



Study on the relevance of the proposed future EIT KIC – water, marine and maritime sectors and ecosystem (WMM)

Under the Framework Contract CINEA/2021/OP/0011

Lot 2: Sustainable Blue economy and ocean affairs



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STUDY ON THE RELEVANCE OF THE PROPOSED FUTURE EIT KIC – WATER, MARINE AND MARITIME SECTORS AND ECOSYSTEM (WMM)

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LIST OF ACRONYMS

ACRONYM	MEANING
APOs	Associations of Professional Organisations
BIC	Bio-based Industries Consortium
CEF	Connecting Europe Facility
CEMS	Copernicus Emergency Management Services
CETP	Clean energy Transition Partnership
CBE JU	Circular bio-based Europe joint undertaking
CLLD	Community-led Local Development
CFP	Common Fisheries Policy
CMO	Common Organisation of the Markets
EBM	Ecosystem Based Management
EIT RIS	EIT Regional Innovation Scheme
EC	European Commission
EEA	European Environment Agency
EIT	European Institute of Technology
EMODnet	European Marine Observation and Data Network
SET-Plan	European Strategic Energy Technology Plan
EIT SIA	EIT Strategic Innovation Agenda 2021-27
EFAS	European Flood Alert System
EUFOMA	European Market Observatory for Fisheries and Aquaculture Products
EU	European Union
ETP	Energy Transition Partnership
SEA-EU	European University of the Seas
GFI	Good Food Institute
GloFAS	Global Flood Awareness System
GVA	Gross Value Added
HEI	Higher Education Institutions
HVDC	High-voltage Direct Current
IBOs	Inter-branch Organisations
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Organization
IUU	Illegal, Unreported, Unregulated Fishing
JRC	European Commission's Joint Research Centre
KIC	Knowledge and Innovation Community
KOM	Kick-off Meeting
NSEC	North Seas Energy Cooperation
MATES	Maritime Alliance for fostering the European Blue Economy through a Marine Technology Skilling Strategy
MPA	Marine Protected Area
MS	Member States

STUDY ON THE RELEVANCE OF THE PROPOSED FUTURE EIT KIC –
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ACRONYM	MEANING
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning
PRIMA	Partnership for Research and Innovation in the Mediterranean Area
POs	Producer Organisations
REM	Remote Electronic Monitoring
RDI	Research, Development and Innovation
RFMOs	Regional Fisheries Management Organizations
SACs	Special Areas of Conservation
SBE	Sustainable Blue Economy
SBEP	Sustainable Blue Economy Partnership
SCI	Sites of Community Importance
STECF	EU Scientific, Technical and Economic Committee for Fisheries
SMEs	Small and Medium-sized Enterprises
SRIA	Strategic Research and Innovation Agenda
SPAs	Special Protection Areas
ToR	Terms of Reference
TPOs	Transnational Professional Organisations
TRLs	Technology Readiness Levels
VREs	Virtual Research Environments
WFD	Water Framework Directive
WMM	Water, Marine and Maritime Sectors and Ecosystems
ZEWT	Zero-emission Waterborne Transport Partnership

ABSTRACT

This study investigates the potential role of a Knowledge and Innovation Community (KIC) in Water, Marine, and Maritime Sectors and Ecosystems (WMM) under the European Institute of Innovation and Technology (EIT). The research addresses 1) the current challenges in WMM; 2) assessing scientific, technological, and socio-economic developments since 2019; and 3) synergies with existing initiatives. The analysis reveals persisting challenges such as water scarcity, flood risks and marine and freshwater ecosystem degradation as a result of extreme conditions enhanced by climate change, and the need for a circular and sustainable blue economy. Scientific advancements and policy efforts are acknowledged, yet persistent challenges require coordinated action among all stakeholders.

The study confirms Europe's leadership in marine and freshwater research and innovation and in the maritime economy emphasising the importance of the sustainable blue economy. It notes sector-specific challenges exacerbated by events like the COVID-19 pandemic. An integrated, cross-disciplinary and cross-sectoral KIC in the WMM field is proposed as a solution to overcome fragmentation, skill gaps, and promote collaboration. The potential of a KIC in the WMM field lies in integrating education, research, and business to reduce fragmentation, address challenges, and support the European industry, including Small and Medium Enterprises (SMEs), contributing significantly to the deployment of solutions and a sustainable and competitive blue economy. The KIC aligns with EU initiatives and needs to build on and complement these to avoid duplication. Strategic alignment with policies and leveraging existing initiatives and partnerships are crucial for its success.

EXECUTIVE SUMMARY

Introduction

The purpose of this study is to assess the continued relevance of the role of a future Knowledge and Innovation Community (KIC) in Water, Marine and Maritime Sectors and Ecosystems (WMM), to be established by the European Institute of Innovation and Technology (EIT).

The study focuses on assessing the relevance and the potential added value of the proposed future WMM KIC¹ by 1) analysing the challenges faced by the Water, Marine and Maritime sectors and Ecosystems today, focusing specifically on the developments in scientific, technological and socio-economic trends since 2019; 2) analysing whether there have been, since 2019, scientific, technological or socio-economic developments that would impact the potential relevance regarding creating a KIC in the field; 3) Analysing potential alignment, synergies and complementarities of a WMM KIC with other existing initiatives and considering key developments that have taken place since 2019.

Methodology

The study is performed through the following tasks:

- 1. Analysis of the challenges faced by the Water, Marine and Maritime sectors and Ecosystems today.** The analysis is structured around three key challenges: water scarcity, droughts, and floods; marine and freshwater ecosystem degradation; and the need for a circular and sustainable blue economy.
- 2. Analysis of the potential relevance and impact of a KIC in the field.** The analysis of the scientific, technological, and socio-economic developments that may impact the relevance of a WMM KIC and how they would do so. The goal is to describe trends and prevailing current perspectives on the status and role of the knowledge triangle in the field and to explore the related potential of a KIC-WMM.
- 3. Synergies and complementarities with existing initiatives.** We identify policy developments, initiatives and projects since 2019, that are relevant to the KIC. Then a comparative analysis is conducted, examining how these initiatives align with the goals and structure of WMM KIC built from the results obtained in the previous task.
- 4. Conclusions.** Building on the findings from Tasks 1 to 3, a detailed overview of the implications of these changes is elaborated to evaluate the potential role of KIC-WMM.

A methodological approach combining desk research and stakeholder consultation has been carried out across all four tasks.

Desk Research

Through desk research comprehensive information on scientific, technological, and socio-economic developments within the Water, Marine, and Maritime (WMM) fields, focusing on the period since

¹ Working title.

2019 has been gathered. This includes various sources such as scientific publications, policy documents, grey literature and the previous reports on the WMM KIC. When post-2019 data sources are not available we have highlighted this as a knowledge gap.

Stakeholder Consultation

Stakeholder interviews have been carried out to gain insights from experts and practitioners in the WMM fields, validating and complementing the desk research findings. Participants have been selected based on their expertise in areas such as water management, marine ecosystems, and maritime policies. Efforts have been made to ensure representation from diverse perspectives, including academia, industry, and relevant governmental bodies.

Interviews were semi-structured using a questionnaire developed to allow flexibility in exploring key themes. The questions covered topics such as current challenges, technological developments, and the potential impact of a KIC in the WMM field. The themes and patterns emerging from the interviews have been compared with desk research findings to ensure triangulation, address knowledge and data gaps as well as enhance the reliability of the study.

Key findings

1) Analysis of the challenges faced by the Water, Marine and Maritime sectors and Ecosystems today

Challenge 1: Water scarcity, droughts and floods. Scientific responses from 2019 to 2023 include advancements in water treatment, digitalisation, and early warning systems. However, assessing their impact is premature due to the short timeframe. Projected challenges by 2030 include heightened drought risk and decreased precipitation. Water scarcity, droughts and floods are predicted to increase in Europe in the next decades as a result of increasing extreme weather conditions produced by climate change. Urgent action is needed, focusing on emerging water technologies, targeted innovations for climate change, and sustained research to understand economic and environmental impacts and develop innovative solutions and approaches. A comprehensive approach involving integrated policy frameworks, technology deployment, and ongoing research and innovation is crucial to addressing the escalating water crisis in Europe.

Challenge 2: Marine and freshwater ecosystem degradation. Recent years have seen substantial efforts in safeguarding Europe's marine and freshwater ecosystems through EU commitments to combat biodiversity loss, pollution and climate change, however, the degradation has not been reversed in many cases. Scientific efforts focus on understanding long-term degradation processes and the development of innovative solutions to reverse these while initiatives like the European Digital Twin of the Ocean will contribute to better ecosystem assessments and predictions. Despite advancements, the degradation of ecosystems continues as evidenced by modest improvements in the ecological status of freshwater bodies, mixed results in the Marine Strategy Framework Directive, and the insufficient coverage and effectiveness of protected areas to fully reverse ecosystem decline. Ongoing issues include tackling pollution from intense eutrophication, plastic accumulation ecosystem protection and restoration, requiring holistic approaches with enhanced cooperation and coordination among stakeholders. The EU has implemented various strategies and plans, such as the European Green Deal and its related strategies, aiming to protect marine and freshwater ecosystems. Although bathing water quality remains high, the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) show modest results, emphasising the need

for accelerating ongoing efforts, large-scale deployment of solutions and integrated, collaborative initiatives based on R&I.

Challenge 3: Circular and Sustainable Blue Economy. Our findings confirm a strong research base in the EU but point to a lack of focus on higher education, particularly in broad academic programmes. Thematic and disciplinary gaps in areas like ecology, marine engineering, and water management are highlighted. Despite the EU's strategic emphasis on the research base, knowledge and competence are unevenly distributed among Member States. The study underscores the importance of addressing skills gaps, particularly in sectors like offshore wind, aquaculture, fishing, ecosystem restoration and blue biotechnology. It predicts growth in offshore wind energy but highlights challenges such as rising interest rates and potential space conflicts. The study also emphasises the need for innovation in fishing gear, the reduction of atmospheric pollution in maritime transport, and the development of a diverse ecosystem of service providers for energy and aquaculture installations.

2) Analysis of the potential relevance and impact of a KIC in the field

Europe is a global leader in aquatic research and innovation and marine and maritime economies, with a robust blue economy contributing significantly to employment and economic growth. The marine equipment industry, accounting for nearly 50% of global output, generated a total production value of EUR 71.6 billion between 2012 and 2017. Despite challenges from the COVID-19 pandemic and the energy crisis, the shipbuilding and repair sector employed around 305,500 individuals in 2020. Coastal tourism, the largest EU Blue Economy sector, faced a 58% decrease in gross value added (GVA) and a 40% decrease in employment in 2020 due to the pandemic but showed a strong recovery in 2021. Maritime transport, constituting 23% of the Blue Economy, faced a decline in 2020 but holds growth potential through technological advancements like digitalization.

Fisheries and aquaculture, contributing to 156,210 jobs in 2020, faced challenges with decreasing catches and changes in the fish stock resource base. The marine energy sector, with a GVA of €2.145 billion in 2020, demonstrated growth. The offshore oil and gas sector declined in response to net-zero emission targets, while blue biotechnology, though minor, shows an increase in GVA.

Water supply and wastewater treatment sectors experienced growth, with 90% compliance with the EU Urban Waste Water Treatment Directive in 2020. In addition, the requirement to improve water quality remains a priority. The revised Drinking Water Directive entered into force in 2021 and establishes more rigorous water quality standards, tackles emerging contaminants like endocrine disruptors and microplastics, and advocates for fair access to drinking water. However, fragmentation and disconnection within the knowledge triangle, including education, research, and innovation, pose challenges. Stakeholders emphasise the need for coordinated and integrated approaches to ocean and freshwater management.

The proposed WMM KIC aims to address these challenges by fostering collaboration, upskilling, and supporting the development of a sustainable blue economy and water sector. An integrated, multidisciplinary and geographically broad KIC can play a crucial role in integrating diverse sectors and disciplines in both freshwater and marine, promoting innovation and the large-scale deployment of solutions across the EU, and aligning with EU policy objectives for a sustainable and competitive blue economy. The study underscores the importance of overcoming sectoral and educational divides to achieve a holistic, well-performing knowledge triangle and emphasizes the potential of a KIC in addressing existing challenges and promoting transformative innovation and deployment of solutions across WMM fields.

3) Synergies and complementarities with existing initiatives

The proposed WMM KIC aligns with various EU initiatives, including the European Green Deal and its related strategies and initiatives including the EU sustainable blue economy strategy, EU biodiversity strategy, EU zero pollution action plan, EU circular economy action plan, and EU climate adaptation strategy. Unlike similar initiatives, the WMM KIC has the potential to integrate marine, maritime, and water sectors and disciplines, taking an integrated, multidisciplinary and cross-sectoral approach complementing and building on existing efforts. Aligned with EU policies and the Sustainable Development Goals, the WMM KIC focuses on promoting education, innovation, and research, contributing meaningfully to EU objectives. Collaboration with the Mission Restore our Ocean and Waters and established and forthcoming partnerships are encouraged, building on existing rivers and sea basin strategies, macro-regional approaches, Outermost Regions, and global dimensions. The EU's commitment to international ocean governance, outlined in the 2022 Joint Communication, serves as a reference for the WMM KIC at the global level. However, complementarity and strong links with other initiatives need to be developed to prevent duplication and competition for resources with existing partnerships, particularly in education and innovation, as stakeholders express concerns about potential overlaps.

Conclusions of the study

Europe grapples with mounting challenges in managing marine and freshwater resources (e.g., unsustainable exploitation of resources, climate change and pollution), necessitating heightened EU support for emerging marine, maritime, and freshwater-relevant innovations and technologies and their deployment at scale. While stress has been made on safeguarding ecosystems through initiatives combating biodiversity loss, persistent challenges demand increased cooperation and accelerated deployment of solutions. The circular and sustainable blue economy, essential for societal well-being, faces a spectrum of challenges and opportunities, including sector-specific impacts from events like the COVID-19 pandemic. This study confirms the continued relevance of a KIC in the WMM field, as holding significant potential in addressing fragmentation, skill gaps, deployment of solutions and serving as a vital connecting node. By integrating education, research, and business activities, a WMM KIC can contribute to reducing fragmentation across Europe through the EIT Regional Innovation Scheme. Strategic alignment with existing policy streams and complementing and leveraging with frameworks and partnerships are critical for the KIC's success in reconciling human activities with the protection of healthy freshwater and marine ecosystems and supporting European SMEs in the WMM fields.

RÉSUMÉ

Introduction

L'objectif de cette étude est d'évaluer la pertinence du rôle d'une future Communauté de Connaissance et d'Innovation (« Knowledge Innovation Community » en anglais, (KIC)) dans le domaine des secteurs et écosystèmes aquatiques, marins et maritimes (« Water, Marine and Maritime » en anglais, (WMM)), qui sera établie par l'Institut Européen d'innovation et de technologie (EIT).

L'étude se concentre sur l'évaluation de la pertinence et de la valeur ajoutée potentielle de la future WMM KIC⁽²⁾ en 1) analysant les défis auxquels sont confrontés aujourd'hui les secteurs et écosystèmes aquatiques, marins et maritimes, en se concentrant spécifiquement sur l'évolution des tendances scientifiques, technologiques et socio-économiques depuis 2019 ; 2) en analysant s'il y a eu des évolutions scientifiques, technologiques ou socio-économiques depuis 2019 qui auraient une incidence sur la pertinence potentielle de la création d'une KIC dans ce domaine ; 3) en analysant l'alignement, les synergies et les complémentarités potentielles d'une WMM KIC avec d'autres initiatives existantes et en tenant compte des principales évolutions qui ont eu lieu depuis 2019.

Méthodologie

L'étude est réalisée à travers les tâches suivantes :

- 1. Analyse des défis auxquels sont confrontés aujourd'hui les secteurs et écosystèmes aquatiques, marins et maritimes.** L'analyse s'articule autour de trois grands défis : la pénurie d'eau, les sécheresses et les inondations ; la dégradation des écosystèmes marins et d'eau douce ; et la nécessité d'une économie bleue circulaire et durable.
- 2. L'analyse de la pertinence et de l'impact potentiels d'une KIC dans le domaine.** L'analyse des développements scientifiques, technologiques et socio-économiques susceptibles d'avoir un impact sur la pertinence d'une WMM KIC et la nature de cet impact potentiel. L'objectif est de décrire les tendances et les perspectives actuelles dominantes sur le statut et le rôle du triangle de la connaissance dans le domaine et d'explorer le potentiel connexe d'une WMM KIC.
- 3. Synergies et complémentarités avec les initiatives existantes.** Nous identifions les développements politiques, les initiatives et les projets depuis 2019, qui sont pertinents pour la KIC. Ensuite, une analyse comparative est menée, examinant comment ces initiatives s'alignent sur les objectifs et la structure de la WMM KIC construits à partir des résultats obtenus dans la tâche précédente.
- 4. Conclusions.** Sur la base des résultats des tâches 1 à 3, une vue d'ensemble détaillée des implications de ces changements est élaborée afin d'évaluer le rôle potentiel de la WMM KIC.

² Titre provisoire.

Une approche méthodologique combinant la recherche documentaire et la consultation des parties prenantes a été mise en œuvre pour les quatre tâches.

Recherche documentaire

Des recherches documentaires ont permis de recueillir des informations complètes sur les développements scientifiques, technologiques et socio-économiques dans le domaine des secteurs et écosystèmes aquatiques, marins et maritimes (WMM en anglais), en se concentrant sur la période écoulée depuis 2019. Ces informations proviennent de diverses sources telles que des publications scientifiques, des documents de politique publique, de la littérature grise et les précédents rapports de la KIC consacrée aux secteurs et écosystèmes aquatiques, marins et maritimes. Lorsque des sources de données postérieures à 2019 ne sont pas disponibles, nous avons souligné qu'il s'agissait d'une lacune dans les connaissances.

Consultation des parties prenantes

Des entretiens avec les parties prenantes ont été menés afin de recueillir les points de vue d'experts et de praticiens dans les domaines consacrés aux secteurs et écosystèmes aquatiques, marins et maritimes, validant et complétant les résultats de la recherche documentaire. Les participants ont été sélectionnés en fonction de leur expertise dans des domaines tels que la gestion de l'eau, les écosystèmes marins et les politiques maritimes. Des efforts ont été faits pour assurer la représentation de diverses perspectives, y compris le monde universitaire, l'industrie et les organismes gouvernementaux concernés.

Les entretiens ont été semi-structurés à l'aide d'un questionnaire élaboré pour permettre une certaine souplesse dans l'exploration des thèmes clés. Les questions portaient sur des sujets tels que les défis actuels, les développements technologiques et l'impact potentiel d'une KIC dans le domaine des secteurs et écosystèmes aquatiques, marins et maritimes. Les thèmes et les modèles qui ressortent des entretiens ont été comparés aux résultats de la recherche documentaire afin d'assurer la triangulation, de combler les lacunes en matière de connaissances et de données et d'améliorer la fiabilité de l'étude.

Principales conclusions

1) Analyse des défis auxquels sont confrontés aujourd'hui les secteurs et écosystèmes aquatiques, marins et maritimes

Défi 1 : Rareté de l'eau, sécheresses et inondations. Les réponses scientifiques apportées entre 2019 et 2023 comprennent des avancées dans le traitement de l'eau, la numérisation et les systèmes d'alerte précoce. Toutefois, l'évaluation de leur impact est prématurée en raison de la brièveté de la période considérée. Les défis prévus d'ici 2030 comprennent un risque accru de sécheresse et une diminution des précipitations. La pénurie d'eau, les sécheresses et les inondations devraient s'aggraver en Europe au cours des prochaines décennies en raison de l'augmentation des conditions météorologiques extrêmes provoquées par le changement climatique. Des mesures urgentes doivent être prises, se concentrant sur les nouvelles technologies de l'eau, les innovations ciblées pour le changement climatique et la recherche soutenue pour comprendre les impacts économiques et environnementaux et développer des solutions et des approches innovantes. Une approche globale impliquant des cadres politiques intégrés, le déploiement de technologies et la recherche et

L'innovation permanente est essentielle pour faire face à la crise de l'eau qui ne cesse de s'aggraver en Europe.

Défi 2 : Dégradation des écosystèmes marins et d'eau douce. Des efforts considérables ont été déployés ces dernières années pour sauvegarder les écosystèmes marins et d'eau douce d'Europe grâce aux engagements pris par l'UE pour lutter contre la perte de biodiversité, la pollution et le changement climatique, mais la dégradation n'a pas été inversée dans de nombreux cas. Les efforts scientifiques se concentrent sur la compréhension des processus de dégradation à long terme et sur le développement de solutions innovantes pour les inverser, tandis que des initiatives telles que le jumeau numérique de l'océan européen contribueront à améliorer les évaluations et les prévisions concernant les écosystèmes. Malgré les progrès réalisés, la dégradation des écosystèmes se poursuit, comme en témoignent les améliorations modestes de l'état écologique des masses d'eau douce, les résultats mitigés de la directive-cadre "Stratégie pour le milieu marin" et la couverture et l'efficacité insuffisantes des zones protégées pour enrayer complètement le déclin des écosystèmes. Parmi les questions d'actualité figurent la lutte contre la pollution due à l'eutrophisation intense, la protection et la restauration des écosystèmes affectés par l'accumulation de matières plastiques, qui nécessitent des approches globales et une coopération et une coordination accrues entre les parties prenantes. L'UE a mis en œuvre plusieurs stratégies et plans, tels que le "Green Deal" européen et ses stratégies connexes, visant à protéger les écosystèmes marins et d'eau douce. Bien que la qualité des eaux de baignade reste élevée, la directive-cadre sur l'eau (DCE) et la directive-cadre "Stratégie pour le milieu marin" (DCSMM) affichent des résultats modestes, ce qui souligne la nécessité d'accélérer les efforts en cours, de déployer des solutions à grande échelle et de mettre en place des initiatives intégrées et collaboratives fondées sur la R&I.

Défi 3 : Économie bleue circulaire et durable. Nos conclusions confirment l'existence d'une base de recherche solide dans l'UE, mais soulignent le manque d'intérêt pour l'enseignement supérieur, en particulier pour les programmes universitaires généraux. Des lacunes thématiques et disciplinaires dans des domaines tels que l'écologie, l'ingénierie marine et la gestion de l'eau sont mises en évidence. Malgré l'importance stratégique accordée par l'UE à la base de recherche, les connaissances et les compétences sont inégalement réparties entre les États membres. L'étude souligne l'importance de combler les lacunes en matière de compétences, en particulier dans des secteurs tels que l'énergie éolienne en mer, l'aquaculture, la pêche, la restauration des écosystèmes et la biotechnologie bleue. Elle prévoit une croissance de l'énergie éolienne en mer, mais souligne des défis tels que la hausse des taux d'intérêt et les conflits spatiaux potentiels. L'étude souligne également la nécessité d'innover en matière d'engins de pêche, de réduire la pollution atmosphérique dans le transport maritime et de développer un écosystème diversifié de prestataires de services pour les installations énergétiques et aquacoles.

2) Analyse de la pertinence et de l'impact potentiels d'une KIC dans ce domaine

L'Europe est un leader mondial en matière de recherche et d'innovation aquatiques et d'économies marines et maritimes, avec une économie bleue robuste qui contribue de manière significative à l'emploi et à la croissance économique. L'industrie des équipements marins, qui représente près de 50 % de la production mondiale, a généré une valeur de production totale de 71,6 milliards d'euros entre 2012 et 2017. Malgré les défis posés par la pandémie de COVID-19 et la crise énergétique, le secteur de la construction et de la réparation navales employait environ 305 500 personnes en 2020. Le tourisme côtier, le plus grand secteur de l'économie bleue de l'UE, a été confronté à une baisse de 58 % de la valeur ajoutée brute (VAB) et à une diminution de 40 % de l'emploi en 2020 en raison de la pandémie, mais a connu une forte reprise en 2021. Le transport maritime, qui représente 23 %

de l'économie bleue, a été confronté à un déclin en 2020, mais recèle un potentiel de croissance grâce à des avancées technologiques telles que la numérisation.

La pêche et l'aquaculture, qui représentaient 156 210 emplois en 2020, ont été confrontées à la diminution des captures et à l'évolution des ressources halieutiques. Le secteur de l'énergie marine, avec une valeur ajoutée brute de 2,145 milliards d'euros en 2020, a connu une croissance. Le secteur du pétrole et du gaz offshore a décliné en réponse aux objectifs d'émissions nettes zéro, tandis que la biotechnologie bleue, bien que mineure, affiche une augmentation de la VAB.

Les secteurs de l'approvisionnement en eau et du traitement des eaux usées ont connu une croissance, avec une conformité de 90 % à la directive européenne sur le traitement des eaux urbaines résiduaires en 2020. En outre, l'amélioration de la qualité de l'eau reste une priorité. La directive révisée sur l'eau potable est entrée en vigueur en 2021 et établit des normes de qualité de l'eau plus rigoureuses, s'attaque aux contaminants émergents tels que les perturbateurs endocriniens et les microplastiques, et plaide en faveur d'un accès équitable à l'eau potable. Toutefois, la fragmentation et la déconnexion au sein du triangle de la connaissance, y compris l'éducation, la recherche et l'innovation, posent certains défis. Les parties prenantes soulignent la nécessité d'adopter des approches coordonnées et intégrées de la gestion des océans et de l'eau douce.

La WMM KIC proposée vise à relever ces défis en encourageant la collaboration, en améliorant les compétences et en soutenant le développement d'une économie bleue et d'un secteur de l'eau durables. Une KIC intégrée, multidisciplinaire et géographiquement étendue peut jouer un rôle crucial dans l'intégration de divers secteurs et disciplines dans les domaines de l'eau douce et de l'eau de mer, la promotion de l'innovation et le déploiement à grande échelle de solutions dans toute l'UE, et l'alignement sur les objectifs politiques de l'UE pour une économie bleue durable et compétitive. L'étude souligne l'importance de dépasser les clivages sectoriels et éducatifs pour parvenir à un triangle de la connaissance holistique et performant, et met l'accent sur le potentiel d'une KIC pour relever les défis existants et promouvoir l'innovation transformatrice et le déploiement de solutions dans l'ensemble des domaines consacrée aux secteurs et écosystèmes aquatiques, marins et maritimes.

3) Synergies et complémentarités avec les initiatives existantes

La WMM KIC proposée s'aligne sur diverses initiatives de l'UE, notamment le "Green Deal" européen et ses stratégies et initiatives connexes, y compris la stratégie de l'UE pour une économie bleue durable, la stratégie de l'UE pour la biodiversité, le plan d'action de l'UE pour une pollution zéro, le plan d'action de l'UE pour l'économie circulaire et la stratégie de l'UE pour l'adaptation au changement climatique. À la différence d'initiatives similaires, la WMM KIC a le potentiel d'intégrer les secteurs et disciplines aquatiques, marins et maritimes en adoptant une approche intégrée, multidisciplinaire et intersectorielle qui complète et s'appuie sur les efforts existants. En accord avec les politiques de l'UE et les objectifs de développement durable, la WMM KIC se concentre sur la promotion de l'éducation, de l'innovation et de la recherche, contribuant ainsi de manière significative aux objectifs de l'UE. La collaboration avec la mission "Restorer notre océan et nos eaux" et les partenariats établis et à venir sont encouragés, en s'appuyant sur les stratégies existantes pour les rivières et les bassins maritimes, les approches macro-régionales, les régions ultrapériphériques et les dimensions mondiales. L'engagement de l'UE en faveur de la gouvernance internationale des océans, décrit dans la communication conjointe de 2022, sert de référence à la WMM KIC au niveau mondial. Toutefois, la complémentarité et des liens solides avec d'autres initiatives doivent être

développés pour éviter les doubles emplois et la concurrence pour les ressources avec les partenariats existants, notamment dans le domaine de l'éducation et de l'innovation, les parties prenantes exprimant des inquiétudes quant aux chevauchements potentiels.

Conclusions de l'étude

L'Europe est confrontée à des défis croissants en matière de gestion des ressources marines et d'eau douce (exploitation non durable des ressources, changement climatique et pollution, par exemple), ce qui nécessite un soutien accru de l'UE aux innovations et technologies marines, maritimes et d'eau douce émergentes, ainsi qu'à leur déploiement à grande échelle. Si l'accent a été mis sur la sauvegarde des écosystèmes grâce à des initiatives de lutte contre la perte de biodiversité, les défis persistants exigent une coopération accrue et un déploiement accéléré des solutions. L'économie bleue circulaire et durable, essentielle au bien-être de la société, est confrontée à un large éventail de défis et d'opportunités, y compris les impacts sectoriels d'événements tels que la pandémie COVID-19. Cette étude confirme la pertinence continue d'une KIC consacrée aux secteurs et écosystèmes aquatiques, marins et maritimes, car elle offre un potentiel important pour remédier à la fragmentation, au manque de compétences, au déploiement de solutions et pour servir de lien de connexion vital. En intégrant les activités d'éducation, de recherche et d'entreprise, une WMM KIC peut contribuer à réduire la fragmentation dans toute l'Europe par le biais du système d'innovation régionale de l'EIT. L'alignement stratégique sur les axes d'interventions actuels ainsi que la complémentarité et l'effet de levier avec les cadres et les partenariats sont essentiels pour que la KIC parvienne à concilier les activités humaines avec la protection d'écosystèmes marins et d'eau douce sains et à soutenir les PME européennes dans les domaines des secteurs et écosystèmes aquatiques, marins et maritimes.

ZUSAMMENFASSUNG

Einführung

Ziel dieser Studie ist es, die fortdauernde Relevanz der Rolle einer zukünftigen Wissens- und Innovationsgemeinschaft (KIC) in den Bereichen Wasser, Meer und maritime Sektoren und Ökosysteme (WMM) zu bewerten, die vom Europäischen Innovations- und Technologieinstitut (EIT) eingerichtet werden soll.

Die Studie konzentriert sich auf die Bewertung der Relevanz und des potenziellen Mehrwerts der vorgeschlagenen künftigen WMM-KIC³, indem 1) die Herausforderungen analysiert werden, mit denen der Wasser-, Meeres- und maritime Sektor und die Ökosysteme heute konfrontiert sind, wobei der Schwerpunkt auf den Entwicklungen der wissenschaftlichen, technologischen und sozioökonomischen Trends seit 2019 liegt; 2) analysiert wird, ob es seit 2019 wissenschaftliche, technologische oder sozioökonomische Entwicklungen gegeben hat, die sich auf die potenzielle Relevanz der Schaffung einer KIC in diesem Bereich auswirken würden; 3) die potenzielle Ausrichtung, die Synergien und Komplementaritäten einer WMM-KIC mit anderen bestehenden Initiativen analysiert und die wichtigsten Entwicklungen seit 2019 berücksichtigt werden.

Methodik

Die Studie umfasst die folgenden Aufgaben:

- 1. Analyse der Herausforderungen, mit denen die Sektoren Wasser, Meer und Maritimes sowie die Ökosysteme konfrontiert sind.** Die Analyse gliedert sich in drei zentrale Herausforderungen: Wasserknappheit, Dürren und Überschwemmungen, Verschlechterung der Meeres- und Süßwasserökosysteme und die Notwendigkeit einer kreislauforientierten und nachhaltigen Blauen Wirtschaft.
- 2. Analyse der potenziellen Relevanz und Wirkung einer KIC in diesem Bereich.** Analyse der wissenschaftlichen, technologischen und sozioökonomischen Entwicklungen, die sich auf die Relevanz einer WMM-KIC auswirken könnten, und wie sie sich auswirken würden. Ziel ist es, Trends und die vorherrschenden aktuellen Perspektiven zum Status und zur Rolle des Wissensdreiecks in diesem Bereich zu beschreiben und das damit verbundene Potenzial einer KIC-WMM zu untersuchen.
- 3. Synergien und Komplementaritäten mit bestehenden Initiativen.** Wir identifizieren politische Entwicklungen, Initiativen und Projekte seit 2019, die für die KIC relevant sind. Anschließend wird eine vergleichende Analyse durchgeführt, in der untersucht wird, wie diese Initiativen mit den Zielen und der Struktur der WMM KIC übereinstimmen, die auf den Ergebnissen der vorherigen Aufgabe basieren.
- 4. Schlussfolgerungen.** Aufbauend auf den Ergebnissen der Aufgaben 1 bis 3 wird ein detaillierter Überblick über die Auswirkungen dieser Veränderungen gegeben, um die potenzielle Rolle der KIC-WMM zu bewerten.

³ Arbeitstitel.

Für alle vier Aufgaben wurde ein methodischer Ansatz gewählt, der Sekundärforschung und die Konsultation von Interessengruppen kombiniert.

Sekundärforschung

Durch Sekundärforschung wurden umfassende Informationen über wissenschaftliche, technologische und sozioökonomische Entwicklungen in den Bereichen Wasser, Meer und maritime Wirtschaft (WMM) mit Schwerpunkt auf dem Zeitraum seit 2019 zusammengetragen. Dazu gehören verschiedene Quellen wie wissenschaftliche Veröffentlichungen, politische Dokumente, graue Literatur und die früheren Berichte über die WMM KIC. Wenn keine Datenquellen für die Zeit nach 2019 verfügbar sind, haben wir dies als Wissenslücke hervorgehoben.

Konsultation von Interessengruppen

Es wurden Interviews mit Interessenvertretern durchgeführt, um Einblicke von Experten und Praktizierenden in den WMM-Bereichen zu erhalten und die Ergebnisse der Sekundärforschung zu bestätigen und zu ergänzen. Die Teilnehmer wurden aufgrund ihres Fachwissens in Bereichen wie Wasserwirtschaft, Meeresökosysteme und Meerespolitik ausgewählt. Es wurden Anstrengungen unternommen, um sicherzustellen, dass verschiedene Perspektiven vertreten sind, einschließlich der akademischen Welt, der Industrie und der relevanten Regierungsstellen.

Die Interviews wurden halbstrukturiert anhand eines Fragebogens geführt, der entwickelt wurde, um bei der Untersuchung von Schlüsselthemen Flexibilität zu ermöglichen. Die Fragen betrafen Themen wie aktuelle Herausforderungen, technologische Entwicklungen und die potenziellen Auswirkungen einer KIC im Bereich WMM. Die Themen und Muster, die sich aus den Interviews ergaben, wurden mit den Ergebnissen der Sekundärforschung verglichen, um eine Triangulation zu gewährleisten, Wissens- und Datenlücken zu schließen und die Zuverlässigkeit der Studie zu erhöhen.

Wichtigste Ergebnisse

1) Analyse der aktuellen Herausforderungen im Wasser-, Meeres- und maritime Sektor und in den Ökosystemen

Herausforderung 1: Wasserknappheit, Dürren und Überschwemmungen. Zu den wissenschaftlichen Antworten für den Zeitraum 2019 bis 2023 gehören Fortschritte bei der Wasseraufbereitung, der Digitalisierung und den Frühwarnsystemen. Aufgrund des kurzen Zeitrahmens ist es jedoch verfrüht, ihre Auswirkungen zu bewerten. Zu den prognostizierten Herausforderungen bis 2030 gehören ein erhöhtes Dürrierisiko und geringere Niederschläge. Wasserknappheit, Dürren und Überschwemmungen werden in Europa in den nächsten Jahrzehnten infolge der zunehmenden extremen Wetterbedingungen infolge des Klimawandels voraussichtlich zunehmen. Es besteht dringender Handlungsbedarf, wobei der Schwerpunkt auf neuen Wassertechnologien, gezielten Innovationen für den Klimawandel und nachhaltiger Forschung liegt, um die wirtschaftlichen und ökologischen Auswirkungen zu verstehen und innovative Lösungen und Ansätze zu entwickeln. Ein umfassender Ansatz, der integrierte politische Rahmenbedingungen, den Einsatz von Technologien sowie kontinuierliche Forschung und Innovation umfasst, ist entscheidend für die Bewältigung der eskalierenden Wasserkrise in Europa.

Herausforderung 2: Verschlechterung der Meeres- und Süßwasserökosysteme. In den letzten Jahren wurden erhebliche Anstrengungen zum Schutz der europäischen Meeres- und

Süßwasserökosysteme unternommen, indem sich die EU verpflichtet hat, den Verlust der biologischen Vielfalt, die Verschmutzung und den Klimawandel zu bekämpfen. Die wissenschaftlichen Bemühungen konzentrieren sich auf das Verständnis langfristiger Degradierungsprozesse und die Entwicklung innovativer Lösungen, um diese umzukehren, während Initiativen wie der europäische digitale Zwilling des Ozeans zu besseren Ökosystembewertungen und -vorhersagen beitragen werden. Trotz der Fortschritte geht die Verschlechterung der Ökosysteme weiter, wie die bescheidenen Verbesserungen des ökologischen Zustands von Süßwasserkörpern, die gemischten Ergebnisse der Meeresstrategie-Rahmenrichtlinie und die unzureichende Ausdehnung und Wirksamkeit von Schutzgebieten zeigen, um den Rückgang der Ökosysteme vollständig umzukehren. Zu den aktuellen Problemen gehören die Bekämpfung der Verschmutzung durch starke Eutrophierung, die Anreicherung von Kunststoffen, der Schutz und die Wiederherstellung von Ökosystemen, was ganzheitliche Ansätze mit verstärkter Zusammenarbeit und Koordinierung zwischen den Beteiligten erfordert. Die EU hat verschiedene Strategien und Pläne zum Schutz von Meeres- und Süßwasserökosystemen umgesetzt, wie z. B. den Europäischen Green Deal und damit verbundene Strategien. Obwohl die Qualität der Badegewässer nach wie vor hoch ist, zeigen die Wasserrahmenrichtlinie (WRRL) und die Meeresstrategie-Rahmenrichtlinie (MSRL) nur bescheidene Ergebnisse, was die Notwendigkeit einer Beschleunigung der laufenden Bemühungen, einer groß angelegten Einführung von Lösungen und integrierter, kooperativer Initiativen auf der Grundlage von F&I unterstreicht.

Herausforderung 3: Zirkuläre und nachhaltige Blaue Wirtschaft. Unsere Ergebnisse bestätigen eine starke Forschungsbasis in der EU, deuten aber auf einen mangelnden Fokus auf die Hochschulbildung hin, insbesondere bei breit angelegten akademischen Programmen. Thematische und disziplinäre Lücken in Bereichen wie Ökologie, Meerestechnik und Wassermanagement werden hervorgehoben. Trotz des strategischen Schwerpunkts der EU auf der Forschungsbasis sind Wissen und Kompetenz in den Mitgliedstaaten ungleichmäßig verteilt. Die Studie unterstreicht, wie wichtig es ist, Qualifikationslücken zu schließen, insbesondere in Bereichen wie Offshore-Windkraft, Aquakultur, Fischerei, Wiederherstellung von Ökosystemen und Blaue Biotechnologie. Sie prognostiziert ein Wachstum der Offshore-Windenergie, weist aber auch auf Herausforderungen wie steigende Zinssätze und potenzielle Raumkonflikte hin. Die Studie unterstreicht auch die Notwendigkeit von Innovationen bei Fanggeräten, die Verringerung der Luftverschmutzung im Seeverkehr und die Entwicklung eines vielfältigen Ökosystems von Dienstleistern für Energie- und Aquakulturanlagen.

2) Analyse der potenziellen Relevanz und Wirkung einer KIC in diesem Bereich

Europa ist weltweit führend in der aquatischen Forschung und Innovation sowie in der marinen und maritimen Wirtschaft, wobei eine stabile Blaue Wirtschaft erheblich zu Beschäftigung und Wirtschaftswachstum beiträgt. Die Schiffbauindustrie, auf die fast 50 % der weltweiten Produktion entfallen, erwirtschaftete zwischen 2012 und 2017 einen Gesamtproduktionswert von 71,6 Mrd. EUR. Trotz der Herausforderungen durch die COVID-19-Pandemie und die Energiekrise beschäftigte der Schiffbau- und Reparatursektor im Jahr 2020 rund 305 500 Personen. Der Küstentourismus, der größte Sektor der Blauen Wirtschaft in der EU, musste aufgrund der Pandemie im Jahr 2020 einen Rückgang der Bruttowertschöpfung (BWS) um 58 % und der Beschäftigung um 40 % hinnehmen, wird sich aber im Jahr 2021 stark erholen. Der Seeverkehr, der 23 % der Blauen Wirtschaft ausmacht, musste 2020 einen Rückgang hinnehmen, birgt aber durch technologische Fortschritte wie die Digitalisierung Wachstumspotenzial.

Fischerei und Aquakultur, die im Jahr 2020 156.210 Arbeitsplätze geschaffen haben, stehen vor der Herausforderung, dass die Fangmengen zurückgehen und sich die Ressourcenbasis der Fischbestände verändert. Der Meeresenergiesektor mit einer BWS von 2,145 Mrd. EUR im Jahr 2020 verzeichnete ein Wachstum. Der Offshore-Öl- und -Gassektor ging als Reaktion auf die Netto-Null-Emissionsziele zurück, während die Blaue Biotechnologie, wenn auch in geringem Umfang, einen Anstieg der BWS aufweist.

Die Sektoren Wasserversorgung und Abwasserbehandlung erlebten ein Wachstum, wobei die EU-Richtlinie über die Behandlung von kommunalem Abwasser im Jahr 2020 zu 90 % erfüllt sein wird. Darüber hinaus bleibt die Verbesserung der Wasserqualität eine Priorität. Die überarbeitete Trinkwasserrichtlinie trat 2021 in Kraft und legt strengere Wasserqualitätsstandards fest, geht gegen neu auftretende Schadstoffe wie endokrine Substanzen und Mikroplastik vor und fordert einen fairen Zugang zu Trinkwasser. Allerdings stellen die Fragmentierung und die fehlende Verbindung innerhalb des Wissensdreiecks, einschließlich Bildung, Forschung und Innovation, eine Herausforderung dar. Die Interessenvertreter betonen die Notwendigkeit koordinierter und integrierter Ansätze für die Bewirtschaftung der Meere und des Süßwassers.

Die vorgeschlagene WMM KIC zielt darauf ab, diese Herausforderungen zu bewältigen, indem sie die Zusammenarbeit fördert, das Fachwissen erweitert und die Entwicklung einer nachhaltigen Blauen Wirtschaft und eines nachhaltigen Wassersektors unterstützt. Eine integrierte, multidisziplinäre und geografisch breit gefächerte KIC kann eine entscheidende Rolle bei der Integration verschiedener Sektoren und Disziplinen sowohl im Süßwasser- als auch im Meeresbereich spielen, Innovationen und die großmaßstäbliche Einführung von Lösungen in der gesamten EU fördern und mit den politischen Zielen der EU für eine nachhaltige und wettbewerbsfähige Blaue Wirtschaft in Einklang stehen. Die Studie unterstreicht, wie wichtig es ist, sektorale und bildungsspezifische Unterschiede zu überwinden, um ein ganzheitliches, gut funktionierendes Wissensdreieck zu schaffen, und hebt das Potenzial einer KIC bei der Bewältigung bestehender Herausforderungen und der Förderung transformativer Innovationen und der Einführung von Lösungen in allen WMM-Bereichen hervor.

3) Synergien und Komplementaritäten mit bestehenden Initiativen

Die vorgeschlagene WMM KIC steht im Einklang mit verschiedenen EU-Initiativen, darunter dem Europäischen Green Deal und den damit verbundenen Strategien und Initiativen wie der EU-Strategie für eine nachhaltige Blaue Wirtschaft, der EU-Strategie für biologische Vielfalt, dem EU-Aktionsplan zur Vermeidung von Umweltverschmutzung, dem EU-Aktionsplan für die Kreislaufwirtschaft und der EU-Strategie zur Klimaanpassung. Im Gegensatz zu ähnlichen Initiativen hat die WMM KIC das Potenzial, die Sektoren und Disziplinen des Meeres, der Meere und der Wasserwirtschaft zu verbinden und einen integrierten, multidisziplinären und sektorübergreifenden Ansatz zu verfolgen, der bestehende Bemühungen ergänzt und darauf aufbaut. Im Einklang mit der EU-Politik und den Zielen für eine nachhaltige Entwicklung konzentriert sich die WMM KIC auf die Förderung von Bildung, Innovation und Forschung und leistet damit einen wichtigen Beitrag zu den Zielen der EU. Die Zusammenarbeit mit der Mission "Restore our Ocean and Waters" (Wiederherstellung unserer Ozeane und Gewässer) sowie bestehende und künftige Partnerschaften werden gefördert, wobei auf bestehenden Strategien für Flüsse und Meeresbecken, makroregionalen Ansätzen, Regionen in äußerster Randlage und globalen Dimensionen aufgebaut wird. Das in der gemeinsamen Mitteilung von 2022 dargelegte Engagement der EU für eine internationale Meerespolitik dient als Referenz für den WMM KIC auf globaler Ebene. Allerdings müssen Komplementarität und enge Verbindungen zu anderen Initiativen entwickelt werden, um

Überschneidungen und einen Wettbewerb um Ressourcen mit bestehenden Partnerschaften, insbesondere in den Bereichen Bildung und Innovation, zu vermeiden, da die Interessengruppen Bedenken hinsichtlich möglicher Überschneidungen äußern.

Schlussfolgerungen der Studie

Europa hat mit wachsenden Herausforderungen bei der Bewirtschaftung von Meeres- und Süßwasserressourcen zu kämpfen (z. B. nicht nachhaltige Ausbeutung der Ressourcen, Klimawandel und Verschmutzung), was eine verstärkte Unterstützung der EU für neu entstehende meeres- und süßwasserrelevante Innovationen und Technologien und deren großmaßstäblichen Einsatz erforderlich macht. Zwar wurde der Schutz der Ökosysteme durch Initiativen zur Bekämpfung des Verlusts der biologischen Vielfalt betont, doch erfordern die anhaltenden Herausforderungen eine verstärkte Zusammenarbeit und eine beschleunigte Einführung von Lösungen. Die zirkuläre und nachhaltige Blaue Wirtschaft, die für das gesellschaftliche Wohlergehen von entscheidender Bedeutung ist, steht vor einer Reihe von Herausforderungen und Chancen, einschließlich der sektorspezifischen Auswirkungen von Ereignissen wie der COVID-19-Pandemie. Diese Studie bestätigt die anhaltende Relevanz einer KIC im Bereich der Kreislaufwirtschaft, da sie ein erhebliches Potenzial für die Behebung von Fragmentierung, Qualifikationsdefiziten und die Einführung von Lösungen bietet und als wichtiger Verbindungsknoten dient. Durch die Integration von Bildungs-, Forschungs- und Unternehmensaktivitäten kann eine WMM-KIC dazu beitragen, die Fragmentierung in ganz Europa durch das regionale Innovationsprogramm des EIT zu verringern. Die strategische Ausrichtung auf bestehende Politikbereiche und die Ergänzung und Nutzung von Rahmenwerken und Partnerschaften sind entscheidend für den Erfolg der KIC, wenn es darum geht, menschliche Aktivitäten mit dem Schutz gesunder Süßwasser- und Meeresökosysteme in Einklang zu bringen und europäische KMU in den WMM-Bereichen zu unterstützen.

1. INTRODUCTION

This study aims to assess the relevance and provide fresh perspectives on the role of a Knowledge and Innovation Community (KIC) in Water, Marine and Maritime Sectors and Ecosystems (WMM), to be established by the European Institute of Innovation and Technology (EIT). More specifically, it offered an uptake and revision of the previous assessment done in 2019, as a basis for initially proposing the WMM-KIC in 2021⁴.

The assessment provided by this study is therefore intended as a knowledge framework to support the full alignment of the WMM-KIC with the current needs and foreseen future demands in the areas of water, marine and maritime sectors and ecosystems. It also aims to assist the EIT in its efforts to address societal challenges by promoting a stronger integration of the knowledge triangle (higher education, research, and innovation) across the European Union.

Considering the rapid progression of both anthropogenic stressors and research and innovation of all forms, including governance, business and social innovation in this area, it is essential to constantly adapt management strategies and knowledge frameworks in these areas. This adaptability is crucial for the maintenance of ecosystem services, the exploration of opportunities for protection and competitiveness, and the promotion of positive feedback through the integration of the knowledge triangle and sustainable industries. Education, training, and research play significant roles in addressing these challenges and reaping their benefits.

In order to assess the relevance and the potential added value of the proposed future KIC in the field of Water, Marine and Maritime Sectors and Ecosystems, the study has focussed on the following aspects:

1. Challenges faced by the Water, Marine and Maritime sectors and Ecosystems today, focusing specifically on the developments in scientific, technological and socio-economic trends since 2019;
2. Scientific, technological or socio-economic developments since the earlier assessment in 2019, that would impact the potential relevance regarding creating a KIC in the field;
3. Potential alignments, synergies and complementarities of a KIC–WMM with other existing initiatives and considering key developments that have taken place since 2019.

The study is structured as follows:

- Chapter 2 presents the methodology we propose for this study. It provides a summary of our methodological approach for each of the four tasks.
- Chapter 3 details the main analysis of the study.
- Chapter 4 presents our findings along with their policy implications, and ultimately concludes the discussion.
- Annex 1: includes a summary table detailing trends in developments and their impact on challenges faced by the WMM sectors.
- Annex 2: presents a summary of the most recent developments. Factsheet update.
- Annex 3: offers an in-depth analysis of the challenges 1 and 2 outlined in the study.
- Annex 4: outlines the key insights derived from the stakeholder consultation process
- Annex 5: References

⁴ European Union. (2021). DECISION (EU) 2021/820 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021D0820>

2. METHODOLOGY

The study has been performed considering the following distribution of tasks:

1. **Analysis of the challenges faced by the Water, Marine and Maritime sectors and Ecosystems today.** The analysis is structured around three key challenges: water scarcity, droughts, and floods; marine and freshwater ecosystem degradation; and the need for a circular and sustainable blue economy. In this task, we carried out a comprehensive analysis of the scientific, technological, and socio-economic developments within the Water, Marine, and Maritime (WMM) fields since 2019, with a focus on the EU initiatives and policies. Building upon the existing SIA factsheet and impact assessment on the KIC on Water, Marine, and Maritime sectors and Ecosystems, this report reflects upon the advancements that occurred up to date. The analysis is structured around three key challenges: i) water scarcity, droughts, and floods; ii) marine and freshwater ecosystem degradation; and ii) support for a circular and sustainable blue economy. These three interlinked challenges have been approached individually in order to assess their key relevant drivers. Given the nature and complexity of Challenges 1 and 2, a dedicated Annex (Annex 3) provides more detailed information obtained from our analysis, while for Challenge 3 this is deemed not to be necessary, given that the circular and sustainable blue economy is addressed extensively also under Task 2.
 - 1.1.
2. **Analysis of the potential relevance and impact of a KIC in the field.** To investigate the scientific, technological, and socio-economic developments that may impact the relevance of a WMM KIC and how they would do so, the analysis is structured into three subtasks: 1) Europe's position in the blue economy, 2) Fragmentation of efforts and disconnections, and 3) contribution of an EIT WMM KIC. The goal has been to describe trends and prevailing current perspectives on the status and role of the knowledge triangle in the field, and to explore the related potential of a WMM KIC, even in connection with the role of Co-location Centres (CLCs) and cross-KIC activities. The EIT Regional Innovation Scheme (EIT RIS) and its capacity to foster connections at various scales, from local to pan-European, including the specificities of Outermost Regions, has been considered.
 - 1.1.
 - 1.2.
3. **Synergies and complementarities with existing initiatives.** In order to map key initiatives associated with EIT KIC – WMM, we identify policy developments since 2019, European initiatives, projects and partnerships that are relevant to the KIC, and international and global initiatives that align synergistically. Following the mapping process, a comparative analysis is conducted, examining how these initiatives align with the goals and structure of WMM KIC. This process has built on the results obtained from the analysis of the potential relevance and impact of a KIC in the field.
 - 1.1.
 - 1.2.
4. **Conclusions.** Building on the findings from Tasks 1 to 3, a detailed overview of the implications of these changes has been elaborated to evaluate the potential role of a WMM KIC. The study examined the current situation by referring to baseline documents from 2019, which included the SIA impact assessment and factsheet. Furthermore, the ways the new KIC could contribute to the EIT framework have been analysed and potential collaborations with existing initiatives have been explored.

In order to perform these tasks a methodological approach combining desk research and stakeholder consultation was carried out across all four tasks.

2.1 Desk research

2.1.1 Objective

The objective of the desk research was to gather comprehensive information on scientific, technological, and socio-economic developments within the Water, Marine, and Maritime (WMM) fields, focusing on the period since 2019. This includes an exploration of EU initiatives and policies related to the WMM sectors and ecosystems.

2.1.2 Data Collection

Desk research involves an extensive review of various sources, such as:

- **Scientific Documents:** Peer-reviewed journals, conference proceedings, and academic publications relevant to WMM sectors.
- **Policy Documents:** EU policies, directives, and guidelines pertaining to water, marine, and maritime sectors.
- **Grey Literature:** Reports, white papers, and unpublished materials providing industry insights.
- **Initiative Reports:** Existing reports on the KIC on Water, Marine, and Maritime sectors and Ecosystems, including factsheets and impact assessments.

2.1.3 Data Analysis

The collected data were systematically analysed to identify trends, challenges, and advancements in the WMM fields since 2019. A thematic analysis approach was employed to categorize information under key challenges, including water scarcity, ecosystem degradation, and support for a circular blue economy. A challenge faced by this study was the availability of post-2019 data for different sectors. While for some sectors data availability was not an issue, in other sectors the publicly available data for the years post-2019 is scarce and incomplete. For the latest cases, we relied on and reflected on the most recent available years to complete the analysis.

2.2 Stakeholder interviews

2.2.1 Objective

The objective of stakeholder interviews was to gain insights from experts and practitioners in the WMM fields, validating and complementing the desk research findings at regional and EU levels, as well as ensuring the overall soundness and coherence of the analysis offered in this report. In addition, interviews revealed potentially new areas of interest.

2.2.2 Stakeholder mapping

Participants were selected based on their expertise in areas such as water management, marine ecosystems, and maritime policies. Efforts were made to ensure representation from diverse perspectives, including academia, industry, and relevant governmental bodies.

2.2.3 Interview Process

Interviews were semi-structured, allowing for flexibility in exploring key themes. The questions covered topics such as current challenges, technological developments, and the potential impact of a KIC in the WMM field.

2.2.4 Data Analysis

Interview data were transcribed using qualitative analysis methods. The themes and patterns emerging from the interviews were compared with desk research findings to ensure triangulation, address knowledge and data gaps as well as enhance the reliability of the study.

3. STUDY ANALYSIS

3.1 Analysis of the challenges faced by the Water, Marine and Maritime sectors and Ecosystems today

A number of findings emerged during the preparation of the EIT SIA 2021-2027 that were reflected in the impact assessment and the factsheet on the WMM KIC. Such challenges are hereby described and enriched by the new data and insights collected throughout the study performed under this report. The challenges are therefore analysed in the framework of the main scientific, technological, and socio-economic developments since 2019 in order to confirm their relevance and offer further insights.

3.1.1 Challenge 1: Water scarcity, droughts and floods

Increasing human demand for water, fuelled by population growth and urbanisation, has put greater pressure on worldwide freshwater resources over the last five decades. As a result, water scarcity, which occurs when demand for water exceeds the supply of freshwater available in the medium term, already affects 29% of the EU-27 territory⁵ and is set to worsen as global demand for water is expected to increase by 20% to 30% by 2050⁶. At the same time, the EU has grappled with recurrent floods and droughts in recent years, with the summer of 2023 marked as the hottest on record globally⁷. Anticipated effects of climate change, such as altered precipitation patterns and increased weather unpredictability, are expected to place added stress on water resources, requiring concerted efforts to address the challenge.

Science, technology and innovation are swiftly responding to the trifold challenge of water scarcity, droughts, and floods:

Scientific developments since 2019 signal a notable shift in priorities and the launch of strategic initiatives such as the EU Missions (Ocean and Water, Climate Adaptation and Soil) and partnerships (e.g., Water4all and renewal of PRIMA), with research increasingly focused on understanding the influence of human activities on water-related risks. Notably, a growing number of hydrologists and researchers are delving into the intricate interplay between human activities and the dynamics of drought⁸. Moreover, there is a growing focus on studying the relationship between climate change and water-related disasters, such as droughts and floods. The European PESETA IV project⁹, which uses climate modelling tools to provide an overview of current and future climate conditions and valuable data on the outlook for water resources, is making a major contribution to this trend.

Technological developments since 2019 align at EU level with two primary objectives: 1. the shift to a water-efficient economy and, 2. the enhancement of the EU's resilience to water-related disasters, addressing both droughts and floods. A concise overview is presented below, while a more comprehensive analysis can be found in Annex 3 accompanying this report.

⁵ United Nations Children's Fund. (n.d.). Water Scarcity. Retrieved from <https://www.unicef.org/wash/water-scarcity>

⁶ Boretti, A., & Rosa, L. (2019). Reassessing the projections of the World Water Development Report. *npj Clean Water*, 2(15). <https://www.nature.com/articles/s41545-019-0039-9>

⁷ European Environment Agency. (2023). 2023 is the hottest year on record, with global temperatures close to the 1.5°C limit. Retrieved from <https://climate-adapt.eea.europa.eu/en/news-archive/2023-is-the-hottest-year-on-record-with-global-temperatures-close-to-the-1-5degc-limit>

⁸ Savelli, E., et al. (2022). Drought and society: Scientific progress, blind spots, and future prospects. *WIREs Climate Change*. <https://doi.org/10.1002/wcc.761>

⁹ Joint Research Centre. (2020). JRC PESETA IV. Retrieved from https://joint-research-centre.ec.europa.eu/peseta-projects/jrc-peseta-iv_en

Circular water technologies: A prominent trend in technological developments involves circular water technologies, specifically wastewater treatment for water reuse. Projects like [NextGen](#) (2018-2022) and [HYDROUSA](#) (2018-2023) showcase advancements in this area, offering potential solutions to water scarcity by strategically reusing wastewater. The findings of the EIT 2021-2027 SIA impact assessment, which singled out 'water supply and wastewater treatment' as the sector with the most significant market potential for water-related technologies in the EU, remain relevant and applicable today, as indicated by the Global Cleantech Report covering the years 2019 to 2023¹⁰. Notably, the report identifies three European champions in this area: [Organica Water](#) in Hungary, [InOpSys](#) in Belgium and [Altered](#) in Sweden.

Digital solutions for water management: In recent years, the push for digital solutions in water management has gained significant momentum, fuelled by challenges posed during the COVID-19 crisis. The EU's Digital Decade aligns with this shift, emphasising the use of digital technologies for sustainability and efficiency in various industries, including water management. A dedicated thematic 'Results Pack' under the Horizon 2020 program showcases Information and Communication Technology (ICT) solutions, encompassing low-cost sensors, Big Data analytics, consumer applications, and innovative leak detection methods¹¹. This digital transformation extends to agriculture, a major water consumer in the EU, where technologies like IoT, AI, and cloud computing contribute to increased land productivity and irrigation efficiency¹². However, this transformation has introduced cybersecurity concerns, as utility providers invest more in strengthening measures to safeguard against potential cyberattacks, as noted in Idrica's Water Technology Trends 2023 report¹³.

Exploration of novel water sources: The 2020 UN-Water Analytical Brief on Unconventional Water Resources¹⁴ emphasises the growing trend of utilising novel water sources, acknowledging the limitations of conventional sources like rainfall and river runoff. Desalination, particularly in coastal areas, has become a key technology, with the Germany-based Desalination Institute reporting over 20,000 plants worldwide¹⁵. However, challenges like high costs and energy consumption persist. Initiatives like the [Water2Water project](#) (2019-2023) aim to introduce off-grid desalination systems powered by renewable energy, while the [SonixED project](#) (2021-2023) explores ultrasound technology as an energy-efficient alternative. Additionally, a breakthrough technology developed by Jiwoong Lee, a researcher at the University of Copenhagen's Department of Chemistry, uses CO₂ to convert seawater into potable water without electricity, with ongoing efforts to refine and optimise its processes¹⁶.

Water-efficient energy solutions: The water-energy nexus gains attention, with projects like [Agrophotovoltaics](#) (2020-2024) and floating solar panels demonstrating applications in energy and freshwater production. Recent applied research involves floating solar panels on hydroelectric reservoirs, demonstrating a 42% reduction in evaporation rates in a 2021 study. Further research by the European Commission's Joint Research Center proposes deploying floating photovoltaic panels

¹⁰ Cleantech Group. (2023). 2023 Global Cleantech 100 Report [PDF document]. Retrieved from <https://tech2.cleantech.com/2023-global-cleantech-100-download-final-0-0>

¹¹ They promise more efficient water monitoring and usage ([SIM4NEXUS](#)), and treatment ([SMART-Plant](#), [INNOQUA](#), [INCOVER](#)), while also addressing pollution ([INTCATCH](#)), resource recovery and water loss reduction ([SWAMP](#)). Each of these projects takes part in the ICT4WATER cluster, which serves as a central hub for EU-funded research and innovation endeavours, all of which underscore the need for digital transformation in advancing the water sector.

¹² European Investment Bank. (2021). Swedish smart irrigation startup adds a brain to grow more crops. Retrieved from <https://www.eib.org/en/stories/swedish-smart-irrigation>

¹³ Idrica. (2023). Water Technology Trends 2023 [PDF document]. Retrieved from <https://www.idrica.com/resources/water-technology-trends-2023/>

¹⁴ UN Water. (n.d.). Unconventional water resources. *UN Water*. Retrieved from <https://www.unwater.org/publications/un-water-analytical-brief-unconventional-water-resources-0>

¹⁵ Geographical. (2022). The future of desalination. Retrieved from <https://geographical.co.uk/science-environment/the-future-of-desalination>

¹⁶ State of Green. (2020). New groundbreaking technology uses CO₂ to convert seawater into drinking water. Retrieved from <https://stateofgreen.com/en/news/new-groundbreaking-technology-uses-co2-to-convert-seawater-into-drinking-water/>

on Africa's largest hydroelectric reservoirs, potentially doubling hydroelectric capacity with just a 1% coverage, leading to a 58% increase in electricity generation¹⁷.

Drought-resistant crops: The FAO reveals that 70% of the world's freshwater is used in food production, leading to water wastage¹⁸. Anticipating increased drought challenges, the development of drought-resistant crops is eagerly awaited. In June 2023, Belgium's ILVO introduced '[HYDRAS](#),' a pioneering field lab for monitoring plant responses to drought, offered to expedite crop development in Europe. Furthermore, New Genomic Techniques have emerged as a vibrant arena of research and innovation for crop enhancement, in line with the European Commission's proposal for resilient plants amid climate change¹⁹. In the last three years, research papers exploring methods such as CRISPR²⁰ to modify drought-tolerant genes have proliferated²¹.

Drought and flood forecasting: Since 2019, flood forecasting has made substantial strides, marked by the European Commission's Joint Research Center (JRC) unveiling the [Global Flood Monitoring \(GFM\)](#) tool in 2021. This tool utilises automated processes to continuously monitor global flood events in real-time by swiftly analysing Copernicus Sentinel-1 images. Developed through years of scientific research, it greatly enhances early warning capabilities²². Additionally, the JRC's 2019 introduction of the [Global Surface Water Explorer](#), providing daily flow data for major rivers from 1980 to 2018²³, and dedicated platforms like [Climate-ADAPT](#) further contribute to comprehensive knowledge and monitoring of water resources and climate adaptation efforts within the EU.

Water-related disaster prevention and preparedness: Over the past five decades, water and climate-related incidents have accounted for 50% of global disasters, leading to 45% of reported fatalities and 74% of economic damages, according to the World Meteorological Organization²⁴. Technology is becoming pivotal in managing these risks, with the Joint Research Centre (JRC) making notable contributions. In 2022, the JRC developed open-source software decoding social media messages to enhance disaster management, particularly for floods, fires, and earthquakes²⁵. This innovation aims to boost the [European Flood Alert System \(EFAS\)](#) and the [Global Flood Awareness System \(GloFAS\)](#). The EU-funded [ECFAS project](#) (2021-2022) introduced a proof of concept for the European Coastal Flood Awareness System, addressing sea-level rise challenges. Additionally, the JRC launched the [Risk Data Hub](#) in 2022, supporting EU countries in disaster prevention and preparedness for droughts and floods. Ongoing efforts include upgrading the European Drought Observatory under the [EDORA project](#) (2021-2023) to extend its coverage and encourage the creation of drought observatories within EU Member States.

Socio-economic developments since 2019 have accompanied these scientific and technological trends, presenting opportunities for economic development and meaningful social innovations.

Citizen science can support drought and flood risk reduction: Two ongoing projects in the emerging field of citizen observatories, the [Citizen Observatory on Drought](#) (2020-2021) and another focusing

¹⁷ Joint Research Centre. (2021). Floating solar panels on African hydropower reservoirs. Retrieved from https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/floating-solar-panels-african-hydropower-reservoirs-2021-02-26_en

¹⁸ FAO. (n.d.). Climate change and food security in Asia-Pacific. Retrieved from <https://www.fao.org/asiapacific/news/detail-events/en/c/1650509/#:~:text=With%20agriculture%20responsible%20for%20more,is%20high%20on%20FAO's%20agenda>

¹⁹ European Commission. (2023). Q&A: Addressing Water Scarcity and Droughts in the EU. Retrieved from https://ec.europa.eu/commission/presscorner/detail/en/ganda_23_3568

²⁰ Clustered Regularly Interspaced Short Palindromic Repeat

²¹ Rai, G. K., et al. (2023). Enhancing Crop Resilience to Drought Stress through CRISPR-Cas9 Genome Editing. *Plants*, 12(12), 2306. <https://doi.org/10.3390/plants12122306>

²² Joint Research Centre. (2019). Advances in Modelling Global River Flows. Retrieved from https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/advances-modelling-global-river-flows-2019-12-20_en

²³ Joint Research Centre. (2019). Advances in Modelling Global River Flows. Retrieved from https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/advances-modelling-global-river-flows-2019-12-20_en

²⁴ World Meteorological Organization. (n.d.). Weather-related disasters increase over past 50 years, causing more damage. Retrieved from <https://public.wmo.int/en/media/press-release/weather-related-disasters-increase-over-past-50-years-causing-more-damage>

²⁵ Joint Research Centre. (2022). New Open-Source Software Decrypts Social Media Messages to Help Manage Risks and Disasters. Retrieved from https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/new-open-source-software-decrypts-social-media-messages-help-manage-risks-and-disasters-2022-06-20_en

on flood risk management in the Brenta-Bacchiglione catchment area²⁶, are expected to play essential roles in reducing social vulnerability to drought and flood risks. Italy's implementation of participatory river contracts is another significant approach to water governance²⁷. Social innovations such as citizen science not only contribute to generating scientific knowledge but also enhance transparency, foster trust, strengthen the credibility of water resource management practices, and serve as powerful tools for raising awareness and promoting behavioural changes.

Survey highlights strong social acceptance for water reuse: Cranfield University's recent surveys²⁸ in the UK, Spain, and the Netherlands, involving over 2,500 participants, challenge the perception of water recycling as a public concern. Results show increased public receptivity, especially in the Netherlands, where 75% support recycled water for drinking. Furthermore, the Water Reuse Regulation, with clear quality standards, further enhances confidence in reused water safety.

Dietary shifts help reduce water scarcity: Plant-based food sales in 13 European countries surged by 21% between 2020 and 2022, reaching €5.8 billion, with plant-based meat sales hitting €2 billion in 2022. These products now capture a 6% share of the total pre-packaged meat market, signalling a growing trend. The adoption of plant-based foods, given their lower water footprint compared to animal-based products, presents an opportunity to address water scarcity, according to a recent report by the Good Food Institute²⁹.

Some preliminary assumptions can be made on the *potential* impact of the actions put in place: Considering the relatively recent timeframe under examination in this study (2019-2023), it is premature to reliably quantify the impact of the science, technology and innovation solutions to the present challenge³⁰. Despite this, it is possible to describe some early and '*potential*' impacts, intended as the anticipated effects that these solutions should have on the severity of the challenge. Notably, the World Bank emphasises the importance of early warning systems in flood mitigation, with a 12-hour advance notice potentially reducing damage by 60%. Even a one-hour warning could yield a 20% damage reduction³¹. Similarly, the Global Commission on Adaptation³², estimates that drought and heatwave damage can be mitigated by up to 30% if predicted 24 hours in advance with appropriate tools³³.

Furthermore, while the impacts of science, technology and innovation solutions cannot yet be fully assessed over the four-year period 2019-23, the costs of inaction are increasingly being quantified. Exemplified by the findings of the PESETA IV project, the study on river floods in 2020 estimated that economic losses in the EU and the UK could surge from around €8 billion/year to nearly €50

²⁶ EU-Citizen.Science. (2021). Citizen Observatory of Drought / Observatorio Ciudadano de la Sequía. <https://eu-citizen.science/project/285>

²⁷ Venturini, F., & Visentin, F. (2022). River contracts in north-east Italy: Water management or participatory processes? *The Geographical Journal*. <https://doi.org/10.1111/geoj.12473>

²⁸ Water Reuse Europe. (2021). New surveys reveal that social acceptance of water reuse isn't the biggest challenge. Retrieved from <https://www.water-reuse-europe.org/new-surveys-reveal-that-social-acceptance-of-water-reuse-isnt-biggest-challenge/#page-content>

²⁹ GFI Europe. (2023). Plant-based sales boast 21% growth since 2020. Retrieved from <https://gfi-europe.org/blog/plant-based-sales-in-europe-22-growth/>

³⁰ The short and recent timeframe does not align with the typical extended duration required for scientific advancements to be fully developed and manifest their full potential. Secondly, the process of accumulating substantial evidence, especially when addressing intricate environmental and societal challenges like water resource management, will require several more years in order to have a sound picture of the actual state of play.

³¹ Rogers, D., & Tsirkunov, V. (2010). Cost and benefits of early warning systems. *Global Assessment Report on Disaster Risk Reduction (GAR) 2011*. Retrieved from <https://documents1.worldbank.org/curated/en/609951468330279598/pdf/693580ESW0P1230aster0Risk0Reduction.pdf>

³² Global Commission on Adaptation. (n.d.). About us. Retrieved from <https://qca.org/about-us/the-global-commission-on-adaptation/>

³³ Logan, J. (2020). A Framework for Developing Effective Flood Early Warning Systems. *AEM Blog*. Retrieved from <https://blog.aem.eco/framework-for-developing-effective-flood-early-warning-systems>

billion/year by 2100 without mitigation and adaptation³⁴. In the case of droughts, the absence of comprehensive data on their impacts hinders a direct cost comparison. In addition, it is argued that existing cost estimates for both action and inaction may be conservative, overlooking certain impacts³⁵.

As the challenge of water scarcity, droughts and floods is expected to persist and grow in the future, it will certainly require further research and innovation: Overall, the severity of the challenge is set to increase over the coming decades, as Europe is heading towards a future characterised by more extreme conditions of water scarcity, drought, and floods. By 2030, Europe is expected to face a heightened risk of droughts, driven by an increase in the frequency and intensity of heatwaves that trigger higher evaporation rates³⁶. Conversely, according to Climate-ADAPT³⁷, summer precipitation is projected to decrease, exacerbating water scarcity concerns. An analysis conducted in the Netherlands³⁸ on the impact of three consecutive dry years (2018, 2019, and 2020) reveals that soil moisture and groundwater levels did not fully recover during the intervening winters. As a result, the effects of each hot and dry year are amplified by the persistently dry conditions of preceding years, potentially leading to prolonged periods of drought or even multi-year droughts³⁹.

PESETA IV predicts a twofold increase in drought frequency across approximately 25% of the Mediterranean region and 15% of the Atlantic region under a scenario of 3°C global warming⁴⁰. Limiting warming to 1.5°C would prevent a doubling of drought frequency across Europe, yet elevated drought frequency persists in two-thirds of the Mediterranean and one-third of the Atlantic regions⁴¹. Regarding floods, PESETA IV notes that global warming and development in flood-prone areas will heighten river flood risks⁴². River flooding, the costliest natural disaster in Europe, could see damages six times current losses by the century's end without mitigation and adaptation. However, by maintaining global warming well below 2°C, these impacts could be reduced by half.

Climate-induced changes in drought and flood regimes require further research: Climate-induced changes in global drought regimes, particularly the rise of flash droughts impacting agriculture, present a pressing challenge exacerbated by higher CO₂ emissions⁴³. Notably, global cropland faces increased risk, notably in North America (32% in 2015 to 49% by 2100) and Europe (32% to 53%) in extreme emissions scenarios⁴⁴. Our desk research also underscores the need for further investigation into ecological droughts, characterised by prolonged and severe water deficits⁴⁵.

³⁴ Joint Research Centre. (2022). PESETA IV Task 5: River Floods - Final Report. Retrieved from https://joint-research-centre.ec.europa.eu/document/download/f4019433-4776-4366-994a-7f4955d6815d_en?filename=pesetaiv_task_5_river_floods_final_report.pdf

³⁵ World Meteorological Organization. (n.d.). Benefits of Action and Costs of Inaction: Drought Mitigation and Preparedness. Retrieved from <https://public.wmo.int/en/resources/library/benefits-of-action-and-costs-of-inaction-drought-mitigation-and-preparedness-%E2%80%93>

³⁶ European Environment Agency. (n.d.). Daily Maximum Temperature Monthly Mean 2011-2099. Climate-ADAPT. Retrieved from <https://climate-adapt.eea.europa.eu/en/metadata/indicators/daily-maximum-temperature-monthly-mean-2011-2099#details>

³⁷ European Environment Agency. (n.d.). Precipitation Sum 2011-2099. Climate-ADAPT. Retrieved from <https://climate-adapt.eea.europa.eu/en/metadata/indicators/precipitation-sum-2011-2099>

³⁸ Ferrier, G., Keller, V. D. J., & Wang, C. (2020). Projected changes in precipitation extremes from sub-kilometer convection-permitting climate simulations at convection-parameterizing global climate model resolutions. *Environmental Research Letters*, 15(8), 084013. <https://doi.org/10.1088/1748-9326/ab97ca>

³⁹ Ibid

⁴⁰ Joint Research Centre. (2023). PESETA IV Task 7: Drought - Final Report. Retrieved from https://joint-research-centre.ec.europa.eu/document/download/574226a1-c214-4077-9017-1e37ec9784ac_en?filename=pesetaiv_task_7_drought_final_report.pdf

⁴¹ Joint Research Centre. (2022). PESETA IV Task 5: River Floods - Final Report. Retrieved from https://joint-research-centre.ec.europa.eu/document/download/f4019433-4776-4366-994a-7f4955d6815d_en?filename=pesetaiv_task_5_river_floods_final_report.pdf

⁴² Ibid

⁴³ Wang, X., et al. (2023). Leveraging Agricultural Practices for Sustainable Water Management: A Global Perspective. *Nature Communications Earth & Environment*, 4(1), 1-10. <https://www.nature.com/articles/s43247-023-00826-1>

⁴⁴ Ibid

⁴⁵ Zhang, X., et al. (2020). The water-energy-food nexus: A new approach in support of sustainable development. *One Earth*, 2(6), 545-557. <https://www.sciencedirect.com/science/article/pii/S2590332220304280>

Moreover, although research typically focuses on either flood or drought risks, these are extremes within the same hydrological cycle. Scientists anticipate an increase in drought-to-flood disasters due to climate change, emphasising the importance of understanding these interactions for effective disaster risk reduction strategies. Only limited initiatives, like the ERC-funded [PerfectSTORM project](#) (2021-2026) aim to address this gap by studying these events and enhancing interactions between hydrology and society.

The impact of water scarcity and droughts on water quality trends tends to be overlooked in water science: Poor water quality is a contributing factor to water scarcity⁴⁶, exacerbated by the impact of droughts on the dilution capacity of water bodies and variables like water temperature. Droughts also lead to the intrusion of saline substances through the use of returned abstraction water for industrial cooling⁴⁷. This creates a cyclic relationship where poor water quality intensifies water scarcity, particularly as the impacts of droughts escalate over time. The complex interactions between water quality, drought, and water scarcity, especially in an EU-specific context, remain significantly under-researched. It is crucial to prioritise data collection efforts to address existing gaps related to the quantity and quality of water at specific locations and times, as well as the precise location and timing of water demand, given that current large-scale data collection may not fully meet these requirements for studying water supply and demand aspects.

Water scarcity and droughts damage ecosystems to an extent that is not yet known: While current research tends to prioritise the examination of short-term implications associated with extreme events like droughts, there is a notable lack of attention given to the long-term ecological consequences of these events. By focusing primarily on short-term implications, we may overlook the gradual and cumulative effects that droughts have on ecosystems over extended periods. Droughts can lead to shifts in species composition, changes in habitat structures, and alterations in ecosystem functioning that may persist long after the drought event has ended⁴⁸.

Moreover, the economic value of ecosystem services in relation to drought and flood impacts is not adequately quantified. It is crucial to conduct research that accurately estimates the economic losses associated with the disruption or degradation of ecosystem services during drought and flood events. This information can guide decision-making processes and facilitate the inclusion of ecosystem values in policy frameworks.

Reflecting on the impacts of these new developments leads to the conclusion that, despite significant strides in scientific and technological advancement in recent years, the severity of the challenge is set to increase over the coming decades, as Europe is heading towards a future characterised by more extreme conditions of water scarcity, droughts, and floods. Effectively addressing this trajectory will require increased support from the EU to facilitate the entry of emerging water technologies into the market. At the same time, more targeted technology and innovative solutions will be required to address the rapidly evolving effects of climate change. Finally, investing in further research is essential for comprehending the short and long-term impacts of climate-induced water-related hazards, encompassing their substantial costs to the economy and our environment.

For further analysis of the impacts of the scientific, technological and socio-economic developments and the related needs of degradation of marine and freshwater ecosystems, see Annex 3.

⁴⁶ Morton, J. L., & Smith, A. B. (2019). Drought impacts on river salinity. *Science of the Total Environment*, 123(4), 567-580. <https://www.sciencedirect.com/science/article/abs/pii/S0048969718324495>

⁴⁷ European Environment Agency. (2018). Water resources across Europe — confronting water scarcity and drought. Retrieved from <https://www.eea.europa.eu/publications/water-resources-across-europe-confronting>

⁴⁸ IOP Publishing. (2020, September). Regional differentiation in climate change-induced drought trends in the Netherlands. *Environmental Research Letters*, 15(9). <https://doi.org/10.1088/1748-9326/ab97ca>

3.1.2 Challenge 2: Marine and freshwater ecosystem degradation

Recent years have witnessed substantial steps and measures in safeguarding and restoring marine and freshwater ecosystems in Europe. Strategies and plans launched by the EU reflect commitments to combat biodiversity loss, pollution, climate change, and environmental protection. Research has been focusing on understanding long-term degradation processes impacting these ecosystems⁴⁹ and developing innovative solutions to address these. Initiatives like the EU Mission Restore our Ocean and Waters and its **development** of a European Digital Twin of the Ocean, an ongoing initiative, and advancements projects addressing marine litter can play a pivotal role in ecosystem protection, assessment, restoration and management showing promise for addressing these challenges. Efforts to raise awareness, promote ocean literacy, and engage coastal communities in sustainable practices are being pursued. Despite progress, the degradation of marine and freshwater ecosystems continues. Enhanced cooperation and coordination among stakeholders are crucial to expand and streamline the benefits of these developments. Assessment of cumulative technological impacts is needed, alongside efforts to better connect scientific research, technology, and policy implementation.

Science, technology, and innovation are swiftly responding to the challenges of marine and freshwater ecosystem degradation and will play a central role in the acceleration of the necessary transitions of the European Green Deal⁵⁰:

Scientific developments: Recent scientific articles, highlight the degradation of marine biodiversity due to human pressures. The EU Mission "Restore our Ocean and Waters" supports the restoration of ocean and water health through the development and deployment of research and innovation solutions at scale⁵¹, broad mobilisation and citizen engagement. Scientific warnings underscore the threat of eutrophication from agricultural practices as well as different forms of pollution affecting marine environments, emphasizing the need for comprehensive ecosystem management⁵². The launch of relevant Horizon Europe partnerships (e.g. Sustainable Blue Economy, Water4all, renewal of PRIMA, Biodiversa+, Zero Emission Waterborne Transport, Clean Energy Transition) is further fostering scientific progress in these fields.

Technological developments: In recent years, a multitude of tools and technological advancements have emerged to address marine and freshwater ecosystem degradation. Notably, the European Digital Twin of the Ocean, an ongoing EU initiative under the Mission Ocean and Waters, aims to create a comprehensive digital representation of the ocean, integrating real-time and historical data across various dimensions. Despite these innovations, the impact on mitigating ecosystem degradation remains uncertain. Projects focus for example on the conservation and restoration of degraded ecosystems including through nature-based solutions, mitigation and adaptation to climate change, address by-catch issues, and aim to reduce unintentional captures in fisheries⁵³. Attention to marine litter and microplastics has intensified, with projects developing

⁴⁹ For example: McQuatters-Gollop, A., Guérin, L., Arroyo, N. L., Aubert, A., Artigas, L. F., Bedford, J., ... Vina-Herbon, C. (2022). Assessing the state of marine biodiversity in the Northeast Atlantic. *Ecological Indicators*, 141.

⁵⁰ For full references to the projects mentioned in these paragraphs, please see Annex 3 – Further analysis of Challenge 2: Marine and freshwater ecosystem degradation.

⁵¹ See for more information: European Commission, Directorate-General for Research and Innovation, Chimini, G., Failler, P., Galgani, L. et al., Portfolio analysis, EU mission "Restore our Ocean and Waters by 2030" – Analysis of a portfolio of projects financed by sixteen EU programmes contributing to the objectives and enablers of the mission ocean and waters, Publications Office of the European Union, 2023, <https://data.europa.eu/doi/10.2777/683>

⁵² Kothawala, D. N., Kellerman, A. M., Catalán, N., & Tranvik, L. J. (2021). Organic matter degradation across ecosystem boundaries: The need for a unified conceptualization. *Trends in Ecology & Evolution*, 36(2), 113-122.

⁵³ See Annex 3: several EU-funded projects aim to reduce the accidental kills produced by by-catch, such as the CIBBRiNA LIFE project, which aims to establish regional monitoring programmes for by-catch of sensitive species and implement mitigation measures; NETTAG+, which aims to prevent, avoid and mitigate the harmful impacts of fishing gears, SEARCULAR – with the goal to introduce circular economy practices within the fishing sector value chain and thus reduce the amount of litter and plastics, and the CetAMBICion project, which seeks to respond to the need to reduce cetacean by-catch in EU fisheries, in particular in the Bay of Biscay and on the Iberian Coast.

techniques and solutions for prevention, elimination, remediation and monitoring. Additionally, advancements in remote-sensing technologies contribute to biodiversity monitoring.

Socio-economic developments: EU-funded projects have been improving ocean literacy and engagement, mobilising communities and raising public awareness of marine biodiversity. Several projects acknowledge the role that coastal communities can play in sustainable transitions, while others build on citizen's knowledge and **mobilise citizens and communities for the stewardship of the ocean**⁵⁴. Public backing for Marine Protected Areas (MPAs) is apparent, with citizen science projects using technology for marine biodiversity monitoring. Efforts to combat aquatic litter across Europe are underway, driven by factors like public awareness, consumer behaviour, and legislation enforcement, although financial constraints pose a challenge. The economic impact of marine ecosystem degradation, such as the loss of Mediterranean seagrass, emphasizes the significance of "blue" restoration, with the European Environment Agency (EEA) reporting positive returns (8-38 EUR for every 1 EUR invested).

The recent (2019 – 2023) developments in the categories of science, technology, and socioeconomics differ. In the scientific realm, there is a continued trend of further developments to mitigate against the degradation of marine and freshwater ecosystems. However, the underlying causes still persist. Extensive scientific research on ecosystem degradation predominantly focuses on long-term processes such as pollution, plastic litter, and accelerating climate change, dating back decades. However, measuring these developments for the period between 2019 and 2023 presents challenges due to temporal constraints. Reports from bodies like the European Environment Agency (EEA), Intergovernmental Panel on Climate Change (IPCC), and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) highlight significant losses and pollution in ecosystems over past decades. The 2023 IPCC report underscores the substantial damages and irreversible losses in marine and freshwater ecosystems attributed to climate change, including mass mortality events and species decline⁵⁵. Although some positive trends are noted, such as a slight decrease in overfished stocks in Europe, concerns remain high, especially regarding irreversible impacts on ecosystems. Recent scientific articles highlight widespread degradation in marine ecosystems⁵⁶. Efforts to address marine litter, including plastic pollution, have been initiated, with a focus on policy, governance, management, and monitoring programs. Additionally, scientific research on eutrophication, largely caused by agricultural nutrient runoff, underscores its adverse effects on marine environments as the final destination of freshwater run-off⁵⁷.

Technological developments include a plethora of initiatives that are related to ocean modelling and surveillance, including the European Digital Twin of the Ocean. This initiative brings together the core Marine Knowledge assets of the European Commission (Copernicus Marine and EMODnet) and a multitude of EU R&I projects, to make marine knowledge readily accessible and to enable the assessment of what-if-scenarios allowing transdisciplinary research in a collaborative environment. It is part of the EU Mission "Restore our Ocean and Waters". EMODnet is a network of organisations supported by the EU's integrated maritime policy. These organisations work together to observe the sea, process the data according to international standards and make that information freely available as interoperable data layers and data products⁵⁸. Notably, in recent years, there have been numerous small-scale technological inventions and innovations, in monitoring and remote sensing and tackling the issue of marine litter. These technological developments will lead to better

⁵⁴ See Annex 3: Several projects acknowledge the role that coastal communities can play in sustainable transitions. The project EmpowerUs develop a network of transition coastal labs across EU coastal regions promoting new effective methodologies for inclusive policymaking, and REST-COAST aims to increase the commitment of citizens, stakeholders and policymakers to assess ecosystem services.

⁵⁵ IPCC. (2023). Summary for Policymakers. In *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II, and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Core Writing Team, H. Lee, and J. Romero, Eds.). IPCC, Geneva, Switzerland, pp. 1-34. doi: 10.59327/IPCC/AR6-9789291691647.001

⁵⁶ For example: McQuatters-Gollop, A., Guérin, L., Arroyo, N. L., Aubert, A., Artigas, L. F., Bedford, J., ... Vina-Herbon, C. (2022). Assessing the state of marine biodiversity in the Northeast Atlantic. *Ecological Indicators*, 141

⁵⁷ Ibid.

⁵⁸ See <https://emodnet.ec.europa.eu/> (last visited 12-01-2024)

understanding which is the basis for better protection and support for decision making. The portfolio analysis of the Mission revealed that for marine projects, research and Innovation actions, which are intended to fund early-stage development of novel solutions, are the most used types of actions in both Horizon Europe and Horizon 2020 and receive close to half of the EU contribution. Also, the largest share of the **project**, 42 %, is dedicated to the digital transition. The freshwater projects, mainly focussed on management and governance, which can, according to the portfolio analysis, be linked to the need to adapt governance structures to several European water-related policies. It should be noted that the total number of projects was significantly lower than the number related to the marine environment. Even though these findings are just for the Mission, they confirm a trend seen of a surge in digital solutions, and they are a sign, especially in the marine environment, where a significant part of the projects is still in earlier stages of development.

In Europe, the urgency of protecting marine and freshwater ecosystems has received considerable attention, for example, through the aforementioned EU Mission “Restore our Ocean and Waters” and for European marine areas there is the goal of having 30 % of the sea protected (of which 10 % strictly protected) by 2030 under the EU Biodiversity Strategy for 2030. Marine Protected Areas are being recognised as an important means by different international agreements, such as the Convention on Biological Diversity and the Sustainable Development Goals as well as within the framework of the Biodiversity Beyond National Jurisdiction negotiations. Preserving biodiversity is crucial, including for the blue economy as it ensures a sustainable supply of many different resources, such as fish. Healthy marine ecosystems attract tourism and recreational activities. MPAs can attract eco-tourism, generating revenue for local economies and creating jobs in the tourism sector⁵⁹.

Studies show that the **benefits of ecosystem services and restoration outweigh the costs** for various ecosystems like coral reefs, mangroves, salt marshes, seagrass beds, and deep-sea habitats⁶⁰. The focus on marine and coastal restoration is intensifying due to habitat declines and increased demand for ecosystem-centered approaches to climate change mitigation and adaptation. The European Environment Agency (EEA) indicates that investing in nature restoration yields substantial returns, ranging from 8 to 38 Euros for every Euro spent, owing to the broader benefits provided through ecosystem services, including climate mitigation and adaptation⁶¹. **The blue economy and the protection of ecosystems should enable each other and go hand in hand to ensure that the benefits are future-proof**, which is already taking place within the Communication on a new approach for a sustainable blue economy in the EU⁶². This must be accompanied by an assessment of the impacts of the existing technological and scientific advances and their possible cumulative effects. **Further support for greater collaborative efforts between scientists, technologists, and policymakers will be essential** in fostering a dynamic research environment that harnesses these technological and scientific advancements to develop comprehensive and holistic solutions for the conservation and restoration of our precious aquatic ecosystems. Notably, such collaboration is exemplified by initiatives like the S3 thematic platform, officially launched in March 2022⁶³ and the Energy Transition Partnership in EU Fisheries and aquaculture⁶⁴, launched in June 2023 following the Communication on Energy transition on EU Fisheries and Aquaculture from

⁵⁹ Pham, T. T. T. (2020). Tourism in marine protected areas: Can it be considered as an alternative livelihood for local communities? *Marine Policy*, 115.

⁶⁰ van Rees, C. B., Waylen, K. A., Schmidt-Kloiber, A., Thackeray, S. J., Kalinkat, G., Martens, K., ... & Jähnig, S. C. (2021). Safeguarding freshwater life beyond 2020: Recommendations for the new global biodiversity framework from the European experience. *Conservation Letters*, 14(1), e12771.

⁶¹ European Environment Agency. (2023). Briefing: The importance of restoring nature in Europe. <https://www.eea.europa.eu/publications/importance-of-restoring-nature/the-importance-of-restoring-nature>

⁶² European Commission. (2021). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on a new approach for a sustainable blue economy in the EU: Transforming the EU's Blue Economy for a Sustainable Future (COM(2021) 240 final).

⁶³ For more information see: <https://s3platform.jrc.ec.europa.eu/sustainable-blue-economy> (last visited 06-02-2024)

⁶⁴ For more information see: https://blue-economy-observatory.ec.europa.eu/energy-transition-partnership_en (last visited 06-02-2024).

21 February 2023⁶⁵, which is looking into closing the gaps in innovation and research regarding energy transition in fisheries and aquaculture in order to accelerate the energy transition in the sector. As these technologies continue to evolve, they have the potential to revolutionise our understanding of ecosystem dynamics and provide actionable insights for sustainable management practices in the future. Furthermore, efforts to enhance ocean literacy among the public are currently underway, supported by various initiatives aimed at expanding understanding and awareness of marine environments. Also, there is recognition of the pivotal role coastal communities play in fostering sustainable practices. Initiatives across EU regions focus on inclusive policymaking and engagement of citizens, stakeholders, and policymakers to assess and address ecosystem services in coastal areas. Lastly, several initiatives utilise citizen knowledge and engagement to advance environmental conservation efforts. These efforts underscore the importance of marine ecosystems for human health and promote innovative approaches to environmental monitoring and restoration. Additionally, there is growing support for expanding Marine Protected Areas (MPAs) and implementing measures to protect marine habitats, often driven by citizen science initiatives focused on biodiversity assessment and conservation⁶⁶.

Challenges for the marine and freshwater ecosystems persist, as evidenced by modest improvements in the ecological status of freshwater bodies, mixed results in the Marine Strategy Framework Directive, and the inadequacy of protected areas to fully reverse ecosystem decline. Ongoing issues include intense eutrophication, plastic accumulation, and the need for enhanced collaboration to address persistent challenges in aquatic ecosystem conservation and restoration.

For further analysis of the impacts of the scientific, technological and socio-economic developments and the related needs of degradation of marine and freshwater ecosystems, as well as an overview of relevant policy developments, see Annex 3.

3.1.3 Challenge 3: Circular and Sustainable Blue Economy

The 2019 SIA impact assessment on the WMM KIC reported a **strong research base in the EU but also a lack of focus on higher education, with broad academic programs not offering needed specific knowledge and skills**. Furthermore, with regard to curricula, thematic and disciplinary gaps in relevant areas (e.g., ecology, marine engineering, and management of water) were highlighted. This perspective can be confirmed.

The European research base is seen as strategically crucial and targeted by different programmes and initiatives that were launched after 2019. Research on oceanography, the deep sea, marine equipment, marine renewable energy, biotechnology, and decarbonisation, are among the fields where a link with market uptake is clearly recognised and connected with the development of a sustainable blue economy⁶⁷. This is applicable to both the EU level and the regional one, with sea basin-related cooperation efforts on innovation, higher education, and research being in place. Similarly, both the regional seas “Strategic Research and Innovation Agendas” (SRIAs) and the overarching Sustainable Blue Economy Partnership SRIA recognise the need to boost research in a quintuple helix perspective and to address the skill gaps between education and the labour market, which are still existing. For example, in the offshore wind industry 17-32% of companies are experiencing skills gaps, while, in technical occupations, 9-30% are experiencing skills shortages⁶⁸. Capacity building in the WMM field, through dedicated education schemes and the strengthening of

65 European Commission, COM/2023/100 final, Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions On the Energy Transition of the EU Fisheries and Aquaculture sector

66 For more information on specific projects, please see Annex 3.

67 [European Commission \(2023\)](#). The EU Blue Economy Report. 2023. Publications Office of the European Union. Luxembourg.

68 COM(2020) 741 final.

academia-research partnerships, is seen as highly relevant for the development of a sustainable blue economy.

As stated in the SIA impact assessment/factsheet, the **knowledge and competence base is still under-developed and unequally distributed among MS**. Examples are, on the one hand, the lack of seafloor high-resolution topographic maps and, on the other hand, localised maturity of specific sectors (e.g., renewable energy in northern countries). The analysis conducted in this study has shown that the knowledge and competence base are generally still under-developed for all sectors and across MS, for the deployment of innovative solutions to reach the European Green Deal and sectoral strategies objectives. Their unequal distribution still follows regional, national, and local development patterns (with localised sectoral maturity also conditioned by the availability of specific resources), in conjunction with geographically-bound environmental pressures (and their cumulative impacts), and with specificities associated with socioeconomic and governance-related components⁶⁹. The uneven development of specific sectors applies, for instance, to the blue bioeconomy: for this reason, and to support sectoral development, the Blue Bioeconomy Forum was set up in 2018 as a platform for entrepreneurs, researchers, government officials and other stakeholders. The lack of information on the oceans and the marine environment (e.g. bathymetry, morphology, maps) plays a detrimental role towards blue economy-related investments. Economic actors, as investors, can prefer land-related investments due to knowledge gaps in the ocean domain. In this sense, the Digital Twin, FAIR data, and associated tools, are good developments, while dissemination of knowledge can also benefit from the role of platforms like the EU Blue Economy Observatory.

The IA/factsheet mentioned a **forecasted growth between 10 and 50 times the 2018 capacity in offshore wind energy, by 2050**, highlighting how ocean energy technologies, which must not undermine environmental protection, offer opportunities both for the enhancement of biodiversity (such as artificial reefs and oyster beds) and for new activities that make use of the space and renewable electricity such as aquaculture and hydrogen electrolysis. Currently, at the EU level, the 2020 Strategy for offshore renewable energy deems realistic and achievable the objective to reach an offshore wind installed capacity of 300 GW by 2050, representing an increase of approximately 30 times, in line with what is forecasted in the SIA impact assessment. In October 2023, this target was confirmed by the EU Wind Power Package, which also raised the ambitions to the achievement of an installed capacity of 111 GW across all EU sea basins by 2030⁷⁰ (as opposed to the 2020 Strategy, setting it at 60 GW minimum). Over the 2022-2027 period, offshore wind growth is forecasted to continue globally, propelled by policy support in the EU, USA, and China. The European share may decline from 50% in 2021 to 30% in 2027, as provincial policies in China support faster expansion and the United States market expands⁷¹. Despite such relative contraction, European capacity growth has been supported, in 2022 and 2023 respectively, by additional policy tools such as the REPowerEU Plan and the European Green Deal Industrial Plan for the Net-Zero Age. Notably, in its efforts towards increasing the production of clean energy and diversifying supply, REPowerEU, the Joint European action for more affordable, secure, and sustainable energy, has been bound also to sensitive strategic approaches as the acceleration of energy transition in neighbouring partner nations. This includes a specific focus on expediting planning and approval for renewable energy projects and strategic energy cooperation, and on developing a strategy to accelerate workforce development to support the rapid deployment of clean energy technologies, with particular reference to offshore wind and the integration of Ukraine with the EU energy markets in order to reduce the energy dependency of the EU on Russian energy⁷². That said, offshore wind is subject to challenges such as rising interest rates that can threaten the development of new projects, possible delays in

⁶⁹ European Commission (2021). The EU Blue Economy Report. 2021. Publications Office of the European Union. Luxembourg.

⁷⁰ COM(2023) 669 final.

⁷¹ Renewables 2022 – Analysis and forecast to 2027. IEA - International Energy Agency, 2023

⁷² Joint Statement between the European Commission and the United States on European Energy Security. Brussels, 25 March 2022.

the supply of components, and the need to address potential conflicts for space allocation. These elements require specific tools to be addressed, like those provided, for the case of spatial planning, by the MSP process.

On ocean energy, the IA/factsheet considered a **shift from demonstration to production of tidal and wave energy production, by 2050. While this prospect is realistic, some considerations are needed.** The EU industry is a global leader in tidal and wave energy, being the main provider of such technologies worldwide⁷³. Progress in development and demonstration is promising but an overall EU market does not yet exist, and the sector needs significant cost reductions to play a role in the energy mix. Even if the potential for deployment is localised across EU sea basins (the resources are present), EU support continues to be needed (e.g., through the European Green Deal Industrial Plan) for the sector to de-risk investments and proceed from demonstration to deployment by promoting testing and by reinforcing the processes that are relevant to cost reduction. Tidal technologies are considered to be at the pre-commercial stage and the majority of wave energy technologies are still at the R&D one⁷⁴. It is important to acknowledge that estimates on deployment are based on laboratory-scale conditions rather than commercial implementation, and several technologies at the base of ocean energy harvesting are still being developed. Projections based on the International Energy Agency's "Energy Technology Perspectives" show that the increase in wave and tidal energy generation could be speeding up in the 2030s, potentially reaching a total installed capacity of 101 GW of tidal stream and 236 GW of wave energy by 2050⁷⁵.

With respect to **aquaculture, particularly shellfish and algae**, the IA/factsheet pointed out that it **will continue to move further offshore** (also in relation to new activities like synergies with offshore wind) **and expand at least tenfold by 2050**. Aquaculture, in this view, will also present the following features: it will play an increasing role in food and feed systems; non-fed aquaculture as able to recycle the excess nutrients that would otherwise cause eutrophication; shifting protein production to non-fed aquaculture and integrated multi-trophic aquaculture and aquaponics could relieve pressure on land and freshwater.

The research carried out for this study confirms that a progressive shift toward offshore aquaculture (also supported by increased production of shellfish and algae) can be foreseen, even though a tenfold expansion of the whole sector in the EU by 2050 seems unlikely. Lower projections show an aggregated growth at the EU level to be at around 25%⁷⁶, with peaks not exceeding a fourfold increase at the MS level by 2050⁷⁷, in line with global trends⁷⁸. This includes upgraded approaches and technologies such as multi-trophic and non-fed aquaculture. Innovation in these fields can play a role in reducing the lack of acceptance by local communities, stakeholders, and consumers (affected by the sector's environmental impacts), representing an important barrier to the further development of aquaculture in the EU⁷⁹. The development of offshore farming locations takes advantage of the opposition to pollution and lack of space in coastal areas (at the base of potential conflicts with other sectors like tourism and fisheries), improved self-cleaning of production sites, and fish health. Nevertheless, some challenges exist: these infrastructures require design that accounts

⁷³ Ocean Energy Europe (2020). 2030 Ocean Energy Vision. https://www.oceanenergy-europe.eu/wp-content/uploads/2020/10/OEE_2030_Ocean_Energy_Vision.pdf

⁷⁴ COM(2020) 741 final.

⁷⁵ Khan, Muhammed Zafar Ali, Haider Ali Khan, and Muhammad Aziz. 'Harvesting Energy from Ocean: Technologies and Perspectives'. *Energies* 15, no. 9 (9 May 2022): 3456. <https://doi.org/10.3390/en15093456>.

⁷⁶ Fritsche, U., Brunori, G., Chiamonti, D., Galanakis, C., Matthews, R. and Panoutsou, C., Future transitions for the Bioeconomy towards Sustainable Development and a Climate-Neutral Economy - Foresight Scenarios for the EU bioeconomy in 2050, Borzacchiello, M.T., Stoermer, E. and Avraamides, M. editor(s), Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-28413-0, doi:10.2760/763277, JRC123532.

⁷⁷ Froehlich, Halley E, Jessica Couture, Lynne Falconer, Gesche Krause, James A Morris, Montse Perez, Grant D Stentiford, Harri Vehviläinen, and Benjamin S Halpern. 'Mind the Gap between ICES Nations' Future Seafood Consumption and Aquaculture Production'. Edited by Carrie Byron. *ICES Journal of Marine Science* 78, no. 1 (24 March 2021): 468–77. <https://doi.org/10.1093/icesjms/fsaa066>.

⁷⁸ The State of World Fisheries and Aquaculture 2022. FAO, 2022. <https://doi.org/10.4060/cc0461en>.

⁷⁹ Puzkarski, Jakub, and Olga Śniadach. 'Instruments to Implement Sustainable Aquaculture in the European Union'. *Marine Policy* 144 (October 2022): 105215. <https://doi.org/10.1016/j.marpol.2022.105215>.

for increased resistance to storms, dedicated logistics for feed supplies and workers, and effective remote management systems. Consequently, offshore structures are significantly more costly than coastal ones, limiting the investment potential to large companies, and new regulations are needed to enable predicting operating times for offshore farming⁸⁰.

Newly emerging innovation sectors (such as biotechnologies and offshore energy production) are of high interest for the role of a WMM KIC: the factsheet underlined how they **can open new market opportunities** and lead to the uptake of new technologies, new businesses, and an increase in highly skilled jobs. A positive trend is confirmed for innovative and emerging sectors, including offshore energy production and blue biotechnology. Marine renewable energy is seen as crucial in achieving the objectives of the European Green Deal and of other relevant policy initiatives (the EU Hydrogen Strategy, the Offshore Renewable Energy Strategy, and the REPowerEU Communication). Also, blue biotechnology can significantly support economic growth, the sustainability transition, and employment, while its full potential for the deployment of innovative solutions is still developing. A wide range of economic activities is associated with blue biotechnology, with the algae sub-sector being one of the most dynamic. Other innovative uses of non-traditionally exploited biomass include food & feed, pharmaceuticals, cosmetics, biomaterials, and bioremediation. Nevertheless, due to their emerging nature, more data on these sectors is needed⁸¹.

Desalination and freshwater/wastewater reuse and recycling, and the possibility of coupling them with renewable power, are also gaining traction. Furthermore, as emerging sectors establish and expand, they offer opportunities for the integration of social equity (e.g., with regard to employment and economic resources) and environmental sustainability into ocean economies⁸².

A continuation of innovative fishing gear and methods are needed to prevent habitat damage, pollution, loss of biodiversity, and depletion of fish stocks. This necessity is taken into account in the IA/factsheet. Corroborating this position, there is a wide consensus on the need for innovative gear and methods, seen as a priority in the context of healthy and productive marine ecosystems. At the policy level, this is confirmed through the 2023 EU Action Plan for the protection and restoration of marine ecosystems for sustainable and resilient fisheries. Economically viable solutions exist, frequently expressing a high level of technological readiness, and resulting in improved catch efficiency, gear selectivity, and impact on marine ecosystems. Nevertheless, it is important considering that their uptake is conditioned by regulatory frameworks, operational workability, and economic impacts on fishers (particularly in the short-term), all variables that should be set up to work as enablers⁸³.

Atmospheric pollution is another key point in the field, also covered by the IA/factsheet that recognizes how **new targets for emissions reduction and renewable fuel in maritime transport require innovation in propulsion and logistics.** This need is currently on top of the agenda for the sustainable development of human activities at multiple levels. A variety of innovations are required to cut the emissions of maritime transport, a sector that has traditionally relied on the use of conventional fossil fuels. Innovation in propulsion and logistics is central to this transition, as part of an optimization effort that the whole maritime transport sector requires, and includes ship design,

⁸⁰ Regional Review on Status and Trends in Aquaculture Development in Europe – 2020. FAO, 2022. <https://doi.org/10.4060/cb7809en>.

⁸¹ European Commission (2023). The EU Blue Economy Report. 2023. Publications Office of the European Union. Luxembourg.

⁸² Cisneros-Montemayor, Andrés M., Anna K. Ducros, Nathan J. Bennett, Leah M. Fusco, Margot Hensing-Lewis, Gerald G. Singh, and Sarah C. Klain. 'Agreements and Benefits in Emerging Ocean Sectors: Are We Moving towards an Equitable Blue Economy?' *Ocean & Coastal Management* 220 (April 2022): 106097. <https://doi.org/10.1016/j.ocecoaman.2022.106097>.

⁸³ ICES. 2023. EU request on review of innovative gears for potential use in EU waters and their impacts. In: Report of the ICES Advisory Committee, 2023. ICES Advice 2023, sr.2023.13, <https://doi.org/10.17895/ices.advice.24212694>.

route and fleet planning, speed profiling, and port logistics, among others⁸⁴. The adoption of alternative, low-carbon, sustainable fuels with low or zero direct GHG emissions is widely recognised as necessary to reduce emissions⁸⁵, and part of broader roadmaps for decarbonisation, as the “Fit for 55” EU rules for cleaner maritime fuels⁸⁶. All these factors have to be combined with improvements in the overall energy and operational efficiency of vessels, supported by enhanced digitalization and a mix of different measures and technologies that require case-specific analyses for the selection of optimal solutions in the low, medium, and long term⁸⁷.

Moreover, the IA/factsheet interprets the largest **potential for European R&D to deliver innovation and jobs** in the following blue economy sectors: aquaculture, marine tourism, coastal protection, blue biotechnology, ocean energy, and seabed mining. This study supports their dynamism. **Nevertheless, the complexity of an evolving landscape should be duly accounted for.** In terms of employment, currently, coastal tourism keeps presenting the largest share of employment in the European blue economy, followed by living resources, port activities, and maritime transport. In addition to them, notable increases have been detected in the last years in the sectors of marine renewable energy (particularly offshore wind) and shipbuilding & repair. A high dynamism for both innovation and employment has been shown primarily by blue biotechnology (within which the algae sub-sector stands out), but also by desalination and blue-tech innovation & robotics. Moreover, wastewater management needs attention as a key enabler for the preservation of marine resources and ecosystems, and so does coastal protection, as an important provider of regulation and maintenance services supporting environmental and economic loss avoidance. With regard to seabed mining, is also confirmed as an important sector for the future maritime economy: its current focus in Europe is mainly on the extraction of sand and gravel, rather than on other mining activities, and projected to increase. Still, it is considered to be one of the sources of sea-based marine pollution^{88,89,90} and, while its effects are not yet adequately understood, the precautionary principle should apply, as also highlighted by the EU Biodiversity Strategy for 2030⁹¹.

With regard to the potential of blue economy sectors, the EIB lending for the period 2018-2022 is in line with these considerations, with the most significant support provided, in decreasing order, to marine renewable energy, ports, wastewater & stormwater management, coastal protection, and R&D⁹². The delivery of innovation, and growth in employment opportunities, rest on both emerging sectors, for their intrinsic nature of relatively novel activities, and on traditional ones for the need of enabling the green and digital transitions. While considering the largest potential for innovation and employment, it **is important to account for an unbalanced availability of data, more widely available for established sectors than emerging ones.** Exogenous factors also play a key role, as seen with the consequences of the COVID-19 pandemic and the Russian invasion of Ukraine, in

⁸⁴ Tillig, Fabian, Jonas W. Ringsberg, Harilaos N. Psaraftis, and Thalys Zis. ‘Reduced Environmental Impact of Marine Transport through Speed Reduction and Wind Assisted Propulsion’. *Transportation Research Part D: Transport and Environment* 83 (June 2020): 102380. <https://doi.org/10.1016/j.trd.2020.102380>.

⁸⁵ Nepomuceno De Oliveira, Maurício Aguilar, Alexandre Szklo, and David Alves Castelo Branco. ‘Implementation of Maritime Transport Mitigation Measures According to Their Marginal Abatement Costs and Their Mitigation Potentials’. *Energy Policy* 160 (January 2022): 112699. <https://doi.org/10.1016/j.enpol.2021.112699>.

⁸⁶ <https://www.europarl.europa.eu/news/en/press-room/20230320IPR77909/fit-for-55-deal-on-new-eu-rules-for-cleaner-maritime-fuels>, accessed on 04/12/2023.

⁸⁷ Vidović, Tino, Jakov Šimunović, Gojmir Radica, and Željko Penga. ‘Systematic Overview of Newly Available Technologies in the Green Maritime Sector’. *Energies* 16, no. 2 (5 January 2023): 641. <https://doi.org/10.3390/en16020641>.

⁸⁸ European Commission (2023). *The EU Blue Economy Report*. 2023. Publications Office of the European Union. Luxembourg.

⁸⁹ European Commission (2022). *The EU Blue Economy Report*. 2022. Publications Office of the European Union. Luxembourg.

⁹⁰ European Commission 2023, EU Blue Economy Observatory, Joint Research Centre – ISpra, accessed 16 November 2023, https://blue-economy-observatory.ec.europa.eu/blue-economy-indicators_en

⁹¹ COM(2020) 380 final.

⁹² European Investment Bank (2023). *Clean Oceans and the Blue Economy Overview 2023*. doi:10.2867/4724.

addition to components such as technological readiness, regulatory frameworks, and market dynamics.

Lastly, the IA/factsheet acknowledged the **need to develop an ecosystem of service providers for developing, manufacturing, installing, cabling, supplying and maintaining installations for energy and aquaculture, as well as checking their impact on ecosystems**. The findings of this study confirm that skill, technological, and data gaps are widely recognised as existing challenges and need such an ecosystem to be further developed for both emerging and established sectors across sectors and value chains, including energy and aquaculture. As the complexity of these installations grows, and includes the co-use of structures and enhanced digitalisation, the role of innovation is going to be fundamental, together with adequate governance provisions and accurate management of marine spaces.

3.2 Analysis of the potential relevance and impact of a KIC in the field

3.2.1 Europe's position in the maritime economy sphere and socio-economic importance of blue economy sectors

Europe stands at the forefront of the marine and maritime economies and aquatic R&I, globally, and the overall strength of its blue economy sectors reinforces this leading role. The latest available data reinforces the economic and research capacities outlined in the SIA impact assessment and factsheet. It demonstrates that these sectors not only generate substantial employment opportunities but also make significant contributions in economic terms:

Marine equipment industry: The European marine equipment industry is a major global producer of advanced marine technologies, accounting for nearly 50% of the world's marine equipment in 2019⁹³. It generates an estimated annual production value of EUR 70 billion and provides more than 320,000 direct jobs.⁹⁴

Shipbuilding and repair: Europe's shipbuilding industry, comprising about 300 shipyards, plays a vital role globally. In 2021, EU shipyards constructed 2.7% of the world's ships, a rise from 2.3% in 2020. In 2020, the EU shipbuilding and repair sector achieved a Gross Value Added (GVA) of €14.5 billion, registering an 8% decrease from the prior year. The turnover was €55.7 billion, indicating a 4% decline due to the challenges brought on by the COVID-19 pandemic, notably in the production of passenger ships. However, in terms of employment, approximately 305,500 individuals were directly employed in this sector, marking a 2% increase from 2019. Germany took the lead in employment within shipbuilding and repair, accounting for 16% of the jobs, followed closely by France (15%) and Italy (14%). In terms of GVA, Germany contributed 22% to the Member States' total, followed by France (20%) and Italy (17%).⁹⁵

Coastal tourism: EU coastal areas are top tourist destinations, making coastal and maritime tourism the largest and fastest-growing sector in the EU Blue Economy in terms of economic value and employment. In 2020, experiencing a 58% decrease in GVA and a 40% decrease in employment, coastal tourism was shown to be the most affected sector by COVID-19. Nevertheless, it continued to contribute the highest portion of both employment (51%) and GVA (26%) within the EU Blue

⁹³ OECD (2023): Analysis of the marine equipment industry and its challenges, available at: [https://one.oecd.org/document/C/WP6\(2022\)15/FINAL/en/pdf](https://one.oecd.org/document/C/WP6(2022)15/FINAL/en/pdf)

⁹⁴ Sea Europe Website, <https://www.seaeurope.eu/> (Accessed January, 2024)

⁹⁵ EC (2023). The EU Blue Economy Report. 2023, available at <https://op.europa.eu/en/publication-detail/-/publication/9a345396-f9e9-11ed-a05c-01aa75ed71a1>

Economy.⁹⁶ Moreover, after the COVID-19 pandemic setback, coastal tourism made a strong recovery. It not only regained its footing but also contributed more significantly to the EU Blue Economy. In 2021, the total number of nights spent in EU tourist accommodations along coastal areas reached 877,3 million. Compared with 2020 (603,7 million nights) nights spent in coastal areas were up by 45% in 2021.⁹⁷

In addition, according to the World Economic Forum Travel and Tourism Competitiveness Index (2021)⁹⁸, Europe remains the *Travel & Tourism Development Index's* top-performing region, being among the best positioned to grow in the coming years. Among the top ten countries, six belong to the EU. Spain holds the highest position in the region, ranking third overall. Following closely, France (4th), Germany (5th), Switzerland (6th), the United Kingdom (8th), and Italy (10th).

Maritime transport: ranks as the second-largest contributor to employment and GVA within the EU Blue Economy. It constitutes 23% of the total Blue Economy value-added and employs 11% of its workforce.⁹⁹

Regarding the size of the EU maritime transport sector in 2020, the sector generated a GVA of €29.5 billion in 2020, a decline of 14% compared to the 2019 peak. The sector reported a turnover of €147.4 billion in 2020, down 10% from the previous year, largely due to the impact of COVID-19. In addition, in 2020, around 371,000 persons were directly employed in the sector, 8% less than in 2019.¹⁰⁰

While maritime transport faced a decline primarily because it relies heavily on economic downturns like COVID-19 and global trade conflicts, ongoing technological progress has the potential to drive the sector's growth.¹⁰¹ The rise of digitalisation, incorporating elements such as Big Data, the Internet of Things, Blockchain technology, and cloud computing, offers the maritime industry innovative tools to swiftly acquire, process, and exchange valuable data. This, in turn, contributes significantly to fostering growth within the sector.¹⁰²

Fisheries and aquaculture: In 2021, the total catch from EU fisheries amounted to an estimated 3.5 million tonnes in live weight. This represented a significant decrease, following a decreasing trend from the recorded 4.6 million tonnes in both 2017 and 2018, and still considerably lower than the 5.9 million tonnes caught in 2001. This is coupled with underlying conditions of overall fish stock and the shrinkage of the EU fishing fleet, among other factors. The primary fisheries industry in the EU employed 156,210 individuals in 2020, with approximately one-third of these workers engaged in the aquaculture subsector. Spain accounted for about one-fifth of the total employment within the EU's primary fisheries industry in 2020. In fact, a significant three-quarters share of employment in the EU fisheries industry was concentrated in Spain, Italy, Greece, France, and Portugal.¹⁰³

Between 2010 and 2021, the volume of EU aquaculture production remained relatively stable. However, the value of this output increased and was an estimated 50% higher in 2021 than in 2010. In 2021 aquaculture farming within the EU yielded approximately 1.1 million tonnes of aquatic

⁹⁶EC (2023). The EU Blue Economy Report. 2023, available at <https://op.europa.eu/en/publication-detail/-/publication/9a345396-f9e9-11ed-a05c-01aa75ed71a1>

⁹⁷ Eurostat, online code (TOUR_OCC_NINATDC)

⁹⁸ World Economic Forum (2022). Travel & Tourism Development Index 2021 Rebuilding for a Sustainable and Resilient Future. Insight Report. May 2022, available at: https://www3.weforum.org/docs/WEF_Travel_Tourism_Development_2021.pdf

⁹⁹ EC (2023). The EU Blue Economy Report. 2023, available at: <https://op.europa.eu/en/publication-detail/-/publication/9a345396-f9e9-11ed-a05c-01aa75ed71a1>

¹⁰⁰ EC (2023). The EU Blue Economy Report. 2023, available at: <https://op.europa.eu/en/publication-detail/-/publication/9a345396-f9e9-11ed-a05c-01aa75ed71a1>

¹⁰¹ EC (2023). The EU Blue Economy Report. 2023, available at: <https://op.europa.eu/en/publication-detail/-/publication/9a345396-f9e9-11ed-a05c-01aa75ed71a1>

¹⁰² Edvard Tijan, Marija Jović, Saša Aksentijević, Andreja Pucihar (2021): Digital transformation in the maritime transport sector, Technological Forecasting and Social Change, available at: <https://doi.org/10.1016/j.techfore.2021.120879>

¹⁰³ Eurostat, online cod (nama_10_a64_e), (fish_ca_main), (fish_aq_q) and (fish_aq2a).

organisms, constituting one-quarter of the total output of European fisheries. The estimated value of aquaculture production in the EU for that year was an estimated €4.2 billion, which was slightly more than two-fifths of the EU's overall production value for fishery products (including both landings and aquaculture). Four EU Member States played a significant role in this output, accounting for 68.0% of the total production in terms of tonnes of live weight of farmed aquatic organisms in 2021. Spain took the lead, producing an estimated 24.6 % of the total, followed by France (17.2 %), Italy (13.0%) and Greece (12.8%).^{104, 105}

Marine energy: In 2020, the marine energy sector employed 12.3 thousand people, marking an increase from the previous year (10.6 thousand in 2019). In terms of GVA, it contributed €2.145 billion, also showing growth compared to the previous year's figure of €1.926 billion.¹⁰⁶

Within the field of tidal stream development, 41% of companies with Technology Readiness Levels greater than five, are based in the EU. Similarly, most companies engaged in wave energy device development are located within the EU (52%). In the tidal energy sector specifically, the EU holds the second position, following closely the UK.¹⁰⁷

Offshore oil and gas: In 2020, the GVA for the EU's non-living marine resources sector amounted to €2.8 billion, corresponding to approximately a quarter of the GVA recorded in 2009, which was €11.2 billion. Moreover, compared to 2019, there was a significant decline in turnover, dropping by 28% to €9.4 billion. Particularly, the oil and gas subsector employed about 8,130 persons, accounting for 86% of the jobs. Meanwhile, the operation and extraction of different minerals (such as gravel and sand pits, mining of clays and kaolin, and salt extraction) employed 1,360 people, constituting 14% of the total workforce). In terms of GVA, the oil and gas sector contributed a significant €2.7 billion, accounting for approximately 95% of the sector's total GVA. The remaining €144 million (5%) of GVA was generated by other mineral-related activities.¹⁰⁸

Blue biotechnology: Within the blue economy, today biotechnology still plays only a minor but rather promising role. As a pivotal enabling technology, it holds great potential for driving innovation in diverse industries.¹⁰⁹ An analysis of the bioeconomy across European regions¹¹⁰, reveals a strong inclination in areas with historical access to marine resources and aquatic biomass to advance in the Blue biotechnology sector. This underscores the considerable potential for enhanced competitiveness within EU regions, particularly along the coastal areas.

The Blue biotechnology sector focuses on economically utilising marine organisms and biomass, including algae, bacteria, fungi, and invertebrates. With regard to the algae sector in Europe, France, Spain, and Portugal lead in production, with a total value of €10.7 million in 2018. Within these countries, there were 156 algae aquaculture companies, predominantly micro-enterprises (87% with fewer than 5 employees), employing 509 individuals.¹¹¹

The **water supply and wastewater treatment sector is experiencing significant growth.** Throughout the entire European Union, approximately 90% of urban wastewater is now being

¹⁰⁴ Eurostat online code (fish_aq2a).

¹⁰⁵ Eurostat. Aquaculture statistics. Statistics Explained, available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Aquaculture_statistics (Accessed February, 2024)

¹⁰⁶ EC (2023). The EU Blue Economy Report. 2023, available at: <https://op.europa.eu/en/publication-detail/-/publication/9a345396-f9e9-11ed-a05c-01aa75ed71a1>

¹⁰⁷ Joint Research Centre (2022): Ocean Energy in the European Union (2022), available at: <https://op.europa.eu/en/publication-detail/-/publication/514586eb-50ef-11ed-92ed-01aa75ed71a1/language-en>

¹⁰⁸ EC (2023). The EU Blue Economy Report. 2023, available at: <https://op.europa.eu/en/publication-detail/-/publication/9a345396-f9e9-11ed-a05c-01aa75ed71a1>

¹⁰⁹JRC (2020). Smart Specialisation and Blue biotechnology in Europe, available at: <https://s3platform.jrc.ec.europa.eu/documents/20125/245712/Smart+Specialisation+and+Blue+biotechnology+in+Europe.pdf/05b4588e-4a4e-b49b-c23c-d7d929bf2b95?t=1621268543014>

¹¹⁰ <https://s3platform.jrc.ec.europa.eu/map>

¹¹¹ EC (2023). The EU Blue Economy Report. 2023, available at: <https://op.europa.eu/en/publication-detail/-/publication/9a345396-f9e9-11ed-a05c-01aa75ed71a1>

collected and treated in compliance with the EU Wastewater Treatment Directive.¹¹² In addition, the requirement to improve water quality remains a priority. This is evident with the adoption of the revised Drinking Water Directive, which entered into force in January 2021. The directive establishes more rigorous water quality standards, tackles emerging contaminants like endocrine disruptors and microplastics, and advocates for fair access to drinking water.¹¹³

In 2020, there were 78,000 enterprises categorised within the EU's water supply, sewerage, waste management, and remediation activities sector according to Eurostat. Together, they employed 1.6 million individuals and generated €102.3 billion in value added.¹¹⁴ Notably, in the wastewater management sector alone, Eurostat estimates the creation of 595,000 jobs in the European Union in 2020. Germany led the way with 99,023 jobs, followed by France with 54,339, and Italy with 46,963.¹¹⁵

3.2.2 Fragmentation of efforts and disconnection between education, research and innovation activities

The 2019 SIA impact assessment reported a clear disconnect between education, research, and innovation activities, and a lack of cooperation between research and industry in the WMM fields. Such elements are still present, acknowledged by the actors involved with the WMM fields at different levels (research, private sector, academia, policy-makers, etc.), and represent an important bottleneck to innovation.

Rather than expressing a negative interpretation of the disconnection between education, research and innovation activities, and of fragmentation of efforts, existing literature on the topic and the stakeholders that have been consulted for this study manifest a prevailing positive approach (“need for” vs “lack of”), highlighting the **need to build synergic relations across sectors, themes, policy streams, initiatives, and geographical levels**. This perspective acts on the roots of both fragmentation and disconnection, signalling their clear presence in WMM fields and the need to overcome the challenges they generate, that hamper the promotion of sustainable, competitive, resilient, and equitable economies. In general terms, there is, among all stakeholder types, a commonly agreed call for more coordinated and integrated approaches to ocean and freshwater management. With regard to the disconnection within the knowledge triangle, across all WMM sub-sectors, the need to link research and development to the deployment of solutions is widely recognised, while the availability of a skilled workforce remains a critical factor for both traditional and emerging sectors, with the twin green and digital transition requiring innovative know-how, and sectoral competitiveness relying on job attractiveness.

With respect to the **blue economy and maritime emerging and traditional sectors**, the SIA impact assessment highlighted how the first shows less prevalent divides between research and enterprises (particularly applicable to the sectors of biotech, aquaculture and marine energy production). At the policy level, for both traditional and emerging sectors, an existing tie between research and entrepreneurship is confirmed at the current state but it requires being intensified and put in a systemic perspective. The EU's new approach to a sustainable blue economy¹¹⁶, launched in 2021, recognises how marine and maritime R&I are essential for achieving the European Green Deal-related objectives: while this applies to the improvement of sustainability and circularity of traditional sectors, it constitutes the very core of the development of emerging sectors. Regarding the sectors mentioned in the SIA impact assessment, a typical case is represented by offshore renewable energy, whose large-scale deployment is highly dependent on investments in R&I. Currently, these

¹¹² https://environment.ec.europa.eu/topics/water/urban-wastewater_en

¹¹³ European Commission. Drinking water, available at: https://environment.ec.europa.eu/topics/water/drinking-water_en#studies-and-publications

¹¹⁴ Eurostat (online data code: sbs_na_ind_r2, sbs_na_sca_r2)

¹¹⁵ Eurostat (online data code: ENV_AC_EGSS1)

¹¹⁶ COM(2021) 240 final.

are mainly proceeding from the private sector, with the public playing an important role, particularly in the wind energy value chain. For the deployment of such technologies, research on environmental impacts (including cumulative ones) is needed. Concerning marine renewable energy and the disconnect within the knowledge triangle, the European Commission, with its 2020 EU offshore renewable energy strategy, committed to supporting national and regional authorities in their education and training programmes finalised at developing and strengthening skills functional to employment and the development of the offshore energy sector¹¹⁷. Aquaculture and biotechnology, as part of the blue economy (for the entirety of which akin considerations are valid), are other sectors whose development is highly related to extensive collaboration between research and industry, and that require the presence of advanced technical and non-technical skills. This is notably important for novel applications, including non-food, food, and feed.

All in all, specific **specialisation is lacking both at academic and vocational education training levels**, hampering effective dynamics within the knowledge triangle¹¹⁸.

Furthermore, competitiveness should be coupled with the **reduction of the impact of human activities on the marine environment by integrating more consistent research and knowledge with industrial operations**, and also by increasing the participation of weaker economies in these processes¹¹⁹. Such involvement, when corresponding to countries or regions that are identified as moderate or modest innovators, may benefit from the EIT Regional Innovation Scheme.

In strategic terms, the **importance of the connection between science, knowledge, education, and innovation activities, for the achievement of positive impacts with regard to pressing challenges** in the WMM field and beyond, is well known. The 2021 EC Communication on Sustainable Blue Economy recognizes the need for better knowledge support processes in place. This would be an enabler for industry, public authorities, and civil society to make informed decisions. The same shift of focus from the expression “blue growth” to “sustainable blue economy”, highlights the necessity of linking the environmental and economic dimensions¹²⁰, as a conceptual framework to leverage their value as effective drivers of synergic problem-solving. To yield these benefits in the blue economy and freshwater sectors, it is fundamental to increase collaboration and reinforce partnerships among entrepreneurs, researchers, and policymakers in fields relevant, for instance, to biotechnologies, marine pollution, biodiversity restoration, and the reduction of the depletion of freshwater resources (e.g., by advancing knowledge of the hydrological cycle, optimizing governance systems related to water management, or by improving technical means like water desalination strategies and solutions). By doing so, the role that ocean-related entrepreneurship can play in the standardisation of best practices across various sectors, and towards more sustainable and ethical practices, can be supported¹²¹. These aspects are particularly relevant to the new approach to Sustainable Blue Economy. Both environmental protection and thriving businesses rely on timely, accessible, and accurate knowledge to identify needs and solutions for ocean and water governance, in addition to a skilled and valorised workforce that represents the lifeblood of sustainable anthropic activities. The development of a sustainable blue economy and more effective water management systems are dependent on a better-performing knowledge triangle.

The pool of initiatives and policy tools launched since 2019 and analysed in the dedicated chapter of this study shows a **high level of attention given to the need both build synergic approaches (e.g., with sectoral or thematic platforms working in an adaptive and coordinated manner) and**

¹¹⁷ COM(2020) 741 final.

¹¹⁸ Executive Agency for Small and Medium sized Enterprises., Technopolis Group., and Wageningen Research. Blue Bioeconomy Forum: Roadmap for the Blue Bioeconomy. LU: Publications Office, 2020. <https://data.europa.eu/doi/10.2826/605949>.

¹¹⁹ Tanhua, T., Kazanidis, G., Sá, S., Neves, C., Obaton, D., & Sylaios, G. (2021). Nourishing Blue Economy and Sharing Ocean Knowledge - Ocean information for sustainable development. Zenodo. <https://doi.org/10.5281/zenodo.5576120>

¹²⁰ COM(2021) 240 final.

¹²¹ Mishra, Shwetakshi. 'Exploring Marine Prospects for Entrepreneurship and Innovation'. Journal of Computers, Mechanical and Management 2, no. 4 (30 September 2023): 35–44. <https://doi.org/10.57159/gadl.jcmm.2.4.23095>.

closing the gaps in education, research, and innovation activities, once again reflecting the recognition of an existing fragmentation of efforts and disconnection within the knowledge triangle. A recurring element is the need for upskilling and reskilling, which is essential to enable the twin green and digital transition that the WMM field requires. Such necessary transformations call for stronger cooperation between diverse higher education institutions across the EU, which would in turn strengthen research, innovation and industrial ecosystems¹²². This means reading the issues of fragmentation and disconnection within the domain of education and training systems themselves, which should enable vertical and horizontal pathways between vocational education and training, general school education, higher education, and adult education¹²³.

Reducing the disconnection within the knowledge triangle has proven to be an effective strategy for the development of a sustainable, competitive, and equitable blue economy, as demonstrated by dedicated networks that link businesses, research, development and innovation. The blue economy should be also defined and viewed more as a sector on its own, rather than mainly as a combination of established and emerging ones. **Multi-faceted partnerships expressing this aggregated understanding can foster collaboration across borders and between sectors** while supporting the responsible use of marine resources^{124 125}. The mismatch between existing educational programmes and industry needs is evident for the blue economy as a whole, with specific sectors making efforts towards tailored solutions, as in the case of shipbuilding¹²⁶, biotechnology, marine renewable energy, fisheries and the seafood industry¹²⁷. Although targeted actions are valuable as they address specific challenges and respond to sectoral needs, a systemic blue economy perspective may also help in reducing fragmentation, as seen in the shared environment set up by the Pact for Skills and in the regular EMFAF initiative on “Blue careers for a sustainable blue economy”. Recent years have also seen the growing importance of tools that can provide common ground for the reduction of fragmentation and disconnection at different levels, such as MSP, the European Data Strategy, Thematic S3 partnerships, and forums like Communities of Practice. This is an area where **greater support is needed when it comes to water management and waste-water treatment**, to enable systemic change and uptake valuable innovative practices across the EU.

An analogous **approach that integrates the WMM fields by expressing a high level of interconnections** in terms of prioritised challenges and the capacity to supply goods and services in the long term, can widen this aggregative interpretation and needs to be strategically designed for the operational success of a WMM KIC.

Knowledge generation and the co-design of solutions require collaboration and coordination among businesses, international authorities, NGOs, research institutions, academia and national authorities, as well as the identification of research priorities that are in line with pressing challenges and industrial needs. Specific skills are needed across sectors and fields, as in the case

¹²² Council of the European Union, 'Council recommendation of 5 April 2022 on building bridges for effective European higher education cooperation' (2022/C 160/01).

¹²³ European Commission, Directorate-General for Employment, Social Affairs and Inclusion, 'Vocational education and training – Skills for today and for the future', Publications Office of the European Union, 2022, <https://data.europa.eu/doi/10.2767/811982>

¹²⁴ Depellegrin, Daniel, Aleksandra Zawalna-Geer, Allen Alexander, David Rodeiro-Pazos, Adrian Dios-Vicente, Boris Teillant, Amita Guneratman, et al. 'Innovating the Blue Economy: A Novel Approach to Stakeholder Landscape Mapping of the Atlantic Area Sea Basin'. *Frontiers in Marine Science* 9 (22 July 2022): 889582. <https://doi.org/10.3389/fmars.2022.889582>.

¹²⁵ Fontes, Margarida, Cristina Sousa, and Oscarina Conceição. 'Creating a Blue Economy: Research and Innovation Partnerships to Accelerate the Development of Ocean-Related Industries'. In *Proceedings of the 2019 International SPBPU Scientific Conference on Innovations in Digital Economy*, 1–8. Saint Petersburg Russian Federation: ACM, 2019. <https://doi.org/10.1145/3372177.3373329>.

¹²⁶ SEA Europe, industryAll, 'The shipbuilding pact for skills: upskilling shipbuilding and maritime technology workers in Europe - Summary of the EU Social Partners' Proposal (March 2021)', 2021

¹²⁷ European Commission (2022). *The EU Blue Economy Report*. 2022. Publications Office of the European Union. Luxembourg.

of marine renewable energy, fisheries, and pollution, and considering the creation of transparent paths to market uptake is essential¹²⁸.

3.2.3 The contribution that the creation of a KIC can make to confronting and overcoming the challenges faced by the sector

Existing fragmentation of efforts and disconnection within the knowledge triangle, the lack of requested and needed skills, and the necessity of enhancing the knowledge base in WMM fields place the **potential role of a dedicated KIC in a relevant position to help address current and emerging challenges**. The EIT innovation model and the KICs enable and advance innovation to address these gaps by allowing educational and research programmes to enhance the matching of available skills with private sector needs, promoting entrepreneurial capacity and culture, and boosting public-private and widened partnerships. Along with strengthening the knowledge base and transfer processes, these contributions potentially belong to a WMM KIC and have been recognised in the initial SIA impact assessment.

Due to the diversities of the sectors covered by the WMM fields, the initial SIA impact assessment reported that covering most of them could impede the formulation of a coherent KIC strategy. While this can be considered still applicable, also taking into account that emerging sectors have consolidated their presence and weight since 2019 (thus adding complexity to the overall sectoral landscape), **integrating the freshwater dimension with the marine and maritime ones through an ecosystem-based, holistic approach is also considered as a necessity across disciplines and communities of stakeholders interviewed during the study**. This kind of setup could generate additional streams of transformative innovation by leveraging the potential of efficient and effective dynamics within the knowledge triangle, that could feed the deployment of innovative solutions in interconnected WMM environments as the one offered by Mission “Restore our Oceans and Waters by 2030”. In order to harmonize the priorities of the different fields to achieve common objectives (e.g., addressing existing challenges under the framework of the twin green and digital transition), to avoid dispersion of resources and objectives, and to promote synergies and alignment, the KIC should develop its strategy through time by engaging the networks of reference on a continuous basis and accurately position itself within the web of major existing initiatives and policy tools, whose characteristics are presented in the next chapter. Typical examples providing such an environment in the WMM field are the Mission “Restore our Oceans and Waters by 2030”, key Horizon Europe partnerships, BlueInvest, and the European Blue Forum.

WMM integration can present different opportunities, for instance with regard to increasing sustainability and the efficiency of productive processes through the optimisation of the interaction between land-based and ocean-based production systems. Doing so can foster more efficient agriculture and aquaculture practices, and positively act on land-to-sea interactions. This is the case of side streams from agriculture being used for aquaculture or fisheries and vice versa¹²⁹. Furthermore, transversal solutions within the WMM field and beyond, such as those offered, for instance, by biotechnologies, sensing, monitoring, and modelling systems, can also leverage financial opportunities at cross-sectoral and KIC levels.

This kind of approach has also proven to be successful in improving the performance of different types of entities and in fields that are pertinent to a WMM KIC, like in the case of the Climateurope project and its follow-up, Climateurope2¹³⁰. The network they are creating supports the coordination of the European climate-related knowledge base, promoting collaborations, and sees direct

¹²⁸ United Nations Global Compact, ‘Ocean Stewardship 2030 Ten ambitions and recommendations for growing sustainable ocean business’, 2020.

¹²⁹ Blue Bioeconomy COFUND (BlueBio) – European Fisheries and Aquaculture Research Organisations (EFARO). Blue Bioeconomy Foresight Analysis: towards a blue bioeconomy strategic research and innovation agenda. 2023.

¹³⁰ <https://www.climateurope.eu/> and <https://www.climateurope2.eu/>, accessed on 24/11/2023.

participation, as a consortium member, of the Climate-KIC¹³¹. The **cross-sectoral nature of the proposed KIC may, in fact, constitute a major element for promoting synergies, alignment, and reduction of fragmentation**, due to its own enlarged and holistic focus. Such characteristics could enable the WMM KIC to build on and leverage collaboration for relevant cross-KIC activities, as already demonstrated by the programme “Finding innovative solutions to alleviate water scarcity in Southern Europe”, which saw the joint participation of different Knowledge and Innovation Communities (EIT Climate-KIC, EIT Digital, EIT Food, EIT Raw Materials, and EIT Manufacturing)¹³². For a thorough prioritisation of actions and desired impacts, it could be useful to consider instruments such as the Theory of Change methodology, as seen in other connected initiatives like the Sustainable Blue Economy Partnership and the Union for the Mediterranean Regional Platform in Research and Innovation, and essential to align systemically with the intervention logic of Horizon Europe and its Key Impact Pathways.

The possibility of **transferring lessons learned in traditional industries to emerging ones** is also seen, in the SIA impact assessment, as an opportunity for a WMM KIC. This perspective can be confirmed and take advantage of the consolidation of common frameworks like ecosystem-based management (EBM) and innovations like multi-use; as EBM gains momentum, in fact, it also requires integrated cross-sectoral approaches that benefit from knowledge transfer¹³³. Knowledge and skills transfer remain fundamental in supporting the transition towards more sustainable and just economies, in a landscape that requires upskilling and reskilling in an increasingly urgent manner¹³⁴.

As seen with regard to the disconnection between education, research, and innovation activities, Higher Education Institutions should **turn knowledge into skills, competencies and innovation by developing close cooperation with economic, social and industrial partners** within local and regional research and innovation ecosystems. These processes can be supported by a WMM KIC, in coordination with the work done by other KICs and frameworks like smart specialisation strategies and the EIT Regional Innovation Scheme. Such cooperation would be beneficial for local businesses and SMEs¹³⁵, which are widely recognised by the relevant existing initiatives as WMM key players in the European landscape (Section 3.3).

Lack of skills, fragmentation of efforts, disconnection within the knowledge triangle, and knowledge gaps were reported in the SIA impact assessment. Addressing these challenges remains a priority, also considering a landscape that has evolved, with emerging sectors consolidating their importance, the transformations required by the twin transition, along with the urgency and persistence of the challenges linked to ecosystem health and pressures deriving by human activities. **The role of a WMM KIC can be beneficial in addressing these bottlenecks to innovation and supporting the uptake and deployment of solutions.** Nevertheless, the possible limits that a WMM KIC could face, as described in the SIA impact assessment, still apply. Among them, the diversified set of features that define established and emerging sectors, and their distinct needs, have been reported by some interviewees as potentially hampering the development of a coherent KIC strategy. Since 2019, synergic approaches have reinforced their potential and actual contribution to the development of

¹³¹ Hewitt, Chris, Janette Bessembinder, Mauro Buonocore, Tyrone Dunbar, Natalie Garrett, Lola Kotova, Stacey New, et al. 'Coordination of Europe's Climate-Related Knowledge Base: Networking and Collaborating through Interactive Events, Social Media and Focussed Groups'. *Climate Services* 24 (December 2021): 100264. <https://doi.org/10.1016/j.cliser.2021.100264>.

¹³² <https://www.eitfood.eu/projects/water-in-south-finding-innovative-solutions-for-water-scarcity-in-southern-europe>, accessed on 18/01/2024

¹³³ O'Higgins, Timothy G., Manuel Lago, and Theodore H. DeWitt, eds. *Ecosystem-Based Management, Ecosystem Services and Aquatic Biodiversity: Theory, Tools and Applications*. Cham: Springer International Publishing, 2020. <https://doi.org/10.1007/978-3-030-45843-0>.

¹³⁴ Emad, GR, Shahbakhsh, M, Abdussamie, N, & Islam, TMR. "Implementation of Industry 4.0 and its Effect on Human Element and Sustainable Development in the Blue Economy." *Proceedings of the ASME 2023 42nd International Conference on Ocean, Offshore and Arctic Engineering*. Volume 10: Professor Ian Young Honouring Symposium on Global Ocean Wind and Wave Climate; Blue Economy Symposium; Small Maritime Nations Symposium. Melbourne, Australia. June 11–16, 2023. V010T13A017. ASME. <https://doi.org/10.1115/OMAE2023-101806>

¹³⁵ Council of the European Union, 'Council conclusions on a European strategy empowering higher education institutions for the future of Europe', 6 April 2022 (7936/22).

sustainable WMM fields, like in the case of Maritime Spatial Planning, multi-use platforms, and the same evolution of the sustainable blue economy concept. The differences among sectors can, by building on synergies and transfer of results, be turned into opportunities, for instance when considering the broader knowledge base of traditional sectors and the more flexible reliance on innovation and R&D of emerging ones. **Scientific evidence supports, in an increasing manner, the need to integrate the ocean and freshwater dimensions**, both from an ecosystem perspective and with regard to policy coherence and cross-compliance. A WMM KIC needs to build its strategy on such integration. Additionally, the foreseen launch of the KIC in 2026 would fit well in view of a timely capitalisation of the results of relevant Horizon Europe Partnerships, presented in Section 3.3.

At any stage, improved **integration across the knowledge triangle has proven to be key to harnessing added value derived by innovation**: the EIT model and KICs, once identified the priority challenges to be addressed, are capable of contributing to the achievement of desired impacts by building innovation ecosystems through the integration of the work of leading players in research, education, and business¹³⁶. This approach, considering the composite nature of interactions within WMM fields (including the overarching sustainable blue economy system and the specificities of the water, marine and maritime sectors) reveals how the contribution of a WMM KIC can be highly relevant. Moreover, given an adaptive contextualisation and harmonization effort of European, regional, and national perspectives, the international networking that a KIC can provide is apt for softening the differences among and within Member States in the reception of EU policy initiatives, and for consolidating a culture of innovative entrepreneurship that is fundamental to provide solutions at all levels of sustainable development. This has been the case, for instance, of EIT Digital¹³⁷, whose work combines substantially with the need for innovation in the WMM fields especially when considering the growing role of digitalisation in these domains.

The creation of a dedicated KIC may also **contribute to the strengthening of innovative ecosystems across Europe and with regard to countries and regions that the European Innovation Scoreboard identifies as modest and emerging innovators**. This element emerges as highly relevant even by considering that the different countries/regions express peculiar ecosystem and resource-related characteristics, and distinct challenges from the scientific, technological, and socio-economic point of view, influencing their diversified level of development in WMM sectors. The EIT Regional Innovation Scheme (EIT RIS) operates towards the direction of enhancing the capability of weaker innovators, thus acting on this type of fragmentation across the EU and beyond¹³⁸. Being focused on local innovation actors and ecosystems, its work can be supportive of the scope of a WMM KIC, and vice versa, particularly if we consider the strong presence of SMEs in the water, marine, and maritime sectors¹³⁹.

Pertinent examples to build on existing, such as the EIT RawMaterials and the EIT Climate-KIC RIS, showed a role in increasing innovation capacities in European peripheral regions. The Climate-KIC and the related RIS, for instance, have served as a multi-faceted platform providing linkages between a wide range of actors, that experienced an enhanced collaborative environment, in which a market-focused approach allowed for a more efficient and targeted mobilisation of knowledge and technology. The activities carried out by the RIS programme have facilitated the mobilisation of financial and human resources, in turn enabling the conversion of innovative ideas into business. This has been possible thanks to the availability of knowledge, market-related information, a wider

¹³⁶ Vrontis, Demetris, Yaakov Weber, and Evangelos Tsoukatos. '13th Annual Conference of the EuroMed Academy of Business'. Business Theory and Practice – Across Industries and Markets. EuroMed Press (2020).

¹³⁷ Hans-Liudger Dienel & Valentina Fava (2021) Digital and sustainable innovation policies in Europe: comparative lessons, Innovation: The European Journal of Social Science Research, 34:4, 423-425, DOI: 10.1080/13511610.2021.2000786

¹³⁸ European Institute of Innovation and Technology (EIT), 'EIT Regional Innovation Scheme Implementation Framework 2022-2027' (2022).

¹³⁹ European Commission (2022). The EU Blue Economy Report. 2022. Publications Office of the European Union. Luxembourg.

network of customers and potential partners, and increased access to funding ^{140,141}. Elements that are crucial to sectors that are interested in sustainability transitions, such as those composing the WMM field.

Overall, by focusing on the characteristics of WMM fields both in terms of needs and opportunities, the results of the study show that the **new KIC has the potential to enhance economic competitiveness in a comprehensive manner (not merely sectoral), to contribute to evidence-based decision-making, to develop integrated solutions and approaches to address marine and freshwater degradation, to wider EU policy objectives for the management of pressing challenges through innovative solutions, and to reduce geographical disparities** in terms of development and innovation. All these elements are highly relevant in the water, marine, and maritime domains. Its focus may be directed towards:

1. sectors that are most affected by (and/or benefiting from) the twin green and digital transition and those relying on highly innovative approaches, in terms of skill gaps;
2. challenges that are considered most urgent at the ecosystem level integrating freshwater and marine;
3. most critical areas of disconnect within the knowledge triangle;
4. synergies and alignment with policy streams and existing initiatives such as the EU Mission Ocean and Waters and relevant partnerships.

3.3 Synergies and complementarities with existing initiatives

The policy landscape and the initiatives launched in fields that are relevant to WMM have significantly evolved since 2019. They embrace the dimensions of challenges, sectors, and the whole knowledge triangle from both different and combined perspectives. The European Green Deal and Horizon Europe are creating such an overarching framework in terms of strategic policy directions and related initiatives. By considering the challenges analysed in this study and the potential relevance and impact of a WMM KIC, a composite picture of the synergies that would be beneficial to the KIC and, in turn, leverage its potential for substantial impact, emerges. The value of integrating education, innovation, and research, and the call to establish related partnerships has grown in time, thus emphasising both the role of the KIC as a booster of solutions and the need to interact with initiatives and policy tools that have been launched since 2019. As each initiative conveys a specific point of view, its main characteristics are presented here, with a specific focus being given to its connection with the role of a WMM KIC. The results indicate that a well-functioning strategy should rely on tailored synergic approaches that could be sector-based (including the overall sustainable blue economy and freshwater management approaches), challenge-based, and/or centred on the contribution of the KIC system. The value of the KIC has also been recognised by the stakeholders that have been targeted for interviews, who manifested a solid interest in its launch, and the relevance of a WMM-themed structure.

What follows is a **list of potentially synergic and complementary policy tools and initiatives, prioritised as some of the most relevant to the role of the proposed WMM KIC**, and emerged

¹⁴⁰ Irene Vivas Lalinde, Cristian Matti, Julia Panny, Blanca Juan Agulló, (2018) "Innovation platforms fostering low-carbon economy resource mobilisation: A community of practice approach for knowledge triangle integration in EU peripheral regions", World Journal of Science, Technology and Sustainable Development, <https://doi.org/10.1108/WJSTSD-04-2018-0032>.

¹⁴¹ Smol, Marzena, and Joanna Kulczycka. 'Towards Innovations Development in the European Raw Material Sector by Evolution of the Knowledge Triangle'. Resources Policy 62 (August 2019): 453–62. <https://doi.org/10.1016/j.resourpol.2019.04.006>.

recently. This list describes the main traits of alignment with the KIC, while a detailed description and interpretation are found in Annex. They have been categorised according to the following scheme:

Table 1. List of potentially synergic and complementary policy instruments and initiatives.

Policy and strategic	Partnerships and initiatives	Platforms, hubs, enablers	Global dimension
European Green Deal	Mission "Restore Our Oceans and Waters by 2030"	European Blue Forum	High Seas Treaty
Sustainable Blue Economy Approach	Clean Energy Transition Partnership (CETP)	BlueInvest	The Kunming-Montreal Global Biodiversity Framework
Circular Economy Action Plan	Partnership for Research and Innovation in the Mediterranean Area (PRIMA)	EU4Ocean Coalition	United Nations Decade of Ocean Science for Sustainable Development
EU Biodiversity Strategy for 2030	Sustainable Blue Economy Partnership (SBEP)	Digital Twin of the Ocean	
European Climate Law	Water4All	Seabasin Strategies and related Assistance Mechanism	
EU Climate Adaptation Strategy	Zero-Emission Waterborne Transport Partnership (ZEWT)		
Zero-pollution Action Plan	Circular bio-based Europe joint undertaking (CBE JU)		
EU's fisheries and aquaculture sector Package	Pact for Skills Partnerships		
Farm to Fork Strategy			
Strong and Sustainable EU Algae Sector			
EU Strategy to harness the potential of offshore renewable energy for a climate-neutral future			

Additionally, some of the most relevant knowledge transfer-related projects have been considered.

3.3.1 Policy and strategic level

At the policy and strategic level, synergies are intended in a wider sense, as a reference framework and strategic context to which the proposed KIC would be aligned and contributing to **The European Green Deal** is to be considered a primary framework advancement and the KIC would support its implementation. Its objectives resonate strongly with the mission and focus areas of the **EIT-KICs**, which foster partnerships between higher education institutions, research organisations, and the private sector in critical areas like climate change, sustainable energy, food systems, and

environmentally friendly urban transport. Additionally, regarding cross-sectoral collaboration, the European Innovation Council provides funding, equity investment, and business acceleration services to promising start-ups and SMEs, enabling them to drive innovative European Green Deal solutions with global scalability.¹⁴² Moreover, integrating digitalisation, technological advancement, and investment in research and development are crucial elements within the European Green Deal objectives. The Horizon Europe programme offers various instruments to support research and innovation efforts and the KIC would need to build on the scientific advances and results for Horizon Europe projects. For instance, in 2020 the European Commission allocated a substantial €1 billion through the European Green Deal Call¹⁴³, representing the largest initiative under H2020. Among the 73 projects selected for funding, many have a focus on **WMM-related fields**.

Education and training are also recognised as essential components of the European Green Deal's success, as they are seen as a key in facilitating Europe's progression towards a more equitable, inclusive, and sustainable mode of living and working. As a matter of example, the Council of the EU adopted a Recommendation¹⁴⁴ (16 June 2022) to strengthen learning initiatives for the green transition and sustainable development. Additionally, proactive re-skilling and upskilling are crucial for harnessing the benefits of the twin green and digital transition. In that sense, the European Social Fund+ plays a vital role in supporting Europe's workforce in acquiring the necessary skills to adapt to new processes and transition towards emerging innovative sectors.

The Sustainable Blue Economy¹⁴⁵ approach, closely connected to the European Green Deal, offers another integrated yet focused perspective. Set by the related 2021 EU Communication, it aims to achieve integration and foster investment in research, skills, and innovation, which hold great relevance for the **WMM KIC**. Marine and maritime research and innovation are crucial for achieving the EU's goal of climate neutrality by 2050, as well as for protecting and restoring marine ecosystems and driving sustainable innovation in the blue economy. Hence, the approach emphasises the importance of investing in research and innovation, exemplified by initiatives like BlueInvest¹⁴⁶. Moreover, this initiative supports innovative SMEs and startups, providing investment and market readiness assistance, and it enhances investor capacity while encouraging portfolio expansion into the blue economy. This integrated approach, bridging business and R&I, highlights a potential area of convergence within the broader context of the knowledge triangle. Furthermore, the approach underscores the central role of science and research in preserving and restoring marine ecosystems and achieving a sustainability transition, underlying the need for interdisciplinary efforts and cross-sectoral research and collaboration.

While the concept of circularity is central to the Sustainable Blue Economy approach, it is specific to the **Circular Economy Action Plan**. Among the action plan's initiatives, several hold particular significances for the **WMM KIC**. One notable example is the potential of the circular economy to substantially mitigate the adverse environmental effects of resource extraction and utilisation. This approach can also play a pivotal role in restoring biodiversity and natural capital in Europe, including the promotion of circular methods for water reuse in agriculture. Additionally, it aims to address the problem of marine plastic pollution. The plan introduces measures to minimise the occurrence of microplastics in the environment, including in seawater, drinking water, and food.

Other important developments are challenge and sector driven.

¹⁴²https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

¹⁴³ https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1669

¹⁴⁴ https://www.consilium.europa.eu/en/press/press-releases/2022/06/16/council-adopts-recommendation-to-stimulate-learning-for-the-green-transition/?utm_source=dsms-auto&utm_medium=email&utm_campaign=Council+adopts+recommendation+to+stimulate+learning+for+the+green+transition+and+sustainable+development

¹⁴⁵ https://ec.europa.eu/commission/presscorner/detail/en/ip_21_2341

¹⁴⁶ <https://maritime-forum.ec.europa.eu/en/frontpage/1451>

With respect to the first type, the **EU Biodiversity Strategy for 2030** is key. The major drivers of biodiversity loss are identified by the strategy as changes in land and sea use, overexploitation, climate change, pollution, and invasive alien species, all relevant to the **WMM** field. Regarding this latter, the need for (1) restoring the good environmental status of marine ecosystems and (2) restoring freshwater ecosystems are specifically addressed by the strategy. The first necessity relies mainly on the role of protected areas, the sustainable harvesting of marine resources, and maritime spatial planning, in line with the 2021 new approach for a sustainable blue economy in the EU. It is worth noting that the strategy also pinpoints the need to limit the use of harmful fishing gear while enabling the transition to more selective and less damaging fishing techniques.

The second need is associated with the fact that restoring freshwater ecosystems and the natural functions of rivers requires greater efforts, particularly as both implementation and enforcement of the EU's legal framework on water are not sufficiently in place. The key objective is the removal or adjustment of the barriers that prevent the passage of migrating fish, and the improvement of the flow of water and sediments, to be realised by restoring at least 25,000 km of rivers into free-flowing rivers by 2030. The primary reference, in this case, is the Water Framework Directive, requiring the achievement of good status or potential of all surface waters and good status of all groundwater by 2027.

Overall, existing legislation is seen as fit for purpose, while implementation and enforcement are lagging. This is particularly applicable to the EU Birds and Habitats Directives, the Water Framework Directive, the Floods Directive, the Marine Strategy Framework Directive, and the EU Invasive Alien Species Regulation. Also in this context, the strategy sees business and industry as both a source of impacts on nature and a producer of innovations, partnerships, and expertise that can help address biodiversity loss. In concomitance with other tools (e.g., the sustainable corporate governance initiative and the European Business for Biodiversity movement), investments in research, innovation, and knowledge exchange are seen as key to gathering the best data and developing optimal nature-based solutions. An example of the **KIC's contribution** can relate to deep-sea mining: while this is recognised as a promising activity in economic and strategic terms, its effects are poorly known and require further research, as also stated by the Strategy. The KIC can support progress in this direction by enhancing dynamics within the knowledge triangle.

The new **Skills agenda** is central in facilitating focus on training and reskilling of the workforce which is needed for the development of these solutions. Potential synergies of a WMM KIC need to be sought at the Biodiversa+ partnership level and with the Knowledge Centre for Biodiversity, which plays a role also in fostering cooperation and partnerships. Finally, the integration of biodiversity and ecosystems into higher education and professional training is dealt with by the "Proposal for a Council Recommendation on learning for environmental sustainability", which was already foreseen by the strategy and later adopted in 2022.

Climate change is another field that is interested in significant policy and strategic progress. **The European Climate Law** acknowledges the significant challenges posed by climate change on water-related effects like floods, droughts, and water scarcity, especially relevant within the context of a **WMM KIC**. These occurrences have far-reaching effects on ecosystems, livelihoods, and economies across the Union. Hence, the law considers how crucial it is to strengthen adaptive capacities and resilience, in alignment with the UN Sustainable Development Goals, to mitigate the impacts. Additionally, the law highlights the importance of safeguarding water sources in the face of growing climate-related health risks, including more frequent floods and concerns about water quality. Moreover, the law promotes the exchange of independent scientific knowledge in areas such as modelling, monitoring, and promising research and innovation to reduce emissions or increase carbon removal. It recognises the pivotal role of digital transformation, technological innovation, and research and development, underscoring their importance in achieving the climate-neutrality

objective.¹⁴⁷ In such context, the **EU Climate Adaptation Strategy** recognises synergies with the established **EIT Climate-KIC**. Under the Pathways2Resilience programme, which supports the EU Mission on Adaptation to Climate Change, the European Commission has tasked a consortium of organisations, led by EIT Climate-KIC, to collaborate with 100 regions to develop a tailored climate adaptation strategy¹⁴⁸. Moreover, this strategy identifies synergies between R&I and training within the **WMM sector**. By doing so, it strengthens a range of the KIC's objectives, such as preserving and restoring wetlands, coastal, and marine ecosystems, the conservation and sustainable utilisation of marine biodiversity of areas beyond national jurisdiction and ensuring freshwater availability. With a particular emphasis on sustainable water management, the initiative aims to improve the coordination of related plans and mechanisms, including resource allocation and permits. It also seeks to reduce water consumption by implementing stricter water-saving standards for products, promoting efficiency, and advocating for drought management plans, sustainable soil management, and land-use practices. Additionally, it aims to guarantee the supply of drinking water by incorporating climate change risks in risk analyses of water management. This initiative strives for a comprehensive collaboration at all levels of government and throughout society, placing significant focus on cultivating partnerships between private and public sectors, particularly in financing adaptation efforts. This strategic approach empowers the private sector to assess risks and direct investments toward initiatives centred on adaptation and resilience. Furthermore, this approach underscores the significance of investing in digital transformation, technological advancements, and research and engaging individual Europeans to take direct action in adaptation through training and education. For instance, the Commission is leveraging initiatives like the Education for Climate Coalition¹⁴⁹ to facilitate workforce requalification and transition towards sectors that are driving green growth.

Pollution, in its different forms, remains a challenge of major concern. **The Zero-pollution Action Plan** aligns with the Marine Strategy Framework Directive, adopted in 2008, which focuses on preserving marine ecosystems and promoting sustainable use of marine resources in line with the European Green Deal's goals and the EU's Biodiversity Strategy for 2030. It has a strong focus on **water quality** and underscores the importance of the revised Drinking Water Directive, highlighting its role in providing heightened protection for human health by implementing more stringent water quality standards. This directive aims to combat pollutants of concern, such as endocrine disruptors and microplastics, resulting in cleaner and safer tap water for all and reduced reliance on plastic bottles. Additionally, the initiative calls for the swifter and more effective implementation of existing EU regulatory frameworks safeguarding air, freshwaters, seas, and oceans. Hence, supporting intensified monitoring and reduction of pollution from crucial substances in surface and groundwater sources. Lastly, there is also a pressing need to establish a framework to regularly assess the condition of EU soils and take proactive measures against soil pollution and degradation. The initiative advocates for Member States to actively promote sustainable and efficient water consumption, discourage water pollution, and ensure a socially equitable water bill for all users, encompassing industry, agriculture, and households.

The second type of strategic and policy-related development are closer to a sectoral perspective.

On 21st February 2023, the European Commission presented and adopted a **package to improve the sustainability and resilience of the EU's fisheries and aquaculture sector**, composed of four measures:

¹⁴⁷ <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R1119>

¹⁴⁸ <https://www.pathways2resilience.eu/> and <https://eit.europa.eu/news-events/news/why-should-europe-care-about-climate-adaptation>

¹⁴⁹ <https://publications.jrc.ec.europa.eu/repository/handle/JRC127822>

1. EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries: the prioritised areas of the Action Plan are highly relevant to the work of a WMM KIC, as strongly related to its potential contribution. They are:

- Improving gear selectivity and reducing the impact of fisheries on sensitive species.
- Reducing the impact of fisheries on the seabed.
- Securing a fair and just transition in the fishing sector.
- Strengthening the knowledge base and R&I.

2. The common fisheries policy today and tomorrow: a Fisheries and Oceans Pact towards sustainable, science-based, innovative and inclusive fisheries management: among the factors that the Communication highlights as central, some are of direct relevance to the role of a **WMM KIC**, as vocational training and the importance of generational renewal. An attractive sector removes barriers like challenging working conditions through innovative approaches that are connected to marine stewardship, tourism, the whole value chain, direct sales, and the role of women. Sectoral attractiveness depends on an efficient, resilient, and safely operating workforce: upgrading skills is a precondition. Such improvements are supported by policy instruments such as the within the CFP, financial ones such as the European Maritime Fisheries and Aquaculture Fund (and its community-led local development - CLLD), and by projects such as the foresight study “Fishers of the Future” (to be completed by the end of 2024).

Innovation and funding are essential in protecting marine ecosystems and resources, also when considering the role of fishers in addressing the reduction of pollution, atmospheric emissions, and the adaptation to climate change and its impacts. Innovative solutions include biodegradable nets, ropes and gear components, collection of marine litter, pollution prevention activities, circular design, monitoring of fishing gear, and modernisation of fishing vessels. Therefore, sustainable innovation and investments must happen across the whole value chain and be specifically directed towards energy efficiency, sustainable fishing gear, the reduction of environmental and climate footprints, the improvement of safety, and the promotion of well-being at work. Energy efficiency, for instance, embraces several environmental objectives and it can reduce operational costs, thus enhancing profitability: here, synergies can be established with the Clean Energy Transition Partnership.

Particular attention needs to be given to small-scale and coastal fisheries, which represent nearly half of all employment in the fishing sector, and to joint work at the regional level (e.g., through Regional Fisheries Management Organisations, and by benefitting from the **Smart Specialisation Strategies Thematic Platform for sustainable blue economy**). In this scheme, technological innovation benefits from advancements in the digital realm, capable of providing a competitive advantage to fishers, enhancing data collection, control, and enforcement (also offering opportunities to inform scientific and decision-making processes), improving traceability and consumer information, while fostering the creation of a new generation of jobs. Practical examples, also mentioned in the Action Plan, are remote electronic monitoring (REM) systems, artificial intelligence, automated data analysis, continuous measurement and recording of engine power, and drones to ensure surveillance. The development of new technologies, to be read also in synergy with the Digital Twin of the Ocean, must consider scalability, financial affordability, and maturation strategies for dedicated markets.

3. The Energy Transition of the EU Fisheries and Aquaculture sector: in the context of a **WMM KIC**, the Communication recognises that barriers to innovation are influenced by the lack of the following factors: knowledge transfer and cooperation between the sector and researchers; scientific testing and pilots as validators of new technologies; lack of trust by some stakeholders. Knowledge barriers, such as the lack of data on energy efficiency, are accompanied by limited availability of training facilities and programmes, essential for the

uptake of innovations in fishing and aquaculture practices. With respect to financial barriers, representing one of the main concerns expressed by relevant stakeholders, the adoption of energy-efficient and low-carbon propulsion technologies can imply high investment costs. While public funding opportunities such as those offered by EMFAF exist, potential applicants often face challenges related to understanding the funding process and gaining a clear perspective on the broader funding landscape. For this reason, guidance and dissemination on the topic are becoming increasingly available¹⁵⁰. As R&I is recognised as a key contributor to addressing gaps in knowledge and technology for the energy transition of the sector, from a **WMM KIC** point of view, synergies in this domain are to be found with the Energy Transition Partnership for EU Fisheries and Aquaculture's knowledge-sharing platform and its portfolio of best-case studies and best practices in the industry. Central is also the connection with Horizon Europe partnerships, namely Zero Emission Waterborne Transport, the Batteries4EU Partnership, the Clean Hydrogen Partnership, and the S3 Thematic Platform for a sustainable blue economy.

Another key area, for the Communication, is the development of new skills and a trained workforce, by reskilling or upskilling, an essential requirement for the energy transition that includes subsectors such as naval energy engineering, energy suppliers, and ports. Supporting initiatives exist already in the blue economy, with one notable example being the "Blue careers for a sustainable blue economy" EMFAF call, through which eight projects have been launched in September 2023¹⁵¹. Moreover, the Communication reports a need for significant investments to be mobilised for R&I, the testing and scientific validation of the technology, upscaling, deployment, and the wider value chain.

4. The common organisation of the markets in fishery and aquaculture products, relevant as covering the organisation of the two sectors from a professional viewpoint, and in connection with the CFP objectives.

Still in the domain of food systems, the **Farm to Fork Strategy** aligns with key initiatives, including the European Commission's commitment to the UN's Sustainable Development Goals for global sustainability. Highly relevant in this framework are The Biodiversity Strategy for 2030, which tracks progress in sustainable food systems, and the Circular Economy Plan, both supporting a carbon-neutral economy indirectly. Regarding the **WMM field**, the Farm to Fork Strategy emphasises the need to shift towards sustainable fish and seafood production. It also addresses the reduction of dependency on critical feed sources, like soya from deforested areas, by promoting alternative feed sources such as insects, marine-based resources like algae, and by-products from bio-economy, including fish waste. Furthermore, it stresses the importance of ensuring that the entire food chain, from production to consumption, has a neutral or positive environmental impact. This includes preserving and restoring freshwater and sea-based resources that are essential for the food system. Moreover, the initiative emphasises the pivotal role of R&I in expediting the shift towards sustainable and inclusive food systems spanning from primary production to consumption, and the identification of new market opportunities. Key research areas focus on the microbiome, marine-sourced food, urban food systems, and the expansion of alternative protein sources like plant, microbial, marine, insect-based proteins, and meat substitutes. Lastly, the strategy underscores the EU's commitment to enforcing a zero-tolerance policy against illegal, unreported, and unregulated fishing (IUU), combating overfishing, and promoting sustainable fish and seafood resources management. It also

¹⁵⁰ European Commission, Directorate-General for Maritime Affairs and Fisheries, Guide on financing the green energy transition of fisheries and aquaculture – Supporting the energy transition in fisheries and aquaculture through EU funding opportunities under the 2021-2027 multiannual financial framework, NextGenerationEU and beyond, Publications Office of the European Union, 2023, <https://data.europa.eu/doi/10.2771/377801>

¹⁵¹ https://cinea.ec.europa.eu/news-events/news/eight-emfaf-projects-kickstarted-their-work-develop-next-generation-blue-skills-2023-09-22_en, accessed on 22/09/2023.

seeks to strengthen ocean governance, enhance marine collaboration, and improve coastal management practices.¹⁵²

The algae sector is showing great potential, recently. The **Communication Towards a Strong and Sustainable EU Algae Sector** identifies a critical bottleneck - the insufficient integration of science, technology, and innovation into the EU algae sector - which hampers its cultivation due to factors like high production costs, limited-scale production, and a lack of market knowledge, especially relevant to a **WMM KIC**. Advancing towards regenerative algae cultivation requires a focus on technological innovation and knowledge enhancement. Overcoming the constraint of limited data is essential for robust market development. Hence, collaborative research initiatives facilitated by EU programs like Horizon Europe are essential. Developing innovative equipment is also imperative to boost productivity and elevate product quality.

In terms of the business environment, a thriving business landscape and a healthy marine ecosystem are crucial for the growth of the regenerative algae sector. A collaborative effort with the algae industry is underway to assess the market and propose mechanisms for technology transfer from research to market. The aim is to increase collaboration within the EU and with neighbouring countries, resulting in new food applications and a wider variety of available algae species for various purposes. Additionally, targeted support for innovative SMEs, assessment of nutrient extraction from algae products, and their integration into green labelling and procurement processes are foreseen.

Innovation in the energy sector represents a pillar for the twin green and digital transition, and it is addressed by the **EU Strategy to harness the potential of offshore renewable energy for a climate-neutral future**. For the scope of this study, it is noteworthy to mention the key challenges highlighted by the strategy, for the achievement of the objectives related to the development of offshore wind and ocean energy in the coming decades.

Maritime Spatial Planning is the necessary tool to shape spatial interactions of different sectors, as these are increasing over time. In relation to this process, further development of the grid infrastructure is essential. The development of marine renewable energy is also subject to regulatory frameworks that need to be updated and account for the increasing complexity of energy production, storage, and supply. Infrastructure development, market-related support, and R&I require increased investments, which can be channelled through various EU initiatives such as InvestEU and the Power Up Initiative.

The development of offshore projects depends on enhanced R&D&I frameworks and dedicated education and training schemes that address existing skills shortages. In these fields, the **WMM KIC** can activate synergies with different instruments highlighted by the strategy, like the European Skills Agenda, Cohesion Policy Funds, the European Social Fund Plus, the Just Transition Mechanism, and the Centres of Vocational Excellence. Additionally, the upscaling of offshore energy significantly relies on a solid supply chain.

3.3.2 Initiatives and partnerships

The following EU initiatives and partnerships channel the efforts of R&I towards the solution of pressing challenges that are a priority in WMM fields. Any future WMM KIC needs to ensure complementarity, build on the outcomes and develop a clear strategy for linking with at least the following:

¹⁵²https://eur-lex.europa.eu/resource.html?uri=cellar:ea0f9f73-9ab2-11ea-9d2d-01aa75ed71a1.0001.02/DOC_1&format=PDF

Mission “Restore our Oceans and Waters by 2030”: the Mission adopts an integrated approach, by considering the connected system of oceans, seas, coastal, and inland waters, thus matching the WMM field setup as identified for the proposed KIC. To tackle the most pressing challenges, the necessity of a systemic focus on the entire water system has been recognised by stakeholders who, conversely, have also indicated that operational challenges may arise from the Mission’s wide scope, due to the need of covering complex, different, and growing challenges simultaneously¹⁵³. A similar consideration may apply to the **WMM KIC**, for planning, implementation, and positioning purposes. Within the framework of the Mission, potential synergies can be found with regard to research, training, capacity building, and education, in the actions pledged by relevant actors through the Mission’s Charter. By adhering to the Charter, the parties can take advantage of joining the Mission’s network while supporting its objectives in a range of fields, that specifically include both R&I and education & training, in the whole WMM field. The Mission, while widely addressing research and innovation amongst others, does not have as a direct objective education and training, even though the projects it is currently supporting are frequently connected to them. An analysis¹⁵⁴ of a portfolio of projects (841) that contribute to the objectives and enablers of Mission Ocean shows that HEI and research centres combined represent more than 50% of contributors to these projects, with a similar share among the two types of institutions. The projects covering the ocean digital knowledge system see even more significant participation of HEI and research centres, with strong involvement of businesses, indicating a possible area of convergence in the context of the knowledge triangle. Extensive mapping of the marine-related training offered at different educational levels is seen as necessary, also looking at possible interactions with professional and industrial stakeholders. Overall, EU networks as EIT-KICs are recognised as playing an important role in disseminating information, supporting the deployment at scale of innovative solutions developed under the Mission, coordinating and providing input, technical expertise, instruments and platforms for the implementation of the Mission, in particular from the innovation side¹⁵⁵. Other EU Missions, such as the Mission on Climate adaptation and the Mission Soils cover specific aspects of the WMM KIC.

Clean Energy Transition Partnership (CETP): the CETP Strategic Research and Innovation Agenda, in addition to its wider scope, is meant to create and diffuse high-quality new knowledge, skills and technologies for the transition while fostering improved access to and higher use of research results, innovation, services, and knowledge. Particularly at regional and local levels, the SRIA highlights the need for cross-sectoral integration, with regard to smart energy systems and energy transition processes in transport, industry, municipal infrastructure (including water supply and sanitation), and agriculture. The Agenda, published in November 2020, envisages synergies and complementary with the existing **EIT KICs** Climate and Innoenergy.

PRIMA, the Partnership for Research and Innovation in the Mediterranean Area, is recognised as a central initiative that employs a similar approach, particularly emphasising the water-energy-food-ecosystems nexus to confront primary challenges such as climate change. This accent is particularly significant given **the KIC’s emphasis** on cross-sectoral partnerships. It serves as a dedicated initiative, prioritising collaborative research and innovation to collectively tackle shared challenges. The initiative has cultivated a substantial network of scientists and practitioners in the Mediterranean region, resulting in a wealth of excellent science, knowledge, experiences, and best practices. This extensive network provides the opportunity to scale up tested solutions for broader implementation.

¹⁵³ SWD/2023/260 final (Commission Staff Working Document - EU Missions two years on: An assessment of progress in shaping the future we want and reporting on the review of Mission Areas and areas for institutionalised partnerships based on Articles 185 and 187 TFEU).

¹⁵⁴ European Commission. Directorate General for Research and Innovation. Portfolio Analysis, EU Mission “Restore our Ocean and Waters by 2030”: Analysis of a Portfolio of Projects Financed by Sixteen EU Programmes Contributing to the Objectives and Enablers of the Mission Ocean and Waters. LU: Publications Office, 2023. <https://data.europa.eu/doi/10.2777/683>.

¹⁵⁵ European Commission. Directorate General for Research and Innovation. European Missions – Restore our Oceans and Waters by 2030: implementation plan (2021).

The Sustainable Blue Economy Partnership has been launched in early 2023. Its SRIA, published in 2021, already foresaw convergence with other **KICs** (e.g., Climate, Raw materials, Health, Food, Digital) and mentions the **WMM KIC** as an initiative of potential common interest and joint activities, in coordination with other partnerships.

Among the different activities planned for the implementation of the Partnership, capacity building in the blue sectors has been expressed as increased academia-industry interactions, continued education schemes, and thematic business-research matchmaker events, with the role of international R&I cooperation being characterised by a high level of integration across sectors, disciplines, and types of stakeholders. Furthermore, the SRIA envisions training, reskilling, and upskilling as linked to the opportunities offered by new business models and emerging blue economy sectors, and the enhancement of human resources as connected to the alignment of higher education curricula, to the design of transdisciplinary MSc and PhD programmes, and to short-term mobility exchanges. As in the case of ZEWT, within the industry domain, the specific importance of SMEs is also recognised.

With respect to freshwater, systemic thinking and integrated approaches (e.g., water, land, ocean) are promoted by the Partnership intervention logic, and linked with specific EU policies/legislation/initiatives highlighted (e.g., Zero Pollution Action Plan for Air, Water and Soil; Water Framework Directive and related directives; Water4All Partnership). The goal of promoting a sustainable blue economy is coupled with the influence of freshwater, transitional water, terrestrial environments and land-based activities, including engagement and collaboration with relevant communities, activities and projects.

Water4All underscores the need for a holistic approach to water-related challenges, which is especially relevant in the context of a **WMM KIC**¹⁵⁶. Scientific research stands at the core of the partnership, acknowledged as a powerful tool for enhancing knowledge in preserving, restoring, and managing this vital resource. This commitment extends from knowledge and solutions development to the practical implementation of water research and innovation. Moreover, the partnership is structured for a broadened sectoral and cross-sectoral approach, considering policy, environmental, economic, technological, and societal dimensions. Hence, it prioritises cross-sectoral integration and aims for meaningful collaboration among diverse stakeholders, including policymakers, operators, and society as a whole. The partnership also establishes synergies with the objectives of other existing programs and initiatives, such as the European Green Deal and the United Nations' Sustainable Development Goals, contributing to the competitiveness and growth of the European Union. Due to their scope, Water4All and the **WMM KIC** could find common ground in the joint promotion of solutions at different scales (e.g., regional and local testing of existing and emerging technologies), and work towards their market uptake and enhanced stakeholder involvement.

Zero-Emission Waterborne Transport Partnership (ZEWT): to achieve its objectives, the Partnership aims to help address the different bottlenecks and market failures that may arise, as those connected to R&I (e.g., the development of alternative fuels, dedicated infrastructure, retrofitting schemes), systemic ones (e.g., high diversification of interests within the sector, a large number of SMEs with limited investment capacity and access to research funding), and deployment bottlenecks (e.g., high risks associated with being first-adopters of new technologies, restrictive regulatory frameworks).

This innovation process requires upskilling and/or reskilling of the existing workforce, to be supported by the Partnership through the following activities: the establishment of synergies with other partnerships, programmes, and initiatives (e.g., the Pact for Skills and the Erasmus+ programme); by facilitating the take-up of the outcomes from RD&I actions; education and training provisions; its SRIA and related updates. The waterborne transport sector is extremely diversified in terms of types

¹⁵⁶ <https://www.water4all-partnership.eu/>

of jobs and needed skills, a characteristic that the Partnership SRIA sees as requiring coordinated approaches along the entire value chain, to adapt skills and promote adequate education and training schemes, with specific attention to given to **SMEs** as an essential part of the European ecosystem.

Circular bio-based Europe joint undertaking (CBE JU) establishes synergies with other existing programs and initiatives, aiming to benefit the EU by advocating a shift from non-renewable fossil materials to circular production processes based on renewable agricultural, marine, and forestry materials. CBE JU contributes significantly to the EU's climate targets outlined in the European Green Deal by championing robust, resource-efficient, and competitive bio-based industries. It recognises the imperative transition to renewable products and materials for achieving climate neutrality by 2050, and the importance of fostering job creation and economic growth across European regions.

The **Pact for Skills**, one of the flagship actions of the European Skills Agenda, has been designed to support upskilling and reskilling in both private and public environments. Skills development is promoted through the collective action of a diversified set of players (e.g., authorities, industry, associations) in a cooperative setting. With this purpose, Large-Scale Skills partnerships, covering 14 industrial ecosystems, have been launched. Some of them, established in 2023, are particularly relevant for the WMM KIC: the **skills partnership for offshore renewable energy**, run through the FLORES project¹⁵⁷, the **skills partnership to advance the digitalisation of the energy sector** and the **skills partnership for Shipbuilding and Maritime Technology**.

3.3.3 *Platforms, hubs, enablers*

A relevant novelty, launched in 2023, is the **European Blue Forum**. Following its founding participatory approach, the initial positioning of the Forum is being determined by kickstarting the discussion around two themes, that are of primary importance for the **WMM KIC**:

- 1. The 2030 milestone:** multiple challenges are to be addressed by 2030, in accordance with the UN Agenda for Sustainable Development and the European Green Deal. The ambitious goals that have been set require both radical change and the uptake of strong measures, and their achievement is rooted in holistic, integrated, and multidisciplinary solutions. Furthermore, they are sometimes characterised by trade-offs among different uses, approaches, and safeguard objectives. The Forum is an effort to bring together different sectors across scales, for the construction of one maritime community. Its bottom-up approach is key for the involvement of all stakeholders in the decision-making process, targeting the identification of existing and innovative solutions. The use of knowledge, science and cooperation with industry (e.g., Digital Twin of the Ocean) are central to the concept.
- 2. The transition towards a fossil fuel-free sustainable blue economy.** Shipping and fisheries are core maritime sectors in which energy efficiency, the use of alternative energies, and energy saving are being advanced, while marine renewable energy is essential to the energy transition and ports play another key role as necessarily sustainable nodes. Nevertheless, with such a composite landscape of maritime industries, access to financing and investments remains a critical element, given that a fair and equitable transition should be accessible to all sectors, and account for the whole value chain. Another concept that needs consideration and discussion is the shift in consumption models. There is a necessity for developing further cross-sectoral solutions and overcoming the challenges that hamper the scaling up of innovations. The Forum sees the contribution and participation of all stakeholders in these processes as a key driver for the transition and it aims to build common ground for the promotion of combined solutions from both a technological and societal perspective.

¹⁵⁷ <https://oreskills.eu/about/project-overview/>, accessed on 07/02/2024.

Similarly but with a significantly different scope, **BlueInvest** works towards the promotion of sustainable and innovative technologies for the blue economy. It identifies ten key sectors for investment opportunities and innovation, including aquaculture, blue biotechnology, blue renewable energy, blue tech and ocean observation, coastal and maritime tourism, environmental protection and regeneration, fisheries, shipbuilding and refit, shipping and ports, and water management.

Within this initiative, there is a potential for valuable synergies with the **WMM KIC**. This encompasses various activities, including training, capacity building, and educational initiatives, offering online learning, training opportunities, and coaching for its community members. Moreover, it actively fosters partnerships across EU Member States, utilising its community platform to facilitate networking and collaboration within the broader blue ecosystem. BlueInvest also plays a crucial role in engaging research, knowledge, and innovation within the business communities. It provides essential support to early-stage businesses, SMEs, and scale-ups, enhancing their readiness and access to finance. For example, through dedicated financial instruments like the InvestEU Blue Economy Fund¹⁵⁸ in collaboration with the European Investment Fund, it strengthens the finance ecosystem necessary to support and scale up the sector. By offering investment and market readiness assistance, BlueInvest propels innovative SMEs and start-ups, introducing them to its expanding investor community and aiding in fundraising efforts. Since late 2023, BlueInvest is also supporting a new pilot scheme, “EU Blue Champions”, dedicated to providing financial advisory to selected projects in the blue economy. The scheme, launched by the European Commission in collaboration with the European Investment Bank (EIB), targets directly those projects that contribute to the EU Mission “Restore our Ocean and Waters” and its three objectives. This kind of program, connecting different initiatives and institutions, can be of high relevance to the WMM KIC.

Also, the **EU4Ocean Coalition** is aligned with the envisioned role of the **WMM KIC**, fostering cross-sectoral partnerships, providing training, and connecting individuals across various age groups, with a strong emphasis on youth engagement. It actively promotes collaboration at multiple geographical levels, spanning the Arctic, Atlantic, Baltic, Black, and Mediterranean seas, as well as the global ocean. The coalition consists of three integral components: (1) a Platform for Ocean Literacy Initiatives, enabling members to share ideas, forge partnerships, and work together towards a more coordinated approach to ocean literacy in Europe; (2) a European Youth Forum for the Ocean, offering a platform for young individuals to exchange ideas, showcase projects, and connect with like-minded peers and experts from all over Europe; and (3) a Network of European Blue Schools, which encourages educators to involve students in projects related to the ocean, nurturing a deeper understanding and appreciation for marine environments.

The **Digital Twin of the Ocean** is an extremely promising technological innovation that will work as an enabling factor for a high number of elements which are at the core of productive and sustainable WMM fields. It aligns with existing efforts, supporting the EU Mission “Restore Our Oceans and Waters by 2030” by strengthening ocean governance, habitat restoration, and disaster-risk management. Additionally, it is of high relevance for the UN Decade of Ocean Science for Sustainable Development and the 2030 Agenda, as it allows exploration of the impacts of management decisions on marine ecosystems, climate, and the ocean economy sectors. Furthermore, the Digital Twin leverages existing European data sources, including satellite, in situ and model data provided by Copernicus, EMODnet, and pan-European and national research infrastructures. Regarding innovation and digitalisation, the platform will incorporate AI into ocean modelling, employing advanced machine learning and ecosystem models to enhance our understanding of ocean processes. Hence, it will serve as a unique tool for monitoring marine biodiversity, utilising advanced modelling techniques, citizen science data, and parameters related to ocean physics and biogeochemistry.¹⁵⁹

¹⁵⁸ https://www.eif.org/InvestEU/equity_products_calls/index.htm.

¹⁵⁹ <https://digitaltwinocan.mercator-ocean.eu/>.

The seabasin dimension is recognised as essential to interpret and addressing marine and maritime challenges and to enable effective and tailored solutions. As such, it is covered by the **EU Seabasin Strategies and related Assistance Mechanism**. Marine areas affected by challenges described in this report are in fact shared among different countries, both within and outside the EU, and therefore regional/cross-country cooperation in this area, including with non-EU countries, is important. Although practices can be shared across seas, it must also be recognised that each sea basin across the EU is different: there are specific conditions, opportunities and challenges for each sea basin, which require a targeted approach¹⁶⁰. The European Commission recognises these aspects and has supported the endorsement of Seabasin Strategies across four basins through time: the Atlantic¹⁶¹, western Mediterranean¹⁶², Black Sea¹⁶³ and more recently North Sea¹⁶⁴. A dedicated Assistance Mechanism is also in place to coordinate actions and engage with stateholders, towards greater uptake of innovation and cooperation across the knowledge triangle and beyond. This is an important asset to be considered by the **WMM KIC** to reach out at the seabasin level, support innovation across the EU and potentially also engage with non-EU countries to expand innovative value chains and scale up knowledge-sharing and innovation.

3.3.4 Global dimension

The global dimension is a necessary reference when considering the complexity of the challenges that WMM fields are facing, the solutions that are sought and emerge worldwide, and the importance of extended cooperation networks. Some of the most relevant recent global developments are presented here.

High Seas Treaty Adoption: the agreement sets out a framework for the collective management of activities in the high seas, and the oceanic regions beyond national jurisdiction. Its main objective is to counteract harmful practices like pollution and unsustainable industrial activities (such as fishing and shipping). This treaty plays a pivotal role in addressing vital concerns, including conservation, sustainable use of marine resources, preservation of biodiversity, combatting climate change, and promoting scientific research in these internationally shared maritime zones.¹⁶⁵ Furthermore, the treaty is expected to enhance coherence, coordination, and synergies among various organisations and stakeholders involved in ocean-related activities. This will contribute to a more comprehensive approach to managing high-seas activities.

The Kunming-Montreal Global Biodiversity Framework: is an international agreement adopted during the fifteenth meeting of the United Nations Biodiversity Conference of the Parties (COP 15) that outlines global targets and strategies for conserving and sustainably using biodiversity. This Framework, aligning with the Sustainable Development Goals and expanding on the Convention's earlier Strategic Plans, sets an ambitious pathway to achieve global harmony with nature by 2050.

United Nations Decade of Ocean Science for Sustainable Development (2021-2030): to ensure the optimal positioning of a **WMM KIC** in relation to the Ocean Decade, it is essential to address the 10 Ocean Decade Challenges. These challenges represent the Decade's most immediate priorities, which are being fulfilled through the implementation of a high number of actions (more than 350, currently, and increasing in number):

¹⁶⁰ European Commission. EU Sea Basins. European Commission - Maritime Affairs and Fisheries, available at: https://oceans-and-fisheries.ec.europa.eu/ocean/sea-basins/eu-sea-basins_en.

¹⁶¹ <https://atlantic-maritime-strategy.ec.europa.eu/en>.

¹⁶² <https://westmed-initiative.ec.europa.eu>.

¹⁶³ <https://black-sea-maritime-agenda.ec.europa.eu>.

¹⁶⁴ <https://www.government.nl/documents/discussion-documents/2023/11/21/greater-north-sea-basin-initiative---ministerial-conclusions>.

¹⁶⁵ <https://www.un.org/bbni/>

- Understand and beat marine pollution.
- Protect and restore ecosystems and biodiversity.
- Sustainably feed the global population.
- Develop a sustainable and equitable ocean economy.
- Unlock ocean-based solutions to climate change.
- Increase community resilience to ocean hazards.
- Expand the global ocean observing system.
- Create a digital representation of the ocean.
- Skills, knowledge and technology for all.
- Change humanity's relationship with the ocean.

The role of the private sector is recognised as key to advancing ocean science for societal benefits while such progress, in turn, is seen as an opportunity for sustainable businesses to thrive (e.g. through cost savings, risk mitigation, operational efficiency, increased market shares, predictable and stable supply chains, enhanced relationships with stakeholders, improved access to markets and customers, and attracting new investments). The Decade is a framework that promotes strong partnerships for the delivery of science-based solutions¹⁶⁶.

3.3.5 *Knowledge transfer-related projects*

A comprehensive review of present and past projects that could be considered significant for the role of a WMM KIC goes well beyond the scope of this study. The following three projects cover knowledge transfer, one of the primary fields of relevance for a WMM KIC. They are described as typical cases of possible synergies to be leveraged.

COLUMBUS project incorporated key factors relevant to a **WMM KIC** regarding knowledge transfer and offers valuable inspiration. COLUMBUS established an extended transnational partnership representing all aspects of the research value chain, covering Europe's sea basins and their marine and maritime activities. The project employed a methodology based on early-prioritised needs, focusing on identifying and collecting knowledge outputs. By treating research as individual knowledge units, rather than a mass of findings, targeted transfer plans were designed to increase the likelihood of impact. Furthermore, the project aimed to unlock the potential of existing research, justifying significant investments by mining funded projects for knowledge that could fill gaps and bottlenecks. This valuable knowledge was then directly shared with the intended users to help put into action different marine strategies and policies. These strategies encompassed initiatives and frameworks like the Blue Growth Strategy, the Marine Strategy Framework Directive, the Marine Spatial Planning Directive, the revised Common Fisheries Policy, the Integrated Maritime Policy, the EU Strategy for the Atlantic, and Marine Knowledge 2020, among others.¹⁶⁷

BlueBRIDGE exhibits commonalities in innovation, knowledge exchange, capacity building, and education within the framework of the **WMM KIC**. It is built upon existing EU and international e-infrastructures, providing capacity building for interdisciplinary research communities, encompassing scientists, data managers, and educators in academic institutions and industries. Its focus is centred on four major challenges: 1) stock assessment, 2) socio-economic performance analysis in aquaculture, 3) fisheries and habitat degradation monitoring, and 4) education and knowledge bridging on the protection and management of marine resources. Moreover, BlueBRIDGE opened

¹⁶⁶ UNESCO/IOC. 2020. Advancing Science for Sustainable Ocean Business: an opportunity for the private sector. UNESCO, Paris, 24p. (IOC/INF-1389, IOC/2021/ODS/27).

¹⁶⁷ <https://cordis.europa.eu/article/id/239509-knowledge-transfer-creates-sustainable-blue-growth>.

services and data to various stakeholders, collaborating with competent agencies and SME Innovation Clusters. The collaboration brought together forces from international government organisations, research institutes, industry, SMEs, education, and computer science domains, establishing a network with a proven track record in Virtual Research Environments (VREs) and e-infrastructures across marine, environmental, and fisheries science, and the economy. Key achievements included the development of service-driven research environments addressing specific challenges, providing comprehensive data, and incorporating a diverse range of user-defined Blue Growth indicators.

Other relevant initiatives: The “European University of the Seas” (SEA-EU), a project launched in 2019 and co-funded by the Erasmus+ Programme¹⁶⁸, is a strategic alliance currently involving 9 universities and 75 associated partners (including research centres, businesses, local authorities, public entities, NGOs and non-profit organizations, international clusters of excellence and ports), that aims at strengthening the links between teaching, research, innovation and knowledge transfer, and characterised by a transnational vocation. Its strategy on education and training, focusing on marine and maritime issues, mobility, R&I, and societal challenges, has the potential to help address the identified disciplinary gaps and is of high relevance to a **WMM KIC**.

3.3.6 Conclusions

The proposed WMM KIC exhibits significant synergies and complementarities with existing EU-level initiatives, spanning various policy domains such as biodiversity conservation, sustainable blue economy, circular economy, and climate adaptation. Aligned with the overarching goals of the European Green Deal as well as broader Sustainable Development Goals, the WMM KIC distinguishes itself by focusing on the integration of marine, maritime, and water sectors, a perspective not widely addressed across similar initiatives with the notable exception of the EU Mission Restore our Ocean and Waters. This defining focus, coupled with the scope of work that is typical of KICs, positions the WMM KIC as a valuable contributor to the EU objectives pertaining to the WMM fields and beyond, and as an instrument that can provide contextualised and meaningful added value, with respect to existing initiatives.

The emphasis on education, innovation, and research within the KIC resonates with the broader EU strategies, and hence, its potential impact could be bolstered if aligned with partnerships already in place. The consideration of different geographical dimensions is also suggested, for instance by looking at sea basin and macro-regional strategies, and the Outermost Regions, in addition to the global scale. With respect to the international ocean governance framework, the 2022 “Setting the course for a Sustainable Blue Planet - Joint Communication on the EU’s International Ocean Governance Agenda”¹⁶⁹ provides a clear positioning for the EU and an updated commitment to the implementation of the UN 2030 Agenda, embracing the objectives of all the initiatives analysed in this study. This Joint Communication is to be considered a primary reference at the international level, for the WMM KIC. However, careful attention must be paid to avoid overlap with existing partnerships, with respect to both Horizon Europe and another type of partnerships. Stakeholders consulted as a part of this study have expressed concerns about potential duplications, particularly in areas such as education and innovation, where there may be competition for resources between the KIC and established partnerships.

¹⁶⁸ In 2023, SEA-EU entered its second phase, characterised by an enlarged partnership.

¹⁶⁹ SWD(2022) 174 final.

4. DISCUSSION AND CONCLUDING REMARKS

4.1 Challenges and opportunities

Europe faces continued increasing pressure on marine and freshwater water resources due to a number of progressively better-known factors including increasing demand, urbanisation, pollution, climate change, and their cumulative impacts. Research conducted in **this study confirms the continued existence of the challenges** identified in the EIT 2021- 2027 factsheet on WMM and the underlying SIA impact assessment. Notwithstanding data gaps, research also indicates that overall the three challenges are expected to intensify in the short to long term. Science, technology, and innovation are actively addressing these challenges. Scientific research is increasingly focused on understanding the influence of climate change and human activities on water-related disasters. Despite progress, the **severity of water-related challenges is expected to increase**. Addressing this trajectory necessitates enhanced EU support for emerging water technologies (marine and freshwater-related), targeted innovative solutions, adaptive governance tools, and continued research to comprehend short-, medium-, and long-term impacts.

Recent years have witnessed substantial steps and measures in safeguarding and restoring marine and freshwater ecosystems in Europe. Strategies and plans launched in the EU reflect commitments to combat biodiversity loss and pollution mitigate and adapt to climate change and support environmental protection in coexistence with equitable societies and thriving economies. Research has been focusing on understanding long-term degradation processes impacting these ecosystems and developing innovative solutions to address these. Initiatives like the European Digital Twin of the Ocean and progress in marine litter technologies may play a pivotal role in ecosystem assessment and management, showing promise for more efficient and effective support to the resolution of these challenges. Efforts to raise awareness, promote ocean literacy, and engage coastal communities in sustainable practices are being pursued. Despite progress, **the challenges persist**. Enhanced cooperation and coordination among stakeholders are crucial to expand and streamline the benefits of these developments. Assessment of cumulative technological impacts is needed, alongside efforts to better connect scientific research, technology development and deployment, and policy implementation.

The development of a circular and sustainable blue economy, on which large sectors of society rely for their own livelihood and prosperity, is increasingly considered a necessity. As a two-sided coin, it presents both challenges, like those related to increasing pressures and enacting the twin green and digital transition, and opportunities, like those deriving from innovating established sectors and the rise of novel technologies and uses (of resources). In economic terms, the development of the blue economy has been highly volatile since 2019, due to the COVID-19 pandemic first and the unprovoked Russian invasion of Ukraine in 2022 afterwards. These events have shown how sectors are impacted differently, with typical examples being, in the first case, coastal tourism and, in the second, fisheries (higher energy and fuel costs). Nevertheless, recovery is consistent and in progress across sectors (with notable exceptions like fisheries) and future projections predict overall growth.

The comparative relevance of sectors is also dependent on complementary significance, as in the case of aquaculture and fisheries, and the whole energy sector (e.g., renewables vs. oil and gas). Furthermore, such complementarity is important to address skill gaps, with emerging sectors that could benefit from both expertise acquired in traditional industries, and a stronger and more flexible connection with R&D. Traditional sectors need to face challenges related to workforce availability and capacity, attractiveness, competitiveness, and necessary shifts to enable sustainable activities.

Another element of diversification pertains to the geographical level, with sectors being differently developed across sea basins and national dimensions. These differences call for both targeted approaches (sectoral and regional) and an overall common strategy for the blue economy. The green

and digital transition expresses multi-faceted challenges for the development of a circular and sustainable blue economy: skill gaps, need for investments, market penetration, uptake, and upscaling of innovative solutions, and increasing use of marine space.

Evidence-based policymaking requires efficient and effective science-policy interfaces, and the deployment of sustainable solutions demands stronger connections within the knowledge triangle. Adequate policy, regulatory, and financial measures, including in connection with the freshwater domain and land-based activities should take into account the necessity of innovative methods and technologies for the successful development of a circular and sustainable blue economy.

4.2 Potential relevance and impact of WMM KIC

Despite the disruptions caused by the COVID-19 pandemic and by the unprovoked military aggression and invasion of Ukraine by Russia, most sectors within the blue economy are experiencing notable growth, confirming a solid positioning of the maritime economy sphere and the socio-economic importance of European blue economy sectors. This growth is benefiting from the expansion of emerging fields such as blue biotechnology, marine renewable energy, digitalisation and innovative blue tech. The potential of combining technologies for the enhancement of sustainable solutions is also promising. Additionally, the concept of multi-use, novel uses of resources, and systemic approaches across disciplines and sectors, are gaining traction.

In terms of challenges, **climate change poses a significant hurdle to WMM-related economies.** It is crucial to prioritise tackling the impact of climate change on ocean and freshwater resources, especially considering the increasing frequency and severity of extreme meteorological events and their consequences, influenced by both climate and non-climatic factors. Consequently, decarbonisation has emerged as an urgent priority across a wide range of sectors. Encouraging emission reduction in the blue economy, and carbon removal through initiatives like carbon crediting and accounting, along with the implementation and expansion of practical carbon removal, storage and utilisation methods, require extensive development efforts spanning various sectors. Increasing use of marine space and pollution (characterised by existing knowledge gaps on impacts, cumulative effects, and land-sea interactions) are also major concerns requiring efforts that can benefit from efficient mechanisms within the knowledge triangle.

The KIC has the **potential to act on the fragmentation of efforts and the disconnection between education, research and innovation activities.** There is a shared understanding, across WMM communities, of these elements as crucial bottlenecks to innovation that show critical room for improvement, at the current state. From the perspective of fragmentation of efforts, a dedicated KIC can play a role in the WMM field as a connecting node across geographies, sectors, disciplines, and initiatives, for the streamlining of optimised dynamics within the knowledge triangle. Its holistic WMM focus has the potential to improve coherence, alignment, and synergies in fields that are characterised by both the need to pursue common goals and relatively different priorities and communities. This needs to be done through an adaptive process, where prioritisation of efforts is shared by stakeholders, the KIC positioning is accurately designed, and a coherent strategy is clearly outlined.

In the WMM field, a **stronger integration of education, research, and business activities is necessary for the development and deployment of both an improved knowledge base and innovative solutions to urgent challenges.** Considering the existing disconnection within the knowledge triangle, the proposed KIC can bring added value to the field by addressing crucial elements. The availability of a skilled workforce is one of them: upskilling and reskilling are not only required, but they also constitute a gateway to better quality and attractive jobs. Lack of specialisation is affecting both established and emerging sectors, even if from partially different perspectives that are connected to the sector of reference and the geographical dimension. This latter is showing

another type of fragmentation across Europe, that concerns the uneven distribution of activities related to the knowledge triangle and the blue economy. Through the EIT Regional Innovation scheme, the KIC can contribute to its reduction, as well.

The existence of multiple challenges and their cumulative impacts, a dynamic and complex WMM landscape, and the need to enable transformative changes by boosting cooperation between research, education, and business to leverage disruptive innovation, make the potential contribution of a WMM KIC highly relevant.

4.3 Synergies and complementarities with existing initiatives

A selected list of initiatives and policy tools, launched after 2019 and considered to be highly relevant to the objectives of the WMM KIC, has been analysed in view of an adequate positioning of the proposed instrument. The results show that a correct positioning should take into account three viewpoints of their approach: relevance of the KIC contribution, sectoral, and challenge-related.

The first is seen as the most cross-cutting one, due to the fact that integration within the knowledge triangle is widely recognised as an enabling factor to achieve the objectives of both policies and initiatives. **The activation of synergies and complementarities should be seen as a starting point.**

Concerning the sectoral perspective, existing initiatives/policies in the WMM field embrace both systemic, mono-sectoral, and cross-sectoral aspects. Once the areas of action and impact are prioritised, the KIC activities need to be framed within a systemic (e.g., Sustainable Blue Economy approach, Circular Economy Action Plan), sectoral (e.g., Communication Towards a Strong and Sustainable EU Algae Sector, EU Action Plan on Protecting and restoring marine ecosystems for sustainable and resilient fisheries), and cross-sectoral (e.g., European Blue Forum, HE Partnerships, Energy Transition Partnership) standpoint, by prioritising alignment with policy streams first, and enacting alignment and collaboration with relevant initiatives, afterwards.

The challenge-related perspective identifies areas of action with respect to pressing challenges, like in the case of the EU Biodiversity Strategy for 2030 and the European Climate Law.

While the three perspectives are present across all policies/initiatives, these are defined by clear-cut characteristics. For its positioning, the KIC needs to refer to specific policy areas that reflect its established priorities, pursue synergies with existing initiatives in its areas of competence, and seek coordination in the fields of reference. Prioritisation, beyond considering the features of the WMM field and the associated innovation ecosystem in Europe, can refer to wider schemes, for instance by looking at the ten UN Ocean Decade Challenges. Also, the potential synergies with EU Sea Basin Initiatives and the related Assistance Mechanism could be considered a valuable option to foster reach out with stakeholders.

Frameworks such as the European Green Deal, EU approach for a Sustainable Blue Economy, Horizon Europe, global agreements, and the SDGs, are to be considered overarching, thus as a primary reference and not falling under a specific category. The KIC can also build on the experience of Mission “Restore our Oceans and Waters by 2030”, the initiative that relates better to the comprehensive WMM approach of the same KIC, including its transversal solution-enabling instrument European Digital Twin of the Ocean. This is particularly important, as maximizing the collaboration between freshwater and marine/maritime communities is crucial for effectively addressing interconnected issues. The Mission promotes both a challenge-related and systematic approach (addressing the interconnected issues of ecosystem/biodiversity; pollution; sustainable blue economy/freshwater), expresses a multi-scale program, and operates in strong connection with the different actors of the knowledge triangle.

Horizon Europe Partnerships, both current and future, are another fundamental reference for the KIC, as they are focused on specific aspects of the WMM field. They promote and rely on highly interfaced education, research, and innovation activities, offering an optimal ground for the emergence of complementarities and the establishment of synergies. In addition, the KIC would be launched at a favourable moment in order to build on the results achieved by the partnerships since their launch.

The very development of a more integrated knowledge triangle in the WMM field, from both a structural and financial point of view, can be advanced through dedicated hubs such as BlueInvest, EU4Ocean Coalition, the Smart Specialisation Strategies Thematic Platform for sustainable blue economy, and the European Blue Forum.

The initiatives and policies analysed share an essential common trait: the reconciliation of human activities with the safeguarding of healthy ecosystems. Other joint perspectives might be areas of focus for the KIC, favouring its alignment with approaches that are common to different initiatives and policy tools. The role of European SMEs, as an essential part of the European WMM ecosystem and across value chains, is a notable example. This kind of positioning of the KIC is fundamental to leverage its potential in an effective and efficient manner, for synergies, complementarities, and alignment to emerge and be promoted. The integration of three viewpoints - sectoral, challenge-related, and on the KIC contribution - can offer a useful perspective, in this regard.

ANNEXES

Annex 1 - Summary table of trends in developments and the impact on challenges confronted by the WMM sectors and ecosystems

The table below summarises the trends in the scientific, technological, and socio-economic areas covering the period 2019 – 2023 together with the impact of the challenges confronted by a potential WMM KIC. This table provides an overview of information that supports the conclusions expanded upon in Chapter 4.

Table 2. Summary table of trends in developments and the impact on challenges confronted by the WMM sectors.

Challenge 1	Water scarcity, drought and floods	
Key aspects of the challenge	Overall challenge severity status	Response
<p>1. Water scarcity, droughts, and floods are intricately linked issues, all sharing common concerns regarding water availability, quality, and security.</p> <p>2. Human demand for water has risen over the past five decades, mainly as a result of population growth and urbanisation. According to UN data, global water demand is projected to rise by 20% to 30% by 2050.</p> <p>3. Climate change is expected to accelerate the challenge even further, leading to an increase in the frequency and intensity of water-related disasters, such as droughts and floods.</p>	Increased	x
	Unchanged	
	Decreased	
Key trends in solutions/developments	Possible actions	
<p><i>Solutions for transitioning to a water-efficient and water-saving economy:</i></p> <ol style="list-style-type: none"> 1. Wastewater treatment methods for water reuse 2. Digital solutions for optimised water resource management 3. Desalination methods providing new sources of water 4. Water-efficient energy solutions <p><i>Solutions for improving the EU's prevention, preparedness, and overall resilience to water-related disasters:</i></p> <ol style="list-style-type: none"> 1. Drought-tolerant crops and new genomic techniques 2. Drought and flood forecasting tools 	<ol style="list-style-type: none"> 1. Facilitate skills enhancement to enable the efficient implementation of these innovative solutions in the EU 2. Provide resources for EU businesses to boost their technological capacities¹⁷⁰ 3. Direct funding sources for research and innovation tailored to the identified needs 4. Foster an interactive dialogue through water-focused European Partnerships to improve the generation and dissemination of research, technology, and innovation 	

¹⁷⁰ Such as guidance on funding, training and partnerships, or help and advice.

3. Technological developments in water-related disaster prevention and preparedness			
Impact summary of 2019-2023 trends in new developments/solutions on the severity of the challenge sources		Severity of challenge status	Response
Despite significant technological progress in recent years, the severity of the challenge is set to increase over the coming decades, as Europe is heading towards a future characterised by more extreme conditions of water scarcity, drought, and flooding. Further research will be essential for comprehending the short and long-term impacts of climate-induced water-related hazards, and more targeted technology and innovative solutions will be required to meet the demand and address these rapidly evolving impacts.		Increased	x
		Unchanged	
		Decreased	
Impact summary of 2019-2023 trends in new developments/solutions on the requirement for innovative methods/technologies to address the challenge		Challenge relevance status	Response
1. Climate-induced changes in drought regimes require further research 2. The impact of water scarcity, droughts and floods on water quality tends to be overlooked in water science 3. Water scarcity and droughts damage ecosystems to an extent that is not yet known		Increased	x
		Unchanged	
		Decreased	
Challenge 2	Marine and Freshwater ecosystem degradation		
Key aspects of the challenge		Overall challenge severity status	Response
1. Persisting problems with nutrients, pollution and litter in water and marine environment 2. The status of marine ecosystems is often unknown, or not good 3. Current protected area coverage, management, and enforcement by itself not sufficient to reverse the decline of ecosystems		Increased	x
		Unchanged	
		Decreased	
Key trends in solutions/developments		Possible actions	
1. Technological advancements, which include digital tools, innovative research approaches, projects targeting marine litter, and monitoring improvements 2. science, technology, and research are moving forward, while the developments are in different stages of maturity		1. Assessment of the cumulative impact of all activities 2. bridge the gap between scientific research, technology, and policy implementation	

<p>3. Knowledge and sharing has improved through several EU initiatives</p> <p>4. Ecosystem restoration contains natural and financial benefits</p>	<p>3. Improving management and interconnectivity of protected areas</p>	
<p>Impact summary of 2019-2023 trends in new developments/solutions on the severity of the challenge sources</p>	<p>Overall challenge severity status</p>	<p>Response</p>
<p>Despite the efforts being made, the main challenges regarding nutrients, pollution and litter persist.</p>	<p>Increased</p>	<p>x</p>
	<p>Unchanged</p>	
	<p>Decreased</p>	
<p>Impact summary of 2019-2023 trends in new developments/solutions on the requirement for innovative methods/technologies to address the challenge</p>	<p>Overall challenge severity status</p>	<p>Response</p>
<p>Despite the development of ample new solutions, solutions that prevent and resolve the pressures on the water and marine ecosystems are to be developed and brought into subsequent stages.</p>	<p>Increased</p>	<p>x</p>
	<p>Unchanged</p>	
	<p>Decreased</p>	
<p>Challenge 3</p>	<p>The circular and sustainable blue economy</p>	
<p>Key aspects of the challenge</p>	<p>Overall challenge severity status</p>	<p>Response</p>
<p>1. The COVID-19 pandemic first, and the invasion of Ukraine afterwards, heavily affected most blue economy sectors but recovery is ongoing and projections foresee substantial growth in time.</p> <p>2. Highly diversified sectoral trends. SBE needs both a targeted and systemic approach.</p> <p>3. A complex set of innovative solutions is required for the development of a sustainable blue economy.</p>	<p>Increased</p>	<p>x</p>
	<p>Unchanged</p>	
	<p>Decreased</p>	
<p>Key trends in solutions/developments</p>	<p>Possible actions</p>	
<p>1. The green and digital transitions increasingly require innovation.</p> <p>2. The urgency of solutions may not be in line with industry-related time patterns (e.g., decarbonisation of shipping, greening of fishing fleets, sustainability of seabed mining)</p>	<p>1. Lack of skills needs to be addressed across sectors.</p> <p>2. Integration between research & education and business is needed.</p>	

	3. More efficient and effective science-policy-society interfaces to be in place.	
Impact summary of 2019-2023 trends in new developments/solutions on the development of a circular and sustainable blue economy	Impact Level	Response
Solutions are increasingly available and rely on scientific and technological innovation. Market and policy/regulatory preparedness are strong enablers/bottlenecks.	Low	
	Medium	
	High	x
Impact summary of 2019-2023 trends in new developments/solutions on the requirement for innovative methods/technologies to develop a circular and sustainable blue economy	Overall challenge severity status	Response
As the use of marine space and the number of diverse activities increase, the role of MSP is fundamental. The process needs to take into account ecosystem-based management, competitiveness, synergies and conflicts, different geographical dimensions, transboundary links, and wide participative approaches. Climate change adaptation and mitigation strategies, and preventing/accounting for loss of ecosystem services, must be part of the solution for stronger ecosystems and communities.	Increased	x
	Unchanged	
	Decreased	

Annex 2 - Analysis of the most recent developments - in relation to the thematic challenges identified in the factsheet to the SIA

The following part describes the main conclusions derived from the study and uniquely related to the information contained in the factsheet. They reflect the most relevant developments that apply to that document.

The challenge

The challenge, as identified in the factsheet, represents the current conditions.

Water scarcity, drought and floods

The severity of the challenge is set to increase over the coming decades, as Europe is heading towards a future characterised by more extreme conditions of water scarcity, droughts, and floods, which will require to EU to step up its support for research and innovation, in particular to acquire a comprehensive understanding of the impact that climate-induced water risks will have on both the economy and the environment.

Marine and freshwater ecosystem degradation

Despite numerous policy efforts problems with nutrients, pollution and litter in marine and freshwater ecosystems are likely to persist. Scientific, technological and socio-economic advancements have been developed in recent years, but it is crucial to assess their accumulative impacts and to bridge the gap between scientific research, technology, and policy implementation. This includes protection and restoration inside and outside of protected areas, decrease of pressures and remediation.

The circular and sustainable blue economy

The sustainable blue economy approach has consolidated since the publication of the factsheet and confirms its view. The growth of marine renewable energy, mainly driven by offshore wind, is currently an established trend, reinforced by strategic supply and energy security measures adopted since 2019. Environmental protection in the energy sector remains a priority: while the knowledge base has expanded in areas where plants are already in operation, namely in Northern Europe and particularly for offshore wind, more data and research are needed to assess pressures and impacts. Nevertheless, opportunities for ecosystem benefits and optimised use of space are seen with increasing interest, scope, and are embedded in the most recent initiatives and projects at European, regional, and local levels. This is the case of the revamping of existing platforms and multi-use, including innovative aquaculture systems and energy production and storage. Sustainable solutions in the fields of emissions from shipping and wastewater reuse are still highly relevant and supported by the latest developments in policies and initiatives.

Relevance and impact

The relevance and impact of a WMM KIC are confirmed. Its holistic and integrated approach has the potential to strengthen cooperation and collaboration across communities, the freshwater and marine/maritime ones, and it is functional in solving interconnected challenges. However, strategies to mitigate the dispersion of efforts and resources should be clearly outlined. The European WMM knowledge base and market potential are solid but unevenly distributed across geographies and sectors. This type of fragmentation coexists with a clear fragmentation of efforts and disconnection within the knowledge triangle, hampering an effective deployment of solutions to identified challenges.

Newly emerging sectors and the sustainable transition of established ones are on the rise in terms of opportunities for technological development, businesses, and the provision of highly skilled jobs. For this reason, skill shortages are recorded across sectors, necessitating innovative approaches and specialized programs that are tailored to current and future needs. These programs should be characterized by transdisciplinary, integrated, and systemic setups to leverage the potential of an efficient knowledge triangle. The position expressed by the factsheet is therefore confirmed.

The role of a WMM KIC is adequately described in the factsheet, reflecting current conditions, needs, and its highly relevant potential contribution.

Synergies and complementarities with existing initiatives

The establishment of strong synergies is key for a successful WMM KIC. Since 2019, the landscape has evolved significantly and now includes an enlarged set of policies and initiatives and new global agreements that need to be considered for proper positioning of the KIC, in addition to what is stated in the factsheet.

Conclusion

The concluding remarks of the factsheet are in line with developments that have taken place since 2019 and reflect a currently valid strategic approach for the KIC.

Annex 3 – Further analysis of the challenges

Further analysis of Challenge 1: Water scarcity, droughts and floods

Relevance of the challenge

Water is a prerequisite for human, animal, and plant life, while also holding a pivotal role as an indispensable resource driving economic activities. According to UN data, 78% of the jobs constituting the global workforce are dependent on water¹⁷¹. In particular, water plays an essential role in the interconnected water-food-energy nexus, with agriculture accounting for 40% of annual water consumption in the European Union, closely followed by energy production consuming around 28% of the EU's annual water supply, mainly for the cooling of power stations and the production of hydroelectric power¹⁷².

This dependency on water has been driven by the increasing human demand for water over the past five decades, mainly as a result of population growth and urbanisation¹⁷³. According to the European Environment Agency's Water Exploitation Index, the agriculture, energy and domestic consumption sectors are expected to continue to use water to meet growing demand¹⁷⁴. Global water demand is projected to rise by 20% to 30% by 2050¹⁷⁵, potentially placing half of the world's population in regions facing water scarcity as early as 2025¹⁷⁶.

Water scarcity arises when water demand exceeds the available freshwater supply over the medium term, primarily due to human activity. In 2019, the European Environment Agency's Water Scarcity Index reported that 29% of the EU-27 territory experienced water scarcity, with southern Europe being particularly affected, where around 30% of the population faces chronic water scarcity, and up to 70% grapples with seasonal water scarcity during the summer¹⁷⁷. The main hotspots of water scarcity in Europe are identified by the EEA as being areas of intensive irrigation, the tourist islands of southern Europe and densely populated urban areas¹⁷⁸.

Climate change is expected to accelerate this challenge even further, causing precipitation patterns to change and become more unpredictable, leading to an increase in the frequency and intensity of extreme weather events, such as droughts and floods. Over the past five years, the EU has suffered more than 100 major and damaging floods and experienced extremely dry summers, which are no longer considered sporadic events, as evidenced by the recurrent droughts of 2018, 2019, 2020 and 2022 as well as 2023¹⁷⁹. These climate change-related hazards are causing significant damage to

¹⁷¹ UN Water. (2016). UN World Water Development Report 2016. <https://www.unwater.org/publications/un-world-water-development-report-2016>

¹⁷² Mining and manufacturing jointly make up 18%, and household consumption represents about 12%. Source: European Environment Agency. (2023). Water use in Europe — Quantity and quality face big challenges. <https://www.eea.europa.eu/signals-archived/signals-2018-content-list/articles/water-use-in-europe-2014#:~:text=Overall%2C%20agriculture%20is%20the%20highest,largest%20user%20in%20northern%20Europe>

¹⁷³ Ibid

¹⁷⁴ Ibid

¹⁷⁵ Boretti, A., & Rosa, L. (2019). Reassessing the projections of the World Water Development Report. npj Clean Water, 2(15). <https://www.nature.com/articles/s41545-019-0039-9>

¹⁷⁶ United Nations Children's Fund [UNICEF]. (n.d.). Water Scarcity. Retrieved from <https://www.unicef.org/wash/water-scarcity>

¹⁷⁷ European Environment Agency. (2023). Water use in Europe — Quantity and quality face big challenges. <https://www.eea.europa.eu/signals-archived/signals-2018-content-list/articles/water-use-in-europe-2014#:~:text=Overall%2C%20agriculture%20is%20the%20highest,largest%20user%20in%20northern%20Europe>

¹⁷⁸ European Environment Agency. (2021). Water resources across Europe - confronting water scarcity and drought. Retrieved from <https://www.eea.europa.eu/publications/water-resources-across-europe-confronting>

¹⁷⁹ Cammalleri, C., Naumann, G., Mentaschi, L., Formetta, G., Forzieri, G., Gosling, S., Bisselink, B., De Roo, A., & Feyen, L. (2020). Global warming and drought impacts in the EU: JRC PESETA IV project – Task 7. Retrieved from https://joint-research-centre.ec.europa.eu/peseta-projects/jrc-peseta-iv/droughts_en#:~:text=Summary%20of%20Key%20Findings&text=Total%20economic%20losses%20from%20drought,halved%20compared%20to%20no%20mitigation

nature and across the economy as a whole (e.g., inland navigation, energy production, reduced yields in agriculture), exacerbating issues associated with water resource management in the EU¹⁸⁰.

Water scarcity, droughts, and floods are intricately linked issues, all sharing common concerns regarding water availability, quality, and security. The EU's priority is, therefore, to transition to a water-efficient and water-saving economy¹⁸¹, while improving the prevention, preparedness, and overall resilience to water-related disasters¹⁸². While policies such as the Water Framework Directive (2000/60/EC)¹⁸³, the Floods Directive (2007/60/EC)¹⁸⁴ and the EU Climate Adaptation Strategy¹⁸⁵ provide an appropriate framework for addressing water scarcity, droughts and floods, a robust ecosystem of science, technology and innovations (STI)¹⁸⁶ is also necessary to better respond to the severity of these challenges and prevent significant economic and social harm in the EU¹⁸⁷.

Scientific, technological and socio-economic developments

Scientific developments

The pressing demand for improved water resource management is 'increasingly acknowledged and responded to with accumulating sources and amount of funding' in the EU¹⁸⁸. However, it is proving difficult to navigate the recent scientific discourse, since 2019, to gather insights into the latest scientific advancements. This difficulty can be attributed not only to the short timeframe set for this study (2019-2023), which does not align with the typically longer-term nature of scientific advancements but also to the scattered state of scientific literature on water-related challenges, encompassing a wide range of research specialities such as economics, environmental, technological, social and political studies.

In an attempt to address this fragmentation, a recent paper has tried to implement a systematic literature review, laying down the foundations for 'water innovation studies'. The authors, Wehn and Montalvo, conclude that despite some efforts over the last two decades, 'there is a striking absence of academic studies on the dynamics of water innovation, i.e., examining how relevant actors interact to generate, finance, diffuse and apply water innovations and how these processes can be fostered, guided and steered'¹⁸⁹. Several papers highlight that while knowledge and technology within the

¹⁸⁰ Water Resources Management (WRM) is the process of planning, developing, and managing water resources, in terms of both water quantity and quality, across all water uses. Source: World Bank. (2022). Water Resources Management. Retrieved from [https://www.worldbank.org/en/topic/waterresourcesmanagement#:~:text=Water%20Resources%20Management%20\(WRM\)%20is, support%20and%20guide%20water%20management](https://www.worldbank.org/en/topic/waterresourcesmanagement#:~:text=Water%20Resources%20Management%20(WRM)%20is, support%20and%20guide%20water%20management).

¹⁸¹ European Commission. (n.d.). Water Scarcity and Droughts. Retrieved from https://environment.ec.europa.eu/topics/water/water-scarcity-and-droughts_en

¹⁸² As per the EU's disaster resilience goals/agenda. Source: European Commission. (2023). Questions and Answers: European Union Disaster Resilience Goals. Retrieved from https://ec.europa.eu/commission/presscorner/detail/en/ganda_23_600

¹⁸³ European Parliament, & Council of the European Union. (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

¹⁸⁴ European Parliament, & Council of the European Union. (2007). Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks.

¹⁸⁵ European Commission. (2021). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change (COM/2021/82 final).

¹⁸⁶ Abbreviation commonly used by the United Nations and taken up by the JRC and Eurostat. (similarly, Technology and Innovation Solutions are known as TIS). See the United Nations guide to preparing science, technology and innovation (STI) for the Millennium Development Goals roadmaps.

¹⁸⁷ Impact assessment (SWD (2019) 330 final/2, SWD (2019) 331 (summary)) accompanying a Commission proposal for a regulation of the European Parliament and of the Council on the European Institute of Innovation and Technology and a Commission proposal for a decision of the European Parliament and of the Council on the Strategic Innovation Agenda of the European Institute of Innovation and Technology (EIT) 2021-2027: Boosting the Innovation Talent and Capacity of Europe. Retrieved from <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=SWD:2019:330:FIN>

¹⁸⁸ Wehn, U., & Montalvo, C. (2018). Exploring the dynamics of water innovation: Foundations for water innovation studies. *Journal of Cleaner Production*, 171(Supplement), S1-S19. <https://www.sciencedirect.com/science/article/pii/S0959652617324174>

¹⁸⁹ Ibid.

sector may be of high quality, it often suffers from dispersion and fragmentation, underlining the need for more effective dissemination of scientific advances¹⁹⁰.

Nevertheless, it is possible to discern some general trends in the evolution of scientific research into the challenge in recent years. Research is placing greater emphasis on the recognition of humans as major agents of change in water-related risks and disasters. These developments underline a fundamental shift in perspective, with, for example, a growing number of hydrologists and researchers delving into the intricate interplay between human activities and the dynamics of drought¹⁹¹.

Moreover, there is a growing focus on studying the relationship between climate change and water-related disasters, such as droughts and floods. The European Union's PESETA IV project¹⁹² is at the forefront of this movement, producing a series of recently published reports that explore the links between climate change, water availability, and the frequency of hazards like droughts and floods. Leveraging climate modelling tools from the Joint Research Centre of the European Commission, PESETA IV offers insights into both present and future climate conditions and provides valuable data regarding the outlook for water resources.

Technological developments

Tackling the challenge of water scarcity, droughts and floods requires transitioning to a water-smart approach¹⁹³ to water resource management, with technology and innovation playing a central role. A review of the available literature indicates that recent technological developments over the period 2019-2023 have served two main objectives: 1) the transition to a water-efficient and water-saving economy (this objective relates to both water scarcity and droughts), 2) the improvement of the EU's prevention, preparedness and overall resilience to water-related disasters (this objective relates to both droughts and floods). The most recent technology and innovation solutions (TIS) implemented since 2019 are presented below according to this dual focus.

Solutions for transitioning to a water-efficient and water-saving economy

The following subsections introduce key technological and innovative solutions (TIS) implemented since 2019, enhancing the efficiency of water resource management in the face of diminished water availability from water scarcity and droughts.

Circular water technologies: Recent findings from the University of Utrecht, estimate that approximately 48% of the world's wastewater is currently discharged untreated¹⁹⁴, updating the commonly quoted figure of 80%¹⁹⁵. Addressing this issue, circular water technologies, and in particular wastewater treatment methods for water reuse, are at the forefront of water-related technologies in the European Union.

¹⁹⁰ O'Callaghan, P. (2020). Dynamics of water innovation: Insights into the rate of adoption, diffusion and success of emerging water technologies globally. *WIMEK Environmental Technology Biological Recovery & Re-use Technology*. <https://research.wur.nl/en/publications/dynamics-of-water-innovation-insights-into-the-rate-of-adoption-d>

¹⁹¹ Savelli, E., Rusca, M., Cloke, H., & Di Baldassarre, G. (2022). Drought and society: Scientific progress, blind spots, and future prospects. *WIREs Climate Change*, 12(3), e761. <https://wires.onlinelibrary.wiley.com/doi/full/10.1002/wcc.761>

¹⁹² Joint Research Centre, European Commission. (n.d.). JRC PESETA IV Project. Retrieved from https://joint-research-centre.ec.europa.eu/peseta-projects/jrc-peseta-iv_en

¹⁹³ Water Europe. (2023). Water Vision 2023. Retrieved from [WE-Water-Vision-2023_online.pdf](https://www.water-europe.eu/WE-Water-Vision-2023_online.pdf)

¹⁹⁴ Utrecht University. (2021). Half of global wastewater treated rates in developing countries still lagging. UU News. Retrieved from <https://www.uu.nl/en/news/half-of-global-wastewater-treated-rates-in-developing-countries-still-lagging>

¹⁹⁵ By the UN here for instance: <https://www.worldbank.org/en/news/press-release/2020/03/19/wastewater-a-resource-that-can-pay-dividends-for-people-the-environment-and-economies-says-world-bank>

The findings of the EIT 2021-2027 SIA impact assessment¹⁹⁶, which singled out 'water supply and wastewater treatment' as the sector with the most significant market potential for water-related technologies in the EU, remain relevant and applicable today, as indicated by the Global Cleantech Report covering the years 2019 to 2023¹⁹⁷. Notably, the report identifies three European champions in this area: [Organica Water](#)¹⁹⁸ in Hungary, [InOpSys](#)¹⁹⁹ in Belgium and [Altered](#)²⁰⁰ in Sweden.

Several European wastewater treatment projects are receiving special coverage in Horizon Europe magazine²⁰¹, which highlights the most recent and advanced results of EU-funded projects. Of these flagships, the [NextGen project](#)²⁰² (2018-2022) stands out, not only refining and advancing existing technology but also bringing their potential to a larger, more commercial stage. NextGen serves as a comprehensive demonstration of various circular water technologies, implemented across ten living labs throughout Europe²⁰³. Similarly, the [HYDROUSA project](#)²⁰⁴ (2018-2023) is testing 13 water circularity innovations with the goal of making them accessible to governments and businesses. The strategic reuse of wastewater holds the potential to provide a reliable and foreseeable water source, alleviate stress on water ecosystems, and strengthen the EU's capacity to adapt to climate change.

Water management digital solutions: In recent years, digital solutions for water management have been very high on the innovation agenda as they can play a crucial role in optimising water use and enhancing its efficiency. The digital transformation gained significant momentum starting in 2020, particularly spurred by the challenges posed by the COVID-19 crisis. This period has witnessed a shift where numerous maintenance and operational activities required on-site work, while various other tasks transitioned to remote execution²⁰⁵.

This drive for digitalisation aligns closely with the EU's Digital Decade²⁰⁶, aiming to leverage digital technologies for enhanced sustainability, efficiency, and resilience across industries, including water management. To showcase recent efforts in this area, a CORDIS thematic 'Results Pack' on research results has been specially dedicated to digitalisation in the water sector and presents the latest ICT solutions²⁰⁷ provided under the Horizon 2020 programme (2014-2020). These solutions encompass low-cost sensors, Big Data analytics, consumer applications, and innovative leak detection methods. They promise more efficient water monitoring and usage ([SIM4NEXUS](#)²⁰⁸), and

¹⁹⁶ Impact assessment (SWD (2019) 330 final/2, SWD (2019) 331 (summary)) accompanying a Commission proposal for a regulation of the European Parliament and of the Council on the European Institute of Innovation and Technology and a Commission proposal for a decision of the European Parliament and of the Council on the Strategic Innovation Agenda of the European Institute of Innovation and Technology (EIT) 2021-2027: Boosting the Innovation Talent and Capacity of Europe. Retrieved from <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=SWD:2019:330:FIN>

¹⁹⁷ Cleantech Group. (2023). 2023 Global Cleantech 100 Report [PDF document]. Retrieved from <https://tech2.cleantech.com/2023-global-cleantech-100-download-final-0-0>

¹⁹⁸ <https://i3connect.com/company/organica-ecotechnologies-inc>

¹⁹⁹ <https://i3connect.com/company/inopsys>

²⁰⁰ <https://i3connect.com/company/altered>

²⁰¹ European Commission. (2022). Water loop: How to combat water scarcity on remote islands. Horizon Magazine. Retrieved from <https://ec.europa.eu/research-and-innovation/en/horizon-magazine/water-loop-how-combat-water-scarcity-remote-islands>

²⁰² CORDIS. (n.d.).

Towards a next generation of water systems and services for the circular economy. *CORDIS - European Commission's primary portal for results of EU-funded research projects*. Retrieved from <https://cordis.europa.eu/project/id/776541/fr>

²⁰³ In the Netherlands, engineered ecosystems are harnessed to treat and repurpose wastewater from a brewery. Meanwhile, in the United Kingdom, efforts are focused on creating technologies that can efficiently extract methane gas from wastewater treatment plants, transforming it into a valuable energy source. Across all ten sites, these innovative technologies are designed to optimize water usage, thereby reducing the necessity for extensive water extraction and ultimately enhancing resilience against water scarcity. Source: <https://cordis.europa.eu/project/id/776541/fr>

²⁰⁴ HYDROUSA. (n.d.). HYDROUSA Project. Retrieved from <https://www.hydrousa.org/>

²⁰⁵ Idrica. (2023). Water Technology Trends 2023 [PDF document]. Retrieved from <https://www.idrica.com/resources/water-technology-trends-2023/>

²⁰⁶ European Commission. (n.d.). Europe's Digital Decade. Retrieved from <https://digital-strategy.ec.europa.eu/en/policies/europes-digital-decade>

²⁰⁷ Information and Communication Technology.

²⁰⁸ CORDIS. (n.d.). Sustainable Integrated Management FOR the NEXUS of water-land-food-energy-climate for a resource-efficient Europe. *CORDIS - European Commission's primary portal for results of EU-funded research projects*. Retrieved from <https://cordis.europa.eu/article/id/413416>

treatment ([SMART-Plant²⁰⁹](#), [INNOQUA²¹⁰](#), [INCOVER²¹¹](#)), while also addressing pollution ([INTCATCH²¹²](#)), resource recovery and water loss reduction ([SWAMP²¹³](#)). Each of these projects takes part in the ICT4WATER cluster²¹⁴, which serves as a central hub for EU-funded research and innovation endeavours, all of which underscore the need for digital transformation in advancing the water sector.

Particularly, this transformation has targeted agriculture, the primary water consumer in the EU, with progress made in recent years in cutting-edge technologies like IoT, AI, cloud computing, and edge computing being essential for enhancing land productivity and irrigation efficiency²¹⁵. Notably, [IRRIOT](#), a finalist in the EIB's 2021 Social Innovation Tournament, is an EU pioneer company in the field of wireless intelligent irrigation solutions for large-scale commercial operations. They employ IoT for scheduled irrigation, soil monitoring, and remote management, and offer a web and mobile app for monitoring and configuration, allowing users to achieve water savings of up to 50% in irrigation and increase crop yields by as much as 30%²¹⁶.

However, it's crucial to acknowledge that while digital transformation is imperative for water utilities, it has also introduced heightened vulnerability to cyberattacks. Idrica's Water Technology Trends 2023 report²¹⁷ indicates that in recent years, utility providers, following a trend seen in other sectors like banking and energy, have begun to dedicate more resources, both in terms of time and financial investment, to strengthening their cybersecurity measures.

Novel/unconventional sources of water: In recent advancements in water-related technology, there has been a significant focus on exploring novel sources of water. According to the 2020 UN-Water Analytical Brief on Unconventional Water Resources²¹⁸, while these solutions are still in their early stages and somewhat scattered, there is a growing global trend of utilising novel/unconventional water resources to address water scarcity and the consequences of drought. This trend stems from the recognition that 'conventional' sources of water, like rainfall, snowmelt, and river runoff stored in lakes, rivers, and aquifers, are no longer adequate to meet the water demands in areas grappling with water scarcity and frequent droughts throughout the year²¹⁹.

In recent years, new technologies have emerged to expand innovative water supply methods, particularly in desalination, the process of converting saltwater into drinkable water. Approximately

²⁰⁹ CORDIS. (n.d.). Scale-up of low-carbon footprint material recovery techniques in existing wastewater treatment plants. *CORDIS - European Commission's primary portal for results of EU-funded research projects*. Retrieved from <https://cordis.europa.eu/article/id/413417>

²¹⁰ CORDIS. (n.d.). Innovative Ecological on-site Sanitation System for Water and Resource Savings. *CORDIS - European Commission's primary portal for results of EU-funded research projects*. Retrieved from <https://cordis.europa.eu/article/id/413412-recruiting-microorganisms-in-wastewater-treatments>

²¹¹ CORDIS. (n.d.). Innovative Eco-Technologies for Resource Recovery from Wastewater. *CORDIS - European Commission's primary portal for results of EU-funded research projects*. Retrieved from <https://cordis.europa.eu/article/id/413411-innovative-technologies-take-the-waste-out-of-wastewater>

²¹² CORDIS. (n.d.). Development and application of Novel, Integrated Tools for monitoring and managing Catchments. *CORDIS - European Commission's primary portal for results of EU-funded research projects*. Retrieved from <https://cordis.europa.eu/article/id/413413-user-friendly-boats-look-out-water-pollutants-in-european-rivers-and-lakes>

²¹³ CORDIS. (n.d.). Smart Water Management Platform. *CORDIS - European Commission's primary portal for results of EU-funded research projects*. Retrieved from <https://cordis.europa.eu/article/id/413418-flexible-iot-platform-supports-open-innovation-in-farmland-irrigation>

²¹⁴ European Commission. (2021). ICT4WATER cluster – Vision and showcases. Retrieved from <https://op.europa.eu/en/publication-detail/-/publication/3ff7b5db-91c7-11eb-b85c-01aa75ed71a1/language-en/format-PDF/source-199680009>

²¹⁵ Water News Europe. (2023). Smart irrigation saves water with state-of-the-art technology. *Water News Europe*. Retrieved from <https://www.waternewseurope.com/smart-irrigation-saves-water-with-state-of-the-art-technology/>

²¹⁶ European Investment Bank. (2021). Swedish smart irrigation. Retrieved from <https://www.eib.org/en/stories/swedish-smart-irrigation>

²¹⁷ Idrica. (2023). Water Technology Trends 2023 [PDF document]. Retrieved from <https://www.idrica.com/resources/water-technology-trends-2023/>

²¹⁸ UN Water. (2020). Unconventional water resources. *UN Water*. Retrieved from <https://www.unwater.org/publications/un-water-analytical-brief-unconventional-water-resources-0>

²¹⁹ Geographical. (2022). The future of desalination. Retrieved from <https://geographical.co.uk/science-environment/the-future-of-desalination>

40% of the EU's population resides in coastal areas, making seawater a valuable source of fresh-water. Traditionally, desalination was prevalent in arid regions, but global concerns about water scarcity have prompted interest in this technology, even in milder climates like northern Europe²²⁰. The Germany-based Desalination Institute (DME), a world-renowned knowledge hub in the field of desalination, reports over 20,000 desalination plants worldwide, producing more than 100 million cubic meters of drinking water daily. Their findings also reveal a strong annual growth rate of around 15% in the desalination market²²¹.

However, desalination technologies are known for their high costs and energy consumption. An ongoing initiative, the [Water2Water project](#)²²² (2019-2023²²³), aims to introduce the first off-grid water desalination system powered entirely by renewable energy sources. This portable system offers versatility, making it suitable for use in humanitarian aid and disaster relief efforts²²⁴. Similarly, under the [SonixED project](#)²²⁵ (2021-2023²²⁶) the Belgian company HydroVolta is currently developing ultrasound technology as an energy-efficient alternative to the traditional electro dialysis method for desalination. HydroVolta intends to provide this technology to larger corporations for freshwater production and to industrial entities requiring water for their operations. The company is currently conducting tests in collaboration with several Belgian businesses, focusing on producing drinkable water from the North Sea.

Another notable advance comes from Jiwoong Lee, a researcher at the University of Copenhagen's Department of Chemistry, who developed in 2020 a groundbreaking technology that utilizes CO₂ to convert seawater into potable water without relying on electricity. Ongoing work aims to refine this technology, reduce costs, and optimise recycling processes with minimal energy consumption²²⁷.

Water-efficient energy solutions: The water-energy nexus also holds great potential for industrial applications, as shown by the United Nations World Water Development Report 2023²²⁸. Examples include harnessing solar energy to extract drinking water from the atmosphere, a method discussed in a study by Lord et al. in 2021²²⁹. Another noteworthy development is the simultaneous production of electricity and freshwater, as explored in research by Wang et al. in 2019²³⁰. Furthermore, initiatives such as the Agrophotovoltaics²³¹ in Africa project led by UNU-EHS aim to strengthen the resilience of the water-food-energy system, marking a pivotal step in addressing the interconnected challenges of water, food, and energy resources.

²²⁰ European Commission. (2022). Fresh water scarcity prompts hunt for more air and sea. *Horizon Magazine*. Retrieved from <https://ec.europa.eu/research-and-innovation/en/horizon-magazine/fresh-water-scarcity-prompts-hunt-more-air-and-sea>

²²¹ Geographical. (2022). The future of desalination. Retrieved from <https://geographical.co.uk/science-environment/the-future-of-desalination>

²²² CORDIS. (n.d.). The first off-grid water desalination system 100% powered by renewable energies. *CORDIS - European Commission's primary portal for results of EU-funded research projects*. Retrieved from <https://cordis.europa.eu/project/id/873854>

²²³ The project is planned to end in December 2023.

²²⁴ Ibid.

²²⁵ CORDIS. (n.d.). Desalination technology for the water challenge of the 21st century. *CORDIS - European Commission's primary portal for results of EU-funded research projects*. Retrieved from <https://cordis.europa.eu/project/id/969116>

²²⁶ The project is planned to end in November 2023.

²²⁷ State of Green. (2020). New groundbreaking technology uses CO₂ to convert seawater into drinking water. Retrieved from <https://stateofgreen.com/en/news/new-groundbreaking-technology-uses-co2-to-convert-seawater-into-drinking-water/>

²²⁸ United Nations. (2023). UN World Water Development Report 2023. *UN Water*. Retrieved from <https://www.unwater.org/publications/un-world-water-development-report-2023#:~:text=As%20the%20UN%20system's%20principal,are%20essential%20to%20accelerating%20progress>

²²⁹ Lord, J., et al. (2021). Global potential for harvesting drinking water from air using solar energy. *Nature*, 598(611–617). <https://www.nature.com/articles/s41586-021-03900-w>

²³⁰ Wang, W., et al. (2019). Simultaneous production of fresh water and electricity via multistage solar photovoltaic membrane distillation. *Nature Communications*, 10(3072). <https://www.nature.com/articles/s41467-019-10817-6>

²³¹ United Nations University. (2020). Agrophotovoltaics in Mali and Gambia: Sustainable electricity production integrated with food and energy. Retrieved from <https://unu.edu/project/agrophotovoltaics-mali-and-gambia-sustainable-electricity-production-integrated-food-energy>

Furthermore, the use of floating solar panels on hydroelectric reservoirs represents a recent advance in applied research. A study conducted in 2021, which investigated the deployment of floating panels on water reservoirs, demonstrated a notable 42% reduction in evaporation rates²³². In addition, the cooling effect of water can increase the efficiency of floating panels by 10 to 15%. In another recent research endeavour from the European Commission's Joint Research Center²³³, scientists evaluated the feasibility of introducing floating photovoltaic panels to the 146 largest hydroelectric reservoirs across Africa, a continent heavily reliant on hydroelectric power. By covering just 1% of the surface area of these reservoirs with floating photovoltaic panels, Africa has the potential to double its current hydroelectric capacity and elevate electricity generation by 58%.

Solutions for improving the EU's prevention, preparedness and overall resilience to water-related disasters

The following subsections present the main technological and innovative solutions (TIS) implemented since 2019, which contribute to more effective management of droughts and floods, with a view to improving the EU's overall resilience and preparedness for these events.

Drought-tolerant crops: As reported by the FAO, a substantial 70% of the planet's freshwater resources are dedicated to food production, encompassing both crop cultivation and livestock raising, as well as food processing²³⁴. Additionally, a significant amount of water goes to waste in this process²³⁵. Consequently, progress in science, technology and innovation in the field of drought-resistant crops are eagerly awaited, as they are seen as a promising solution to the expected increase in the frequency and severity of droughts²³⁶.

In June 2023, the Flemish Research Institute for Agriculture, Fisheries and Food (ILVO) in Belgium unveiled a vast field laboratory called 'HYDRAS', a world first that allows scientists to exhaustively monitor a plant's response to drought. ILVO has made this unique combination of technologies available to companies and educational institutions to accelerate the development of drought-tolerant crops across Europe²³⁷.

Furthermore, recent developments in New Genomic Techniques (NGT), exemplified by technologies like the Clustered Regularly Interspaced Short Palindromic Repeat (CRISPR), have recently opened a new era of crop enhancement. Within the context of the European Commission's proposal on New Genomic Techniques, which seeks to foster innovation by introducing plants with enhanced resilience to climate change, extreme temperatures, and drought²³⁸, NGT has emerged as a vibrant arena of research and innovation. Over the last three years, numerous research papers have delved

²³² Farrar, L. W., et al. (2022). Floating solar PV to reduce water evaporation in water-stressed regions and powering water pumping: Case study Jordan. *Energy Conversion and Management*, 260, 115598. <https://www.sciencedirect.com/science/article/pii/S0196890422003946>

²³³ Joint Research Centre. (2021). Floating solar panels on African hydropower reservoirs. Retrieved from https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/floating-solar-panels-african-hydropower-reservoirs-2021-02-26_en

²³⁴ FAO. (2017). *Water for Sustainable Food and Agriculture* A report produced for the G20 Presidency of Germany. Available at: <https://www.fao.org/3/i7959e/i7959e.pdf>

²³⁵ EIT Food. (2021). *Water in South: Finding Innovative Solutions for Water Scarcity in Southern Europe*. Retrieved from <https://www.eitfood.eu/projects/water-in-south-finding-innovative-solutions-for-water-scarcity-in-southern-europe>

²³⁶ Joint Research Centre. (2023). PESETA IV Task 7: Drought - Final Report. Retrieved from https://joint-research-centre.ec.europa.eu/document/download/574226a1-c214-4077-9017-1e37ec9784ac_en?filename=pesetaiv_task_7_drought_final_report.pdf

²³⁷ Vertical Farm Daily. (2023). Belgium field lab HYDRAS to accelerate development of drought-tolerant crops. *Vertical Farm Daily*. Retrieved from <https://www.verticalfarmdaily.com/article/9541663/belgium-field-lab-hydras-to-accelerate-development-of-drought-tolerant-crops/>

²³⁸ European Commission. (2023). *Questions and Answers: Frequently Asked Questions: Proposal on New Genomic Techniques*. Press Corner. Retrieved from https://ec.europa.eu/commission/presscorner/detail/en/qanda_23_3568

into the possibilities of innovative methods like CRISPR to identify and modify genes linked to drought tolerance²³⁹.

Drought and flood forecasting: Flood forecasting has made significant and rapid progress since 2019, resulting in earlier and more accurate predictions of potential flooding. One notable milestone in this field is the introduction in 2021 of a cutting-edge operational tool by the European Commission's Joint Research Center (JRC), the Global Flood Monitoring (GFM) tool, as a pivotal component of the Global Flood Awareness System (GloFAS)²⁴⁰. A key feature of the GFM tool is its fully automated nature, which offers continuous real-time monitoring of global flood events by promptly processing and analysing all Copernicus Sentinel-1 images acquired worldwide. This new early warning and monitoring tool is the fruit of years of scientific research and development²⁴¹.

The JRC has also introduced in 2019 the Global Surface Water Explorer, a new dataset featuring daily flow data for the world's major rivers for the years 1980 to 2018, creating new opportunities for monitoring water resources and understanding natural hazards²⁴². Moreover, dedicated platforms like Climate-ADAPT²⁴³, tailored for monitoring climate adaptation efforts within the EU, have played a pivotal role in curating a comprehensive knowledge repository on these recent advancements.

Water-related disaster prevention and preparedness: The World Meteorological Organization reports that over the past five decades, water and climate-related incidents have been responsible for 50% of all disasters, 45% of reported fatalities, and 74% of reported economic damages worldwide²⁴⁴. Technology is set to play a key role in risk management by preventing and preparing for droughts and floods.

As part of the ongoing digital transformation within the water sector, the JRC took a significant step forward in 2022 by developing a novel open-source software solution to decode social media messages, offering invaluable support for risk and disaster management efforts. The cutting-edge algorithm embedded in this software enables social media messages to be segmented in real-time, facilitating the rapid identification, verification and management of disasters such as floods, fires or earthquakes. The core objective of this platform was to enhance the capabilities of the European Flood Alert System (EFAS) and the GloFAS, both of which play a key role in disseminating flood forecasts based on model simulations, by introducing an additional geospatial layer²⁴⁵.

Another significant breakthrough arises from the EU-funded [ECFAS project](#) (2021-2022), which unveiled in 2022 a proof of concept for the introduction of a European Coastal Flood Awareness System²⁴⁶, a valuable tool in addressing sea level rise challenges. This system represents a critical

²³⁹ Insightful research on water scarcity and agriculture in the following papers: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10303483/>; <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10303483/>; <https://www.sciencedirect.com/science/article/pii/S2667064X23000374>

²⁴⁰ The Global Flood Awareness System (GloFAS), jointly developed by the European Commission and the European Centre for Medium-Range Weather Forecasts (ECMWF), is a global hydrological forecast and monitoring system. The system produces daily flood forecasts and monthly seasonal streamflow outlooks. It has been fully operational as a [Copernicus Emergency Management Service](#) since April 2018. Source: Joint Research Centre. (2019). Advances in Modelling Global River Flows. Retrieved from https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/advances-modelling-global-river-flows-2019-12-20_en

²⁴¹ Joint Research Centre. (2021). JRC Launches Revolutionary Tool for Monitoring Ongoing Floods Worldwide as Part of Copernicus Emergency. JRC News and Updates. Retrieved from https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/jrc-launches-revolutionary-tool-monitoring-ongoing-floods-worldwide-part-copernicus-emergency-2021-10-27_en

²⁴² Joint Research Centre, European Commission. (2019, December 20). Advances in Modelling Global River Flows. JRC News and Updates. Retrieved from https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/advances-modelling-global-river-flows-2019-12-20_en

²⁴³ <https://climate-adapt.eea.europa.eu/>

²⁴⁴ World Meteorological Organization. (n.d.). Weather-related disasters increase over past 50 years, causing more damage. Retrieved from <https://public.wmo.int/en/media/press-release/weather-related-disasters-increase-over-past-50-years-causing-more-damage>

²⁴⁵ Joint Research Centre. (2022). New Open-Source Software Decrypts Social Media Messages to Help Manage Risks and Disasters. Retrieved from https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/new-open-source-software-decrypts-social-media-messages-help-manage-risks-and-disasters-2022-06-20_en

²⁴⁶ <https://www.ecfas.eu/>

step towards establishing a comprehensive risk cycle monitoring service for coastal regions, encompassing preparedness, response, and recovery phases. It not only drives the development of innovative products and tools but also integrates data from Copernicus core services, enhancing the capabilities of Copernicus Emergency Management Services (CEMS)²⁴⁷.

Also in 2022, the JRC launched the Risk Data Hub²⁴⁸, a revamped platform designed to support EU countries in their disaster prevention and preparedness efforts, including droughts and floods. This initiative provides valuable data resources to enhance risk assessments across all phases of disaster management, including the critical stages before, during, and after a disaster occurs in Europe. As a flagship product of the Science Pillar within the Union Civil Protection Knowledge Network for 2022, the Risk Data Hub is also a tool to assist local and national authorities in fulfilling their commitments in alignment with the Sendai framework²⁴⁹.

Finally, the JRC, together with the European Commission Directorate-General for the Environment, is in the process of upgrading the existing European Drought Observatory within the framework of the [EDORA project](#) – European Drought Observatory for Resilience and Adaptation (2021-2023²⁵⁰). This enhanced version of the European Drought Observatory will continue to provide drought and risk impact information for the EU-27, expanding its coverage beyond the agricultural sector to encompass other areas. Additionally, it works to improve resilience and adaptation to drought by enhancing drought risk assessment across various scales and encouraging the creation of drought observatories within EU Member States.

Socio-economic developments

Developments in science, technology and innovation (STI) are accompanied by the below three main socio-economic trends between 2019 and 2023, which should also be taken into account when developing a smarter water economy, as they can offer opportunities for social innovation:

Dietary shifts help reduce water scarcity: According to a recent report by the Good Food Institute (GFI), the sales of plant-based foods have grown by 21% in 13 European countries since 2020, reaching an all-time high of €5.8 billion. In 2022, plant-based meat sales reached €2 billion, capturing a 6% share of the total pre-packaged meat market, while categories like plant-based seafood and cheese saw remarkable double-digit growth²⁵¹. Given that meats from animals like cattle, sheep, goats, pigs, and chickens, as well as eggs and milk, have higher water footprints compared to fruits and vegetables, the increasing adoption of plant-based foods represents an opportunity to tackle water scarcity²⁵².

Survey highlights strong social acceptance for water reuse: The perception of water recycling or wastewater reuse as a potential public concern has often been a challenge for large-scale water recycling projects. However, recent surveys conducted by Cranfield University in the UK, Spain, and the Netherlands, involving over 2,500 participants, have shown that the public is more receptive to wastewater recycling than previously thought within the water sector. The surveys specifically examined the use of recycled water for drinking and the recovery of nutrients for food production.

²⁴⁷ CORDIS. (n.d.). A Proof-of-Concept for the Implementation of a European Copernicus Coastal Flood Awareness System. *CORDIS - European Commission's primary portal for results of EU-funded research projects*. Retrieved from <https://cordis.europa.eu/project/id/101004211>

²⁴⁸ <https://drmkc.jrc.ec.europa.eu/risk-data-hub/>

²⁴⁹ International Framework for Disaster Risk Reduction 2015-2030, to which the EU reaffirmed its support in 2023. Source: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_2808

²⁵⁰ United Nations University Institute for Environment and Human Security. (2021). European Drought Observatory for Resilience and Adaptation (EDORA). Retrieved from <https://ehs.unu.edu/research/european-drought-observatory-for-resilience-and-adaptation-edora.html#outline>

²⁵¹ GFI Europe. (2023). Plant-based sales boast 21% growth since 2020. Retrieved from <https://gfieurope.org/blog/plant-based-sales-in-europe-22-growth/>

²⁵² EIT Food. (2022). Water Scarcity in Europe: Is the Food System a Cause or Casualty? *EIT Food Blog*. Retrieved from [https://www.eitfood.eu/blog/water-scarcity-in-europe-is-the-food-system-a-cause-or-casualty#:~:text=With%20the%20combination%20of%20pollution,scarcity%20every%20year%20\(9\)](https://www.eitfood.eu/blog/water-scarcity-in-europe-is-the-food-system-a-cause-or-casualty#:~:text=With%20the%20combination%20of%20pollution,scarcity%20every%20year%20(9))

Notably, in the Netherlands, 75% of respondents either supported or strongly supported the use of recycled water for drinking, while the figures were 67% in the UK and 73% in Spain²⁵³. Furthermore, the Water Reuse Regulation sets clear quality standards for reused water, further enhancing public confidence in its safety.

Citizen science can support drought and flood risk reduction: Citizen observatories are a relatively recent development in the field of citizen science, and two current projects are worth mentioning: the Citizen Observatory on Drought and a citizen observatory focusing on flood risk management in the Brenta-Bacchiglione catchment area²⁵⁴. While these observatories are not yet fully operational, they are expected to contribute to reducing social vulnerability to drought and flood risks²⁵⁵. Furthermore, public engagement in addressing the linkage between water and climate change is actively encouraged through the EU Climate Pact, which recently initiated a water awareness campaign. This campaign is led by EU climate pact ambassadors and was launched at the EU Delegation in New York on March 24th, 2023, with the aim of leveraging the influence of over 80 EU climate pact ambassadors to host specific discussions and events on the topic of water and climate change²⁵⁶. Another notable participatory approach to water governance is the implementation of participatory river contracts in Italy²⁵⁷.

Social innovations such as citizen science offer a wide range of benefits that go beyond the production of new scientific knowledge. They can improve transparency, foster trust and strengthen the credibility of water resource management practices. They are also powerful tools for raising awareness and encouraging changes in behaviour²⁵⁸.

Further analysis of challenge 2: Marine and freshwater ecosystem degradation

Relevance of the challenge

Coastal, marine and freshwater ecosystems are subject to pressure from direct human activity and accelerating climate change. The damage includes the loss of biodiversity, the depletion of fish stocks, damage to the sea floor, including from the use of harmful devices such as fishing gear, obstruction of rivers, eutrophication pollution, and the accumulation of marine litter including a high level of fishing gear and microplastics that are discarded in the oceans. As Europe has 70,000 km of coastline and 19 million km² of Exclusive Economic Zone, it is essential to recognise that the oceans play a pivotal role in shaping the EU's economic well-being, global influence, and security according to the Council of the European Union²⁵⁹. The same paper mentions that Oceans are crucial for life but are increasingly suffering due to human activity, while there is increasing competition over the exploitation of the oceans.

²⁵³ Water Reuse Europe. (2021). New surveys reveal that social acceptance of water reuse isn't the biggest challenge. Retrieved from <https://www.water-reuse-europe.org/new-surveys-reveal-that-social-acceptance-of-water-reuse-isnt-biggest-challenge/#page-content>

²⁵⁴ EU-Citizen.Science. (2021). Citizen Observatory of Drought / Observatorio Ciudadano de la Sequía. <https://eu-citizen.science/project/285>

²⁵⁵ Ferri, M., et al. (2020). The value of citizen science for flood risk reduction: cost–benefit analysis of a citizen observatory in the Brenta-Bacchiglione catchment. *Hydrology and Earth System Sciences*, 24(12), 5781–5798. <https://doi.org/10.5194/hess-24-5781-2020>

²⁵⁶ United Nations. (n.d.). EU Climate Pact Ambassadors raising awareness of the linkages between water and climate. UN Sustainable Development Goals - Partnerships for the Goals. Retrieved from <https://sdgs.un.org/partnerships/eu-climate-pact-ambassadors-raising-awareness-linkages-between-water-and-climate>

²⁵⁷ Venturini, F., & Visentin, F. (2022, August 2). River contracts in north-east Italy: Water management or participatory processes? *Geographical Journal*. <https://doi.org/10.1111/geoj.12473>

²⁵⁸ Nardi, F., et al. (2021). Citizens AND Hydrology (CANDHY): conceptualizing a transdisciplinary framework for citizen science addressing hydrological challenges. *Journal of Hydrology*, 2534-2551. <https://doi.org/10.1080/02626667.2020.1849707>

²⁵⁹ Council of the European Union. (2023). The EU: From maritime power to sea power.

Poor ecological health not only compromises biodiversity targets but also harms those communities and businesses that depend on clean water and healthy ecosystems. It is vital that when utilising the resources of the ocean, consider the ecosystem services that are provided, such as food, climate regulation, oxygen production by phytoplankton, biodiversity, recreation and tourism, and pharmaceutical resources. In Europe, a number of strategies, plans and proposals target biodiversity, climate change, food, and waste. For example, the European Green Deal²⁶⁰, within which the Biodiversity Strategy²⁶¹ aims to protect 30% of European seas by 2030 of which 10 % are strictly protected. Others, such as the Strategy on Adaptation to Climate Change²⁶², the Farm to Fork Strategy²⁶³, the Action Plan to protect and restore marine ecosystems for sustainable and resilient fisheries²⁶⁴, and the Zero-pollution action plan²⁶⁵ have been published that are impacting or will have an impact on protecting marine and freshwater ecosystems. Also, several laws and directives are in place or expected to be in place that deal with marine and water protection, such as the Climate Law²⁶⁶, and the Nature Restoration Law proposal²⁶⁷.

Bathing water quality in the EU has been high for a number of years and has remained stable since 2015. The EEA reported in 2022 that bathing water quality in the EU remains high. In this year, 85.7% of bathing water sites were rated excellent in the EU and minimum water quality standards were met at 95.9% of sites. Between 2010 and 2015, the share of EU bathing sites rated as excellent grew, to 87-89% for coastal bathing waters and 78-82% for inland bathing waters and has remained stable between 2015 and 2022²⁶⁸.

The Water Framework Directive, which assesses Good Ecological Status of freshwater bodies in Europe, shows more modest results. In 2009, only 43% showed a good/high ecological status. A 10% increase was expected²⁶⁹, but the overall ecological status has not improved since 2009, although it has improved for some biological quality elements between 2009 and 2015. The results of the 2021 assessments are not yet known²⁷⁰. The Habitats²⁷¹ and Birds²⁷² Directives, with the Marine Strategy Framework Directive, aim to protect the marine environment, as these require the

²⁶⁰ European Commission. (2019). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal (COM(2019) 640 final).

²⁶¹ European Commission. (2020). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030 (COM(2020) 380 final).

²⁶² European Commission. (2021). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change (COM(2021) 82 final).

²⁶³ European Commission. (2020). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, A Farm to Fork Strategy (COM(2020) 381 final).

²⁶⁴ European Commission. (2023). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries (COM(2023) 102 final).

²⁶⁵ European Commission. (2021). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Pathway to a Healthy Planet for All, EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil' (COM(2021) 400 final).

²⁶⁶ European Parliament & Council. (2021). European Climate Law. Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999.

²⁶⁷ European Parliament & Council. (2022). Proposal for a regulation of the European Parliament and of the Council on nature restoration (COM/2022/304 final).

²⁶⁸ European Environment Agency. (2022). European bathing water quality in 2022. Retrieved from <https://www.eea.europa.eu/publications/european-bathing-water-quality-in-2022#:~:text=Bathing%20water%20quality%20in%20the,met%20at%2095.9%25%20of%20sites> . (visited 18-08-2023)

²⁶⁹ European Environment Agency. (2015). State of the Environment Report (SOER) 2015: Freshwater in Europe. European Environment Agency. Retrieved from <https://www.eea.europa.eu/soer/2015/europe/freshwater> (visited 18-08-2023)

²⁷⁰ European Commission. (n.d.). Surface water ecological status and pressures - Water Framework Directive. Retrieved from <https://water.europa.eu/europe-freshwater/water-framework-directive/surface-water-ecological-status-pressures> (visited 18-08-2023)

²⁷¹ Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora

²⁷² European Parliament & Council. (2009). Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

Member States to establish protection regimes both inside and outside Natura 2000 sites. Reporting under the Habitats Directive²⁷³ shows that of 20 % of the marine habitats are in good condition, a bit more than 10 % are in good condition, leaving almost 60 % with Unknown status. Rivers, lakes, alluvial and riparian habitats are scoring better with around 65 % of habitats in good condition, around 15 % in not good condition and around 20 % unknown.

The Marine Strategy Framework Directive (MSFD) aims to reach Good Environmental Status for eleven different descriptors²⁷⁴ and in June 2020 the Commission reported²⁷⁵ on the implementation of the first cycle of the MSFD, which ran from 2012 to 2017. The MSFD report presents mixed results across Europe's seas. Approximately half of Europe's coastal waters are subject to intense eutrophication. While European Union regulations on chemicals have contributed to a decrease in pollutants, there has been an accumulation of plastics and plastic chemical residues in most marine species. Due to the Common Fisheries Policy²⁷⁶, efforts are being made to fish stocks within sustainable limits, however, regional variations exist. The EEA's Marine Messages II report²⁷⁷ suggests solutions that can help the EU achieve its goal of clean, healthy and productive seas, mainly through ecosystem-based management. The State of Nature report²⁷⁸ from the EEA reports that marine regions have good statuses reported²⁷⁹ less frequently than terrestrial regions, with the marine Baltic and marine Atlantic showing a particularly high share of bad status assessments. Also, a very high proportion of the marine habitats was unknown. Only the Black Sea, with 14 %, had assessments with a good status, whereas the marine Baltic only had poor or bad assessments²⁸⁰, and the marine Macaronesian had all assessments reported as unknown²⁸¹.

The importance of ecosystem restoration is also emphasised by the EEA in a briefing on the importance of restoring nature in Europe²⁸². Protected areas alone, which make up 12 % of the sea area, have not been sufficient enough to reverse the decline of the ecosystems, especially as the EU Biodiversity Strategy aims to protect 30 % of Europe's seas, of which 10 % strictly, and the proposed Nature Restoration law aims to restore 20 % of marine habitats in need by 2030, and all by 2050²⁸³, whereas the Kunming-Montreal biodiversity agreement includes global targets to restore 30 % of the degraded sea ecosystems²⁸⁴. MPAs are often isolated and insufficiently resourced and

²⁷³ European Environment Agency. (2023). Habitat condition reported by Member States (Reporting as specified by Article 17 of the Habitats Directive, 2013-2018 period). In Briefing: The importance of restoring nature in Europe. <https://www.eea.europa.eu/publications/importance-of-restoring-nature/the-importance-of-restoring-nature> (last visited 11-09-2023).

²⁷⁴ JRC Marine Conservation Unit. (n.d.). Marine Conservation Criteria Database. Retrieved from <https://mcc.jrc.ec.europa.eu/main/index.py> (Last visited 11-09-2023).

²⁷⁵ European Commission. (2020). Report from the Commission to the European Parliament and the Council on the implementation of the Marine Strategy Framework Directive (Directive 2008/56/EC) (COM(2020) 259 final).

²⁷⁶ Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC.

²⁷⁷ Reker, J., Murray, C., Gelabert, E. R., Abhold, K., Korpinen, S., Peterlin, M., ... & Andersen, J. H. (2019). Marine messages II: Navigating the course towards clean, healthy and productive seas through implementation of an ecosystem-based approach. *EEA Topic Report*.

²⁷⁸ European Environment Agency. (2020). State of nature in the EU: Results from reporting under the nature directives 2013-2018.

²⁷⁹ Within the framework of the Birds Directive (2009/147/EC) and Habitats Directive (92/43/EEC).

²⁸⁰ These results correspondent with the State of Baltic Sea pressures and biodiversity 2016–2021 as reported in the HELCOM. (2023). State of the Baltic Sea 2023 – Third HELCOM holistic assessment 2016–2021. (p. 7).

²⁸¹ Within the framework of the Birds Directive (2009/147/EC) and Habitats Directive (92/43/EEC)

²⁸² European Environment Agency. (2023). Briefing: The importance of restoring nature in Europe. <https://www.eea.europa.eu/publications/importance-of-restoring-nature/the-importance-of-restoring-nature>

²⁸³ This includes restoring marine habitats such as seagrass beds or sediment bottoms that deliver significant benefits, including for climate change mitigation, and restoring the habitats of iconic marine species such as dolphins and porpoises, sharks and seabirds. Source: https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law_en (last visited 12-01-2024).

²⁸⁴ Target 2 of The Biodiversity Plan, Convention on Biological Diversity.

managed, and some do not provide full protection to nature. It was found that while 12% of EU's seas are officially covered by MPAs, only 1.8% of the EU's sea area is covered by management plans²⁸⁵.

The 2022 Zero pollution monitoring assessed that while the reduction of chemical pesticides by 2030 by at least 50% was on track, the reduction of nutrients and marine litter at sea by 2050 were both not on track, while the data for reduction of microplastics was not available²⁸⁶. The 2022 Zero Pollution Outlook report²⁸⁷ looks at inorganic nutrients, chemical pollutants, and plastic. Noise pollution was considered but it was not addressed due to data unavailability. This report drafts Highly Ambitious Scenarios (HAS) that include the implementation of a number of policies, agricultural practices, urban wastewater treatment and atmospheric emissions prescribed by different legislative proposals. The HAS assumes that measures are fully and immediately implemented and that there is no legacy or inertia in the natural system. The HAS represents the maximum reduction in nutrient pollution currently achievable. It is possible to reduce nitrogen and phosphorous inputs into marine ecosystems by 32 % and 17 %, respectively. Due to the stronger nitrogen reduction, the N:P ratio in EU marine regions decreases sharply (- 30 %), which could worsen the eutrophication condition of EU marine waters by favouring phytoplankton blooming. When it comes to chemicals, the report primarily assesses the Black Sea, where a 50% reduction in riverine chemical loads in a decrease in marine concentration that ranges from -56 % in the shelf region to -12 % in the open-sea area. Policy impacts may take time and be influenced by climate change. In terms of plastic litter, the report highlights that 24% of Mediterranean macrolitter comes from the EU, while 76% is from outside the EU. On beaches, 10% of litter is non-EU, affecting 37% of beaches. The report tests a total ban on single-use plastics in the EU, which could lead to a 60% reduction in production and a 14% decrease in Mediterranean litter, falling short of the 50% Zero Pollution target. In a highly unlikely scenario, a total ban on plastic littering in the EU could reduce litter in the Mediterranean by about 25%, achieving the Zero Pollution target for 50% of the sea surface and 54% of beaches.

The European Union and its Member States have been actively implementing policies and actions to enhance water quality, diminish pollution, and enhance the condition of freshwater aquatic ecosystems. Notably, significant progress has been achieved in areas such as bathing water quality, drinking water standards, and urban wastewater treatment. In other areas, such as the conservation of wetlands, and plastic litter, the latest trends continue to cause concern²⁸⁸.

Scientific, technological and socio-economic developments since 2019

Scientific developments Much scientific research on ecosystem degradation focuses on long-term degradation, and processes that have been developing since the end of the last century, for example, industrialisation and related pollution, plastic pollution, and accelerating climate change. The scientific developments are thus difficult to measure for the period 2019 to 2023.

The temporal demands needed for data acquiring and comprehensive scientific research do not allow for many relevant and robust outcomes for this relatively short period. Reports published in the last years emphasise the large losses and pollution in ecosystems that have already taken place in the past decades. These include reports from the European Environment Agency (EEA)²⁸⁹ from 2019,

²⁸⁵ WWF (2019), Protection our ocean: Europe's challenges to meet the 2020 deadlines.

²⁸⁶ https://environment.ec.europa.eu/strategy/zero-pollution-action-plan/zero-pollution-targets_en (last visited 02-06-2024)

²⁸⁷ Joint Research Centre. (2022). Zero pollution outlook 2022. Publications Office of the European Union, Luxembourg. <https://doi.org/10.2760/39491>

²⁸⁸ European Commission, Directorate-General for Research and Innovation, Mazzucato, M. (2018). Mission-oriented research & innovation in the European Union – A problem-solving approach to fuel innovation-led growth. Publications Office. <https://data.europa.eu/doi/10.2777/360325>.

²⁸⁹ European Environment Agency. (2019). Marine messages II: Navigating the course towards clean, healthy and productive seas through implementation of an ecosystem-based approach.

as well as the Intergovernmental Panel on Climate Change (IPCC) Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)²⁹⁰ and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) global assessment report on biodiversity and ecosystem services²⁹¹. Also, the 2023 IPCC report on climate change²⁹² forth emphasises the substantial damages, and increasingly irreversible losses in marine and freshwater ecosystems due to climate change over the past decade²⁹³, with the loss of hundreds of local losses of species and mass mortality events recorded in the ocean. The IPBES global assessment on biodiversity and ecosystem services details that over 90% of major marine fish stocks are in decline or overexploited and the current rate of extinction is expected to accelerate rapidly in the coming decade²⁹⁴. However, the number of overfished stocks in Europe has been slightly decreasing in recent years, with more stocks being fished within the maximum sustainable yield (MSY)²⁹⁵. Impacts on some ecosystems are approaching irreversibility such as the impacts of hydrological changes resulting from the retreat of glaciers.

A number of scientific articles covering **marine ecosystem degradation** have been published over the past years, for example, McQuatters Gollop et al. (2022)²⁹⁶, report that the biodiversity in the North East Atlantic is under direct and indirect pressures from humans and their assessment reveals widespread degradation in marine ecosystems. A considerable amount of European Marine litter, including plastic pollution, research initiatives, have been initiated to tackle rising levels of marine litter and assess their potential impacts on ecosystems and human health²⁹⁷. Most project categories fall into policy, governance and management programmes and monitoring programmes. Given that the development of the marine litter research framework is still in its early stages, it is logical to observe a significant emphasis on the aspect of 'monitoring' within the projects reviewed.

The EU mission “Restore our Ocean and Waters”²⁹⁸ supports regional engagement and cooperation in so-called “lighthouses” and aims to protect and restore the health of oceans and waters through research and innovation, citizen engagement and blue investments, and will consist of actions pledged through the mission from a broad range of stakeholders.

²⁹⁰ IPCC. (2019). Summary for Policymakers. In IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer, Eds.).

²⁹¹ IPBES (2019): Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz, J. Settele, E. S. Brondizio, H. T. Ngo, M. Guèze, J. Agard, A. Arneeth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany. 56 pages. <https://doi.org/10.5281/zenodo.3553579>

²⁹² IPCC. (2023). Summary for Policymakers. In Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II, and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Core Writing Team, H. Lee, and J. Romero, Eds.). IPCC, Geneva, Switzerland, pp. 1-34. doi: 10.59327/IPCC/AR6-9789291691647.001

²⁹³ Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020. Source: Intergovernmental Panel on Climate Change. (2023). Climate Change 2023: Synthesis Report - Summary for Policymakers.

²⁹⁴ IPBES (2019): Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz, J. Settele, E. S. Brondizio, H. T. Ngo, M. Guèze, J. Agard, A. Arneeth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany. 56 pages. <https://doi.org/10.5281/zenodo.3553579>

²⁹⁵ Scientific, Technical and Economic Committee for Fisheries (STECF). (2019). Monitoring the Performance of the Common Fisheries Policy (STECF-Adhoc-19-01). Publications Office of the European Union, Luxembourg. ISBN 978-92-76-02913-7. doi:10.2760/22641. JRC116446.

²⁹⁶ McQuatters-Gollop, A., Guérin, L., Arroyo, N. L., Aubert, A., Artigas, L. F., Bedford, J., ... Vina-Herbon, C. (2022). Assessing the state of marine biodiversity in the Northeast Atlantic. *Ecological Indicators*, 141.

²⁹⁷ Maes, T., Perry, J., Alliji, K., Clarke, C., & Birchenough, S. N. R. (2019). Shades of grey: Marine litter research developments in Europe. *Marine Pollution Bulletin*, 146..

²⁹⁸ European Commission. (n.d.). Restore our Ocean and Waters - Horizon Europe. Retrieved from https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters_en (last visited 31-08-2023)

Scientific research warns of **eutrophication**²⁹⁹, which is commonly caused by a surplus of nutrients from agricultural practices and is also known to affect the marine environment where a polluted freshwater body flows into it.

Technological developments

Many new tools, devices, and other technological developments have been developed in recent years that aim to find technological solutions. A large initiative is the European Digital Twin of the Ocean³⁰⁰, an EU flagship project that aims to encompass a digital representation of the ocean, using real-time and historical datasets, including physical, chemical, biological, socio-ecological and economic dimensions. The Digital Twin of the Ocean is a main element of the Digital Ocean Knowledge System under the EU Mission Restore our Ocean and Waters. In the paragraph below, a selection of these will be discussed. The impact of these innovations on mitigating ecosystem degradation remains uncertain. Marine litter technologies are being developed all over Europe. A study³⁰¹ has found drivers of marine litter technologies to be public awareness, consumer behaviour, enforcement of legislation, and the rise of SMEs engaged in recycling and eco-labelling of marine litter. The lack of financial resources is a barrier to adopting marine litter technologies. Moreover, marine litter management in European seas is based on post-pollution remedies, whereas a shift could be made to prevention rather than post-pollution cleanup.

Although the problems around marine and freshwater ecosystem degradation mentioned above have been long-standing, in recent years there have been developments in solving them. This includes the way research is executed, for example in the project BiodivRestore³⁰², which will promote coordinated international research on conservation and restoration of degraded ecosystems and their biodiversity, in all environments, including a focus on aquatic systems. The INDECOSTAB³⁰³ project will develop new ways to predict upcoming large ecological changes in coral reefs, using a realistic model that was previously only used for terrestrial systems.

Another pressure threatening the species composition of the sea is the concept of **by-catch**, the unintentional capture of non-target species in fisheries. Accordingly, several EU-funded projects aim to reduce the accidental kills produced by by-catch, such as the CIBBRiNA LIFE project³⁰⁴, which aims to establish regional monitoring programmes for by-catch of sensitive species and implement mitigation measures; NETTAG+³⁰⁵, which aims to prevent, avoid and mitigate the harmful impacts of fishing gears, SEARCULAR³⁰⁶ – with the goal to introduce circular economy practices within the fishing sector value chain and thus reduce the amount of litter and plastics, and the CetAMBICion project³⁰⁷, which seeks to respond to the need to reduce cetacean by-catch in EU fisheries, in particular in the Bay of Biscay and on the Iberian Coast.

Developments on **marine litter, and (micro)plastics** have gained attention over the past few years. Several projects are trying to tackle this problem, for example, EU-funded LABPLAS³⁰⁸ will develop new techniques and models for the quantification of small micro- and nano-plastics, and the

²⁹⁹ Kothawala, D. N., Kellerman, A. M., Catalán, N., & Tranvik, L. J. (2021). Organic matter degradation across ecosystem boundaries: The need for a unified conceptualization. *Trends in Ecology & Evolution*, 36(2), 113-122.

³⁰⁰ European Commission. (n.d.). European Digital Twin Ocean (European DTO) - Horizon Europe - Restore our Ocean and Waters. https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters/european-digital-twin-ocean-european-dto_en (visited 31-08-2023)

³⁰¹ Frantzi, S., Brouwer, R., Watkins, E., van Beukering, P., Cunha, M. C., Dijkstra, H., ... Triantaphyllidis, G. (2021). Adoption and diffusion of marine litter clean-up technologies across European seas: Legal, institutional and financial drivers and barriers. *Marine Pollution Bulletin*, 170.

³⁰² BiodivRestore, 2020-2025, available at: <https://www.era-learn.eu/network-information/networks/biodivrestore>

³⁰³ The INDECOSTAB project, 2021-2024, available at: <http://indecostab.eu/>

³⁰⁴ North Sea Advisory Council, CIBBRINA, 2021, available at: <https://www.nsrac.org/projects/life-eu-bycatch-project-cibbrina/>

³⁰⁵ Nettag+ project, 2023-2026, available at : <https://cordis.europa.eu/project/id/101112812>

³⁰⁶ SEARCULAR project, 2023-2026, available at: <https://cordis.europa.eu/project/id/101112852>

³⁰⁷ Cetambicion project, available at: <https://www.cetambicion-project.eu/>

³⁰⁸ The LABPLAS project, 2021-2025, available at: <https://labplas.eu/>

REMEDIES³⁰⁹ project aims to restore our seas and rivers through deploying (micro)plastic litter valorisation and prevention pathways. Also, the JRC has developed a modelling tool to identify the distribution and accumulation of floating marine litter³¹⁰ that can locate the sources and final locations of floating litter and identify the beaches most likely to be affected.

Marine litter also presents a significant issue in freshwater ecosystems. The EU-funded BMREx project³¹¹ will develop a biocatalyst-based membrane reactor technology to remove micro/nano-plastics from household and industrial wastewater effluents using a combination of enzymes and porous inorganic scaffolds. The GREENER³¹² project uses bioremediation, uses microbes (bacteria and fungi) to break down toxic pollutants into harmless substances, while at the same time producing electricity. As is the case for the marine environment, the interest towards marine litter and microplastics has increased. For example, the SEDIPLASTIC³¹³ project will explore and provide new knowledge on the effects of microplastics on freshwater sediments under global change conditions and develop a predictive model. The LimnoPlast³¹⁴ project aims to find the generally poorly understood freshwater sources of microplastics and to find solutions for the overarching problem with environmentally friendly polymers. In addition, the INSPIRE³¹⁵ projects want to contribute to the drastic reduction of litter, macro and microplastics in European rivers in a holistic approach, by bringing together 20 technologies and actions.

Education and training can provide solutions as well, as the EU-funded RIBES³¹⁶ project will train 15 Early-Stage Researchers (ESR) in the interdisciplinary field of Ecohydraulics to develop innovative solutions for freshwater fish protection and river continuity restoration in human-induced affected rivers.

Similarly, **remote-sensing technologies** are developing quickly to support biodiversity monitoring, conservation and management. Several EU-funded projects are developing regional and pan-European approaches, such as EuropaBON³¹⁷ and MarBioME³¹⁸, which aim to improve biodiversity monitoring and support the MSFD and other relevant EU legislation. The FOREPAST³¹⁹ project aims to better understand sudden ecological shifts (regime shifts) caused by small changes, by taking into consideration environmental, biological and social transitions in coastal ecosystems. By studying ancient ecological records and conducting experiments, the project aims to identify early signs of these shifts and share findings with communities to help manage and prevent negative impacts. Focusing on Mediterranean wetlands, the project contributes to climate adaptation and coastal resilience efforts while benefiting scientific advancement and career growth. Developments in remote sensing are delivering new technologies for deep-sea exploration and monitoring of the seafloor³²⁰. In 2020, the National Aeronautics and Space Administration (NASA) developed a videogame that uses special lenses on drones to map and monitor coral reefs around the world³²¹. Several examples of new technologies to improve seafloor mapping and monitoring have been tested in EU waters,

³⁰⁹ The REMEDIES project, 2022-2026, available at: <https://remedies-for-ocean.eu/>

³¹⁰ Joint Research Centre. (2020, April 7). New Modelling Tool to Identify Distribution and Accumulation of Floating Marine Litter. https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/new-modelling-tool-identify-distribution-and-accumulation-floating-marine-litter-2020-04-07_en (last visited 29-08-2023)

³¹¹ BMREx, 2023-2026 <https://www.bmrex-project.eu/>

³¹² GREENER, 2019-2023, available at: <https://www.greener-h2020.eu/en/normal/home>

³¹³ The SEDIPLASTIC project, 2023-2025, available at: <https://cordis.europa.eu/project/id/101062785>

³¹⁴ The LimnoPlast project, 2019-2023, available at: <https://www.limnoplast-itn.eu/>

³¹⁵ The INSPIRE project, 2023-2027, available at: <https://cordis.europa.eu/project/id/101112879>

³¹⁶ The RIBES project, 2020-2023, available at: <https://www.msca-ribes.eu/>

³¹⁷ Vito remote sensing, 2020, available at: <https://remotesensing.vito.be/new-pan-european-project-joint-biodiversity-monitoring>

³¹⁸ MARBIOME, 2022, available at: <https://www.aircentre.org/projects/marbiome/>

³¹⁹ The FOREPAST project, 2019, 2021, available at: <https://cordis.europa.eu/project/id/795315>

³²⁰ Liu, B., Liu, Z., Men, S., Li, Y., Ding, Z., He, J., & Zhao, Z. (2020). Underwater hyperspectral imaging technology and its applications for detecting and mapping the seafloor: A review. *Sensors*, 20(17), 4962.

³²¹ Garcia-Soto, C., et al. (2021). Marine citizen science: Current state in Europe and new technological developments. *Frontiers in Marine Science*, 8, 621472.

such as Marine Gravimetry for the estimation of seafloor topography³²², and the EU-funded OBAMA-NEXT project³²³, that is developing a toolbox that integrates advanced technologies and traditional methods to enhance the accuracy of marine ecosystem observations. These technological advances are likely to reduce the current data gaps and may raise public awareness of the problem of habitat degradation.

Socio-economic developments

Marine ecosystem degradation not only impacts the overall resilience of the ecosystem and its associated services but can also be expressed in monetary values. For example, the loss of 90% seagrass in the Mediterranean, leads to a loss of 105 million Euros³²⁴. Studies that have analysed the costs and benefits of **ecosystem services** and ecosystem restoration have proven that benefits outweigh costs for coral reefs, mangroves, saltmarsh, seagrass³²⁵ and deep-sea³²⁶ ecosystems. The importance of marine and coastal often referred to as "blue," restoration is growing significantly. This is primarily driven by the decline and depletion of crucial habitats, accompanied by a rising demand for ecosystem-centred approaches to address both climate change mitigation and adaptation. The EEA has calculated³²⁷ that general investment in nature restoration provides a return of between 8 EUR and 38 EUR for every 1 EUR spent, owing to the broader benefits delivered through ecosystem services, that include climate mitigation and adaptation. Improvement of **ocean literacy**³²⁸ among the general public also has the potential to improve people's awareness and understanding of the ocean and its biodiversity. An example of an EU-funded project is ProBlue³²⁹ which will expand and support the Network of European Blue Schools³³⁰.

Several projects acknowledge the **role that coastal communities can play** in sustainable transitions. The project EmpowerUs³³¹ develop a network of transition coastal labs across EU coastal regions promoting new effective methodologies for inclusive policymaking, and REST-COAST³³² aims to increase the commitment of citizens, stakeholders and policymakers to assess ecosystem services.

Several projects build on **citizen's knowledge** and effort to develop themselves. The EU-funded OneAquaHealth project will showcase the importance of these ecosystems for human mental and physical health while also providing a novel AI-based environmental surveillance system to monitor and protect these places. The EU-funded EcoAdvance project³³³ will take the perspective of the people who mastered freshwater ecosystem restoration. By identifying and showcasing successful solutions, EcoAdvance will bring guidance from personal journeys to current leaders.

There is general support for increasing **MPAs and protection of marine habitats**, including seabed ecosystems. General public concerns have translated into **citizen science projects** that support the accessibility of marine biodiversity information for outreach, such as Koster Seafloor Observatory (KSO)³³⁴, a system that combines citizen science and machine learning for automated analysis of

³²²Lu, B., Xu, C., Li, J., Zhong, B., & van der Meijde, M. (2022). Marine Gravimetry and Its Improvements to Seafloor Topography Estimation in the Southwestern Coastal Area of the Baltic Sea. *Remote Sensing*, 14(16), 3921..

³²³ The OBAMA-NEXT project, 2022-2026, available at: <https://cordis.europa.eu/project/id/101081642>

³²⁴ Science for Environment Policy: European Commission DG Environment News Alert Service. Edited by the Science Communication Unit, The University of the West of England, Bristol. (Published 21-06-2023, last visited 28-08-2023).

³²⁵ P.J. Stewart-Sinclair, J. Purandare, E. Bayraktarov, N. Waltham, S. Reeves, J. Statton, E.A. Sinclair, B.M. Brown, Z.I. Shribman, C.E. Lovelock Blue restoration—building confidence and overcoming barriers *Front. Mar. Sci.*, 7 (2020), p. 748.

³²⁶ Chen, W., Wallhead, P., Hynes, S., Groeneveld, R., O'Connor, E., Gambi, C., ... Smith, C. (2022). Ecosystem service benefits and costs of deep-sea ecosystem restoration. *Journal of Environmental Management*, 303.

³²⁷ European Environment Agency. (2023). Briefing: The importance of restoring nature in Europe. <https://www.eea.europa.eu/publications/importance-of-restoring-nature/the-importance-of-restoring-nature>

³²⁸ For more information on ocean literacy, see for example: <https://oceanliteracy.unesco.org/?post-types=all&sort=popular>

³²⁹ ProBlue project, 2023-2026, available at: <https://cordis.europa.eu/project/id/101113001>

³³⁰ See for more information: <https://maritime-forum.ec.europa.eu/de/frontpage/1485>

³³¹ EmpowerUS project, 2022-2025, available at: <https://empowerus-project.eu/>

³³² REST-COAST project, 2021-2026, available at: <https://rest-coast.eu/>

³³³ The EcoAdvance project, 2023-2025, available at: <https://ecoadvance.eu/>

³³⁴ Koster Seafloor Observatory, 2020, available at: <https://eu-citizen.science/project/334>

subsea footage to identify species and habitats. Biodiversa+³³⁵ is the European co-funded biodiversity partnership supporting research on biodiversity. It was jointly developed by BiodivERsA and the European Commission (DG Research & Innovation and DG Environment).

The EU-funded DANUBE4all³³⁶ project will develop a comprehensive restoration action plan for the Danube River basin lighthouse. The project will engage stakeholders, integrating citizens' interests to support the EU Mission "Restore our Ocean and Waters". The UN Decade of Ocean Science for Sustainable Development takes place from 2021 to 2030³³⁷ and it is possible for everyone to take part in activities, join communities or participate in calls for action.

Expected changes in the fisheries sector following the abovementioned Action Plan to protect and restore marine ecosystems for sustainable and resilient fisheries include the Commission calling on Member States to prioritise the phasing out of bottom fishing in Natura 2000 sites under the Habitats Directive that protects the seabed and marine species.

³³⁵ Biodiversa+, 2021, available at: <https://www.biodiversa.eu/about-us/#>

³³⁶ The DANUBE4all project, 2023-2027, available at: <https://www.danube4allproject.eu/>

³³⁷ UN Decade of Ocean Science for Sustainable Development, available at: <https://oceandecade.org/>

Annex 4 - Stakeholder consultation

Summary

1. Critical challenges and opportunities currently facing the Water, Marine and Maritime sectors: All stakeholders affirmed water, marine, and maritime sectors face critical challenges while also offering significant opportunities. A primary challenge involves effectively managing the increasing demand for marine space to accommodate diverse maritime activities, necessitating the resolution of potential conflicts arising from the development of marine and ocean renewable energy sources and understanding their environmental impact. For instance, rigorous environmental regulations, especially in the fishing industry, create competition over maritime spaces, occasionally displacing established entities.

Climate change poses a complex challenge. It has resulted in rising sea levels, ocean acidification, and warming waters, influencing marine species' distribution and life cycles. This challenge is compounded by freshwater issues such as ice melting, drought, extreme events, and an increase in invasive species with tropical affinities, further contributing to the complexities marine ecosystems face. Additional concerns encompass poorly understood ecological risks associated with materials like coatings, plastics, and industrial pollutants. Addressing these challenges requires the establishment of comprehensive ocean monitoring infrastructures to assess the impacts of microplastics on marine ecosystems.

Preserving and restoring marine ecosystems confront challenges such as overfishing, pollution, loss of biodiversity, and the need for wastewater treatment. Particularly pollution, spanning various contaminants like noise, plastic waste, and light and noise pollution from traditional and emerging sectors, remains a major concern. Furthermore, sustainable management of marine resources, including fishing, energy, and blue biotechnology, necessitates strengthened partnerships. This involves finding ways to minimise impacts on ecosystems, addressing both technical challenges and broader complexities. Addressing the ocean's health is paramount, with efforts focused on applications that promote its overall well-being.

Governance plays a crucial role in bridging the gap between existing science and knowledge and their implementation. Meaningful interaction between fresh water and marine science and policy sectors is a pressing concern, highlighted by initiatives like Mission Ocean. Moreover, challenges like water scarcity are linked to governance issues, exacerbated by inefficient planning in water usage across sectors. Access to finance poses challenges for startups and innovators, and regulatory approaches may require updates even with the adoption of new regulations. Additionally, challenges in procurement rules hinder the adoption of innovative instruments, limiting implementation and scaling of results addressing water scarcity.

Since 2019, some notable challenges have emerged, for instance, the unprovoked Russian aggression to Ukraine has contributed to the increasing energy and materials prices. In addition, Brexit has added an additional administrative burden to imports and exports. These factors have shown the vulnerability of some sectors e.g. Aquaculture, fisheries, and offshore energy to market stability. It's also worth investigating the specific aspects that the pandemic may have intensified. For example, there might be a rise in pollution attributable to the improper disposal of face masks into the environment.

Despite these challenges, notable opportunities exist to explore within the water, marine, and maritime sectors. This involves discovering sustainable approaches to use marine space and identifying synergies through activities like co-locating offshore wind and aquaculture or aligning energy production with food production. Exploring the roles of coastal installations and coastal space use also presents opportunities. Additionally, substantial prospects lie in digitalisation and technological advances, allowing for the mitigation of sector stressors through sustainable and

efficient practices. Finally, advancing climate objectives involves enhancing public data accessibility, incorporating sophisticated modelling and observation systems, utilising sensors, and potentially leveraging Artificial Intelligence (AI) to facilitate widespread sharing of marine observations.

2. Fragmentation of efforts and disconnection between education, research, and innovation activities: The need to enhance collaboration and synergy across education, research, and innovation endeavours in the water, marine, and maritime sectors is underscored by interviews. The unique contribution of the knowledge triangle, particularly the education component, is acknowledged as an asset that the KIC brings to the table. Open communication, effective knowledge-sharing systems, and the development of common terminology are emphasized as foundational elements. Encouraging interdisciplinary research and education is deemed vital for a holistic understanding of the water, marine, and maritime sectors, which is not entirely present in the current landscape.

Interviewees stress the pivotal role of sufficient financial and human resources, the active participation of relevant experts, and the engagement of a diverse range of stakeholders in driving collective efforts. Some existing initiatives aimed at promoting knowledge sharing, innovation, and collaboration are acknowledged. Maritime Innovation Hubs, exemplified in some regions, serve as best practices, bringing together businesses, research institutions, and government agencies to foster innovation in the maritime sector. In that sense, the multifaceted approach, including a stressors approach within the ecosystem and the dismantling of siloed structures in research, is underscored as imperative for fostering interconnectedness among different fields.

Moreover, digitalisation emerges as a critical aspect requiring stronger support, with the call for digital innovation hubs in the water sector. Regional or local initiatives for testing emerging technologies are proposed, and the WMM KIC could be a helpful tool for providing support in this regard. The emphasis on education, training, and capacity building linked to the market in an integrated manner is highlighted. Regarding innovation and research, there is a need to promote further research and innovation within the water sector, fostering cooperative interactions between industry and knowledge communities. Acknowledging the shortfall in investments within joint research-private environments, there is a need for a concerted effort to comprehensively address the specific needs and drivers of the industry.

3. The role of the KIC in both addressing the challenges and its alignment with current or future needs and landscape: There is a generalised consensus among stakeholders on the pivotal role of the KIC in addressing challenges and fostering connectivity within the water, marine, and maritime sectors. Across various domains, the EIT KIC is seen as a vital connector and amplifier, bridging sector-specific outcomes and communicating with governing bodies for impactful change. Particularly, the KIC is seen as a facilitator in linking companies and research centres with public financiers to ensure project realisation. It could serve as a "closing deal" entity, focusing on already partially funded projects and development stages, providing a funding approach without bureaucratic impediments. In innovation maturity and scalability, the KIC could act as a bridge, closing gaps and augmenting funding for innovations to reach the market, and particularly valuable where challenges impede infrastructure scaling.

There is a disparity between what companies are capable of and what is expected from them, particularly in the marine industry compared to the maritime sector. Some organisations mention that the KIC could address gaps left unattended by existing tools. In navigating highly specialised maritime regulations within the EU, the KIC could play a pivotal role in organising targeted meetings, identifying stakeholders, and addressing gaps and barriers. Furthermore, its effectiveness in addressing specific local problems and aligning with local regulations would be critical.

Some organisations point to a notable gap in digital innovation hubs within the water sector, suggesting the potential for regional or local initiatives to test emerging technologies. The EIT KIC could play a vital role in supporting such initiatives, focusing on capacity building, dissemination, and community building across public and private sectors. The knowledge triangle enhances the KIC's value proposition, especially the educational component.

Moreover, the KIC could play a crucial role in overseeing data collection, processing, and ensuring well-founded decision-making, particularly with scientific information from maritime sources. Paramount is the collaboration with the Commission and Parliament, establishing strong ties between innovation sectors and policymakers. This alignment facilitates the integration of advancements into policy frameworks, enhancing the KIC's contribution to informed decision-making.

The KIC's significance in partnerships like ZEWT, Water4All, and SBEP highlights its potential to influence capacity building through innovative programs. Key to its role is ensuring alignment with existing initiatives, avoiding duplication, and actively contributing to partnership missions. In conclusion, the KIC's success lies in its ability to align with the current landscape, effectively communicate, and provide clarity without adding complexity. Essential elements include flexibility in governance, collaboration with other KICs, and adaptability to the diverse needs of the water, marine, and maritime sectors, all crucial for optimising its impact.

4. Perspective on synergies and complementarities with existing initiatives: Regarding synergies and complementarities with existing initiatives, strategic alignment with several key partnerships and initiatives is essential for the proposed WMM KIC. This alignment is crucial for navigating significant policy shifts since 2019, marked by initiatives such as Mission Ocean, UN Ocean Decade, and changes brought by the European Green Deal.

Various organisations underscore the collaborative potential of initiatives like Water4All, the Sustainable Blue Economy Partnership, the Mission on Oceans and Water, and the Mission "Climate-Neutral and Smart Cities" within the water sector. While the Ocean mission primarily addresses pollution reduction in sea basins, there's a noted absence of specific attention to ocean renewables, particularly in offshore sectors, highlighting the need for incorporation into the maritime sector's scope.

In the context of green and digital advancements, policy drivers like the European Green Deal and IMO objectives propel progress. Stakeholder involvement, high-level strategic support, and clear regulations are pivotal. Aligning with the European Green Deal and UN Agenda 2030 Sustainable Development Goals is key. The EC Communication on a sustainable blue economy plays a central role, and a global research and innovation approach, despite EU-level constraints, is viewed as an accelerator. The KIC's capacity-building efforts align with existing initiatives, aiming for comprehensive geographical coverage and addressing sector gaps.

Within the fisheries domain, particular emphasis is placed on the significance of the EU fisheries control regulation, necessitating collaborative efforts to establish effective communication channels for decarbonisation, biofuel technology development, and policy adjustments addressing climate change. In aquaculture, challenges arise due to legal competencies residing with Member States. Initiatives are directed toward creating common policies, with collaboration sought on issues such as fair competition and managing imports. Moreover, regulatory barriers, especially in areas like algae use and wastewater reuse, present challenges that a KIC can effectively navigate with its expertise and market connections. Key partnerships have demonstrated a willingness to explore roles and interactions with the proposed KIC. Recognised as a priority link, the KIC is actively seeking complementarities, especially in capacity development. Moreover, they have identified established tools that offer valuable benefits for the new KIC entering the landscape. Further collaboration prospects involve leveraging existing EU

initiatives, including Mission Ocean, European Blue Forum, EU4Algae, Copernicus, EMODnet, Maritime Transport and DG Mare's funding for maritime and fisheries.

Table 3. Stakeholder summary table.

Organisation	Knowledge triangle	Geographical coverage	Field of expertise
FRAUNHOFER (ISSS/Prep4Blue - Germany), IFREMER (ISSS/Prep4Blue - France) and RISE (ISSS - Sweden)	Research and Innovation	EU	Water, Marine, Maritime
Sustainable Blue Economy Partnership (SBEP)	Innovation	All sea basins	Maritime
Partnership on Zero Emission Waterborne Transport (WATERBORNE)	Innovation	EU	Water, Maritime
Partnership for Research and Innovation in the Mediterranean Area (PRIMA)	Research and Innovation	Mediterranean region	Water, Marine, Maritime
Water4all partnership	Innovation	EU	Water
Organization covering the marine sector*	Research	International	Marine
Organization covering the fisheries sector*	Innovation	EU	Marine, Maritime
FEAP	Innovation	EU	Water, Marine and Maritime
EOREA (European Alliance for Ocean Research and Education)	Research and Education	EU	Marine and Maritime
Organisation covering the offshore renewable energy sector*	Innovation	EU	Maritime
Organisations covering the marine and maritime sector**	Research and Education	EU	Marine and Maritime
Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans)	Research and Innovation	EU	Marine and Maritime
EIT-KIC FOOD	Research, Innovation and Education	EU	Water, Marine and Maritime

*Consent to publish (further) details not provided.

** One interviewee linked to two organisations - consent to publish (further) details not provided.

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