國際海洋資訊
International Ocean Information

17
April 2022
雙月刊 | Bimonthly

長時海洋環境監測的海洋雷達觀測網
Oceanographic Radar Observation Network for Long-term Marine Environmental Monitoring

葡萄牙海洋資訊
Portugal Ocean Information

海洋委員會 Ocean Affairs Council 發行

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Building a Marine Country on the Cornerstone of Sustainable Marine Development

Translated by Linguitronics

Minister of the Ocean Affairs Council: Chung-Wei Lee

Sustainably managing our oceans and rationally utilizing marine space and resource allocation are crucial issues that all countries must soberly consider. Many countries use marine spatial planning (MSP) to formulate their overall marine policies. One such country, Portugal, is introduced in this issue. With each of its government departments having its own goals for marine use, and with coopetition between the offshore wind power industry and fisheries, MSP can establish a coordination mechanism based on sustainable thinking to achieve effective marine governance. In addition, the Portuguese Ministry of the Sea has proposed the National Ocean Strategy (NOS) for 2021–2030, which, aside from complying with international maritime norms, specifically responds to the EU's "Blue Growth Strategy" with the aim of regaining Portugal's maritime sovereignty. The Intergovernmental Oceanographic Commission (IOC) under the UN and the Directorate-General for Maritime Affairs and Fisheries (DG MARE) of the European Commission published the "MSPglobal International Guide on Marine/Maritime Spatial Planning" in 2021. It is divided into 6 stages, from setting the scene to monitoring, evaluation and adaptation after implementation. It provides practical tools both for governments and marine spatial planners to formulate marine space plans, and promotes cross-border cooperation in marine space planning. In this issue's "Regulatory Systems" we introduce the Lisbon Agreement, which was formulated in response to major oil spills through transnational cooperation with the purpose of protecting the marine environment of the Northwest Atlantic.

Marine scientific research and resource application also lie at the heart of sustainable oceans. This issue's "Special Report" introduces Taiwan's establishment and technological development of its ocean radar observing network, which can monitor surface ocean currents in the surrounding sea areas and collect environmental information that serves as the basis of marine scientific research; in our "Latest News" section, we introduce key offshore substation technologies for offshore wind power and the state of development of floating substations required for development in deeper sea areas. On this occasion of the United Nations "Decade of Ocean Science for Sustainable Development," Taiwan's R&D and application of ocean radar and floating substations will be an important cornerstone for Taiwan's promotion of marine sustainability and enhancing its marine power in the future.

Autonomous Regions of the Madeira
Source/ https://pixabay.com/photos/portugal-madeira-ponta-do-sol-4823826/

Oceanographic Radar Observation Network for Long-term Marine Environmental Monitoring

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Keywords: Remote Sensing, Ocean Currents, Waves, Tsunami, Boundary currents, Ocean Observing System

The long-term monitoring information of the marine environment is an important reference for decision-making, whether in the response to marine affairs or in the issue of global environmental change. With the development of technology, ocean observation from point to line to plane to three-dimensional development, from shore, ship, ground base, mooring, airborne to spaceborne, can be said to be changing with each passing day. Moreover, promoting the integration of various observation systems to build the integrated ocean observation network has also become an important subject in modern ocean observation technology and application. After the end of World War II, radar operators and scientists discovered the interaction mechanism between radio waves and sea surface waves and gradually completed theoretical models. Since oceanographic radar has the advantages of wide range, continuous, near real time and low operating cost compared with traditional field survey, since the 1970s, the United States, Germany, Japan, China and other countries have successively invested in the development of special-purpose oceanographic radar and sea-state algorithms for continuous observation of oceanographic features. And with the establishment of the oceanographic radar observation network, a new page has been opened for two-dimensional plane ocean observation.

In the 2000s, countries headed by the United States rapidly built oceanographic radar systems, and established marine high-frequency radar observation networks in the United States, Mexico and Canada. Almost in the same era, under the promotion of the ocean science community, Taiwan also planned to use 18 sets of high-frequency radar stations for long-term observation of ocean currents in the waters around Taiwan in the "Research Planning Proposal of Ocean Science Discipline Cluster for the Next Ten Years". The construction work was handed over by the government to the Taiwan Ocean Research Institute (TORI), National Applied Research Laboratories (NARLabs). In 2016, the establishment of the observation network around Taiwan was completed. Its radar station network and observation results are shown in Figure 1. It has become the first country in the world that can monitor the surface ocean currents in the surrounding seas for a long time.

According to the statistics of the Group on Earth Observations (GEO) in 2019, there should be more than 400 high-frequency oceanographic radar stations built by countries around the world, of which nearly 140 are in the Asia-Pacific region, and the number continues to increase year by year [1]. With the efforts of countries around the world, the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), co-sponsored by the World Meteorological Organization and the United Nations Educational, Scientific and Cultural Organization (WMO-IOC), held the JCOMM-5 meeting in 2017. The Resolution 25 adopted GEO's proposal to include the high-frequency oceanographic radar observation network as a part of the ocean observation system. This progress not only realizes large-scale, near-real-time, and continuous monitoring of ocean waves and currents, but also systematically strengthens the collection of basic environmental information required for topics such as global ocean scientific research, ocean affairs response, and global environmental changes. At the same time, it is a great encouragement to the development of radio telemetry ocean technology.

Ocean Monitoring Technology Using Radio Waves

With the rapid progress of human beings in electromagnetism in the 19th century, the use of radio wave reflection and scattering characteristics to monitor long-range aircraft and ships has become an important technology in the World War II. At the end of the war, the coastal defense radar operators on guard duty responded that the radar signal was always disturbed by unknown reasons. Until 1955, Douglass D. Crombie revealed that "the interaction of electromagnetic waves with a wavelength of tens of meters and the roughness of the ocean surface will produce Bragg resonance and backscattering phenomena [3]", Crombie's research provides a reasonable physical explanation for the interference found by radar soldiers staring at the screen all day, and opens a new page for the application of radio waves in the detection of sea conditions over-the-horizon. Then, between 1968 and 1972, Dr. Donald E. Barrick, who worked at the National Oceanic and Atmospheric Administration (NOAA), completed the theoretical derivation of the backscattering mechanism of the radio waves caused by sea surface roughness. The detection of ocean surface features by radio waves has established a solid theoretical foundation [4]. In terms of microwave radars with higher radio frequencies and wavelengths of several centimeters, Mattie and Harris have confirmed that X-band radar is indeed suitable for the observation of sea surface ripples since 1978 [5]. Young et al. (1985) found from the X-Band marine radar signal that a three-dimensional energy spectrum was established based on a sequence of radar echo images, and the wave dispersion relationship was used as the extraction signal and noise separation, which could be used for sea surface wave spectrum and surface current mapping. He established the theoretical foundation for the microwave radar's functions of both nautical navigation and remote measurement of sea state [6].

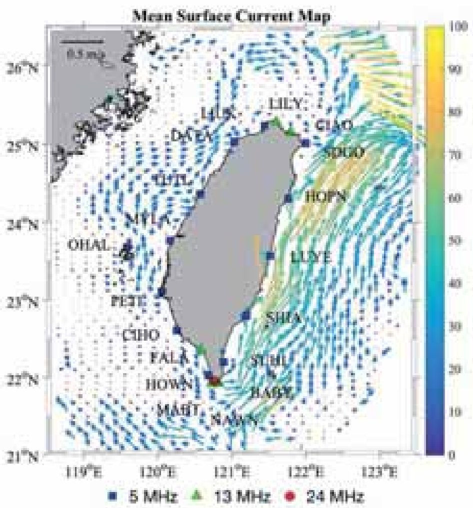

Figure 1/ The first generation of Taiwan's first-generation shore-based radar for surface current mapping network built by the TORI, NARLabs

Image by Jian-Wu Lai

Oceanographic radar uses radio echo signals to extract target objects we care about (such as ships) and invert marine environmental characteristics (i.e., wind, waves, currents). And like most observing systems, observations are subject to environmental influences and physical limitations. Generally speaking, high-frequency radar can be transmitted along the curvature of the earth on the sea surface, so it has the title of over-the-horizon radar. The effective observation range of waves and ocean currents by high-frequency radar using the main frequency of 5MHz radio waves can reach 120 kilometers and 240 kilometers, respectively. However, if the system using 30MHz frequency is only 20 kilometers and 40 kilometers. For microwave radars with radio wave frequencies up to GHz level, due to differences in radio wave transmission mechanisms, they can usually only provide observation information of sea conditions within a line of sight of 3 to 5 kilometers. The relevant information discussed above is organized as shown in Table 1. In terms of the range resolution of sea state information, oceanographic radar is mainly limited by the radio wave modulation bandwidth approved by the National Communications Commission. In Taiwan, a 5MHz system can usually achieve a modulation bandwidth of tens of kHz, while a 30MHz system can achieve a modulation bandwidth of several hundreds of kHz. Therefore, the spatial resolution of the former is at the level of several kilometers, while the latter can reach a finer level of hundreds of meters. Such resolution limitations also affect the application of radar systems to observation of oceanic features at different scales. Therefore, the oceanographic radar observation network of NOAA's Integrated Ocean Observing System (IOOS) in the United States is a two-layer structure composed of 5MHz and 13MHz. They provide observational products with a resolution of 6 km in the wide area (within a range of 200 km offshore) and 1 km resolution in the coastal waters (within a range of tens of kilometers offshore) [7].

Table 1/ Range Capability of Oceanographic Radar

System	Sea state inversion signal basis	Maximum observation range (km)		
		waves*	currents*	Potential influencing factors
High-frequency radar	Doppler spectrum	600/Freq (Freq. in MHz)	1,200/Freq (Freq. in MHz)	Sea surface gravity wave characteristics, radio interference, ionosphere, waveguide effect of atmospheric inversion layer, Geometric Dilution of Precision of observation network, etc.
microwave radars	Sea-echo image	3~5	3~5	Sea surface capillary wave characteristics, radio interference, radio wave grazing angle, rainfall, etc.

*The maximum observation distances of waves and currents of high-frequency radar are affected by the main frequency used. Here are approximate estimation formulae.
Source/ Jian-Wu Lai

Forward ahead into a new situation of oceanographic radar

The initiative of Taiwan's oceanographic radar observation network in the oceanographic community and the efforts of the TORI of the NARLabs for many years, such as data release, technology research and development, and value-added applications, have contributed to a group in ocean scientific research, signal processing technology, research and development of instruments and equipment, and domestic related scientific and technological development such as search and rescue, and pollutant dispersion.

In recent years, the Government of Taiwan has established the Ocean Affairs Council (OAC) to integrate ocean affairs and ocean science and technology development. It coincides with the decade of ocean science for sustainable development proclaimed by the United Nations, the National Chung-Shan Institute of Sciences and Technology actively promotes the value-added application of military and civilian general technology industries, the development of marine energy in the energy transition, and the policy of paying tribute to the sea. This has prompted various government departments to promote the construction of shore-based oceanographic radar systems to improve the application of marine environmental monitoring and disaster prevention technology in Taiwan. Technical officers and researchers from various ministries and associations will gather in November 2021 to exchange views on the deployment of observation networks and common data formats, hoping to promote cross-agency data flow and improve governance efficiency under the government's open data policy. The participants dubbed it a "Taiwan Oceanographic Radar Minor League".

Between 2019 and 2024, more than 42 oceanographic radar stations in various government departments will be built and put into operation successively, including 12 of the Central Weather Bureau (CWB) of the Ministry of Communications (6 high-frequency radars and 6 microwave radars), and 3 of the Institute of Harbor and Marine Technology (IHMT) of the Ministry of Communications (2 high-frequency radars, 1 microwave radar), and 27 of the National Academy of Marine Research (NAMR) of the OAC (12 high-frequency radars and 15 microwave radars). In addition, the Water Resources

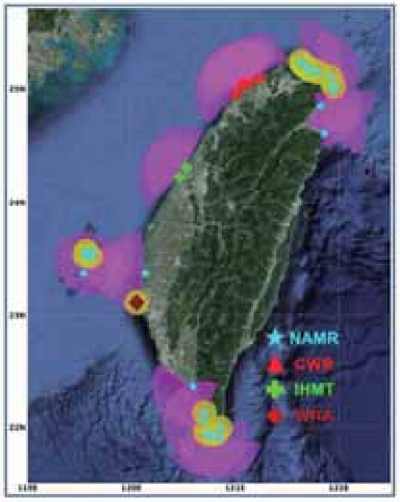

Figure 2/ The coverage map of the oceanographic radar observation network under construction by the various ministries of the Taiwan government
Image by Jian-Wu Lai

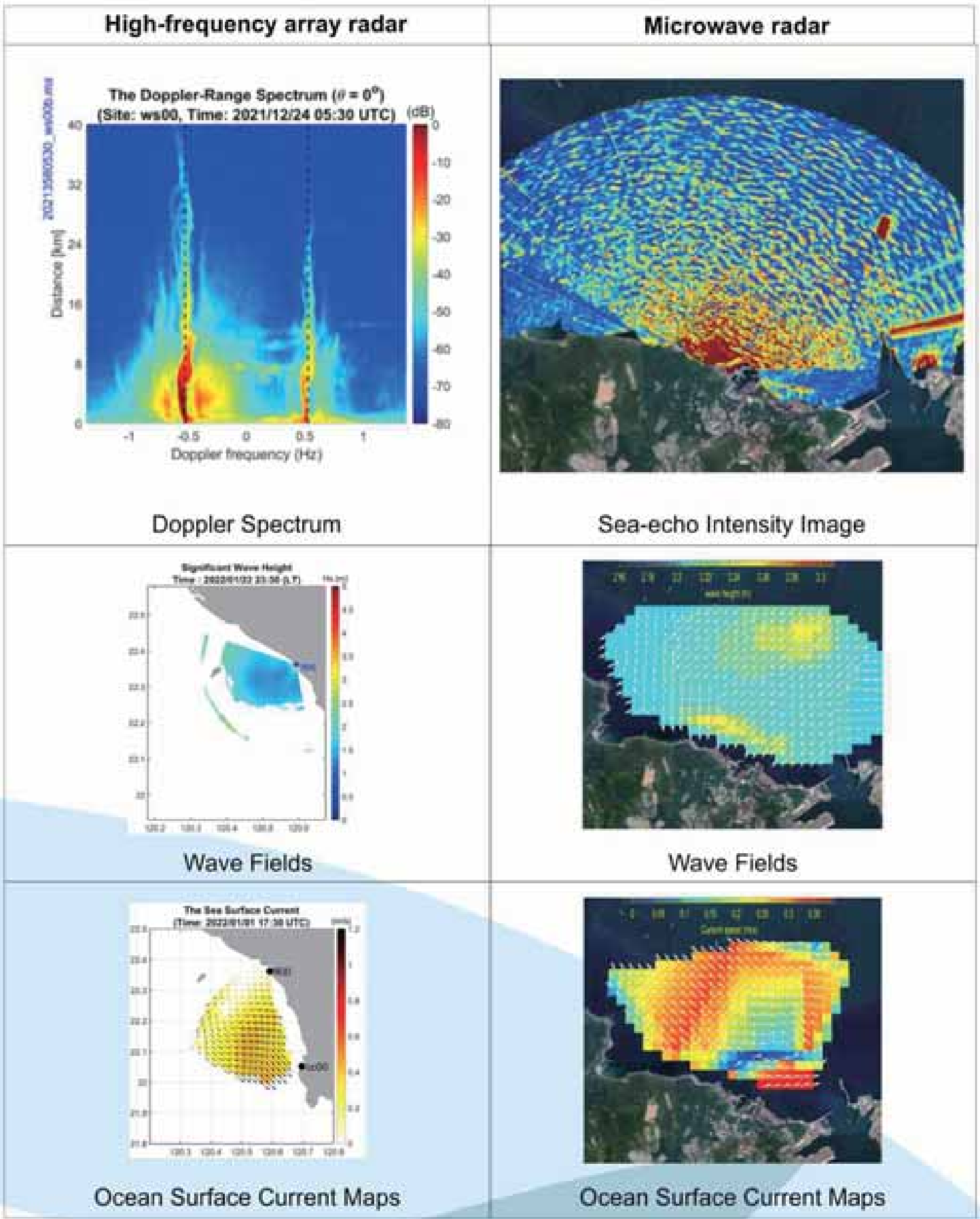

Figure 3/ Examples of Ocean Observation Achievements by High-Frequency Array Radar and Microwave Radar
Image by Jian-Wu Lai

Bureau of the Ministry of Economic Affairs also has a microwave oceanographic radar in Qigu, Tainan. The observation station network constructed by various government departments is shown in Figure 2. It is believed that these telemetry remote sensing systems will give full play to the benefits of long-term observation in the aspects of metocean observation, navigation safety, marine energy assessment, marine recreation risks, marine disaster rescue and pollution prevention and response. Figure (P5) shows the current situation of various oceanographic radars built in Taiwan. The top left panel is the CODAR compact type radar system used by TORI, and the bottom left panel is the University of Hawaii Generic HF phase array radar which is being newly built by the IHMT, CWB and NAMR, and the microwave marine radar system on the right panel.

At present, the main products of ocean high-frequency array radar and microwave radar are wave field and ocean surface current maps. Take the high-frequency radars at cosat of PingTung and the microwave radar at coast of Keelung as examples, draw the basis of the sea state inversion signal (Doppler spectrum or echo intensity image) and the inversion wave field and surface current map diagram. As shown in Figure 3, the figures in the left panel are the results of the high-frequency array radar observation, and its single-station observation range is about 30 kilometers, and the figures in the right panel are the observation results of the microwave radar with the range in 3 kilometers. Through the wave field and surface current maps produced by radars, we can get a glimpse of the ocean features and their temporal and spatial changes within the effective observation range. These are achievements that cannot be achieved with traditional mooring system observation or research vessel observation on the route, and it can also be said to be an irreplaceable advantage of oceanographic radar. In addition to the observation of waves and currents, inversion technologies for sea surface wind field, tsunami wave transmission, coastal topography, and ship detection are also being developed in Taiwan. We can expect to be able to add regular observation products to the operational observation network in the future.

Epilogue

Looking back at the development of oceanographic radar in Taiwan, the participation of experts and scholars from the industry, government, academia and research fields in oceanography and communication electronics in the past ten years has contributed to the rapid growth of radar applications in long-term marine observation and the independent development of software and hardware. It is believed that in the future, under the joint cooperation of government departments, it will promote the effective utilization of resources, the international visibility and leading position of ocean scientific research based on Taiwan's unique geographical location and improve ocean observation ability and information mastery from "point" to "surface", and enrich the content of the national ocean database. The construction of these infrastructures, in addition to the value of academic research, will also benefit the marine information needs of environmental protection, navigation, energy, fishery, disaster prevention, disaster relief, leisure, entertainment, military, and national defense.

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A Roadmap to Secure Ocean Prosperity: International Guide on Marine/Maritime Spatial Planning

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Keywords: marine spatial planning, marine spatial plan, sustainable development of the ocean

Intergovernmental Ocean Commission of United Nations Educational, Scientific, and Cultural Organization' Intergovernmental Oceanographic Commission (IOC-UNESCO) and European Commission's Directorate-General for Maritime Affairs and Fisheries (DG MARE) jointly propose International Guide on Marine/Maritime Spatial Planning (MSPglobal Guide), in order to promote blue economy developments and ensure ocean sustainability worldwide. MSPglobal Guide is a follow-up of the first IOC-UNESCO guide, Guidance for Marine Spatial Planning, published in 2009. The purpose of this guide is to assist governments and marine spatial planning practitioners in the development of marine spatial plans, improving cross-border and transboundary cooperation in marine spatial planning (MSP), promoting planning processes in regions where they are not yet launched and empowering planners in their own countries and regions. MSPglobal Guide lays out six phases concerning MSP, including setting the scene, designing the planning process, assessments for planning, the marine spatial plan, enabling the implementation of the marine spatial plan, and monitoring, evaluation and adaption. Work items of each stage has been specified, serving as a guide for initiating and engaging MSP in marine areas.

Figure 1/ MSP plans spaces for multiple uses, reducing conflicts between uses, generating benefits and ensuring ocean sustainability
Image by Chung-Ling Chen

Marine spatial planning

MSP is the process of planning the ocean space. Its purpose is to analyze ocean uses and allocate specific areas for the uses or exclude specific uses from specific areas, in order to reduce conflicts between uses and maximize benefits, while ensuring resilience of marine ecosystems. MSP is an ecosystem-based, participative, multisectoral, and transboundary cooperation approach in the planning and management of the marine environment. It contributes to achieving target 2 of Sustainable Development Goal 14 (SDG 14) of the United Nations 2030 Agenda. The target 14.2 says that sustainably manage and protect marine and coastal ecosystems to avoid significant, adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve a healthy and productive ocean.

In addition, MSP contributes to increased economic and social benefits of the areas being planned, and examines possible trade-offs between economic, social and environmental objectives in order to find a balance between them. At the same time, MSP can drive the achievement of many international agreements, such as the Convention on Biological Diversity (CBD) and the Paris Agreement on Climate Change.

This article gives an overview of MSPglobal Guide, jointly proposed by IOC-UNESCO and DG MARE. This guide describes six phases of the MSP process and details specific work items pertaining to each phase, serving as a guide for engaging MSP at difference scales of marine areas, including cross-border and transboundary areas.

MSPglobal Guide

MSPglobal Guide points out that the MSP process involves achieving agreements in objectives of various sectors, making regulations and management measures, participation of key stakeholders, securing the source of funding for MSP, and reviewing the results of MSP and modifying marine spatial plans. Specifically, MSP consists of six phases, including setting the scene, designing the planning process, assessments for planning, the marine spatial plan, enabling the implementation of the marine spatial plan, and monitoring, evaluation and adaption.

Phase I: Setting the scene

Setting the scene refers to having a basic understanding and recognition of the background information regarding the relevant rules, laws and regulations, and institutional frameworks, stakeholders, sources of funding available for the MSP process, and existing needs for planning ocean resources. Specifically, the work items at this stage include, but not limited to, creating an MSP working group, identifying existing national legal and institutional frameworks, identifying existing international laws, regulations and agreements applicable and/or adopted by the country, identifying key stakeholders, identifying sources of funding for MSP, identifying existing needs for planning ocean resources at local, national or regional scale, inducing transboundary aspects, and considering how MSP will be established within the existing governance and legal framework related to the coasts and ocean.

The purpose of the working group is to begin organizing the process and coordinate perspectives and expertise from multiple sectors for the launch of MSP. The group consists of the competent authorities, experts with experience in marine planning, members of civil society and relevant key stakeholders. Specifically, it develops a Terms of Reference document, outlining its roles and responsibilities, schedule of meetings, timeline, etc. In addition, it conducts a review of existing legal and institutional frameworks related to MSP and sustainable blue economy, and evaluate whether the concerned authorities have the capacity in coastal and marine planning.

The documents reviewed include national ocean policy, blue/ocean strategy, sectoral policies, sectoral management plans, integrated coastal zone management (ICZM), renewable energy targets, regional and/or local development programs (especially for coastal regions), climate change adaption strategies, and international legal instruments. In particular, at the global scale, MSP facilitates achieving international legal instruments and is thus able to solve transboundary marine issues such as climate change and illegal, unreported ad unregulated (IUU) fishing. Relevant international legal documents include United Nations on the Law of the Sea, United Nations 2030 Agenda for Sustainable Development, United Nations Framework Convention on Climate Change, United Nations Fish Stocks Agreement, FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, etc.

At this stage, key stakeholders have to be identified and transparent and equitable participation ensured. It is noted that key stakeholders change over time. The stakeholder list thus should be kept up to date. In addition, existing needs for planning ocean space and resources at local, national or cross-border/transboundary scale have to be identified. The needs are important drivers for the MSP process, which generally derive from the context: use-use and use-nature spatial conflicts, synergies between/among multi-uses, strategies to promote specific maritime sectors or the whole ocean economy, strategies to promote area-based conservation (e.g., network of MPAs).

Phase II: Designing the planning process

Designing the planning process refers to outlying the key steps of an MSP process and sets out how to proceed MSP work in an efficient way. The tasks needs to be taken care of at this stage include creating the planning team as well as the technical planning team, defining the planning boundaries and time frame, defining the planning principles, initial vision and goals, planning the monitoring and evaluation plan, and assessing risks and developing contingency plans.

Planning principles generally revolves around sustainable management, ecosystem approach, precautionary principle, participation and transparency, high-quality data an information, transnational coordination and consultation, coherent terrestrial and maritime spatial planning, planning adapted to characteristics and special conditions at different areas. The monitoring and evaluation plan involves the selection of indicators. The UN publication *An Introduction to Indicators* gives the criteria for designing indicator, which are relevant, measurable/verifiable, scientific, easily understood and interpreted, comparable, responsive, and cost-effective, etc.

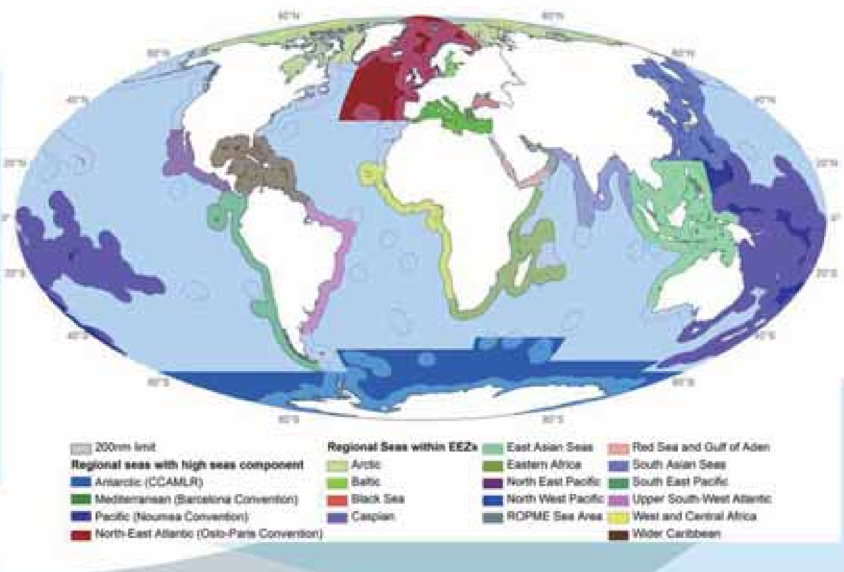

Figure 2/ Regional Sea Programs can serve as international legal institutions for cross-border cooperation in MSP
Source/ [2]

Phase III: Assessment for planning

This phase focuses on defining the different scales of planning, identifying existing conditions in the marine space being planned, analyzing its future conditions and trends, and development of public information systems.

The factors to consider when determining the scale of a plan include the international legal regime of marine waters, marine ecosystems and species distribution and dynamics, range of human activities at sea, and the political-administrative organization of adjacent territories. The relevant international legal regimes of marine waters are such as Regional Sea Programmes, tuna Regional Fisheries Management Organizations etc. Existing conditions refer to the current physical, biological, social, ecological and governance characteristics of the marine plan area. The amount of data and information is substantial and thereby there is a need to organize the data in a public information system. When analyzing future conditions and trends of the marine space being planned, new demands of ocean space from established, new and emerging maritime sectors should be taken into account.

Phase IV: The marine spatial plan

This stage concerns the development of the marine spatial plan, public consultation on the plan to solicit opinions from the public, and endorsement of the plan. The plan is a policy instrument that represents the agreed objectives among stakeholders. The content of the plan includes environment assessment, spatial allocation of marine uses, priority areas for marine conservation, various management actions, organizational frameworks, channels for implementation control, budget and financial allocation, and development of MSP capacities. As for capacity development, planners need to learn how to develop zoning, how to develop a strategic environment assessment, and how to place the marine spatial plan within the governance and legal framework, etc.

As an illustration, Seychelles used Marine Spatial Planning to Meet the 30 Per Cent Marine Protected Areas Target (i.e., the ratio of the area of MPAs over the area of EEZs). The OSPAR, a cross-border international legal regime, adopted a marine spatial plan which identified marine protected areas for the use of conservation.

Figure 3/ Seychelles used marine spatial plan to meet the 30% MPAs target

Source/ [3]

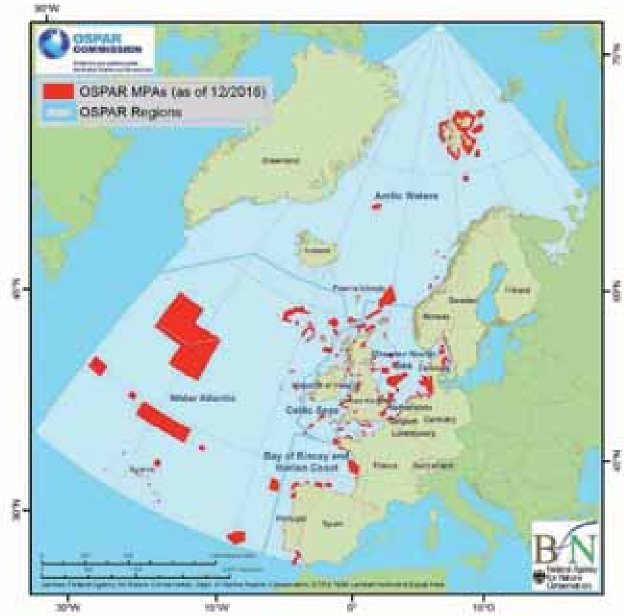

Figure 4/ The OSPAR marine spatial plan identifies areas for MPAs
Source/ [2]

Phase V: Enabling implementation of the marine spatial plan

This stage is to enable the implementation of the marine spatial plan. The tasks involved include establishing regulations relevant to the implementation of the plan, establishing a regular dialogue with sectors, training competent authorities and marine sectors on the matters regarding the implementation of the plan. The regulations are the important basis for the implementation of as well as compliance with the marine spatial plan. For transboundary marine spatial plans, the related conventions and agreements are the basis for the implementation. They often requiring efficient communication between two or more countries.

Phase VI: Monitoring, evaluation and adaption

At this stage, evaluation of each phase in the MSP process is conducted and the outcomes of the implementation of the marine spatial plan are monitored and evaluated. Based on the evaluation results, the MSP process as well as the plan is further reviewed, and revised and adapted accordingly.

Conclusion

MSP is a practical tool to promote a more inclusive and rational use of the ocean, facilitating the sustainable development of blue economy. In the context of increasingly crowded ocean spaces, MSP is indeed a tool to encourage multiple uses. The marine spatial plan allocates specific areas/sites for new and emerging uses, thereby increasing investor confidence and promoting investment in science, innovation and technologies.

MSP is widely regarded and accepted as an approach to ocean resource management. This article gives an overview of MSPglobal Guide. The Guide exactly describes the phases that are needed to engage in MSP at the local, national or regional scale. It is envisioned that via the implementation of MSP across the globe, the goal of sustainable development of the ocean can be achieved.

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Coopetition between Offshore Wind Power Policy and Marine Spatial Planning in Portugal

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Translated by Linguitronics
Keywords: Portugal, offshore wind power, marine spatial planning (MSP)

In 2020, Portugal passed a medium-term path towards carbon neutrality by 2050, namely its National Energy and Climate Plan for 2021-2030 (Plano Nacional Energia e Clima–"PNEC 2030"). PNEC 2030 focuses on GHG reduction, energy efficiency, renewable energies, energy security, and energy market (including energy poverty) and uses strategies to innovate, develop, and enhance competitiveness, thereby accelerating net-zero carbon emission policy. In the future, renewable energy will account for 47% of the Portugal's overall energy consumption, and about 80% of the electricity will come from renewable energies. Among which, capacity from wind power generation will account for the highest proportion, growing from 5.43GW in 2020 to 9.3GW by 2030.

Although Portugal has a long coastline, it is relatively conservative in the development of offshore wind power; it has risen by only from 0.03GW to 0.3GW. While the capacity remains small, the rate of growth is tenfold, which has a great impact on the marine space. This article mainly introduces the coopetitive relationship between offshore wind farms and marine spatial planning (MSP), and provides a reference for the promotion of Taiwan's marine industry through various norms and discussions on MSP regulations and development of marine-related industries.

Offshore Wind Farm Site Selection and Assessment

Portugal installed its first power generating units on Madeira Island in 1986. In 2020, the total installed capacity of onshore wind power generation reached 5.4GW, and it is planned to install more than 9GW by 2030. Also being one of the countries with the longest coastline in Europe, Portugal is also planning offshore wind power projects. Assessment of offshore wind power started in 2006, followed by re-assessment in 2010. In the second offshore wind power potential assessment, although the conditions may have been different, the final site was still chosen at the same location (Figure 1) [1].

The 6 assessment of possible offshore wind farms from Figure 1, subject to the influence and constraints of the Plano de Ordenamento do Espaço Marítimo, POEM (Marine Spatial Planning), such as the impact of coastal development on human activities, energy, and geological conditions. First of all, areas E and F are tourist attractions, so there are no wind farms planned for those areas. Were wind farms to be set up in those areas, it would seriously affect their natural ecological reserves and the development of aquaculture and fisheries. In addition to being affected by POEM, Area D is also affected by other environmental-related laws and regulations. With the exception of some protected areas, this area overlaps with major human activities. The installation of wind farms has a large impact at the social level.

Area C partially overlaps with the wind farm site designated by POEM. This area also has good potential for a wind farm, but borders the Berlengas Natural Reserve and is also subject to possible oil extraction activities as well as the impact of aquaculture and fisheries activities. Area B is also one of the offshore wind farm locations referred to by POEM. Similar to Area C, it impacts human activities, such as nature reserves and fisheries. If the wind farm is to be developed, the permit process will be time-consuming. Finally, Area A is the best offshore wind farm site in Portugal. In addition to being listed as an offshore wind farm by POEM, there is no nature reserve in the area, and it has the least impact on oil extraction and fisheries. It is the best site for development of an offshore wind farm in Portugal [2].

Offshore Wind Power Installation Plan

All wind power installation plans in Portugal are in Area A (the northernmost offshore area) mentioned previously; there are 5 existing wind farms (including those installed in shallow water and deep water). As of 2019 there are three wind turbines operating in deep waters in Wind Float Atlantic; it is the world's 2nd commercially operated windfarm to use floating wind turbine technology. With its total of 25MW, it is estimated that it can provide for the annual electricity consumption of about 6,000 households. However, planning for a total of 428MW installed capacity in nos. 2, 4, and 5 in Table 1 has been cancelled; a total of 350MW in nos. 7 and 8 is the area to be developed in the future to 2030. In addition to offshore development, the planning of further offshore wind turbines has also started on outlying islands (Porto Santo). Offshore wind turbines, due to their noise and vibration, will negatively interfere with wild species and affect the local ecology. Although the unit can be set further away from the coast, doing so would affect the cost and feasibility of their installation. Currently, Portugal is rather conservative in offshore wind turbine installation relative to the rest of the EU.

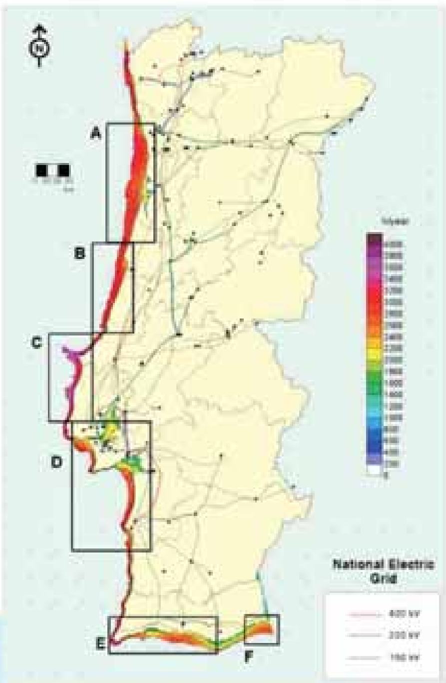
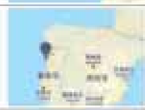


Figure 1/ Offshore Wind Farm Potential Site in Portugal
Source/ [1]

Table 1/ Portugal's Offshore Wind Power Plans at a Glance

Wind Farms	Installed Capacity	Condition	Location
1.WindFloat 1 Prototype (WF1)	2 MW	Decommissioned	
2.Branca	301 MW	Canceled	
3.WindFloat Atlantic (WFA)	25 MW	In Operation	
4.WindFloat Atlantic (WFA) - phase 2	125 MW	Canceled	
5.DEMOGRAVI3	2 MW	Canceled	
6.Offshore Island Porto Santo	10 MW	Planned	
7.Emergent Demand 1	150 MW	Under Development	
8.Emergent Demand 2	200 MW	Under Development	

Source/ [3]

The State of Marine Spatial Planning in Portugal

Marine Spatial Planning (MSP) is a decision-making tool for countries to govern the oceans and promote cross-border or cross-ministerial management; its purpose is to ensure that human activities on the ocean take place in an efficient, safe and sustainable way; it uses models and tools to analyze or allocate spatial and temporal distribution of marine human activities in order to achieve the ecological, economic, and social objectives of sustainable development. The advantages of using MSP as an ocean management strategy are: Internationally, cross-border cooperation between countries can be increased; domestically, in the same space, reducing the conflict between industries (offshore wind power and fisheries) and establishing a coordination mechanism between departments can also minimize damage to the ecosystem during development of the marine industry.

Portugal's National Ocean Strategy (NOS) has two phases: NOS2006-2016 and NOS2013-2020. NOS2013-2020 incorporates guidelines for the integrated management of marine space and precautions for resource development as well as guidance principles for the effective participation of all parties. The five main objectives of NOS2013-2020 are:

I. "reaffirm the national maritime identity in a modern, proactive and entrepreneurial framework."

II. "realising the economic, geostrategic and geopolitical potential of the national maritime territory, turning the Mar-Portugal into an asset with permanent economic, social and environmental benefits."

III. "in 2020, create conditions for attracting investment, both national and international, in all Ocean economy sectors, promoting growth, employment, Ocean sector in the national GDP in around 50%."

IV. "strengthen national scientific and technological capacity, stimulating development of new areas of action that promote the knowledge of the Ocean and effectively, efficiently and sustainably enhance its resources, use and activities as well as the ecosystem's services."

V. "consecrate Portugal on a worldwide level, as a maritime nation and as an unchangeable part of the IMP and of the EU maritime strategy, in particular for the Atlantic area."

In 2008, Portugal started POEM-related work in order to comply with the EU's Marine Spatial Planning directive. The main goal of the initial plan is to investigate the current situation and possible future activities and uses of the marine area in Portugal, including medium and long-term development activities, relevant sustainability goals, and various marine monitoring plans. MSP principles and recommendations at the highest level were formulated, and in 2014, it was planned according to relevant Portuguese and EU regulations. The objectives for MSP in Portugal are: Promoting the development of marine resources and ecosystem services, considering employment opportunities for citizens across generations in the use of the Portugal's marine space, and ensuring compatibility and sustainability of marine activities. In 2019, a new marine spatial plan, the Plano de Situação do Ordenamento do Espaço Marítimo (PSOEM), was proposed, which divided the spatial plan into three parts: the Portuguese mainland, Madeira Island, and the extended continental shelf.

There are two modes of thinking about incorporating sustainable development in MSP. The first is "hard sustainability," which focuses entirely on ecological protection; the second is "soft sustainability," the strategy currently adopted by various countries, in which ecological protection is only a part of MSP. The other core focuses of sustainable development still include fisheries, energy, tourism, and waterway safety. The second model is based on sustainable development, and its goal is to promote the economic development of the marine sector; it sees the development of the blue economy as the core. In

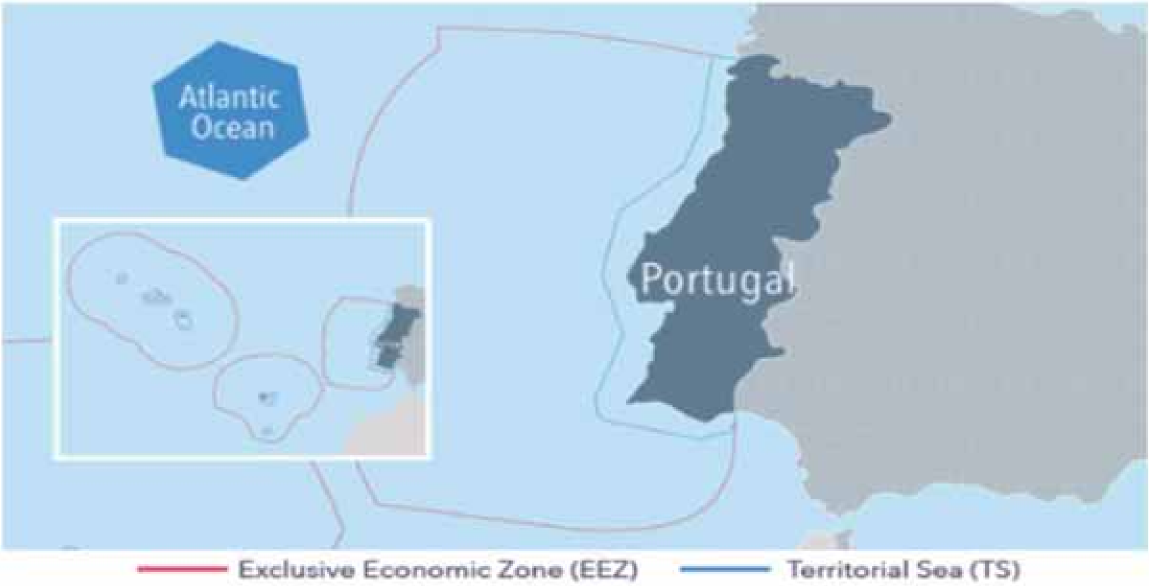


Figure 2/ Scope of Marine Spatial Planning in Portugal
Source/ [4]

summary, Portugal's MSP is set to solve environmental concerns in the utilization of marine space. That said, environmental issues are not the main goal of MSP. Its core goal is sustainable development. Maintaining the development of the marine industry, while maintaining compatibility with management policies for environmental protection (for example, using policy-oriented environmental impact assessment to achieve balance) are the important issues to be solved by MSP policy.

Case analysis: Coopetition between Offshore Wind Development and Fishing Activities in Portugal

Offshore wind power is the fastest growing item of the blue economy (marine industry) in Europe. Portugal's first offshore wind farm, Wind Float Atlantic (WFA), has a total of 3 units and a total installed capacity of 25MW, and began operating in 2019. It is the second wind farm in the world to use floating offshore wind turbine technology. WFA was developed in accordance with the Portuguese MSP specifications, but because fisheries or fishing boats are mostly prohibited in specific areas of the wind farm, it affects fishing activities and even ship navigation. WFA inevitably impacts on fishing culture in Portugal. MSP was unable to resolve the conflict between the wind turbine and fishing industries. To address the various social and economic impacts offshore windfarms may have on fisheries, it is recommended to consider allowing fisheries to participate in the decision-making process during MSP planning and to create MSP policies that are more fishery-friendly. Effective solutions are made through communication. And during the policy-making process, it is important to have more trust and more transparency amongst departments.

According to a study by Braga (2020) [5], small-scale fishery users were unable to participate in important decision-making consultation in the planning and installation processes of WFA, which could only be alleviated through after-the-fact economic compensation. However, compensation was not possible to be given to all fishermen in the area, but only to the fishermen who had joined the fishery associations in that area. In addition, the impact of WFA on fishermen is not only limited to fishing in specific areas. Submarine cables often catch on fishing gear or may even cause fishing boats to overturn. The construction and operation of offshore wind turbines also cause ecological changes in fish and destroy traditional fishing grounds, increasing the operating costs of fishermen and affecting their livelihoods as a result. On the other hand, the impact of wind power development on society is often excluded from assessment and planning, resulting in the inability of stakeholders to reach a consensus—thus, only the economic compensation mechanism can be used. Introducing mechanisms for communication among stakeholders in the early stages of wind power development is a very important task. At the initial planning stage, there must be preventive strategies that integrate and resolve conflicts among stakeholders and developers.

Table 2/ Solutions to Alleviate Conflicts Between Offshore Wind and the Fishery Sector

Strategic solutions planned to prevent the conflicts	
1	Participatory process early in the project, involving all the actors
2	Social services to help identify early trade-off
3	Integrated assessment of the ecosystem in the area of the project
4	Empowerment to the weaker sectors
5	Public consultation being less formal, having more space to creativity, new collaborative and interactive approach
6	Structures of governance need to be stronger creating a high-level policy
7	More scientific data and knowledge should be available
8	Creating an Alliance

Solutions to deal with the current conflict, trying to minimize as much as possible	
1	Financial compensations
2	Transparency in the process
3	Participatory development of a strategic plan with evaluation and revision
4	Co-management practices with a co-location of the two activities
5	Design migration corridors for the species
6	Allow fish vessels to transit in the offshore wind farms areas

Source/ [5]

Conclusion

Offshore wind power forms one of the important policies for the development of the blue economy in various countries. MSPs in a number of EU countries have introduced public participation systems. However, economic compensation should not be the only way to deal with coopetition issues between offshore wind power and fisheries. Information openness and transparency and public participation offer an effective mechanism for promoting dialogue between stakeholders and developers, and can achieve a win-win strategy for the utilization of marine space.

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A Preliminary Study on Portugal's National Marine Policy

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Keywords: Portugal, Ministério do Mar, National Ocean Strategy

Portugal, officially the Portuguese Republic (Article 1 of the Constitution), adopted a semi-presidential constitution in 1976 (revised 2005). The Constitution was established after the Carnation Revolution (Revolução dos Cravos) of 1974, which overthrew the socialist dictator António de Oliveira Salazar. The Portuguese government is composed of the Prime Minister, Ministers and Secretaries and Under Secretaries of State (Secretária de Estado) (Article 183 of the Constitution). The Under Secretary of State is responsible for the handling of particularly matters under its authority. For example, the Secretary of State for Fisheries (Secretária de Estado das Pescas) of Ministry of the Sea is responsible for fisheries matters. It is currently the 22nd government Cabinet in Portugal (XXII Governo Constitucional de Portugal, 2019-), since the establishment of the Republic in 1976.

Ministério do Mar (Ministry of the Sea)

The Ministry of the Sea of Portugal has been in the process of development over the past decades. Prior to the founding of the establishment of the Third Republic in 1976, there existed a "Ministério da Marinha", which was responsible for overall coordination of maritime and naval affairs. Bear in mind that Portuguese maritime armed force is presently managed by the Direcção-Geral da Autoridade Marítima (DGAM) under the Ministry of Defense (Ministério da Defesa Nacional) [1]. However, "Ministério da Marinha" has been reorganized and renamed several times since its origin. It has always been continued debates about whether the "Ministry of Sea" is really necessary or relevant to the situation.

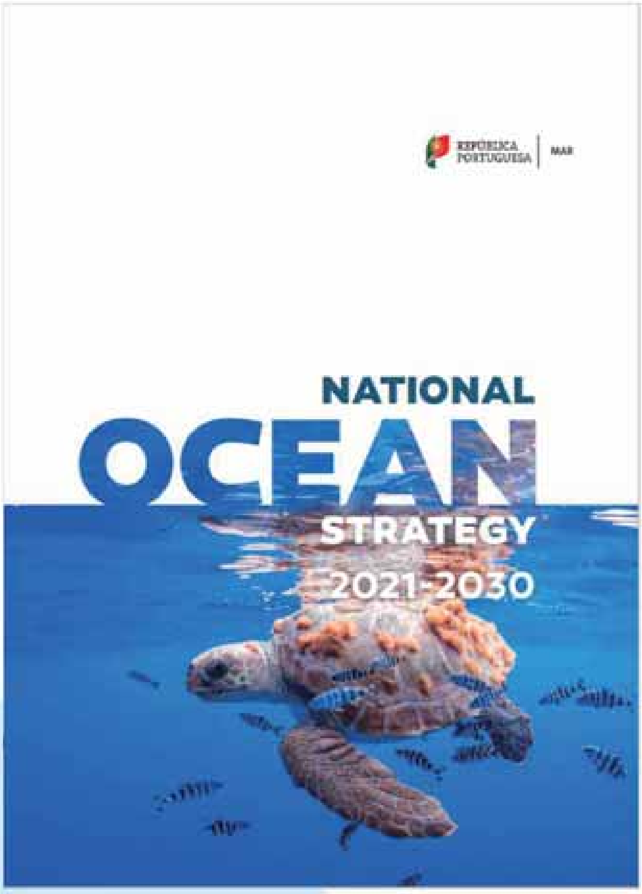

Figure 1/ National Ocean Strategy 2021-2030 Cover
Source/ https://www.dgpm.mm.gov.pt/enm-21-30

Table/ The history of the Ministry of the Sea

Time	Title	Armed Forces
-1976	Ministério da Marinha	Y
1976-1983	Ministério da Marinha	N
1983-1985	Ministério do Mar	N
1985-1991	Ministério da Agricultura, Pescas e Alimentação	N
1991-1995	Ministério do Mar	N
1995-2011	Ministério da Agricultura, do Desenvolvimento Rural e das Pescas	N
2011-2013	Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território	N
2013-2015	Ministério da Agricultura e do Mar	N
2015-	Ministério do Mar	N

Source/ Portuguese regulations

The roles of Ministério do Mar

The roles of the current Ministry of the Sea are provided for by law, namely Decreto-Lei n.º 251-A, and they are identified as follows: I. the coordination of cross cutting issues of the sea; II. the monitoring of the National Strategy for the Sea; III. the promotion of scientific knowledge, innovation and technological development in the area of the sea; IV. the management and exploitation of resources of the sea; V. the promotion of a sustainable use of the marine resources; VI. the management of European funds relating to the sea [2]. In addition to the aforementioned "Secretary of State for Fisheries", the Ministry of the Sea also includes 5 agencies: I. A Direção-Geral de Política do Mar (DGPM); II. A Direção-Geral de Recursos Naturais, Segurança e Serviços Marítimos; III. O Gabinete de Investigação de Acidentes Marítimos e da Autoridade para a Meteorologia Aeronáutica; IV. A Comissão Técnica do Registo Internacional de Navios da Madeira; V. A Autoridade de Gestão do Programa Operacional Mar 2020 [3]. Among them, the DGPM has four functions, namely, politics, economy, finance and education. It also supervises the "Blue Foundation" (Fundo azul) [4].

Portuguese law specifically regulates the relationship between the Ministry of the Sea and other ministries, such as the Ministro de Estado e dos Negócios Estrangeiros (jointly handle foreign affairs relating to law of the sea), the Ministra da Agricultura (jointly handle affairs relating to fishing, environmental and spatial planning), the Ministro das Infraestruturas e da Habitação (jointly handle affairs relating to port management); the Ministro da Ciência, Tecnologia e Ensino Superior (jointly handle affairs relating to maritime education and technology); the Ministro da Defesa Nacional (jointly handle affairs relating to continental shelf maritime safety) [5]. In addition, there is an inter-ministerial committee, namely, Comissão Interministerial para os Assuntos do Mar (CIAM) [6], which is chaired by the prime minister or the minister of the Ministry of the Sea [7].

National Ocean Strategy

Portugal regularly publishes the so-called National Ocean Strategy, and the current phase is expected to run from 2021 to 2030 [8]. The strategy has a dual function: it not only responds to the international community, particularly to the EU's "Blue Growth strategy" in 2012; it also allows Portugal to regain maritime sovereignty. The Strategic Goals of the National Ocean Strategy are generally as follows[9]:

I. "Fight Climate Change and Pollution and Protect and Restore Ecosystems": "Due to its extensive coastline and biogeographic position, Portugal must face the challenges of climate change". It is therefore necessary to develop scientific knowledge and technical capacity, while enhancing monitoring capacity to select the most threatened ecosystems in order to focus more intently on conservation and restoration.

II. "Foster Employment and a Circular and Sustainable Blue Economy": The blue economy includes "all sectors with a direct or indirect link to the ocean as a source, means, or target of business and its development." The development of the blue economy must be founded on healthy ecosystems by using "the principles of circularity, inclusiveness, equality, and sustainability."

III. "Decarbonise the Economy and Promote Renewable Energies and Energy Autonomy": By ratifying the Paris Agreement, Portugal committed to reduce emissions by at least 85% by 2050. Portugal will also follow the Sustainable Development Goals (SDG) 7, 9 and 14 of the UN 2030 Agenda, which focus on sustainably use.

IV. "Invest in Guaranteeing Sustainability and Food Security": "Portugal has one of the highest fish consumption per capita but about 75% of the ocean-based products consumed in the country are imported." Portugal must feed itself in a sustainable way for the sake of safety and autonomy, which is also in line with the European initiative "From Farm to Fork". It is necessary to increase aquaculture production to achieve this goal. Some biological technologies, such as the applications of 3D printing, are expected. Portugal will become one of the world's leading marine technology countries by 2030.

V. "Facilitate Water Access & Supply": "The growing use of water for public supply, agricultural and animal production, recreational uses, and industry, among others, has exerted an enormous pressure on global water resources." One of solutions of this problem is the desalination systems powered by renewable ocean energy.

VI. "Promote Health and Wellbeing": The marine ecosystem services that provide not only "oxygen and sequester carbon dioxide," but also "opportunities for various recreational activities" which "offer several benefits, including aesthetical satisfaction, the improvement of physical and mental health, and an added feeling of well-being." In addition, "the ocean is also a source of bioactive substances that can be produced by blue biotech from a plethora of marine organisms."

VII. "Stimulate Scientific Knowledge, Technological Development and Blue Innovation": The "use of ships allocated to maritime transport and touristic operations, as well as fishing vessels, as an opportunity to increase the amount of data collected and the area they span." In addition, Portugal can make "the best use of the specific conditions of the Azores and Madeira archipelagos", such as the development of scientific infrastructure abilities of Atlantic dimension.

VIII. Improve Education, Qualification, Culture and Ocean Literacy: "Portugal should increase the amount and quality of educational and training offer in all ocean-related areas." In addition, culture is important in the SDGs of the UN 2030 Agenda.

IX. Incentivize Reindustrialization and Productive Capacity and Ocean Digitalization: Portugal and European countries have been "losing industrial-based productive capacity." Portugal believed that reindustrialization is essential, and "ocean economy will play a key role."

X. Ensure Safety, Sovereignty, Cooperation and Governance: Portugal has unique relationship with the Atlantic countries, such as the Community of Portuguese Speaking Countries (CPLP).

VISION

To promote a healthy Ocean as a path to achieve a sustainable blue development, people's wellbeing and to consolidate Portugal as a global leader in Ocean governance, supported in scientific knowledge.

10 STRATEGIC GOALS FOR THE DECADE

- SG1 Fight Climate Change and Pollution, Restore Ecosystems
- SG2 Foster Employment and a Circular and Sustainable Blue Economy
- SG3 Decarbonization, Renewable Energies and Energy Autonomy
- SG4 Food Security and Sustainability
- SG5 Water Access & Supply
- SG6 Health and Wellbeing
- SG7 Scientific Knowledge, Technological Development and Blue Innovation
- SG8 Education, Qualification, Culture and Ocean Literacy
- SG9 Reindustrialization, Productive Capacity and Ocean Digitalization
- SG10 Safety, Sovereignty, Cooperation and Governance

Figure 2/ National Ocean Strategy 2021-2030 General Infographic
Source/ https://www.dgpm.mm.gov.pt/enm-21-30

One thing to bear in mind is the regime of the autonomous regions of the Azores and Madeira, because the most part of Portugal's EEZ belongs to them.

While Portugal is a unitary country [10], its constitution allows special autonomy provisions for both regions. Since the original text of the constitution is unclear, there have been many debates about the scope of autonomous matters [11]. However, the constitution was amended in 2005, and the amendment of Article 227 provides detailed regulations governing the autonomous region.

The autonomous regions enjoy a great degree of autonomy. They enjoy the right to participate in foreign policy decision-making. For example, the autonomous regions enjoy the right to receive the necessary information, to express their opinions, and to make recommendations as they see fit. This means that the Portuguese government must consult with the autonomous regions in marine affairs [10].

Conclusion

There are several differences between Portuguese and Taiwanese marine department, and they are summarized as follows: I. The Portuguese Ministry of the Sea does not have the power to command the armed forces; II. Portuguese law stipulates all relations between the Ministry of the Sea and other ministries, and there are several agencies that are jointly supervised by the Ministry of the Sea and other departments; III. In addition to the Ministry of the Sea, there is an inter-ministerial committee for marine affairs; IV. the most part of Portugal's EEZ belongs to Portuguese autonomous regions, and the Portuguese government must consult with the autonomous regions in marine affairs; V. Ministerial changes in Portugal are much more frequent than Taiwan, and the 2021-2030 National Ocean Strategy not only means the development of marine policy but serve as evidence to support the significance of the Ministry of the Sea.

In closing, the 10 goals of the National Ocean Strategy are actually related to scientific, technological and educational issues. Therefore, the relationship between the Ministry of the Sea and relevant ministries is a key factor for success.

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Hubs on the Offshore Green Energy Transmission Corridor - Planning and Development of Offshore Wind Power Substations

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Translated by Linguitronics

Keywords: Offshore substations, floating substations, cables

Wind turbines and the amount of power they generate have increased along with the development of offshore wind farms. Energy loss occurs frequently over long-distance low-voltage power transmission, and a surplus of cables is likely to have an impact on the offshore environment. Substations offer a solution to these problems while making electricity generation more efficient.

The function of offshore substations is to collect and output power generated by wind turbines; they are an important component of large offshore wind farms. The main function of the offshore substation is to stabilize voltage and improve the power generation efficiency of the wind turbine. After the cables in the wind farm are collected and stepped-up, they are then connected to the 161kV Taiwan Power Company ultra-high voltage (UHV) system and transmitted to the onshore power grid for the daily use of people or industry.

What is the difference between onshore and offshore substations? Onshore substations are an important part of power system transmission and power distribution. Their purpose is primarily to meet the daily energy needs of domestic or industrial users with continuous, safe, and reliable power supply. Design of onshore substations have undergone many years of practical use; a standardized, typical design is formed for these stations, and their construction and operation and maintenance costs are relatively stable.

At present, the main function of offshore substations is to integrate the offshore wind power into the power grid. What should be emphasized is that when the wind farm has power transmission demand, it can reliably transmit power, while reducing the loss of power transmission as it goes ashore and improving the power generation efficiency of wind turbines. Also, for many years now, offshore substations have been located in harsh marine environments with wind and waves, ocean currents, and high salinity, which has made subsequent maintenance operations quite difficult. Therefore, the level of difficulty in construction and maintenance and the respective costs are higher than those of onshore substations.

Offshore substation status and turbine planning

Offshore substations serve as power transmission hubs for the entire offshore wind farm. Compared with onshore substations, the overall construction cost is relatively low (including costs for cables), there are fewer subsea cables, and land acquisition is easier than for onshore substations. However, there are disadvantages, the main one being: maintenance is relatively difficult, a factor that results in certain differences from onshore substations in terms of design. Electrical design principles of substations include reliability, flexibility, and economy. Generally speaking, two primary transformers are used as mutual backup or as backup between separate wind farms to avoid power supply failure when one transformer becomes damaged and prevent the resultant economic losses.

This achieves the effect of continuous, stable power supply. Also, in order to make maintenance convenient, factors such as modularization, miniaturization, and resistance to damage from saltwater should be considered for equipment; the equipment should also be compact enough to reduce the area it occupies [1]. In the design of offshore substations, necessary considerations include wave conditions, earthquake considerations, and corrosion resistance to avoid damage to important facilities at the substation. For the above design requirements, relevant international codes can be used as reference, including codes such as the Det Norske Veritas (DNV) and American Bureau of Shipping (ABS).

Structurally, offshore substations have three main sections; from top to bottom, these are: the topside substation section, the transition section, and the substructure [2]. As can be seen from Figure 1, the substation substructure is actually similar to the basic support structure of a wind turbine. The most commonly used offshore substation foundations are monopile foundations and jacket foundations. The monopile foundation is the only pile with a large-diameter steel pipe; it directly transfers the weight of the upper structure to the seabed. Currently, monopiles are one of the mainstream solutions for subsea foundation used in Europe. The monopile foundation is generally used on a solid seabed. Its construction costs increase along with the increase of the water depth. Generally speaking, monopiles are mostly used in waters with a depth of less than 20 meters. In addition to depth, littoral drift and other situations must also be considered. Jacket foundations have a more complicated truss structure, so manufacture is more labor-intensive and costs are higher, but they have better stability. Jackets are mainly used in waters with a depth of more than 20 meters and are more economical. Compared with other foundations, the amount of steel used in jacket foundations is lower. Looking at offshore wind farms in Changhua, Taiwan as an example, one can see that if a monopile foundation is used, its design weight will be twice that of the jacket foundation [3][4].

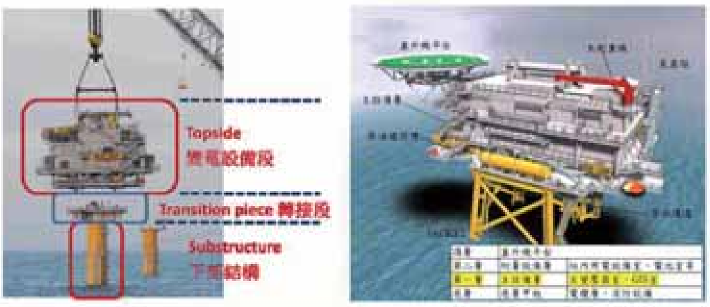

Figure 1/ Offshore Substation Structural Diagram
Source/ [2][3]

Figure 2/ Monopile Foundation and Jacket Foundation
Source/ [4]

Taking the 4-layer 200kV fixed offshore substation in Europe as an example: it can be adjusted according to the size of the wind farm and the form of the equipment. The top layer consists of a helicopter platform; the second, an auxiliary equipment layer that includes electric equipment, emergency diesel generator room, tool room, and storage room; the first, the main equipment floor that includes the main transformer, battery room, communications room, low-voltage power distribution room and control room; the lowest is the deck layer, whose highest layer at the lower part is above the peaks of the maximum wave height under extreme high tide levels, it includes life-saving equipment storage, firefighting pump rooms, and it is also the subsea cable configuration layer.

The scale of offshore substation equipment expands with the scale of the wind farm; and the equipment also becomes more complete. Looking at offshore substations in Europe as an example, one can see that the first-gen substations consisted of only a single transformer, their equipment capacity was about 100-150MW, and they weighed in at about 1,000 tons. There were no plans for backup transformers or power cables. Therefore, in the event of an equipment accident, power was completely unavailable for output. Second-gen substations were equipped with multiple transformers, had an equipment capacity of about 200-300MW, and weighed in at about 3,000-4,000 tons; in addition, they were planned for multiple output cables. This is currently the main planned substation form for North Sea wind farms in Europe. The equipment capacity of third-gen substations is about 600-800MW. Since AC transmission will cause a large amount of power loss, after power is collected and rectified, it is transferred to the land substation using high-voltage DC. The total weight of third-gen substations can be as high as 15,000 tons, so self-floating and jack-up technologies have been used in the station body to overcome lifting problems [2].

Table 1/ Substation Specification Sheet

	First-gen substation	Second-gen substation	Third-gen substation
Transformer/Shunt Reactor/ AC-DC Rectifier	1/0/0	2/2/0	2/4/2
Capacity	100～150MW	200～300MW	600～800MW
Topside Substation Section	1,000 tons	3,000～4,000 tons	15,000 tons
Deck (layer)	2	3～4	7
Substation body diagram			

Source/ [2]

Practical applications of offshore substations

Offshore substations currently in operation are still mostly in by European wind farms, such as the London array offshore wind farm in the United Kingdom. The London array wind farm is located at the outer Thames Estuary in the United Kingdom, about 11 km away from the north coast of Kent in waters with depth of about 25 meters. The London array wind farm has a total capacity of 630MW and consists of 175 Siemens 3.6 MW wind turbines and 2 offshore substations, as well as a network of approximately 210km of 33kV inter-array undersea cables. After the power generated is collected at two identical offshore substations, it is transmitted to an onshore substation near the north-east of Kent through four 150kV undersea export cables [5].

There are several windfarms currently being installed in Taiwan ; one such windfarm, the Greater Changhua wind farm, is located slightly farther from shore, and so an offshore substation has been planned and is currently under construction. The wind farm is located about 35 to 60 kilometers off the coast of Changhua, at a water depth of about 20 to 40 meters. Of which, the capacities of Greater Changhua South West and Greater Changhua South East are about 300MW and 600MW, respectively, and the two offshore substations under the charge of Ørsted will complete power-on tests in December 2021 and January 2022, respectively [6].

Future development of offshore substations

Following the development of offshore wind power, wind turbines are established from land to sea; fixed foundation piles are mainly used in shallow sea areas with water depths of less than 50 meters. As wind farms gradually populate shallow sea areas, the number of good wind farms that can be developed will also decrease. In the future, it will be necessary to develop in deeper sea areas. Therefore, many developers are now targeting wider deep-sea areas and setting up floating offshore wind turbines. Fixing to the seabed through tether cables helps to increase the scope of offshore wind power installation, and more stable wind energy in the open sea can be used to achieve higher efficiency.

Following the trend of large-scale wind turbines and offshore wind farms moving farther and farther off shore, offshore substations that can reduce power transmission loss have received increasingly more attention; also, the form of offshore substations is no longer limited to fixed foundations. The Fukushima, Japan plan uses a floating platform as the foundation for construction; and other countries have conducted research on floating substation platforms (such as BW Ideol in Norway, and the United States). Future development of offshore substations is expected to still be built using the floating form in the deep sea. The following is an introduction based on the development status in different countries.

I. Floating substation in Fukushima, Japan

Fukushima FORWARD is a symbol of Fukushima's recovery from nuclear power plant disaster caused by the 2011 earthquake and tsunami. The substation, known as Fukushima KIZUNA, has a voltage capacity of 25MVA, including 66kV gas-insulated switch equipment and 22kV vacuum-insulated switch equipment. The 22kV voltage generated by the wind turbine is boosted to 66kV by the substation and transmitted to land through the 66kV subsea cable. In addition to its function as a substation, the Fukushima floating offshore substation is also equipped with facilities such as observation towers and heliport, which are provided for wind condition surveying in the nearby sea area [7][8].

II. Norway floating substations

Ideol and Atlantique Offshore Energy (AOE) jointly develop floating substations based on the barge floating platform; the barge floating offshore substation is designed (including patented damping pool design) to operate in the world's most extreme environments and provide maximum modularity. Significant improvements can be achieved by installing the superstructure on the dock area, including equipment such as backup generators, helipads, cranes, etc., testing and pre-debugging on the dock area, and installing without heavy offshore operations, which can lower the respective costs. This versatile and modular floating substation is expected to have a significant impact on the offshore substation market; and it is preparing the market for bidding for floating substations in France and around the world. Market potential is huge, with 115GW of offshore installed capacity expected to be installed globally by 2030 [9].

III. US floating substations

In recent years, the United States has begun to design floating substations. In Figure 4, one can see that the floating substation is a combination of the semi-submersible platform of the floating wind turbine and the upper substation structure of the fixed offshore substation. Numerical verification has been carried out for the sea conditions near wind farms in the United States; results show that the stability of the platforms complies with specifications and that they are able to support floating wind farms in deeper waters, such as the those in the northeastern United States and other parts of the country [10].

Figure 3/ Norway BW Ideol Floating Substation Concept Diagram
Source/ [9]

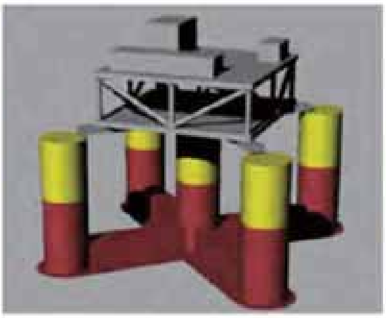

Figure 4/ United States Floating Substation Design Concept Diagram
Source/ [10]

Figure 5/ Taiwan Floating Substation Model Diagram
Images by Department of Hydraulic and Ocean Engineering, National Cheng Kung University

IV. Taiwan Floating Substation

This floating substation (Figure 5) has been tested by the research team of National Cheng Kung University. The team has considerable experience in the stability characteristics of the platform and related technologies such as the mooring system. According to the research and test results, the platform can maintain a certain level of stability under the wave conditions in the western waters of Taiwan, in both normal and extreme sea conditions. The output cables of the substation can also subsist in various environmental conditions and will not be damaged by the offshore environment. This shows that Taiwan, in response to future trends, still has the potential to install floating substations following the installation of wind farms in deeper sea areas.

Conclusion

Following the development of offshore wind power, the scale of wind farms has gradually expanded, and the demand for offshore substations has also increased. The purpose of offshore substations is to shorten the distance of wind turbine power transmission and the resultant loss in the transmission process. Thus they play an important role in the development of offshore wind farms. In addition to fixed-foundation offshore substations, floating offshore substations suitable for use in deep sea areas are also being developed, following the gradual saturation of nearshore wind farms. This means that the installation of offshore substations in the future will not be affected by offshore distance or water depth. They will eventually become hubs of the marine green-energy transmission corridor.

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1990 Lisbon Agreement: A Marine Pollution Control System Formulated by Portugal, France, Spain, Morocco, and the European Union

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Keywords: Lisbon Agreement, marine pollution

After the Torrey Canyon oil spill in 1967, the International Maritime Organization (IMO) passed in 1990 the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC Convention), under which framework six regional response centers were established. The existence of several marine pollution area alliances, such as the OSPAR Commission established in 1972 to protect the marine environment of the Northwest Atlantic, and the Lisbon Agreement, adopted in 1990 and entered into force in 2014, aim to protect the marine environment of the Northwest Atlantic.

International Legislative System

After the Torrey Canyon oil spill in 1967 (120,000 tons of oil spilled into the English Channel), a series of oil pollution legislations were formulated internationally which covered three aspects: pollution control operations (MARPOL), high seas intervention (Intervention) and compensation (CLC+Fund). After the Exxon Valdez oil spill on March 24, 1989 (37,000 tons of oil spilled in Alaska), the international community found that international legislation on "oil spill preparedness and response capacity" was still lacking. The International Maritime Organization (IMO) urgently resolved to begin research in October 1989; then, in November 1990, the 1990 International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC) was formulated and passed. The OPRC Convention, as the name suggests, lays a global foundation for countries' oil pollution emergency response systems, international mutual assistance, and multilateral cooperation. Under the OPRC framework, regional response centers such as the NOWPAP MERRAC (Northwest Pacific), REMPEITC-Caribe (Caribbean), MEMAC (Persian Gulf), REMPEC (Mediterranean), PEMSEA (East Asia), PERSGA/MEMAC (Red Sea/Gulf of Aden) have been established around the world [1]. In addition to regional response centers operating in regional cooperation under the framework of the OPRC Convention, there are still other marine pollution regional alliances, such as those protecting the Northwest Atlantic. Fifteen governments (Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and England) formed the "OSPAR Commission" in 1972 (OSPAR is Oslo and Paris Conventions ["OS" for the Oslo Convention against dumping from 1972 and "PAR" for Paris Convention against land-based sources of marine pollution and the offshore industry from 1974]; the two conventions were later combined to form the OSPAR Convention in 1992). The topic of this paper, the Lisbon Agreement, was adopted by four countries in 1990 and entered into force in 2014, is also aimed at protecting the marine environment of the Northwest Atlantic.

Background of the 1990 Lisbon Agreement: the Khark 5 and Aragon oil spills

During the development of the OPRC Convention from October 1989 to November 1990, two major oil spills occurred in succession, only 10 days apart, off the coasts of Portugal and Morocco: Khark 5 (December 19, 1989) and Aragon (December 29, 1989).

I. The Khark 5 spill: On December 19, 1989, the Very Large Crude Carrier (VLCC) Iranian Khark 5, carrying a deadweight tonnage of up to 385,000 tons, encountered bad weather 112 miles west of the coast Morocco. The hull ruptured, causing an explosion and fire. Two of the 14 oil tanks on the ship ruptured, making extinguishing the fire and towing operations very difficult. Roughly 70,000 tons of crude oil spilled, covering 600 square kilometers. The Moroccan government requested assistance from England, France, Spain, and Portugal. Before the oil slick drifted to the coast of Morocco, the Moroccan government and hundreds of European volunteers used a large amount of chemical dispersant to break up the oil slick [2].

II. The Aragon spill: On December 29, 1989, the Spanish VLCC Aragon, carrying a deadweight of up to 240,000 tons, suffered severe damage 360 miles out from the Moroccan coast from bad weather during towing after the failure of its steering engine, resulting in the no. 1 central oil tank leaking roughly 25,000 tons of Mexican crude oil. After three weeks of emulsification, the spilled crude oil drifted to Madeira Island, a famous tourist destination in southwest Portugal, wreaking havoc across the entire eastern coast of the region. Not only did Madeira Island itself not have the necessary pollution cleanup equipment, but Portugal as a whole did not have the capacity to respond to such a severe oil spill. Portugal requested assistance from the European Commission, and several EU member countries formed emergency teams and provided emergency equipment/materials, which were transported to the rescue effort on dedicated aircrafts. The cleanup operation took a total of 7 weeks, and equaled the removal of a total of about 15,000 tons of crude oil; the recovered oil was then shipped to the Netherlands for processing [3].

The 1990 Lisbon Agreement

ITOPF has compiled statistics of oil spills that have occurred internationally from 1967 to 2021 [4]; waters in the Northeast Atlantic have always been a hotspot of major oil spills from oil tankers over the years. In light of the Khark 5 and Aragon incidents as well as the principles of mutual support and national cooperation proactively created with reference to the IMO OPRC draft that was nearly at the end of its development, Portugal, which had the most important stake in both incidents, appealed to the European Economic Community with a proposal: Portugal, France, Morocco, Spain and the European Economic Community should reach a regional agreement to deal with marine pollution incidents covering the waters of the Northeast Atlantic. Before the OPRC was passed, the contracting parties signed the "Lisbon Agreement" with the then European Economic Community on October 17, 1990. Its full title was "COOPERATION AGREEMENT for the protection of the coasts and waters of the north-east Atlantic against pollution." On May 20, 2008, the agreement was amended by a protocol to change the southern boundary. Spain did not ratify the agreement until February 1, 2014, which then brought the Lisbon Agreement into force. The purpose of the Lisbon Agreement is to ensure that the parties can cooperate in the event of marine pollution accidents. The agreement also requires that each party establish its own prevention and control system, equip itself with pollution control equipment, and formulate its own national plan of action.

The full text of the Lisbon Agreement includes the purpose, 27 articles, and 2 annexes, of which Articles 1 through 19 are substantive norms, Articles 20 to 27 are final clauses, including amendments to the convention (§20), proportions of secretariat expenses (§21), ratification, acceptance or approval or deposit, and entry into force (§22), invitation to accession (§23), entry into force of accession (§24), withdrawal (§25), denunciation (§26), and text and depositing (§27, with Portugal as the depositary country). Articles 1 through 19 are substantive norms, their main contents being:

Article 1 Agreement obligations: "The Contracting Parties to this Agreement ... undertake, individually or jointly ... to take all appropriate measures under this Agreement ... to deal with an incident of pollution at sea."

Article 2 Definitions: Defines pollution incidents, hydrocarbons, and other hazardous substances.

Article 3 Scope of agreement: In principle, the scope is the Northeast Atlantic region outside the exclusive economic zones of each of contracting state.

Article 4 Obligations of contracting states: Includes the establishment of a minimum amount of emergency equipment, national emergency response systems, protection of endangered sensitive areas, itemizing of equipment and human resources, recovery, storage and disposal of pollutants, and personnel training.

Article 5 Joint action plan: "The contracting parties shall jointly draw up and determine guidelines covering the practical, operational and technical aspects of joint action," covering information, new technologies and methods, and identification of major pollution incidents.

Article 6 Expanded application: The joint action plan also covers the loss of container equipment such as containers carrying hazardous substances at sea.

Article 7 IMO compliance: Government personnel and crew members of national ships and platforms shall comply with various IMO provisions, including pollution avoidance, emergency response, and incident notification.

Article 8 Division of powers and responsibilities in the agreement area: The contracting state party responsible for the area where the contamination is located shall conduct an assessment and notify other state parties of emergency action.

Article 9 Areas of joint interest: Negotiation, adoption, leadership, coordination, and assistance of joint actions for areas of joint interest.

Article 10 Requests for assistance and cooperation: Requests for assistance shall indicate the circumstances in which assistance is required; the requested state shall make every effort to assist.

Article 11 No prejudice to the sovereignty of States: Declares that the exercise of this Agreement may not prejudice the sovereignty and sovereign rights pursuant to international law concerning the exclusive economic zones and continental shelves.

Article 12 Monitoring and research of shipping activities: The relevant shipping authorities of the contracting states shall formulate shipping monitoring methods and conduct relevant studies.

Article 13 Contracting states' burden of cost: The agreement area adopts the principle of parties bearing the costs of their respective actions, whether it is requested assistance or voluntary assistance; the areas of joint interest adopt the principle of burden sharing; it also stipulates the termination of assistance and expert reporting and reviewing of costs.

Article 14 No prejudicing rights of the contracting parties to recover costs from third parties: "Article 13 ... may not in any circumstances be interpreted as prejudicing the rights of the Parties to recover from third parties the costs involved...."

Article 15 Meetings of the parties to the agreement: Approval of regular meetings, rules of procedure, etc.

Article 16 Exercise of European Economic Community voting rights: One vote per contracting state, the European Economic Community itself has no right to vote.

Article 17 Tasks of the meetings of the parties: Supervision, inspection, and identification of particularly sensitive areas, etc.

Article 18 Establishing an international center: Located in the depository country, its purpose is to be able to respond quickly to pollution incidents.

Article 19 Functions of the International Centre: Suggestions on the flexibility and complementarity of emergency supplies and equipment, and increasing inventory of each contracting party.

Annex 1 to the Agreement: Areas correspond to the exclusive economic zones of each contracting state
Annex 2 to the Agreement: Guidelines for defining the functions of the International Action Centre

A Short Summary

After the adoption of the Lisbon Agreement in 1990, two major oil spills, i.e., the 1992 Aegean Sea incident (74,000 tons spilled in La Coruna, Spain) and the 2002 Prestige incident (63,000 tons spilled in Galicia, Spain) occurred successively in the agreement area, but the agreement required the four original contracting states to have ratified or accepted the agreement before it could enter into force, and Spain had not ratified and deposited the agreement until February 1, 2014. Since the Lisbon Agreement came into force on February 1, 2014, the number of major international oil spills has been greatly reduced, and with the continued operation of the previous and larger OSPAR Commission in the Northwest Atlantic, so the operating rate of the Lisbon Agreement was basically low. According to the "Review of Maritime Transport 2021" released by the United Nations Conference on Trade and Development (UNCTAD), 1,060.2 million tons (or nearly 57%) of the 1,863.6 million tons of crude oil unloaded around the world in 2020 were unloaded in Asia [5], with most of that unloaded in East Asia. The sea area around Taiwan has always been a hot spot/frequent trade route for crude oil; consequently, it is also a hot spot for marine pollution accidents. Although Taiwan currently has a "Major Marine Oil Pollution Emergency Response Plan" (revised Jan. 3 2017), it is only applicable to Taiwan. Due to the realities of the international political scene, Taiwan has not signed on to regional marine pollution cooperation agreements with its neighboring countries like the Lisbon Agreement discussed here. But pollution knows no borders. Such regional marine pollution cooperation models can be emulated by Taiwan. On the foundation of APEC, Taiwan is engaged in discussions on topics such as disaster response and environmental protection, and it has similar marine pollution cooperation agreements with neighboring countries.

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國際海洋資訊 17
April 2022
雙月刊 | Bimonthly
International Ocean Information

發行：海洋委員會
地址：806610高雄市前鎮區成功二路25號4樓
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Published by Ocean Affairs Council
Address：4F., No. 25, Chenggong 2nd Road,
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Publisher：Chung-Wei Lee
Associate Publisher：Ching-Piao Tsai, Mei-Wu Chou
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國際海洋資訊

17 April 2022 雙月刊 Bimonthly

International Ocean Information

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中華民國111年4月出版（每雙月出版）
中華民國108年8月創刊
ISSN 2706-638X （紙本）
ISSN 2706-6398 （電子）
中華郵政高雄雜字第236號執照登記為雜誌交寄
高雄郵局許可證 高雄字第2084號

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海洋委員會 Ocean Affairs Council 發行
台灣經濟研究院 編印

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