European Union and its Member States contribution for the 2023 United Nations Informal Consultative Process on Oceans and the Law of the Sea

"New maritime technologies: challenges and opportunities"

European Union

Contribution of the European Union on the topic of focus of the twenty-third meeting of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea: "New maritime technologies: challenges and opportunities".

Waterborne transport decarbonisation

Shipping is the most energy-efficient form of transport but still makes up 3% of global greenhouse gas (GHG) emissions. There is no consensus yet on the most appropriate technology to achieve the required reduction, but a variety of options exist for different ship types and operating profiles, like battery electric, hydrogen or ammonia (used either in fuel cells or internal combustion engines), biofuels, e-fuels or wind-assistance are already being demonstrated and tested. Further to climate change, impacts of shipping on the marine and coastal environment and health, including air pollution, underwater noise, illegal or accidental discharges (such as lost containers) as well as impacts of large-scale ships, including cruise tourism or high traffic passenger ships, should also be kept in mind.

Reduction of GHG emissions is one of the main challenges of the waterborne transport sector at European and global level. Achieving the GHG emissions reduction goals in international maritime transport requires using both less energy by increasing energy efficiency and replacing the fossil fuels by renewable and low-carbon fuels.

Relevant technologies related to hull design, power and propulsion and fuels and alternative energy sources, as well as operational, coordination and support measures can help in decreasing the impact of waterborne transport GHG emissions.

Nearly EUR 1 billion has been invested in waterborne transport decarbonisation research projects realised under the Seventh Framework Programme (FP7) and Horizon 2020 (H2020). Three quarters of this amount came from European Union (EU) funds while the rest (EUR 239 million) from contributions by beneficiary organisations. Approximately 65% of waterborne transport projects in FP7 and H2020 deal with decarbonisation. The majority are technical projects followed by operational and coordination and support measures projects.[1]

The shipping industry and the EU's research and innovation programme Horizon Europe (2021-2027) is going to co-invest nearly EUR 4 billion (EUR 530 million from the EU budget and EUR 3.3 billion of the industry commitment) in a Zero-Emission Waterborne Transport partnership[2] to develop and demonstrate zero-emission technologies for all main types of ships and services by 2030 with a view to enabling zero emission waterborne transport by 2050.

[1] Source: Grosso, M., Marques Dos Santos, F., Gkoumas, K., Ortega Hortelano, A., Stepniak, M., Tsakalidis, A. and Pekár, F., Waterborne transport in Europe - the role of Research and Innovation in decarbonisation - An analysis of waterborne transport, based on the Transport Research and Innovation Monitoring and Information System (TRIMIS). EUR 30636 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-32316-7, doi:10.2760/077690, JRC123670.

[2] https://www.waterborne.eu/partnership/partnership

Deployment of the innovative technologies is supported by the Innovation Fund, Connecting Europe Facility-Transport, Alternative Fuel Infrastructure Facility, Motorways of the Sea, InvestEU, regional funds and national programs.

Even though there seems to not be a single measure which can be considered as a problem solver, the combination of the following innovations should provide significant improvement in energy efficiency and decarbonisation. The innovation in power and propulsion technologies focuses on development use of sustainable alternative fuels technologies and increasing energy efficiency of ships and their operations, thereby providing important environmental benefits. The use of wind propulsion and reuse waste heat bring up to 14% of overall CO_2 reduction (*e.g*. LeanShips project) or up to 40% reduction of energy consumption (*e.g.* Green Fast Ferry (GFF) project).

Zero and low carbon fuels are key technological areas in relation to waterborne decarbonisation. In addition, operational measures can substantially help in decreasing maritime emissions through increased efficiency, *e.g.* through adjusted vessel navigation speed and allocation and the support of port handling systems.[3]

Marine renewable energies

Up to now the driver for ocean technology has been the offshore petroleum industry which has allowed exploitation at ever greater depths. Deepwater (defined here as greater than 400 metres) is the fastest growing source of petroleum. From just 300,000 barrels of oil equivalent per day in 1990, production expected to hit 10.4 million by 2022.

But this is changing. We will need to leave oil and gas in the ground if we are to reach our climate goals. Indeed, it is already happening. Offshore wind is the fastest growing source of electricity in the EU. Plans are already in place for a quintupling of capacity by 2030 and projections suggest that it will be providing a quarter of the EU's electricity by 2050.

The marine renewable energy sector comprises different technologies to produce renewable energy: offshore wind (with bottom-fixed foundation to the seabed or anchored floating devices), ocean energy (tidal and wave power, ocean thermal energy conversion, salinity gradient), floating solar photovoltaic (FPV), and renewable hydrogen production offshore.

Large commercial-scale bottom-fixed wind projects are currently operating in European waters, but other technologies are starting to catch up. Some European Union Member States have announced large commercial floating wind energy projects, and ocean energy is reaching a level of maturity that makes them attractive to future applications.

Ocean energy is a largely untapped renewable energy source, despite its significant potential to unlock further decarbonisation of the EU energy system. Tidal and wave energy technologies are the most advanced among the ocean energy technologies, with significant potential located in different EU Member States and regions. For tidal energy, there is significant potential in France, Ireland and Spain, and localised potential in other Member States. For wave energy, high potential is to be found in the Atlantic and localised potential in the North Sea, Baltic, Mediterranean, and Black Sea.

[3] Source: Grosso, M., Marques Dos Santos, F., Gkoumas, K., Ortega Hortelano, A., Stepniak, M., Tsakalidis, A. and Pekár, F., Waterborne transport in Europe - the role of Research and Innovation in decarbonisation - An analysis of waterborne transport, based on the Transport Research and Innovation Monitoring and Information System (TRIMIS). EUR 30636 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-32316-7, doi:10.2760/077690, JRC123670.

Tidal technologies can be divided into two main categories: tidal stream and tidal range. Tidal range technologies are currently at a commercial stage, but tidal stream technologies, which are currently the most promising ones are still under development. Tidal stream is considered at pre-commercial stage with some individual designs being at a commercial state, benefitting from design convergence, significant electricity generation (over 70 GWh in Europe since 2016) and several projects and prototypes deployed across Europe and worldwide. In contrast, most of the wave energy technological approaches are at Research and Development (R&D) stage, some at a pre-commercial stage and a handful of devices are in a commercial stage. Many positive results on wave energy are stemming from ongoing European and national projects. Over the past 5 years significant technology progress has been achieved thanks to the successful deployment of demonstration and first-of-a-kind farms; with the sector showing particular resilience in overcoming the setbacks that have hindered the industry in 2014/15.

The total installed capacity of ocean energy worldwide amounts for 574 MW, including more than 494 MW of tidal range projects (240 MW in France and 254 MW in the republic of Korea). Excluding tidal range (not a new technology *per se*), the total cumulative installed capacity of ocean energy worldwide reached 64 MW by the end of 2021. However, the active contributing to the network capacity is smaller, with some of the devices having been decommissioned following the successful completion of testing programmes. About 75 % of the global capacity is installed in European waters, equally split between deployments in EU-27 and in the United Kingdom (15.6 and 15.9 MW respectively).

More investments are needed for these technologies to truly flourish globally. EU instruments, such as InvestEU, the Connecting Europe Facility (CEF) or the Innovation Fund, could help mobilise the funds needed to support such endeavour. The CEF provides incentives for cross-border cooperation in the field of renewable energy, and could be used to, for example, fund the joint development of a floating wind farm. The Innovation Fund can support the demonstration of innovative clean technologies at commercial scale, such as ocean energy, new floating offshore wind technologies or projects to couple offshore wind parks with battery storage or hydrogen production. Likewise, in May 2022, the EU and representatives of the electrolyser manufacturing industry pledged a ten-fold increase of EU manufacturing capacity for electrolysers to produce green hydrogen by 2025.[4] This would produce 10 million tonnes of renewable hydrogen by 2030.

At the same time, we must consider the possible impacts on the marine and coastal environment, especially since we want to scale up the production capacity, in view of decarbonising our economies and contributing to security of energy supply. Threats such as habitats disturbance and degradation, increased underwater noise affecting marine mammals, disruption of seabed integrity and collision of wind turbines with sea birds are just a few examples of the potential negative impacts of offshore renewable energy on the marine environment; our attention should also be raised on the possible cumulative impacts at local and regional scales. The EU has in place the proper legal framework, addressing, *inter alia*, quality of the marine environment, maritime spatial planning and protected species and habitats; it is based on the ecosystem approach and aims to protecting the seas and oceans, while enabling the sustainable use of marine goods and services.

[4] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_2829

Energy transition in EU fisheries and aquaculture

To increase the economic resilience and reduce the carbon footprint of the EU fisheries and aquaculture sector, the EU is committed to increase its efforts to accelerate the energy transition in the sector by increasing energy efficiency and further developing and encouraging the adoption of clean and renewable energy sources and propulsion techniques.

There are different existing technologies that give opportunity to increase the energy efficiency by modification of gears, vessel and fishing strategy, such as more hydrodynamic gears, fitting bulbous bows, more energy-efficient propellers or switching to more sustainable fishing techniques that are less energy intensive. For aquaculture similar technologies exist for service vessels, next to adopting more energy efficient equipment and feed options.

The challenges for the further development of technologies for the energy transition in the sector lay primarily in the further development and adoption of clean and renewable energy sources, propulsion techniques and their wider (port) infrastructure. Technical challenges such as space and safety requirements, knowledge and innovation gaps, a lack of required skills in the workforce and financial challenges provide further challenges for their adoption and further development.

New technologies in fisheries monitoring and control

To ensure that fisheries are environmentally, economically, and socially sustainable and provide a source of healthy food, the EU is working to make fishing fleets more selective in what they catch, to phase out the practice of discarding unwanted fish, to reduce the by-catch of sensitive species and to fight illegal, unreported and unregulated (IUU) fishing vigorously. IUU fishing depletes fish stocks, destroys marine habitats, distorts competition, puts honest fishers at an unfair disadvantage and weakens coastal communities, particularly in developing countries. The EU is equally working to close the loopholes that allow operators to profit from their illegal activities.

To be successful, a technologically advanced and effective fisheries monitoring, and control system is being put into place, highly relying on new technologies and further digitalisation.

Numerous new advanced tools are being or will be applied to fisheries controls, such as, closed-circuit television (CCTV), sensor data in real-time, automatic species recognition software, artificial intelligence, machine learning, robotics, remotely piloted surveillance platforms, high resolution satellite imagery, internet connected systems and real-time transmission of catch and traceability records, improved systems for data analysis, data cross-checking, and data sharing, radio-frequency identification (RFID), block chain technology (with special reference to traceability for labelling, rapid DNA-based assays, open access to ship owner register and flag data), digitalisation of catch documentation schemes, traceability systems from vessel to market (intelligent supply chains), and handheld vessel positioning and logbook systems suited to small-scale and recreational fleet.

To strengthen the EU's actions in this area, new technological solutions are being funded and developed to improve: (i) detection of illegal discards; (ii) weighing systems and accurate catch registration; (iii) data management and remote monitoring systems on vessels; (iv) monitoring and control of small-scale fisheries and recreational fisheries (RecFishing.eu web-platform for catch reporting); (iv) monitoring and control of long-distance fleets, (vi) traceability of fisheries products, (vii) identification of IUU fishing and fishing related activities as well as fisheries products stemming from those activities, (viii) promotion of data standards and protection, remote access to data and automatic data sharing protocols, and (x) innovative tools to assess compliance with technical requirements and measures applicable to fishing vessels, such as continuous engine power monitoring.

Together with opportunities come challenges. The European Union is fully aware of the difficulties that emerging technologies and tools might pose while helping solve fisheries-related challenges at national, European, and global levels. Therefore, the EU is working to fund technologies that are environmentally conscious, cost-effective, able to transmit real-time data and are adaptive to emerging challenges. The EU is promoting solutions that ensure data protection and privacy, can overcome stakeholder's resistance, contribute to the standardisation of data and processes, are able to be scaled up and expanded worldwide and are robust to evolve from prototype to market.

Research and Innovation (R&I)

The EU's key research and innovation programme Horizon Europe, in synergy with other programmes and policies, together with the European Maritime, Fisheries and Aquaculture Fund (EMFAF), offers tools to facilitate collaboration and strengthen the impact of research and innovation in developing, supporting and implementing new maritime technologies. In particular through its Mission "Restore our Ocean and Waters by 2030", the "European Partnership for a climate neutral, sustainable and productive Blue Economy", and the "Zero Emission Waterborne Transport (ZEWT) partnership".

This EU research and innovation funding programme is an opportunity for addressing the transition to renewable energy for shipping, where large sea-going vessels are used, including for fishing vessels. Mission Ocean and Waters sets ambitious objectives to make the blue economy carbon-neutral and circular, as well as to protect and restore marine ecosystems and biodiversity. Smart and environmentally friendly fishing gears, multi-purpose use of marine space, green and energy-efficient small-scale fishing vessels and related operations are among key priorities. This comes in combination with the development of breakthrough solutions to reduce fuel use and pollutant emissions. The targets in mind are linked to eliminate greenhouse gas emissions from maritime economic activities in the EU and sequester those emissions that cannot be avoided (i.e. net zero maritime emissions). The ZEWT may particularly offer synergies with the innovation needs in the energy transition, including in vessels used for fisheries and aquaculture, aiming at demonstrating by 2030 deployable solutions needed for all main types of waterborne transport to become net zero emission by 2050 at the latest.

Ocean Observation

Advances in technology are helping us here. Unmanned drones, driven by wind, currents or the sun are already increasing the coverage and range of ocean observation. E-DNA, the sampling of seawater for traces of genetic material shed by marine life promises to revolutionise our understanding of biodiversity. Technology is needed to increase the portability and simplification of the equipment and draw conclusions about the distribution and abundance of species from DNA extracted from faeces, skin or scales.

A whole ecosystem of innovative businesses is springing up, nurtured by business clusters, technology parks, incubators, catapults or accelerators that take advantage of advances in science to provide the tools and services needed by this new economy – lightweight materials that resist corrosion and biofouling, underwater internets based on acoustics, processes for creating bioplastics from seaweed, artificial intelligence for image analysis and much more. Much of this is unfamiliar to investors so the EU has developed a BlueInvest facility that not only brings business skills to the start-up and scale up companies that have developed the technology but helps investors understand the market and its potential for growth.

All of this means that that ocean technology will lead the way in transforming the EU's economy to one that can meet the challenges facing our planet.

Digital Twin Ocean

A digital twin of the ocean (DTO) is a virtual representation of the ocean and its systems, using historical and real-time data and models to represent the past and present, and to simulate future "what if" scenarios. It will help the ocean economy by providing insights and information that can be used to optimize operations and improve decision-making by all ocean actors to mitigate the impacts of human activities, such as pollution and climate change, on the ocean and its ecosystems. For example, a digital twin of the ocean can be used to: monitor and track the movements of fish stocks, which can help with sustainable fishing practices; to identify and predict the impact of human activities such as pollution, shipping, and marine energy exploitation on ocean biodiversity and ecosystems, allowing for proactive measures to be taken to minimize these impacts; to monitor and predict ocean currents, tides, weather patterns, extreme heat waves and sea level rise, which can help with the planning and management of coastal and offshore infrastructures and areas. Overall, a digital twin of the ocean can provide knowledge and interfaces necessary to make informed decisions about the use and management of ocean resources, helping to support a sustainable ocean economy.

Under the EU Mission "Restore our Ocean Waters by 2030, the EU is developing a core EU DTO infrastructure, conceived as a public good, to foster the development of such digital twins, DTO. The European Digital Twin Ocean's ambition is to make ocean knowledge readily available to citizens, entrepreneurs, scientists and policymakers by providing them with an innovative set of user-driven, interactive and visualisation tools. This knowledge will help design the most effective ways to restore marine and coastal habitats, support a sustainable blue economy and mitigate and adapt to climate change.

Use of space technologies in maritime

Global Navigation Satellite Systems (GNSS) and Earth Observation (EO) satellite technologies have fundamentally changed the maritime domain with the sector being an early adopter of the technology.

For the Maritime sector, in 2022 the revenues for GNSS devices per application reached EUR 1.5 billion. And the total amount of EO data and services for 2022 accumulates to EUR 134 million revenues across the six main regions (Europe, non-EU Europe, North America, Asia Pacific, Latin America, Africa & Middle East). Europe represents the second largest market and will become the largest market over the coming decade. These numbers consider the contribution from maritime, inland waterways, search and rescue and fisheries applications[5].

Global Navigation Satellite Systems (GNSS) are used within waterborne sector for Navigation (N), positioning (P) reporting and timing (T) applications.

GNSS is the primary means to support mariners in resilient navigation either at sea or inland waterways. **EGNOS** (European Geostationary Navigation Overlay Service) started to be employed in the recreational segment since 2012 in view of its higher accuracy at a low cost. Today EGNOS penetration in receivers' models is 90% and continuous work is done within

[5] https://www.euspa.europa.eu/sites/default/files/uploads/euspa_market_report_2022.pdf

IALA (maritime) and CESNI (EU Inland Waterways) to support the adoption of EGNOS in vessels with a) the retransmission of differential corrections using Medium Frequency radio-beacons and AIS stations and with b) the declaration of a new maritime service planned for 2024.

The use of **Galileo** in commercial shipping began in 2016 with its recognition by IMO as part of the Worldwide Radio Navigation System (WWRNS)[6], and now more than 40% of receivers' models are Galileo enabled. Major manufacturers offer **Galileo-enabled Search and Rescue (SAR) beacons** since 2018 and Return Link Service (RLS)-enabled beacons since 2021. With the support of authorities and manufacturers, further evolutions for SAR RLS are being explored, as the use of the Galileo return link to enable the remote activation of beacons.

Galileo OS-NMA (Navigation Message Authentication), planned to be operational in 2024, is already being implemented in multi-frequency multi-constellation receivers, with the objective to increase the resiliency and trust in the position computed, with the authentication of navigation messages. The fisheries control authorities are very interested in the use of Galileo OS-NMA for position reporting, introducing another layer of security to monitor the vessels.

Additionally, many maritime and inland waterways operations require high level of accuracy (*e.g.* pilotage, bathymetries, ports operations, marine engineering supported by dynamic positioning, water-level buoys, etc.). **Galileo High Accuracy Service (HAS)** provides decimetre accuracy globally, will cover this need.

For **timing applications**, GNSS ensures the synchronisation of transmissions shore-to-ship, ship-to-shore and ship-to-ship, which are relevant for the transmission of differential corrections, new ranging signals (*i.e.* R-MODE[7]) and position reporting with a time stamp. Galileo contributes to the resiliency of the solution.

Copernicus provides EO data and services that can be used to increase safety of navigation, optimise routes, monitor the environment and support fisheries, aquaculture and offshore activities. It provides data (*e.g.* wind, waves, currents, sea-ice) to support operations as well as safety.

Copernicus data help **fisheries industry** in achieving better performances by using satellite imagery coupled with ocean modelling techniques, to provide information services such as ocean forecasts, zooplankton observations, to select the right spots with fish stocks (fish stock detection). In **aquaculture** Copernicus data helps characterising the adequacy of the location (pH, salinity, temperature, and data on currents, wind, waves, etc) for farm siting and production. Copernicus and GNSS contribute to increase the efficiency of their operations and alert about the environmental characteristics impacting the aquaculture sites *(e.g.* algae bloom).

Copernicus data is also key for **offshore platform** activities including the development of marine renewable energies, as 1) site selection, 2) installation 3) operations and maintenance activities based on climate records and short-term forecasts of currents, waves, tides and winds. **Copernicus** can be used by Administrations for **maritime spatial planning** for many different uses: navigation, fisheries and aquaculture, energy and other floating infrastructure.

[6] IMO SN.1/Circ.334 on the Recognition of the Galileo as a Component of the WorldWide Radionavigation System - 20 May 2016

[7] Ranging Mode (R-Mode) uses existing maritime radio signals as ranging sources.

Copernicus is also helpful to support safety at sea for any kind of offshore operations as well as maritime transport delivering ocean and current forecasts daily to support ship routing and as well thanks to the Copernicus maritime surveillance service in charge of monitoring vessels activities with various reporting systems such as AIS, LRIT, VMS or VDES.

The **Copernicus Maritime Surveillance** (CMS) Service provides Earth Observation products (satellite images and value adding products), in direct compliance with the law of the sea, to support a better understanding and improved monitoring of human activities at sea, within a wide range of operational functions such as maritime safety, maritime security, customs, law enforcement, marine pollution monitoring, fisheries control and international cooperation.

The EU space services provided by Copernicus, Galileo and EGNOS contribute to the objectives of the European Green Deal. Copernicus, along with improved access to relevant climate science, data and information from sources and services, supports regional and local authorities and other stakeholders to monitor the environment and improve the understanding of climate risk. EGNOS and Galileo contribute to the European Green Deal through positioning, navigation and timing solutions used, for instance, for reduction of maritime emissions through route optimisation.

Moreover, the recent consolidation of the EU Space Programme and EU’s key funding schemes for research and innovation, addresses climate change, helping to achieve the United Nation’s (UN) Sustainable Development Goals (SDGs), boost the EU’s competitiveness and growth, facilitate collaboration and support the implementation of EU policies.

Finland

New technologies related to the ongoing automation and digitalization developments of maritime transport and seaborne trade have great potential to increase the safety, efficiency and sustainability of shipping. However, the use of new technology does not guarantee in itself that the aforementioned aims are fulfilled. Finland recognizes that active regulation is needed in order to reap the societal benefits of automation and digitalization and on the other hand to enable the development and mobilization of new technologies.

Finland works actively to develop the regulation needed for new maritime technologies at the International Maritime Organization (IMO) as well as at the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). A recent government resolution on the promotion of transport automation from 2021 guides the Finnish approach to the development of the relevant regulations such as the MASS Code being developed at the IMO.

In the development of the MASS Code, which will enable the safe and sustainable introduction of higher levels of maritime automation, Finland consistently promotes a human-centric and technology-neutral approach. The automation technologies that are currently being developed will assist seafarers in their work instead of replacing them. The regulations developed will have to take into account the interaction of humans and automation systems both in the context of highly automated ships operating alongside more conventional vessels as well as the interaction of automation systems and the personnel operating and overseeing such systems.

Automation and digitalization work together to increase the efficiency and sustainability of transport chains. New technologies have a major potential for gathering, disseminating and utilizing data. Consequently, the communications capabilities of both highly automated and more conventionally operated ships is important as is the connectivity of ships and fairway infrastructure and port facilities in order to realize the full potential for efficiency gains. Optimizing transport chains leads also to decreases in emissions as ships can for example optimize their sailing speeds to arrive just on time for unloading or loading.

Finland is working on developing intelligent fairways and has also taken part in the MASSPorts collaboration between likeminded countries to find new solutions to make ports and fairways ready for increasing levels of automation and digitalization of maritime transport and to tie maritime transport more closely to the overall supply and trade chains.

Furthermore, Finland has taken an ambitious approach to the European Maritime Single Window and is implementing a very forward-looking national maritime single window system called NEMO. NEMO will include functionality well in excess of the required capabilities for a maritime single window system and it will be capable of combining and sharing information from many different sources in order to make supply chains and maritime traffic more effective and sustainable.

In addition, other new technological solutions apart from automation and digitalization play an important role in the sustainability of marine traffic. Finnish companies play an important role in improving the efficiency of engines, propulsion systems and ships' hulls to reduce fuel consumption and emissions. Furthermore, Finnish companies have played an active part in developing engines that are capable of utilizing novel fuels further reducing emissions.

Portugal

Key Challenges and opportunities in Marine Technologies

Marine technology is essential to provide the solutions to address the key challenges of **Ocean Health and Sustainability**, as expressed in the **United Nations Decade of Ocean Science for Sustainable Development (2021-2030)**. These challenges require a **sustained, persistent, and affordable presence in the oceans,** with a densified **global observation network, both at sea and from space**. This can only be properly implemented through strong international cooperation. Such a network is crucial to better understand, adequately monitor and address key issues such as climate change, sea level rise and warming, ocean acidification, eutrophication, unsustainable fishing, marine pollution and loss of habitats and biodiversity, but also to implement efficient **early warning systems** for **extreme events** such as incoming storms, floods and other **marine hazards such as tsunamis**, and to minimize their impacts on coastal populations and ensure safety of operations at sea.

This global observation network will allow the creation of a **Digital Twin of the Ocean**, essential to better model, predict and minimize natural and anthropogenic hazard impacts. In addition to the more traditional sectors such as fishing, aquaculture, ports and maritime transport, new challenges arise from the increased relevance of emerging sectors in the **Blue Economy**, such as oceanic renewable offshore energies, marine biotechnology, eDNA/eRNA mapping, and the exploitation of ocean natural resources (living and non-living), including seabed mining.

It is therefore essential to **develop new tools to monitor the impacts of these activities in real time to allow for informed and timely decision-making**. There has been tremendous interest worldwide in the development of new technologies that will afford scientific and commercial end-users advanced tools for ocean exploration at **unprecedented temporal and spatial scales, over extended periods of time and high resolution.**

We are also at the threshold of a new era where **multiple marine robots will work in cooperation, without close supervision of human operators,** with a view to acquiring relevant data over large ocean volumes and their boundaries with the seafloor and the atmosphere. A major challenge is to **fully embed and better coordinate national efforts with larger regional and global initiatives** (e.g. CEOS, GOOS, IODE, GEO, All-Atlantic Ocean Research Alliance, UN Decade of the Oceans, etc.) and to effectively increase international collaboration, namely in the Atlantic Area, including through fostering seamless **Trans-National Access to marine research infrastructures** (e.g. JA AA-MARINET, Eurofleets, POGO).

Meeting these goals **requires the development of cutting-edge technologies to solve a number of outstanding problems mentioned above**, some of which are listed below.

(1) **Cooperative marine vehicles for ocean exploration** - development of advanced robots and systems for networked multiple vehicle mission navigation and control in the presence of the formidable constraints imposed by the harsh marine environment and navigation safety. Key challenges include addressing the multiple **legal challenges** of autonomous navigation. Further, the command and control of networked underwater, surface, air, and ocean vehicles pose complex changes that must be addressed with a correct **implementation of a formal command and control architecture**.

(2) **Systems for Sustained presence at sea**: development of a new generation of cooperative marine robotic systems (AUVs, IUAVs, ASVs and gliders) capable of operating at sea for **extensive periods of time** (several months) by making use of yet to be designed **energy harvesting devices** and exploiting the utilization of **new types of docking systems for energy re-charging and data uploading/downloading**.

(3) **Adaptive ocean sampling and mapping using networked marine robots** (surface and underwater vehicles) - development of systems that will leverage prior available data (e.g. from satellites in the case of surface phenomena or remote acoustic sensing from research ships in the case of underwater environments) and use online acquired data to collectively make decisions regarding the best strategy to maneuver and sample a desired volume of water or map a given area using appropriate sensors. This will require the use **advanced tools for distributed mission and motion planning, navigation, control, and real-time decision making**, the combination of which is still in its infancy.

(4) **Multimodal Communication Networks**: study and development of new underwater communication systems that **combine acoustical, optical, and electromagnetic communication channels and have the capability to selectively adapt** the best type of communication procedure in accordance with the mission being performed and in response to the environmental conditions perceived online.

(5) **Bioinspired Navigation and Control**: derive new methods for underwater vehicle design, navigation, and control by leveraging fast paced developments in areas that are at the intersection of biological systems and robotics.

(6) Design of innovative **low-cost, low weight, low power consumption, plug and play modular systems, easy to deploy and maintain sensors and sensor platforms**.

(7) Sea bottom observatories - Key challenges include effective **real time communications**, since the use of dedicated submarine cables is expensive. There is also a need for harmonization of data acquisition methods, focused on **priority observations** (e.g., **Essential Ocean Variables** - EOVs) with improved data quality. Another challenge is **decreasing costs in terms of deployment, acquisition and maintenance** and innovative solutions concerning **energy supply**.

(8) **Submarine Communication Cables** – If the commercial telecommunication submarine cables that are deployed every year were instrumented, becoming **SMART (Science Monitoring And Reliable) cables**, they could revolutionize the offshore **earthquake monitoring**, and also measure continuously different ocean variables, including ground motion, sea bottom absolute pressure, and temperature, for the life span of the submarine cables (25 years), contributing for the monitoring of climate change by providing calibrated and non-aliased data for other indirect measurements like the ones given by satellite. A major challenge consists of **ensuring the complete separation of the geophysical/oceanographic acquisition and communication channels from the telecommunication channels that are the primary users of the cables**. Other submarine cable technologies, such as **Distributed Temperature Sensing** (DTS), **Distributed Acoustic Sensing** (DAS), **Laser Interferometry**, and **State of Polarization (SoP) technology** are also promising but require further refinement.

(9) **Passive Ocean Observation -** Ocean acoustic models can be significantly improved with a global passive acoustic data observation that will allow to effectively obtain truthful sound levels and provide means for field validation and calibration of sound

models. **ARGO Floats instrumented with acoustic sensors/recorders could represent a major opportunity** to this end, as there are currently approximately 4000 Argo floats drifting in the world oceans. There are already a few initiatives to include acoustic recorders in drifting floats.

(10) **Observation from space -** Need for higher frequency (every 2-3 hours) and lower latency (less 1 hour) observations for applications such as monitoring of natural disasters and extreme weather events, fishery protection, search and rescue operations or detailed modelling of ocean phenomena, among others, by developing a **new generation of micro or nanosatellites** with high performance.

(11) **Ocean Literacy, Training, Capacity Development and Citizen Science** - Fast paced developments in the areas of robots, sensors, and communication devices are currently driving the **emergence of miniaturized and affordable systems for telepresence at sea** that will afford end-users not only to witness the unfolding of scientific missions remotely, but also to actively participate (including through citizen science). An Ocean literate society is therefore required and **training opportunities, namely at sea, are essential**.

Other Challenges include: (i) increasing International Coordination and Cooperation, with research initiatives/infrastructures that aim to increase capacity building for ocean observation in different countries; (ii) Harmonization of data acquisition methods, focused on priority observations (e.g., Essential Ocean Variables) with improved data quality and data products; (iii) Increased spatial coverage and multidisciplinary in ocean observations, through data sharing following interoperable metadata standards.

All these challenges and opportunities require **global cooperation and coordination** at national, regional and global observing systems, open databases to access **validated ocean data** in commonly agreed standardized formats, and **promoting capacity development** of LDCs and SIDS, regarding setting up, operating and maintaining national ocean observing systems, and enabling them to fully access ocean data, make use of ocean data mining facilities, feed this data to global databases, improve data processing and modeling capacity to transform data into information, critical to support informed decisions.

Marine Technology Developments and Projects in Portugal

A few examples of marine technology projects in which Portugal is involved include:

SMART Cables. The new submarine cable ring to join Portugal mainland, the Azores and Madeira Islands (CAM Ring), for which a Request for Tender has been issued in December 2022, will likely be the first SMART cable in operation, to be expected in 2025. DAS is a promising technology but lacks for the moment the ability to provide quantifiable data that can be reliably used for environment and natural hazards monitoring (a national research project is now dedicated to exploring the use of DAS on real-time monitoring for earthquakes and tsunamis and to calibrate DAS data with in-situ measurements).

Digital Twins. The Portuguese Navy and other institutions in Portugal are developing Digital Twins for several coastal areas with the goal of providing digital representations of these areas to support human development activities as well as to study these areas with unprecedented detail.

Long endurance vehicles. The EMSO-PT and the Bluehub initiatives are enabling several Portuguese institutions to acquire long range and long endurance vehicles, namely gliders and long endurance ASVs, for Atlantic crossings. The operation of these assets will be tentatively coordinated with the Atlantic Autonomous Robotics Consortium to maintain a 24/7 control of the assets at minimum cost.

Atlantic Autonomous Robotics Consortium. The goal of this initiative is to create and coordinate a unique set of long-distance testing courses and facilities for use by companies, government agencies and NGOs from around the world. The vision is to have Distributed, coordinated operations & support centers in Eastern Atlantic (Azores, Canary Islands, Lisbon, Madeira, & Porto), representing a half-circular arc around the entrance to Mediterranean to support 24/7 operations center for data and vessel communication and to create a network to attract international companies while promoting inter-operability across platforms and domains.

Infrastructure networks. Portugal led the H2020 EU Marine robots' infrastructures project which included 15 key players in marine robotics from 10 European countries. The project provided access for free to the robotic infrastructures of the partners through open calls. Overall, there were over 50 successful Transnational Access Projects proposed by institutions from all continents.

Large scale experimentation, inter-operability, and inter-changeability. The 2022 edition of the NATO annual REPMUS exercise, co-organized by the Portuguese Navy, Porto University, the MUSI initiative from NATO and the Centre for Maritime Research and experimentation from NATO involved over 120 unmanned vehicles, working in conjunction with over 16 ships from 27 countries. This exercise brings together the triple helix (academia, industry, and the armed forces) to evaluate and test new developments, systems, and technologies in an operational environment, focusing on inter-operability and inter-changeability by providing a software framework within which vehicles and operators from different countries could effectively exchange messages and commands.

Other projects with strong international collaboration, to name a few:

- **RAIECO** - Hybrid underwater robotic systems and Artificial Intelligence-based seabed imaging tools for marine ecosystem studies, (FCT, India-Portugal Cooperation Program, IST/UAveiro/NIO; India, 2022-2025), addressing the development of marine robotic-based systems capable of operating in fully autonomous mode, while allowing for human intervention in tele-operation or co-control modes based on real time information provided by AI based sensing and environmental classification tools.
- **ECOBOTICS.SEA** - (H2020-MSCA-RISE-2018, 2019-2024). International research and training project to extend current state-of-the art in robotics for the analysis and monitoring of marine species communities, focusing mainly on aquatic biodiversity.
- **RAMONES**- Radioactivity Monitoring in Ocean Ecosystems (FETPROACT- EIC-08-2020, 2021-2024). Innovative combination and advancement of recent developments in sensory materials, low-power autonomous robotic systems, and process modelling theories.
- **BlueRoSes** - Blue robotics for sustainable ecofriendly services aimed at innovative marinas & leisure boats (EMFF Blue Economy- 2019-2022). EU-funded project that aimed to exploit the state-of-the-art technology in marine robotics (networked control of Remotely Operated Vehicles - ROVs) and ICT (IoT middleware for sensor networks, smart apps) to develop innovative services for marinas and leisure boats to adapt to changing demands from users and address environmental challenges.
- **EUMarineRobots** EUMR (H2020- INFRAIA-2017-73110, 2018-2022), aimed at opening key national and regional marine robotics research infrastructures (RIs) to all European researchers, from both academia and industry, ensuring their optimal use

and joint development to establish a world class marine robotics integrated infrastructure.

- **EMSO-PT**, FCT, 2017-2023 - European Multidisciplinary Seafloor Observatory Portugal, a research infrastructure selected for the Portuguese Roadmap of Research Infrastructures that brings together 14 partners in charge of developing technological systems to support the Portuguese nodes of the European initiative EMSO
- **EU-SCORES**. Combination of offshore wind with wave and offshore solar PV energy, paving the way towards bankable multi-source parks prepared to explore synergies, with applications to underwater environmental monitoring, underwater inspections, and operations support, among others.
- **EU-TRIDENT**. Develop a reliable, transparent, and cost-effective system for continuous environmental impact assessment and monitoring of exploration and exploitation activities in the deep sea.
- **EU-NETTAG+.** The project aims to provide a portfolio of three suitable innovative smart and sustainable solutions to address the negative impacts of fishing gears on marine life and habitats, in line with the second issue of the call “Environmental impacts of fishing gears”.