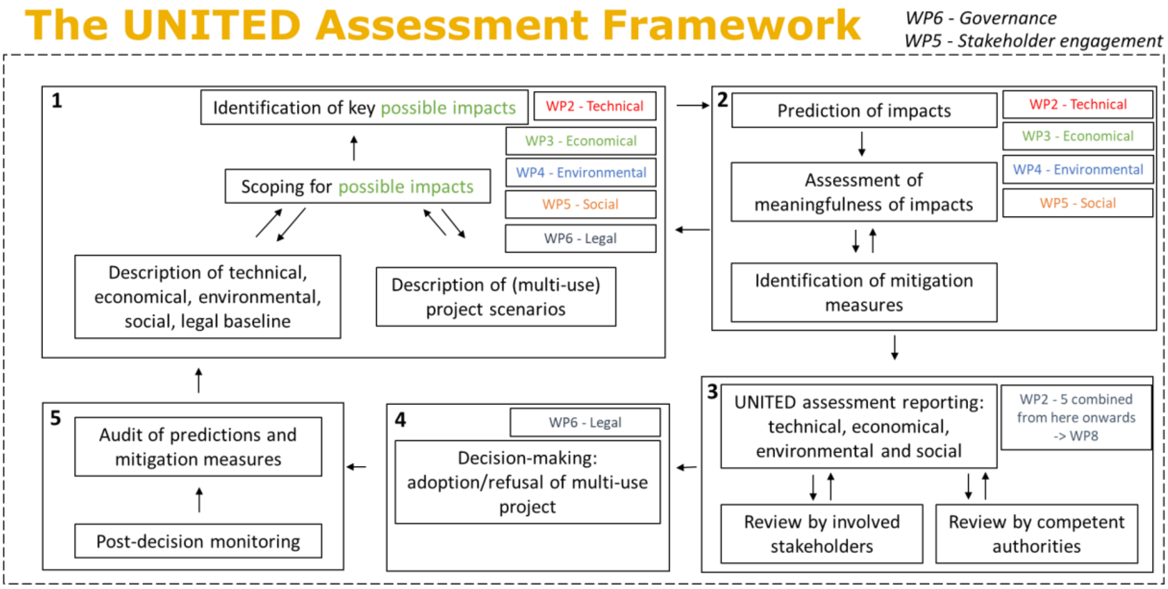
Each pillar will use different assessment tools, assessment criteria and Decision Support Systems (DSS) to help reaching conclusions for each of the identified scenarios of alternative uses of marine space.

The UNITED Assessment Framework aims to assess the impacts (can be positive or negative) of multi-use projects in the marine space against alternative management and use options, including a baseline option, combinations of single-use and multi-use options, with the possibility of including different combinations of multi-uses. As such, the UNITED Assessment Framework will quantify the added value of multi-use projects in comparison with alternatives. To do this, the possible impacts of multi-use projects will be assessed, after which the outcomes will be compared with the outcomes of the assessments of the alternatives.

[1] The term ocean multi-use will be used to refer generally to multi-use, including but not limited to co-location in maritime platforms.

It is thus critical to define relevant management and use options and be able to compare these within each of the UNITED pillars. Each of the pillars will apply different assessment tools and assessment criteria in the scoping for possible impacts and assessment of these impacts, allowing flexibility for each pillar. However, the key steps that are followed will be the same for all pillars and these steps form the backbone of the UNITED Assessment Framework (see figure 1.3).

Figure 1.3: Schematic representation of the overall UNITED Assessment Framework



Source: Kerkhove et al. 2020

The proposed economic assessment framework will be aligned with the overall UNITED Assessment Framework, in order to ensure the consistency of the evaluation with other work packages.

1.4. Current status of socio-economic information in the five UNITED pilots

This report aims to develop an economic assessment framework to guide the economic evaluation of the added value of ocean multi-use in Europe. The framework will be structured to assess the financial costs and revenues of ocean multi-use and their economic efficiency (value for money).

A previous report (D3.1) described the current status of socio-economic information in the five UNITED pilots based on background information from the project proposal and responses to a questionnaire (see van Duinen et al., 2020).

Box.1 below highlights the key findings of this report.

Box 1.1: Status of socio-economic information in the five UNITED pilots

- ➔ Message 1: An important angle to cover under any business-focused analysis should be on profitability and financial costs associated with the range of final goods and services (outputs) generated by the specific activities in the pilots, which can be roughly clustered for instance as energy, food and tourism.
- ➔ Message 2: D3.1 has helped to identify potential synergies of the proposed multi-use combinations on their locations. These to be considered in task 3.2 are:
    - o Increased effectiveness of production (more output) and increased cost-efficiency of production (higher profits at least costs) as part of multi-use as opposed to single use. Some identified examples by the pilots:

- Cost savings due to economies of scale and optimization of planning and maintenance work, for example related to:
  - the optimization of transportation and logistics through the joint use of transport vehicles (vessels, helicopters etc.) and port and offshore facilities.
  - the technical improvements from use combination.
  - faster licensing of joint operations.
- Increased outputs - Increased goods and services generated in a given marine space (increase in efficiency of use)
- Improved knowledge of environmental impacts signalling through joint monitoring
- Direct benefit from service provision of one activity by the other use of the **multi-use** (direct use of offshore wind energy by monitoring equipment for aquaculture in the FINO3 pilot, wave dampening effects of floating solar on the safety of aquaculture production in the North Sea Innovation Lab pilot).

- Increased societal acceptance of ocean **multi-use**.

➔ **Message 3:** consider the value of marine space for the establishment of multi-use schemes. The framework should cover how to account for the opportunity costs of alternative uses and locations.

➔ **Message 4:** development of relevant baselines needs to consider different stages of implementation of the **multi-use** concept in the pilots: the distinction between no-use, single-use and multi-use concepts is an important one. Also, it is important to assess if potential cost advantages to be gained if the multi-use is considered right from the start (and not as an "add on" for a given infrastructure).

➔ **Message 5** clarify expected TRL developments in the pilots and if those have been set in terms of **multi-use** development or existing single uses.

➔ **Message 6** explore methods to assess sources of funding for capital investments (e.g. from public grants and/or loans public-private investors). Consider funding possibilities leading to the commercial role out phase.

➔ **Message 7** develop a consolidated glossary for the use of "economic terms" in WP3 and a hands-on guidance document to help application of the framework in the pilots

➔ **Message 8:** Specific criteria to be considered in the development of the economics assessment framework:
- Business model analysis: considering pilot needs for economic analysis, it is important to understand the role of impact assessments (e.g. environmental, social, economic…) in private business decision-making. This will consider a review of existing sectoral business models and impact assessments as they are present in the activities included in the pilots (e.g. off-shore wind platforms, aquaculture, tourism, solar off-shore, etc.).
- Financial analysis: include financial (projections of costs and revenues) and business (e.g. profitability and attractiveness for investors) relevant topics
- Socio-economic impact analysis: Explore methodologies to account for a broad range of socio-economic impacts (externalities) in order to understand all potential benefits from **multi-use**:
  - changes in ecosystem services -> Link with WP4 "environmental impacts"
  - further socio-economic indicators: job creation, social acceptance of multi-use, attractiveness of multi-use for social business investment-> Link with WP5 "stakeholder involvement"
  - sources of funding: explore the use of economic policy instruments, such as payment for ecosystem services, to promote and ensure the long term financial viability of MU activities

Source: van Duinen et al., 2020

1.5. Structure of this report

Key in our understanding of the WP3 objectives in UNITED is the distinction between Public and Private Sector decision-making practices. Focusing on multi-use objectives and their promotion, the objective is to answer the following research questions.

1) Is ocean multiuse more desirable than single use?

For example, is there an increased economic efficiency in terms of fewer negative/environmental impacts from multi-use in one location compared with single activities located in different marine areas? Can we show that economies of scale from multiple operations at the same time and location are feasible? and would exploiting synergies between different marine activities bring additional public benefits? Answers to such questions are relevant for public policy, decision makers, local authorities, etc. Fundamentally, the interest lies here in the promotion of multiuse and their associated economic activity/ies that are able to deliver net benefits to society.

2) Does multiuse, rather than single use, make business sense?

This is a different question than the one above, and interests primarily the private sector. The answer to this question aims to identify whether ocean multi-use could be more profitable or otherwise more attractive business developments than single uses of marine space. As well as of particular importance to private users of marine space (such as project developers, companies), this will also be of interest to lenders (e.g. banks) and investors.

Therefore, we propose to divide this report and the framework into two distinctive, yet compatible, blocks: 1) The UNITED economic assessment framework and 2) The UNITED business analysis framework.

2. SETTING THE SCENE: UNDERSTANDING THE ECONOMICS OF MARINE MULTIUSE

European seas and oceans host a variety of economic activities or uses that are sometimes mutually exclusive and in some other cases can coexist in the same space. Thus, potentially benefiting from each other in the form of multi-use. Ultimately, marine space is a scarce resource. When confronted with different choices for its use, allocation of space needs to be carefully considered as it becomes a limiting decision-making factor. When a portion of ocean space is allocated to an exclusive activity or a combination of activities, that same location cannot be allocated to other types of uses. Framed under the question of opportunity costs, it becomes a necessity to allocate available marine space to those uses that are deemed most valuable. The concept of value can have many different interpretations, but in this case our focus is on the identification of options that are most desirable from a social point of view – that is when the net benefits outweigh the costs.

In order to be successfully applied across European member states and sectors, an economic framework for analysing the added-value of multi-use needs to be set up and put in context of the different types of economic uses that occur in European oceans and seas, as well as on existing policies and previous experience from research & development knowledge. This chapter 2 is aimed at understanding the different contexts that we consider essential for the design of an economics framework of marine multiuse.

For this, we start in chapter 2.1 by introducing important recent policy strategies such as the blue economy concept, marine spatial planning and ocean multi-use, as well as the relevance they have currently for Europe. We continue by framing these concepts under existing regulatory settings within the EU in chapter 2.2.

Based on the EU blue economy report 2020 that describes the economic activities that occur in European oceans and seas, we consider in chapter 2.3 those marine-based activities that are currently and will be in the future of economic and political relevance in the EU. By 'marine-based', we mean exclusively those activities that are undertaken *in* the ocean or sea. Whether these identified uses are actually suitable for multi-use is discussed afterwards, after discussing an economic typology of multi-use in chapter 2.4 based on the work of previous related projects, in chapter 2.5 we assess the identified marine uses according to the aspects that make them potentially suitable for multi-use.

Finally, in chapter 2.6 we introduce feasible baselines and options for application of the framework. This sets the basis for allowing us to assess and compare the added value of single uses versus different combination of uses later on in the UNITED pilots.

2.1. Introduction

Multi-use of marine space has the potential to support the EU to achieve two concurrent societal objectives: economic growth and sustainability. The ocean contributes to economic growth, with the so-called "blue economy" having a turnover of €750 billion in 2018 (European Commission, 2020a). Blue growth related sectors include fishing and aquaculture, renewable energy, maritime transport and tourism activities, which have all been growing steadily over the past decade. For example, Europe has come short from achieving its 2020 target of reaching 20% of Europe's energy from renewable sources by 2020 (18% in 2018) and is aiming for 32% by 2030 (Eurostat, 2020). With offshore wind energy making up over 90% of the world's total renewable installed capacity, this sector is expected to play a particularly prominent role in the achievement of these policy goals (European Commission, 2020a). Among the socio-economic benefits of the seven established sectors of the EU Blue Economy are for example the direct employment of close to five million people in 2018 (European Commission, 2020a). Moreover, emerging sectors include ocean energy (e.g. wave and tidal energy, floating solar photovoltaic energy), blue bioeconomy and biotechnology, desalination, marine minerals, maritime defence and submarine cables).

Alongside its blue growth objectives, the EU aims to achieve sustainability, as captured by the European Green Deal. While Europe's seas are subject to the development of marine infrastructure to meet economic demands, marine biodiversity and ecosystems require a largely undisturbed environment. Pressures on the environment are building and the limited and thus highly contested space is at a premium in Europe's "urbanized" oceans, especially the Mediterranean, North and Baltic Sea (Schupp et al., 2019). The governance of marine resources has been traditionally very fragmented, dominated by the concurrence between different sectors for the use of marine space. However, new concepts are emerging, such as the blue economy, which acknowledges the inter-dependency between different maritime sectors as they rely on common skills and shared infrastructure such as ports and electricity distribution networks (de Andrés González et al., 2018). As a part of these developments, maritime spatial planning (MSP) has emerged as a tool to manage related conflicts and improve the use of marine space towards more sustainability and social benefits. While breaking away from sector-oriented management to a more holistic approach, MSP has also enabled the rise of a new ocean use concept during the last decades: the joint "multi-use" of ocean space. The premise of multi-use, in contrast to single-uses, is to maximise spatial efficiency and productivity by allocating multiple economic activities to the same ocean space with the goal of avoiding conflicts and exploiting synergies among the different uses (Schupp et al., 2019).

One way in which maritime multi-use promises to offer synergies between sectors and benefits to economic ambitions, while reducing the impact on the environment as a whole, is for instance the combination of multiple functions within the same infrastructure (EC Maritime Forum, 2018). Due to limited vacancy in the near-shore area, maritime activities often have to move further offshore in order to be developed on a wider scale, which results in high capital investments. In this context, one important synergy for sectors with low investment capacity (e.g. small-scale fishery or tourism) for engaging in multi-use together with large blue economy sectors (i.e. renewable energy) is the opportunity to move further offshore due to savings in operation costs e.g. from sharing maintenance vessels (Schultz-Zehden et al., 2018). In such cases, particularly when the competition to operate near-shore is too high, the opportunity costs of engaging in multi-use are likely the lowest, representing the most financially feasible option for businesses (Schultz-Zehden et al., 2018). However, this is not true for all multi-use combinations, since not all combination of uses imply sharing infrastructure features.

With regards to the multitude of possible multi-use scenarios, one can differentiate between multi-use of geographical, human and biological resources creating benefits for society and single actors (e.g. offshore wind and tourism) and multi-use if technical resources (marine infrastructure and platforms) creating added value through integration instead of side-by-side use (Przedrzymirska et al., 2018). In terms of sequence, a *joint development* of uses where two or more combined uses apply for licenses, funding and insurance together (e.g. two blue growth sectors) stand opposite a staggered development of uses, where one existing use is already in place and a new use is added (e.g. developing tourism in a site where underwater heritage protection is already in place).

The two sectors driving maritime multi-use in Europe are tourism and offshore renewable energy (Schultz-Zehden et al., 2018). The tourism sector is generally a driver for 'soft' multi-use combinations, requiring no infrastructural integration of fixed structures, but which are rather co-located or an existing infrastructure is used without major modifications (e.g. tourism and aquaculture). These multi-use combinations are applicable on a smaller scale and are mainly present in Southern Europe, where the tourism sector has experienced a steady increase over the past years. Offshore fixed structures (or floating in a single place) on the other hand offer 'hard' multi-use combinations (e.g. offshore wind farms and aquaculture), which are largely present in Northern Europe. For example, North Sea countries are the frontrunners in Europe when it comes to marine spatial planning and offshore renewable energy. Belgium, Germany and the Netherlands developed their first marine spatial plans a decade ago due to the growing demand for space in the offshore industry. These countries are currently in the second or the third round of planning (Frazão Santos et al., 2019), while there are still no offshore facilities in the operation phase in the Mediterranean due to technical and administrative limitations (Garcia et al., 2020). On the other hand, continental Europe's first wind farm WindFloat with an installed capacity of 25 Mega Watt (MW) became fully operational off the Atlantic coast of Portugal in 2020[2].

[2] See https://www.edp.com/en/innovation/windfloat

In terms of future development, a further option for multi-use applied in the North Sea and Northern Adriatic is re-use of decommissioned platforms of the oil and gas industry for aquaculture and tourism. The rapidly growing established sector of aquaculture is also driving multi-use combinations with the emerging sector of wave energy. Stakeholders of the MUSES project identified that a wide range of opportunities exist for creating positive synergies among different maritime uses compared to what has been previously associated with the multi-use concept. Stakeholders identified new technological solutions such as floating offshore wind farms, hydrogen energy storage or various wave energy generation technologies that can tap into a wider range of socio-economic and environmental benefits if multi-use solutions are considered in their designs right from the outset, through the application of the life cycle assessment, systems design approach or circular economy principles (Schultz-Zehden et al., 2018).

2.2. Policy landscape in the EU governing multi-use of marine space

Multi-use platforms can harbour diverse activities, from energy extraction to fishing or even touristic attractions, which are more or less managed in a coordinated approach in one shared space. This complex condition of multi-use demands adequate governance tailored to the distinctive features, infrastructure and societal benefits of each individual structure. Overarching, the policy framework in place governing the European sea is in favour of allowing a diverse array of maritime activities, may they be economic, environmental or cultural, as long as they prove beneficial to society. However, issues related to governance fragmentation linked to the manifold of activities present in a shared space may complicate implementation and operation of ocean multi-use.

Europe's integrated maritime policy (IMP) of 2007 approaches maritime issues in a coordinated manner, taking into account the inter-connectedness of different sectors/industries and actors/activities utilising the same space. In particular, IMP pursues three main targets:

1. Sustainable development of the European maritime economy
2. Protection of the environment
3. Cooperation of all maritime players across sectors and borders

Congruent to reaching the first target of the IMP, the EU blue growth strategy aims to strengthen the €500 billion annual gross value added of "blue" sectors in three ways: 1) Develop sectors that have a high potential for sustainable jobs and growth; 2) Develop essential components to provide knowledge, legal certainty and security in the blue economy; 3) Sea basin strategies to ensure tailor-made measures and to foster cooperation between countries.

The EU's strive towards blue growth has been governed by multiple sectoral policies, including for instance the Common Fisheries Policy, which governs all operations linked to the commercial extraction of marine species, or the Communication on Short Sea Shipping, which is part of a larger network of policies regulating maritime shipping in EU waters. In addition, financing mechanisms come into play, such as the European Maritime Fisheries Fund (EMFF), which promotes the development of fisheries and other maritime activities, and the strengthening of their competitiveness to safeguard rural coastal communities and promote their economies and job creation.

The environmental pillar of the IMP is put into practice by the Marine Strategy Framework Directive (MSFD). The MSFD aims to protect Europe's marine waters and their biodiversity, while at the same time enabling sustainable use of Europe's marine resources. The MSFD proposes an integrated and holistic, *ecosystem-based* approach to ensure that marine environments thrive, focusing not just on protecting, preserving and restoring the marine environment but also proactively preventing harmful, human-sourced pollution or inputs before they reach the marine environment. Fundamentally, this approach represents a departure from the traditional focus on single species, sectors, activities, or concerns by considering the cumulative impacts of different sectors in the whole marine ecosystem. In addition, the MSFD provides a framework that requires all Member States to monitor and report on the health of all marine waters, seabed and subsoil that fall within their jurisdiction. Member States are further required to take actions to protect the marine environment, and to take actions to ensure healthy and sustainable waters. The most commonly implemented instrument for conservation are so-called marine protected areas (MPAs). While currently 10% of marine area is protected by MPAs, the EU Biodiversity Strategy adopts the target of protecting 30% of the EU's seas by 2030, with 10% under strict protection, e.g. no-take zones (EC 2020b).

In order to reconcile economic and environmental ambitions in the EU, the third target of IMP "cooperation of all maritime players across sectors and borders" has become subject to maritime spatial planning (MSP), which has emerged as a tool to manage related conflicts derived from competing uses of marine space. The Marine Spatial Planning Directive (MSP Directive), adopted in 2014, requires Member States to develop maritime spatial plans with the aim of promoting the coexistence and sustainability of relevant activities and uses, and to balance the distinct policy objectives promoting competing and often conflicting uses of marine space.

In relation with environmental protection, the MSP Directive makes explicit reference to the MSFD within its legal text, stipulating that maritime spatial planning should apply an ecosystem-based approach and help to achieve the aims of good environmental status and coordinate timelines with the MSFD to the extent possible.

For the adoption and implementation of a multi-use approach to marine space and resources, the central governing policies on EU level are the IMP, which is put into practice through the MSFD and MSP Directive. However, many other EU sectoral and environmental policies also affect the use of marine space. As issues related to governance fragmentation still persist in the current legal framework, sectoral policy and ambitions need to be considered and unified for each potential multi-use scenario. This brings into the complex governance equation the additional inclusion of regional, national and local policies that are included in policy frameworks governing a specific marine space throughout Europe. Figure 2.1 confronts those policies with environmental targets vs those with blue growth targets.

Figure 2.1: the complex policy landscape surrounding multi-use of marine space governance

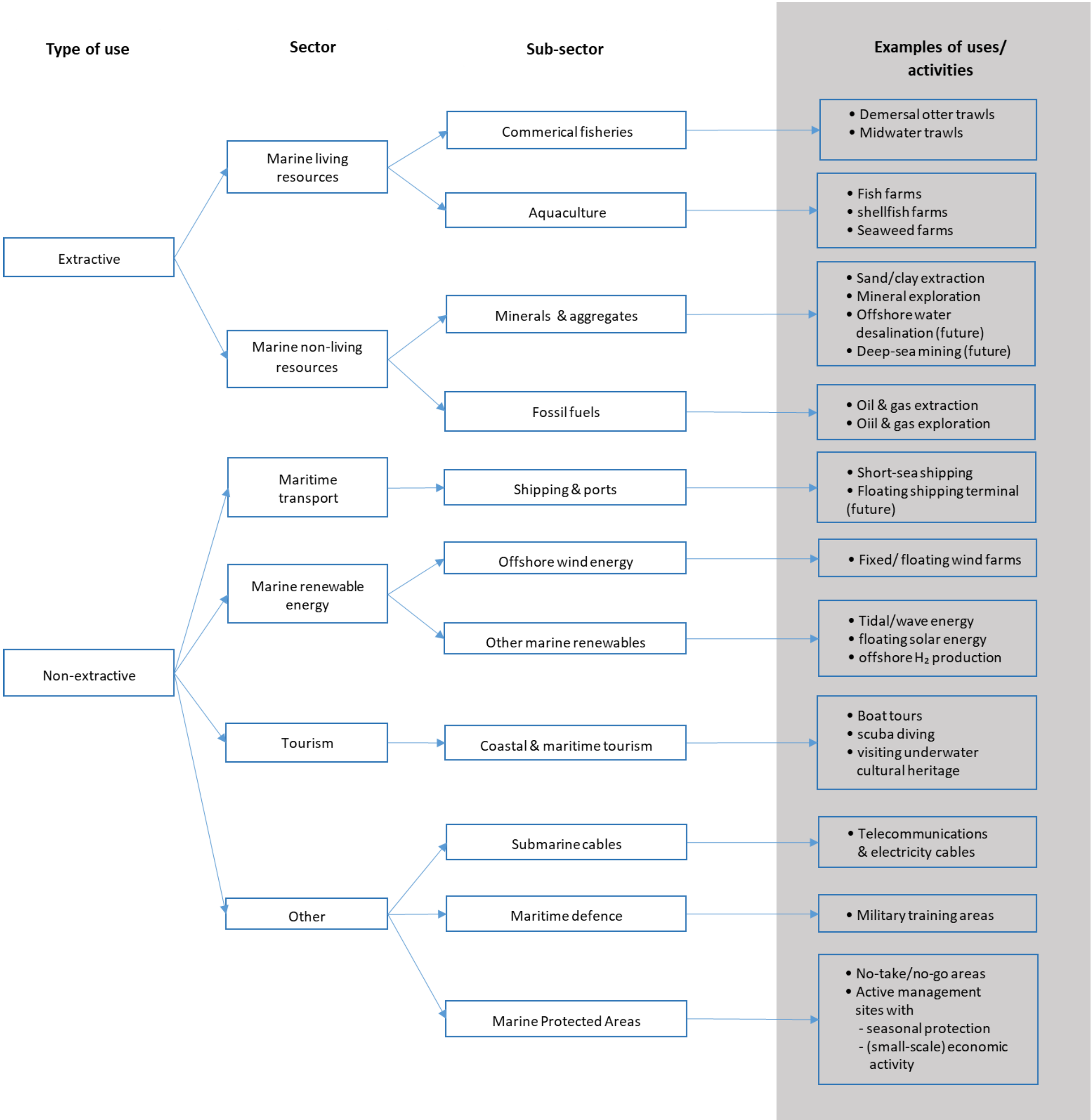
2.3. Economic characterisation of type of marine uses in Europe

At the time that the Blue Growth Strategy was adopted, the EU estimated Europe's seas, coasts and maritime sectors and regions to have 5.4 million jobs and a gross value added (GVA) of just under EUR 500 billion per year (European Commission 2017). Thus, the strategy formally recognized the important role of oceans, seas and coasts as drivers for the European economy, as well as their large potential for innovation and growth. All the economic activities associated to blue growth are generally summarised under the overarching term "blue economy". As it is defined by the EU Blue Economy Report 2020, the blue economy "encompasses all sectoral and cross-sectoral economic activities related to the oceans, seas and coasts", making a differentiation between *marine-based activities* and *marine-related activities* (European Commission, 2020a). According to that report, which provides a yearly updated account of developments and trends in the blue economy, the general trend in recent years has been generally of high growth across its different sectors. This applies particularly to those considered as “established sectors”, i.e. the ones that generate the largest share of jobs, namely (for 2020): those dedicated to the extraction of (living and non-living) resources from the seas, those related to maritime transport (including shipbuilding and repair), marine renewable energy production (offshore wind) and coastal tourism. Data for 2018 show that established marine sectors were the source of direct employment for 5 million people (2,2 % of the entire EU-28 economy), generated around EUR 750 billion of turnover and EUR 218 billion of gross value added (1,5 % of the entire EU-28 economy) (European Commission, 2020a). Other relevant or emerging sectors considered in 2020, for which data availability is still relatively low, are for instance: other forms of marine renewable energy production (e.g. tidal & wave energy, floating solar energy and offshore hydrogen generation), the “blue bioeconomy & biotechnology”, water desalination, maritime defence and underwater cables.

While the sectorial classification in terms of blue economy is useful as it is associated with relevant economic data, the focus on established and emerging sectors has also some limitations for its use in this assessment. For instance, sectors that are similar in nature are classified separately, such as seaweed or mussels production, which fall under the category “blue bio-economy and biotechnology”, from traditional (fish and shellfish) aquaculture and not as aquaculture.[3] For the purpose of assessing the economic added value of multi-use, it is only relevant to evaluate activities that are marine-based. The reason for this is that these are the ones involved in potential conflicts of use or trade-offs emerging from marine spatial planning activities. Therefore, not all blue economy sectors will be of interest for the present assessment. Moreover, other marine activities that are important for marine spatial planning and multi-use are not considered by the blue economy but will be considered in this assessment, for instance the use of marine space for environmental protection in the form of marine protected areas.

[3] In this example, the main reason for this different classification is the lack of available data and the innovative character of some of their end-applications related to biotechnology. For the purpose of this assessment, we have grouped together certain uses that are similar in terms of their use of maritime space, even though they are considered different sectors according to the blue economy report.

Figure 1.2: overview of the marine-based economic sectors and their corresponding activities/uses[4]



The following is a selection of the most economically important blue economic sectors that are marine-based and thus potentially relevant for ocean multi-use (see Figure 1.2), including description of the associated activities and some key economic data:

[4] The understanding of 'extractive' economic sectors is based on the EU blue economy report 2019, which characterizes two overarching sectors 'Extraction and commercialization of marine living resources' and 'marine extraction of minerals, oil and gas' (EC 2019). These economic activities mainly rely on the harvesting/extraction, processing and commercialization of marine abiotic and biotic resources. Thus, the technical consideration of extractive and fed aquaculture is not relevant for this classification.

Extraction of marine living resources[5]

- **Commercial Fisheries**[6]**:** Also known as (wild) capture fisheries, the EU commercial fishing industry is a very important economic sector in Europe. Fishing is, along with shipping, one of the sectors with the longest history of claiming for marine space and is therefore frequently in conflict with new marine uses (European MSP Platform, 2018). As of 2019 it was still the main source of human-food production from the oceans (European Commission, 2019), surpassing aquaculture (in 2013) by a margin of over 3 million tonnes of live weight (European Commission, 2016). With a gross value added (GVA) of around EUR 4.6 billion for 2017, generated mainly by the large-scale industrial fleet, profits increased by 35% since 2009[7]. The sector was the source of employment for 151163 persons in 2017, showing an 11 % decrease from 2009. However, overall quantities of captured fish have had a constant decrease since 1990 (European Commission 2018). Offshore fisheries in the EU consist mainly of large tonnage vessels and most commonly used fishing gear are demersal otter trawls (37 % of the total gross tonnage of the EU fleet uses this technique), followed by midwater otter trawls (18%) (Gascoigne & Willsteed, 2009). The environmental pressures of commercial fisheries on marine and coastal ecosystems are caused by intensive fishing methods such as trawling, which can impact food-web dynamics, stock resilience and overall stock levels (EEA, 2017). However, the trends for value added and employment are projected to continue in the future due to an expected recovery in imported fish stocks, an increase in fishing opportunities and improvements in the revenue due to higher market prices and reduction of operating costs (European Commission, 2020a).

- **Aquaculture**[8]**:** Aquaculture can be understood as the controlled process of cultivating aquatic organisms, especially for human consumption (Global Aquaculture Alliance, 2019). The EU aquaculture represents 1.2% of the global production volume and 1.9% of the sales value of aquaculture production. Moreover, it has contributed to an increasing share of the total seafood production in the EU since the 1990 (STECF, 2018). Aquaculture production in 2016 for EU-28 reached 1.42 million tonnes, accounting for approximately EUR 4.9 billion (STECF, 2018). The GVA was estimated at EUR 2 billion for 2017, a 59 % increase since 2009. Overall employment is estimated at 72 801 persons, a decrease in 3 % for the same time period (European Commission, 2019).[9] However, while it may not appear like that when looking at its overall contributions to the EU total production volume or value, the shellfish aquaculture industry has a very high social importance in terms of employment. This sub-sector is often more labour intensive than other aquaculture types and consists predominantly of small family owned businesses which give it often a large social importance in their regions (STECF, 2018). Overall aquaculture production quantities have stagnated over the last decade, mainly in the mussel farming sector which has been affected by diseases and lack of mussel seeds. However, the production of higher value species such as salmon, seabass and seabream have increased by almost 40%

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[5] The EU blue economy report 2020 sub-divides this sector as “primary sector” (capture fisheries and aquaculture), the “processing of fish products” and “distribution of fish products”. As the focus of this assessment is on activities that take place in the seas and oceans (mainly those that require maritime space), only fisheries and aquaculture will be considered.

[6] NACE Code A 03.10 Capture Fisheries (EU fishing fleet, data from DCF) – maritime proportion: 100%. Data has been taken from Blue economy report 2019, as the one for 2020 presents the data of aquaculture and fisheries aggregated as a single category “primary production”.

[7] On average for all European seas, this has not been the case in the Mediterranean Sea. The figures reflect only for capture, i.e. do not include fish processing activities that take place on the seas.

[8] Nace Code A 03.20 Aquaculture sector (onshore and offshore production, data from DCF) – maritime proportion: 100%. Data has been taken from Blue economy report 2019, as the one for 2020 presents the data of aquaculture and fisheries aggregated as a single category “primary production”.

[9] Data for EU aquaculture sector comprises production of fish and shellfish species that have a long standing history, also including fresh water aquaculture. Newer types of aquaculture, e.g. of seaweed or some novel species of shellfish (e.g. for biotechnological purposes) are not included in these figures. However, for this assessment we will also consider these other types of aquaculture, as in terms of marine space all types of aquaculture share important similarities and are potentially relevant for multi-use.

between 2008 and 2016 (European Commission, 2019). The development of EU aquaculture is expected to be of continuous growth for species that can be kept under a high degree of control, whereas other species such as mussels kept in the open sea are less predictable, as they are highly dependent on environmental factors and international competition (European Commission, 2020a).

Marine non-living resources

- **Extraction of minerals and aggregates[10]:** implies the extraction minerals from the seabed, other underwater geological formations or directly from the water (dissolved minerals like salt or water itself). The most important minerals that are extracted from seas and oceans are aggregates for construction (e.g. sand and gravel), clay and kaolins, and salt. The sector is of relatively low relevance for the EU, having generated just below EUR 150 million of GVA and employed only about 1 700 persons in 2018. Profits have declined by 26% between 2009 and 2018 (European Commission, 2020a). The sector is however expected to become more economically relevant, as the extraction of other types of minerals is becoming more economically attractive.[11] Activities in this sub-sector generally compete with coastal tourism, fisheries, aquaculture and maritime transport. Traditional activities such as gravel extraction can have an impact on the reproduction cycle of certain fish species. More novel technologies such as deep sea mining can also have a potentially high impact in terms of sediment dispersion and disruption of the habitat of sea-floor species (European Commission, 2020a).

- **Extraction of fossil fuels[12]:** by far the most economically relevant of the marine non-living resources, the offshore extraction of the fossil fuels accounts for more than 80% of the total oil and natural gas production in the EU. However, while the sector has been and still is of high economic importance in the EU with a GVA of EUR 19.4 billion in 2018, the sector has been in decline for some years, showing a 29 % decrease in GVA since 2009. The offshore oil and gas sector employed more than 45 300 persons in 2018, showing also a decrease of 29% since 2009. This decline is mainly related to decreasing production quantities, increasing production costs, low oil prices in the market and, not least, due to increased efforts to transition to renewable energies to reduce carbon emissions. The relevance is also set to decrease within the EU, as more than 70% of the GVA and jobs in the sector are located in the UK (European Commission, 2020a).

Maritime transport[13]

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[10] Data from blue economy report 2020; Nace Codes: B 08.12 (Operation of gravel and sand pits mining of clays and Kaolin) – marine proportion: aggregates extraction; B 08.93 (Extraction of salt) – maritime proportion: salt production, B 09.90 (Support activities for other mining and quarrying) – Maritime proportion: SBS proportions.

[11] Emerging sectors such as extraction of marine placers in shallow waters, deep sea mining of polymetallic nodules, or offshore water desalinization (technically also the extraction of a mineral) are not reflected in the data, as data availability for these sub-sectors is very limited. However, these will be considered as potential uses within this sector.

[12] Data from blue economy report 2020; Nace Codes: B 06.10 (Extraction of crude petroleum); B 06.20 (Extraction of natural gas); B 09.10 (Support activities for petroleum and natural gas extraction) – Maritime proportion for all: Oil production. These figures include oil and gas pipes.

[13] The blue economy report 2020 considers “maritime transport” (here summarized under the general term “shipping”) and “port activities” (here considered as “ports”) as two separate sectors. However, for this assessment the sector “maritime transport” will be considered more broadly to include also port activities together with shipping as one single sub-sector, as these are closely intertwined with the transport of goods and persons. In this understanding, a further sub-sector of “maritime transport” could be the blue economy sector “shipbuilding and repair”, which will not be further considered in this assessment due to its limited relevance for the use of marine space. However, as ports are at present still a predominantly land-based activity, the focus of the assessment will be laid on shipping.

Shipping & ports[14]: Technically two separate sectors, shipping and ports (including services for transport) are required for the transportation of goods and persons through seas and oceans and are of vital importance for the European Economy. Together with capture fisheries, these sectors also have the longest history of marine space use. Ports are multi-activity transport and logistic nodes, which make them crucial in the development of maritime sectors. In 2018, more than 410 million passengers embarked and disembarked at EU ports, 5.6 % more than the previous year. Moreover, the number of containers heading into European ports has almost quadrupled in the last two decades. Shipping generated a GVA of EUR 35.6 billion in 2018, a 19 % increase from 2009, while the GVA accounted for EUR 35.2 billion, 24% increase from 2009 (European Commission, 2020a). Ship transport employed directly around 407 825 persons in 2018 (7 % more than in 2009). During the same year, ports employed 549 340 persons (20 % increase since 2009). All in all, ports accounted for a total of 11% of all the jobs, 16% of the GVA and 15% of the profits in the entire EU blue economy. Both ports and shipping are expected to continue growing as 75 - 90% of EU external trade is seaborne. An observable trend of increasing ship sizes and optimization of routes by transport companies to reduce costs can cause increasing conflicts with other uses (European Commission, 2020a).
Most of shipping in Europe takes place under the concept of Motorways of the Sea and legally described in Article 21 of the TENT Regulation 1315/2013. Shipping types in Europe include container vessels, bulk carriers, tankers, reefers, gas carriers, cruise vessels, ferries, offshore vessels, etc. The EU controls 60% of all container vessels and around 50% of the world's multi-purpose vessels, 43% of the world's tankers and 37% of the world's offshore vessels. The majority of shipping in Europe can be considered short sea shipping, namely maritime transport services which do not involve an ocean crossing (OECD 2001).
Maritime transport is linked to physical damage to the seabed, while the construction of ports can cause changes in the morphology of freshwater habitats and coastlines (EEA, 2017). Moreover, shipping is the most prominent pathway for the introduction of invasive species in oceans (Keller et al., 2011).

Marine renewable energy[15]

- **Offshore wind energy[16]:** offshore wind energy, mainly produced by wind turbines that are fixed to the ocean floor, is a particularly important sector for the EU in the context of the European Green Deal. With 22.1 Giga Watt (GW) installed capacity from 5 047 grid-connected wind turbines, more than 90 % of the world's total offshore wind installed capacity is located in Europe, the world leader in installed capacity of offshore wind energy. The sector is growing very rapidly, making it the newest "established sector" in the blue economy. The GVA generated by the production and transmission of Offshore wind energy was around EUR 1.1 billion, a 1 276 % increase compared to 2009 (€79 million). Such significant growth can also be observed in employment, which increased from 582 persons in 2009 to 4624 persons in 2018 (European Commission, 2020a). [17] Offshore wind energy in Europe is still concentrated mainly in shallow waters such as in the North Sea.

[14] Data from blue economy report 2020, including the established sectors "port activities" and "Maritime Transport". Nace Codes: H 52.22 (Service activities incidental to water transportation) – maritime proportion: 100%; H 52.24 (Cargo handling (port services)) – maritime proportion: 50% (or country specific information); F 42.91 (Construction of water projects) – maritime proportion: 100%; H 50.10 (Sea and coastal passenger water transport (water transport)) – maritime proportion: 100%; H 50.20 (Sea and coastal freight water transport (water transport)) ; H 50.30 (Inland passenger water transport) – maritime proportion: 100%; H 50.40 (Inland freight water transport) – maritime proportion: 100%; N 77.34 (Renting and leasing of water transport equipment) – maritime proportion: 100%; H 52.29 (Other transportation support activities) – maritime proportion: 50% (or country specific information).

[15] The EU blue economy report 2020 considers marine renewable energy as "all renewable energy sources that can be generated at sea such as offshore wind energy and ocean energy, as well as floating solar PV" (EC 2020a). However, due to data availability, "marine renewable energy" only reflects the data for fixed offshore wind energy. Thus, information for the subsector "offshore wind energy" is extracted from the EU blue economy sector "marine renewable energy". Nonetheless, floating offshore wind will also be considered in this assessment if applicable.

[16] Data from blue economy report 2020; Nace Codes: D 35.11 (Production of Electricity) – Maritime proportion: no information available; D 35.12 (Transmission of electricity) Maritime proportion: no information available.

[17] Even though the EU blue economy report 2020 considers offshore wind energy as an established sector, the data availability is still very limited. For instance, Eurostat data for Germany, one of the EU leaders in EU offshore wind, is still not available and was therefore excluded from the report. Hence, the numbers presented in the report can be expected to be higher.

However, wind farms are increasingly moving further offshore and into deeper waters due to the better wind conditions, as well as space constrains in closer to shore locations. In this context, the use of floating wind turbines is expected to increase in relevance in the future, as this technology could potentially enable the cost effective harvesting of wind energy in deeper locations, for instance in the Atlantic Ocean and the Mediterranean Sea (European Commission, 2020a).

- **Other marine renewable energies:** Besides offshore wind energy, other renewable energies that can be produced in oceans and seas and have a considerable future potential are for instance *tidal and wave power* (also called *"ocean energy"* as it uses the energies of the ocean for energy production), *floating solar photovoltaic* (FPV), and *renewable offshore hydrogen production*. For ocean energy, the total global installed capacity in 2019 was 55.8 MW, most of it located in EU waters (39.5 MW) (European Commission, 2020a). In the case of FPV, their deployment in seas and oceans is still under trial, as it is still not very clear how the harsh conditions in these environments can affect the systems. The generation of hydrogen offshore (for instance by means of hydrolysis) using electricity from other marine renewable energies, is seen highly relevant for storing produced offshore energy and for making these systems less dependent on grid developments. All of these technologies are still in early stages of development and therefore their economic significance is still very low. Moreover, their market and supply chains are not yet consolidated, which hampers the assessment of their future economic potential for the EU. Nonetheless, research and development expenditure has been high in these sectors, accounting for instance €3.84 billion for ocean energy (wave and tidal) between 2007 and 2019 (European Commission, 2020a).

Tourism

- **Coastal and maritime tourism[18]:** *Coastal tourism* includes beach-based tourism and recreational activities in coasts while *maritime tourism* involves water-based activities and nautical sports, such as sailing and scuba-diving, which can also include visiting underwater cultural heritage such as ship wrecks and ruins. While the latter is the most relevant for the use of marine space, both types of tourism are closely related and only combined data is available.[19] The coastal and maritime tourism in Europe is the single largest sector of the EU blue economy, generating a GVA of EUR 88.6 billion in 2018, a 20% increase since 2009 and a total 41% of the EU blue economy (European Commission, 2020a). Moreover, the sector was the source of direct employment for about 3.1 million persons in the same year, an 18% increase from 2009 and a total of 62% of the entire EU blue economy.[20] While coastal and maritime tourism have grown in recent years and the trend was expected to continue, the sector has been severely impacted by the outbreak of COVID-19. While the economic impact of the pandemic to this sector is still not completely clear, signs of major disturbances in terms of jobs and revenues can already be observed (European Commission, 2020a). Coastal and maritime tourism depend highly on good environmental conditions for specific areas to be attractive. However, touristic development tends to alter the ecological conditions of previously pristine areas, causing, for example, changes in siltation that significantly disturb organisms in a coastal environments (WWF, 2014; EEA,

[18] Data from the EU blue economy report 2020. Nace Codes: G 47.60 (Retail sale of cultural and recreation goods in specialised stores); G 47.70 (Retail sale of other goods in specialised stores); I 56.00 (Food and beverage service activities). I 55.10 (Hotels and similar accommodation); I 55.20 (Holidays and other short-stay accommodation); I 55.30 (Camping grounds, recreational vehicle parks and trailer parks); I 55.90 (Other accommodation); G 47.30 (Retail sale of automotive fuel in specialised stores); H 49.10 (Passenger rail transport, interurban); H 49.30 (Urban and suburban passenger land transport); H 50.10 (Sea and coastal passenger water transport); H 51.10 (Passenger air transport). Marine proportion for all: Share of tourist nights spent on coastal municipalities over MS total.

[19] Data is only available for the activities related to "accommodation", "transport" and "other expenditures" such as consumer goods for tourist. Other aspects that are very relevant for marine-based touristic activities have not been taken into account in the report due to incomplete information. These have been for instance following NACE codes: N 79.11 (travel agency activities); N 79.12 (Tour operator activities); N 79.90 (other reservation service and related activities).

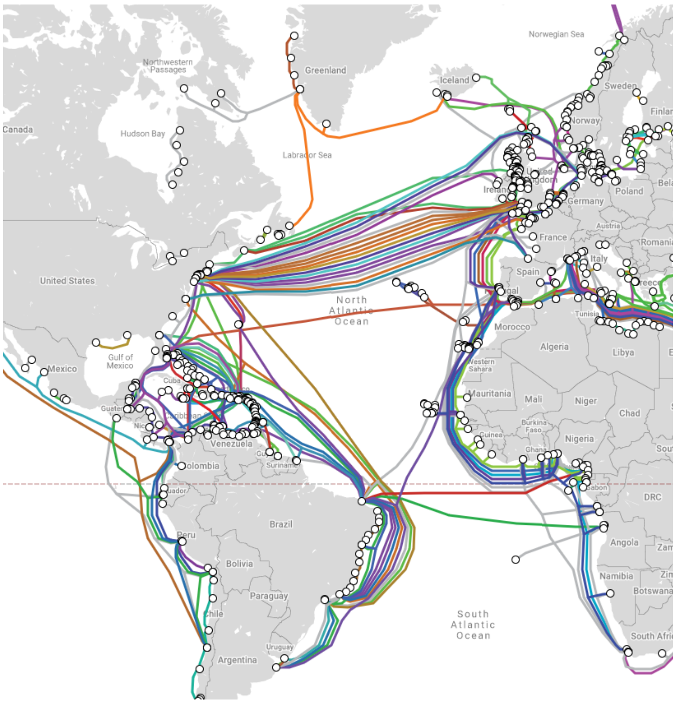
[20] It is important to point out that the majority of the GVA and employment of tourism have been generated by the accommodation sub-sector, which at the moment is mostly not marine-based.

2017). Moreover, tourist facilities are estimated to generate up to 16% of the waste from shoreline and recreational activities (UNEP/MAP, 2007).

Other

- **Submarine cables**: since the first intercontinental telegraph cables were installed in the late XIX century, the effective transmission of data, telecommunication and power[21] within the EU and between the EU and third countries is highly dependent on submarine cables (see Figure 2.3). Particularly telecommunication cables, e.g. optic fibre, constitute critical infrastructure that will continue to become more economically relevant in the context of increasing interconnectedness and digitalisation of the global economy. More than 99% of international data transfer and communication travels through submarine cables, including more than EUR 10 trillion in daily financial transactions. As of 2019, a total of 205 submarine cables were connected to EU Member States, totalling approximately 564 000 kilometres in length, a large proportion of which were laid in the early 2000s or before. Due to their designed service life of 25 years, a large proportion of these cables are set to be replaced in the coming years, which will likely increase the economic relevance of the sector. Next to the submerged part, submarine cable infrastructure also consists of landing points where the submarine cables connect with terrestrial grids.

Figure 2.2: overview of submarine cables connected between America to the EU Member States



Source: www.submarinecablemap.com

Source: copyright unknown

- **Maritime defence:** aimed at ensuring the capabilities for armed combat, maritime defence encompasses mainly the activities of navies, their fleets and areas used for training. While there is not much publicly

[21] Submarine cables for energy transmission of renewable energies to mainland are considered here as part of marine renewable energy.

available information about this sector, the total defence expenditure of the European Defence Agency (EDA) members in 2018 was EUR 224 billion (1.4% of the GDP).[22] While the amounts spent decreased during the EU economic crisis, these have started to recover since 2014. An estimate of 177 090 persons worked as naval maritime personnel in 2017, a decrease of about 36%. Nonetheless, this represented ca 14.1% of the entire EU military personnel in the same year, ca 1.7% increase from 2006 (European Commission, 2020a). The main issues that arise with the planning of maritime defence are for instance that its spatial needs are often uncertain, with very few exceptions such as training exercises and training areas in peace-time. Moreover, other uses may interfere with military operations, e.g. offshore wind parks with radar systems. Nonetheless, as the information on military practices is often classified, this further hinders its coordinated interaction with other uses. As a result, maritime defence activities constitute often exclusive uses of marine space, since national defence has usually a higher priority than other uses (European MSP platform, 2019).

- **Marine protected areas:** The health of marine ecosystems is vital for the sustainable blue growth the EU envisions for the next decade. Blue economy sectors such as fisheries and tourism rely on an abundance of diversity of species and habitats. While marine biodiversity, ecosystems and their linked services and functions respond best to strict protective measures, the EU has implemented protective sites with different degrees of active management to control or limit economic activities while still allowing for growth. Hence, while there are several conflicts between blue economy sectors and environmental protection, also some synergies are possible. Important examples of marine environmental protection are so-called marine protected areas (MPAs), which aim at mitigating and reducing anthropogenic stressors within a specific maritime area. There is wide evidence that MPAs can bring both benefits for the ecosystem and to society through positive synergies with various economic sectors by means of ecosystem service provision (Davis et al., 2019). The strictest form of protection in terms of MPAs is a "No-take/no-go area/marine reserve" (Day et al., 2019). Currently these type of MPAs make up a very small fraction of total MPAs in Europe (Day et al., 2019), but the Biodiversity Strategy for 2030 aims to designate 10% of the EU's marine realm under such strict limitations. There are other MPA types, which are labelled as active management sites that allow for the presence of economic activities to varying degrees, for instance on a seasonal basis or depending on their scale and potential environmental impacts. While some actively managed MPAs allow solely for traditional subsistence fishing on the basis of a community's heritage, others may allow for a multi-use approach, sharing the space e.g. with wind farms.

2.4. Developing an (economic) typology of ocean multi-use

Ocean space can be considered a scarce resource that can serve as input to a range of productive economic and ecological processes. As such, different sectors and their respective uses of a certain marine space may compete with other uses.

The discussion surrounding access rights of different economic activities in a specific marine space, which is inherent of MSP, is pivotal for the development of an economic assessment framework that is relevant for multi-use. Such economic assessment ultimately deals with the allocation of a scarce resource, in this instance the limited available marine space. Because of existing allocation rules, certain sectors benefit more than others regarding decisions taken under an MSP context, potentially giving way to trade-offs with other sectors that are rather disadvantaged (COGEA et al., 2020). Allocations of scarce marine space should ideally be justified from a social point of view. This means that the overall economic benefits outweigh costs regardless of which specific stakeholder bears them. On the other hand, there are also cases where a planning decision like combining multiple activities in the same space, causes no trade-offs, or even causes win-win situations as all involved parties are better off (COGEA et al., 2020).

Arguably, not all activities are compatible with other uses and therefore some cannot be combined. Competing uses may be seen as exclusive or incompatible with other uses (in a given location), for instance due to existing regulations, or because the activities of one use interfere considerably with others. In other cases, multiple use in the same maritime space can be potentially feasible (Veum et al., 2012). For this reason, it is highly important

[22] Total defence expenditure, proportion of maritime defence not specified.

to develop an economic characterization of different types of uses of maritime space which takes into consideration their (in) compatibility with other uses. This will serve as an important base for the economic assessment framework and will be helpful for defining the different scenarios of use combinations and the opportunity costs associated to them.

In terms of terminology, Kite-Powell (2017) avoids the use of the term exclusive marine uses, but rather applies instead incompatible uses, which is always relative to which other activities could be combined within the same space. According to Veum et al. (2012, p.11), a spatial incompatibility (or non-compatibility) "describes a situation where two or more use functions cannot co-exist within the same given area". This means that some uses may exclude certain other uses, but that does not make them per-se exclusive. This may be the case for instance where there is a legal allocation of exclusive rights to a specific use, but that is only one of the aspects that make a use potentially compatible with another one or not. Another relevant factor can be the presence of certain physical components or fixed structures, along with respective safety zones, which may seriously interfere with other activities and therefore hinder their presence in the area (Veum et al., 2012). Moreover, for two or more activities to be compatible on a specific maritime space, the conditions that will be available for all uses in that area must be attractive for carrying out its targeted economic activity. This can be related for instance to aspects such as the distance to shore, nutrient fluxes, currents, wind conditions or the proximity to protected areas (Kite-Powell 2017).

The compatibility of a specific marine use is generally not discrete quality, but rather a relative characteristic that depends mainly on degrees of compatibility with the characteristics of the other use it is intended to be combined with. For example, an offshore wind farm may be compatible with a variety of uses, e.g. with aquaculture or maritime tourism (Depellegrin et al., 2018), making it *potentially compatible* with other marine uses in general terms. On the other hand, certain uses of the marine space, for instance maritime defence, rule out the vast majority of other uses. The sector is only compatible with a very small subset of marine uses and under very strict pre-arranged conditions, making the maritime defence sector as *generally incompatible* with other uses. In this case, some multi-use examples can be found with seasonal artisan fisheries or off-shore wind farms, but maritime defence has the primary use rights of the allocated marine space under operation due to national security interests and "sharing the space" its solely at the armed forces discretion (EEA 2017; Veum et al., 2012).

Different European research projects (e.g. TROPOS, MERMAID, MARIBE, MUSES, H2Ocean, among others) have recently started to investigate the concept of multiuse with a view to understand the feasibility of different potential combinations of uses, as well as their potential positive and negative impacts (MUSES, MARIBE). The MUSES project developed a preliminary typology for combinations of uses, i.e. for multi-use. This is rooted in the analysis of different dimensions based on evidence from available case studies around Europe (Schupp et al., 2019). Different types of multi-use are then defined according to the potential degree of connectivity (Schupp et al., 2019):

- Spatial Dimension: A connection of uses in this dimension (i.e., "close geographic proximity") occurs when the spaces occupied by two or more uses overlap. This dimension is intrinsic to all multi-use scenarios!
- Temporal Dimension: refers to the timeframe in which the uses in question take place: Two or more uses connected in this dimension take place at the same time
- Provisioning Dimension: encompasses activities/processes servicing and supporting the main function of a use (e.g., monitoring of environmental data, marketing, etc.). A connection of uses in this dimension usually implies sharing those services or their associated costs in order to reduce the financial burden of operation (can also be a trade-off if such sharing limits other activities).
- Functional Dimension: refers to the main function of a use (e.g., power production and transmission or seafood production). A connection of uses in this dimension implies a direct linkage, e.g. in the form of shared infrastructure like multi-purpose vessels. Its clear distinction from the Provisional Dimension requires a clear understanding of the operations of each use.

Those activities that share time and space as dimensions of their connectivity of the use of marine space can be further differentiated based on the characteristics of the added operating efficiency derived from working with other uses. This is linked with the provisioning and functional dimension introduced above and ultimately refers to the potential benefits from multiuse. This is good to highlight but not critical for the development of the economic typology of marine uses for the development of a decision-making assessment framework. Ultimately, efficiency gains from multiuse combinations will be included in the assessment. Arguably, it is in this case more relevant to analyse the aspects of multiuse that derive from a connectivity in terms of time and space (temporal and spatial dimensions).

Furthermore, the MUSES project, considering the above dimensions on understanding the degree of connectivity between the involved uses, identified the following types of multiuse:

Table 2.1: Typology for multi-use according to their degree connectivity

#	Multiuse type	Definition	Example
1	Multi-Purpose/ Multi-Functional	- Uses share the same space, occur at the same time, share provisioning services and, their main functions are intrinsically connected, - highest level of connectivity (all dimensions) between users.	Multi-purpose marine platforms example, floating power plant (FPP) combining multiple marine renewable energies from wind to tidal and wave power.
2	Symbiotic Use	- Connection of the provisioning services (cost savings), - characterized by connections in the spatial, temporal, and provisional dimensions. No sharing of infrastructure (platform).	Mussel aquaculture in between offshore wind turbines or touristic visits of OWFs in the North Sea.
3	Co-existence/ Co-location	- Share of space and time.	Commercial fisheries within areas occupied by offshore wind farms.
4	Subsequent Use/ Repurposing	- Repurposing the permanent installation of a maritime use (e.g., oil and gas, offshore wind) after end of its lifetime and is repurposed for another maritime use, - same space but at different times.	Repurposing of oil and gas platforms in recreational opportunities, environmental protection and possible research and monitoring stations.

Modified from: Schupp et al., 2019

In addition, Kite-Powell (2017) introduces a further distinction that it is relevant for developing an economic typology of the different types of marine uses. His typology is based on the fact that uses can be either transitory and non-transitory depending on whether they take place constantly in the same space at the same time (non-transitory or permanent, e.g. aquaculture with cages or offshore wind energy production) or in the same space only during a certain/limited period of time (transitory, e.g. commercial fishing with trawls or diving).

2.5. Proposed characterisation of marine uses

As it has been mentioned before, a key element for classifying different maritime sectors in economic terms is their compatibility to share the same space with other uses. To this regard, we propose classifying different marine space uses as either“(generally) incompatible” or “compatible” (i.e. potentially feasible for multi-use) with other uses. On the other hand, it is also relevant to account for the temporal presence of an economic activity in a given space, namely whether these are *permanent* or *transitory* uses.

Assuming that an economic activity is a process that, based on inputs, leads to the manufacture of a good or the provision of a service, we can find the following types and definitions:

- Transitory use: it is a recurrent activity of a seasonal nature, in which activity takes place at the same location (e.g. summer time whale watching or fisheries seasonal catch). In this category, we also include temporary one-off activities that take place at a given location and a specific period of time (e.g. oil and gas exploration). Key in the identification of transitory marine uses is the time limit consideration regarding the length of the economic activity. In this context, a maritime economic activity is considered transitory when the activity only lasts for a short time in a given time period at a specific marine space, for example a few days or months in a given year at the same location.

- Permanent use: A maritime activity is considered permanent when the activity or the infrastructure that supports the economic activity is constant in time at a given specific location (example: offshore wind energy).

In developing these definitions, the following aspects needs to be considered. Please note that the life of the activity is an important issue to consider. An offshore wind platform may have a life span of 25 years before decommissioning and therefore, it can be considered by some as transitory over the long term as opposed to a permanent use. But for our definitions we use a natural year (365 days) as the condition for the distinction between transitory and permanent, we apply the term permanent to an activity that leads to the manufacture of a good or the provision of a service during the 365 days of a year.

Additionally and for the development of an economic typology, (in some cases) it is important to consider the cumulative impacts of single activities for the distinction between permanent or transitory uses. In the maritime transport sector and using ferry transport as an example, we consider shipping routes as the maritime activity (a sea lane, sea road or shipping lane is a regularly used route for vessels on oceans and large lakes). In this instance, the regularity of the ferry route would make the activity to be considered as permanent. As ferries come and go in constant intervals through the shipping lanes, the environmental impact to be considered is not that of a single ship but of all ferries that use the lane in combination.

Considering the above described aspects of spatial compatibility and temporal presence, it is possible to classify single uses of the marine space (in relation to the combination with other uses) in one of the following categories (see Figure):

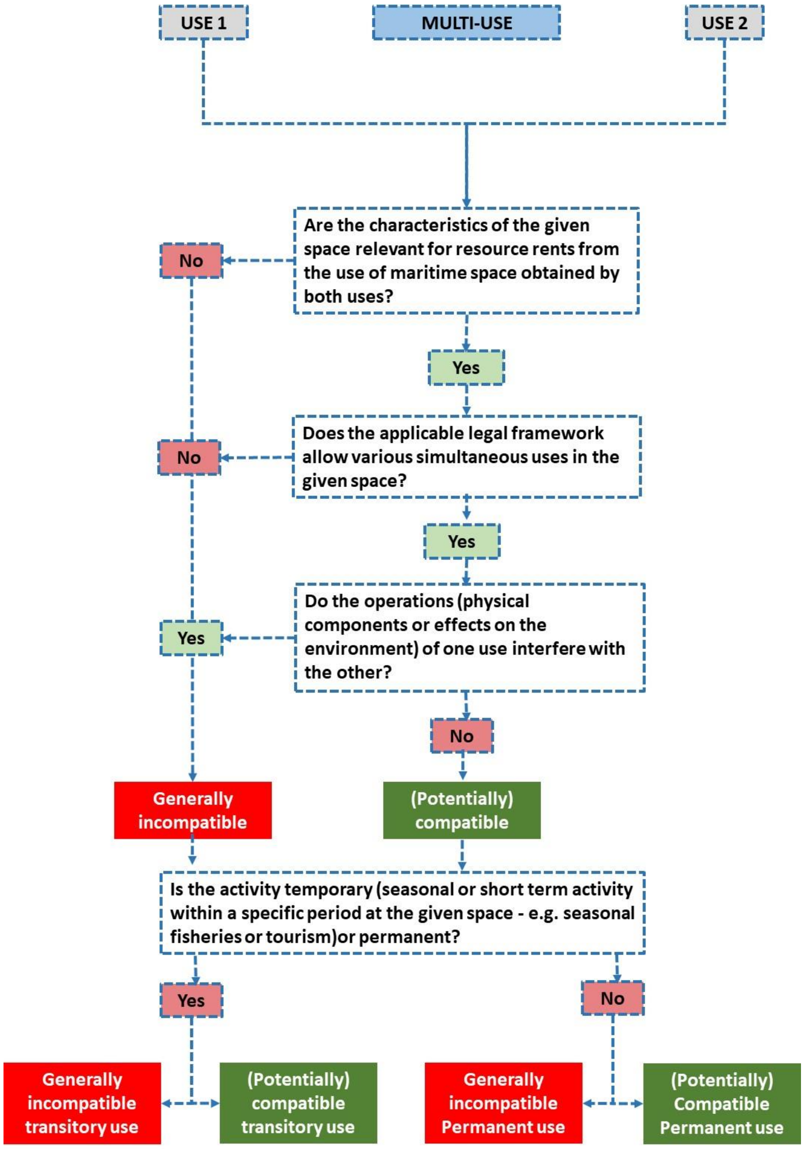
1. (Generally) incompatible - transitory use

2. Compatible - transitory use

3. (Generally) incompatible - permanent use

4. Compatible - permanent use

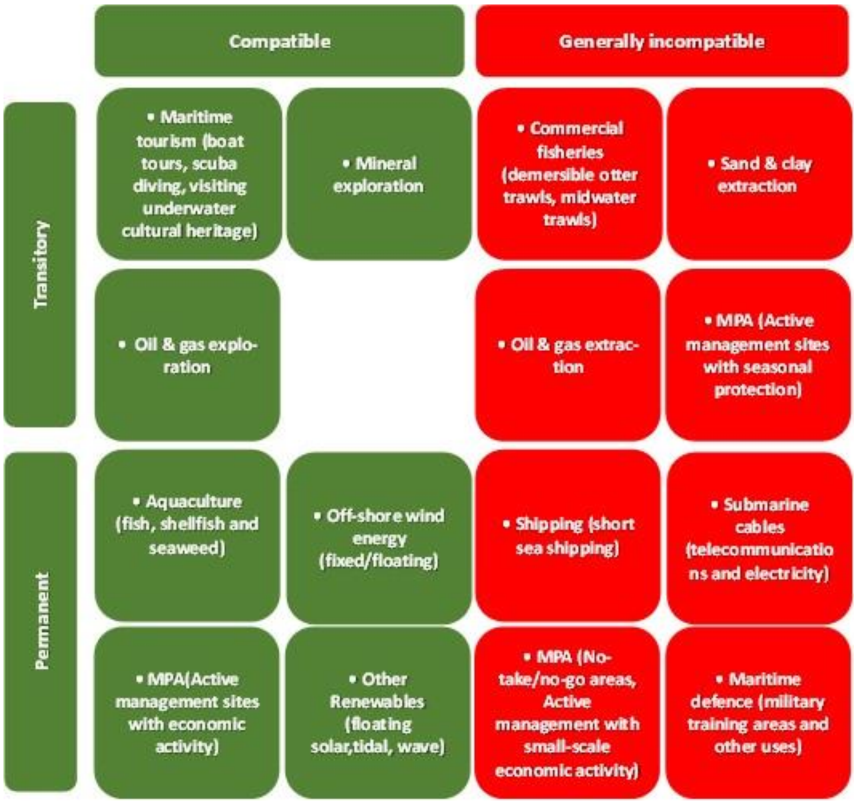
Figure 2.4: Decision tree for the characterization of marine economic activities according to their mutual compatibility and temporal presence in the marine space



The following Figure .5 classifies examples of the marine-based economic uses of ocean space described in chapter 2.1.2 using the above described typology. Some adjustments and assumptions were necessary for the sorting out and labelling of existing maritime activities into the different marine space use categories. This is because each main marine-based economic sector is often subdivided in many different uses and each of these have their own specific characteristics. In order to set boundaries to the scope of our analysis, we have focused on highlighting the main types of uses that can be found in European seas at the present. Hence, activities that are still on a very early development stage such as floating shipping terminals, deep-sea mining, offshore water desalination and offshore hydrogen production are not considered.

Further, we attempt to narrow down our categories to only those economic activities that are marine. In this context, we consider certain limits: 1) those activities that rely on land use planning regulations are not considered (these apply to activities in the coastline); and 2) we employ water depth as a proxy indicator to consider only marine activities away from the coastline (only those activities taking place above a certain depth will be considered) This analysis has therefore ignored land based activities and shallow waters (<5 or 10 meters), for instance ports, current water desalination practices and coastal tourism. The economic characterization of maritime activities based on their use of marine space is constrained to the analysis of those activities that take place in shallow waters (>10-30 meters), transitional (30-60 meters) and deep waters (> 60 meters).

Figure 2.5: Types of uses of marine space in Europe



From this classification of the economic activities in the European marine space it will be possible to identify those that are potentially suitable for multi-use and which will be therefore subject of the economic assessment framework. This includes, in first line, the maritime uses that have been identified as (potentially) compatible with various other uses. Furthermore, it is important to consider that a necessary condition for multi-use to happen is the presence of two or more activities with compatible uses of marine resources operating at least in the same space at the same time. For the purpose of this analysis we will not consider combinations of uses that are connected only through the spatial dimension, for instance two transitory activities taking place in the same space but at different times (e.g. fishing and scuba diving) or what Schupp et. al (2019) describe as repurposing. However, this does not mean that transitory uses are excluded, as operations do not need to take place continuously at the same time in the same space, but multi-use will be considered to require at least one permanent use.

2.6. Baseline and options

Scenarios can serve as useful tools in environmental impact assessments for understanding and accounting for environmental, sociocultural and economic problems and assessing responses (project or policies) to resolve them (EEA, 2001). The European Environment Agency applies the definition developed by Alcamo et al., 1995, and defines scenarios as "*projections of the future state of the society and environment based on specific assumptions about key determinants such as population, economic growth, technological change, or environmental policies*". Scenario development addresses the analytical need to evaluate potential changes in impacts between alternative futures and in comparison to reference conditions (i.e. what would happen if none of the alternative options were implemented), which can be used to advise on action.

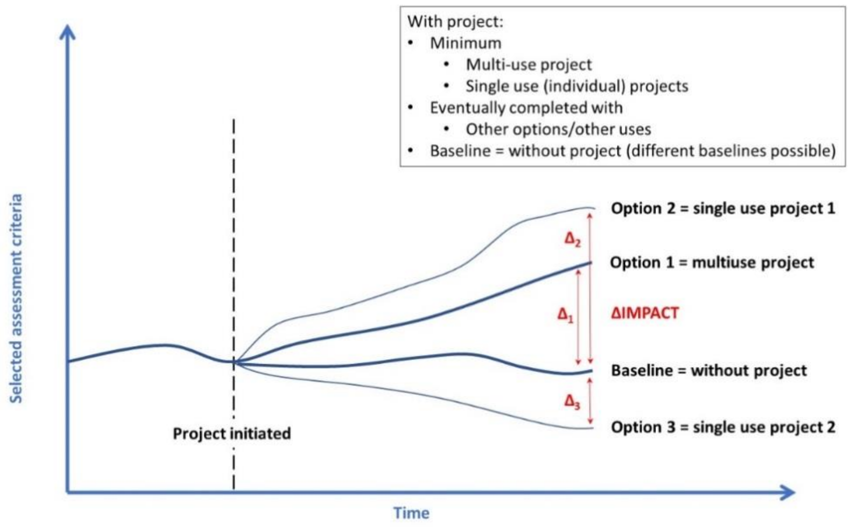
Baseline scenarios (in the context of environmental studies) are also known as reference or benchmark or non-intervention scenarios. As rule of thumb for the selection of a suitable baseline, this can be found in a scenario that excludes the impacts of all policies or actions directly related to the main theme of the scenario (EEA, 2001).

The aim of the UNITED economic assessment framework is to assess the added value of marine multiuse in a given maritime space applied to specific context of the five UNITED pilots. The options, which include single uses on their own and combinations of uses (multi-use), will be measured against a baseline which will be defined for each pilot. Each option will be compared to the same agreed baseline. We define baseline as the previous use of the specific marine space in question – the marine use that was in place in the pilot before considering the existing single or multiuse options.

We propose to select a suitable baseline from a list of the most common incompatible single uses that can traditionally be found in European waters (see chapter 2), such as fisheries, shipping or marine protected areas. However, the specific baseline that will be used in each pilot will be selected with close integration of the views of respective stakeholders. This means that neither all pilots will necessarily consider the same baseline for the assessment, nor that the selected baseline will necessarily have to be a common or traditional use of marine space in the EU (i.e. fisheries, shipping or MPA).

This methodology aligns with the approach of the overall UNITED Assessment Framework (see Kerkhove et al., 2020) which is presented in Figure 2.6. The changes in the socio-economic impact measured against a common baseline (ΔImpact in Figure 2.6) will allow for a comparison of the total added value of the different options.

Figure 2.6: Assessment scenarios under the overall UNITED Assessment Framework



Source: modification of figure from pending publication Kerkhove et al., 2020

Thus, the added economic value of different options of uses will be analysed against a common baseline, which will allow for a comparison between the options, allowing us to estimate ΔImpact. At this point, it is important to bear in mind that the focus of this assessment is to evaluate the multi-use options against likely (and potentially feasible) alternative single uses in order to assess the added value of combining different economic activities in a single maritime space.

3. WHY CARRY OUT AN ECONOMIC EVALUATION?

All decisions involve trade-offs – selecting one option inevitably means declining the alternatives. Each option comes with its own unique set of costs and benefits. These include financial costs and benefits (e.g. upfront investment costs, ongoing operating costs, revenue and profit) as well as broader impacts on the wider society, including positive and negative environmental impacts (e.g. carbon emissions or damage to ecosystems) and social impacts (such as new jobs or public infrastructure). Each option and its associated costs and benefits will also have different distributional effects, where different social groups will "win" or "lose" to differing degrees. Economic evaluations provide evidence that allows decision makers to weigh up different options, including all of the diverse costs and benefits that matter to them, so that they can select the options that will deliver the greatest value.

When it comes to deciding the best use of marine space, decision makers benefit from economic evaluations. This is because answering this question also involves trade-offs, e.g. deciding to approve a multi-use project (e.g. wind farm plus tourism activities) inevitably means the alternative options will not eventuate (e.g. just a wind farm, or just tourism activities, or no use i.e. a marine protected area). To make this decision, the decision maker needs information on the different costs and benefits that would arise under each option. This includes financial costs and benefits (such as the cost of building a offshore wind farm, the costs of borrowing money, and the income gleaned from wind power and tourism activities). They must also consider environmental costs and benefits, which can be significant in marine spaces that are home to valuable flora and fauna that would be affected by the combination of uses selected, with some options resulting in more or less damage to seafloor habitats, increased or decreased noise pollution, or even in the creation of protected areas. Decision makers must also consider the distributional impacts, as the costs and benefits of different marine space use options will fall differently on different social groups, such as fishers or coastal property owners or the unemployed. Accordingly, decision makers will need comprehensive economic evaluations of different potential options to reach good decisions regarding the use of marine space.

3.1. Who needs economic evaluations?

Different decision makers have different concerns and values and accordingly require different information to reach decisions. In this project, we consider two types of decision-makers: project developers and public authorities.

Project developers are the private companies or organisations, individuals, or groups thereof who undertake private market activities in marine space in the hopes of turning a profit and meeting their own objectives. They need to understand the financial costs and benefits associated with different options, i.e. whether the options are affordable and which one will be most lucrative.[23]

Public authority: Public authority refers to the public decision maker responsible for deciding how a piece of marine space should be used. They need to understand the broad social costs and benefits of the different options. This includes those costs and benefits that a project developer would be interested in (i.e. what the levels of profit will be for the different options) but also includes other costs and benefits to society, such as the environmental impacts of the different options, and the impact of different options on other societal goals, such as reducing inequality or lifting rural living standards. Public authorities also have to consider the costs that they will bear, i.e. the costs of regulating and enforcing the option that is considered, as well as any risks that might be passed on by the project developer to society, such as health and safety or environmental accidents. Only if they have evidence on these broader criteria will they have sufficient information to select which option will deliver the highest net benefits to society.

Financial versus economic evaluations

[23] While they may also be personally interested in broader costs and benefits (e.g. positive environmental impacts), as a business, at a minimum they need to break even to survive (i.e. financial costs must be less than financial benefits).

Project developers and public authorities need different types of information, and thus require two different types of evaluations: financial evaluations and economic evaluations.

Financial evaluations take the perspective of a project developer or an investor. Accordingly, they focus narrowly on what financial returns the developer will achieve for each option. Useful for investors, businesses, banks, financial evaluations compare different options in terms of financial feasibility and profitability for the firm. This includes all market costs and benefits[24], plus any other relevant financial costs/benefits for the developer e.g. tariffs, taxes, subsidies, carbon credits, etc.

Economic evaluations consider the total costs and benefits to society. In addition to concerning themselves with the relative profitability of the different options, crucially, they also include non-financial costs and benefits. Only some of the costs and benefits arising under each option will actually be faced as costs or benefits by the project operators. The different options will also have negative and positive effects that would be borne by society. These cost and benefit of these "externalities", which include environmental impacts, such as carbon emissions, underwater noise, seabed impacts, job growth, among other effects, burden or benefit society. Economic evaluations also need to consider transaction costs, that is, the costs associated with completing market transactions, including their own and others administration costs, along with enforcement and monitoring costs. The overarching objective of economic evaluations is to consider all societal costs and benefits, regardless of where they fall, and identify the socially optimal option, i.e. where net benefits (social benefits minus social costs) are highest. As society cares not only about the size of these costs and benefits, but also upon who they fall (i.e. fairness), economic evaluations also need to consider the distributional impacts of the different options.

(In chapter 5 we focus on economic evaluations, in chapter 6 we focus on financial evaluations)

Table 3.1 Differences between financial evaluations and economic evaluations

Evaluation type	**Financial**	**Economic**
Decision maker	Project developer	Public authority
Evaluation question	Which option will maximise the expected returns on investment?	Which option will deliver the highest net benefit to society?
Costs and benefits concerned	Private	Social (including private costs and benefits)
Examples of costs and benefits covered	- Benefits include the expected revenue over the lifetime of each option - Upfront costs (e.g. capital expenditure to cover construction) and the costs of financing this capital expenditure - Lifetime operating costs of each option (e.g. maintenance costs and costs for decommissioning at end-of-life) - Taxes and subsidies - Does not include externalities (e.g. climate impact) unless these can be profited from (e.g. through carbon credits)	- Net financial profit from differing options (i.e. result of financial evaluation) - Externalities (including relative environmental impacts) - Administration, enforcement and other transaction costs - Broader social impacts (e.g. jobs, etc.)

[24] That is, all expenses or income that arise from market transactions, e.g. purchase of construction materials and payment of workers, shipping costs, income from sale of output (e.g. oil, tourist visits, mussels, etc.).

Example of costs and benefits excluded	- Externalities (i.e. costs and benefits that are not borne by the developer, e.g. environmental impacts, broader social impacts)	- Taxes and subsidies that are just transfers from government to recipients (as these have a net-zero effect)
Metric	Money	Money, quantitative, qualitative

3.2. Potential relevant public policy decision-making support tools:

A number of tools have been created to carry out economic evaluations, each which has their own strengths and weaknesses. In this section, we introduce three commonly used decision support tools: cost-benefit analysis (CBA), cost-effectiveness analysis (CEA), and multi-criteria analysis (MCA).

Cost-benefit Analysis

Cost-benefit analysis aims to assess all benefits and costs accruing to society as a whole from different options, so as to calculate the total social welfare under each option. This includes all different types of costs and benefits, including financial, social, and environmental impacts, present and future. To enable comparison of different impacts, cost-benefit analysis requires that these costs and benefits are monetised – i.e. expressed in a common monetary unit (e.g. €). This also requires future costs/benefits to be adjusted into present values. By summing up all costs and benefits, decision makers can calculate the net present social value of each option, identifying whether the options are net benefit for society. The net present social value and other related metrics, such as the benefit-cost ratio, allow decision-makers to compare different options[25].

CBA Strengths	**CBA** Weaknesses
+ assesses overall social benefit of options + widely used and recognised by decision-makers + considers all costs and benefits + considers multiple time-periods + enables comparison between options that deliver different outcomes	- challenging to account for non-marginal effects (e.g. tipping point) - can be challenging to monetise some costs/benefits (e.g. environmental, cultural, non-use values) - does not consider distributional impacts - does not consider the "option value" of deciding later

Cost-effectiveness Analysis

Cost-effectiveness analysis is a subset of cost-benefit analysis that compares different options in terms of their relative costs to deliver outcomes, where outcomes are expressed in real terms (i.e. not monetised). That is, it seeks to find the least cost way to deliver a desired result. It is most appropriate when evaluators cannot complete a cost-benefit analysis because they cannot monetise key outcomes, or the expected outcomes will be very similar. In these cases, cost-effectiveness analysis more simply focuses on the relative costs of different options, i.e. its cost-effectiveness. This assumption that outcomes will be similar means that some CBA challenges, e.g. potential for non-marginal effects, will not be covered[26].

[25] For more detailed information about the CBA method please check: Pearce, David, Giles Atkinson, and Susana Mourato. 2006. Cost-Benefit Analysis and the Environment: Recent Developments. Publication of the Organisation for Economic Co-operation and Development (OECD), HM Treasury 2018. The Green Book. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

[26] For more detailed information about the CEA method please check: Better Evaluation (2020) Cost Effectiveness Analysis https://www.betterevaluation.org/en/evaluation-options/CostEffectivenessAnalysis

Cost-effectiveness analysis Strengths	**Cost-effectiveness analysis** Weaknesses
+ simple + enables selection of "cost-efficient" option that delivers outcomes at lowest cost + covers multiple time-periods	- cannot assess whether options generate a positive social benefit - cannot be used if outcomes expected to be different - does not consider distributional impacts - does not allow comparison of different outcomes through common metric (except for costs)

Multi-criteria Analysis

Multi-criteria analysis evaluates the costs and benefits of different options to enable decision makers to select the option delivering the best set of overall costs and benefits. Multi-criteria analysis differs from CBA and CEA in that rather than monetising all costs and benefits, allows comparison that considers multiple criteria. These criteria should be identified up-front and can include different units, including monetary units (e.g. costs) as well as quantifiable units (e.g. km^2 of marine protected area or number of recreational visitors or number of jobs created) and qualitative units (e.g. aesthetic value). Options are assessed relative to each criteria, with the results then normalised to enable comparison across different options. By weighting different criteria in accordance with the decision-maker, MCA then allows summation of the different criteria into a total overall score. MCA often relies on stakeholder processes to identify values and preferences that enable decision making[27].

Multi-criteria Analysis Strengths	**Multi-criteria Analysis** Weaknesses
+ includes all costs and benefits (including qualitative elements that cannot be monetised or quantified) + explicitly identifies preferences and values (as weights) + considers all costs and benefits + considers multiple time-periods + enables comparison between options that deliver different outcomes + can include distributional impacts	- results are difficult to generalise (as specific to question, context) - the resulting metric is abstract and difficult to understand or communicate - potentially time-consuming - reliant on stakeholder input

3.3. The way forward: Partial Cost-Benefit Analysis

This chapter has introduced the different decision support system (DSS) tools that we can apply in order to assess the potential economic impacts from marine multiuse, and highlighted each of their strengths and weaknesses. Consequently and mainly due to expected data limitations, we believe an application of a partial CBA is the most suited DSS to evaluate economic impacts from multiuse in the UNITED case studies. A partial CBA allow us to focus on gathering available information about significant economic, social and environmental impacts. Our approach will preferably focus on quantifying costs and benefits (i.e. in monetary terms) when available information would make that possible, but the method also allows for a qualitative description of those impacts difficult to quantify. According to the EC Impact Assessment Guidelines, an environmental CBA can be done at various levels, depending on data availability. It can be either a full CBA when the most significant parts of both costs and benefits can be monetised utilizing economic values derived through various economic techniques or a partial environmental CBA in cases where only a part of the costs and benefits can be quantified and/or monetised (EC, 2015).

[27] For more detailed information about the MCA method please check: Geneletti, D. (2013). Multi-criteria analysis. LIAISE Toolbox. Retrieved date, from http://beta.liaise-toolbox.eu/ia-methods/multi-criteria-analysis.

Following the approach to assess the impacts from marine multiuse developed by Koundouri et al., (2017) for the MERMAID project, the next chapter lays out the foundations to apply cost benefit analysis in the UNITED pilots and illustrates typologies of relevant impact indicators in terms of their expected financial and economic costs and benefits. In the next chapter, we further expand the typologies with a tentative list of specific impact indicators and proposed methods to assess them. Special attention needs to be paid to the consideration of all significant relevant impacts, including those that affect other marine users (externalities) and that may be of a positive or negative character.

4. UNDERSTANDING THE COST AND BENEFITS OF MULTI-USE

This chapter focuses on the identification and calculation of the costs and benefits of different marine uses to understand their overall impact on society. First, we introduce a typology to assess financial costs from multiuse (4.1) and then a typology of economic externalities (4.2), tailor-made to assess the social and environmental impacts of multiuse activities. In addition, we make a proposal to assess environmental impacts from multiuse through the application of the ecosystem services concept, in combination with environmental impact assessment in WP4.

To be able to choose between different marine use options, decision-makers need to be advised about the trade-offs associated with each option and potential alternatives. Only if there is a net benefit to society (i.e. when benefits outweigh costs) does it make sense to consider that option. If multiple options have net benefits, then an understanding of the costs and benefits should support the decision maker to reach a decision, for example, they could choose the option with the highest net benefit, or the one option with the highest benefit to cost ratio, or use other decision support tools to select an optimal option.

As outlined in previous sections, different uses of the sea will generate many different types of costs and benefits. The private decision-makers who develop, own, and operate offshore platforms or otherwise use the ocean for private reasons will face private financial costs and benefits, such as construction and operating costs, and income from sale of products and services. In addition to these, different marine space options will also generate costs and benefits that fall on parties other than the private decision-makers (so-called economic externalities), such as environmental impacts, or social costs or benefits that affect others, such as local job creation or noise. In addition, different uses of marine space will imply different costs for regulators (transaction costs), as well as a cost in terms of not being able to implement an alternative use of marine space (the opportunity cost). A social decision maker must consider all of these costs and benefits when weighing up the relative social value of different options (i.e. for the baseline, single-use options, and multi-use options).

To ensure that all important costs and benefits are accounted for, in this chapter, we develop a structured, sequential approach for identifying the relevant private and social costs and benefits for each option. We build in part on previous work from the MERMAID[28] project and AQUACROSS[29] project. We identify cost and benefit categories, providing definitions and examples. After describing the types of costs and benefits, the guidance section introduces how to use this categorisation to support decision-making.

4.1. Private costs and benefits of multi-use activities

Developers and those private parties running single or multi-use projects face numerous costs and benefits. Here, we separate these into three categories: one-off costs, ongoing costs, and income.

One-off costs

These upfront costs are commonly referred to as capital costs, and include all costs that a developer faces to take the project from idea to commercial operation. These are one-off costs that are only faced at the beginning of a project, they are not ongoing. Upfront costs consist of all of the costs associated with developing, planning, and first establishing the option. These include the financial costs associated with paying others, and the time costs of doing it yourself. In addition, here, we include any future costs of decommissioning that the developer will face at the end of the project's life. This can include the following:

- *Design and planning* – i.e. costs associated with initiating the project.
- *Insurance and legal* – e.g. legal fees for contracting and negotiating.
- *One*-off *equipment purchases* – i.e. upfront capital investments in equipment and gear.

[28] FP7 Innovative Multi-purpose offshore platforms: planning, design & operation (MERMAID) http://www.vliz.be/projects/mermaidproject/
[29] H2020 Knowledge, Assessment, and Management for AQUAtic Biodiversity and Ecosystem Services aCROSS EU policies (AQUACROSS) https://www.aquacross.eu/

- *Construction and development* – i.e. costs for any building (materials and services).
- *Financing costs* are the cost of borrowing money to cover upfront costs. This includes interest and any other borrowing fees. Financing costs are often designed to be paid over many years, but can be recalculated to be presented as a one-off upfront cost.
- *Training costs* are expected to cover the training of people who will run the platforms with regard to the safety, financial and environmental implications of the project.
- *Decommissioning costs* – some sea-space use options involve significant assets being installed in ocean areas (e.g. oil platforms). When these come to the end of their functioning life or if there license to operate ends, they will need to be safely de-constructed and removed to enable future other uses of the space, including the restoration of the environmental baseline. It is important to consider these costs when developing a project. We propose using a project lifetime of twenty five years to calculate decommissioning costs.

Ongoing costs

Regardless of the marine space option selected, the developer will face regular ongoing costs. These costs include standard operating costs such ongoing maintenance, staff, and depreciation. These are inherently variable costs, in that many of them will increase or decrease depending on the later success of the option. Accordingly, calculating these costs involves estimation and assumptions. We calculate all ongoing costs assuming a project lifespan of at least twenty-five years, in accordance with the discussion in chapter 2.6 on baselines and options. Ongoing costs include:

- *Maintenance and operation costs* – these are the standard costs of running and operating the option every year. These will differ depending on the option but may include: fuel costs, if applicable, direct costs, staff costs, insurance fees, transport costs, general maintenance and operating costs of equipment, monitoring costs, etc.
- *Regulatory costs* – annual fees for licenses and pollution control measures (note: these only include regulatory costs faced by the developer). In addition and specifically focusing on project developers, regulatory costs include any costs of interacting with regulators and other parties (e.g. co-users of marine space) to negotiate use of marine space and comply with regulations. For example, they would include the costs of required monitoring and data gathering.
- *Depreciation* – this is the annual decrease in value of assets, such as a decrease in the value of equipment due to wear and tear.

Income

From a private developer's perspective, the objective of any multi-use project is to generate an income. Similarly to ongoing costs, income is likely to be variable, depending on the future success of the marine use; accordingly, similar approaches will need to be applied to estimate these. Depending on the type of marine space use, the type of income will differ but key categories include:

- *Payments for goods* – these include any payments received by the developer for outputs produced through their use of marine space, for example, this could include payments for fish, minerals, electricity, or other outputs.
- *Payments for services* – this includes any payments received by the developer for services that they provide through their use of marine space, for example, this could include tickets sold, related consulting or research services, among others.
- *Payment for non-market goods and services* – These include any payments that developers receive for goods and services that are not directly sold in a market. These could include, for example, payments for carbon credits, if the option mitigates greenhouse gas emissions. It could also include other payments for ecosystem services (note: to avoid double counting by the social decision maker, these payments must only be included once – either here or in the social and environmental impacts section.)

4.2. Externalities

In addition to private costs and benefits, different multiuse activities will also generate different environmental and social impacts. While these impacts are external to the project developer's decision (and commonly referred to as "externalities"), the economic assessment must consider these wider costs and benefits, as they affect the overall net benefit of any marine use option for society as a whole. Accordingly, failing to properly consider and account for these broader impacts can result in an option being selected that, while delivering maximum private benefits, would not deliver an optimal social outcome. An example might be gravel extraction, which could feasibly be highly profitable for the project developer but due to potential negative impacts on ecosystems and water quality, worse for society than other options. We consider two types of externalities – environmental, and broader economic externalities. After introducing the theoretical approach here, in the following guidance we identify impact indicators that will assist with the valuation of these external impacts as part of the economic assessment.

Environmental externalities

In UNITED, environmental impacts are identified and quantified using an environmental impact assessment (*see D4.2*). To enable the valuing of these environmental impacts, we propose using the ecosystem services framework, drawing on the CICES[30] ecosystem-services classifications. Ecosystem services are the contributions that ecosystems make to human well-being (Potschin and Haines-Young, 2016; see examples in Figure 4.1). They are comprehensive, in that they capture the effect on human well-being of all changes that occur under the different options to the state of the ecosystem, the functions that occur within ecosystems through their impact on final ecosystem services that humans enjoy. This approach also lends itself to economic evaluation: drawing on existing literature, we can translate how the change in ecosystem services into monetary impacts on human well-being.

Ecosystem services aim to exhaustively capture all value that ecosystems generate for society. These are divided up into three categories: provisioning, regulation and maintenance, and cultural. Drawing on Haines-Young and Potschin (2018), below we define each of these ecosystem services.

Provisioning ecosystem services (biotic and abiotic)

Provisioning ecosystem services include "all nutritional, non-nutritional material and energetic outputs from living systems as well as abiotic outputs (including water)" (Haines-Young and Potschin, 2018). At a general level, this includes:

- *Biomass:* cultivated, wild and reared animals and plants that deliver value to humans, for example by use as energy, nutritional use, or in products.
- *Genetic material*: genetic material from plants, animals, and organisms that are used for maintaining, establishing populations or developing new ones.
- *Abiotic*: non-living provisioning goods, such as water used as an energy or drinking source.

Regulation and maintenance ecosystem services

Regulation and maintenance ecosystem services capture all of "the ways that living organisms mediate or moderate the ambient environment in such a way that affects human health, safety or comfort, together with abiotic equivalents" (Haines-Young and Potschin, 2018). This includes:

- *Transformation of biochemical or physical inputs to ecosystems*: this includes the processing of wastes, toxic substances, and other nuisances such as smells.
- *Regulation of physical, chemical, biological conditions*: including the various ways in which ecosystems mediate the physico-chemical and biological environment of people in a beneficial way. This include climate change mitigation and adaptation.

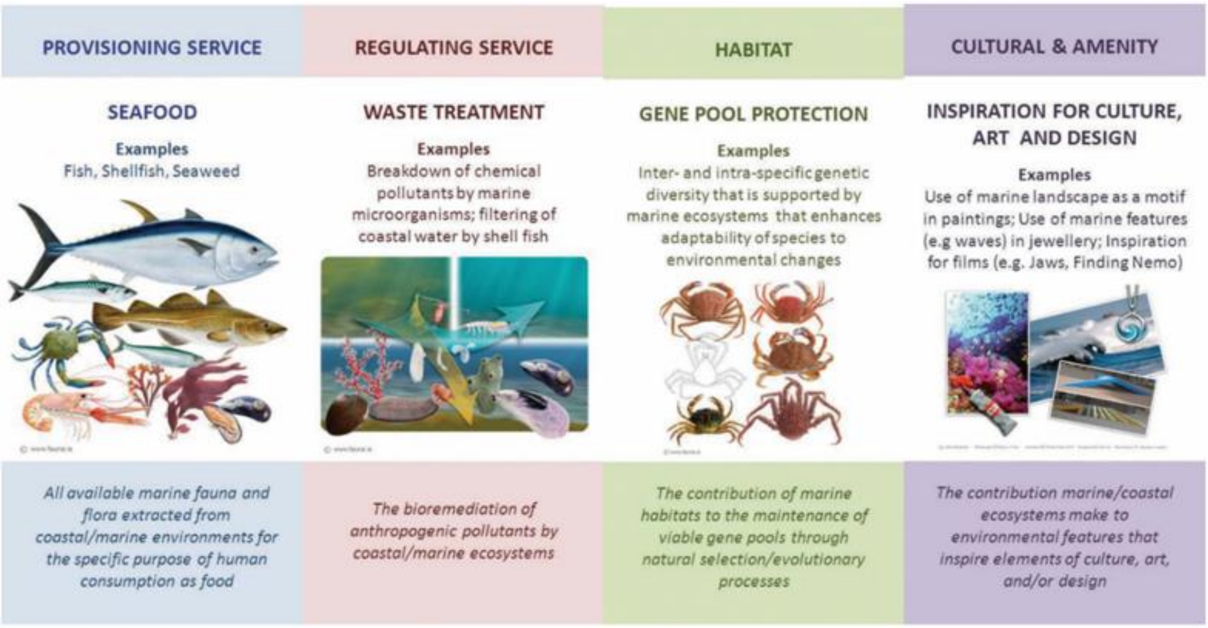
Cultural ecosystem services

[30] CICES = Common International Classification of Ecosystem Services; see also Haines-Young and Potschin (2018)

"All the non-material, and normally non-rival and non-consumptive, outputs of ecosystems (biotic and abiotic) that affect physical and mental states of people. Cultural services are primarily regarded as the environmental settings, locations or situations that give rise to changes in the physical or mental states of people, where the character of those settings is fundamentally dependent on living processes; they can involve individual species, habitats and whole ecosystems. The settings can be semi-natural as well as natural settings (i.e. can include cultural landscapes)" (Haines-Young and Potschin, 2018).

- *Physical and experiential interactions with natural environment*: this includes the value generated by natural systems in the form of enabling recreational activities, including tourism.
- *Intellectual and representative interactions with natural environment*: the value created by living systems through their enabling of valuable academic or artistic work, such as research or artworks.
- *Spiritual, symbolic and other interactions with natural environment*: the symbolic and spiritual values of living ecosystems.

Figure 4.1: Illustrative examples of marine ecosystem services



Source: Robinson et al., 2014

Broader economic externalities

Other secondary impacts should be taken into consideration when weighing up different options for the multiple use of marine space. The selection of marine use space options, in addition to direct financial and environmental impacts, will generate additional external costs and benefits for society. The value of these impacts will differ depending on local context and priorities of decision makers and the stakeholders they consider. Accordingly, these broader economic externalities should be identified in collaboration with stakeholders.

These may include issues such as the following:

- *Employment* – options that create jobs in regions with relatively high unemployment will be preferable to those that do not.
- *Education* – education is a public good and investment in the future, and options that involve training staff or educating the public will be preferable.
- *Energy* – Countries rely on reliable energy supply and may place value on options that secure this, and therefore may prioritise options that generate energy.

- *Food security* - Countries rely on reliable food supply and may place value on options that secure this, and therefore may prioritise options that increase food security.
- *Rural services* – Countries rely on a cohesive network of services across their whole territory. The provision of rural services (schools, doctors, etc.) is ensured by healthy and well-functioning rural communities. Accordingly, social decision maker may value options that support economic activities and services in rural communities that sustain their cohesion.
- *Community involvement* – local management and ownership could be preferable.
- *Health and safety* – social-decision makers need to consider health and safety of employees and staff and potential impacts on the community.

4.3. Resource costs

The economic evaluation must also take into account two additional external costs of using the resource: opportunity costs and transaction costs.

- *Opportunity cost* is a central concept to economics. It refers to the benefits of the next best marine space use foregone due to the selection of an option. The intuition is that there is a cost to the selection of one option instead of an alternative, as the selection of one option means that the alternative cannot be realised (and neither can its benefits). The opportunity cost is usually measured in terms of the net benefit of the next best option.
- *Transaction costs* is a catch all term that covers all expenses (financial, time, or other) borne by participants or administrators/regulators that arise when carrying out a transaction, apart from the expense of the transaction itself. For the project developer, these costs are captured in the cost category *regulatory costs* (which would include the cost of learning how to deal with a complex regulatory regime, negotiate with regulators, etc.). On the regulator's side, these costs include all of the costs of setting up, implementing, and monitoring and evaluating regulations/use of marine space. These will be higher for complex regulatory regimes.

4.4. Valuing economic costs and benefits

The concepts of 'value' and 'valuation' have many meanings and a long history in several disciplines (Farber et al., 2002). Ecological valuation is generally based on bio-physical accounting most often with total neglect of human needs and/or wants. Contrarily, economic valuation is based upon consumer preferences and therefore takes human needs into account (Spangenberg and Settele, 2010). In this context, the value which users derive from an ecosystem service is depicted in the total economic value. The total economic value placed on environmental assets can be disaggregated into economic use values (e.g. direct use values and indirect use values), as well as non-use values, which can be linked to respective ecosystem services (ESS) use indicators.

Economic use values arise from the actual and/or planned use of the service by an individual. Use values can be direct use values, such as when an individual makes actual use of the environmental asset improved, e.g. provisioning services; or indirect use values, such as the benefits derived from ecosystem functions gained that do not translate into a direct use of the resource; such as: ESS derived from regulation functions, like flood control and storm protection.

Non-use values arise independently of any actual or prospective use by the individual. These are usually categorized as Existence Values, which arise from knowledge that the service exists and will continue to exist; and Bequest or Option Values, which measure individuals' preferences to ensure that the service will be available for their own use in the future and that future generations will also have access to the service.

The total economic value of changes in ESS is measured from the preferences of the ultimate beneficiaries for those changes or by measuring the different levels of utility that individuals may place on these changes. The value for the entire population affected is established by the sum of each person's value for changes in ESS or in other words, the area under the demand curve of the environmental good that is improved. After the identification of Direct Use Value indicators of final ESS and their beneficiaries, values can be estimated by using a variety of existing economic valuation methods. This can be through market-based valuation methods or non-market valuation methods by analyzing revealed and/or stated preferences of users that would give an indication of their value. Regarding the classification of valuation methods, these can be broadly divided into two groups:

1. Market-based environmental valuation methods:

> These methods use information from conventional markets, are based on physical linkages, and derive value indirectly using various statistical sources and dose-response functions. The most popular method is the Replacement Cost method, which focuses on costs spent in order to abate, restore or replace a previously damaged marketed or non-marketed good due to degradation of a certain environmental quality.

2. Non-market valuation methods:

> The vast majority of ESS have no market price, as neither directly nor indirectly real or hypothetical market prices can be determined. In this case, Non-Market Valuation Methods can be used to derive price and value calculations using collected data from which one may infer social preferences (Carson and Louviere, 2011). These methods can be divided into two very well differentiated groups: those based on revealed preferences and those based on stated preferences. Methods based on revealed preferences, which obtain ESS values through an analysis of the behaviour of beneficiaries, can only estimate use values from Willingness To Pay (WTP) (i.e. travel cost method (TCM), Hedonic Pricing applied to the property market (HPPM), and Averting Behaviour (AB)). Stated Preference technique methods, which involve asking ESS beneficiaries directly about their choices when confronted with an hypothetical situation that involves trade-offs between their money and changes in the environment, can be used to estimate use and non-use type of values, but very often benefits estimates coming from these valuation methods cannot be disaggregated according to use and non-use type of values. This is because very often any single beneficiary has, at the same time, use and non-use values on the environment.

Finally and due to time and financial constraints, it is important to note the benefits transfer method. Benefits transfer is not an economic valuation method per se, but rather a tool that transfers the valuation results from original valuation studies to predict welfare estimates for other sites of policy significance for which primary valuation estimates are difficult to attain or are unavailable (Johnston and Rosenberger, 2010). The benefits transfer method ranges in form from unit-value or point-estimate transfers, function transfers and meta-analytical approaches that synthesise results of numerous studies deemed somewhat related to the study in question (Iovanna and Griffiths, 2006). Put simply, this approach uses results from similar studies as the basis for calculating value in another, similar situation (e.g. uses the result found in another study regarding the economic value of improving an ecosystem service such as habitat provision as the basis for valuing this in the present economic evaluation).

4.5. Final ecosystem services and the identification of beneficiaries

An economic assessment of the environmental impacts from marine multiuse requires assessing the drivers and pressures in relation to affected ecosystem components, ecosystem functions (EF) and ecosystem services (ESS) in the UNITED pilots. Modelling these changes help advice decision-making about appropriate responses of those components to changes. In UNITED, this information will be provided by WP4.

Different tools are available to support the evaluation of trade-off options regarding the provisioning of ecosystem services. These can be supported by linkage frameworks (e.g., see Robinson and Culhane 2020), by causality links relations (e.g., AquaLinksTool, Nogueira 2018), by spatially-explicit GIS-based modelling tools (e.g., Willaert et al., 2019) or by a combination of the above mentioned decision support tools (e.g., see Lillebø et al., 2020). WP4 in UNITED is proposing to use an integrated Cumulative Effect Assessments (iCEAs) in the pilots. iCEA is defined as a systematic procedure for identifying and evaluating the significance of effects from multiple sources/activities and for providing an estimate on the overall expected impact to inform management measures. The analysis of the causes (source of pressures and effects), pathways and consequences of these effects on receptors is an essential and integral part of the process (Piet et al., 2017). The approach that WP4 will use is an integrated Risk Based Impact assessment (iRBIA), which follows the AQUACROSS linkage framework (Nogueira 2018, Robinson and Culhane 2020).

When assessing the impacts of marine uses and in order to account for how changes in the marine ecosystem may affect our wellbeing, there is a need to identify all impacted beneficiaries that demand these ecosystem services in order to assess how changes in resulting benefits are perceived by them. The identification of beneficiaries helps with the identification of final ecosystem services and therefore, it helps to establish how best we might measure specific contributions to different parts of society (Culhane et al., 2020). This may not always be through measuring an economic value, and different, complementary approaches (including qualitative assessments) may need to be used side by side to fully capture how nature contributes to human wellbeing.

Beneficiaries are "the economic and social entities (enterprises, households, governments) that receive the contributions from ecosystems" (United Nations, 2014). The concept of Final Ecosystem Services is important for impact assessments (see DeWitt et al., 2020). These services are a subset of ecosystem services, generally not including the supporting services that can be directly linked to a beneficiary. When using available ESS classification schemes (MEA[31], CICES, etc.) that do not specify "final" ecosystem services in their established typologies, final ecosystem services may be mixed together with intermediate services. This often results in double-counting the impact of changes in some ESS, as an "intermediate ecosystem service" may be a component of an-other ecosystem final service (Landers and Nahlik, 2013), therefore the analyst may account the intermediate and the related final service separately.

This is why it is important to identify final services associated with direct beneficiaries. Landers and Nahlik (2013) advocate that this system considerably reduces the risk of double counting different components of ecosystem services. This is especially relevant for the economic valuation of changes in final ecosystem services.

Boyd and Banzhaf (2007) define Final Ecosystems Goods and Services (FEGS) as the "components of nature, directly enjoyed, consumed, or used to yield human well-being". According to Landers and Nahlik (2013), the benefits of using such definition for FEGS are:

- Helps place boundaries on ecosystem services.
- Centers on ecosystems and guides measurements of biophysical features.
- Counts only direct interactions between a use (or beneficiary) and the ecosystem, which is critical to avoiding double-counting of ecosystem services.
- Clearly relates to human well-being.

In short, the identification of direct beneficiaries allows separating the infinite list of ecosystem services relevant for any ESS assessment into intermediate ecosystem services and final services, which are the ultimate focus of the economic impact analysis in UNITED. The table 4.1 below illustrates examples of beneficiaries of final marine ecosystem services that may be impacted as a result of marine multiuse.

Table 4.1 Examples of beneficiaries of final marine ecosystem services

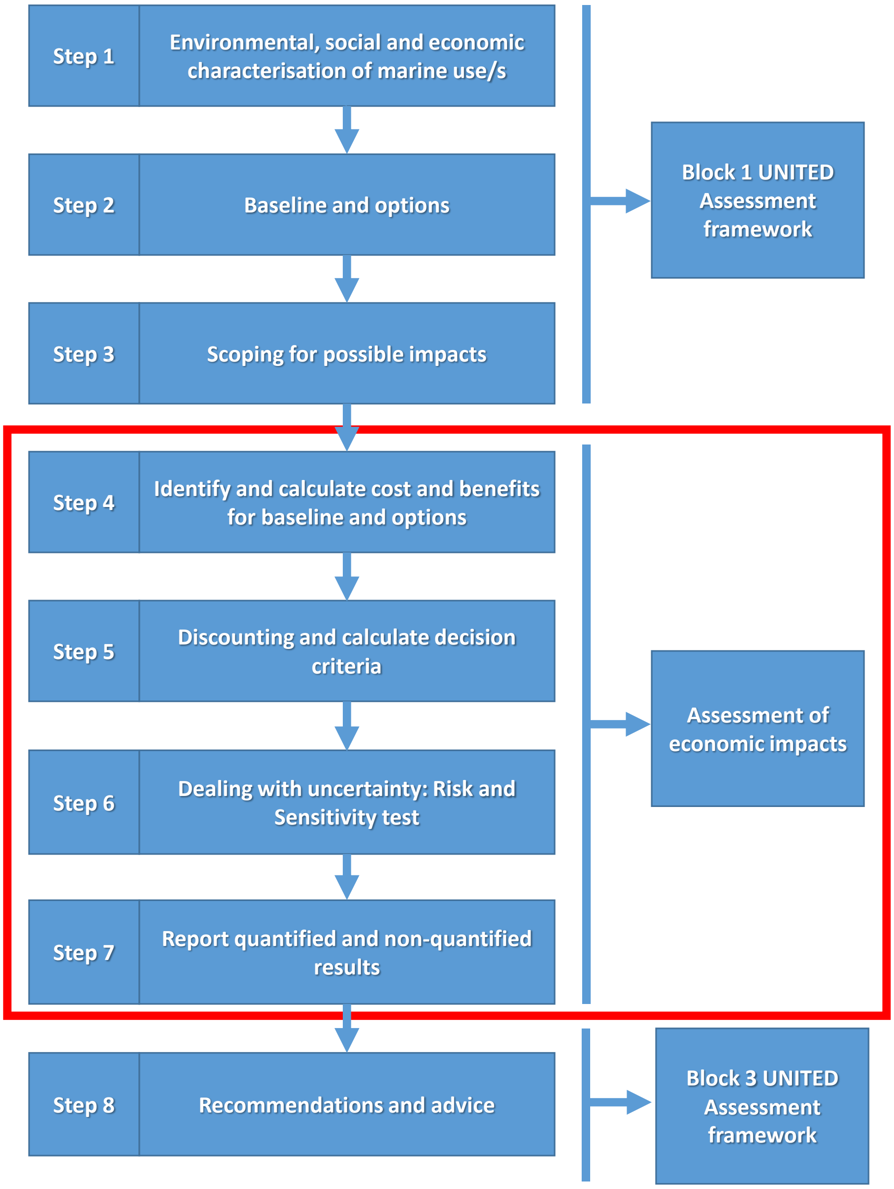
Final ecosystem service	**Activity**	**Beneficiary**
Commercially important seafood species	Aquaculture	Commercial aquaculture producers
High value commercial fish species	Fishing	Fisheries
Water clarity – purification of coastal water	Tourism	Tourists, swimmers, divers
National natural & cultural heritage	Option values	Non-use

[31] MEA = Millennium Ecosystem Assessment

5. PRELIMINARY GUIDANCE TO UNDERTAKE THE ECONOMIC ANALYSIS OF MULTIUSE IN THE UNITED PILOTS

The economic evaluation of the proposed marine multiuses in the UNITED pilots is undertaken in co-ordination with the overall project environmental impact assessment (EIA) concept that has been developed as part of WP8. The sequence and list of steps that are necessary to conduct an economic assessment in the UNITED pilots are illustrated in the figure below.

Figure 5.1: Steps for a Cost Benefit Analysis



This chapter introduces and explains the relevant steps for the application of a cost benefit analysis. All the steps are briefly introduced below, but will be further expanded in the detailed guidance for application in the case studies that will be developed as part of task 3.3.

Step 1: Environmental, social and economic characterisation of marine use/s.

For the scope of this guidance, step 1 relates with the economic characterisation under a multiuse set-up, which along with the environmental and social characterisation will bring useful information to establish the baseline situation in the project pilots.

This first step of the economic assessment framework for the application of cost-benefits analysis is related to understanding the full system under investigation in the UNITED pilots. This requires conducting a preliminary analysis on the drivers-pressures-state-impact chain in the pilot areas. From understanding current key drivers of change (e.g. demand for renewables, food security, etc.) and economic activities taking place in the study sites (e.g. off-shore wind, aquaculture, etc.) to accounting for their subsequent pressures and links to environmental state of the case study sites. This information is necessary to filter significant impacts (step 3 of the CBA figure) and define baseline conditions and relevant options (Step 2) to be investigated in the impact assessment.

Under a marine multiuse setting, the sociocultural, economic and environmental characterisation of the case studies areas is an interdisciplinary joint effort that requires different types of inputs from different pillars of the project in diverse formats and geographic scales. The case study area characterisation (or profiling, as termed by Koundouri et al., 2017) may involve reviewing and collecting qualitative and quantitative information on:

1. Existing legal frameworks (e.g. existing allocation of property rights or environmental standards) at EU, national and case study level→ legal and policy characterisation that will be explored as part of WP6.

2. Current environmental conditions and ecosystem services in the case study site → environmental characterisation performed in WP4.

3. A preliminary understanding of potential impacts from economic sectors involved in multiuse → Socio-economic characterisation, which is the focus of the current economic assessment.

4. Identification of key actors → stakeholder mapping, which will be undertaken in WP5.

Much of the information will be collected under other pillars of the project, but for the purposes of the economic impact analysis, which ultimately is focused on understanding who the winners and losers from advocating multiuse practice are, the following information is useful to characterise "the economics" of the UNITED pilots (Koundouri et al., 2017):

- Defining the area of marine space area that will be considered for the economic assessment (single uses or multi-use development).
- Identifying the adjacent land area (surrounding the development site) which is or would be beneficiary of considered economic activities in the given marine space.
- Developing the social storyline: population, population density and gender balance, household statistics (size, income, education levels), employment.
- Developing the economic storyline: Outlook of economic activities (types and GVA at different scales) and employment.

Step 2: Baseline and Alternatives

Along with other WPs of UNITED this step will reflect on the design of relevant baselines and the defined feasible alternative options to be investigated in the pilots. The selection of relevant timeframes for analysis is a key concept to be discussed in the design of baselines and option.

An overview of possible baselines and options to be considered in the different pilots is presented for illustrative purposes in Table 5.1. These include the single uses directly proposed by the pilots (options S1 – S3 in Table 5.1), their proposed multiuse combination (option M1 in Table 5.1), and other potential combinations (options M2 – M3 in Table 5.1). Moreover, other options could be considered for the different pilots if deemed necessary, provided that the potential uses in question (of the same space) are expected to be feasible or to generate a significant economic and environmental impact in that space and the adjacent land areas. Hence, the exact options that will be part of the assessment will be defined specifically for each pilot, considering for instance their compatibility with other uses (see chapter 2.1.4) in the case of combined uses. Moreover, the selection of the options and the specific uses they will include will be decided in close exchange with involved stakeholders in each pilot.

Table 5.1: Illustrative examples of baselines and options of uses of marine space for the different UNITED pilots

	Single Use options			Multiuse options			Baseline examples		
Pilot	Option S1 (existing single use)	Option S2 (alternative single uses)	Option S3 (alternative single uses)	Option M1 (proposed multiuse)	Option M2 (alternative multiuse)	Option M3 (alternative multiuse)	Baseline 1	Baseline 2	Baseline 3
FINO3 (Germany)	OW	AS	AM	OW + AS + AM	OW + AS	OW + AM	CF	SH	MPA
Belwind (Belgium)	OW	AM	AOR	OW + AM + AOR	OW + AM	OW + AOR	CF	SH	MPA
Northsea Innovation Lab (Netherlands)	OW	OFS	AS	OW + OFS + AS	OW + OFS	OW + AS	CF	SH	MPA
Middelgrunden Wind Farm (Denmark)	OW	TB	TD	OW + TB	OW+TD	OW + Wave energy	CF	SH	MPA
Kastelorizo (Greece)	AF	TD	TB	FA + TD					MPA

Legend: AF = Aquaculture – Fish; **AM** = Aquaculture – Mussels; **AS** = Aquaculture – Seaweed; **AOR** = Aquaculture – flat Oyster (incl. restoration). **OW** = Offshore wind energy; **OFS** = Offshore floating solar energy. **TB** = Maritime tourism – boat tours/visiting attractions. **TD** = Maritime tourism - diving , **CF** = Commercial fisheries, **SH** = Short sea shipping, **MPA** = Marine protected areas – not take/no go zones

Table 5.1 is intended to provide a starting point for identifying and selecting the specific options and baselines for each pilot. For instance, commercial fisheries and short sea shipping, two traditional maritime uses that tend to compete for marine space with other uses such as the ones that are planned to be combined within the pilots, are considered as potential baselines in most of the pilots. However, this is not necessarily the case for all the pilots, as short sea shipping or commercial (large scale) fisheries (the most common uses for these sectors in the EU as defined in Chapter 2.1.2) are potentially not suitable in all the pilot areas. For instance in the case of Greece, as the site is relatively near shore, both these activities are not expected to be feasible in the particular area, either due to potentially low profitability, very high environmental impacts or regulatory restrictions. Other traditional activities such as low-scale gillnet fisheries have not been considered so-far in this exemplary case, as they have a very low economic impact and are therefore unlikely substitutes for other already existing uses or multi-use.

A further baseline alternative that could be considered is the single use of strict marine protected areas under a no-take/no-go regime (Baseline 3 in Table 5.1). While this theoretical option is not considered as practically likely in any of the pilots, it could serve as a reference condition to all other economic activities in the area.

It is worth highlighting that all the considered options will be emphatically focused on the specific area where the pilot is located. The reason for this is that the economic assessment framework aims at maximizing the added value of the use of a specific maritime space. Thus, the considerations for the selection of options and baselines will be further refined when applying the assessment framework in Task 3.3. Furthermore, we will not consider substitution effects in this assessment, namely the economic added value or ecosystem services that would (not) be generated by carrying out the considered maritime uses somewhere else. While accounting substitution effects is indeed relevant for maximizing the added value of the overall use of the entire maritime space, this option falls out of the scope of this assessment. Moreover, doing so would offer a serious methodological barrier, as it would turn the maritime space from a constant (under the approach that we propose) to a variable that would be very difficult to describe, let alone to measure quantitatively.

Step 3 Scoping for possible impacts

Here, information from step 1 will be used by WP4 to identify significant environmental impacts for further consideration.

The first step for each pillar in UNITED starts with the characterisation of the pilot area and a description of the baseline situation and of the different options; be it from a technical, economical, environmental or social perspective. Based on these descriptions, a scope for possible impacts is conducted, followed by the identification of key impacts with help from local stakeholders and experts. These are those possible impacts that are considered priority elements for further processing during the Prediction Stages.

In the scoping and identification of stages, each pillar of UNITED (WPs 3 to 6) identifies the possible impacts. In WP4 as an example, a key possible impact is the disturbance of common scoter by vessel movement, which will in some options for single uses and multiuse options be higher than in others. From a societal view, increased vessel movement might cause visual and noise pollution for the public, while in financial terms, vessel movement comes with high costs.

For the development of the final guidance to be applied in the UNITED pilots, coordination with WP4 and the framework for the assessment of environmental impacts is needed here.

Step 4: Identify and calculate cost and benefits for baseline and options

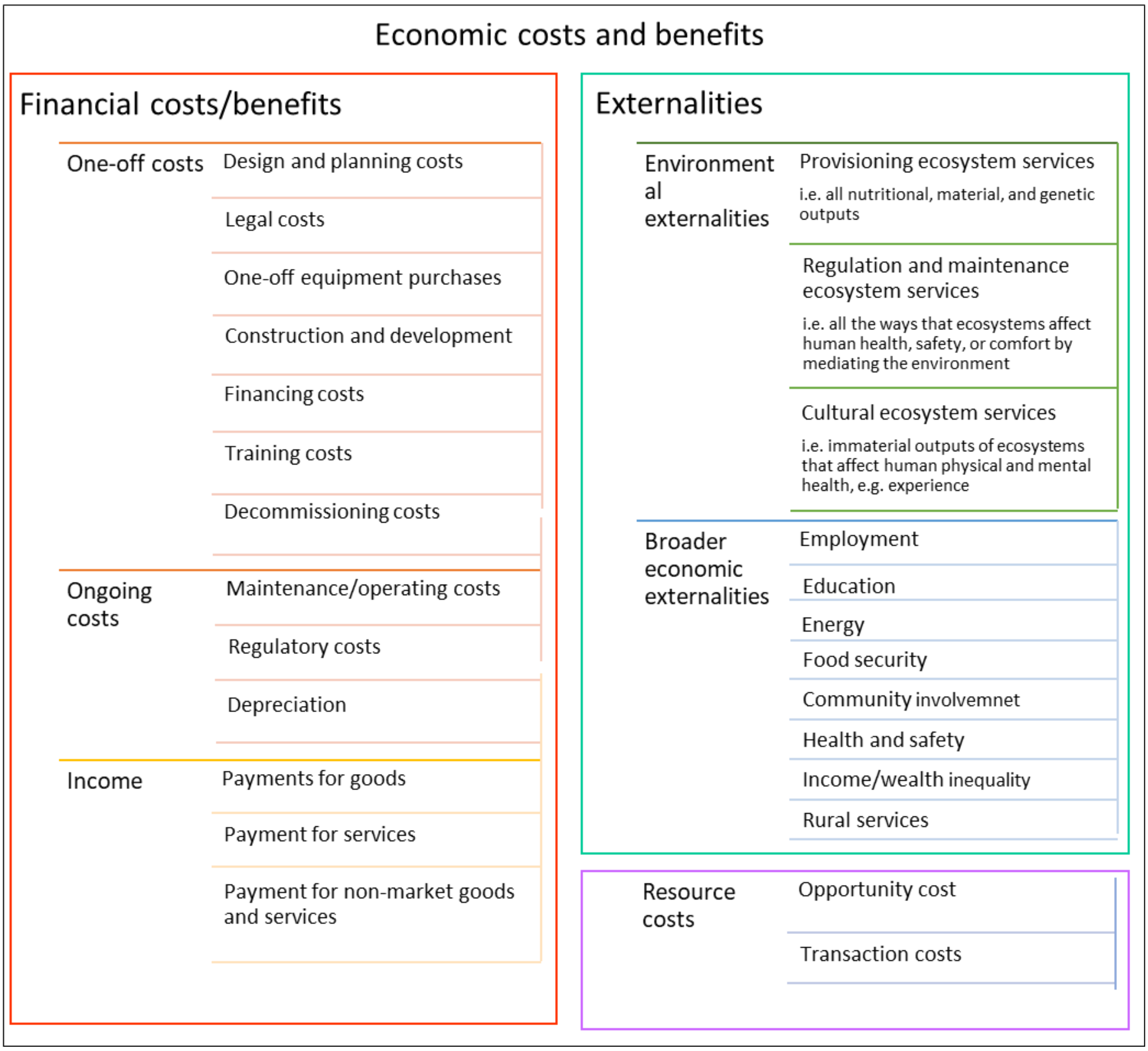
Collecting relevant quantitative and qualitative cost and benefit information of the baseline multiuse scenario and alternative options under consideration is a necessary step for the evaluation of economic impacts. Ultimately, this information will feed into decision making tools (e.g. cost benefits analysis) to be in a position to make recommendations about the added-value of multiuse (**Step 8**). Following chapter 4 of the economic assessment framework, the cost categorisation is summarised in figure 5.2.

The UNITED economic assessment framework proposes using a partial cost-benefit analysis as the key decision support tool to enable decision makers to weigh up the costs and benefits of different marine use options. As previously introduced, cost benefit analysis is primarily concerned with economic efficiency, i.e. what use of marine space delivers the biggest net benefit to society (i.e. which use has the highest benefits – costs?) (OECD, 2006)[32]. Multi-use platforms in marine space generate diverse costs and benefits. We have dealt with financial costs and benefits (e.g. profits, expenses, etc.) and environmental costs and benefits in different sections. Different uses of marine space also have broader impacts, for example affecting local employment, energy security, equity, or other goals. These impacts also generate costs and benefits for society. Accordingly, decision makers also need to be able to understand what the broader impact of different marine use options will be. To ensure that these externalities are considered in decision making, in this section, we propose a set of indicators relevant for the sorts of multi-use marine space options considered in the UNITED project.

The final set of indicators that should be considered in each case will depend on the local context. The indicators must be wide-ranging enough to provide information on all external costs and benefits that are generated by different multi-use projects. To ensure that all externalities are considered, decision-makers should involve stakeholders. The list of proposed indicators below can act as a starting point: in collaboration with stakeholders, it should be adapted, with indicators considered unimportant excluded and additional indicators added if stakeholders identify other important externalities that have not been considered.

Figure 5.2 Illustration of economic costs and benefits categories, including financial costs and benefits and externalities

[32] OECD (2006) Environmental CBA



The indicator selection should also reflect data availability, i.e. if data is lacking on the indicators proposed below but more information is available on related issues, this could be substituted for the indicators proposed below.

Where only limited quantitative data is available, decision makers can supplement quantitative indicators with qualitative information from interviews or workshops. Ideally, CBA analysis aims to convert all differences in impacts arising from different marine use options into a comparable unit: money. We propose to (also) report a separate set of indicators for those difficult to quantify in monetary terms (e.g. broader economic externalities) for two reasons:

- Monetisation is challenging for non-market goods, such as those environmental and broader economic externalities covered in this section. Quantitative or qualitative indicators are easier to collect and require fewer assumptions to be made.
- Clearer illustration of differences: Different stakeholders have different priorities. Monetisation and CBA can have a flattening effect, making it more difficult to understand how different options affect different objectives (other than efficiency). By collecting data on a set of indicators covering the expected broader economic externalities, decision makers and stakeholders can more clearly identify the relative impacts on different issues.

Lastly and an important element to consider is the issue of double counting. There is a chance in assessing multiple impacts for double counting, as these indicators are also related to the outcomes in the other sections of the economic assessment (for example, the financial cost/benefit analysis affects the number of jobs).

Valuing environmental impacts

The WP4 framework accounts for the pressures that are being introduced by human activities and that can impact ecosystem state. Changes in ecosystem state can then affect the supply of services through altered ecosystem functioning. The WP4 framework's integrative approach is important when it comes to considering these interactions because different activities can introduce the same pressures, and multiple ecosystem services can be supplied by the same parts of the ecosystem.

In order to consider environmental impacts in the economic valuation framework, here we propose impact indicators that will enable us to translate the different ecosystem services that arise under the different marine space options into impact indicators that can be easily translated into monetary values. The different ecosystem service outcomes will come from the environmental impact assessment (i.e. in UNITED from WP4). Here, we identify the most relevant ecosystem service indicators for use in evaluating single and multi-uses of marine space, and identify impact indicators. Maes et al. (2016) provides a starting point through an extensive list of indicators of ecosystem services (based on CICES) for the marine realm. The example indicators included below (see Table 5.2) were derived partially from this publication, based on the uses applied in the pilot case studies of UNITED. Maes et al., (2016) does, however, not include indicators for energy activities in the marine realm, so these were added.

Table 5.2 Examples of ecosystem services impact indicators

Activity	Pressure on the environment	Final ecosystem services	Beneficiary	Impact indicator
Aquaculture: Fish, mussels, seaweed, flat oyster	Species extraction	Commercially important seafood species	Aquaculture industry	• Revenue / € • Number of farms • Demand value, consumption per capita
Offshore energy: wind, floating solar	Morphological changes Noise pollution	Long-term reliable energy provision	Energy industry	• Energy harvested / € • Consumption per capita • Number of installations
Maritime tourism: boat tours/visiting attractions, diving	Pollution Morphological changes	Water clarity Presence of culturally valuable biodiversity	Tourism industry Tourists	• Number of boat tours • Number of visitors
Commercial fisheries	Species extraction Pollution	Commercially important seafood species	Fishing industry	• Landings / € • Landings / ton • Number of by-catches • MSC certification yes/no
Short sea shipping	Morphological changes Pollution	Transport of economic goods Import / export	Shipping industry Harbours	• Revenue of import / export in € via route

	Invasive alien species			
Marine protected areas – no take/no go zones	None	Regulating services e.g. protection from storms and erosion Inherent value of the ecosystem	Society (long-term)	• Extent of marine protected areas (km2/ha) • Presence of endangered species (no.)

Measuring broader economic impacts

Different marine use options will also have additional external effects that will generate costs and benefits for society. These secondary impacts are also externalities, i.e. they are not considered by the project developer but should be considered by the social decision maker. The broader economic externalities of different marine uses can be difficult to tease out from the environmental externalities and financial impacts, which were previously covered, and difficult to value. This arises as the broader economic externalities arise as a result of the environmental/financial impacts. However, these broader economic externalities are additional costs and benefits, beyond the direct impacts captured in other parts of the economic framework. Care must be taken to ensure that the broader economic externalities captured here are not simply a double-counting of previously measured impacts but instead focus on this additional element. Given that this section focuses on externalities (i.e. non-market impacts), there is no direct market value for these impacts. Accordingly, these impacts (and their indicators) will need to be valued using revealed or stated preference methods or benefits transfer, or considered qualitatively (these methods are described in section 4.4).

The table 5.3 illustrates a set of preliminary impact indicators for the previously identified broader economic externality. The impact indicators provide a way for these broader economic impacts to be valued and thus considered in the economic evaluation. Indicators come from Hattam et al. (2015), Maes et al. (2015), AQUACROSS (Nogueira, 2018), and MERMAID (Koundouri et al., 2017), OECD (2018).

Table 5.3 Examples of broader economic impact indicators

Broader economic externality	**Description**	**Proposed impact indicators**
Employment	Different marine uses will have different secondary employment outcomes, i.e. they will create different levels of employment in the local region that is affected by the marine use. These additional jobs in secondary markets generate (local) societal benefits but are external to the project developers decision.	- number of secondary jobs created - value of expected salary payments in secondary jobs
Rural services	Different marine uses will support the survival of rural communities to differing degrees, for example, by generating developing local, multi-use infrastructure (such as port facilities, petrol stations, post offices. This can generate external benefits for society in addition to the direct (or employment) effects.	- change in number of rural service facilities (e.g. grocery stores, post offices, petrol stations etc.) - average distance to rural service facility for citizens
Equity	Different marine uses will affect different groups within society differently. If we accept that high inequality has social costs, then any marine use that improves outcomes for disadvantaged communities would increase social welfare. This can be measured by assessing the impact on different groups of beneficiaries (e.g. low income) (OECD, 2018) i.e. income impacts for lowest versus highest quartile.	- Change income for lowest quartile of income earners in local region

Step 5: Discounting and calculate decision criteria

Discounting makes future costs and benefits to be evaluated at a common base year to arrive at a present value (decision criteria). The base year is usually the year in which the evaluation is undertaken and the analyst or the decision maker is faced with comparable units. This step considers the selection of an appropriate discount rate.

Depending on the criteria to be investigated, we need to allow for degrees of flexibility as to some of the elements to be applied by the different groups for the set-up of the framework. For example, the economics framework considers time-frames (e.g. 30 years) for the investigation of costs and benefits. Timeframes are not all that relevant to assess environmental impacts in EIA - baseline year most likely is not the best option (cf. also the baseline will change through time). So flexibility in the consideration of some of these topics is needed.

A discount rate of 3.5% will be considered to annualized cost and benefits. This rate has been applied by the UK treasury (HM Treasury, 2003).

Step 6: Dealing with uncertainty: Risk and Sensitivity test

Risk assessment in economic evaluations involves identifying risk factors and assessing the likelihood of risk occurrence. In addition, sensitivity analysis are helpful to evaluate the robustness of the evaluation results.

Step 7: Report quantified and non-quantified results

The last step on the application of the economic assessment tools will provide a ranking of all assessed options. The ranking sorts out options according to the chosen decision making selection criteria (e.g. options net present value in a cost benefit context).

6. THE UNITED BUSINESS ANALYSIS FRAMEWORK

6.1. Setting the scene: the need for and objectives of a business analysis framework

The combination of multiple compatible economic activities at one offshore platform[33] could lead to cooperation and the development of synergies between sectors. A key question is whether there is a business case for ocean multi-use such as Multi-Use and/or Co-Location Platforms (MUCL), emphasizing the importance of financial costs and revenues for the feasibility of investment in multi-use by private and public parties. A recent study showed that high costs and financial uncertainty form important economic barriers to the implementation of ocean multi-use which is directly related to the attractiveness and confidence of investors in this type of solutions (van den Burg, 2020). To overcome these barriers the development of new methodologies to evaluate business propositions in combination with economic information disclosure from demonstrator pilots could support the development of viable business models are needed (van den Burg 2020). With the five demonstrator pilots that aim to develop viable business models for ocean multi-use, the UNITED project provides the preconditions to contribute to this solution.

The aim of this section is to provide a Business Analysis Framework to support the development of viable business models for ocean multi-use by providing a methodology that allows the systematic evaluation of multi-use business models, including their financial performance. Business Analysis is a methodology that identifies business needs, defines solutions to potential problems and proposes ways to seize business opportunities that may arise during the execution of a business or a project. The business needs are the things a business must have to achieve their goals and objectives, so that the business can serve effectively, efficiently and is profitable, including capability needs (for example: the effectiveness of the UNITED pilots by delivering all the services, etc.) or improvement needs (for example: conducting risk assessment for the UNITED pilots, etc.). To identify the business needs several questions should be asked: what are the results desired? what are the objectives and goals? etc.

[33] Multi-use platforms could also refer to multi-use solutions or multi-use activities.

Business Analyses are usually applied to businesses or projects considering single-use economic activities; they are rarely applied to projects integrating multiple economic activities at one location, but some recent examples in the context of ocean multi-use exist (van den Burg et al., 2017, Dalton et al., 2019, van den Burg et al., 2020). These studies show that there are basically two key research questions that need to be addressed in order to develop viable ocean multi-use business models:

1. What are potential synergies/conflicts and economic risks from combined use and how do these materialize in additional revenues and costs? Examples of case studies producing data and applying adapted metrics and evaluation methods to assess the economic/financial feasibility of multi-use solutions are currently lacking (Dalton et al., 2019; van den Burgh et al., 2020).
2. What are long-term sustainable financial strategies?
   - What is the potential role of public funding to provide financial incentives and surety for investors (Dalton et al., 2019; van den Burg et al., 2020)?
   - What is the potential for the application of financial instruments for the monetisation of ocean multi-use services to generate revenues (e.g. payments for ecosystem services)?

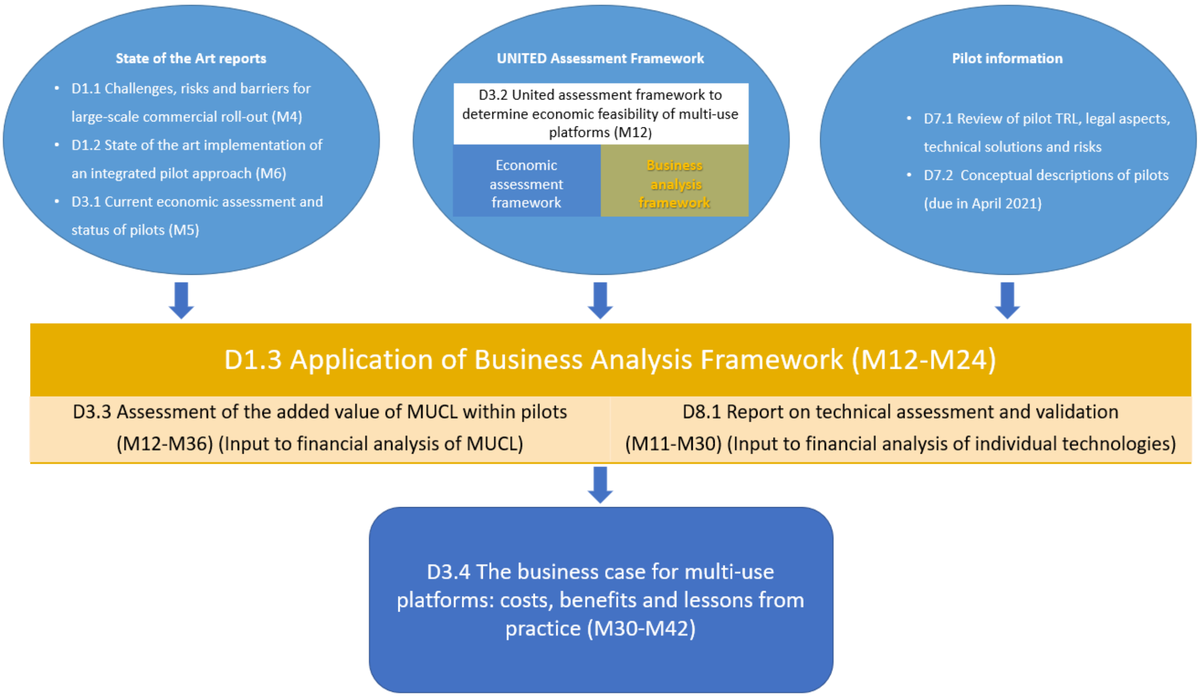
The aim of the UNITED business model analysis is to shed light on these two research questions and thereby contribute to the development of viable multi-use models that foster the large-scale uptake of ocean multi-use solutions. The application of the proposed Business Analysis Framework will allow pilot owners to gain understanding of the economic activities underlying their multi-use pilots and the factors influencing the efficiency of their combination. The framework offers a method to systematically collect and structure economic, financial and business information in a transparent and consistent way so that it directly contributes to the implementation of the pilots. The methodology will allow the pilots to analyse different business requirements, their value propositions, the identification of new opportunities for future development, the identification of TRL development needs, the different funding sources and will propose solutions that drive change in the functioning of the project thereby optimizing the design and operation of the pilot.

6.2. The Business Analysis Framework within UNITED

This section describes the integration of the Business Analysis Framework in the UNITED project, see Figure 6.1. The analyses will not be developed from scratch but will build further on the existing knowledge from other tasks and Work Packages.

1. Three early UNITED tasks aimed to describe the state of the art in pilots, these are D1.1, D1.2 and D3.1. D1.1 reported on the challenges, risks, and barriers for large-scale commercial roll-out of ocean multi-use. Barriers were also discussed by van den Burg et al. (2020) and are related to social acceptance of the project, there exist also economic barriers, technical barriers, etc. For example, the German pilot identified the reduced availability of skilled workers, the limited knowledge about mooring prerequisites for mussel and algae long-lines at site, and long administrative process to get permits from administrations as barriers. The Dutch pilot identified the safe deployment of the different operational activities and the Greek pilot identified barriers related to the 5 pillars of the project (economic, social, technical, legal and environmental). The objective of the Business Analysis Framework is to dig deeper into these barriers by translating them, where possible, into financial risks/consequences and aid the search for and financial evaluation of potential solutions, so that the pilots overcome these obstacles and optimize their financial operation.
2. Existing pilot information reported in D7.1 and D7.2.

Figure 6.3: the Business Analysis Framework within the UNITED project



It is important to note that the successful application of the Business Analysis Framework in task 1.3 is dependent on close collaboration with pilot owners and the disclosure of (financial) information. Furthermore, the analysis should build further on information and data currently developed in other WPs, e.g. information on the legal framework (WP6), the environmental characterisation (WP4), the socio-economic characterisation (WP3) and the stakeholder mapping (WP5). Finally, there will be close cooperation with task 3.3 and 8.2 that focus on specific components of the proposed Business analysis framework (financial analysis). The results of the analysis will eventually feed into task 3.4 that will draw lessons from the application of the Business Analysis Framework in pilots and that will develop generic business models.

6.3. The Business Analysis Framework

A general definition of the Business Analysis is given by the International Institute of Business Analysis[34]: "*The Business Analysis is used to identify and articulate the need for change in how an organization works and to facilitate change*". As for the UNITED project, and more specifically the pilots, the Business Analysis will be used to identify potential economic barriers, risks and opportunities during the development and implementation of the pilot, so that the pilot owners can take actions to improve the design and functioning of the pilots and seize opportunities, thereby enhancing the financial viability of their business model. The Framework presented in this section will make it possible to identify economic opportunities, challenges, and risks in pilots and to help find potential improvements that optimize the design and operation of pilots.

The Business Analysis Framework proposes seven steps to identify economic barriers, risks, and opportunities of the multi-use pilots. The seven proposed steps include:

- **STEP 1**: Describing the multi-use project – What are the combined activities and their current/target TRL levels?
- **STEP 2**: Mapping the pilot context – What are external factors influencing the pilot?
- **STEP 3:** Business canvas model – How does the multi-use create, deliver, and capture value?
- **STEP 4:** SWOT analysis – What are internal factors influencing the pilot?

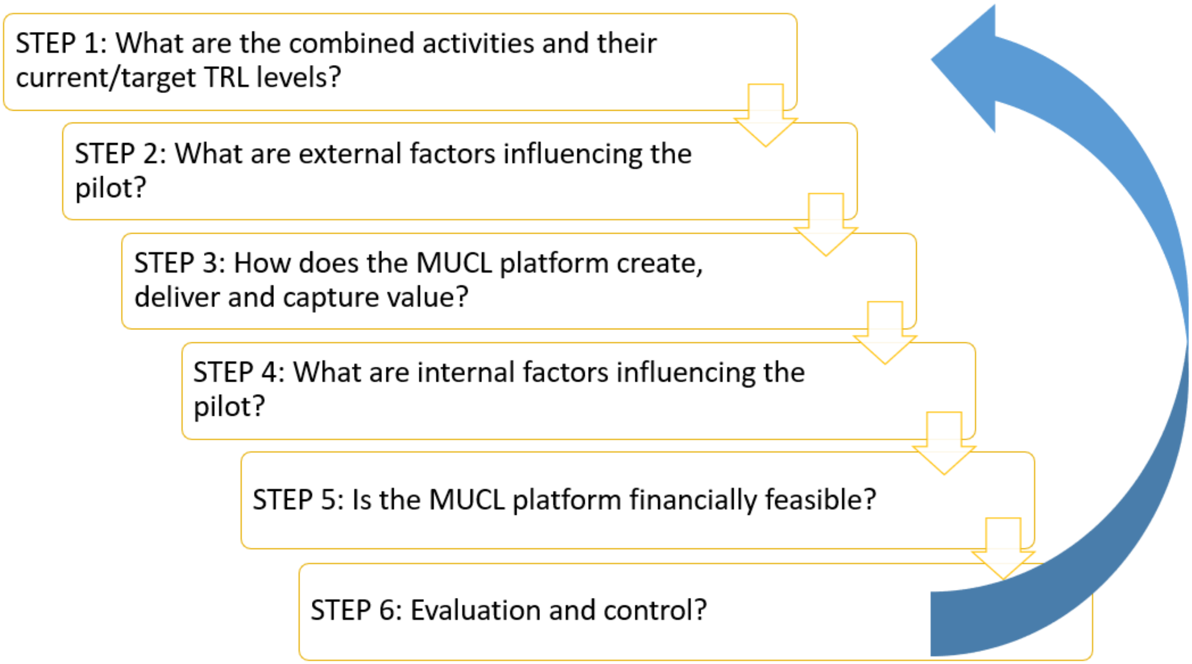
[34] https://www.iiba.org/professional-development/career-centre/what-is-business-analysis/#:~:text=Business%20analysis%20is%20used%20to,an%20organization%20to%20its%20stakeholders.

- **STEP 5:** Financial analysis – Is the project financially feasible?
- **STEP 6:** Evaluation and control.

Each step tries to answer specific questions. For example, for the Step 1: what are the combined activities? This gives the chance for the pilot owners to describe the pilot and the different activities combined and the reasons that led the pilot owner to combine these activities. The reasons could be economical, environmental, societal, political, etc. The following illustration (Figure 6.2) shows the different steps and related research questions.

The Business Analysis Framework will be applied to the combination of economic activities in the UNITED pilots. In the following sections, the Business Analysis Framework will be further developed following the steps presented in Figure 6.2. For each step, a description is given of its objective, how to execute it, and where to find information.

Figure 6.4 Business Analysis Framework: main steps and research questions



STEP 1: Describing the multi-use pilot and their TRL level

As a first step, it is recommended to describe the multi-use pilots. The description should include most up to date information about:

1. Pilot owners. Description of provided technologies, their individual TRL levels, and of provided services.
2. The choice for activity combinations. Ideally the description covers two topics: 1. The compatibility of activities and 2. The expected synergies from activity combination.
    - Compatibility of activities. The description should address the question why pilots chose specific activity combinations over other combinations. As shown in section 2.1.3, not all economic activities can be combined. There exist similarities and differences between the combined activities that make them compatible for combination (or not). For example, some similarities and differences could be related to the legal aspects of combined activities or to the use of an activity that could interfere with the use of the other activity. The information on similarities and differences could be found by doing research on the different combined activities. It also could be found in the technical report of the project where it is explained how the project is constructed and how much it will cost.

- Expected synergies from activity combination. This information will enhance understanding of the relationships between different economic activities operating on the same platform and how one activity influences the operation of the other. Some first information on expected synergies of combined activities has already been presented in Deliverable 3.1. For example, the German pilot combining aquaculture and energy production identified synergies on the level of transportation, planning and maintenance work, social acceptance, environmental surveillance, and monitoring, etc. Many other synergies were identified in other pilots like for example cost reduction for the Dutch pilot, the use of the port facilities for the Belgian pilot, and stimulation of touristic growth, social acceptance of aquaculture activities and cost minimization of activities explained by the benefits from exploiting the same marine space, the co-use of transportation and time management for using the same infrastructure for different activities such as diving and/or aquaculture for the Greek pilot.

3. TRL level of the ocean multi-use.

The TRL (Technology Readiness Level) is a measurement system used to assess the level of maturity of a technology towards full economic operation, particularly with a view to financing research and development or integrating this technology into an operational system (or sub-system). The TRL concept is the most widely used concept to assess the maturity of technologies; it was first introduced by NASA in the 70s to assess the maturity of technologies during complex system development (Olechowski et al., 2015). The concept provides a standardized uniform scale of technological readiness levels that has been used in a wide range of industries and institutes amongst which are space technology, oil and gas industry, US Department of Defence, the US department of Energy and the US Airforce Laboratory.

The TRL-scale is displayed in the table below. Each level has its own characteristic definition. However, various iterations between levels might occur, especially in a development phase. Sometimes it can be hard to determine transitions between certain TRLs. Therefore, several TRL assessment standards and 'calculators' are used to help determine the current level and associated risks.

Table 6.1: TRL definition[35]

TRL LEVEL	DEFINITION
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7	System prototype demonstration in operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in operation environment (competitive manufacturing in the case of key enabling technologies; or in space)

A technology's TRL development and financial performance are closely related; TRLs have implications on the uncertainty of costs. There is little evidence on the financial feasibility of multi-use offshore platforms,

[35] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

let alone relating them to the TRLs, but Dalton et al. (2019) have summarized the economic feasibility of three state-of-the-art multi-use projects relating them to TRL scale:

- One of the multi-use solution case studies was about a combination of seaweed and wave energy converters. They state that TRL7 is associated with the pre-commercial pilot that hosts one single wave energy converter overtopping platform and a small 4 hectares seaweed farm (~80 t/y). The business case was carried out only for the third of three TRL 9 scenarios of a scaled-up commercial farm. The third commercial scenario of TRL 9 consisted of 9 wave energy converters and a 50-fold increase in seaweed space compared to the TRL 7 pilot. This was based on a roadmap to commercialization where 4 scenarios where mapped out of which three are commercialized, associated with TRL 9.
- The second case study combined fish farming and wave energy, where both entry point technologies are considered at TRL 7. This is associated with a pilot combination of one full cage system (1000 t of fish), serviced by a wave system and hybrid plant. This pilot was scaled-up in 3 commercialized scenarios to 96 wave nets and a Hybrid Plant and would service 48 cages. For this example, corresponding TRLs with the 3 commercialized cases are not mentioned.
- The third case study considers the combination of fresh water supply and electricity supply. Both entry point TRL's are at level 6. Like the other case studies, this case study had a strategic roadmap to commercialisation. The first stage comprised an 800 kW demonstration multi-use platform, the second a 2 MW Pilot multi-use platform. Finally, at a commercial level, the 2 MW multi-use platform would be optimised with a maximum output of 3360 m3 per day.

These examples show that the financial feasibility of ocean multi-use platforms are related to TRL levels (through different cost and revenue characteristics per TRL level) and should, therefore, be explicitly considered in financial analyses.

Recent research also shows that a technology's TRL development and business requirements are closely related. For example, recent research shows that the movement from TRL4 upwards is critical from a financial perspective, because moving out from the laboratory into a pilot environment often requires heavy capital investments and little returns; a phase in which public financial support is often required.[36] A critical threshold is also beyond TRL9 in which the technology is proven in an operational pilot environment and is ready for large-scale commercialization. These examples show that on the one hand technologies need to mature, but also the understanding of their economic potential. To assure successful technology diffusion beyond TRL9 various business aspects and market uncertainties should be anticipated, ideally these aspects are described in business plans and financial feasibility assessments that can be more or less extensive based on the technology's TRL.

During the UNITED project, pilot demonstrators will increase the TRL of multi-use projects and further the ease-of-uptake by the market. Table 6.2 shows the current and expected TRL levels of the 5 pilots.

Table 6.2: Current and expected TRLs of the UNITED pilots

PILOT	ECONOMIC ACTIVITIES	CURRENT TRL	EXPECTED TRL
GERMANY	Offshore wind and aquaculture	5	7
NETHERLANDS	Offshore wind, floating solar and Seaweed	5-6	7-8
BELGIUM	Offshore wind, flat oyster restoration and seaweed	5	7
DENMARK	Offshore wind and tourism	6	8
GRECE	Aquaculture and tourism	5	7

The aim of this step is to evaluate TRL development of the UNITED pilots up to the end of the project in order to develop tailor-made business analysis (including financial evaluations) and thereby enhance the chance

[36] Technology Readiness Level - an overview | ScienceDirect Topics

that multi-use solution are commercially ready when reaching the targeted TRL. The description should cover the following three topics:

- Current TRL of the ocean multi-use:
    - Current state of technology
    - Current production and commercialization of services (if relevant)
- Expected TRL of the ocean multi-use:
    - The targeted technological design and operation of ocean multi-use by the end of the UNITED project.
    - Expected production and commercialization of services (types of services, expected volumes) from combined economic activities.

4) Strategic roadmap to reach TRL objectives: technological and business requirements to reach TRL target, including risks and uncertainties (identification of risks and uncertainty also covered by step 4: SWOT analysis). It should be noted that this part of the pilot description can be provided in two steps. A first version of an initial roadmap can be provided at the start of the analysis. Based on the information that will be collected in step 2-5, the strategic roadmap should be updated.

The UNITED Pilots have a baseline /entry point TRL at the start of the project. This baseline TRL was revised again and has not changed for pilots since the start of the project. Pilots assessed their own TRL based on existing templates suggested by the European Commission or templates from other industries. An overview of baseline TRLs and assessment method is present in Table 6.3 below.

Table 6.3: Self-assessment for TRL methods and Context for Pilots

Pilot	Current TRL is about single/multi-use	Baseline / Current TRL	Entry point TRL was assessed by (insert brief reference how it was assessed)
German Pilot	Multi-use	5	Self-assessed according to ENSPIRE and USAFRL calculator (USAFRL 2018); also used as controls: USDOE definition, oriented towards CTE analysis template for the "TRL Assessment Calculator modified for DOE-EM" and New York State Energy Research and Development Authority (NYSERDA 2018) TRL calculator as well as the V-Model and Requirement Specifications model
Belgian Pilot	Single use in the operational phase as commercial wind park (TRL9) Multi-use in pre-operational phase nearshore demonstrated in the intended environment (TRL5-6)	5-6	Self-assessment according to the definitions provided by the EC guidelines on TRL
Danish Pilot	Multi-use	6	Self-assessment according to the definitions provided by the EC guidelines on TRL
Greek Pilot	Multi-use	5	Self-assessment according to European Association of Research and Technology Organisations criteria on TRL Assessment
Dutch Pilot	Multi-use	5-6	Self-assessment according to the definitions provided by the EC guidelines on TRL

Each of the pilots have delivered additionally a description of the methodology applied in assessment of the TRL and which specific factors through the steps they are aiming to reach through their self-assessment. These are listed in detail in Appendix B below.

STEP 2: Mapping the pilot context - PESTEL

The second step aims to describe the pilots’ context, allowing pilot owners to identify external drivers and to anticipate their direct and/or indirect impacts the pilot’s operation. The context of the pilot is the environment in which the pilot operates and differs from pilot to pilot. External factors are events that occur outside of the project and have direct and/or indirect impact on the pilot. To give an example of some external factors it could be the economic performance of the country where an economic crisis may stop the work in the pilot. Another example could be the political factors or the governmental decisions where a sanitary condition could oblige the government to take measures and stop the work in all sectors in the countries (e.g. during the COVID19 pandemic the work has stopped in almost all sectors in EU, hence the delays of the implementation of the project should be taken into consideration).

The PESTEL technique is recommended as a tool to describe the pilot context[37]. This technique comes in accordance with the five different pillars of UNITED: the economical, the environmental, the societal, the legal and the technological pillar. The PESTEL technique comprises 6 factors:

- **P**olitical: these factors determine how the government and political decisions influence the project or other related industries (e.g. government environmental policies).
- **E**conomic: these factors determine how the economic performance of a country/region could have a direct impact on the pilot (e.g. the risk to invest in ocean multi-use).
- **S**ocial: these factors are related to the social environment of the pilot (e.g. the social acceptance of such pilot).
- **T**echnological: these factors are related to the technological advancement of the pilot (e.g. the TRL level of the pilot).
- **E**nvironmental: these factors are related to the different sectors surrounding the pilot (e.g. the NGOs pressure for better environmental policies).
- **L**egal: these factors are related to legal issues like the existing laws and other legal barriers that influence the pilot (e.g. legal standards for permissions and licenses).

If any other factors are encountered in the pilot, they should also be included in the analysis. The following illustration (Figure 6.3) summarises what is discussed above and provides some examples.

Figure 6.5 PESTEL Analysis

P	E	S	T	E	L
- Government policy - Political stability - Corruption - Foreign trade policy - Tax policy - Labour law - Trade restrictions	- Economic growth - Exchange rates - Interest rates - Inflation rates - Disposable income - Unemploy-ment rates	- Population growth rate - Age distribution - Career attitudes - Safety emphasis - Health conscious-ness - Lifestyle attitudes - Cultural barriers	- Technology incentives - Level of innovation - Automation - R&D activity - Technological change - Technological awareness	- Weather - Climate - Environmen-tal policies - Climate change - Pressures from NGO's	- Discrimina-tion laws - Antitrust laws - Employment laws - Consumer protection laws - Copyright and patent laws - Health and safety laws

Source: https://www.business-to-you.com/scanning-the-environment-pestel-analysis

As mentioned earlier, the PESTEL analysis comes in accordance with the five pillars of the UNITED project and information on the external factors can be collected by reviewing the different WPs. For example, for the Political/Legal factors, the pilot owners can review WP6 of the UNITED project on the legal and policy characterisation where the existing legal framework is described at EU and national scales. For the environmental factor, the pilot owners can review WP4 where it is given a detailed description on the current environmental conditions and ecosystem services. For the economic factors, the pilot owners can review WP3 on the socio-economic characterization of the UNITED pilots. And finally, the pilot owners could also find information on the key actors in WP5. Adding to the information found in the UNITED WPs, the information regarding the PESTEL factors could also be found by doing a research on the different factors in the area where the project is located. The information could also be extracted from a previously executed, similar, project. If a similar project is already in place this can help in having a detailed description on the different factors impacting directly or indirectly the project.

STEP 3: Business model canvas

The thirds step aims to describe how the pilot creates, captures, and delivers value, using the business model canvas. The business model canvas was also applied by the MARIBE (2016) project that aimed to unlock the potential of Multi-Use platforms in an offshore economy. The business model canvas is a visual tool that provides a shared language for describing, visualizing, assessing, and innovating business models. It describes the pilot business model through, what is called, 9 building blocks. The 9 building blocks, as described in Dalton et al. (2019) and in MARIBE (2016), comprise:

- Key partnerships: Who are the key partners of the pilot? Who are the key suppliers? etc.
- Key activities: What key activities do the value proposition require? Which services? Which distribution channels? etc.
- Key resources: What key resources do the value proposition require? Revenue streams? etc.
- Value proposition: Who are customers? What value does the project deliver for the consumer? Which consumer needs to the project satisfy? etc.
- Customer Relationships: What type of relationship does each of the pilot customer segments expect to establish and maintain with them?
- Channels: Through which channels are customer segments reached?
- Customer segment: For whom is the pilot creating value? Who are the most important customers?
- Cost structure: What are the most important costs inherent to the busines model?

- Revenue streams: How much are customers willing to pay?

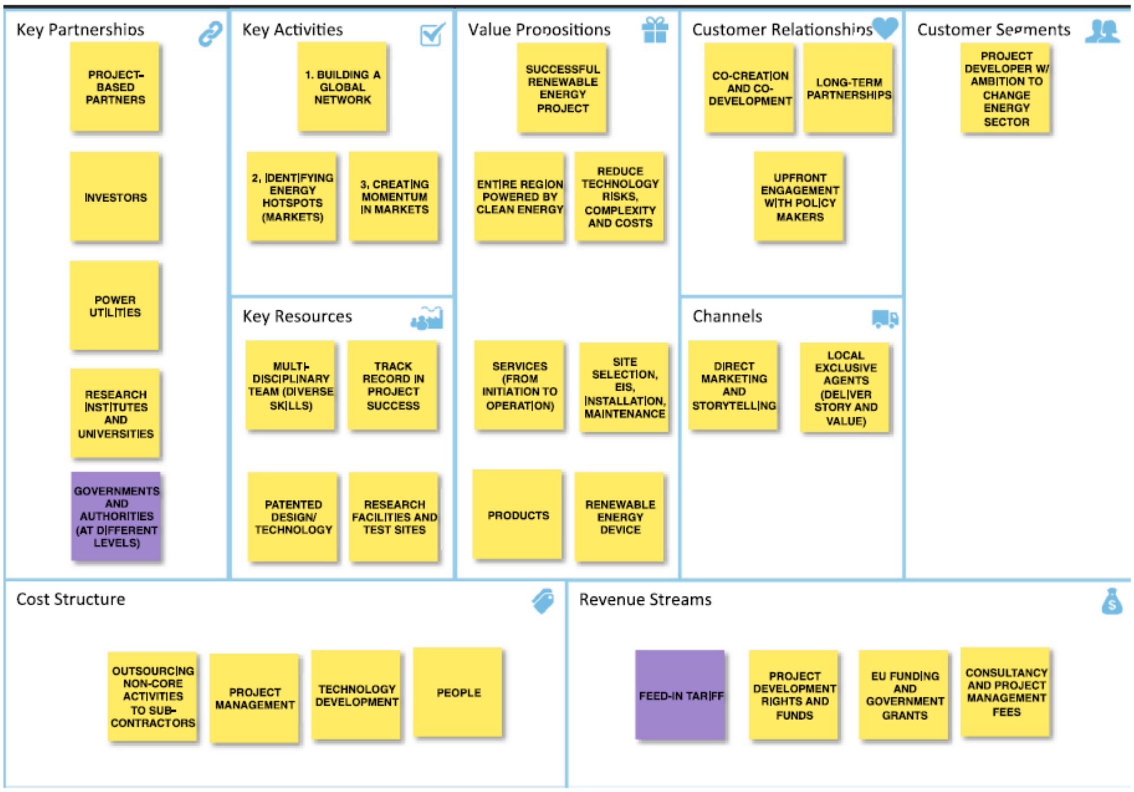
The following illustration (Figure 6.4) gives a more detailed description of the 9 building blocks.

The Business model canvas is, in most cases, applied to analysing a single economic activity (or business proposition) and has never been applied to analyse multi-use activities. In the MARIBE project the tool was mobilized to understand individual businesses underlying multi-use projects separately, but it was not used to assess the value proposition of the combination of economic activities at the pilot level.

Applying the tool to the scale of ocean multi-use (including multiple economic activities) probably complicates the analysis. That is why a two-step approach is recommended:

- First pilot owners apply the business model canvas to the different economic activities. This means that for each activity the pilot owner should identify the different information needed for the different 9 blocks (see Figure 6.4).
- Then pilot owners compare and identify similarities and differences between activities. If differences exist for the 9 blocks of the Business model canvas, this means that the pilot is creating value by targeting for example different customer segments, or by having different key resources.

Figure 6.6 Using the Business model canvas (Dalton et al., 2019)



STEP 4: SWOT analysis

This step aims to identify all internal and external factors influencing a pilot in order to develop a full awareness of all the factors involved in decision-making and to anticipate certain developments by defining strategies to seize opportunities or to overcome weaknesses. For this purpose, a strengths, weaknesses, opportunities, and threats (SWOT) analysis will be applied. This type of analysis was also used by the MARIBE (2016) project on the operational level. The SWOT-analysis consists of the following components:

- **S**trengths: What are the strengths of the pilot? What are the unique resources? How can strengths by fully exploited?
- **W**eakness: What are the main weaknesses (problems, disadvantages, barriers) of the pilot? What are potential improvements?
- **O**pportunities: What opportunities are open for the pilot? What trends could the project take advantage of?
- **T**hreats: What threats could harm the pilot? How can strengths be mobilized to deal with the threats?

Strengths and weaknesses refer to the internal pilot characteristics (e.g. the number of employees or financial resources etc.). For example, the lack of skilled worker in a pilot is considered as a weakness and may lead to not reaching the fixed objective of the pilot (example from the German pilot). The internal factors affect how a pilot operates and hence can impact the way the pilot reaches its objective.

Opportunities and threats refer to external factors that have already been identified during the context analysis (step 2), during the SWOT analysis the external factors will be classified as opportunities or threats. It is recommended to summarize the information for the 4 different characteristics in the following matrix (Figure 6.5):

Figure 6.5 SWOT matrix

It is recommended to give a detailed description about the four factors in the SWOT analysis. The SWOT analysis should start by recalling the objectives fixed for the pilot. Afterwards, the pilot owner should draw the SWOT matrix (Figure 6.5) and identify all the factors that allows him to reach these objectives (Strengths and Opportunities) and the factors that do not allow him to reach these objectives (Weaknesses and Threats). From here the pilot owner will have a detailed description and can draw a strategy or action plan to overcome the weaknesses and threats and reach the fixed objectives.

The information needed for SWOT comes from internal and external sources including financial surveys, market surveys, performance indicators and other projects performance statistics.

STEP 5: Financial analysis and risk analysis

In this section the financial analysis is described. It will allow the pilot owner to study the financial feasibility of their pilot using the financial information provided by the project. It is important to note that in a previous section of this deliverable (section 3.3.1) the costs and benefits of the pilots have been evaluated (one-off costs, ongoing costs, and income). The pilot owner can use the data of this section to do a financial analysis.

A financial analysis is the process of evaluating the pilots' financial transactions to determine their financial performance and suitability[38]. It is usually applied to evaluate economic trends, set financial policies, or to build long-term strategic plans. This is done by evaluating all the revenues and costs of a project for a certain period (preferable for 25 years). This helps in identifying different sources of revenues and potential funding sources for the pilot.

This step of the Business Analysis will help in evaluating the financial performance of the pilot and to determine if it is feasible or not. Typically, this step is used to analyse whether the pilot is stable or not, or profitable enough to warrant a monetary investment. The pilot owners will be able to know if the ocean multi-use pilots is more profitable than a single use activity. As proposed by Dalton et al. (2019), in order to evaluate the financial performance of the pilot, standard financial metrics could be used. The term metrics means measurement. It refers to the financial performance of the pilot. The financial performance is a mathematical measure that evaluate how well a pilot is using its resources to make a profit.

Data collection

Three main financial statements should be provided: 1) the balance sheet, 2) the income statement, and 3) the cash flow statement.

1) Balance sheet

The balance sheet is the pilot report of the financial worth that is broken into three parts: assets, liabilities, and shareholders' equity. The assets of the pilot can tell a lot about the project's operational efficiency. The liabilities include the expenses and the debt that the project is paying off. The shareholders' equity includes the details on equity capital investments and retained earnings from periodic net income. The shareholders' equity is equal to assets minus liabilities. The value obtained is an important performance metric that increases or decreases with the financial activities of the project.

The data that needs to be collected in this sub-section is related to the assets, liabilities, and shareholders' equity. The assets parts concern the accounts of the pilot. The assets may be divided into two sections: short-term assets (e.g. treasury bills, marketable securities, inventory, prepaid expenses, etc.) and long-term assets (e.g. long-term investment, fixed assets, and intangible assets).

The liabilities are the sum of money that the pilot owners owe to other organizations (e.g. a bank credit for example). As for the assets, the liabilities could be divided into current liabilities (payable within one year) and long-term liabilities (payable over a long period).

The information concerning the assets, liabilities and shareholders' equity could be obtained from the treasury of the pilot.

2) Income statement

The income statement could be broken down into the revenues and expenses of the project. This provides us with the net income profit or loss. Like for the balance sheet, the income statement is divided into three parts. The first part is the revenue generated by the pilot and the costs associated to the pilot. The revenue generated by the pilot could be estimated by forecasting the sales of products and services generated by each activity. For example, if the pilot combines energy production with mussel farming, the revenue estimated for the pilot could be the estimated revenue from forecasted electricity production and forecasted mussel production. When it comes to the energy production there is a lot of variables to be taken into consideration. The forecasted energy sales depend on the installed capacity and therefore the expected energy production by the technology (this could be variable because of the uncertainty of renewable energy production due to the state of nature e.g. wind, sun, wave, etc.). It is also related to the renewable energy production schemes for each country (e.g. feed

[38] https://www.investopedia.com/terms/f/financial-analysis.asp#:~:text=Financial%20analysis%20is%20the%20process,to%20warrant%20a%20monetary%20investment.

in tariffs for the renewable energy sale). All the factors related to the energy production should be explicitly mentioned. The revenue of the pilot could also be obtained from the previous section (see Figure 6.4 – Income). On the other hand, the cost of the pilot could also be estimated as the forecasted cost needed to operate the different combined activities. The cost of operation and maintenance are the costs needed to keep going the pilot. It may contain labour cost for example. The maintenance and operation costs should be explicitly mentioned here. This cost could be obtained from the previous section (see Figure 6.4 – ongoing costs). This allows in identifying the profit or loss of the pilot. The second is the operating profit which subtracts indirect expenses such as marketing costs, general costs, and depreciation. The indirect expenses could be estimated by, for example, fixing a depreciation yield and hence a loss in the assets of the operating activities. The third and final is the net profit which deducts interest and taxes.

3) Cash flow statement

The cash flow statement gives an overview of the pilot cash flow from operating activities, investing activities and financing activities. The information needed for the cash flow statement could be obtained from the treasury of the pilot.

Financial metrics

In this section, it is interested to provide a detailed feasibility analysis and to provide some financial indicators as presented in Table 6.3.

Table 6.3 Financial indicators

Financial metric	Definition
Total investment	The total amount of money invested in the pilot with the hope that it will generate income or appreciate in value at some point in the future.
Return on Investment (ROI)	ROI is a performance measure used to evaluate the efficiency of an investment.
Net Present Value (NPV)	NPV is the difference between the present value of cash inflows and present value of cash outflows over a period.
Debt-to-capital ratio	The debt-to-capital ratio is a measurement of a company's financial leverage.
Debt-to-equity ratio	The debt-to-equity ratio is a measure of the degree to which a pilot is financing its operations through debt versus wholly owned funds.

If any other financial metrics are available, they could be provided in this section.

Risk analysis

Risk analysis is the study of the uncertainty of a given course of action and refers to the uncertainty of the forecasted costs, revenues, assets, liabilities, and profitability. This step is important because it will allow the pilot owner to measure the uncertainty of the forecasts that were done in the previous sub-section and hence measure the risk of investment. By measuring the risk, the pilot owner will be aware of the different negative events that could occur and be prepared for taking other courses of actions to limit loss.

The risk analysis starts by identifying what could be wrong. The negative events are then weighted in a probability metric to measure the likelihood of the event occurring. The risk analysis could be qualitative where the pilot owner could use several techniques to measure the risk such as the Monte Carlo Analysis (MCA), and or doing a sensitivity analysis. This will give the pilot owner better information so that it allows him to take better decisions.

The risk analysis could be also qualitative which do not evaluate risk with numerical ratings. It concerns only writing down the uncertainties and analysing the best courses of actions to be taken if a negative event is occurred.

STEP 6: Evaluation and control

This is the final step of the Business Analysis Framework. After acquiring the needed information in the different steps, the final step will help in evaluating commercial readiness of the pilot. In this step, the findings of the business analysis step 1 to step 5 will be reported in one document: the business plan. Besides the results of the analysis, the business plan should include:

- an updated business model canvas. After doing the business analysis, it is required to use the information collected from step 1 to 5 and provide an updated version of the business model canvas. This could help in better identifying the different value creation done by the pilot.
- an updated strategic roadmap for commercialization (see step 1) In this step it is required to give a detailed description and analysis about all the potential challenges encountered with the pilot and propose solutions to change in the way the pilot operates.
- an executive summary of the project should not exceed 1 page. It should contain and highlight the most important information of the project like principal partners, objective of the project, principle results, etc. The executive summary will be used in the future by the pilot evaluators or by future potential investors that the pilot may attract.

7. CONCLUSIONS, LINKS TO OTHER AREAS OF THE PROJECT AND NEXT STEPS

This report presents an economic assessment framework to guide the financial and economic evaluation of the added-value of ocean Multi-Use in the UNITED pilots. The framework considers the distinction between Public (e.g. decision makers, local authorities) and Private Sector decision-making practices (e.g. project developers, lenders and investors). It has been divided into two blocks: 1) The UNITED economic assessment framework and 2) The UNITED business analysis framework.

The economic framework advocates the use of partial cost-benefit analysis to assess the added-economic value from ocean multiuse. Through its application we make proposals as to how to assess the financial costs and revenues of ocean multi-use and their economic efficiency (i.e. ensuring that they deliver social benefits in excess of their costs framed under an ecosystem services concept application). In addition, the business analysis framework proposes a series of exercises that will support the pilots in the development of viable business models, which allows the systematic evaluation of multi-use business models, including their financial performance. These include, an analysis of the internal/external factors influencing the pilot using the PESTEL and the SWOT techniques, identifying the values created, captured and created by the pilot using the business model canvas techniques, and finally a financial and risk analysis that shows the feasibility and assesses the costs and incomes of the pilot.

Both frameworks will be applied and tested in each of the UNITED pilots as part of task 1.3 and 3.3. Therefore, this report proposes step-by-step preliminary guidance protocols to assess the economic efficiency of multi-use accounting for different types of costs, benefits and other relevant economic impact indicators (e.g. employment, ecosystem services). This preliminary version will be expanded into a full, easy-to-use guidance protocol with more details relevant for the application of the economic assessment framework in the context which will occur in task 3.3. Moreover, an analogous guidance protocol will be developed for the application of the business assessment (this will be included in D1.3). The resulting, user friendly guidance documents will be tested within the UNITED pilots and will translate as learning material for others interested in the application of the frameworks outside the project.

Ultimately, the results from application of the proposed framework in the UNITED pilots will turn into the following key deliverables: 1) development of pilot business briefs (M3.1) and 2) a report on assessment on the added value of MUCLs within pilots (D3.3).

In addition and to validate results and approaches and to increase the communication and dissemination of the proposed frameworks, a workshop with relevant actors will be organised. The aim of the workshop is to share the results of socio-economic assessments of the proposed Multi-use activities in the pilots of UNITED, and to ensure legacy of the project by training professionals to make/adapt business models for ocean multiuse, and to take into consideration its socio-economic components. It will also help inhabitants, local and regional planners, and decision makers to understand how their area could benefit from multiuse.

The workshops will build on the following competencies as laid out in D7.3:

- Have a clear view on (socio- economic) impacts and benefits of MUCL on an area/pilot
- Provide hands on experience on how to adapt/build a business plan for multiuse
- Validate the recommendations from UNITED, and share critical views
- Define conditions for successful future of multiuse, and integration with policy

The target stakeholder groups of this workshop will comprise businesses that are already involved (could potentially be involved), and others, such as: urban planners, local/regional decision makers, authorities, inhabitants.

In the end, WP3 of UNITED will make proposals for the development of business models for the commercial rollout of Multi-Use Colocations. Through the consistent application of the proposed economic and business frameworks in the UNITED pilots, the project partners will be able to assess the transferability and upscaling potential of UNITED pilots outside the project remit. The resulting report will highlight the Business Case for Multi-Use Platforms: Costs, Benefits and Lessons from Practice (D3.4).

Finally WP3 outputs will be useful for other areas of the project, such as to contribute to the analysis of business necessities (task 1.3), their associated financial requirements for investment (task 7.1), and their social acceptability (task 8.2). The importance for the achievement of targeted TRLs in terms of design and functioning (WP2) influences the viability and readiness of scaling such activities while factoring in the technological solutions' benefits and cost-saving via synergies between activities (WP2 & task 8.2) can also be captured in the economics of the pilots. Furthermore the socio-economic implications of their environmental impacts (task 4.2 and task 4.3) has a direct influence on the acceptability of the design by all levels of stakeholders from policy to small business (WP5).

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APPENDIX A

Table A1 Template for the TRL Assessment Calculator as Modified for DOE-EM (USDOE, 2009) T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation; NA – Not applicable (used by the German pilot)

TRL 5 Questions for Critical Technical Elements T/P/M*	Y/N/ NA	Criteria
T	Y	1. The relationships between major system and sub-system parameters are understood on a laboratory scale.
T	Y	2. Plant size components available for testing.
T	Y	3. System interface requirements known (How would system be integrated into the plant?).
P	Y	4. Preliminary design engineering begins.
T	Y	5. Requirements for technology verification established; to include testing and validation of safety functions.
T	Y	6. Interfaces between components/ subsystems in testing are realistic (bench top with realistic interfaces).
M	Y	7. Prototypes of equipment system components have been created (know how to make equipment).
M	Y	8. Tooling and machines demonstrated in lab for new manufacturing processes to make component.
T	Y	9. High fidelity lab integration of system completed, ready for test in relevant environments; to include testing and validation of safety functions.
M	Y	10. Manufacturing techniques have been defined to the point where largest problems defined.

T	Y	11. Lab-scale, similar system tested with range of simulants.
T	Y	12. Fidelity of system mock-up improves from laboratory to bench-scale testing.
M	Y	13. Availability and reliability (RAMI) target levels identified.
M	NA	14. Some special purpose components combined with available laboratory components for testing.
P	NA	15. Three dimensional drawings and P&IDs for the prototypical engineering-scale test facility have been prepared.
T	Y	16. Laboratory environment for testing modified to approximate operational environment; to include testing and validation of safety functions.
T	Y	17. Component integration issues and requirements identified.
P	Y	18. Detailed design drawings have been completed to support specification of engineering-scale testing system.
T	Y	19. Requirements definition with performance thresholds and objectives established for final plant design.
P	NA	20. Preliminary technology feasibility engineering report completed; to include compliance with DOE-STD-1189-2008.
T	Y	21. Integration of modules/functions demonstrated in a laboratory/bench-scale environment.
T	Y	22. Formal control of all components to be used in final prototypical test system.
P	Y	23. Configuration management plan in place.
T	Y	24. The range of all relevant physical and chemical properties has

		been determined (to the extent possible).
T	Y	25. Simulants have been developed that cover the full range of waste properties.
T	NA	26. Testing has verified that the properties/performance of the simulants match the properties/performance of the actual wastes.
T	NA	27. Laboratory-scale tests on the full range of simulants using a prototypical system have been completed.
T	NA	28. Laboratory-scale tests on a limited range of real wastes using a prototypical system have been completed.
T	NA	29. Test results for simulants and real waste are consistent.
T	Y	30. Laboratory to engineering scale-up issues are understood and resolved; to include testing and validation of safety functions.
T	Y	31. Limits for all process variables/parameters and safety controls are being refined.
P	Y	32. Test plan for prototypical lab-scale tests executed – results validate design; to include testing and validation of safety functions.
P	N	33. Test plan documents for prototypical engineering-scale tests completed.
P	Y	34. Finalization of hazardous material forms and inventories, completion of process hazard analysis, and identification of system/components level safety controls at the appropriate preliminary design phase.
P	NA	35. Risk management plan documented; to include compliance with DOE-STD-1189-2008.

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Technology & Commercialization Readiness Level Calculator

Profile	
Company/Organization Name:	Forschungs- und Entwicklungszentrum FH Kiel GmbH
Proposal Title:	UNITED - Pilot1 (German Pilot)
Product/Innovation Description:	Offshore-Aquaculutre-Systems for seaweed and mussel cultivation

Technology Readiness Level 5

Commercialization Readiness Level 2

Category	Answer
Technology	Laboratory scale integrated product/system demonstrates performance in the intended application(s)
Product Development	Pilot scale product/system has been tested in the intended application(s)
Product Definition/Design	One or more initial product hypotheses have been defined
Competitive Landscape	Primary market research to prove the product/system commercial feasibility has been completed and basic understanding of competitive products/systems has been demonstrated
Team	Balanced team with technical and business development/commercialization experience running the company with assistance from outside advisors/mentors
Go-To-Market	Customers/partners have been interviewed to understand their pain points/needs, and business model and value proposition have been refined based on customer/partner feedback
Manufacturing/Supply Chain	Relationships have been established with potential suppliers, partners, service providers, and customers and they have provided input on product and manufacturability requirements

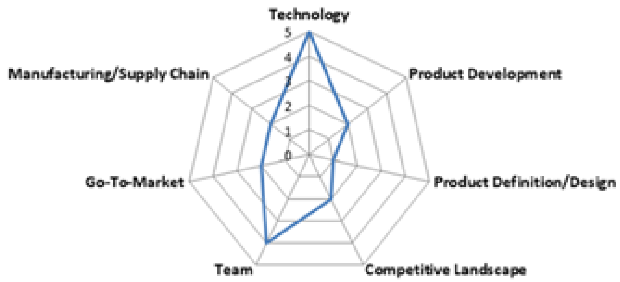

Figure A1 NYSERDA calculator result for the German pilot

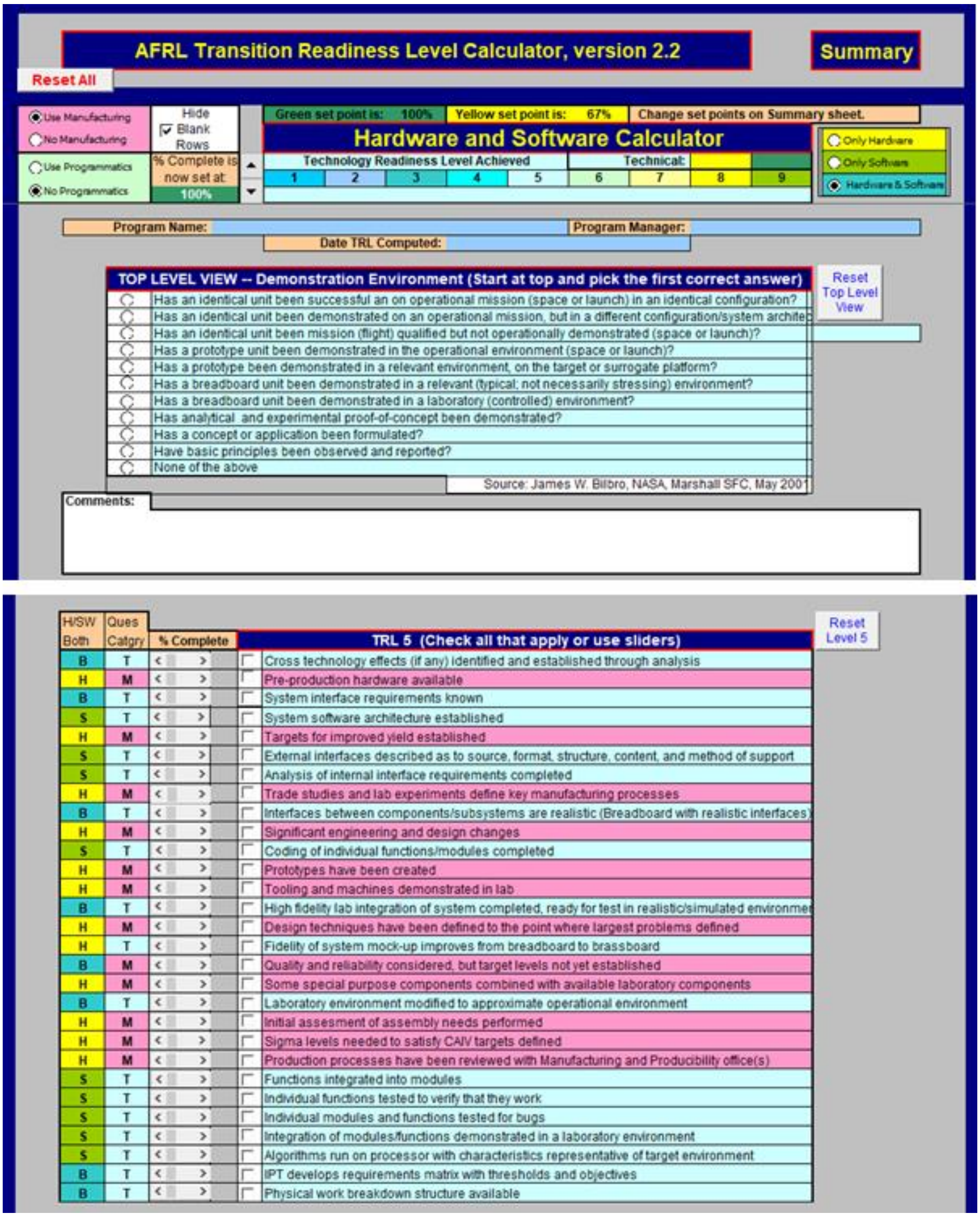

Figure A2 AFRL calculator template for TRL5 used by the German pilot (AFRL 2003)

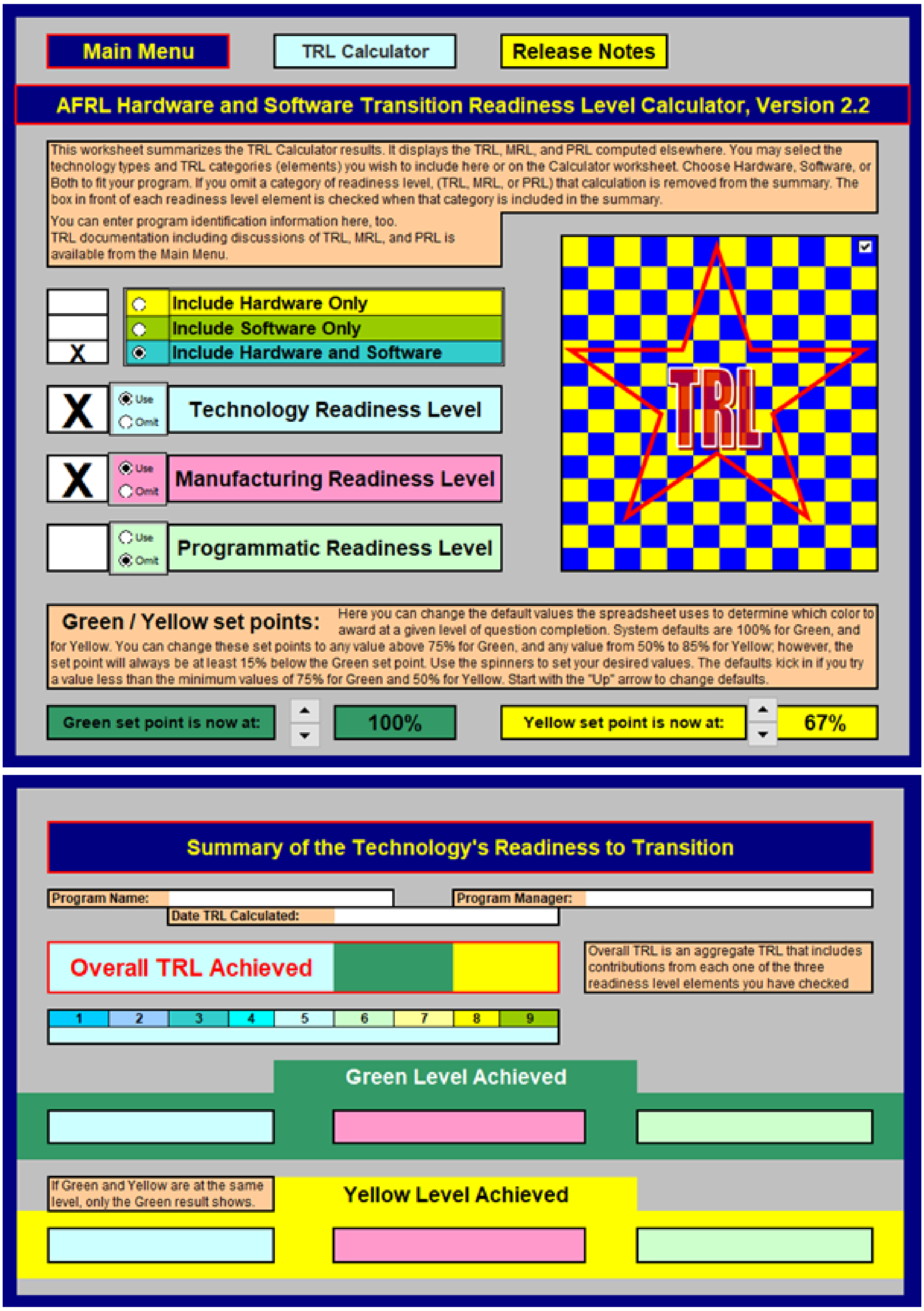

Figure A3 AFRL calculator template for TRL5 used by the German Pilot (AFRL 2003)

APPENDIX B

German Pilot: baseline TRL and transition

Baseline of the German pilot

The TRL 5 of the German Pilot (pilot 1) was estimated, according to the general definition of the Horizon2020 program (ENSPIRE Science, 2020):

"*Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)*"

as well as applying the description of the US Department of Energy (USDOE, 2009):

The US Department of Energy defines the TRL5 as:

"Laboratory scale, similar system validation in relevant environment:

The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity, laboratory scale system in a simulated environment with a range of simulants and actual waste. Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. The major difference between TRL 4 and 5 is the increase in the fidelity of the system and environment to the actual application. The system tested is almost prototypical."

The technical applications and solutions, infrastructure and logistics (e.g. transportation of personnel and equipment) of the offshore research platform FINO3 have been revised, adapted and improved since 2005. The research platform has been constructed according to wind turbines, making good use of advancements in technology and operating in a real life environment.

The combination of this offshore platform and the installation, operation and decommissioning of another offshore installation (research projects) at the same location has been conducted for years. The therefrom gained knowledge and information will be analysed and used for adaptations of the foreseen pilot (e.g. choice of sea cable, installation procedure).

The cultivation of seaweed and mussels, the second activity of the ocean multi-use system of the German pilot, has been tested at the nearshore site at the Kieler Meeresfarm (KMF) prior to the project start as well as during the pre-operational phase of UNITED. The tests included in particular anchors, longlines, collector lines, shackles, chains, buoys and logistics (installation, service and maintenance trips as well as harvesting). The results of these tests are used for the design and adaptation of the planned aquaculture system. The technical components for the aquaculture system, used in UNITED, will be bought off the shelf and combined and adjusted for the environment at the final location. Some components e.g. longlines used as backbones for the systems or buoys to mark the test side in the German pilot are off the shelf materials. Those materials have been tested in similar use but in different locations, which can be stated as simulated environments. Furthermore, the material itself can even be rated as TRL9, as one of Europe's largest seaweed cultivation farm (in Frøya) applies comparable equipment and technology, that has been classified as TRL 9 for seaweed cultivation Dalton (2019). The sensor equipment, to be used for monitoring the seaweed and mussel breadboard offshore, fulfils the manufacturer acceptance tests, laboratory- as well as real life environmental tests, run by 4H Jena during the pre-operational phase. Thus, the "*Top Level Questions for Determining Anticipated TRL5*" defined by the USDOE (2009), whether "*the bench-scale equipment/process testing has been demonstrated in a relevant environment*", can be answered with yes. The table of the USDOE (2009) was used to check for all relevant aspects of TRL5 that are applicable in the case of Pilot1.

"Guide to Technology Readiness Levels for the NDA Estate and its Supply Chain" by the Nuclear Decommissioning Authority (NDA)

Additionally, the Scottish Aquaculture Innovation Centre refers in its procedure for applying for funding for innovative aquaculture programs to the "Guide to Technology Readiness Levels for the NDA Estate and its Supply Chain" by the Nuclear Decommissioning Authority (NDA). The NDA states the TRL5 as a "*off the shelf item that needs minor modification*" which is described as "*The item is in use elsewhere […] for a similar function where the operational conditions […] are different. It is known that modifications are required but these are well understood.*" (NDA 2014)

This definition describes perfectly the current status of the German pilot as explained by the examples above.

Consequently, "the valley of death" for Pilot1 lies within the successful adaptation and implementation of (off the shelf) equipment and technology (most of it passed TRL 5 already, can rather be categorized TRL 9) in a new, high energy environment, which requires (complex) logistical and technical adjustments. It is the novel concept of multi-use demanding a research and development process as well as new business models, in order to make the systems technologically and commercially viable and realize the transition from TRL 5 to TRL 7.

TRL calculators

The New York State Energy Research and Development Authority (NYSEDRA) provides a calculator to determine the TRL from 1-9. The current status of the German pilot results also in TRL5 using this method (NYSERDA 2018). The results from this calculator can be found in [Appendix].

Moreover, the TRL calculator of the US Air Force Research Laboratory (AFRL) (AFRL 2003) states the German Pilot as TRL5 as well. This calculator gives the opportunity to answer more than three questions on the technical aspects like the calculator of the NYSERDA. There are at least five detailed questions on each TRL to rate it the respective TRL. Additionally, there is the option to answer each question not only by "yes" or "no" but also it is possible to rate each question proportional in steps of 5%. This gives the opportunity to answer the questions during the project runtime regularly and rate the TRL of the Pilot in real time. The AFRL templates can be found in the [Appendix].

Due to this flexibility and the comparatively diverse filter options, this calculator can be adapted to the respective project/pilot. Conclusion: The German pilot uses this calculator as an evaluation tool for the further course of the project.

Transition to TRL 7 in the German Pilot

In order for the German pilot to reach TRL7, the general definition of the Horizon2020 program (ENSPIRE Science, 2020)

"*System prototype demonstration in operational environment*"

as well as the according description of the USDOE (2009) is relevant:

"TRL7: Full-scale, similar (prototypical) system demonstrated in relevant environment

This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing full-scale prototype in the field with a range of simulants in cold commissioning. Supporting information includes results from the full-scale testing and analysis of the differences between the test environment, and analysis of what the experimental results mean for the eventual operating system/environment. Final design is virtually complete."

During the development of Pilot1 towards TRL7, the following technical and other essential determining aspects for a successful upscaling will be addressed during UNITED:

Functionality of ocean multi-use: Evidence on the effectiveness of ocean multi-use is needed, while reducing the risk for implementation/operation at affordable costs.

Administration/ government: Solutions for governance (obtaining permissions and licences) that comply with legal standards need to be found/described.

Investors and sales plan: The decision-making process on investing into ocean multi-use needs to be simplified with special/reliable offers for investors regarding financing models/business plans while reducing the overall economic risks (defining risk government actions). Moreover, effective marketing strategies need to be defined to generate a stable turnover of products, as there does not exist a "go to market strategy" for the products (mussel, seaweed) yet.

Standardized infrastructure: The infrastructure for professionally operating a ocean multi-use project needs to be created in order to reduce various costs and risks: training certified offshore staff, optimizing the scheduling of logistics, transportation and maintenance work, reducing energy need, etc.

Technological development: The demonstration of a pilot will be completed and tested at a fully exposed off-shore location with harsh conditions. Several available technical components for onshore or nearshore locations have to be adjusted for these specific conditions. Integrated Load cells of the system are one example for a technical device to optimize the final design for up scaled systems.

Environment: environmental data is required to investigate the impact of ocean multi-use on the environment. If there are negative impacts, these need to be known before up scaling is realised.

Regarding the functionality, the logistics and technical infrastructure as well as the technological development of the German pilot, strict procedures of the V-Model, a graphical representation of a systems development lifecycle, are followed to assure "*testing full-scale prototype in the field*" mentioned above (TRL 7). Hence, the concept description, matches the criteria of an effective Technical readiness Assessment, where the "*Performance objectives"* are defined in the requirement specifications for every (sub-) unit/system, while the achievement of "*Technological readiness level*(s)" for key supporting technologies is assured by validation and authorization during testing (outcomes and lessons learned documented in test protocols). The aspect of "*Research and development degree of difficulty*", is addressed by categorizing priorities within test protocols (e.g., high, medium, low; nice to have/optional, or essential) and defined requirements, deducing "*remaining development hurdles and the projected uncertainty"*.

At the beginning of the system design process, requirements will be specified and prioritized (e.g. high, medium, low) for single components up to the entire system. These requirements will need to pass predefined tests (e.g. factory acceptance test – FAT: at laboratory, conducted by manufacturer or yourself; Sea acceptance test – SAT: at near shore site), only then the next development stage (e.g. Integration of single units, whole system installation) of the design is met. This model approach allows for several iterations, in case the requirements of individual units/systems are not met during testing (unit testing, integration testing, system and acceptance testing). Alongside with the design development, change management documents new/amended/cancelled requirements and tests.

Belgian pilot: baseline TRL and transition

Baseline TRL of the Belgian pilot

The TRL 5-6 of the Belgian Pilot (pilot 3) was estimated, according to the general definition of the Horizon2020 program (ENSPIRE Science, 2020):

"Technology validated and demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)"

The cultivation and restoration of flat oysters and the cultivation of seaweed are currently being tested in the preoperational phase at the nearshore site of Westdiep, 5km off the coast of Nieuwpoort. The tests include amongst others anchors, longlines, frames, nets, shackles, chains, buoys and logistics (installation, service and maintenance trips as well as harvesting). The results of these "tests" are used for the design and adaptation of the planned aquaculture system in the operational phase offshore at the Belwind site, about 50km off the coast of Ostend. The technical components for the aquaculture system, used in UNITED, will be bought off the shelf and combined and adjusted for the environment at the final location. Some components e.g. longlines used as backbones for the systems or buoys to mark the test side in the Belgian pilot are off the shelf materials. Those materials have been tested in similar use but in different locations which can be stated as simulated environments. The installation will be in cooperation with a specialised company that has been installing these anchors and longlines in different locations worldwide, also for commercial purposes. Thus, the "Top Level Questions for Determining Anticipated TRL5" defined by the USDOE (2009), whether "*the bench-scale equipment/process testing has been demonstrated in a relevant environment*", can be answered with yes. The table of the USDOE (2009) was used to check for all relevant aspects of TRL5-6 that are applicable in the case of the Belgian pilot (for the Table: see higher with the German pilot – Table 1).

Upscaling to TRL 7 in the Belgian pilot

In order for Pilot3 to reach TRL7, the general definition of the Horizon2020 program (ENSPIRE Science, 2020) "System prototype demonstration in operational environment" as well as the according description of the USDOE (2009) is relevant:

"TRL7: Full-scale, similar (prototypical) system demonstrated in relevant environment

This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing full-scale prototype in the field with a range of simulants in cold commissioning1. Supporting information includes results from the full-scale testing and analysis of the differences between the test environment, and analysis of what the experimental results mean for the eventual operating system/environment. Final design is virtually complete."

During the development of the Belgian pilot towards TRL7, similar technical and other essential determining aspects for a successful upscaling as described for the German pilot higher will be addressed during the operational phase of UNITED. These are:

Functionality of multi-use site: Evidence on the effectiveness of multi-use is needed, while reducing the risk for implementation/operation at affordable costs.

Administration/ government: Solutions for governance (obtaining permissions and licences) that comply with legal standards need to be found/described.

Investors and sales plan: The decision-making process on investing into multi-use site needs to be simplified with special/reliable offers for investors regarding financing models/business plans while reducing the overall economic risks (defining risk government actions). Moreover, effective marketing strategies need to be defined to generate a stable turnover of products, as there is no "go to market strategy" for the products (oyster, seaweed) yet.

Standardized infrastructure: The infrastructure for professionally operating a multi-use site needs to be created in order to reduce various costs and risks: training certified offshore staff, optimizing the scheduling of logistics, transportation and maintenance work, reducing energy need, etc.

Technological development: The demonstration of a pilot will be completed and tested at a fully exposed offshore location with harsh conditions. Several available technical components for onshore or nearshore locations have to be adjusted for these specific conditions. Integrated Load cells of the system are one example for a technical device to optimize the final design for up scaled systems.

Environment: environmental data is required to investigate the impact of multi-use site on the environment. If there are negative impacts, these need to be known before up scaling is realised.

To evaluate further the potential for commercialization and to go to TRL8 or 9, a business case and life-cycle analysis will be drafted by Belgian UNITED-partner Colruyt.

Danish Pilot: baseline TRL and transition

Single use: offshore wind is mature i.e. TRL9 as Middelgrunden Offshore Wind Farm is commercial in offshore wind as has been producing electricity (about 3% of the electricity of Copenhagen) since 2001.

In combination with tourism it is TRL 6, as the combination of wind & tourism has been demonstrated in relevant environments (we carry out on-demand guided tours) and we aim to expand its utilization and activities. In fact, during UNITED we need to clarify/advance forward:

- insurance;
- full safety instruction for all single operations;
- involving more operators like boat companies (new boat companies are showing interest in participating in tourism activities and are now offering trips);
- develop diver activities to bring it to TRL7/8

Greek Pilot: baseline TRL and transition

Based on existing activities of aquaculture and tourism in the shared marine space, several actions will be taken to increase the TRL level of such multi-use solution. TRL level has started at around number 5 in the beginning of the project, with technology infrastructure (sensors, cameras carefully selected and communication, functionality has been validated in WINGS lab. The TRL has now risen, with current installations in the pilot site, validated functionality of technological devices and communication network properly amplified to satisfy the needs of data transmission. Installation are yet to be completed finally reach TRL7.