Tender for DAM Research Mission

"MARINE CARBON SINKS IN DECARBONIZATION PATHWAYS"

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1 Mission Description

1.1 Executive Summary

The ocean contains more than 50 times as much carbon as the atmosphere. It has, so far, strongly mitigated anthropogenic CO_2 effects by taking up about a quarter of the anthropogenic CO_2 emissions. Yet, this oceanic share of climate mitigation is expected to decrease because ocean warming, acidification, deoxygenation and other human-induced perturbations deteriorate the physical, chemical and biological capacities of the ocean to sequester carbon. While this further underlines the need for urgent emission reductions, all projected pathways that limit warming to 1.5 degrees additionally require the use of active removal of CO_2 from the atmosphere. Current scenarios, such as those used by the IPCC, generally focus on land-based Carbon Dioxide Removal methods. However, meeting climate mitigation targets with land-based methods alone, will be extremely difficult if not impossible. Knowledge on how the ocean might contribute to the required decarbonization effort is limited. In order to support pathways that achieve the Paris Agreement goals, the DAM Research Mission "Marine Carbon Sinks in Decarbonization Pathways" will address as to whether and to what extent the ocean can play a substantial role in removing and storing CO_2 from the atmosphere. In order to examine how marine carbon pools may be utilized in the most sustainable way, interlinkages with, and impacts on, the marine environment, the Earth system and society will also be determined, as well as appropriate approaches for monitoring, attribution and accounting of marine carbon storage in a changing environment. Analyses of individual actions that aim to enhance marine carbon sinks will account for both risks and co-benefits, and assess their potential as well as economic, political, social and legal implications. In order to develop relevant assessment criteria and roadmaps, a tight dialogue with stakeholders will be an intrinsic part of the inter- and transdisciplinary Research Mission. The product will be a Marine Carbon Roadmap for a sustainable utilization of the marine carbon pools on regional to global scales. Given the pace of discussions in politics, it is planned to provide preliminary results of the Mission already after 1.5-2 years to inform policymakers in a manner as timely as possible.

1.2 Introduction

Governments worldwide have recognized via the COP21 Paris Agreement that climate change resulting from human-induced forcing must be limited. Most countries have agreed to "hold the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels". Combating climate change is also included in the Sustainable Development Goals of the United Nations (SDG, UN 2015). This goal – SDG 13 – is closely interlinked to other SDGs addressing e.g. life on land (SDG 15) or life below water (SDG 14). In addition to emission reductions urgently needed, the IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018) highlights with *high confidence* that all projected pathways that limit warming to 1.5°C also require the use of carbon dioxide removal

(CDR) on the order of 100−1,000 Gt CO_2 over the 21st century. The majority of pathways that limit warming to 2°C also require the use of carbon dioxide removal (CDR). Understanding of the potentials, feasibilities, and risks of individual proposed measures is limited, even though it is now clear that CO_2 removal will be needed at scale within the next very few decades, and already in the order of 1 Gt CO_2/yr in 2030, to complement other climate change mitigation activities.

To date the majority of research on CDR has focused on terrestrial-based methods such as afforestation or bioenergy with carbon capture and storage (BECCS). From this research it is already clear that achieving the Paris Agreement goals with land-based CDR methods alone will be extremely difficult, if not impossible due to their side effects, trade-offs with the SDGs, e.g., halting biodiversity loss, zero hunger and competition for land use, limited individual potentials, and/or issues of carbon storage permanence (IPCC, 2019a; Smith et al., 2016; Boysen et al., 2017; Fuss et al., 2018; Heck et al., 2018; Lawrence et al., 2018). Much less is known about ocean-based CO_2 removal and storage approaches, although the ocean covers more than 70% of the Earth's surface, contains many times the amount of carbon in the atmosphere and terrestrial biosphere, and will be the predominant and largest long-term sink for anthropogenic CO_2 (Archer & Brovkin, 2008). While there are trade-offs expected for essentially all approaches, some measures proposed to enhance the marine uptake and storage of carbon have been associated with substantial regional to global co-benefits and synergies with the SDGs (Gattuso et al., 2018; GESAMP 2019; Hoegh-Guldberg et al., 2019).

Given the urgency of societal decisions about viable climate mitigation strategies and the absence of consistent pathways that build on emission reduction and terrestrial CO_2 removal, the DAM Research Mission "Marine Carbon Sinks in Decarbonization Pathways" will provide policymakers, governments and the general public with robust information for taking decisions on potential marine options for mitigating climate change and/or removing CO_2 from the atmosphere. Individual CO_2 removal and storage methods will be assessed with a perspective on the entire ocean system (from coastal systems to the open ocean), physical, chemical and ecological consequences and possible feedbacks. In addition to a comprehensive environmental evaluation, there will be a focus on social and political feasibility and impacts. This also includes a mapping of the relation to the SDGs, i.e. a description of potential synergies and trade-offs with regard to sustainable development.

Until now, the majority of marine carbon sink enhancement methods have not been considered in global, regional or national governance regimes and only one of the methods, ocean iron fertilization, has received significant national and international attention – resulting in the 2013 amendment to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter concerning "marine geoengineering". It remains to be analyzed whether the substantive provisions contained therein, as well as the assessment framework concerning field tests included in the 2013 amendment, can be operationalized in a sufficiently flexible and at the same time precautionary way for marine carbon sink enhancement methods.

Furthermore, the complex and fragmented nature of international, regional and national ocean governance regimes creates potential additional constraints to a larger-scale implementation of ocean-based technologies that have not been taken into consideration yet, and which may impede these applications in the ocean. Such effects have been discussed in the literature at a broader scale, but a sound knowledge base of interactions across a larger set of marine carbon sink enhancement methods with the current ocean governance system and including their relation to key principles such as the precautionary approach or ecosystem-based management is yet to be developed. Via tight collaborations across disciplines, the proposed DAM Research Mission will be able to substantially contribute to the development of ocean governance schemes appropriate for a responsible and sustainable exploration of marine carbon sinks.

The DAM Research Mission will thus identify to what extent, how, under which conditions and governance regimes, and with which trade-offs and co-benefits natural and managed marine systems can play a role in keeping climate change within the limits set by the Paris Agreement. The analysis will include potential interactions with terrestrial CDR methods and address accounting and monitoring questions that arise for temporal as well as permanent storage in a changing environment. We closely interact with stakeholders to conduct environmentally, economically, socially and politically relevant feasibility and public acceptability assessments. These are essential to obtain a viable Marine Carbon Roadmap, both nationally and internationally, that will be the long-term goal of this Research Mission.

1.3 Overarching Goals based on Stakeholder Consultation

Based on a stakeholder workshop held in Hamburg end of August 2019 and subsequent discussions with policymakers and among scientists, the following overarching goals were set for the DAM Research Mission:

- Advising policymakers and society on possible options for enhancing marine CO_2 uptake and storage, both from a national and a global perspective
- Assessing environmental, economic, social and political impacts, risks and co-benefits of individual measures, and mapping synergies and trade-offs with the SDGs
- Building of national competence to support successful international climate politics, development of marine carbon accounting schemes, governance and monitoring schemes
- Contributing to the long-term goal of providing a Marine Carbon Roadmap for a sustainable use of the marine carbon pools

1.4 Work-Package Structure

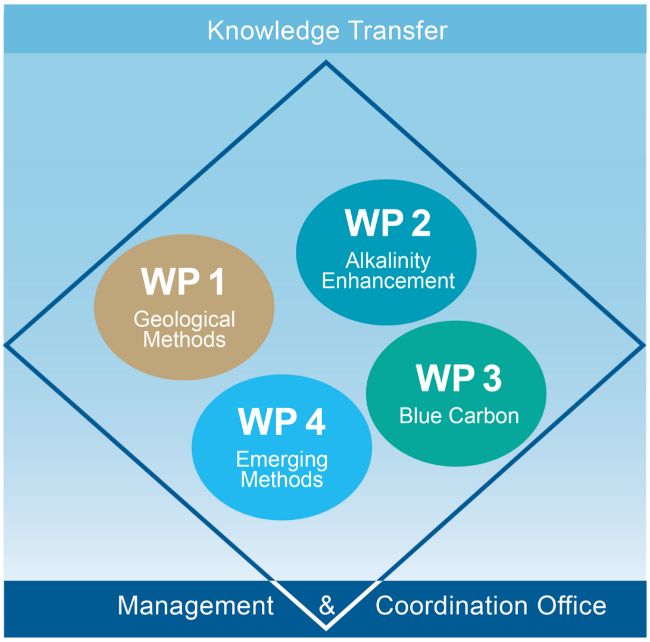
The first three Work Packages (WPs) will be organized around areas that previous research in Germany and elsewhere and, in some cases, proof-of-concept or even implementation in other countries have identified as promising in terms of marine carbon uptake and storage potential. In a fourth WP, we will address emerging methods for which there is as yet insufficient information to suggest a substantial and societally acceptable carbon sequestration and storage potential, as well as possible synergetic or antagonistic effects of different methods, marine and terrestrial, applied simultaneously. Assessments of marine carbon sink enhancements must account for internal and external economic costs and incentives, political and legal enablement or opposition, and how these technologies are supported or opposed by the public and may include ethical considerations. Knowledge of the potential impacts on society is also crucial, so that harms can be avoided or minimized. All these aspects need to be accounted for in each of the WPs, making them truly interdisciplinary efforts. Additionally, in each of the WPs the efficiency of the method under consideration has to be studied in comparison with the background natural variability of the affected marine CO_2 sinks. The management and coordination office of the Research Mission needs to provide the appropriate communication measures to enable cross-disciplinary and cross-WP communication and knowledge exchange within the DAM Research Mission as well as with stakeholders and society as a whole. To optimize workflow and information exchange among the scientists and stakeholders involved in the Research Mission(s), a tight interaction with the DAM core activities Data Management and Digitalization (DAM-DM) and Communication and Transfer will be implemented. Applying scientific consortia are asked to formulate in the proposals their data management & digitalization requirements necessary to answer Mission-related scientific questions, as well as the knowledge transfer pathways and forms of communication with stakeholders and the general public, and the possible transfer to application (see sections 3.2 and 3.3 below).

WP 1 will address capture and storage of CO_2 from industrial sources, which is considered in the new Climate Action Programme of the German government (Eckpunkte zum Klimaschutzprogramm 2030; Die Bundesregierung 2019). One special focus will be on submarine carbon storage in offshore sandstone formations under the North Sea. This is already being utilized by other European countries (deployed in Norway, planned in UK and Netherlands). Against this background, WP 1 will quantify the storage capacities in the German sector of the North Sea, evaluate the associated risks and assess the potential for the reduction of German industrial CO_2 emissions by CO_2 storage below the seabed. WP 1 will also investigate methods of sequestration of CO_2 by carbonation of basaltic formations of the ocean crust, a procedure that has been already tested and applied in Icelandic basalt (Matter et al., 2016). The CO_2 used by these approaches originates from industrial point sources before being emitted to the atmosphere and thus contributes to emission reduction, but not immediately to carbon dioxide removal from the atmosphere. Direct air capture (e.g. Creutzig et al., 2019) in combination with CO_2 storage investigated in this WP could, however, change this picture.

WP 2 will assess the potential, feasibility and side effects of various forms of alkalinity enhancement, which – via the chemical compensation of carbonic acid – reduces the partial pressure of CO_2 in seawater and thereby allows for enhanced uptake of CO_2 from the atmosphere into the ocean. Previous research, e.g. in the DFG Priority Program on the Assessment of Climate Engineering (SPP 1689) and the UK Program on Greenhouse Gas Removal, has identified alkalinity enhancement as one of the few methods for removing CO_2 from the atmosphere with high sequestration potential and possibly safe long-term storage, but until now little is known about the practicality of individual methods. WP 2 will investigate individual methods in greater detail, assess their potential adverse and beneficial environmental and societal effects and deployment aspects. The main objective is to provide sufficient information to society and policymakers as to whether these should be considered further.

WP 3 will assess the so-called ‘blue carbon’ approaches that encompass various forms of biotically-induced enhancement of marine carbon uptake from the atmosphere, predominantly in coastal areas. It includes submerged and amphibious vegetation such as sea grass meadows, salt marshes, macroalgae and mangrove forests. Internationally, blue carbon has received substantial attention (Macreadie et al., 2019), e.g. in the Research Agenda on Negative Emissions Technologies and Reliable Sequestration of the U.S. National Academy of Sciences (2019) and Australia’s Emission Reduction Fund (Australian Government, 2019). WP 3 will specifically assess the potential of blue carbon measures in German waters, but also worldwide options relevant for international climate and sustainability measures and possible carbon accounting schemes.

WP 4 will provide opportunities for the assessment of other approaches that may have received less attention in the past and that may still offer substantial potential for carbon uptake and storage. The main goal of WP 4 is to provide stakeholders and policymakers with fast turn-around in-depth knowledge of emerging marine decarbonization measures being discussed in the quickly evolving scientific and public debate, and to identify strategies other than those described within WPs 1-3 that require detailed study within the mission at a later stage. Interactions between different marine and terrestrial methods and their possible synergies or trade-offs will be determined here as well.



Structure of the DAM Research Mission "Marine Carbon Sinks in Decarbonization Pathways"

1.5 Utilization

The long-term goal of the Research Mission is to provide a Marine Carbon Roadmap for a sustainable utilization of the marine carbon pools on national to global scales. Policymakers can use the Roadmap to shape policies and initiate actions and accountable measures contributing to achieve the goals of the Paris Agreement, the United Nation's SDGs, the Convention on Biological Diversity and several EU directives such as the Marine Strategy Framework Directive. Results of the Research Mission will help to further develop governance schemes for a sustainable use of marine carbon sinks, e.g. via possible amendments to the London Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. On a national level, the results can be used to help fulfilling the demands of Germany and more specifically to Germany´s Climate Action Programme and National Sustainability Strategy.

Moreover, the Research Mission will provide a platform to engage stakeholders from policy (local to federal government agencies), businesses, civil society (including Non-Governmental Organizations) and academia. The continuous dialogue will ensure that solutions proposed in the

Roadmap are based on mutual agreements and presented transparently with all their benefits and trade-offs. It will also provide businesses and industries with robust information for planning and investing into, and moving forward, new technologies and developing new markets that will become important when the promised climate targets are to be met.

1.6 Economic prospects

The DAM Research Mission will help to enable a CO_2 market that includes marine options, with opportunities for individuals, small and medium enterprises, larger companies and the German economy as a whole. It will assist to avoid penalty payments that Germany would have to pay if it cannot meet the promised EU climate protection regulations. Even before marine options will be included in a CO_2 market, the Research Mission provides opportunities for technology transfer for solutions with regional co-benefits (e.g. coastal defence, blue carbon), and hence can immediately open up new markets for the German enterprises and thereby provide economic benefits. If necessary and beneficial, companies and businesses can directly be involved in the Research Mission.

In general, all actions that aim to enhance marine carbon sinks and that are considered in the Research Mission will be examined with regard to their potential (positive and negative) economic impacts. By doing so and by including stakeholders from different fields, e.g. in developing the assessment criteria, it will be ensured that the solutions proposed in the Roadmap will have undergone rigorous practicability tests. If economic trade-offs are identified for certain stakeholders (e.g. conflicts between sand and gravel extraction and blue-carbon approaches), the Roadmap will transparently describe them and – where possible – propose solutions how to address these.

1.7 Link to FONA and MARE:N

The research program Mare:N - Coastal, Marine and Polar Research for Sustainability, was established by the German Federal Government as a component of the „Research Program for Sustainable Development“ (FONA, BMBF 2017). MARE:N addresses topics related to coastal and marine regions and serves as an open, adaptive decision making framework. The DAM Research Mission “Marine carbon sinks in decarbonization pathways” directly responds to this as it addresses a relevant urgent societal and political topic with the goal of providing decision support for society, government and business. In a transdisciplinary process involving stakeholders from different disciplines and fields (society, science, politics and business) this mission will develop a Marine Carbon Roadmap describing possible development and action scenarios for a sustainable use of marine carbon pools.

2 Potential Work Packages

2.1 WP 1: Geological methods for enhancing marine CO_2 uptake and storage

2.1.1 Summary

Geological methods for enhancing marine uptake and storage of CO_2 are centered on carbon storage below the seafloor. Liquid CO_2 can be stored in depleted natural gas fields, saline aquifers, or directly in basalt at the seafloor. Offshore sandstone formations (saline aquifers and depleted oil/gas reservoirs) are already used in Europe to store CO_2 separated from natural gas and industrial sources below the seabed at Sleipner (Norwegian sector of the North Sea, 1 Mio. t/yr since 1996), Snohvit (Barents Sea, 0.7 Mio. t/yr since 2009) and are also targeted by a new initiative to collect and store CO_2 from industrial source in the Rotterdam Harbor (10 Mio. t/yr). Other countries also consider other storage formations, in particular basalt of the oceanic crust that, in order to ensure optimum use of available options nationally and internationally, will be included in the assessment. Capture and storage of CO_2 from industrial point sources is considered in the new Climate Action Programme of the German Government (Klimaschutzprogramm 2030).

2.1.2 Goals

WP 1 will achieve the following goals:

- Assessment of the CO_2 storage capacities, possible leakage rates and environmental impacts and risks of submarine carbon storage, with a special focus on the German sector of the North Sea
- Evaluate the potential for CO_2 storage in ocean crust basalt with regard to long-term stability, technical feasibility and environmental risks
- Develop monitoring schemes to ensure safe operating and early warning of leakage
- Assessment and evaluation of economic and social aspects and risks of submarine carbon storage
- Assessment of the legal dimension and public acceptability issues.
- Promote integration CO_2 storage sites into the spatial planning, with a national focus on the North Sea, and investigate possible conflicting uses (e.g. offshore wind, marine protected areas)
- Mapping the relation (potential synergies and trade-offs) to the SDGs and the German Sustainable Development Strategy

2.1.3 State-of-the-art

In Europe, the largest potential to store CO_2 is located offshore (~240 Gt of CO_2) mostly in deep saline aquifers (e.g. Vangkilde-Pedersen, 2009). More than 80% of the European offshore storage capacity is located in Norwegian waters (Vangkilde-Pedersen, 2009), about 1-3 % in the German North Sea. Geological formations that may be used for CO_2 storage in the German North Sea were explored by the project “Geopotenzial Deutsche Nordsee” (https://www.gpdn.de/). Even though the storage potentials in the German North Sea are not fully explored they may be sufficiently large to store a significant fraction of the German industrial CO_2 emissions over a period of several decades. The full costs for CO_2 capture, transport and storage were reported by numerous projects and amount to about 50-100 € per ton of CO_2 (IPCC, 2005, 2018). Transport and storage costs can be minimized by using offshore infrastructures deployed by the oil and gas industry (FENCO, 2010). The environmental impacts of leakage on benthic ecosystems have been comprehensively assessed by the European ECO_2 project (https://www.eco2-project.eu). Risks include leakage of CO_2 through abandoned wells, the release of formation water, seafloor deformation and micro-seismicity. Social and socio-economic aspects of Carbon Capture and Storage (CCS), including societal acceptance as well as synergies and trade-offs to the SDGs have been addressed e.g. by Karayannis (2014), Koelbl et al. (2016) and IPCC (2018) – but not yet specifically for marine CCS.

Technologies for the monitoring of storage sites are developed by the STEMM-CCS project (https://www.stemm-ccs.eu/). The legal framework for CO_2 storage is defined by the European CCS Directive in place since 2009. The draft for a German legal framework for CCS was approved by the German Government in 2009 and put into force in 2012 (KSpG).

The high porosity and permeability of the upper ocean crust paired with the basaltic basement's high contents of divalent metal cations with a high affinity for carbonation reactions make this environment a target for CCS efforts. Indeed, injection of CO_2 into aquifers within the basaltic oceanic crust has been identified as a potentially huge sink of CO_2 with an integrated storage capacity of >10^5 Gt CO_2 (Snæbjörnsdóttir et al., 2014). Current field test programs on Iceland (CARBFIX) have CO_2 dissolved in water upon injection into the basaltic aquifer, where reactions with the basaltic rocks cause carbonate minerals to form (Snæbjörnsdóttir and Gislasson, 2016; Matter et al., 2016). Other programs (e.g., *Solid Carbon* by the University of Victoria's Pacific Institute for Climate Solutions) also target deep-sea basaltic aquifers (in the Cascadia Basin) as site for sequestration of dissolved inorganic carbon The advantage of these methods is that the carbon is sequestered in minerals and is hence immobilized for very long time scales. But the rate of carbon fixation is ultimately controlled by the rate of dissolution of the basaltic rock, which is slow, albeit somewhat enhanced by the high contents of dissolved CO_2. A lesser explored possibility of considerable potential for rapid storage of CO_2 in the ocean floor is to use cold and deep flanks of mid-ocean ridges, where pressure and temperature conditions are within the stability field of liquid CO_2.

2.1.4 Milestones and Deliverables

The milestones and deliverables of WP 1 are:

- Overview of annual and total CO_2 storage capacity in the German sector of the North Sea, as well as in other regions worldwide
- Overview of potential environmental impacts, risks and co-benefits as well as links to related SDGs (e.g. SDG 14: life below water)
- Overview of economic aspects (e.g. deployment and operation costs, feasibility) and links to related SDGs (e.g. SDG 8: decent work and economic growth)
- Overview of social and socio-economic impacts, risks and co-benefits (e.g. societal acceptance, impacts on local communities) and links to related SDGs (e.g. SDG 3: good health and well-being)
- Knowledge transfer and stakeholder interaction to foster societal acceptance of approaches of actively increasing submarine geological CO_2-storage
- Roadmap for decision makers including development and application scenarios and recommendations

2.2 WP 2: Alkalinity enhancement

2.2.1 Summary

Marine uptake and storage of CO_2 from the atmosphere can be enhanced by the addition of alkalinity to surface waters. Via the chemical reaction with CO_2, the added alkalinity reduces the partial pressure of carbon dioxide and hence facilitates the air-sea flux of CO_2. An important aspect for maximizing uptake via air-sea gas exchange is a long residence time of alkalized waters at the sea surface, and an important aspect for maximizing total storage is the subsequent transport of carbon-enriched waters into the ocean interior.

Until now, different types of ocean alkalinity enhancement have been proposed that differ in the alkaline material added (e.g. olivine, basalt, different forms of calcium-carbonate derived materials), as well as where the CO_2-sequestering chemical reactions occur (e.g., *in situ* vs. *ex situ*). Besides physical conditions (temperature, mixed layer depth), local carbonate chemistry of the targeted sea water is expected to determine the efficiency of carbon sequestration, possibly favoring some coastal areas where upwelling of relative acidic and possibly anoxic waters may occur. A known co-benefit of these approaches is a reduction of ocean acidification (viewed beneficial for coral-reefs and raising interest, e.g. among shellfish farmers in the U.S.), whereas other side effects due to changes in carbonate chemistry and possible physical, chemical and biological effects of the added alkaline substances (e.g. contamination with fertilizing mineral components or possibly toxic impurities) are not well understood. Detailed realistic hydrographic-biogeochemical models evaluated by observations are essential for predicting the propagation and mixing of the treated waters, as well as carbon uptake and biogeochemical feedbacks.

Some alkalinization approaches may piggyback on installations originally planned for other purposes, e.g. coastal defences built with alkaline material, desalination plants with post-processing of brines in order to take up CO_2. All these require rigorous assessments before possible considerations for accounting in a CO_2 trading system can be made.

Issues to be addressed for any deployment approach are detection and attribution as well as accounting and legal questions, because water transport will disperse the chemical effects of alkalinity enhancement, eventually crossing jurisdictional borders and likely reducing the efficacy of any additional alkalinity enhancement downstream.

2.2.2 Goals

WP 2 will achieve the following goals:

- Assessing CO_2 uptake and storage potential of different alkalinization methods, as well as permanency issues and environmental impacts and risks
- Investigating cross-boundary effects of local measures
- Information about possible monitoring systems able to detect and attribute effects against natural variability and anthropogenic trends
- Assessment and evaluation of economic and social aspects, risks and co-benefits
- Assessment of the legal dimension and public acceptability issues
- Mapping the relation (potential synergies and trade-offs) to the SDGs and the German Sustainable Development Strategy

2.2.3 State-of-the-art

Modelling studies suggest a significant potential of ocean alkalinization in the open ocean (Ilyina et al., 2013) and along coasts (Feng et al., 2017), with virtually permanent storage of the bicarbonate ions produced from neutralizing carbonate acid with alkaline substances. While potential biogeochemical side effects of ocean alkalinization have been suggested based on modelling studies, few possible impacts on fundamental biological processes have been addressed. The specific responses and risks of negative side effects will depend on the mineral type applied to increase ocean alkalinity, its transient dose at the site of release, its aggregate state (dissolved prior to deployment vs. particles of specific size range), the timing/frequency (deployment rates), the physical and biogeochemical conditions that determine the duration until equilibration of the perturbed waters with atmospheric CO_2, and the sensitivity and (functional) reaction of the prevailing species on changes in the carbon system. Some of those responses have the potential to attenuate or amplify the CDR capacity, e.g. via the consumption of added alkalinity through enhanced calcification or a strengthening of the biological carbon pump through an increased proportion of diatom production when olivine is used for ocean alkalinization. Obtaining this knowledge is essential in any consideration of the effectiveness and impacts of ocean alkalinization. This is also critical information for marine ecosystem management and ocean governance, that should be part of the societal discourse on alkalinity enhancement.

Preliminary engineering requirements and cost estimates have been calculated for most types of alkalinity enhancement (Renforth and Henderson, 2017). However, these need to be refined for regional deployments of alkalinity enhancement. Some laboratory studies and analyses of available alkaline materials have also been conducted (Hartmann et al., 2013; Renforth, 2019), but the information required to fully understand the alkalinity enhancement, e.g. the dissolution kinetics of various minerals in seawater and the ecological impacts of addition alkaline minerals, is unavailable. Many technical, environmental, social, legal and ethical questions still remain (Renforth, 2019; GESAMP 2019), and relations to the SDGs have not yet been investigated.

2.2.4 Milestones and Deliverables

The milestones and deliverables of WP 2 are:

- Overview of the potential and efficiency of different ocean alkalinization approaches
- Overview of potential sites, minerals and deployment methods for alkalinization within the German/European realm and beyond
- Overview of potential environmental impacts, risks and co-benefits as well as links to related SDGs (e.g. SDG 14: life below water)
- Overview of social and socio-economic impacts, risks and co-benefits (e.g. societal acceptance) and links to related SDGs (e.g. SDG 8: decent work and economic growth)
- Knowledge transfer and stakeholder interaction to foster societal acceptance of approaches of actively increasing marine CO_2-uptake and storage via ocean alkalinization
- Roadmap for decision makers including development and application scenarios and recommendations

2.3 WP 3: Blue carbon approaches

2.3.1 Summary

A number of biological approaches have been suggested to enhance carbon uptake predominantly via photosynthesis, particularly in coastal areas where they are often summarized as ‘blue carbon’ methods. These include enhancing seagrass, salt-marsh, macroalgae (‘blue forests’ with still debated carbon sequestration potential) and mangrove ecosystems. Some of these activities may be considered as restoration efforts, possibly including the conversion of land reclamation areas back to shallow ocean, with possibly different social and public acceptability and governance issues. The systems can also provide a number of services in addition to carbon uptake and storage, such as providing habitats, protecting biodiversity and coastlines, and supporting coastal communities via food provision. Furthermore, here are likely interactions with tourism and shipping, water quality as well as vulnerabilities of coastal communities to changing environmental conditions. A comprehensive and quantitative assessment of blue carbon approaches and of their evaluation in terms of potential environmental and social aspects and also economic aspects and values (i.e. sustainability aspects) is lacking and will be developed in this work package for individual case studies as well as for global assessments.

Farming of algae to be harvested for bioenergy (with carbon capture and storage upon combustion) or to create biochar has also been proposed, in particular for macroalgae which have high carbon-to-nutrient ratios. Different approaches may work very differently in different regions. By definition, biological methods impact the marine biology and thus will have direct ecological side effects. Due to waters moving around, all impacts will have to be considered across space and time scales, requiring the development of appropriate multi-scale models that can realistically represent major biological, physical and chemical effects of 'blue carbon' measures. The work package will provide comprehensive quantitative assessments of regional, national and global CO_2-sequestration potentials of the individual approaches, and address detectability and attribution against natural variability and anthropogenic trends.

2.3.2 Goals

WP 3 will achieve the following goals:

- Assessing carbon stocks, carbon sequestration potential as well as co-benefits and negative side effects of blue carbon approaches in German waters and beyond, under various environmental conditions and a changing climate
- Investigating cross-boundary effects of local measures
- Providing information for effective decisions on, and governance of, marine protected areas.
- Assessment and evaluation of economic and social aspects, risks and co-benefits
- Assessment of the legal dimension and public acceptability issues.
- Mapping the relation (potential synergies and trade-offs) to the SDGs and the German Sustainable Development Strategy

2.3.3 State-of-the-art

The provisioning of the numerous ecosystem services of primary producers including carbon sequestration and storage depends on both the environmental conditions and the species composition of the communities. In particular, long-lived species with high biomass, e.g. many mangroves, macroalgae and seagrass species, may act as carbon store, especially when anoxic saline sediment conditions stabilize sequestered organic matter and hold back climate-active gases. While the general capacity for coastal vegetated ecosystems for high carbon storage per area is now widely acknowledged (Unsworth et al., 2019), current estimates are subject to very large margins of error (Duarte et al., 2013). Moreover, most data to date are dealing with an assessment of carbon stocks underlying macrophytic vegetation while there are only a handful of studies addressing rates of carbon capture (Röhr et al., 2018). Notwithstanding, even if average estimates of the carbon storage of marine vegetation apply, two prime objectives for coastal management are to (i) curb degradation and destruction of such ecosystems to ensure the persistence of their huge CO_2 stocks (ii) explore, develop and implement active habitat restoration to help recovering such ecosystems with high carbon capture capacity (Hoegh-Guldberg et al., 2019). The resilience of marine vegetated ecosystems towards the major global change associated stressors is also largely unresolved. While there are studies suggesting that growth of non-calcifying marine vegetation is enhanced by increasing CO_2 in marine waters (Koch et al., 2013), marine heat waves are threatening many macroalgal and seagrass beds worldwide (Wernberg et al., 2016).

Where vegetated ecosystems have been degraded, as is the case for many saltmarshes, seagrass beds and mangroves worldwide, their re-implementation can result in restoring some ecosystem services. Such restoration measures need to be founded on a sound scientific basis that clearly defines technologies, aims and goals in order to restore long-lasting storage of CO_2. Other than classical restoration practices, Ecosystem Design (Zimmer, 2018) targets particular ecosystem services and implements those assemblages of species that are most efficient in providing these services. There are many co-benefits of protecting and re-implementing seagrass beds, saltmarshes or mangroves, including biodiversity enhancement, coastal protection, decrease of waterborne pathogens, recruitment of harvestable fish and invertebrate populations that make habitat restoration a highly goal for active coastal management. However, the aim of increasing CO_2-extraction from the atmosphere may compete with other more local or regional interests and needs, for example aquaculture and fishing. Hence, such approaches require not only sound knowledge of the structure and functioning of these ecosystems and their responses to environmental change, but also their perception in society and the willingness of people to actively intervene in natural processes, as well as governance frameworks on the basis of societal prioritization of ecosystem services. One known countereffect of blue carbon uptake is a decrease in eutrophication-induced denitrification, i.e. anoxic removal of nitrate. Increased rates of alkalinity production due to denitrification, together with enhanced alkalinity input from land, has been shown to increase alkalinity in the Baltic Sea over the recent past (Müller et al., 2016, Gustafsson et al., 2014). Thus, nutrient management is an important aspect to be considered in blue carbon scenarios.

2.3.4 Milestones and Deliverables

The milestones and deliverables of WP 3 are:

- Overview of the existing carbon stocks and of rates of sequestration of marine vegetation (seagrasses, mangroves, saltmarsh plants, macroalgae, mangroves) as a function of future environmental drivers such as warming, ocean acidification, deoxygenation and sea-level rise.
- Overview of the potential and efficiency of the individual methods
- Overview of potential environmental impacts and co-benefits (biodiversity enhancement/recruitment to harvestable marine populations, coastal protection, impact on eutrophication-induced coastal alkalinity increase) of designing and re-implementing vegetated coastal ecosystems and links to related SDGs (e.g. SDG 2: zero hunger, SDG 14: life below water, SDG 15: life on land).
- Overview of potential social and economic impacts, risks and co-benefits (e.g. competing societal needs and interests, in particular the conflict between other usage of coastal areas

such as aquaculture /fisheries/tourism and the societal acceptance/perception (e.g. of re-implemented and designed ecosystems) including links to related SDGs (e.g. SDG 8: decent work and economic growth).

- Knowledge transfer and stakeholder interaction to foster societal acceptance of approaches of actively increasing CO_2-extraction by marine ecosystems
- Roadmap for decision makers including development and application scenarios and recommendations

2.4 WP 4: Emerging proposals for enhancing marine CO_2 uptake and storage

2.4.1 Summary

Apart from the marine decarbonization measures that will be evaluated in detail in WPs 1-3, other proposals have been, and are being, moved forward, but have so far been discarded due to potential side effects or perceived problems in technical feasibility, legal framework or public acceptability (such as ocean fertilization or direct deep-water liquid CO_2-injection), or are still in their infancy with respect to a level of understanding that could justify a full-scale detailed investigation of their significance for decarbonization pathways (e.g. a number of methods referred to in the recent GESAMP 2019 report). In the absence of viable strategies to reach the promised climate goals, these measures might nevertheless require individual consideration and evaluation, including carbon storage potential, ecological and social side effects, technical and economic feasibility, governance, legal and ethical aspects, and public perception.

WP 4 will evaluate currently under-investigated or newly proposed schemes of enhanced marine carbon uptake and storage through a network of experts and via rapid-response targeted research projects funded via the contingency fund budgeted below under Research Infrastructure and administered by the Mission Management. This WP will thereby allow searching the horizon for promising strategies that might require further in-depth evaluation at a later stage of the Research Mission, and proactively or by rapid response provide information for decision makers on emerging proposals for enhancing marine CO_2 uptake. This also applies to research on economic, legal and societal aspects of individual approaches as well as on possible synergies or trade-offs with other CO2 removal efforts.

2.4.2 Goals

WP 4 will achieve the following goals:

- Science-based assessment of marine carbon storage options that may appear promising but for which a rigorous scientific assessment, required for an informed public and political debate, is still lacking.
- Assessing carbon sequestration potential as well as co-benefits and negative side effects of such measures
- Assessing cross-boundary effects of local measures
- Identify those options for marine carbon storage which require further detailed studies (possibly in later phases of the Research Mission)
- Provide information for effective decisions on, and governance of, these methods.
- Assessment and evaluation of economic and social aspects, risks and co-benefits

- Mapping the relation (potential synergies and trade-offs) to the SDGs and the German Sustainable Development Strategy
- Providing information and maintaining a network of excellence to allow for quick responses and advice needed by policy and decision makers with respect to enhanced marine carbon storage.
- Provide information documents on assessed marine carbon storage options tailored for the scientific community, individual stakeholder groups, and the public, in close collaboration with the Knowledge Transfer Office (see 3.3).

2.4.3 State-of-the-art

A large number of measures aiming to enhance the marine carbon uptake potential have been proposed and evaluated at very different levels of maturity in the past, and for many of which there is insufficient scientific knowledge for a robust assessment (GESAMP, 2019).

Measures to enhance the biotically induced carbon sequestration beyond those addressed as ‘blue carbon’ in WP 3 include fertilization with iron or macro-nutrients that can be introduced into the surface ocean from outside or via redistribution within the ocean. The idea of using macroalgae farming to “short circuit” the biological carbon pump by artificially sinking the biomass into the deep ocean has also been proposed.

Direct disposal of liquid CO_2 below 2.600m, where the density of carbon dioxide exceeds that of seawater and carbon dioxide hydrate formation is expected to occur, has been proposed early as option of marine carbon storage (e.g. IPCC, 2005), but would come at the cost of strong local acidification at depth while reducing atmospheric CO_2 and hence acidification of ocean surface waters (Reith et al., 2019). In particular in marine depressions, hydrate formation and stratification could reduce the tendency for CO_2 dissolution (Fer and Haugan, 2001).

Some other proposed marine carbon sink enhancement methods have been investigated in only few studies or are only idealized concepts, leaving an insufficient understanding of their potential, feasibility, and risks. However, aside from knowing that this is technically possible, other implications remain unknown. Obviously, a large array of knowledge gaps needs to be filled before informed decisions can be made.

The need for enhanced carbon sinks in a zero-emission scenario will inevitably result in new movements and novel suggestions in the international framework. In close collaboration with the knowledge transfer services of the Research Mission (see 3.3), WP 4 will also continuously survey the international research for upcoming new schemes for enhanced marine carbon storage. Consisting of an interdisciplinary team of scientific experts, WP 4 will fill critical knowledge gaps to better determine the potential, feasibility, and risks of other approaches for enhancing marine CO_2 uptake. The approach will be two-pronged and combine a natural science-based investigation of potentials and environmental side effects and a feasibility assessment from the social sciences, international law and ethics perspective. Assessments will be made against the benchmarks of the more narrowly defined and specifically explored methods of WPs 1-3 and form the basis for structuring possible future phases of the Research Mission.

2.4.4 Milestones and Deliverables

The milestones and deliverable of WP 4 are:

- Overview of under-investigated and new emerging marine options for CO_2 uptake and storage
- Installation and maintenance of a network of expertise for quick responses and advice needed by policy and decision makers
- Information of funding agencies and the general public about research required to further develop a Marine Carbon Roadmap
- Overview of potential environmental impacts, risks and co-benefits as well as links to related SDGs (e.g. SDG 14: life below water)
- Overview of social and socio-economic impacts, risks and co-benefits (e.g. social acceptance) and links to related SDGs (e.g. SDG 2: zero hunger, SDG 8: decent work and economic growth)
- Roadmap for decision makers including development and application scenarios and recommendations

3 Central Tasks

3.1 Research Infrastructure

The required research infrastructure ranges from experimental and numerical tools to the use of mobile and fixed ocean observatories, "natural labs', mesocosms, autonomous platforms and research vessels. For many approaches, laboratory and enclosed mesocosm experiments are essential to provide information about process efficiency, reaction kinetics and ecological aspects, before field tests can be envisaged. Whenever possible, natural labs (e.g. natural sub-marine CO_2 sources; specific mineral sites; historical sites of alkaline 'waste' deposition) will be utilized. Marine observatories and research vessel operations will allow for a correct assessment of temporal and spatial scale effects, and evaluation of the efficiency of the proposed method versus the respective natural CO_2 sinks, their variability, and anthropogenic trends. Research infrastructure needs to be justified, budgeted and applied for in the respective WPs. The project management will provide support for efficient use of infrastructure via sharing and collaboration across WPs, including the possibility of add-on mini projects addressing emerging CO_2 removal and storage methods and funded via the contingency fund.

Another area where the optimal use and improvement of research infrastructure is essential for the success of this Research Mission, is the development of appropriate numerical tools: Multi-scale (both in time and space) model systems are required to extrapolate from individual measurements to larger scales and future scenarios, to account for carbon fluxes and reservoirs from local scales of individual societal actors (coastal protection structures, marine protected areas, ecosystems, individual submarine CO_2 storage sites) to global scales and thereby allowing for quantitative assessments of cross-boundary effects and feedbacks with the climate system. Novel model structures will have to be coupled in consistent ways, given that not all processes (e.g. tides, interactions of benthic and pelagic ecosystem with physics and biogeochemistry, competition of individual species) are generally considered in current models of all scales. Physical, biogeochemical and ecological models need to be further developed in order to consider emerging knowledge on new process understanding (such as wave-current coupling in the physical realm, benthic-pelagic coupling in the physical and biogeochemical realm and trophic coupling in the biogeochemical and ecological realm).

Different degrees of complexity in the physical and ecological structures represented in different model components across the different WPs will combine expertise available in the marine research institutions in northern Germany. The Project Management team will coordinate efforts for transparent communication, model structures and interfaces and thereby align model development within the Research Mission as a contribution to a German climate modelling strategy. This will also include new tools for analysis and visualization of model-generated data together with real-world measurements. The Project Management team will coordinate efforts among all WPs to reach the following milestones and deliverables.

Milestones and Deliverables:

- Status report on the experimental and observational infrastructure used in the first phase of the Research Mission and available for possible future phases, for the wider research community, and for a possible monitoring of marine carbon sinks in decarbonization pathways (month 30)
- Report on the new model components developed as part of the research mission, their common interfaces and their portability among models of the Research Mission and beyond (month 36)

3.2 Data Management

All databases and data used will be in agreement to the General Data Protection Regulation (GDPR) (EU) 2016/679, the latest EU law on data protection and privacy for all individuals within the European Union (EU) and the European Economic Area (EEA). All new data produced will be made available adhering to the FAIR (Findable Accessible Interoperable Reusable) principles for data management. Each WP has to provide a data management plan in agreement with the above regulations and in close collaboration with the central Research Mission's data management. Quality control of data and a workflow for delivery of data from observation to archive will be handled within the respective WPs.

The DAM Research Mission will investigate changes in temperature, circulation, water chemistry, and marine ecosystems, already visible in all regions of the world ocean. This is tightly connected to the DAM central task Data Management and Digitalization (DAM-DM), which aims to set up the workflow for high-quality data products from German research vessel's underway data, as there are data from vessel-mounted TSG, ADCP, ferry-boxes and bathymetric data. These data products are essential for Earth system research.

Tasks of the Research Mission's data management include tight collaboration with the individual scientists - e.g. providing support and advice - regarding acquisition, harmonization, assimilation, formatting, processing, archival, integration, quality control and documentation. It will also provide for the Research Mission the processes for findability and access to data as well as interfaces to international data portals and link to the "Nationale Forschungsdateninfrastruktur". It will also develop mission-guidelines for immediate sharing, for online access, long-term preservation and dissemination. Tools for visualization will be developed and standardized. The data management is part of the Research Mission's Coordination Support Team (see 3.4).

The Research Mission will serve as an important customer to get direct feedback on the data products and data services provided by DAM-DM with respect to their relevance and usability in answering global questions of high social relevance. Data services required for the Research Mission are interfaces to international data portals, which are also part of the DAM-DM portfolio. Interactive visualization tools and mapping services are also a requirement that is met by DAM-DM to visualize and distribute the Marine Carbon Roadmap on regional to global scales to support the transdisciplinary dialogue with stakeholders. In order to make high-resolution ocean model results more easily accessible and reusable, new concepts for data access and tools to allow data analysis directly on the data server are necessary.

Milestones and Deliverables

- Research Mission's data policy (month 6)
- Establishment of single data base system for the Research Mission (month 12)

3.3 Knowledge Transfer

The DAM Research Mission "Marine Carbon Sinks in Decarbonization Pathways" will provide stakeholders (policy makers, business, civil society) with robust and targeted information for taking decisions on potential marine options for mitigating climate change and/or removing CO_2 from the atmosphere. The aim of the central task knowledge transfer is to ensure that practical expertise is integrated into the research projects, that science-based options for action are developed in a targeted manner and that they find their way into relevant user groups, institutions and political processes.

In order to develop a viable Marine Carbon Roadmap, stakeholder engagement will, from early on, have a special role in knowledge transfer. This will be coordinated by the Knowledge Transfer office as part of the Coordination Support Team. Input from stakeholders is required to develop appropriate criteria for measuring sustainability, i.e. to identify relevant social, environmental and economic aspects, that need to be considered and assessed, and for measuring compliance with safe operating spaces. These are, in turn, required for developing a useful scientific framework for assessing the role of marine carbon sinks in decarbonization pathways.

The knowledge transfer will enable and foster dialogue towards co-design and sustained development of the Marine Carbon Roadmap by designing public-private partnerships and science-policy interfaces. Interfaces and partnerships with the project's stakeholders are essential during the entire course of the Research Mission. To ensure the flow and exchange of information in the Research Mission, there will be appropriate deliverables in all WPs that are to be coordinated with the central task knowledge transfer.

The knowledge transfer will be achieved by a

1. **Stakeholder Reference Group (SRG)** to enable a targeted interaction with relevant groups of stakeholders. The SRG will be composed of individuals representing diverse groups with different goals, agendas, and interests. The targeted interaction will consider relevant project results of the different WPs for the specific interests of these diverse

groups. It will also support co-development (e.g. scoping of deployment and monitoring scenarios, industry/societal transitions).

2. **Knowledge Transfer Office** that is responsible
   a. for establishing and maintaining contacts among all WPs of the Research Missions and the Stakeholder Reference Group.
   b. for developing and conducting concepts for the translation of scientific results and for producing application-orientated products and tailored briefings in a comprehensive and understandable manner to make maximum use of research.
   c. for developing strategies and materials for capacity building and international knowledge transfer with respect the national and global development of a Marine Carbon Roadmap.
   d. for supporting cooperation between commercial partners and the WPs, and in collaboration with the central DAM office, with policymakers and other DAM initiatives
   e. for informing the wider public via media and public outreach to increase awareness for the ocean as carbon sink.

Communication activities will include:

- Project website informing on scientific progress, outcomes and experiments in an easily consumable way using text, photo, film, animation, graphics and other media. Brochures, leaflets and other printed products will be offered for download. The platform also serves as a central address for those who look for scientific publications and data.
- Regularly newsletters to subscribers and project partners
- Stakeholder events, workshops, briefings for focused engagement with specific users and targets (local and international)
- Summaries for policymakers at the end of each phase to foster the development of a Marine Carbon Roadmap in order to serve the science-policy nexus
- Webinars and development of scenario visualization tools to interface with the general public
- Capacity building activities to empower strategic partnerships internationally, support business development and communicate achievements effectively
- Classical media activities, online and social media presence, publications and events to ensure that results and conclusions are spread widely and far beyond the scientific community
- Capacity to fast respond to related texts in the main media

Milestones and Deliverables

- Stakeholder Reference Group (SRG)_established and meeting at the first annual assembly of the Research Mission (month 6)
- Annual meetings of the SRG with the members of the Research Mission
- Mid-term report on stakeholder interaction (month 18)
- Draft of Marine Carbon Roadmap (month 30)

3.4 Management

The mission management supports the Project Coordinators. It consists of a mission manager supported by a Scientific Secretary, elected from the scientists of the Research Mission. The Scientific Secretary advises the Manager on specific scientific issues as he/she is scientifically involved in the projects and as an expert. The mission management, particularly the Manager is the focal point of contact for the DAM Research Mission and also the liaison with the DAM central office and the parallel running research mission “Protection and Sustainable Use of Marine Areas”. The main responsibility of the Project Management is to support the project’s governance bodies (Executive Board consisting of representatives of all institutions participating in the Research Mission, Scientific Advisory Board, Stakeholder Reference Group, Members General Assembly). The manager aligns the activities of the Coordination Support Team that covers data management, knowledge transfer and public outreach. Exchange with the scientific community as well as the general public can be directed to the Coordination Support Team.

Management and coordination activities specific to the Research Mission include:

- Developing a protocol of responsible innovation in the research environment of marine carbon sinks
- Ensuring knowledge transfer among WPs and stakeholders via use of common protocols, and assessment criteria
- Running internal and deliberative workshops engaging with stakeholders and society.
- Managing the contingency fund, issue calls and organize scientific review of mini-proposals that will become part of WP 4.
- Keeping track of the long-term goal of providing a Marine Carbon Roadmap for a sustainable use of the marine carbon pools
- Organizing an international ‘Marine Carbon Roadmap’ symposium in 2023

Meeting & Workshop Schedule

The Coordination Team will be responsible for organizing all meetings and workshops that will take place within the Research Mission. The costs of the various meetings listed below, including travel and accommodation of all members of the Research Mission, the Reference Stakeholder Group and invited national and international guests will be covered by the management budget. CO_2 neutral meetings are aimed for.

	Year 1		Year 2		Year 3	
	Q 1+2	Q 3+4	Q 1+2	Q 3+4	Q 1+2	Q 3+4
annual assembly & SRG meeting [1)]						
WP meetings [2)]						
mini-proposal calls[3)]						
intern. symposium [4)]						
summary retreat [5)]						

1) Annual assembly:

The annual assembly will take place in the first semester of each project year. Participation of all members of the Research Mission is expected. The objective of the annual assemblies is to inform each other on the progress of the Work Packages (WPs) and to foster intensive scientific exchange among the participants and stakeholders. Guest speakers may be invited to give new insight and aspects to specific themes. The annual assemblies will be combined with meetings of the Stakeholder Reference Group to mutually inform about progress and relevant new issues and questions.

2) WP meetings:

The meetings of the individual WPs will take place in Q 3+4. These meetings will take place at different times to allow the Research Mission Coordinators and the Scientific Secretary to participate in all the meetings if needed. Furthermore, some researchers may want to join more than one WP meeting. Responsible for the coordination of date and location of these meetings is the Project Manager in consultation with the WP leaders. Participation of stakeholders is encouraged and will depend on the objective of the respective WP meetings.

3) Mini-proposal calls:

At the beginning of year 2 of the Research Mission, a first call for mini-proposals will be issued to address emerging issues such as novel proposals for marine carbon uptake and storage (to become part of WP 4), to allow for small experimental or observational projects or the design of specific tools that allow efficient combination of model components newly developed in different WPs. Mini proposals will be evaluated by an external board recruited from the Scientific Advisory Board and Network of Experts.

4) International symposium:

At the beginning of the 3rd year of the Research Mission, the Coordinators together with the members of the Work Packages and supported by the Management & Coordination Office will host an international symposium on Marine Carbon Sinks in Decarbonization Pathways. Location and date will be decided in agreement with the WP leaders. We will aim for a CO_2 neutral symposium.

5) Summary Retreat

As a central activity of the research mission, the results of the WPs will be compiled and used for transfer for different user groups. In order to arrive at these overarching results for the role of marine carbon sinks in decarbonization pathways, a summary retreat of all participating groups will be held. It has the task to develop the major concluding statements and summaries for stakeholders and public.

4 Budget Plan

The budget plan for the research mission is shown below (all costs are given in kEuro).

	2021	2022	2023	*Sum*
Work Packages				
Work Package 1	1,700	1,700	1,700	5,100
Work Package 2	1,700	1,700	1,700	5,100
Work Package 3	1,700	1,700	1,700	5,100
Work Package 4	850	850	850	2,550
Central tasks				
Research Infrastructure	0	0	0	0
Data Management and Digitalization	150	150	150	450
Knowledge Transfer	400	400	400	1.200
Management	500	500	500	1,500
Sum	**7,000**	**7,000**	**7,000**	**21,000**

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