State of the Art of national regulations plans and strategies for the development of offshore wind power for the Mediterranean countries

Overview on offshore wind energy in the Mediterranean

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Introduction

Renewable energy refers to energy sources that are naturally replenished and can be used repeatedly without being depleted. These sources include solar, wind, hydropower, biomass, and geothermal. Renewable energy is considered environmentally friendly and sustainable, as it produces minimal greenhouse gas emissions and reduces reliance on fossil fuels.

Renewable energy occupies a pivotal role in the global pursuit of climate change mitigation and sustainable development, offering a multitude of advantages. Therefore, it was not a surprise that renewable energy was at the center of discussions at COP28 in Dubai (2023), where 197 countries committed to triple renewable energy capacities by 2030. One of its primary contributions lies in the substantial reduction of greenhouse gas emissions. Sources such as solar, wind, and hydropower, integral components of the renewable energy landscape, emit minimal or no greenhouse gases, thereby playing a crucial role in attenuating the adverse impacts of climate change. Moreover, the embrace of renewable energy fosters enhanced energy security by diversifying energy sources and diminishing dependence on fossil fuels. This diversification not only curtails vulnerability to price fluctuations but also fortifies resilience against supply disruptions.

The renewable energy sector extends its positive influence beyond environmental considerations, acting as a catalyst for economic growth and job creation. With significant employment opportunities spanning manufacturing, installation, maintenance, and research and development, this sector emerges as a robust contributor to job markets worldwide. Furthermore, the adoption of renewable energy technologies holds the promise of improved public health outcomes. In stark contrast to traditional fossil fuel-based energy production, renewable energy processes eschew the release of harmful pollutants, thereby mitigating air and water pollution and positively impacting public health.

An often-overlooked aspect of renewable energy lies in its role as a driver of innovation and technological advancement. The ongoing development of renewable energy technologies stimulates innovation, leading to cost reductions, heightened efficiency, and increased deployment of clean energy sources. This catalytic effect not only positions renewable energy as a key player in current energy landscapes but also lays the groundwork for a more sustainable and technologically advanced future.

The imperative to invest in and prioritize the development and utilization of renewable energy cannot be overstated. It represents a linchpin for achieving a sustainable and resilient future, addressing climate change, fostering economic growth, and propelling technological innovation towards a cleaner and more sustainable energy paradigm.

On the other hand, embarking on a project centered on offshore renewable energy encompasses a range of objectives designed to holistically assess, analyze, and advance this dynamic field. Initially, the project aims to assess the potential of offshore renewable energy sources, including wind, wave, and tidal power. Through a rigorous examination, the goal is to quantify available resources and determine optimal locations for harnessing these energies, laying the foundation for informed decision-making.

Simultaneously, a crucial aspect of the project involves conducting a comprehensive analysis of the environmental impact associated with offshore renewable energy projects. Identifying potential negative effects is paramount, and the project seeks to propose mitigation strategies that can effectively minimize ecological consequences, ensuring the sustainability of these endeavors.

Evaluating the feasibility and economic viability of various offshore renewable energy technologies constitutes another pivotal objective. This includes a thorough assessment of technical feasibility, capital costs, operational expenses, and potential returns on investment. Such economic insights are instrumental in making informed decisions and attracting necessary investments for the successful implementation of offshore projects.

Furthermore, the project is geared towards developing integration strategies that seamlessly incorporate offshore renewable energy into the existing energy infrastructure. This involves exploring grid connectivity, storage solutions, and other critical aspects that facilitate the smooth and efficient integration of offshore energy sources.

Recognizing the social and cultural implications of offshore renewable energy projects, the project prioritizes investigating their impact on local communities. An essential component is ensuring community engagement to address concerns and perceptions related to cultural and social dynamics, promoting a harmonious coexistence between projects and the communities they affect.

Identifying and addressing regulatory and policy barriers is a key project objective, with the aim of recommending frameworks that encourage sustainable offshore energy initiatives. This involves navigating existing regulatory landscapes in the Mediterranean countries to propose enhancements that facilitate the development and deployment of offshore renewable energy technologies.

Additionally, the project seeks to promote public awareness and education about the benefits and challenges of offshore renewable energy. Through targeted initiatives, it aims to disseminate information, foster understanding, and garner support from the wider public, crucial for the long-term success and acceptance of offshore energy projects. Marine energy development encompasses more than just technical aspects. It encompasses key considerations such as resource independence, energy market integration, energy accessibility, sustainable tourism, climate adaptation, and international leadership. These aspects highlight the broader benefits of marine renewable energy, including reduced dependency on external energy sources, integration into regional energy markets, increased accessibility to clean energy, promotion of sustainable tourism practices, adaptation to the challenges posed by climate change, and positioning the region as a leader in the global transition towards renewable and sustainable energy alternatives.

Lastly, the project emphasizes collaboration with industry stakeholders, research institutions, and government agencies. By fostering synergies and leveraging collective expertise and resources, the project aims to advance offshore renewable energy initiatives effectively. This collaborative approach enhances the potential for successful project outcomes and contributes to the broader goal of integrating sustainable offshore energy solutions into the global energy landscape.

Offshore renewable energy presents a host of advantages over both non-renewable energy sources and onshore renewable energy projects. In comparison to onshore renewables, offshore projects occupy less land, minimize visual impact on local populations, and eliminate concerns about noise pollution. Additionally, they obviate the need for new long-distance transmission lines as they can be strategically located near load centers. Moreover, offshore wind farms have the capacity to generate more power as the turbines can be larger, capitalizing on the faster and stronger wind at sea to collect more energy. In contrast to non-renewable energy production, offshore renewables exhibit a comparatively minimal impact on ocean ecosystems, relying on abundant natural resources that will never be depleted, in stark contrast to finite fossil fuels. The economic advantages are evident as well, with offshore renewable energy delivering cheaper, more cost-effective power production compared to fossil fuels, thereby reducing electricity bills. Furthermore, these offshore projects contribute significantly to the green transition by providing a sustainable and environmentally friendly alternative, aiding in the reduction of carbon emissions, the pursuit of net-zero targets, and the overall mitigation of climate change (link).

I. Offshore Marine Energy Sources

Offshore renewable energy refers to the production of clean and sustainable energy from renewable sources, such as wind, waves, and tides, in offshore locations. This includes the development and operation of offshore wind farms, wave energy converters, and tidal energy devices. Offshore renewable energy plays a crucial role in reducing greenhouse gas emissions and transitioning to a more sustainable and low-carbon energy future.

A. INVENTORY OF THE PRODUCTION, USE AND GROWTH OPPORTUNITIES

There are four main types of offshore renewable energy types. Each at a different stage of development and with its own unique challenges and opportunities and are as follows:

Wind

Wind power is generated via turbines which use blades to collect kinetic energy from the wind as it blows. This process has been described as working in the opposite way to a fan: the wind causes the turbine blades to spin. These blades are connected to a drive shaft so when they spin, they turn an electric generator. The generator produces power which is then sent to a substation. Here, the electricity is collected and changed to a higher voltage using a transformer before being sent onshore for consumer use.

Wave

As you may have guessed from the name, wave energy generates electricity using the power of ocean waves. The bigger, faster, and longer a wave, the more power it can generate. By placing specialist equipment on the surface of the ocean, it is possible to capture the kinetic energy produced by the periodic up and down movement of the sea. This energy is used to turn a turbine, which is attached to a generator, to create electricity that can then be transported back onshore.

Tidal

As with wind and wave energy, tidal energy is also generated using turbines, however in this instance, the turbines are located beneath the ocean's surface. Underwater turbines are installed out at sea in areas known to have high tidal movements. The movement of the water turns the turbine blades, which in turn drive a generator that produces electricity. The power produced is then sent back onshore via power cables, ready for distribution.

Thermal

Thermal energy typically refers to power generated using either the Sun (solar power) or the Earth's interior (geothermal energy uses heat deep within the Earth to create steam that in turn generates electricity). There are a variety of technologies, such as heat pumps, PVT panels, flat-plate collectors, and solar water heating, which can be used to harvest this thermal energy and convert it into electricity. More recently, we have also seen the emergence of a new type of thermal energy: Renewable natural gas (RNG). RNG is essentially methane which is captured during the decomposition of organic matter at farms, landfills, and wastewater treatment plants. The gas is then cleaned and distributed via the same infrastructure and processes as those used for existing natural gas production.

That said, the best available marine energy technologies (BAT) encompass a range of renewable energy technologies that harness the power of the ocean, including wind, wave, tidal, and thermal sources, notably: Offshore Wind Turbines (similar to onshore wind turbines but specifically designed for installation in marine environments). It can generate significant amounts of electricity due to the consistently strong and steady winds found at sea, Oscillating Water Column (OWC) Devices (using waves to compress and decompress air within a chamber, driving a turbine to generate electricity), Point Absorbers (floating on the water's surface and use the up and down motion of waves to drive a generator), Oscillating Wave Surge Converters (OWSC) which capture the energy from both the horizontal and vertical motion of waves to generate electricity, Tidal Turbines (similar to wind turbines but are specifically designed to operate in tidal currents). They are typically installed on the seabed and capture the energy from the moving tides, Tidal Barrages (built across estuaries or bays and use the potential energy of the tides to generate electricity as water flows in and out of the barrage), and finally, Ocean Thermal Energy Conversion (OTEC), which are systems using the temperature difference between warm surface water and cold deep water to generate electricity. This technology is not necessarily appropriate in the Mediterranean region but rather is most effective in tropical regions with a significant temperature gradient between surface and deep waters.

It's important to note that the effectiveness and availability of these technologies can vary depending on factors such as resource availability, technological advancements, and project economics. Additionally, ongoing research and development efforts are continuously improving these technologies and exploring new approaches to harness marine energy efficiently and sustainably.

Several countries have been involved in offshore wind energy projects, using various types of offshore wind turbines. The specific types and technologies adopted can vary by project and country. Here are examples of some best available technologies (BAT) using offshore wind turbines:

1. **Monopile, Jacket Foundation, and Gravity Base:** These technologies have been explored or deployed in several countries, including Germany, Denmark, the United Kingdom, the Netherlands, and Belgium.
2. **Floating Wind Turbines (Spar-Buoy, Semi-Submersible, Tension Leg Platform):** These technologies have been explored or deployed in various countries, including Portugal, Scotland, Japan, Norway, and the United States.
3. **Horizontal Axis Wind Turbines (HAWTs):** Extensively employed for both onshore and offshore applications, with notable countries featuring offshore wind farms utilizing HAWTs including the United Kingdom, Germany, Denmark, China, and Taiwan.

At the level of the European Union, significant strides were made in advancing wind energy initiatives as part of the Energy Council, where 24 Member States and over 300 wind industry companies signed the European Wind Charter—a pivotal commitment aligning efforts to bolster the development of the EU wind sector, in line with the European Wind Power Action Plan. Concurrently, 21 Member States voluntarily pledged specific volumes for wind energy deployment from 2024 to 2026, reflecting a positive outlook and a solid business case for the EU wind sector. Moreover, the COP28 emphasized the need for political and private commitment to sustain the industry's positive momentum where 159 countries committed, including most of the Mediterranean countries.

While mentioning the Mediterranean region in specific, it presents a compelling growth opportunity for the adoption of offshore renewable energy. With abundant sunlight and strong, consistent winds, the region is well-suited for harnessing solar and wind energy. The strategic geographical location of the Mediterranean Sea as a hub for energy transportation and trade further enhances the significance of investing in offshore renewables. Many countries in the region heavily rely on imported fossil fuels, making the shift to offshore renewable energy crucial for diversifying energy sources, enhancing energy security, and reducing dependence on imports.

The development of offshore wind farms not only generates economic opportunities but also aligns with international climate goals, supporting the transition to low-carbon and sustainable energy systems.

Technological advancements, such as floating solar and innovative offshore wind platforms, contribute to the feasibility and cost-effectiveness of deploying these solutions in the diverse marine environments of the Mediterranean.

Regional collaboration, supportive government policies, and the preservation of the region's natural beauty further reinforce the growth prospects for offshore renewable energy. The Mediterranean can emerge as a research and innovation hub, driving advancements and positioning itself as a leader in clean energy solutions, ultimately contributing to economic development, environmental sustainability, and regional cooperation.

B. TRANSFERABILITY CONDITIONS

Offshore renewable energy presents a promising avenue for countries seeking sustainable alternatives to conventional power sources. The conditions conducive to a successful transition involve a careful consideration of various factors. Foremost among these is the assessment of a country's offshore energy potential. The presence of ample offshore wind or tidal resources is a fundamental condition for the viability of such projects. Nations with extensive coastlines or marine territories rich in renewable energy sources are better positioned to capitalize on offshore renewables.

Technological readiness is another crucial factor influencing a country's ability to embrace offshore renewable energy. The infrastructure and expertise required for the development, installation, and maintenance of offshore wind or tidal projects demand a certain level of technological advancement.

Countries with established capabilities in renewable energy technologies and a commitment to innovation are more likely to take the lead in offshore projects. On the other hand, the role of a supportive policy and regulatory framework cannot be overstated. Governments play a pivotal role in creating an environment that encourages offshore renewable energy development. Clear and favorable policies, along with robust regulatory mechanisms, provide the necessary assurances for investors and developers. Countries that actively foster a conducive policy environment demonstrate a willingness to facilitate the transition to offshore renewables.

A favorable investment climate is essential for the financial viability of offshore renewable energy projects. Availability of financing options, incentives for investors, and a stable economic environment contribute to the attractiveness of these ventures. Mediterranean countries with a commitment to creating an investment-friendly climate for renewable energy projects are more likely to attract the necessary capital for offshore initiatives.

Public acceptance represents a critical aspect that can either propel or impede the adoption of offshore renewable energy. Positive public perception, awareness campaigns, and community engagement are essential for garnering support. Countries with a populace that recognizes the benefits of renewable energy and actively participates in the transition are better poised for the successful integration of offshore projects.

Environmental considerations also feature prominently in the conditions for offshore renewable energy adoption. A commitment to mitigating environmental impacts, such as the protection of marine ecosystems and biodiversity which is of utmost importance in a region such as the Mediterranean with fragile marine and coastal ecosystems and increasing threats to its biodiversity, showcases a country's dedication to responsible and sustainable energy practices. Governments that prioritize environmental conservation demonstrate a willingness to ensure the long-term viability of offshore renewables.

The availability and efficiency of the electrical grid play a vital role in the practical implementation of offshore renewable energy projects. A well-developed and interconnected grid is essential for transmitting the energy generated offshore to population centers. Countries with robust energy infrastructure and plans for grid expansion exhibit a readiness to integrate offshore renewables seamlessly into their energy mix.

Economic viability is a critical condition influencing the willingness of countries to shift to offshore renewable energy. The competitiveness of offshore projects in comparison to traditional energy sources is a key consideration. Countries that prioritize economic feasibility and view offshore renewables as cost-effective alternatives are more likely to incorporate them into their energy portfolios.

International collaboration represents a unique condition that can enhance a country's offshore renewable energy endeavours. Collaborative efforts and agreements with neighboring nations or international organizations facilitate the sharing of knowledge, resources, and experiences. Countries willing to engage in such partnerships demonstrate a commitment to collective efforts in advancing offshore renewables on a global scale.

In conclusion, the conditions and willingness of a country to shift to offshore renewable energy are complex and multifaceted. The interplay of factors such as resource potential, technological readiness, policy frameworks, public acceptance, and international collaboration collectively shapes a nation's trajectory towards embracing offshore renewables. Countries that strategically navigate these conditions stand to reap the benefits of sustainable and environmentally conscious energy solutions.

C. POSITIVE IMPACTS OF OFFSHORE WIND TURBINES EXAMPLES

It is obvious that offshore wind projects bring positive impacts on different sectors, including tourism, aquaculture, and fishing. Hereafter, some examples of such impact.

1. Tourism

- Block Island Wind Farm, Rhode Island, USA*:* this Wind Farm has become a tourist attraction, drawing visitors interested in sustainable energy. Interpretive centers and educational programs enhance the overall tourist experience.
- London Array, UK*:* the London Array offshore wind farm in the UK incorporates visitor centers and educational initiatives, providing tourists with insights into renewable energy and contributing to eco-tourism.
- Alpha Ventus, Germany: this is the first German offshore wind farm, offers guided tours and educational programs, attracting tourists interested in green energy and marine conservation.
- Middelgrunden Offshore Wind Farm in Denmark*:* This wind farm near Copenhagen is accessible to the public, providing boat tours that educate tourists about wind energy and sustainable practices.

- Gemini Offshore Wind Park in the Netherlands*:* This wind park in the North Sea offers educational tours, allowing visitors to witness the positive environmental impact and learn about the benefits of offshore wind energy.

2. Aquaculture

- Nysted Offshore Wind Farm, North Sea, Denmark*:* this wind farm has created artificial reef structures, positively impacted local biodiversity, and provided additional habitats for marine species.
- Egmond aan Zee Wind Farm, North Sea, Netherlands*:* this wind farm has enhanced biodiversity around its turbine foundations, creating opportunities for marine life and benefiting local ecosystems.
- Lillgrund Offshore Wind Farm, Sweden*:* this wind farm has seen positive effects on local marine life, acting as an artificial reef and attracting various fish species.
- Burbo Bank Offshore Wind Farm, UK*:* this wind farm in the UK has been associated with increased marine biodiversity, contributing to a healthier and more vibrant local ecosystem.
- Baltic 1 Offshore Wind Farm, Germany*:* This wind farm has demonstrated positive interactions with marine life, showcasing the potential benefits of offshore wind structures for local aquatic ecosystems.

3. Fishing

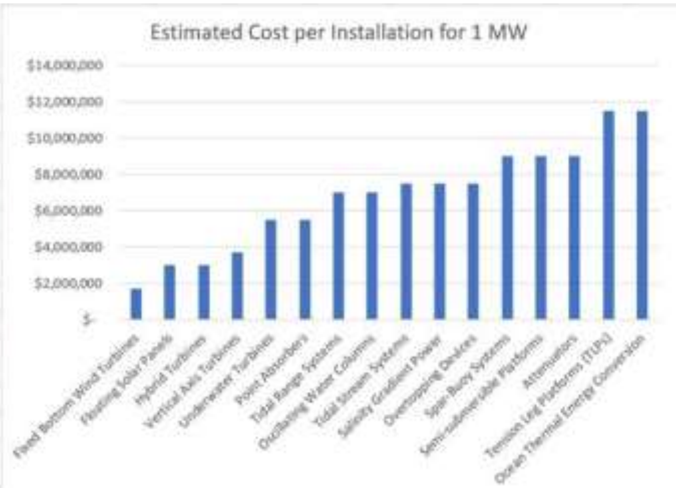
- Thanet Offshore Wind Farm, UK: this wind farm has created new fishing grounds around its structures, benefiting local fishermen with increased catches.
- Horns Rev Wind Farm, Denmark: this wind farm in the North Sea has contributed to the creation of new fishing grounds, demonstrating a positive interaction between offshore wind farms and fisheries.
- Westermost Rough Offshore Wind Farm, UK*:* this wind farm has been associated with improved fishing opportunities, showcasing the coexistence of wind energy and sustainable fishing practices.
- BARD Offshore 1, Germany: this wind farm has demonstrated positive effects on local fisheries, providing evidence that offshore wind farms can contribute to enhanced marine environments.
- Belwind Offshore Wind Farm, Belgium: this wind farm has been recognized for its compatibility with local fisheries, exemplifying the potential for synergy between renewable energy and traditional fishing activities.

II. Socio-economic, environmental, and technological assessment of offshore wind energy

A. ECONOMIC ASSESSMENT

When it comes to assessing the economic feasibility of marine energy types, hereafter we show a comparison between offshore wind energy and the other forms of offshore marine energy.

Marine Energy Type	Estimated Cost per Installation for 1 MW	
Fixed Bottom Wind Turbines	$	1,750,000
Floating Solar Panels	$	3,000,000
Hybrid Turbines	$	3,000,000
Vertical Axis Turbines	$	3,750,000
Underwater Turbines	$	5,500,000
Point Absorbers	$	5,500,000
Tidal Range Systems	$	7,000,000
Oscillating Water Columns	$	7,000,000
Tidal Stream Systems	$	7,500,000
Salinity Gradient Power	$	7,500,000
Overtopping Devices	$	7,500,000
Spar-Buoy Systems	$	9,000,000
Semi-submersible Platforms	$	9,000,000
Attenuators	$	9,000,000
Tension Leg Platforms (TLPs)	$	11,500,000
Ocean Thermal Energy Conversion	$	11,500,000



(1), (2), (3)

As per the benchmark done, it is obvious that the offshore wind energy (fixed bottom wind turbines) is the most cost effective. It is almost half the price of the closest alternative (Floating solar panels).

As per the maturity of the technology and the technology readiness level (TRL), the following table shows the ones with the highest TRL and the ones that need scaling up to reach the market. (Table 1).

Table 1. TRL of offshore wind energy types

Position in TRL	Types / Sources
TRL=9, Mature and Widely Deployed	● Fixed Offshore Wind Turbines ● Floating Wind Turbines (Spar-Buoy Systems, Semi-submersible Platforms, Tension Leg Platforms)
TRL= 6, Promising but developing	● Tidal Energy (Tidal Range Systems, Tidal Stream Systems) ● Wave Energy (Point Absorbers, Oscillating Water Columns, Attenuators, Overtopping Devices) ● Underwater Currents
TRL= 5, Emerging Technologies	● Ocean Thermal Energy ● Salinity Gradient Power
TRL=4, Niche or Limited Deployment	● Floating Solar Panels (more common in specific regions or water bodies)

B. ENVIRONMENTAL ASSESSMENT

Offshore renewable energy, which includes wind, wave, tidal, and ocean thermal energy, has significant environmental advantages over traditional fossil-fuel-based power generation. It does, however, bring some obstacles and considerations (Table 2 & Table 3).

Table 2. Environmental Advantages

Environmental Advantages	Explanation
Reduced Greenhouse Gas Emissions	Offshore renewables create electricity without generating greenhouse emissions, so aiding in climate change mitigation. Wind and tidal energy, for example, generate electricity without the need of fossil fuels.
Improving Air and Water Quality	Offshore renewables help to clean the air and water by reducing pollution caused by the extraction, processing, and combustion of fossil fuels.
Conservation of Biodiversity	Offshore renewable energy projects that are well-designed can have little influence on marine ecosystems. Floating wind farms, for example, can be placed in deeper waters to avoid interfering with seafloor habitats.
Sustainable Resource Utilization	Exploiting offshore renewable resources enables the long-term utilization of natural energy flows like wind and ocean currents without diminishing scarce resources.
Reduced Land Use Pressure	Offshore wind farms do not necessitate large tracts of land, answering concerns about land use change and biodiversity loss.

Table 3. Environmental Challenges

Environmental Challenges	Explanation
Marine Ecosystem Impact	The installation and operation of offshore renewable energy infrastructure can potentially disrupt local marine ecosystems, affecting fish and other marine life. Proper site selection and environmental impact assessments are crucial to minimize these effects.
Underwater Noise	Construction and operation of offshore projects can produce underwater noise, which may affect marine animals like whales and dolphins. Mitigation measures, such as timed construction schedules, can be employed to minimize this impact.
Collision Risks for Birds and Bats	Offshore wind turbines can pose collision risks for birds and bats. This challenge is being addressed through proper project sitting, monitoring, and ongoing research to understand and mitigate impacts.
Visual and Aesthetic Impact	Some stakeholder's express concerns about the visual impact of offshore wind farms, especially in coastal areas. This is subjective and can be addressed through careful project planning and community engagement.
Technological Challenges and Material Use	The manufacturing and disposal of materials used in offshore renewable energy infrastructure, such as turbines and cables, pose environmental challenges. Efforts are being made to improve recycling and reduce the environmental footprint of these technologies.
Storm and Extreme Weather Risks	Offshore facilities are exposed to harsh weather conditions, including storms. Proper engineering and design are essential to ensure the resilience of structures and to minimize the risk of damage during extreme weather events.

To summarize, while offshore renewable energy holds enormous promise for lowering carbon emissions and increasing sustainable energy generation, it must be addressed and mitigated by careful planning, research, and constant monitoring. Technological advancements and improved industrial practices can help to reduce the impact on marine ecosystems and maximize the environmental benefits of offshore renewables.

C. SOCIAL ASSESSMENT

Social and economic impacts of offshore renewable energy projects on local communities can vary based on factors such as project size, location, community engagement practices, and local socioeconomic conditions (4). Here are the main considerations:

1. Social Impacts

Employment Opportunities	Offshore renewable energy projects can create job opportunities, ranging from construction and installation to ongoing maintenance and operation. Local communities may benefit from increased employment and economic activity.
Community Engagement and Participation	Successful community engagement and participation in decision-making processes can foster a sense of ownership and positive attitudes toward offshore renewable projects. (5) (8)
Cultural Heritage and Recreation	Offshore projects should consider the potential impact on cultural heritage and recreational activities. Proper planning and mitigation measures can help preserve cultural values and recreational spaces.

2. Economic Impacts

Local Business Opportunities	Offshore renewable projects can stimulate local businesses, including those providing services and supplies needed for project development and operation. (6)
Infrastructure Development	The development of offshore projects may lead to infrastructure improvements in the region, such as upgraded ports and transportation facilities, benefiting both the project and the broader community.
Tax Revenues and Community Funds	Local governments can receive tax revenues and community benefit funds from offshore projects, contributing to local public services and community development. (7)
Property Values	Studies on the impact of offshore wind farms on property values have shown mixed results. Some studies suggest that the presence of wind farms may have a negative impact on property values, while others find no significant effect.

The social and economic impacts of offshore renewable energy projects on local communities can be significant. These projects often bring job opportunities, economic growth, and investment to the areas where they are located. Local communities may benefit from increased employment in the renewable energy sector, both during the construction phase and throughout the operation and maintenance of the projects.

Furthermore, offshore renewable energy projects can contribute to the diversification of local economies, reducing reliance on traditional industries and creating a more sustainable future. They can also lead to the development of new infrastructure and services to support projects, such as ports, transmission lines, and maintenance facilities.

However, it is important to consider potential challenges and negative impacts as well. Offshore renewable energy projects may cause disruption to fish activities, affecting the livelihoods of fishermen and the fishing industry. They can also have visual and noise impacts, which may affect tourism and recreational activities in the area (Smith & Brown, 2019).

To fully understand the social and economic impacts of offshore renewable energy projects on local communities, it is recommended to refer to studies and research conducted in this field (Smith & Brown, 2019; Jones & Stirling, 2020; Department of Energy and Climate Change, 2014).

III. Regulatory and national Policies Framework in the Mediterranean Sea

As the energy demand, in particular renewables, is expected to increase significantly in the Mediterranean region, the policy and regulatory frameworks must accompany it and should evolve accordingly. In this regard, we are listing the existing policies and regulations related to offshore wind energy in the Mediterranean countries (See Table 4).

Table 4. Regional Policies/National Regulations in the Mediterranean Regarding Offshore Projects*

Region	Country	National Polices/Regulations	References
Northern Mediterranean	Albania	*No existing projects; actively exploring offshore wind potential. *Developing regulations and policies for future implementation.	link
	Croatia	*No existing offshore wind energy projects. *Actively exploring offshore wind potential. *Creating regulations and policies for future implementation.	link
	Greece	***Law** 3851/2010. *Defines licensing and environmental assessments. *2.6 GW offshore wind target by 2030. *EU MSP Directive incorporated: Law 4546 (2018). *Ministry of Environment and Energy's Directorate of Spatial Planning responsible for MSP. *The National Spatial Planning Council was created for stakeholder input. *No current legally enforceable national MSP. *Active in European marine spatial planning initiatives.	link 1.0 link 1.1
	Slovenia	**Foundation Act:** Slovenian Spatial Planning Act (2017). **MSP Execution:** Ministry of Environment and Spatial Planning. **Draft MSP:** Created in early 2020 (AP SPRS). **Consultations:** Open consultations in 2020 and 2021. **Environmental Report:** Contract finalized.	link
	Spain	Law 24/2013 provides a stable legal framework for renewable energy projects. **Target:** Spain aims to install 3 GW of offshore wind capacity by 2030. **Wind Float Atlantic Project:** One of the largest offshore wind energy projects in Spain. **Supportive Regulations and Policies:** Spain has implemented regulations and policies to foster renewable energy growth, including offshore wind.	link link
	Malta	**Offshore Wind Exploration:** *No existing offshore wind energy projects. *The country is exploring offshore wind potential. *Developing regulations and policies for future projects. **Malta's Spatial Planning:** *Replaced Structure Plan with SPED in 2015. *SPED outlines strategic spatial policy up to 2020. *The National Spatial Framework applies to marine waters up to the 25 nm limit of the Fisheries Management Conservation Zone. *Integrates coastlines and marine zones as a single spatial unit.	link
	Monaco	*No existing offshore wind energy projects. *Country prioritizes other forms of renewable energy. *Specific regulations and policies for offshore wind are yet to be developed.	link
	Montenegro	*No Existing Offshore Wind Projects. *Early Exploration Phase. *Regulations and Policies Under Development.	link
	France	**French Offshore Wind Regulations:** *Governed by Code de l'Énergie and Code de l'Environnement. *Define permitting, environmental assessments, and grid connection requirements for offshore wind farms.	link 1.0 link 1.1

		*France targets 5.2 GW of offshore wind capacity by 2028. **National Maritime Strategy:** *Outlined in the Stratégie Nationale pour la Mer et le Littoral. *Adopts sea-basin plans to meet MSFD and MSPD criteria. **Sea-Basin Policies (DSF):** *Include preliminary evaluation, strategic goals, and MSP-related fact sheets. *Developed in collaboration with key players and neighboring nations. *Environmental review by the French Environmental Authority. *Authorization granted for each marine basin. **Floating Offshore Wind Turbine (FOWT) Project:** *Located in the Mediterranean Sea near Marseille. *Features a single 2 MW floating wind turbine.	
	Italy	**Italian Offshore Wind Regulations:** *Governed by Decreto Ministeriale 23/2016. *Sets criteria for permits and authorizations for offshore wind projects. **Offshore Wind Areas:** *Identified in the Adriatic Sea and southern Mediterranean. **Marine Strategy Framework:** *Four marine zones based on marine sub-regions concept. *Each zone has planning units with tactical goals and "vocations." **MSP Strategies Proposal:** *Italian government presented MSP strategies proposal for four marine areas to the European Commission in June 2021. *The proposals will undergo public discussions in each of the Regions after authorization.	link 1.0 link 1.1
Eastern Mediterranean	Cyprus	**Cyprus Offshore Wind Development:** *No existing offshore wind energy projects. *Introducing legislation and regulations to support offshore wind projects. *Licensing process established, regulations and policies under development. **Maritime Spatial Planning (MSP):** *Cyprus implemented the MSP Directive via the MSP Law ratified in October 2017. *Ministry of Transport, Communication, and Works (Department of Merchant Shipping) is responsible for MSP. *An MSP Committee supervises the draft MSP. *Cyprus has not yet produced an MSP Plan but has engaged in various MSP-related European initiatives.	link
	Lebanon	**Lebanon Offshore Wind:** *Exploring potential. *Developing regulations and policies. *No existing projects yet.	link
	Syria	No existing offshore wind energy projects in the country.	link
	Türkiye	**Marmara Offshore Wind Farm (Türkiye):** *The first and only offshore wind energy project in Turkey. *Supported by implemented regulations and policies for renewable energy growth.	link 1.0 link 1.1
	Palestine	Currently, there are no existing offshore wind energy projects in Israel. The country has set a target to generate 10% of its electricity from renewable sources by 2020, which includes offshore wind energy.	Survey
	Israel	**Israeli Offshore Wind Initiatives:** *Recognizes offshore wind's potential for energy diversification and emissions reduction. *Awarded licenses for "Karin" and "Dolphin" projects with a combined capacity of 1.4 GW. *Aimed to reach 10% electricity from renewables by 2020. **Regulatory Framework:** *Established to facilitate offshore wind development. *Specific Mediterranean Sea area allocated. *Licensing and permitting guidelines defined. **Incentives with Feed-In Tariff:** *Introduced to attract investments.	link

		*Guarantees fixed electricity prices over a specified period for financial stability. **Environmental Impact Assessments:** *Conducted to minimize ecological and environmental impact. *Assess effects on marine ecosystems, wildlife, and the overall marine environment. **R&D Investment:** Collaborates with academic institutions and industry partners. Aims to advance offshore wind technology and enhance efficiency.	
Southern Mediterranean	Egypte	**No existing offshore wind turbine still under studies considered as exploring level**	Survey
	Morocco	**Moroccan Offshore Wind Interest:** *Interest in offshore wind energy development. **Legal Framework:** Established through Law No. 13-09. *Covers renewable energy projects, including offshore wind. **Renewable Energy Strategy:** Aims for 52% renewable energy in electricity mix by 2030. **Offshore Wind Potential:** Identifies potential areas on the Atlantic coast. **Key Offshore Wind Project:** Tarfaya Offshore Wind Farm, Morocco's first. **Regulations and Policies:** Implemented to support renewable energy, including offshore wind.	link link
	Algeria	**Algerian Offshore Wind Interest:** Early exploration and development stages. **Offshore Wind Potential Assessment:** Exploring potential sites along the Mediterranean coast. **Energy Mix Diversification:** Increasing the share of renewable energy. **Regulations and Policies:** In the process of developing regulations and policies. **No Current Offshore Wind Projects:** No existing offshore wind energy projects.	link
	Lybia	*No existing offshore wind energy projects. *Political situation impacts the development of regulations and policies for renewable energy, including offshore wind.	link
	Tunisia	* Exploring the potential for projects in its coastal areas. *Identified areas along its coast, such as Bizerte and Gabes, as potential sites for offshore wind development. *No existing offshore wind energy projects. * The country is in the early stages of exploring the potential for offshore wind and is in the process of developing regulations and policies.	link

As per the available data on the existing policies, regulatory framework and on-going projects and the ambitious targets of energy transition in the Mediterranean region, there is a place for offshore wind energy to support the other renewables sources mainly solar and inland wind to increase the share of renewables and triple its capacity by 2030 in the Mediterranean region.

Installing offshore wind energy projects in the Mediterranean requires careful planning and consideration of various factors. First, we need to conduct a thorough assessment of the wind resource in the proposed offshore locations. This involves collecting and analyzing wind data to understand the wind speed, direction, and variability. In addition, we need to ensure that the wind resource is sufficient and consistent for the reliable generation of offshore wind energy. Second, we need to identify appropriate sites for offshore wind farms in the Mediterranean. Some factors are to be considered, such as water depth, seabed conditions, proximity to the shore, and environmental sensitivity. It is pivotal to conduct environmental impact assessments to minimize potential impacts on marine ecosystems, wildlife, and local communities.

On the other hand, it is of utmost importance to engage the key stakeholders, including local communities, fishing industries, environmental organizations, and regulatory authorities, in the planning and decision-making process. We need to seek their input and address any concerns or potential conflicts early on. This can help build support and ensure the project's success.

Another important aspect is the regulatory framework. A deep understanding of the regulatory framework and permitting processes for offshore wind energy projects is a must. We also need to work closely with regulatory authorities to ensure compliance with environmental, maritime, and energy regulations, as well as collaborating with relevant government agencies to establish clear guidelines and streamline the permitting process.

On another note, we need to consider the infrastructure and the grid connection through evaluating the existing electrical grid infrastructure and assess the feasibility of connecting offshore wind farms to the onshore grid. In this regard, it is important to collaborate with grid operators and utilities to determine the most efficient and cost-effective grid connection solutions, and also consider the potential need for grid upgrades or new transmission infrastructure.

On the technology choice, it is important to select appropriate offshore wind turbine technology that can withstand the Mediterranean's unique environmental conditions, including wind, waves, and saltwater corrosion. An important aspect to consider is the water depth and seabed conditions when choosing the foundation type (e.g., monopile, jacket, floating). For that it is pivotal to collaborate with experienced offshore wind turbine manufacturers and suppliers.

As per the financing of such projects of offshore wind energy, developing a robust financial plan is a must. In addition, we need to explore all financing options, including public-private partnerships (PPPs), green bonds, and international funding mechanisms, and we can also assess the potential for revenue streams, such as power purchase agreements (PPAs) or government incentives, to make the projects financially viable.

Another important consideration to take into account is to conduct comprehensive environmental and social impact assessments to identify and mitigate potential risks and impacts. For offshore wind energy projects, we need to implement measures to protect marine ecosystem, habitats, and migratory routes, apart from engaging with local communities (e.g., fishermen, offshore platforms, etc.) to ensure their concerns are addressed and consider the potential for job creation and local economic benefits.

As per the long-Term operation and maintenance (O&M), a comprehensive plan of the offshore wind farm is needed. It should consider factors such as accessibility, maintenance vessels, spare parts logistics, and monitoring systems. Collaboration with experienced offshore wind service providers could be of added value to ensure the reliability and efficiency of the project throughout its lifecycle.

By adopting such measures, we can lay the groundwork for successful offshore wind energy projects in the Mediterranean, contributing to the region's renewable energy transition ambitious targets and decarbonization efforts to achieve net-zero by 2050.

Conclusions

Regulations governing offshore wind energy in the Mediterranean region are currently specific to each country, with Spain, Italy, and Greece making significant strides in establishing their regulatory frameworks. On the Southern Mediterranean side, almost all countries have set ambitious targets when it comes to increasing renewable energy capacity in the mix of energy, and despite that solar and onshore wind apart from hydropower are dominating that part of renewables in the mix, but offshore wind energy is called to play a role and contribute to that mix in the upcoming decade as far as the technology readiness level is increasing and the policies and regulations are converging to supportive ones that would encourage this technology to flourish. Meanwhile, the European Union's Clean Energy Package offers essential guidance and targets for member states embarking on offshore wind projects. Despite increasing interest in offshore wind energy, its development in the Mediterranean remains at an early stage, emphasizing the need for a unified, long-term policy framework to foster sustainable coexistence and environmental protection. Stability in legislative frameworks is a pivotal factor in the issuance of permits and overall project development. The feasibility of offshore wind farms in Mediterranean nations hinges on various considerations, including existing infrastructure, environmental concerns, and potential conflicts among different economic sectors. Given the intricate regulatory, environmental, and financial factors at play, establishing operational offshore wind projects in Southern Mediterranean countries may necessitate a substantial amount of time and investment. Regional cooperation will be of utmost importance to share best available technologies, good practices at the level of policies, regulations and incentives, and know-how between northern and southern Mediterranean countries, and umbrellas offered by UNEP-MAP Barcelona Convention and its Contracting Parties and UfM Secretariat could be the right catalyst of such cooperation, in particular through the renewable energy and energy efficiency Mediterranean platform animated by the Regional Center for Renewable Energy and Energy Efficiency (RCREEE), and the Mediterranean Association of National Agencies for Energy Management (MEDENER).

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Annex: Survey template

These are the questions included in the survey distributed to RCREEE board of trustees (from member states: ministries of electricity/energy).

Name of the country					
Questionnaire regarding national policies and legislation related to wind energy.					
Nb	**Questions**	**No**	**Yes**	**Remarks**	**Descriptions**
1	Is there a specialized authority at the national level responsible for coordinating renewable energy sector affairs? If there is a specialized authority, please mention its name and the tasks entrusted to it at the ministerial and national levels.				
2	Are there any goals set by the government in the short and long term regarding the production of more renewable energy?				
3	Does your esteemed country have a national plan or program for renewable energy? What is the goal of the plan, and what are the sectors and renewable technologies included in the plan?				
4	Are there any policies, legislations, regulations, or laws for the development of onshore or offshore wind power plants in your country?				
5	Are there any conflicts in national legislations regarding the establishment of offshore wind power plants, such as continental shelf nature, territorial waters, marine life, or other obstacles?				
6	Are there any environmental studies that assess marine resources and marine climatic conditions in your country?				
7	Have engineering studies been conducted to identify locations and create offshore wind atlases?				
8	In your opinion, do these policies align with the national energy objectives and the specified National Determined Contributions (NDC)?				
9	Are there any environmental, social, or economic impacts associated with onshore and offshore energy production, and could you summarize these impacts?				
10	Is there an existing infrastructure or plan to integrate offshore energy projects into the national grid?				
11	Are there any challenges related to the transmission, distribution, or storage of renewable energy?				
12	Are there any financial incentives, support grants, or tax exemptions available to encourage investment in onshore or offshore wind power generation?				
13	Are there specialized research centers for the development of offshore wind energy projects? And are there opportunities for collaboration, knowledge exchange, or technology transfer with countries, organizations, or entities to develop these projects?				